PROGRESSIVE REHABILITATION AND CLOSURE PLAN

Curragh Project
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BASIS OF REPORT

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1 Introduction

In accordance with the *Environmental Protection Act 1994* (EP Act), all mining activities approved through a site-specific environmental authority application must develop and submit a Progressive Rehabilitation and Closure Plan (PRCP) to the Department of Environment and Science for assessment. The main purpose of the PRCP is for the holder of an EA to plan for how and where activities will be carried out on land in a way that maximises the progressive rehabilitation of the land to a stable condition, and, to provide for the condition to which the holder must rehabilitate the land before the EA is surrendered.

This PRCP has been developed in accordance with the transition notice issued under section 754 of the EP Act to Coronado Curragh Pty Ltd (CCPL). This PRCP meets the legislative requirements in section 126C and 126D of the EP Act and the statutory guideline: Progressive Rehabilitation and Closure Plans (ESR/2019/4964).

1.1 Relevant Legislation and Policies

1.1.1 Mined Land Rehabilitation Policy

The Mined Land Rehabilitation Policy is a joint departmental policy between the Department of Environment and Science, the Department of Natural Resources and Mines and Queensland Treasury. The Policy presents Queensland Government's position on mine rehabilitation and is the basis of the changes made through the MERFP Act.

The Policy states that, "land disturbed by mining is considered to be rehabilitated when it can be demonstrated it is safe, stable, does not cause environmental harm, and is able to sustain the post-mining land use approved in the PRCP (referred to as 'stable condition'). An area of land that does not sustain a post-mining land use (referred to as a 'non-use management area') may be approved if best practice management can be demonstrated, and:

- Rehabilitating the area would cause greater environmental risk than not rehabilitating, or
- The environmental risks from the area are localised, and the cost of rehabilitation would be so excessive as to not be in the public interest."

The Policy also introduces the prohibition of final voids situated wholly or partly in a floodplain.

1.1.2 Environmental Protection Act 1994

The amendments to the EP Act requiring mines with site-specific EAs to have a PRCP, came into effect on 1 November 2019. The EP Act states the legislative information requirements for the rehabilitation planning part (section 126C) and PRCP schedule (section 126D). The EP Act also details the assessment process for the approval of a proposed PRCP.

The EP Act contains transitional provisions relating to existing site-specific mines. During the three-year transition period, DES will issue notices to existing mines requiring them to develop and submit a proposed PRCP by a specific date (no less than six months from issuing the notice). The transitional provisions also state that existing approvals may be translated into the proposed PRCP without additional assessment or public notification. Final voids approved in a land outcome document are exempt from the prohibition of a final void in a floodplain and the requirement for a public interest evaluation for a non-use management area.

1.1.3 Environmental Protection Regulation 2019

The Environmental Protection Regulation 2019 (EP Regulation) includes PRCP objectives and performance outcomes (schedule 8A) the administering authority must consider when approving a PRCP. The EP Regulation also contains additional requirements for deciding the extent of a floodplain (0.1% Annual Exceedance Probability (AEP)) for the purposes of prohibiting a final void within a floodplain.

1.1.4 PRCP Guideline

The PRCP Guideline is a statutory guideline made under section 550 of the EP Act and includes additional information requirements the administering authority deems necessary or desirable within a PRCP.

The PRCP Guideline provides information about the assessment process for a PRCP, information requirements for the PRCP, relevant post-approval processes and transitional provisions. The PRCP Guideline stipulates the detailed technical information that is expected to be included in a proposed PRCP.

2 Project Planning

2.1 Project Description

The Curragh Project is located within the Central Highlands Regional Council, approximately 6 km north of the town of Blackwater and approximately 200 km west of Rockhampton (**Figure 2-1**). The total mining lease area is about 19,650 ha.

The Curragh Project consists of (**Figure 2-2** and **Figure 2-3**):

- Curragh Central (Pit X-west);
- Curragh Central Extended (Pit X-east & Pit D);
- Curragh Extended (Pit J);
- Curragh South (Pit Z);
- Curragh West (Pit Y);
- Curragh East (Pit A-C, Pit E—I, Pit K-L); and
- Curragh North (Pit s, Pit T and Pit U).

The Curragh Project is an open cut operation producing a variety of coking, PCI and steaming coal products for both the export and domestic markets. The operation is a mix of dragline and truck and shovel fleets. The site is predominantly divided into mining areas 'Curragh Main' and the more recent 'Curragh North'. Curragh Main consists of Curagh East, West and Extended and mining commenced in this area in approximately 1983. Curragh North is a satellite mining operation which commenced operations in 2005 and is connected to Curragh Main by a haul road for supply and servicing and a conveyor for coal transport to the Curragh Main Coal Handling and Preparation Plant (CHPP).

The approved annual run of mine (ROM) production is 18 million tonnes per annum (Mtpa). Coal extraction has been ongoing since 1983, entirely through surface mining methods. Coal is transported from the mine to Gladstone via the Central Rail Line also known as the Blackwater Line. The Project is currently estimated to run until 2044.

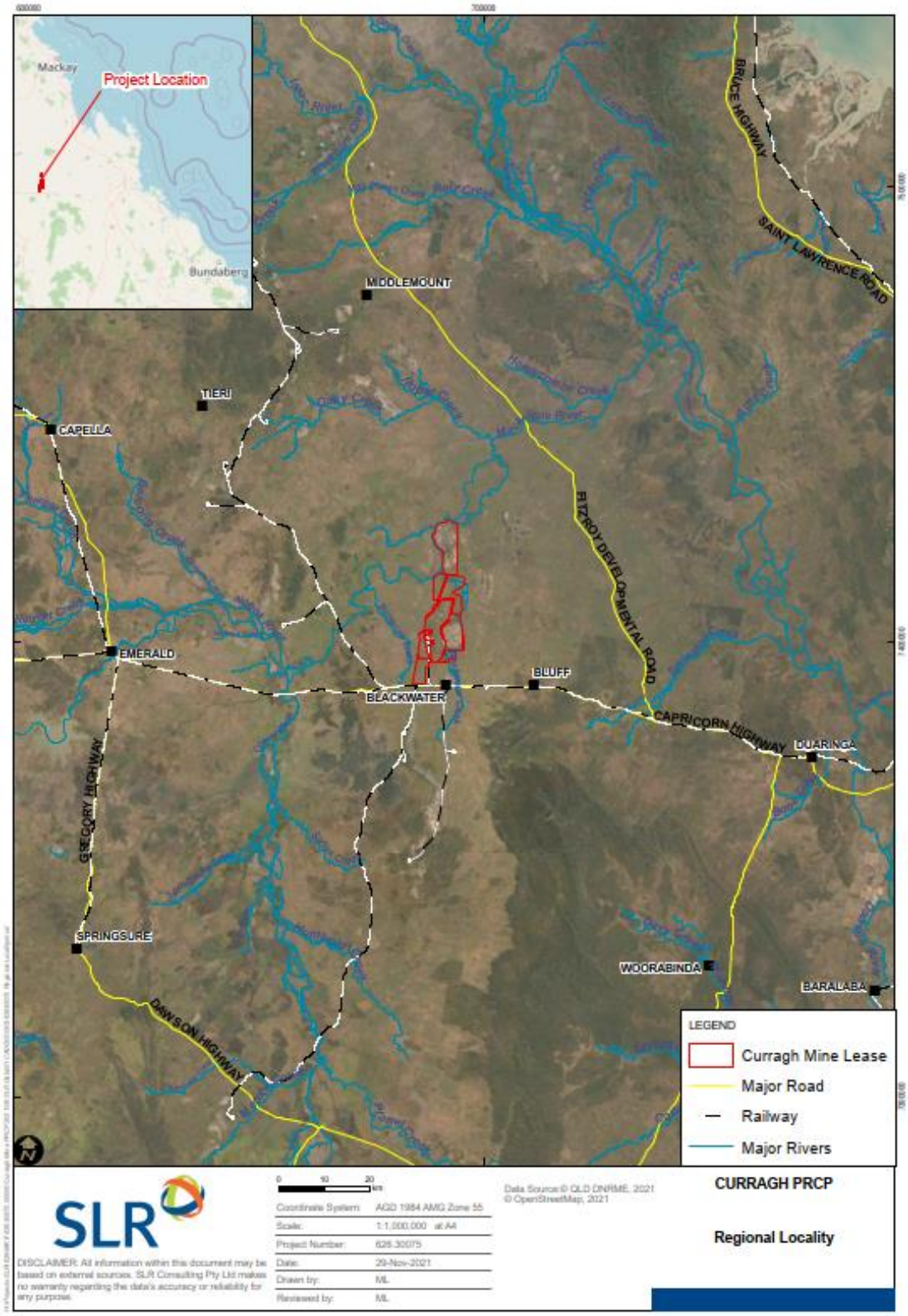


Figure 2-1 Regional Locality

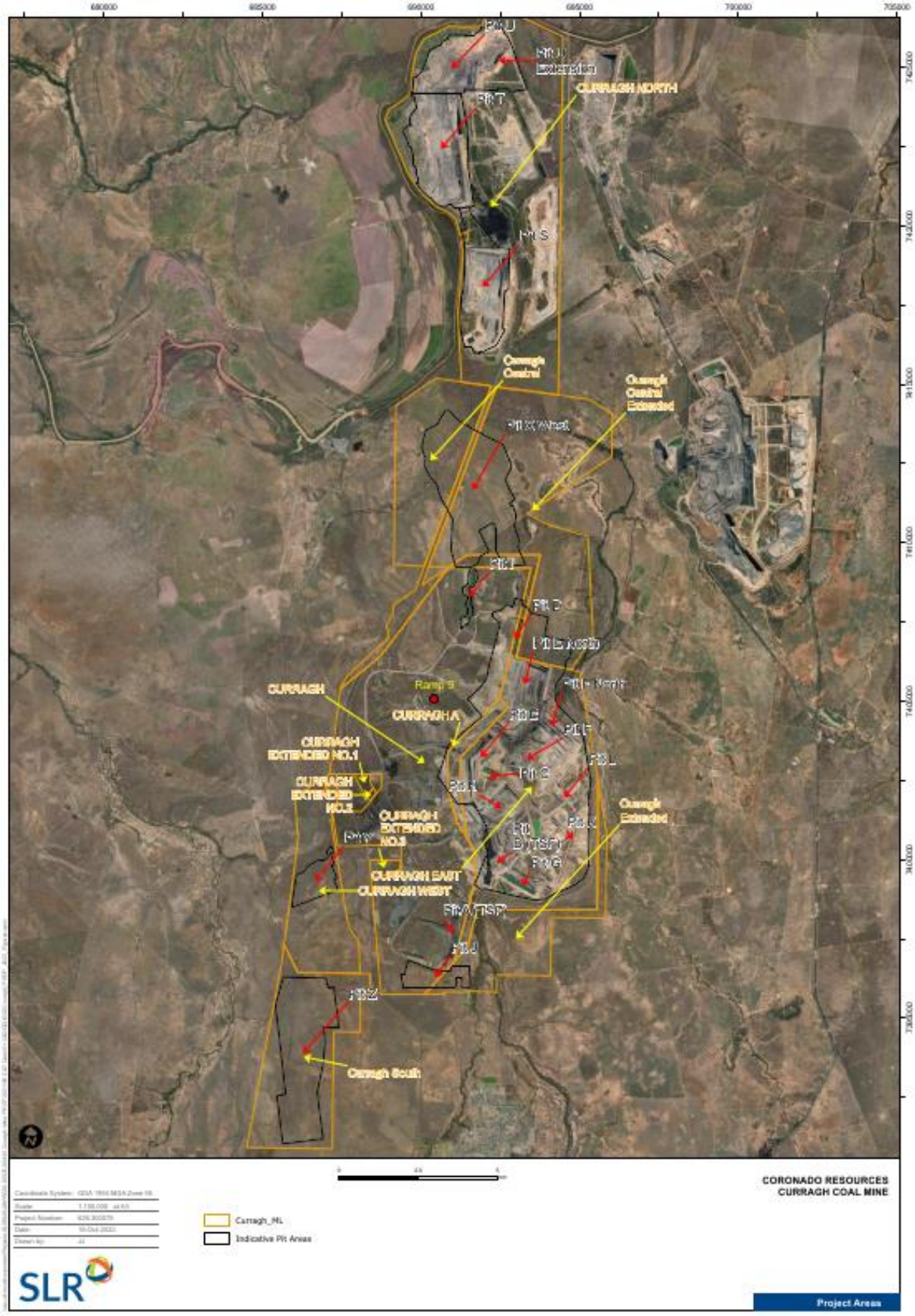


Figure 2-2 Curragh Project Areas

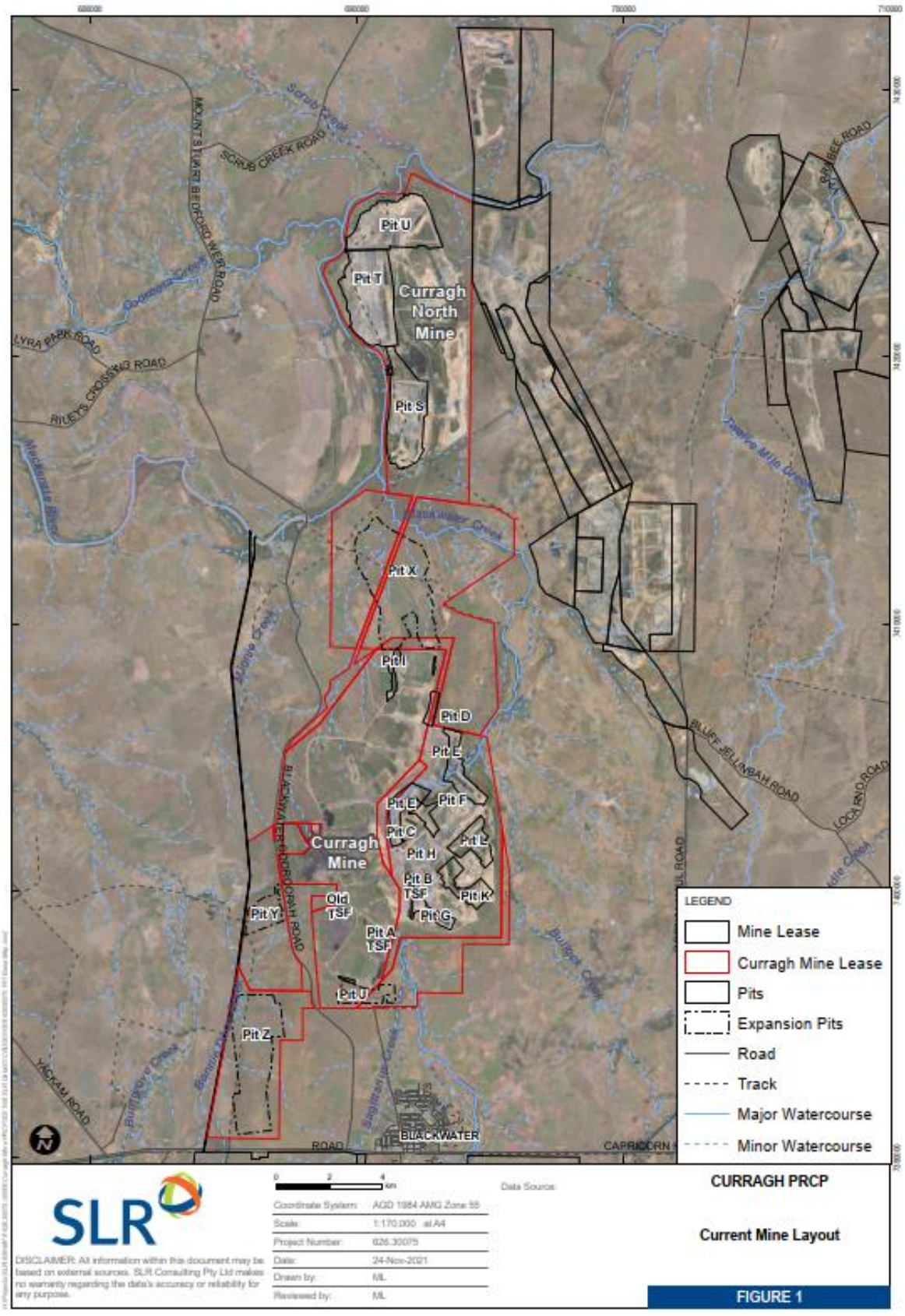


Figure 2-3 Curragh Existing and Proposed Pits

The mine infrastructure and activities on site include, but are not limited to:

- Exploration drilling;
- Clearing vegetation;
- Stripping and stockpiling of topsoil material;
- Explosives;
- Mining;
- Coal processing and stockpiling;
- Tailings and coarse reject disposal;
- Coal stockpiling, train loading and transport via conveyor and rail;
- Rehabilitation of disturbed land;
- Water management;
- Levees and regulated dam management;
- Blackwater Creek Diversion;
- Facilities and Infrastructure;
- Waste management;
- Sewage treatment;
- Mechanical workshops;
- Storage of fuels, oils and chemicals; and
- Village accommodation.

The activities are all undertaken within the relevant mining leases (MLs). The Curragh Project includes 14 MLs the details of which are provided in **Table 2-1**.

Table 2-1 Mining Leases

Tenure	Project Area	Tenure Expiry	Tenure Area (ha)
ML1878	Curragh Main	31/05/2024	4,455
ML1990	Curragh Main	31/05/2023	172.3
ML80010	Curragh Main – Extended No.1	31/05/2023	24.18
ML80011	Curragh Main – Extended No. 2	31/05/2023	6.14
ML80012	Curragh Main – Extended No. 3	31/05/2023	42.57
ML80086	Curragh East	31/10/2025	3,026.19
ML80110	Curragh North	31/07/2044	4859.11
ML80112	Curragh Main – TL218070	30/09/2025	110.33
ML80123	Curragh North	31/07/2044	4.91

Tenure	Project Area	Tenure Expiry	Tenure Area (ha)
ML80171	Curragh West	31/07/2040	952.60
ML700006	Curragh South	30/06/2041	1431.98
ML700007	Curragh Central	30/06/2041	1123
ML700008	Curragh Central Extended	30/11/2040	2643
ML700009	Curragh Extended	30/11/2040	797.31

2.2 Baseline Information

2.2.1 Climate

The climate of the region is subtropical with the highest rainfall and evaporation occurring from October through till March (BoM, 2021). Historical climate data was obtained for the period January 1900 to September 2021 from the Scientific Information for Landowners (SILO) database (Queensland Government, 2021) for the location of the Project area (latitude -23.5, longitude 148.9). **Table 2-2** outlines the total monthly average rainfall (565 mm) and evaporation. The data shows that the total potential average annual evaporation (2,054 mm/yr) is almost four times annual rainfall (565 mm/yr). The high annual evaporation rates are strongly related to seasonal temperatures (**Figure 2-4**).

Table 2-2 Total Monthly Rainfall and Evaporation (January 1900 to August 2021)

Average Total Monthly (mm)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Rainfall	93	88	58	30	29	29	24	16	21	42	56	80	565
Evaporation	229	184	190	151	118	94	103	132	173	214	226	240	2,054

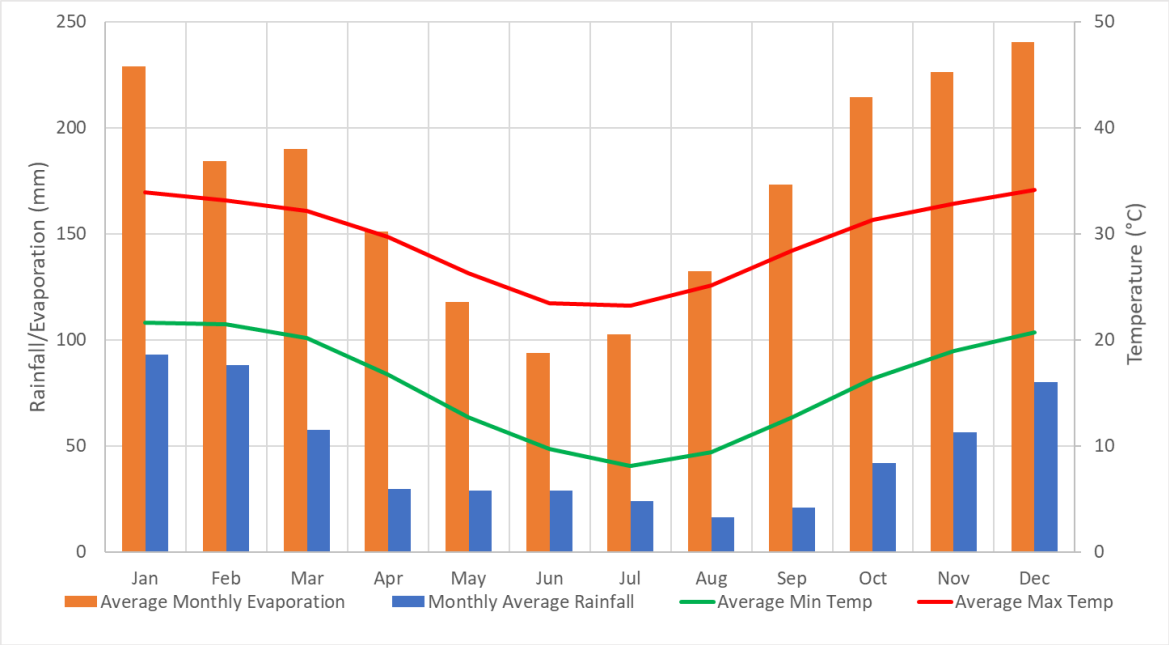


Figure 2-4 Average Monthly Evaporation, Rainfall and Temperature (January 1900 to August 2021)

In order to assess recent rainfall distribution in a historical context for water modelling purposes, the cumulative rainfall departure (CRD) was calculated for the data period 1900 to 2021 (**Figure 2-5**). The CRD is a summation of difference between the actual monthly rainfall compared to the average monthly for the same period. A rising slope in the CRD indicates periods of rainfall above the long term average (e.g., 2010 to 2012), and a falling slope indicates periods when rainfall is below the long term average (e.g., 1999 to 2007). Rainfall volumes over more recent years of the record (2017 to 2021) have been lower than average, as is indicated by the falling slope in the CRD.

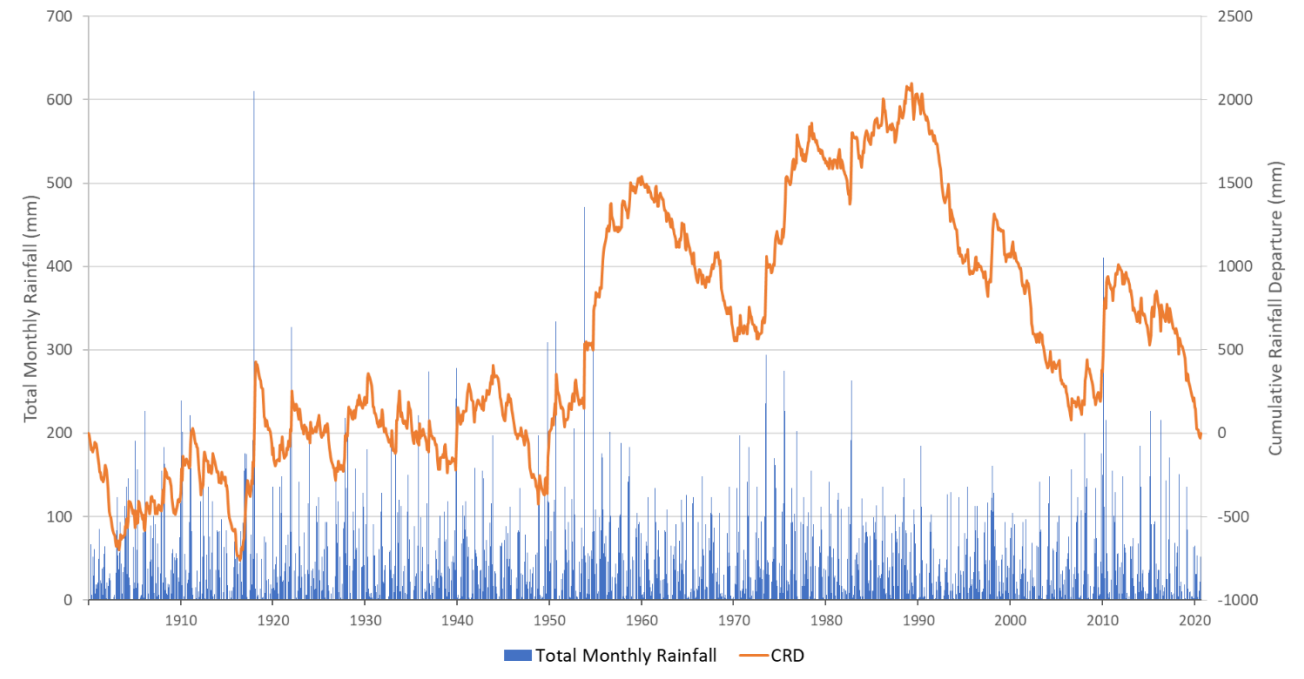


Figure 2-5 Cumulative Rainfall Departure and Total Monthly Rainfall (1900-2021)

Since the start of mining in 1983 the area has generally seen lower than average rainfall except for the remainder of the 1980s and significant wet seasons in late 1998 and 2010/11.

2.2.2 Geography and Topography

The land surrounding the mine is typically gently undulating and comprises the floodplain of Mackenzie River. The topography of the area is dominated by the major drainage features (Mackenzie River and tributaries), creek lines, and the open cut pits and spoil dumps of Curragh Mine and neighbouring mines.

Aside from the Township of Blackwater and the surrounding mines land use is rural with large areas predominantly turned over to livestock grazing with some dryland cropping and minor irrigated cropping adjacent to Mackenzie River.

2.2.3 Geology

The surface geology across the study area (based on the 1:100,000 mapping), is presented in **Figure 2-6** and the regional (solid) geology is presented in **Figure 2-7.**

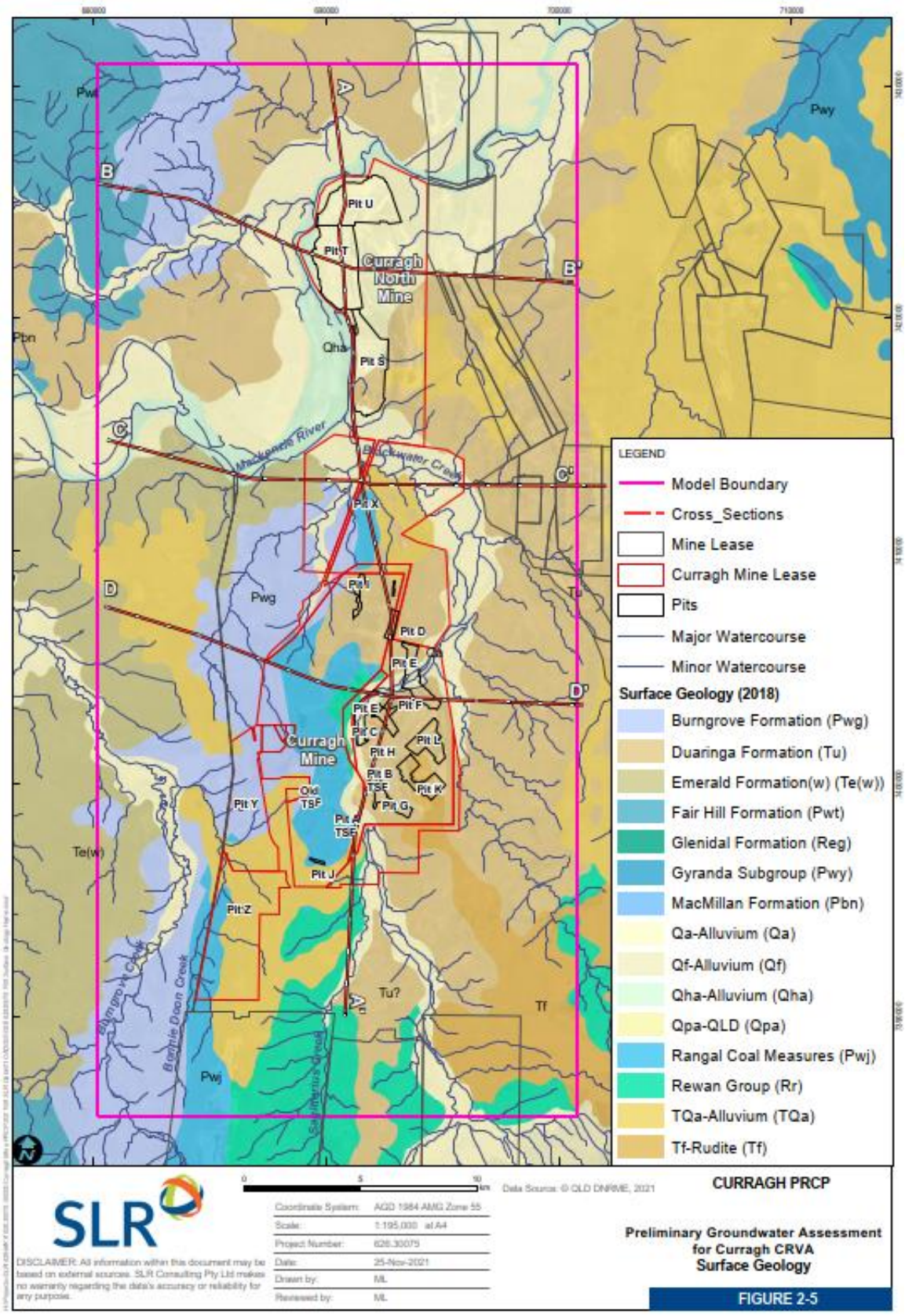


Figure 2-6 Surface Geology

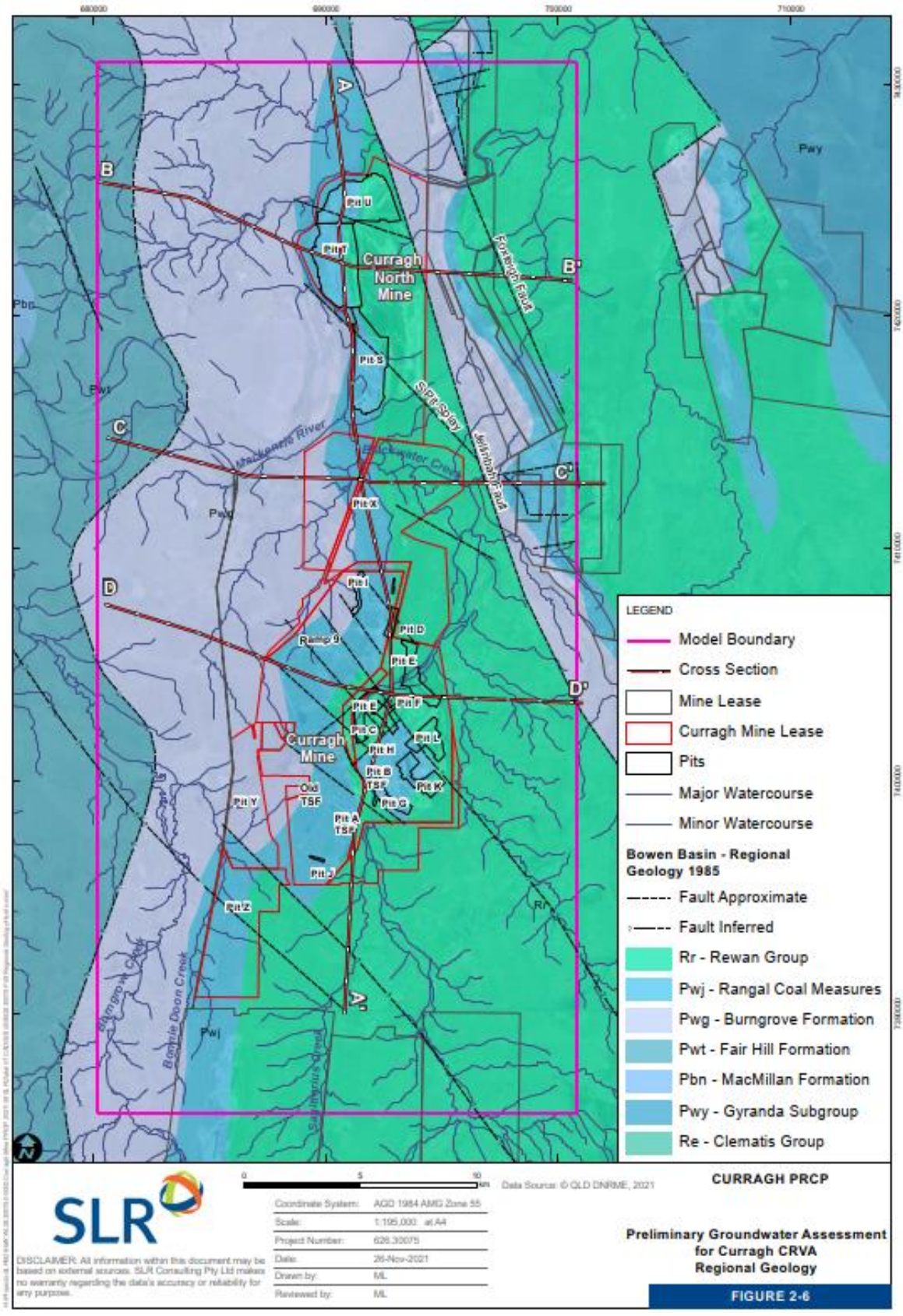


Figure 2-7 Regional Geology

The study area is underlain by Permian to Quaternary sediments located within a gently folded and faulted sequence of the Bowen Basin. The Permo-Triassic sediments dip eastward and include the Triassic Rewan Formation and the underlying Permian Blackwater Group, which includes the Rangal Coal Measures, Burngrove Formation and Fair Hill Formation. The Permian strata are overlain by unconsolidated Quaternary alluvium associated with creeks, rivers and floodplains, and the poorly consolidated Tertiary sediments of the Duaringa and Emerald formations. The Back Creek Group underlies the Blackwater Group and forms the basement of the area.

The stratigraphic sequence underlying the study area is presented in **Table 2-3** and summarised below.

Table 2-3 Regional Stratigraphy

Age	Group	Stratigraphic Unit	Description
Quaternary		Alluvium	Soils, unconsolidated silts, sands, gravels and clays,
Cenozoic (Tertiary)		Duaringa Formation/ Emerald Formation	Claystone, siltstone, sandstone, conglomerate (often poorly consolidated), lignite, basalt
Triassic	Mimosa	Rewan Formation	Mudstone, interbeds of lithic sandstone.
Upper Permian	Blackwater Group	Rangal Coal Measures	Coal seams calcareous sandstone, calcareous shale, mudstone, calcareous tuff in places. Main coal seams include Aries, Castor, Pollux, Orion, Pisces.
		Burngrove Formation	Siltstone, carbonaceous shales and mudstone, fine lithic sandstone, calcareous lithic and feldspathic sandstone, tuffaceous shales and thin coal seams.
		Fair Hill Formation	Lithic and feldspathic labile sandstone, quartzose sublabile sandstone, siltstone, mudstone, calcareous and tuffaceous sandstone, volcanic conglomerate, carbonaceous mudstone, coal
Permian	Back Creek Group	Macmillan Formation	Interbedded mudstone and sandstone, prominent dark grey basal unit.

Quaternary and Tertiary alluvium

Alluvium associated with the main watercourses of the Mackenzie River and Blackwater Creek (and their tributaries) is present across much of the extension areas and Curragh North.

In the proposed Pit X area, exploration drilling indicates the alluvium is typically less than 12m thick and predominantly comprised of clay with occasional channel sand and gravel lenses at depth. Alluvium in the vicinity of proposed Pit J and Pit Z is generally thin (typically 2m but up to 4m) and comprised of clay and silt. Alluvium occurs in the southeast corner of proposed Pit D extension and is typically less than 2m (and up to 10m) and comprised of clay and sand (WSP 2016).

Floodplain alluvium associated with the Mackenzie River occurs extensively at Curragh North and exhibits an overall fining upwards sequence and significant lateral variability with an average thickness of 18 - 20m. Drilling data indicates the alluvium may be up to 35 m thick and the base of the alluvium is deepest close to the Mackenzie River (WSP 2016).

Cenozoic sediments

The Duaringa Formation is present in the proposed Pit X and Pit D extension areas and outcrop extensively in the north, east and south of the study area. In the north of the study area the Cenozoic sediments have been eroded by the Mackenzie River. The Emerald Formation is present in the western section of the proposed Pit X area and outcrop in the west of the study area (WSP 2016).

The Cenozoic sediments consists of interbedded stiff to hard clayey sands, gravels and thick beds of ferruginous clays of medium to high plasticity. They are fluvial and colluvial in origin and partially consolidated. The sequence unconformably overlies Permian coal measures with an indistinct boundary due to the clay rich and ferruginous composition of both horizons caused by in-situ weathering (WSP 2016).

Triassic sediments

The Rewan Formation overlies the Rangal Coal Measures and outcrops / subcrops directly east of the mined areas. It typically comprises thinly interbedded mudstones, lithic sandstones and siltstones. Drilling in the Minyango mine area recorded Rewan Formation up to 350m thick with a depth of weathering between 30 and 70 m (WSP 2016).

Permian sediments

The Permian Rangal Coal Measures (RCM) is the uppermost sequence in the Blackwater Group and comprises predominantly fine grained to occasionally medium grained lithic sandstone, siltstone, mudstone, carbonaceous mudstone and coal.

The RCM contain seams of high quality PCI coal, high quality medium-to-low ash coals suitable for prime coking coal, anthracite and semi-anthracite, and high energy thermal coals. The Cancer, Aries, Castor, Pollux, Orion and Pisces seams within the RCM are mined at Curragh. The strata generally dip to the east at less than 3°, with dips increasing locally in fault zones. The Rangal Coal Measures outcrop / subcrop in Curragh North and Curragh Main areas. The Rangal Coal Measures also subcrop east (the upthrow side) of the Jellinbah Fault where they are extracted at Jellinbah Mine (WSP 2016).

The boundary between the Burngrove Formation and the overlying RCM is the Yarrabee Tuff Bed, a distinctive marker horizon. The tuff lies between the target Pisces seam in the RCM and the Pisces Lower seam. The upper part of the Burngrove Formation (below the Yarrabee Tuff Bed and Pisces Lower seam), comprise dark grey to grey mudstones grading to siltstones. The Burngrove Formation outcrops/subcrops in the proposed Pit X, Y and Z locations and to the west of Curragh Mine (WSP 2016).

The Fair Hill Formation underlies the Burngrove Formation and outcrops/subcrops to the west of the mine. The formation comprises lithic sandstone, conglomerate, mudstone, carbonaceous shale, coal, tuff and tuffaceous mudstone and includes the Fort Cooper Coal Measures.

The upper Permian sediments are weathered. The depth of weathering in the study area is approximately 14 metres below ground level (mbgl), except where Quaternary erosion and deposition has resulted in the replacement of Permian sediments by Quaternary alluvium. Where this occurs deeper weathering up to 35 mbgl is observed (WSP 2016).

2.2.4 Soils

A soil study by Land Reclamation Services (1990) identified seven soil mapping units in the Curragh mine area. **Table 2-4** gives a brief description of the soil units described by Land Reclamation Services and outlines the soils suitability for rehabilitation. Care should be taken when using the table as 'there is considerable variation within these mapping units'.

Table 2-4 Soil Mapping Units at Curragh Project

Soil Unit	Brief Description of Suitability for Rehabilitation
Red brown melonhole clays	Top 10 cm chemically suitable for Rehab Lower horizons are dispersive and have high chloride concentration Melonhole relief makes striping top layer without contamination from lower horizons impossible Therefore this soil is not suitable for rehabilitation
Red brown non- cracking clays	Top 20cm are suitable for rehabilitation Lower horizons are dispersive and have moderate chloride concentrations Topsoil should be carefully stripped to 20 cm
Grey brown cracking clays	High chloride concentrations throughout the profile All horizons are potentially dispersive Recommended that this soil is not used in rehabilitation
Grey brown cracking clays over calcareous material	Well-structured cracking clay with low chlorides and dispersity to at least 60 cm Soil should be stripped to 60 cm depth 0–30 cm should be stockpiled separately to 30-60 cm
Red brown cracking clays – acid sub soil	Only the top 20 cm is chemically suitable for rehabilitation
Mixed clays and texture contrast soils	Only the top 15 cm is suitable for rehabilitation Lower horizons consist of impervious clays which are dispersive
Red texture contrast soils	Only the A horizon should be used for rehabilitation as the lower clays are impervious and dispersive Therefore only the top 15 cm should be stripped and stockpiled for rehabilitation

Curragh East

Additional mapping of the Curragh East Project Area was completed by Environment Health and Safety Systems (1998). Soil samples were taken from 17 sites and soils were described in sufficient detail to classify into mapping units (**Table 2-5** and **Figure 2-8**). In general, the report shows that:

- Soil sample analyses show that the soils of the project area are poorly to moderately fertile;
- Soils are potassium and nitrogen deficient;
- Soils are calcium and magnesium moderately deficient; and
- Sodicity of soils is low although deeper layers may prove more problematic.

Table 2-5 Curragh Main Soils

Soil Type	Description of Soils
Variable Texture Contrast Soils	• Occur on the eastern and north-eastern part of the Curragh East area and are characterised by coarse textured sandy clay loams to sandy clay over-lying coarsely structured alkaline clay subsoil. • The soils are associated with the ridge running north/south over the Curragh East area and support a range of vegetation from tall Poplar Box forest to short mixed forest.
Cracking Clays over Alluvial Parent Material	• This mapping unit is associated with the undisturbed section of the Blackwater Creek streambed. This cracking heavy clay forms a deep layer over an alluvial parent material, the dark brown to grey soil has a coarse blocky structure and ranges from acid to neutral in the upper 0.5 metres to strongly alkaline below this depth.

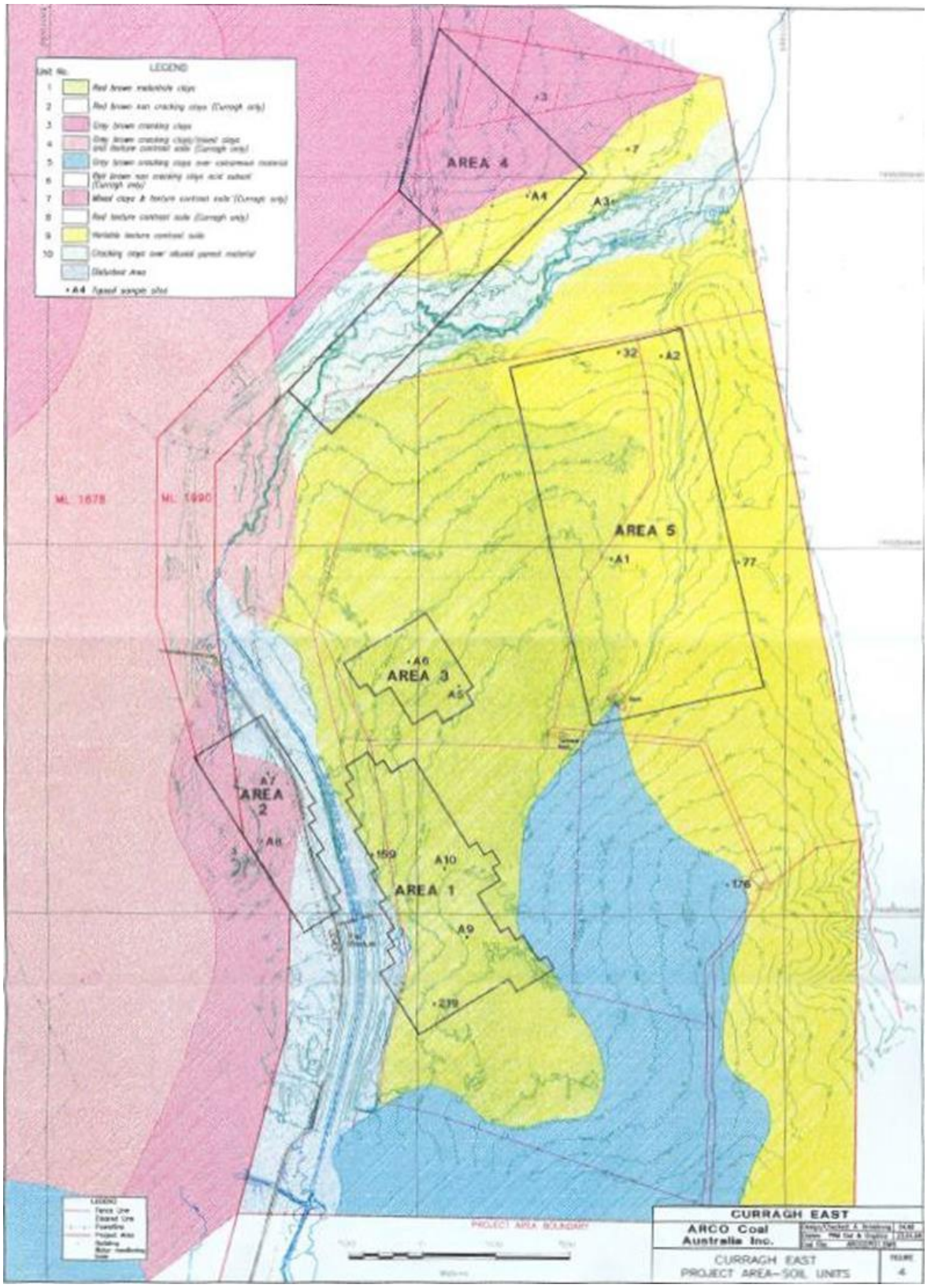


Figure 2-8 Curragh East Soil Types

Three primary soil types were identified using the diagnostic criteria of the *Australian Soil Classification* (Isbell, 1996). The three soil types were allocated into a corresponding Agricultural Management Units (AMU) relevant to the Dawson/Callide District within the Land Management Manual. General trends included:

- Increased clay content in the northern section of the Project Area and progressively decreased in the south;
- Increased CEC within the north section of the Project Area which decreases as the clay content decreases;
- Increased sodicity within the southern section of the Project Area; and
- Decreased effective depth towards the southern section of the Project Area.

Soil Classification

Australian Classification	Agricultural Management Unit	Physical Property Summary	Chemical Property Summary
Black Vertosol	Dee	Black to brownish black self mulching heavy clay. Structure changing with depth from gradual to medium blocky. Effective depth typically beyond 1m.	Alkaline (pH min 6.5, max 8.6, avg 7.8), non-sodic (ESP % min 1.0, max 9.7, avg 3.9) non-saline (EC µS/cm min 34, max 261, avg 130). High CEC (meq/100g min 14.8, max 71.3, avg 38.9).
Black or Brown Chromosol	Callide	Light clay to clay loam A horizon graduating to medium to heavy clay subsoil. Effective depth typically beyond 1m.	Neutral to slightly alkaline (pH min 6.3, max 8.9, avg 7.4), non-sodic (ESP % min 0.4, max 9.75, avg 3.9), non-saline (EC µS/cm min 33, max 353, avg 98) Moderate to high CEC (meq/100g Min 11.3, Max 91, Avg 27.1).
Sodosol	Oombabeer	Sandy clay to clay loam A horizon graduating to medium clay subsoil. Duplex soils. Alluvial influence apparent. Effective depth typically 0.6m to 1.0m.	Neutral to slightly alkaline (pH3 min 6.4, max 8.4, avg 7.2), sodic (ESP % min 2.9, max 18.5, avg 10.3), non-saline (EC µS/cm min 11, max 81, avg 43.5) very low to low CEC (meq/100g min 3, max 12.6, avg 6.9).

Figure 2-9 Soil Classifications at Curragh Mine following the Australian Soil Classification and Agricultural Management Units relevant to Dawson/Callide District Land Management Manual

Curragh North

In 2003, a soil survey of the Curragh North Project (ML80110 and ML 80123) site was conducted by Australasian Resource Consultants Pty Ltd as part of a study of the existing environment for the Curragh North project. The results of this survey included the results of soil sampling undertaken in 1996, 1998 and 2003. In total, 61 samples were collected in these previous sampling episodes. Based on field and laboratory assessment, the soil

types identified at Curragh North have been mapped into 4 different mapping units (**Table 2-6** and **Figure 2-10**).

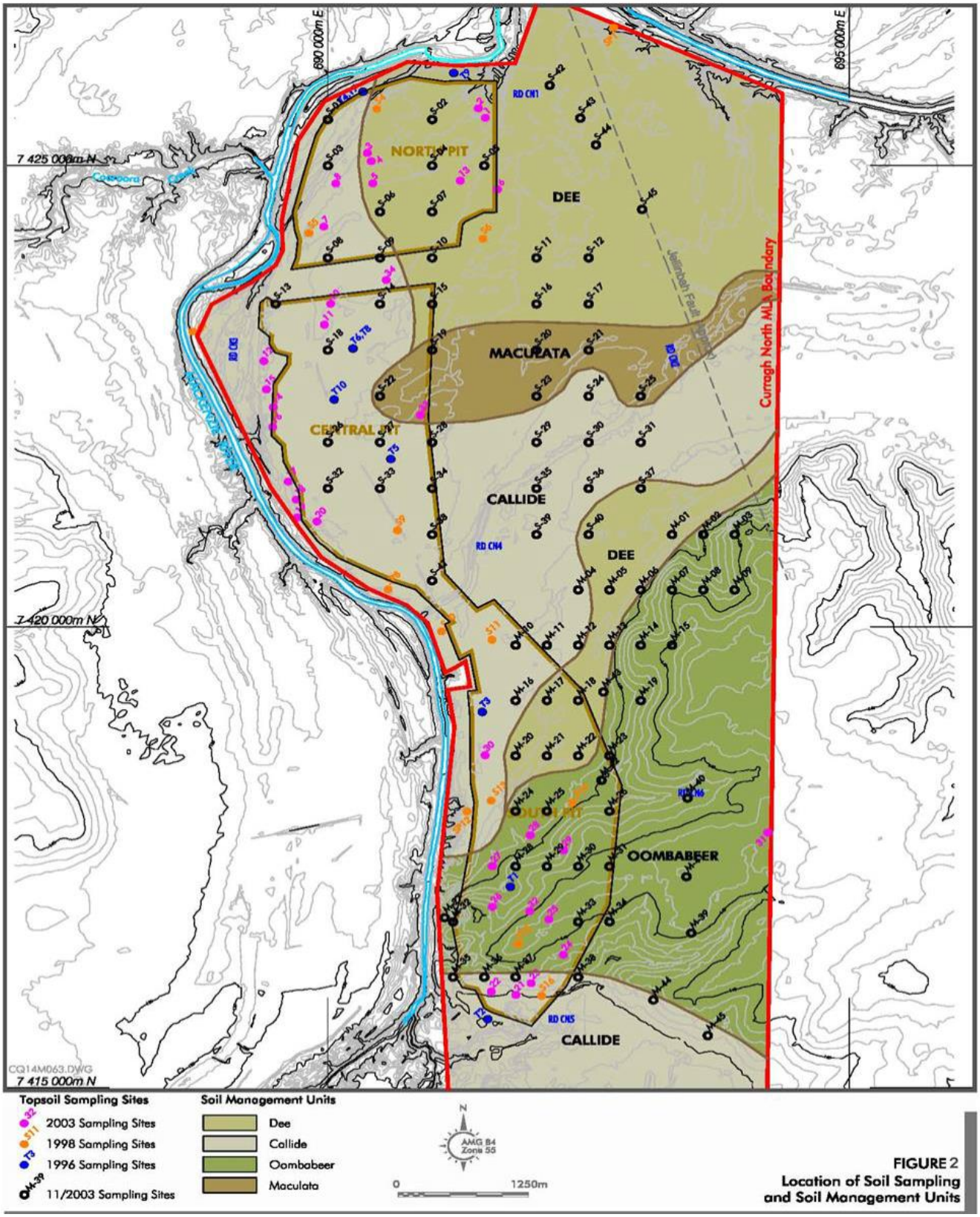


FIGURE 2
Location of Soil Sampling and Soil Management Units

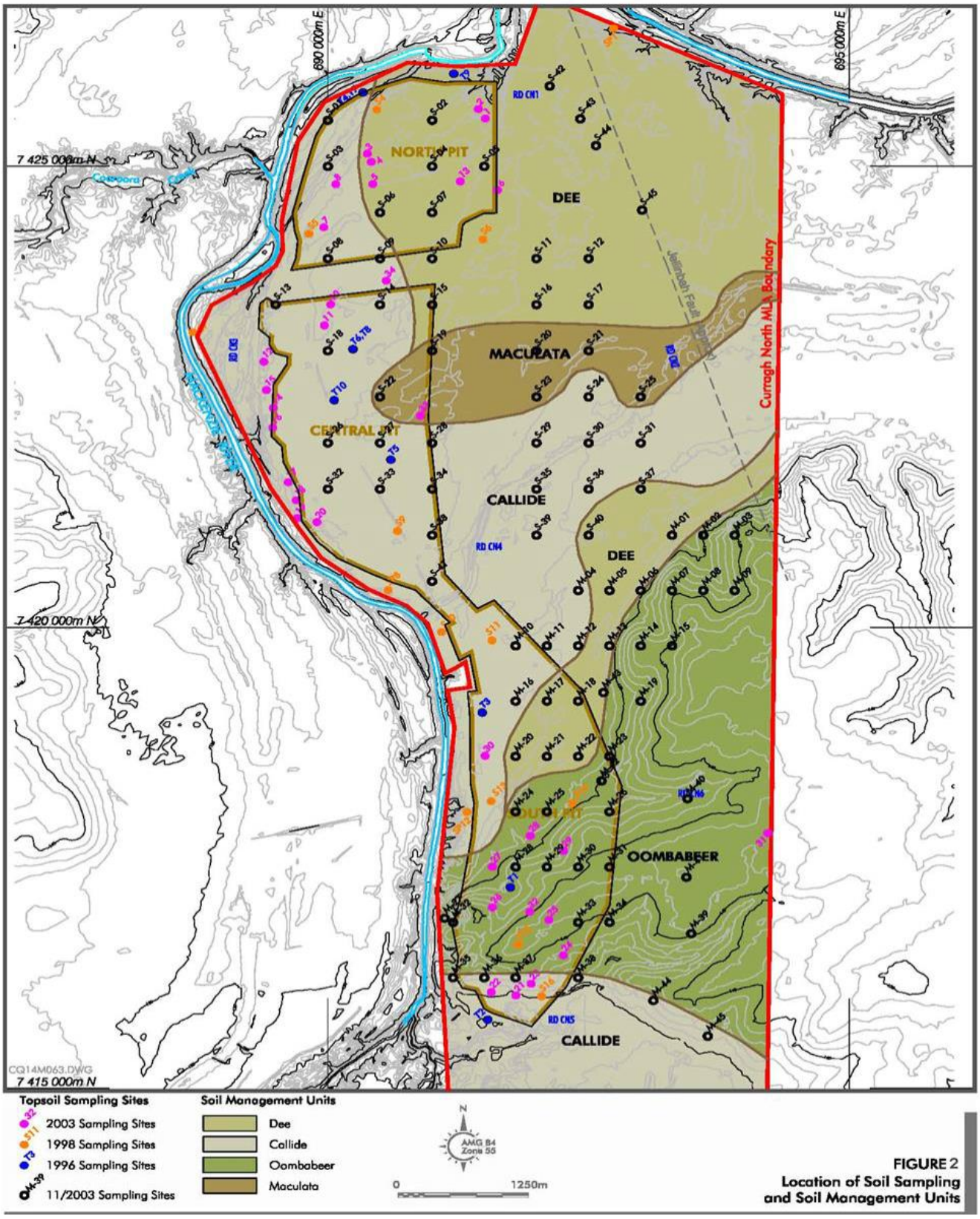


Figure 2-10 Curragh North Soil Management Units

Table 2-6 Curragh North Soil Types

Soil Type	Soil Description
Soil Type 1	• Grey to reddish brown self-mulching clays with a moderate to strong pedal structure with some calcareous inclusions. • The majority of this area has been cleared for low intensity grazing on improved pastures. The topography is of low relief with slopes tending to be less than 2%. This soil type constitutes the Dee soil management unit. • Structure changes with depth to become massive typically at a depth of approximately 30cm. The soil is alkaline to strongly alkaline, non-saline, of low sodicity and a high cation exchange capacity. Calcareous inclusions occur at depths below approximately 30cm.
Soil Type 2	• Light clay to clay loam A horizon (grey to dark reddish brown) graduating to medium to heavy clay subsoil. Moderately pedal structure is typical throughout the profile. • The area has previously been cleared for low intensity grazing. The topography is generally of low relief with slopes tending to be less than 2%. • The area is characterised by grey to dark clay loam to light clay with occasional cracking. The surface is firm and is typically moderately pedal. Peds are less than 20 mm in size. The A horizon is approximately 30 cm in depth, below which a sharp texture and colour change of the lower horizon can be found. Colour becomes darker and texture increases to medium to heavy clays. • The soil is typically slightly acid to neutral with pH increasing with depth. The soils are non-sodic and are of moderate to high cation exchange capacity. This soil constitutes the Callide soil management unit.
Soil Type 3	• Loamy sand to clay loam A horizon (dark reddish grey to black) underlain by sandy loam to silty clay loam horizons. Structure is typically moderate to strongly pedal and polyhedral in nature. • Native vegetation has been cleared from this soil type for low intensity cattle grazing. The topography is of low relief with slopes of less than 2% common. • This soil is typified by loamy sand to clay loam a horizon of approximately 20 cm in depth. The A horizon is dark reddish grey to black in colour. Underlying the A horizon is a sandy loam to silty clay loam horizon which is darker in colour than the A horizon. The boundary between horizons is clear in nature. A polyhedral structure of moderate to strong pedality occurs throughout the profile. • pH of the A horizon is neutral to slightly alkaline, with the pH becoming more alkaline with depth. These soils are non-saline in nature and are of moderate fertility (CEC). This soil constitutes the Maculata soil management unit.
Soil Type 4	• Light yellowish brown to reddish black loamy sand to sandy loam A horizon of weak to moderate pedality overlying loamy sand to silty loam horizons. • Soil type 4 has been cleared of native vegetation for low intensity cattle grazing. Occurring on the upper ridges and steeper slopes of the proposed mining lease area, this soil type is found on gently to moderately inclined relief. • A loamy sand to sandy loam A horizon typifies this soil type. This horizon is generally light yellowish brown to reddish black in colour. The A horizon is of weak to moderate pedality. Underlying the A horizon is a horizon of slightly higher clay content (loamy sand to silty loam). The underlying horizon is also darker in colour and is only weakly pedal or a pedal (granular) in structure. The boundary between these horizons is abrupt.

Soil Type	Soil Description
	• These soils are slightly acid to slightly alkaline in the A horizon, with alkalinity increasing with depth. These soils are slightly to moderately sodic in the surface horizon with exchangeable sodium percent generally increasing with depth. Excessive salinity does not occur in these soils. This soil is one of the three soil types which constitute the Oombabeer soil management unit.
Soil Type 5	• Brown/dark brown A horizon of light clay with strong polyhedral pedality overlying a pale yellow massive B horizon. • This soil type occurs in a portion of the mining lease adjacent to the Mackenzie River on which native woodland is established. Cattle frequently graze this area. This soil type occurs on slopes with a slope of less than 2%. • The A horizon of this soil consists of a brown/dark brown light clay with strong polyhedral (< 20mm) pedality. A pale yellow massive B horizon underlies the A horizon. The boundary between horizons is gradual. • These soils are moderately alkaline in the A horizon, with alkalinity increasing with depth. This soil type is also non-sodic in nature and is of moderate fertility. Salinity is not a limitation to plant growth on this soil. This soil is one of the three soil types which constitutes the Oombabeer soil management unit.
Soil Type 6	• Weak red to dark reddish grey A horizon of loamy sand to clayey sand texture overlying a weak red to pinkish grey B horizon with a single grain apedal structure. Each of these soil types is described below. • This soil type has been cleared for low intensity cattle grazing. Improved pastures are found on this soil type. This soil type occurs on low relief with slopes tending to less than2%. • A weak red to dark reddish grey loamy sand to clayey sand constitutes the A horizon of this soil. This horizon is characterised by a weak pedal structure with peds less than 10 mm. The underlying horizon is a weak red to pinkish grey loamy sand with granular apedal structure. A gradual boundary separates the horizons. • This soil is neutral to moderately alkaline with pH increasing with depth. The soil is also non-sodic, non-saline and of low cation exchange capacity (fertility). This soil is one of the three soil types which constitute the Oombabeer soil management unit.

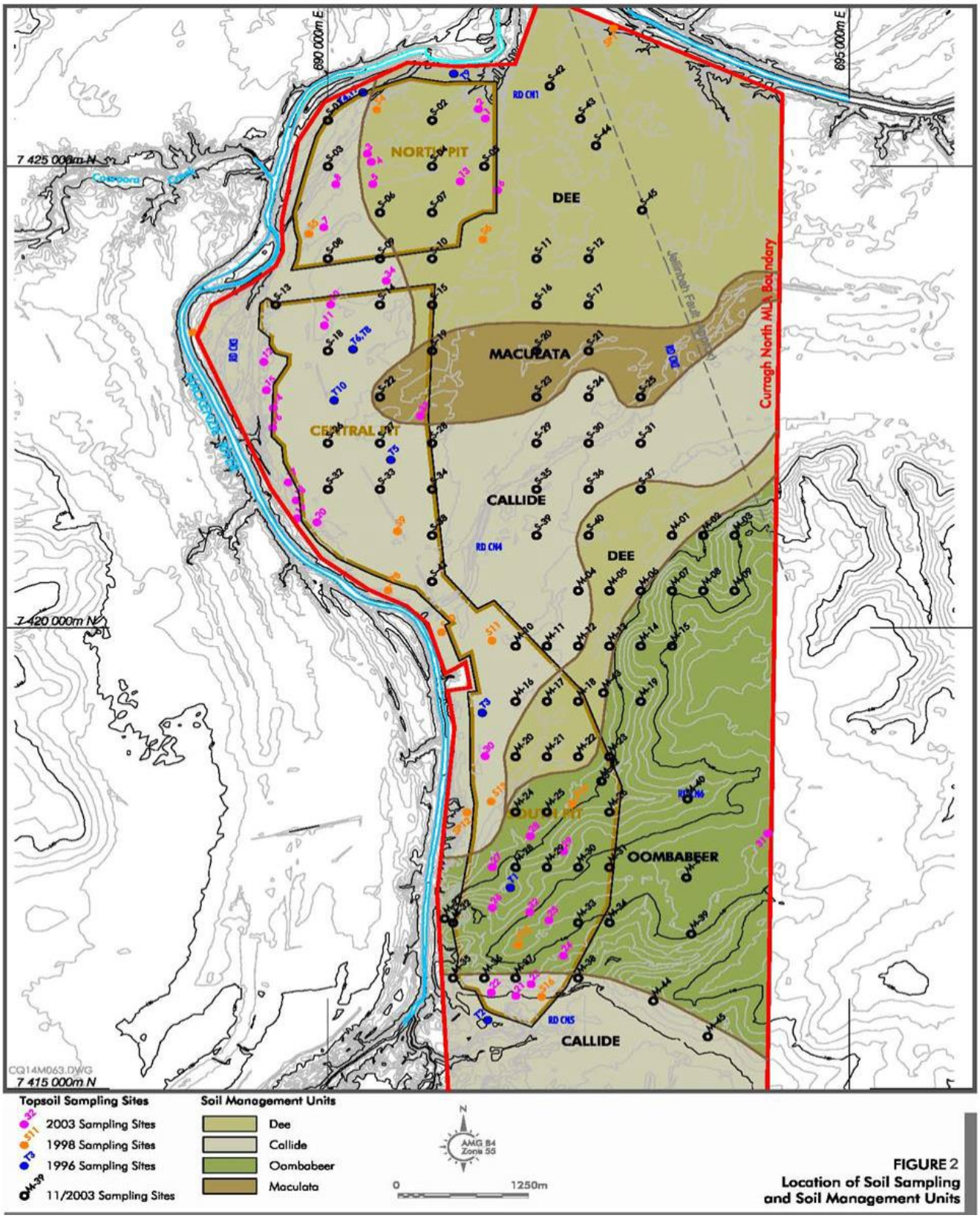


Figure 2-11 Curragh North Soil Types

Curragh West

Existing soils data for Curragh West (ML 80171) is limited to broad-scale mapping based on aerial photo interpretation and limited regional scale fieldwork. A soil investigation was conducted to determine soil types and a summary included in the 2011 Environmental Management Plan prepared by Parsons Brinckerhoff. Selected soil samples were tested to assess their acidity, salinity, dispersion potential, and nutrient content. The results were used to aid classification of individual soil types and to assess reuse potential of soils for future rehabilitation purposes.

Based on the investigation, three soil units were identified within Curragh West. The distribution of soil units is closely related to the topography and geomorphology of Curragh West. Abrupt boundaries between soil types generally do not occur. The three soil types are Grey duplex soils, Grey-brown uniform clays, and Red-brown uniform clays.

Alkaline and sodic soils are generally dispersive and have high erosion potential if exposed. Sodic, alkaline soils are also poor plant growth mediums due to low nutrient availability and should not be used as such in rehabilitation of disturbed areas. The topsoil portion of all encountered soils, are considered suitable for use in rehabilitation however, all soils have some limitations. Subsoils of the Grey-brown duplex and Red-brown uniform clays are considered to be highly sodic and moderately to strongly alkaline. Subsoils of these soil units should not be used as topsoil for any rehabilitated areas. All soils (and overburden) that is alkaline or sodic should be buried below non-dispersive and non-hostile material.

All soils are subject to erosion if vegetation is removed and rehabilitation is not undertaken within an appropriate timeframe. Soils most susceptible to wind erosion are the Grey-brown duplex soils which have loamy topsoils.

The main erosion potential for the site relates to water-induced erosion, in the form of sheet flow and channelised flow. All disturbed sites will be susceptible to water erosion, regardless of slope gradient and whether the sites comprise natural or created terrain. Soils most susceptible to erosion by flowing water are the Grey-brown duplex soils and the Red-brown uniform clays, which have dispersive (sodic) topsoil or upper subsoil.

Curragh Extension Project

Soil data for the Curragh Extension Project (ML700006, ML700007, ML700008 and ML700009) was commissioned by WSP in 2015 by SLR Consulting Australia. Within the Study Area, one soil mapping unit (Soil Map Unit 1) was identified that contained three soil types (**Figure 2-12**):

- Self-mulching Brown Vertosol (dominant);
- Self-mulching Black Vertosol (sub-dominant) and
- Eutrophic Brown Dermosol (sub-dominant).

The Self-mulching Brown Vertosol is characterised by silty clay grading to heavy clay or uniform clay throughout the profile. This soil type is generally alkaline throughout the profile and exhibits increasing concentrations of chloride with depth, reaching extreme soil salinity levels. The profiles are generally non-sodic in the topsoil and marginally strongly sodic in the subsoil.

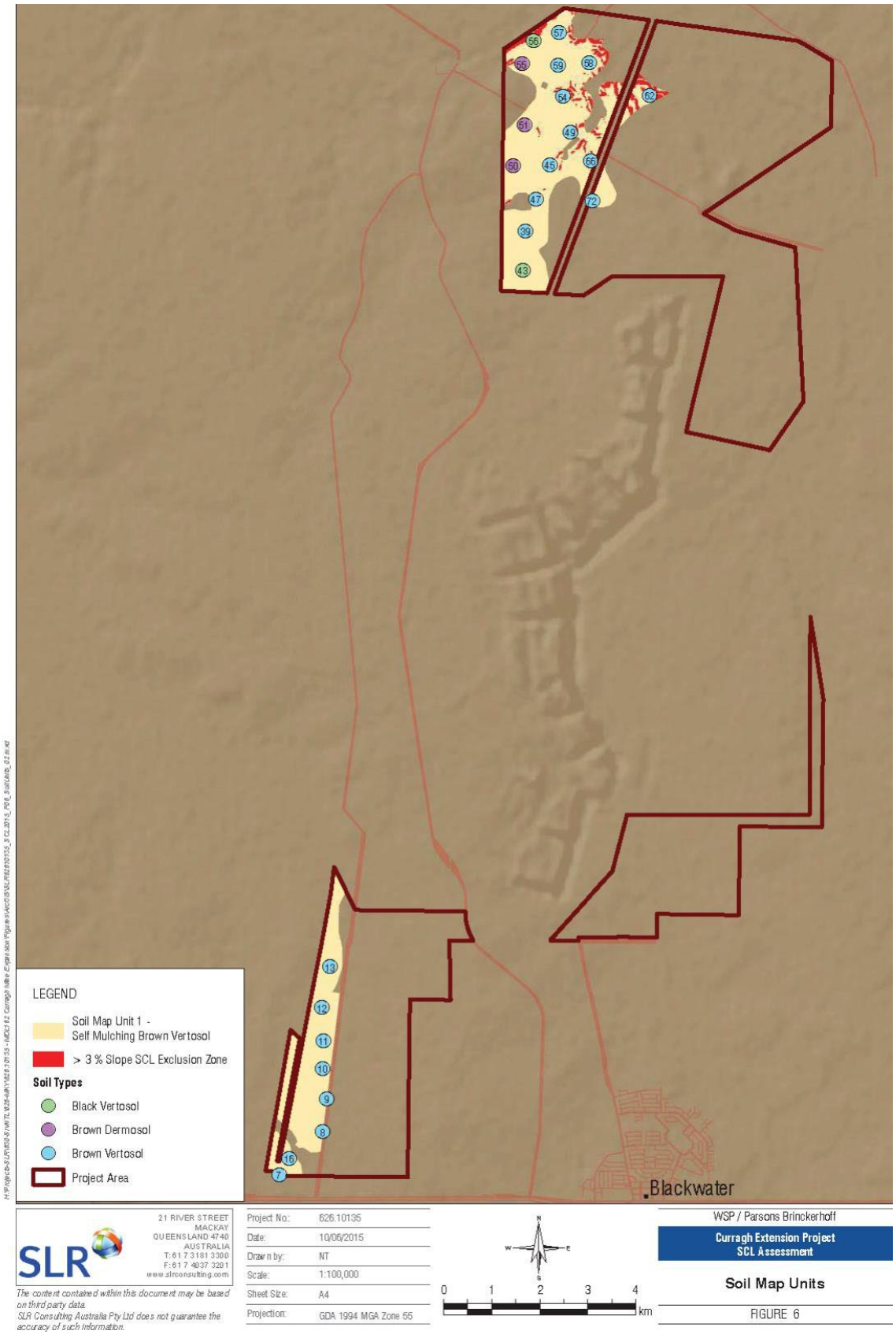


Figure 2-12 Curragh Extension Soil Management Units

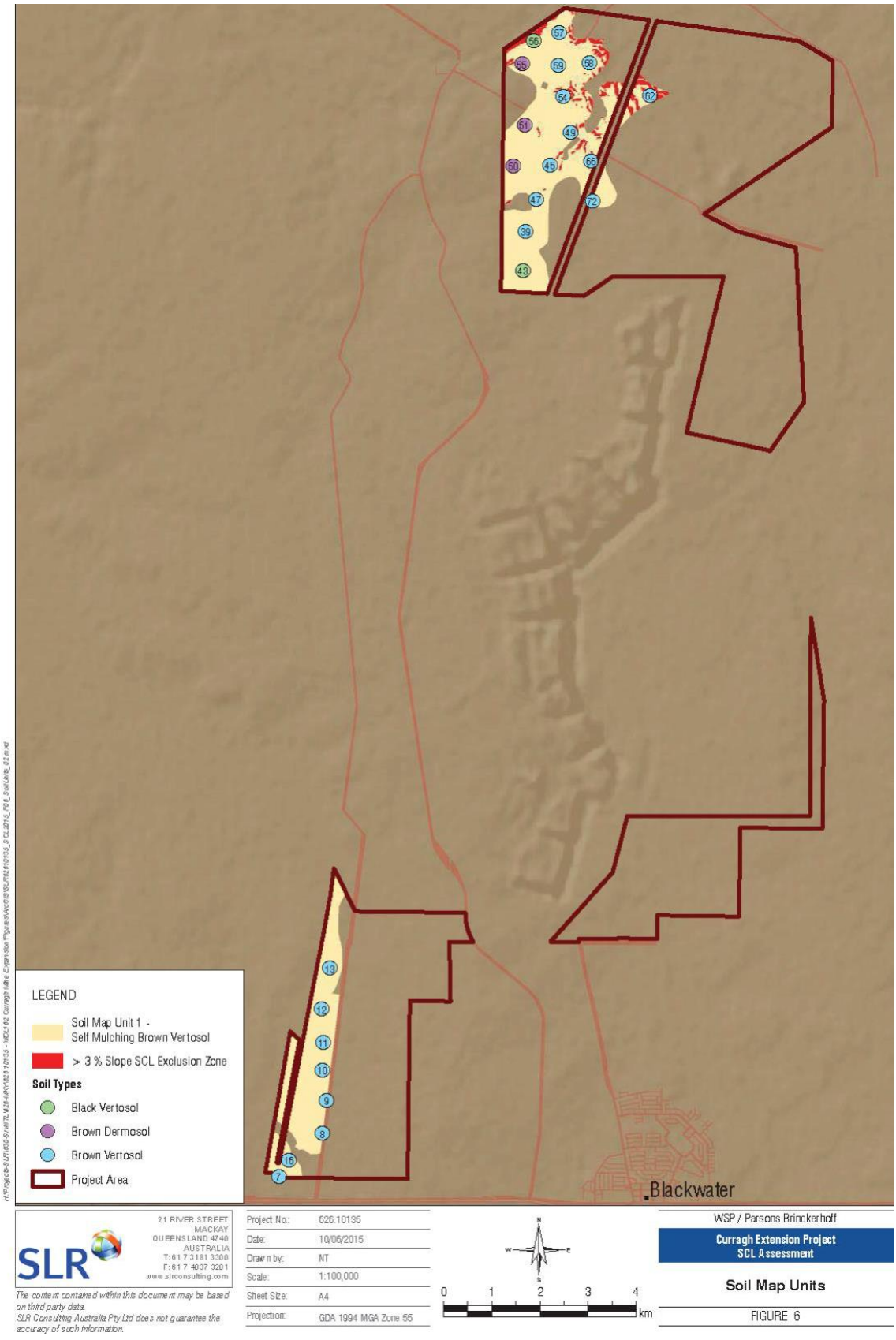


Figure 2-13 Curragh Extension Soil Types

2.2.5 Land Suitability

A land suitability assessment was undertaken within the Curragh North EIS. The assessment included considerations of land use characteristics, land quality attributes and how these match conditions necessary for successful and sustained land utilisation types.

A summary of the land suitability classes for the project area is presented below (Curragh North EIS, 2003).

Table 2-7 Land Suitability Classes present at Curragh Mine

Suitability for Cropping	Suitability for Grazing	Percentage of Project Area
2	1	3.0
3	2	68.6
4	3	28.4

The post mining land capability classes were assessed as the below:

Table 2-8 Post Mining Land Capability Classes at Curragh Mine (Coronado Curragh, 2021)

Class	Description	Hectares
IV	Land primarily used for pastoral uses but can be carefully cropped occasionally	89
VII	Land not suitable for cultivation and only careful pastoral use possible	1,823
VIII	Land not suitable for agricultural or grazing uses	10,789

2.2.6 Ecology

2.2.6.1 Terrestrial Flora

The Vegetation Management Supporting Map (DRNME, 2019) shows that the study area contains five (5) remnant vegetation communities, which are identified below in **Table 2-9**. These communities are mapped to occur as isolated mixed vegetation community polygons characterised as Regional Ecosystems (RE), with the surrounding area dominated by non-remnant vegetation. Field Studies in 2003 identified two (2) further RE communities listed under the Queensland *Vegetation Management Act 1999*. Therefore, there are seven (7) RE's present within the Curragh Project Area.

Table 2-9 Regional Ecosystem Classes present at Curragh Mine

RE Code	VM Act Status	Biodiversity status	REDD Short Description
RE 11.3.1	Endangered	Endangered	*Acacia harpophylla* and/or *Casuarina cristata* open forest on alluvial plains

RE Code	VM Act Status	Biodiversity status	REDD Short Description
RE 11.4.8	Endangered	Endangered	*Eucalyptus cambageana* woodland to open forest with *Acacia harpophylla* or *A. argyrodendron* on Cainozoic clay plains
RE 11.4.9	Endangered	Endangered	*Acacia harpophylla* shrubby woodland with *Terminalia oblongata* on Cainozoic clay plains
RE 11.4.7 (field mapped)	Endangered	Endangered	*Eucalyptus populnea* with *Acacia harpophylla* and/or *Casuarina cristata* open forest to woodland on Cainozoic clay plains
RE 11.3.3	Of Concern	Of Concern	*Eucalyptus coolabah* woodland on alluvial plains
RE 11.3.25	Least Concern	Of Concern	*Eucalyptus tereticornis* or *E. camaldulensis* woodland fringing drainage lines
RE 11.7.1 (field mapped)	Least Concern	Of Concern	*Acacia harpophylla* and/or *Casuarina cristata* and *Eucalyptus thozetiana* or *E. microcarpa* woodland on lower scarp slopes on Cainozoic lateritic duricrust

Curragh has five environmental management areas that are requirements of conditions of approval under the two separate referrals under the Commonwealth *EPBC Act 1999* (**Figure 2-14**). These environmental management areas and the relevant referrals involve:

- Curragh North Coal Mine (EPBC 2003/1096);
    - Brigalow Management Area (55ha) – Condition 2,
    - Brigalow Rehabilitation Area (37ha) – Condition 2, and
    - Transport Corridor Management Area (17ha) – Condition 1.
- Blackwater Creek Diversion and Coal Mine (EPBC2007/3925);
    - Northern Brigalow Area (44.9ha) – Condition 1, and
    - Northern Brigalow Revegetation Area (21.4ha) – Condition 1.

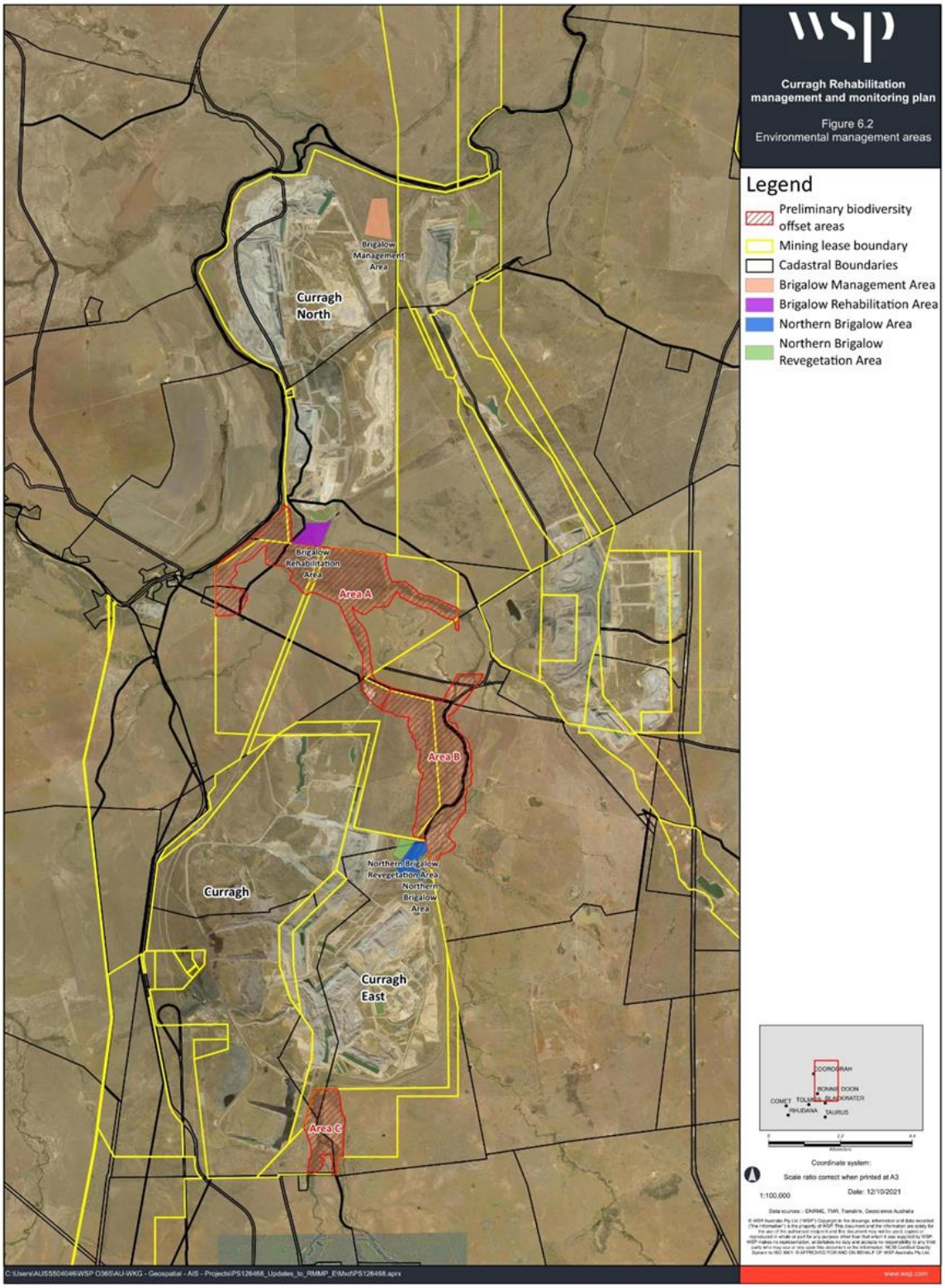


Figure 2-14 Environmental Management Areas at Curragh Mine

2.2.6.2 Flora and Fauna

The riparian vegetation is generally dominated by native species; however, the conditions are poor to moderate due to high disturbance and clearing, combined with low-instream diversity, moderate to extensive bank erosion and fine-sediment dominated substrates (Curragh North EIS, 2003).

Studies of terrestrial vegetation were taken in 1998, 2001 and 2003 by AustralAsian Resource Consultants Pty Ltd (AARC) and within these studies, six vegetation communities were identified on the Project site (**Figure 2-15**):

- Community 1: Fringing River Red Gum (*Eucalyptus camaldulensis*) tall woodland on alluvial plains;
- Community 2: Open Coolabah (*Eucalyptus coolabah*) woodland with a predominantly grassy understorey;
- Community 3: Brigalow (*Acacia harpophylla*) woodland with Yellowwood (*Terminalia oblongata*);
- Community 4: Poplar Box (*Eucalyptus populnea*) and Dallachy's Gum (*Corymbia dallachiana*) open woodland;
- Community 5: Lemon-scented Gum (*Corymbia citriodora*) woodland with Rosewood (*Acacia rhodoxylon*); and
- Community 6: Open Grassland with Scattered Trees.

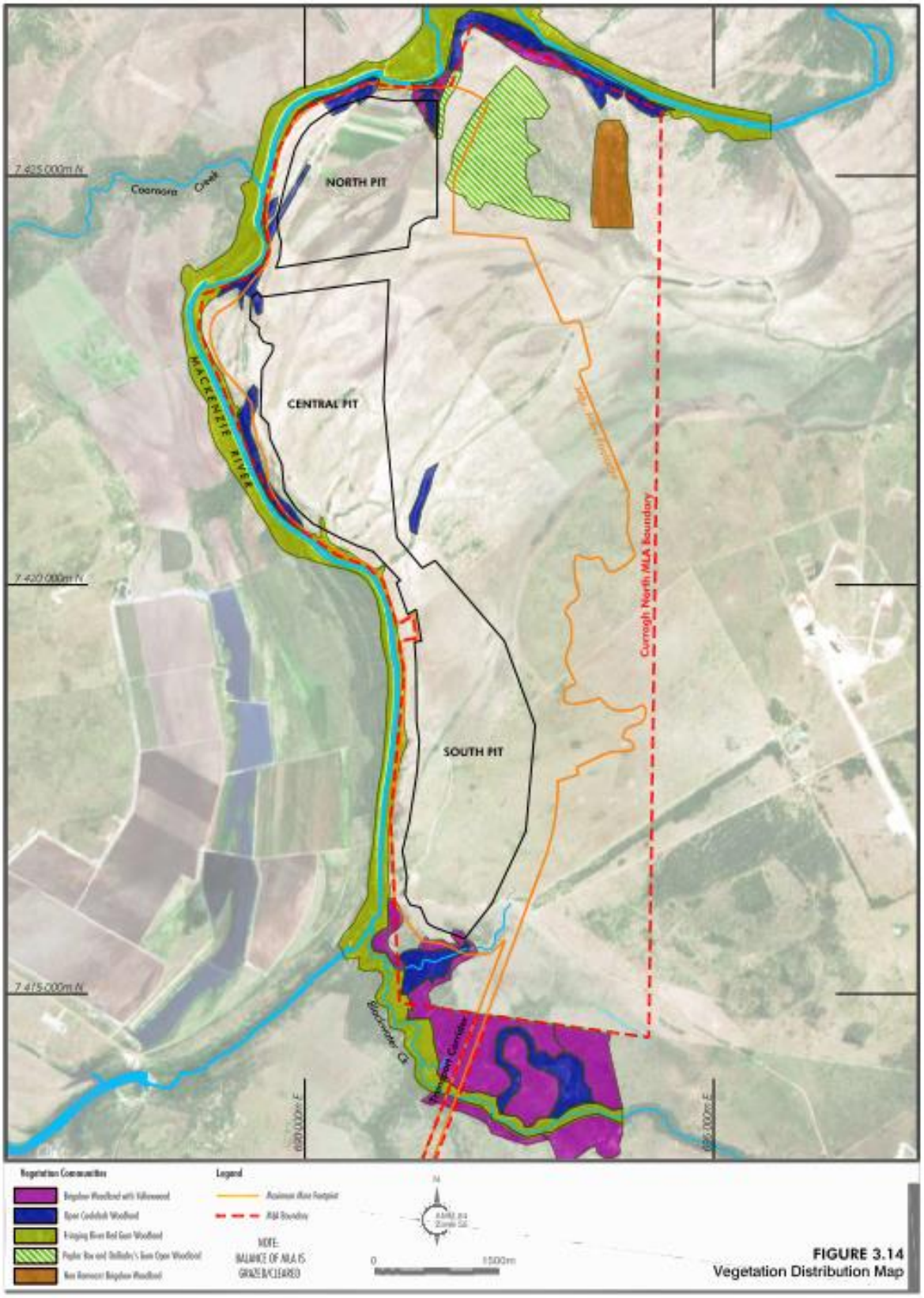


Figure 2-15 Vegetation Communities mapped for Curragh North

During the 1998, 2001 and 2003 AARC surveys a total of 198 fauna species were observed or recorded including 14 butterflies, 15 amphibians, 22 reptiles, 120 birds and 27 mammals were identified.

The following species of conservation significance were recorded at the Curragh project:

- Brigalow Scaly-Foot (*Paradelma orientalis*) (no longer listed);
- Ornamental Snake (*Denisonia maculata*);
- Squatter Pigeon (*Geophaps scripta scripta*) – Vulnerable under EPBC Act; and
- Little Pied Bat (*Chalinolobus picatus*). (no longer listed).

Six species of 'declared plants' under the Queensland *Land Protection (Pest and Stock-route Management) Act 2002* during the field surveys for the Curragh Project, which are included below (**Table 2-10**).

Table 2-10 Declared Plants under the Queensland Land Protection (pest and Stock-route Management) Act 2002 at Curragh Mine

COMMON NAME	BOTANICAL NAME	DECLARED STATUS*
Parthenium weed	*Parthenium hysterophorus*	Class 2
Parkinsonia	*Parkinsonia aculata*	Class 2
Prickly Pear	*Opuntia* sp	Class 2
Mother of Millions	*Bryophyllum tubiflorum*	Class 2
Harrisia Cactus	*Eriocerus* sp	Class 2
Rubber Vine	*Cryptostegia grandiflora*	Class 2

2.2.7 Surface Water

Mackenzie River

The project is located within the Mackenzie River catchment (**Figure 2-16**), which forms at the confluence of the Nogoa and Comet Rivers, is a major tributary of the Fitzroy River which flows through Rockhampton into the Coral Sea (Parsons Brinckerhoff, 2015). The project area is surrounded by ephemeral waterways such as Blackwater Creek and Sagittarius Creek which drain north and north-west to the Mackenzie River (Coronado Curragh, 2021).

The catchments are bordered by the Expedition Range to the east, the Great Dividing Range to the south, the Drummond Range to the west and the Peak Range to the north. The total catchment area of the Mackenzie River to the Bingegang Weir (downstream of project boundary) is approximately 50,960km^2. The catchment areas of the tributaries at the upstream end of the Mackenzie River are approximately 28,550km2 for Nogoa River and 16,510 km^2 for Comet River (SLR, 2021a).

During the dry season, flows are controlled by the upstream structures, including Fairbairn Dam and the Bedford Weir and are usually within the river channel typically a flow width of 30-40 m. During the wet season, flow widths can reach 200-300m during frequent rainfall (Parsons Brinckerhoff, 2004).

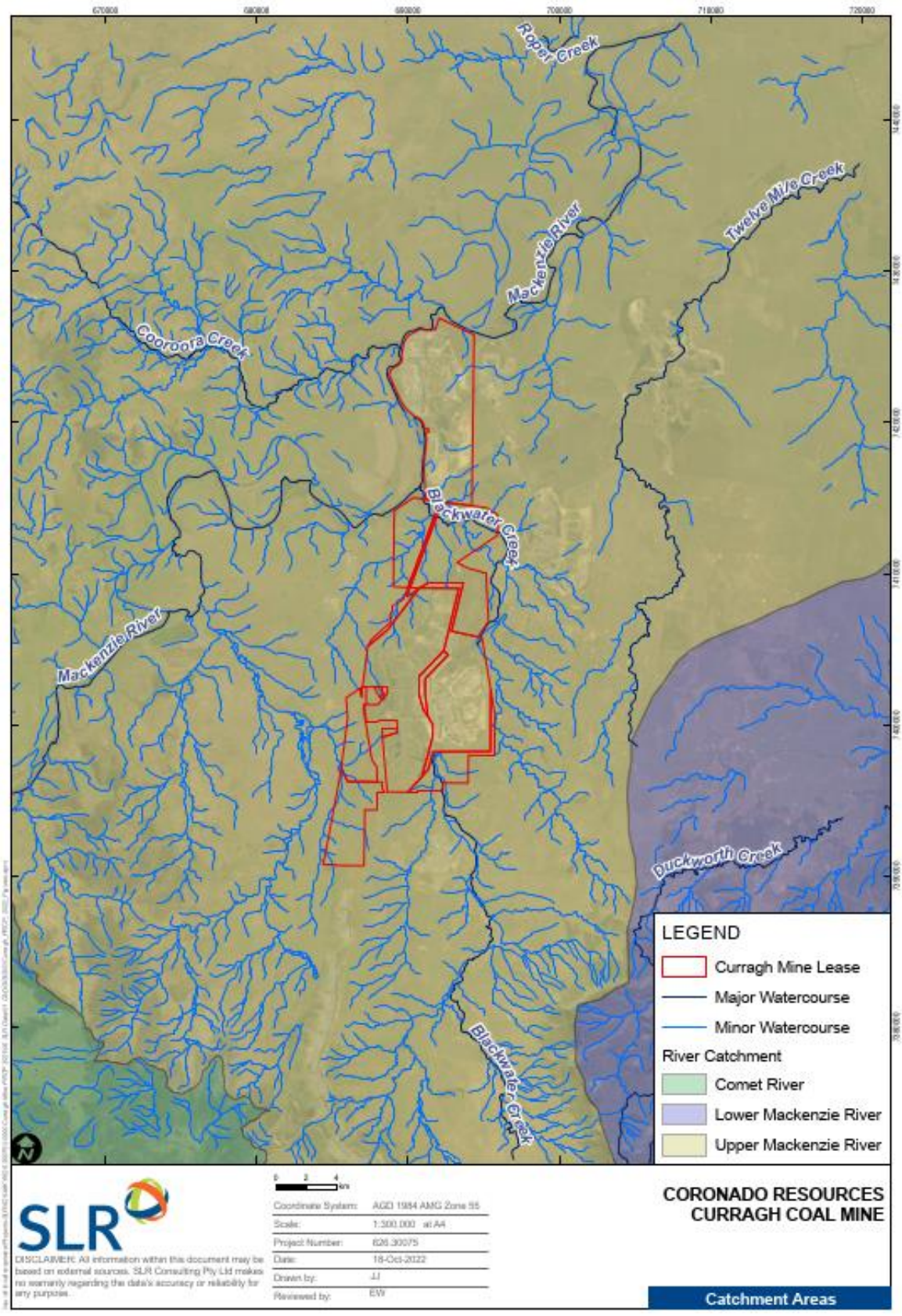


Figure 2-16 Curragh Catchment

Water quality in the Mackenzie River sub-catchment (including Project Area) has previously been categorized as poor to moderate due to (Parsons Brinckerhoff, 2015):

- Turbidity higher than the relevant water quality guidelines;
- Electrical conductivity higher than the relevant water quality guideline;
- Dissolved oxygen that typically lower, but sometimes higher than the water quality guidelines;
- Concentrations of metals (including dissolved aluminium, copper, chromium, iron, lead, silver, zinc and uranium) higher than the relevant water quality guidelines; and
- Concentrations of nutrients (nitrogen and phosphorus) higher than the relevant water quality guidelines.

Blackwater Creek

Blackwater Creek is the main local tributary draining into Mackenzie River about 3.3 km downstream of the Bedford Wier (1 km upstream of project boundary), which flows in a northerly direction through the Project site (SLR, 2021a).

Blackwater Creek has undergone a number of diversions, the last of which was completed in December 2009 to allow for access to additional coal reserves while maintaining the watercourse corridor through the area (Lanyonscapes, 2019). Blackwater Creek has Curragh Coal Mine and numerous other mines (Jellinbah, Curragh, BMA Coal & Cook Mine) dissecting its flow. During the wet season, Blackwater Creek only exhibits intermittent short duration flows.

Just downstream of the diversion around Curragh Main and to the east of the proposed Pit X, Blackwater Creek becomes an ephemeral braided channel system.

Tributaries of Blackwater Creek include Taurus Creek, Sagittarius Creek, Minnie Creek and Bullock Creek, all of which are ephemeral. Minnie Creek flows through the proposed Pit X area and will be subject to a 5.3 km diversion near its confluence with Blackwater Creek plus a 2.9 km diversion of one of its unnamed tributaries around the western side of the pit prior to the commencement of mining in this area (PB 2016).

Minor Tributaries

There are several minor tributary systems of Blackwater Creek that traverse the mining area, and the total catchment area from these tributaries at the confluence of Blackwater Creek and Mackenzie Creek is some 1,082km^2 (SLR, 2021a). These tributaries include:

- Taurus Creek;
- Sagittarius Creek;
- Bullock Creek;
- Minnie Creek;
- Bonnie Doon Creek; and
- Burngrove Creek.

2.2.8 Groundwater

The main hydrostratigraphic units in the vicinity of the mine are described below, from the shallowest to the deepest/oldest:

- **Alluvium** – up to 30m thick in the north associated with the floodplain / channel deposits of the Mackenzie River. Thinner (up to 12 m), near extension Pit X and comprises clay, sand and gravel units. At Curragh Main and southern extension Pits up to 10 m thick but generally much thinner and predominantly clay and silt. The alluvium is dry in many areas. Unconfined water bearing sand and gravel may occur at the base of the alluvial sequence around Curragh North near proposed Pit X, but it is considered unlikely to be significantly water bearing where it occurs in the south of the mine.
- **Regolith** - unconsolidated surface layer of weathered rock which may provide a preferential flow pathway for groundwater. Occurs across the Project area at thicknesses between 5 and 15 m. Includes weathered residual rocks of the Duaringa and Emerald formations, Rewan Formation, Rangal Coal Measures and Burngrove Formation in areas of outcrop and sub-cropping alluvium. Variable permeability.
- **Cenozoic** (Tertiary Duaringa and Emerald formations) - Occurs around Curragh Main extension Pits X and D. Comprises cemented sands and gravels and sandstones, siltstones and mudstones. Water bearing zones may occur in more permeable layers, unconfined to semi-confined.
- **Rewan Group** - is a regional aquitard comprising mudstones interbedded with siltstone and fine to medium grained labile sandstone.
- **Rangal Coal Measures** - Occurs along the strike of the mine and is overlain to the east by the Rewan. Groundwater flow is primarily within the coal seams (via interconnected cleats and fractures), which are confined by low permeability overburden and interburden. The coal measures are highly faulted resulting in "compartmentalisation" with coal seams juxtaposed against lower permeability interburden limiting the lateral continuity of flow. Faults themselves may form barriers to flow or provide conduits.
- **Burngrove Formation** – outcrops/subcrops to the west of the mine dipping east below the Rangal Coal Measures. Groundwater flow occurs primarily via the coal seams and fractured sandstone units with low permeability siltstone and claystone forming aquitards. As with the RCM sequence it is considered to be highly faulted with coal seams juxtaposed against lower permeability interburden limiting the lateral continuity of groundwater flow. This Formation is considered the basement for the purposes of this assessment.

Groundwater quality data is generally available from late 2015 onward with limited data provided from before this time. Historically, groundwater quality monitoring was undertaken infrequently from 1997 to 2012 with the frequency increasing thereafter. Samples were analysed for electrical conductivity (EC), pH, major ions, nutrients, dissolved metals and hydrocarbons and water quality statistics for selected analytes are shown in **Table 2-11**.

Table 2-11 Currently available groundwater quality data

Screened Formation	Bore ID	Data availability	
		From	To
Alluvium	1309MB	28-10-2015	01-04-2020
Alluvium	1312MB	03-10-2019	03-10-2019
Alluvium	1426MB	30-10-2015	10-11-2020
Alluvium	1531MB	28-10-2015	13-05-2020
Alluvium	1410MB	03-03-2016	29-06-2018
Alluvium	1411MB	28-04-2016	11-06-2019
Tertiary (weathered)	1301aMB	30-01-2020	06-01-2021
Tertiary (weathered)	1302MB	03-10-2019	07-01-2021
Tertiary (weathered)	1303MB	03-10-2019	07-01-2021

Screened Formation	Bore ID	Data availability	
		From	To
Tertiary (weathered)	1304aMB	18-09-2013	13-06-2016
Tertiary (weathered Duaringa Fm.)	1419MB	06-08-2015	28-06-2018
Tertiary (weathered Duaringa Fm.)	1420MB	30-12-2016	20-06-2017
RCM	BH1	26-06-2000	09-11-2020
RCM	BH2	09-02-2000	16-11-2020
RCM	BH3	09-02-2000	11-11-2020
RCM (weathered)	1301bMB	03-10-2019	06-01-2021
RCM (weathered)	1304bMB	04-09-2013	06-01-2021
RCM	1529MB	06-08-2015	10-11-2020
RCM	1534MB	06-08-2015	09-12-2020
RCM	1536MB	16-04-2018	14-05-2020
RCM	1538MB	19-08-2015	11-11-2020
RCM	1539MB	29-10-2015	20-08-2018
Burngrove Fm.	BH4	09-02-2000	09-12-2020
Burngrove Fm. (weathered)	1323MB	07-01-2014	09-11-2020
Burngrove Fm. (weathered)	1417MB	05-08-2015	09-11-2020
Burngrove Fm. (weathered)	1418MB	22-06-2015	11-11-2020
Burngrove Fm. (coal seam)	1537MB	30-10-2015	10-11-2020

A Groundwater Dependent Ecosystem (GDE) is one in which the plant and/ or animal community is dependent on the availability of groundwater to maintain its structure and function. The BoM Groundwater Atlas (BoM, 2021) indicates areas of primarily low potential terrestrial GDEs / IDEs (inflow dependent ecosystems) associated with the riparian corridor of the Mackenzie River and, to a lesser extent, Blackwater Creek (**Figure 2-17**). These terrestrial GDEs are vegetation ecosystems that rely on the subsurface presence of groundwater.

The 2016 Parsons Brinckhoff assessment (due to its objective of assessing impacts associated with expansion), considered the potential for impacts on GDEs in considerable detail. The area of potential subsurface GDEs was assumed to be restricted to areas of saturated alluvium based on the results from the numerical groundwater modelling. It was also assumed that within the areas of saturated alluvium that groundwater dependence was related to the depth to the water table and vegetation rooting depth. The following criteria were used to refine the areas of likely and potential subsurface GDEs in the vicinity of the site:

- Where field verified and Queensland Herbarium mapped regional ecosystems associated with likely and potential GDEs intersected with modelled areas of saturated alluvium
- depth to groundwater within the area of saturated alluvium:
    - High – depth to groundwater within saturated alluvium <10 m
    - Possible – depth to groundwater within saturated alluvium between 10 and 20 m
    - Unlikely – depth to groundwater within saturated alluvium >20 m.

The assessment (PB, 2016) identified that much of the reach of the Mackenzie River and Cooroora Creek (tributary of the Mackenzie), within the model domain, and the northern reaches of Blackwater Creek, had a high potential to host terrestrial GDEs along the riparian corridor with a likely depth to groundwater of < 10m.

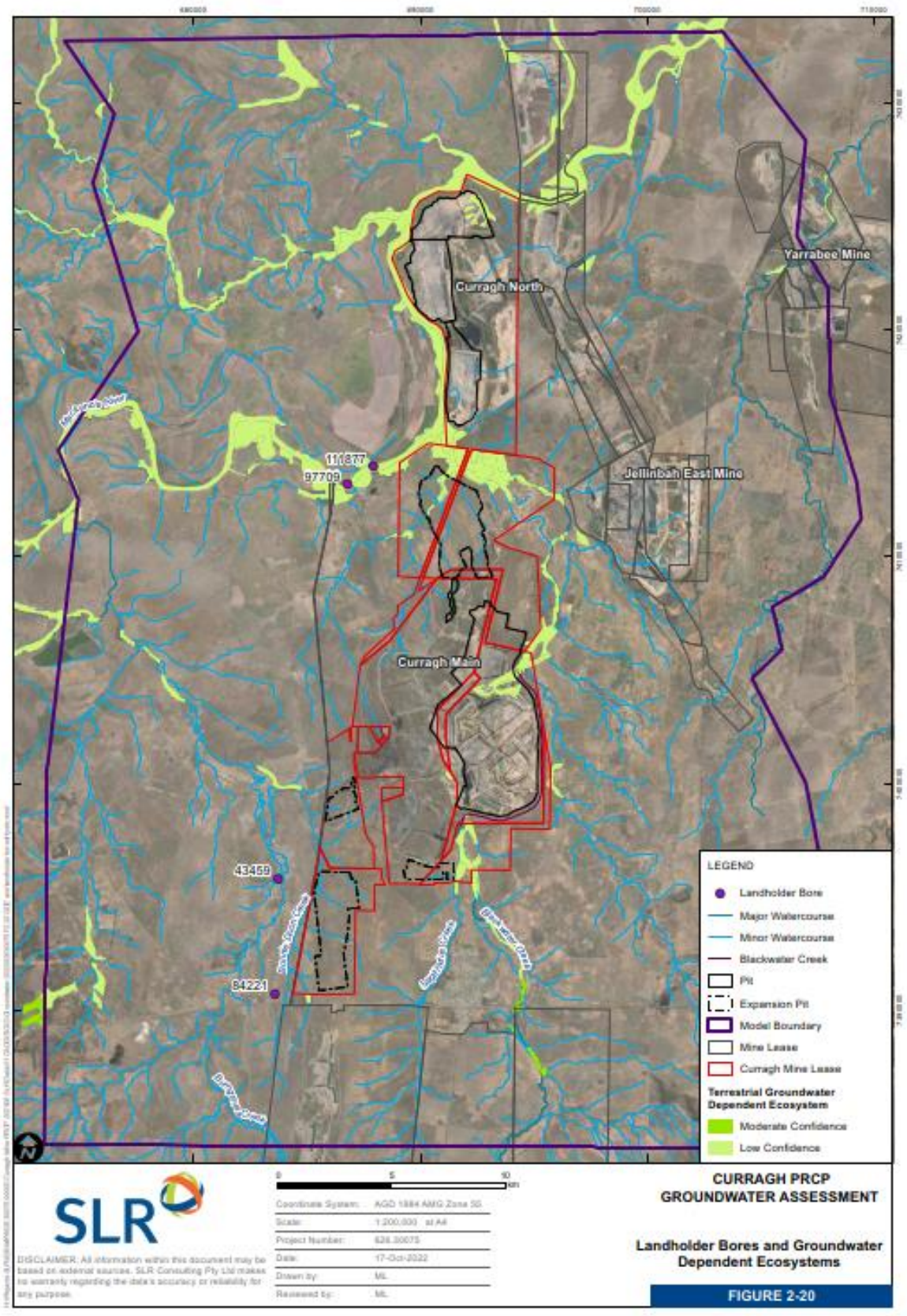


Figure 2-17 Groundwater monitoring network and GDEs

There are four registered bores within 3 km of Curragh mining operations (existing or proposed); details are presented in Table 2-12.

Table 2-12 Registered bores within 3km of Curragh mining operations

RN	Aquifer	Depth (m)	SWL (mbgl)	Water quality	Yield (L/s)	Installed
43459	-	-	-	-	-	-
84221	Burngrove Formation	31	30	salty	0.12	1988
97709	-	57	13	Fresh	3.2	1998
111877	Mackenzie River Alluvium	23	15			2002

RN111877 is owned by Central Highlands Regional Council and located at the campground approximately 150 m south of Bedford Weir on the Mackenzie River. The Council have indicated the bore is used to irrigate grass near and in the toilet block at the campground and that the groundwater is relatively saline. The bore is used to fill a 45,000 L tank 2 to 3 times each week (PB, 2016).

2.2.9 Land Use

The Curragh Complex is located in the Central Highlands Region Local Government Area (LGA) about 30 km north of Blackwater in Central Queensland. The Project is surrounded by land uses including low-intensity cattle grazing, irrigated cultivation and a variety of domestic, industrial and pastoral situations (Coronado Global Resources, 2019). Coal mines in the area include the Curragh Mine, Yarabee, Blackwater and Jellinbah East. Existing land use in the project area is predominantly cattle grazing with a small area at the north-east end historically used for irrigated cultivation. Overall pre-mining land use consisted of beef cattle grazing (85%), conservation (11%) and disturbed areas (4%) (Coronado Curragh, 2019).

Clearing for cattle grazing in the area has been extensive with remnant vegetation remaining on higher ridgelines, major creeklines and highly fragmented on open plains.

2.2.10 Underlying Landholders

The underlying landholders over Curragh mining leases is shown in **Figure 2-18**. Majority of the land is owned by CCPL with some land over Curragh North owned by a private landholder, Peter Dunn, and some land in Curragh East owned by the State of Queensland.

Overlapping Tenure

Overlapping petroleum tenure exists over the southern extents of the CCPL tenements. Under MERCPA 2014 legislation this entails annual information exchange and the provision and maintenance of Joint Information Management Plans with the overlapping tenement holder.

Sensitive Receptors

There are 13 sensitive receptors surrounding the Curragh Project, these are shown in **Figure 2-19**.

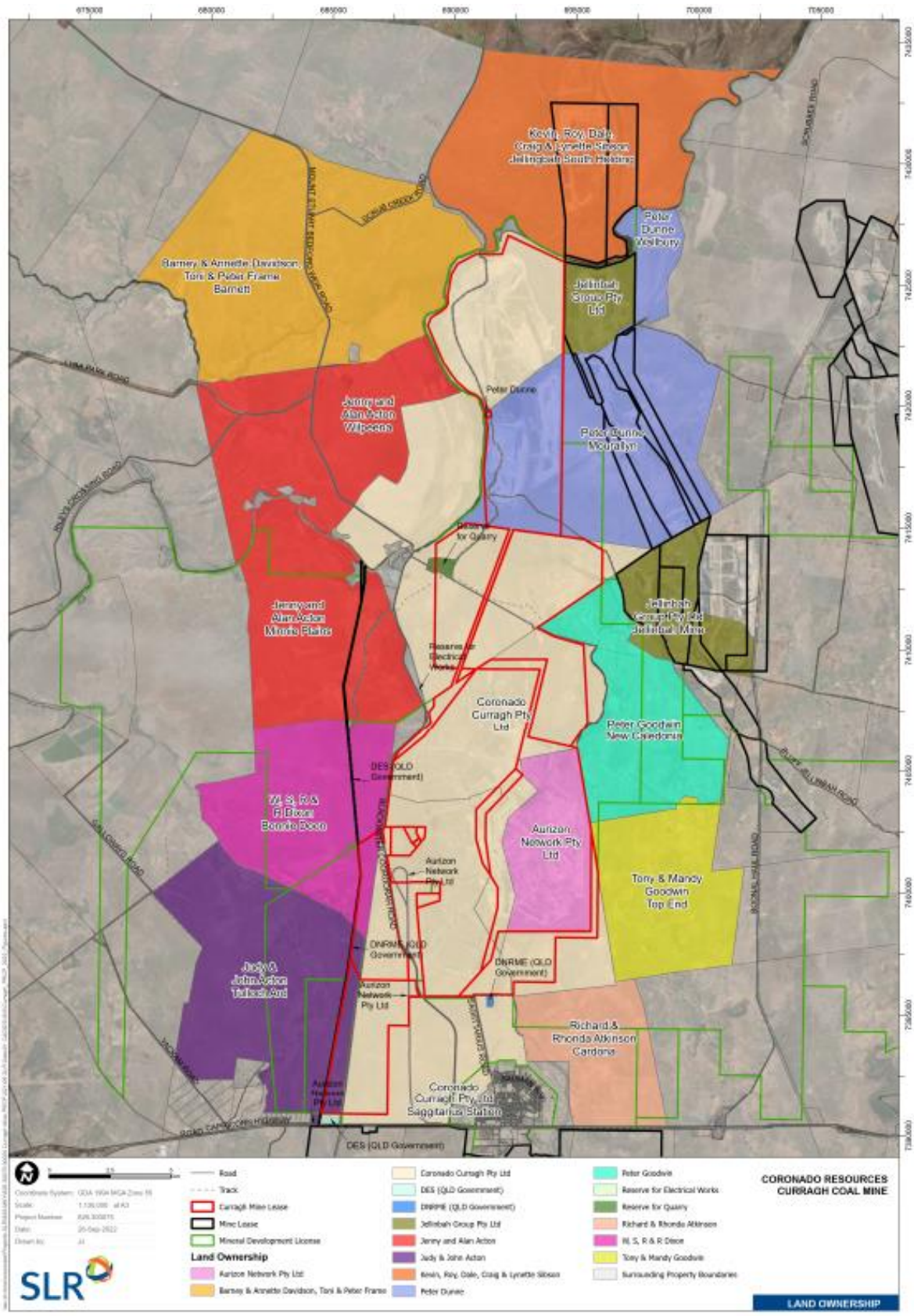


Figure 2-18 Underlying land holders

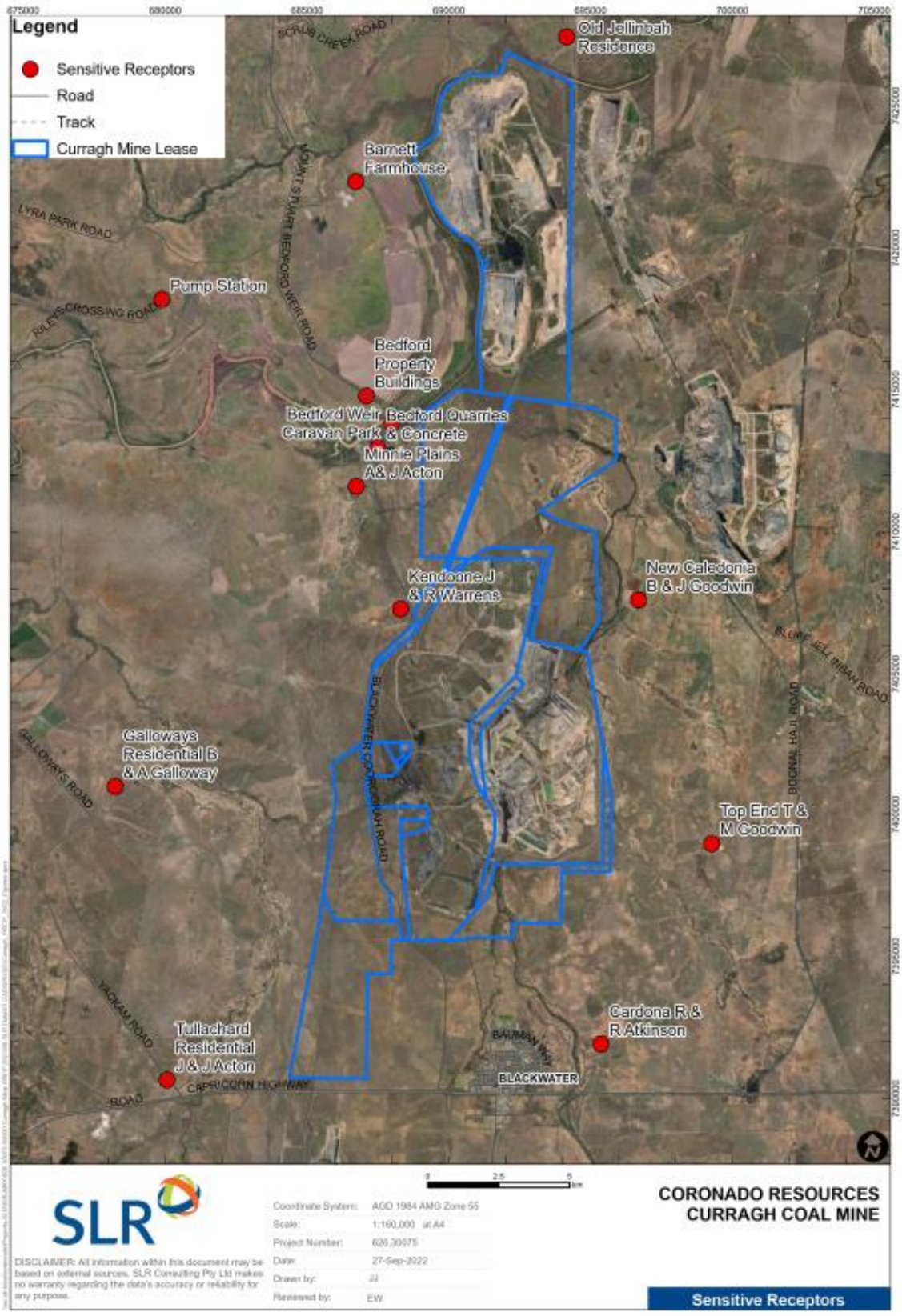


Figure 2-19 Sensitive Receptors

2.3 Design for Closure

Not applicable to existing operations.

2.4 Rehabilitation Planning

The current anticipated life of mine is to 2042. Progressive rehabilitation has already occurred on site and will continue to over the life of the mine. **Table 2-13** shows the key domains on site and the predicted duration of activities.

Table 2-13 Predicted Duration of Activities

Activities	Area (ha)	Predicted Duration of Mining Land Use	Progressive Rehabilitation
Overburden, in pit tailings, stable embankments, ramps	11,253	1985 - 2044	Progressive rehabilitation will occur throughout the mine life.
Voids/Pits	1,499	1985 - 2044	Reshaping of the void area will occur in conjunction with the surrounding overburden as mining in the pits is completed.
Infrastructure areas and miscellaneous activities (buildings, laydown yards, cleared areas, topsoil stockpiles, roads, access tracks, etc.)	542	1983 - 2049	Progressive rehabilitation of infrastructure and miscellaneous activities will be limited as most infrastructure will be required past the end of mining to support rehabilitation activities. Some areas such as topsoil stockpiles will be used throughout the mine life but it's hard to determine when these areas will become available.
Blackwater Creek Watercourse Diversion	185	Permanent structure constructed in 2010	The diversion was constructed in 2010 and will be maintained and monitored over the life of mine and be retained post closure.
Water Infrastructure	65	1983 - 2049	Water infrastructure will be required for the whole life of mine with little opportunity for progressive rehabilitation. The infrastructure may also be required some time after mining has ceased to support rehabilitation activities.
Out-of-pit Tailings Storage Facility (Old TSF)	185	1987 - 2015	There is the potential for tailings to be reprocessed and therefore the TSF is not considered to be available for rehabilitation yet.

CCPL has developed a rehabilitation schedule for the overburden and voids area based on the mine plan and availability of fleet resources. This schedule has been used to inform the PRCP schedule development.

2.5 Existing Rehabilitation

Progressive rehabilitation has been ongoing at Curragh since 1988 (CCPL, 2016). The University of Queensland Centre for Mined Land Rehabilitation (CMLR) undertook rehabilitation monitoring from 2002 to 2016. Since 2019, WSP has been conducting rehabilitation monitoring. Curragh Project currently has 1,264 ha of existing rehabilitation, predominantly in ramps and on placed overburden (**Figure 2-20**).

There is currently no certified rehabilitation at Curragh; however, in 2019 WSP undertook an assessment of existing rehabilitation with the purpose of identifying areas of rehabilitation that are performing at a level suitable for progressive certification application. The report focussed specifically on six areas identified by CCPL:

- Ramp 4 North 2005;
- Ramp 2 North 2002;
- Ramp 2 North SW2000;
- Ramp 7 North 1992;
- Ramp 9 North 1999; and
- Ramp 13 West 2008.

The assessment involved analysing remote sensing and GIS data as well as field based monitoring of existing transects. Based on the monitoring results WSP recommended a combined area of 75.4 ha from RAN2005, SW2000 and R2N2002 could be put forward for progressive certification.

Rehabilitation monitoring has been continued by WSP in 2020 and 2021. Both of these reports found that the rehabilitation was not yet conforming with completion criteria but was on a trajectory towards achieving this. A number of recommendations were made for ongoing monitoring and future rehabilitation, including but not limited to:

- The topsoil/spoil strip method is continued in a modified form (short strips/patches of strips) as it has proven to achieve stability and promote tree and shrub growth in the spoil strips due to the exclusion of topsoil, which supports rehabilitation progression towards a mixed open woodland/light grazing use.
- Establish additional reference sites that reflect a light grazing and open woodland use, ideally on a neighbouring grazed cattle property.
- Areas with a predominant grazing/open grassland outcome should be proposed in 100% topsoil areas.
- Any recalcitrant bare areas >0.1 ha, particularly where groundcover is underperforming, should be tested for soil quality and remediation plans be developed to enable these areas progress towards future certification.
- Buffel grass should be excluded from rehabilitation seed mix due to its impact on native tree and shrub recruitment.

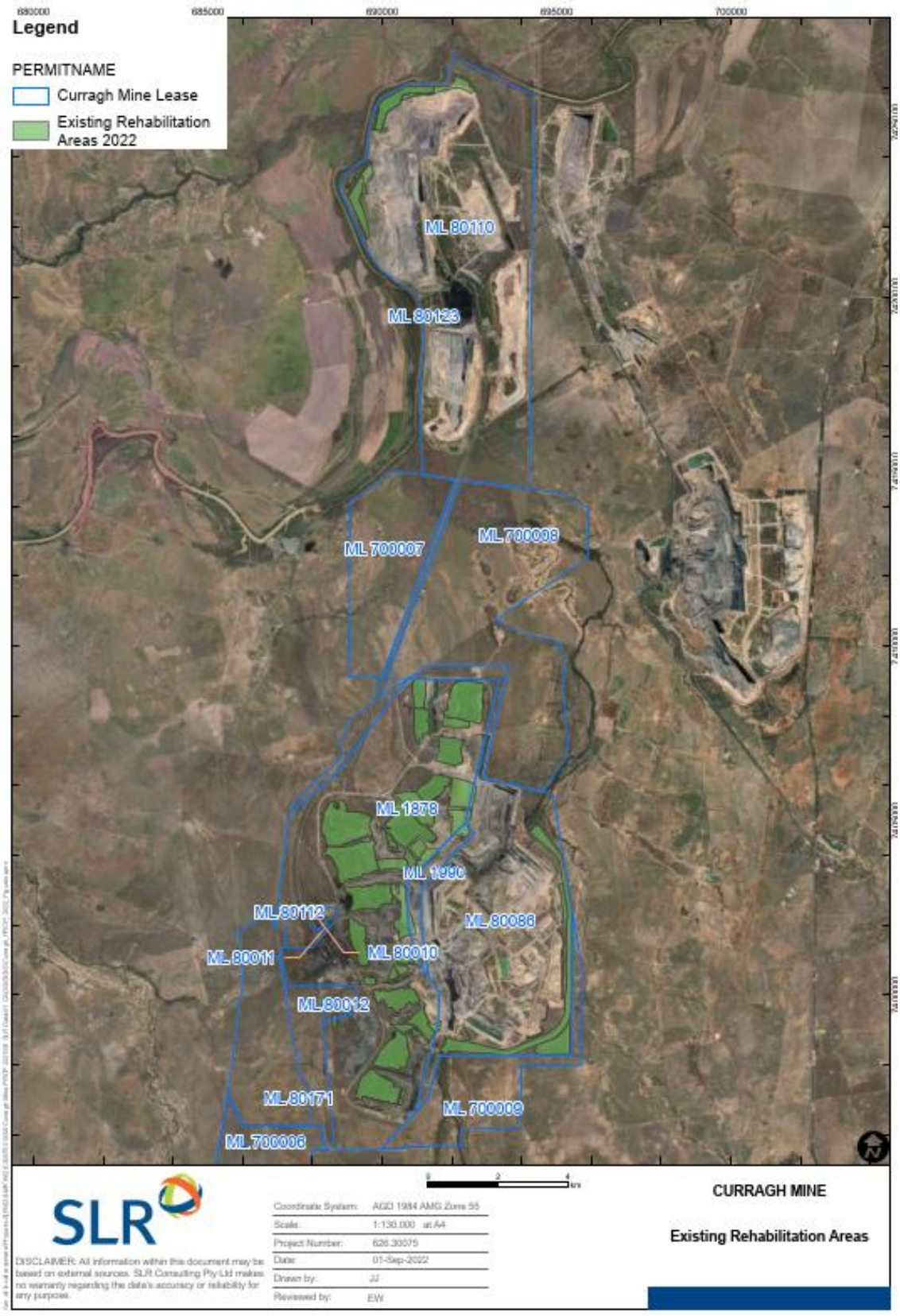


Figure 2-20 Existing Rehabilitation at Curragh Project

3 Community Consultation

SLR has prepared a Community Consultation Plan (**Appendix A**) which includes the required information in the EP Act and PRCP Guideline, including, but not limited to:

- Objectives for community consultation;
- How the community will be engaged;
- Proposed consultation frequency;
- What information will be released for community consultation;
- How feedback/comments will be considered; and
- Community Consultation Register.

3.1 Initial PRCP Consultation

As part of the PRCP process CCPL has engaged three key stakeholders – DES, Traditional Owners Group and Peter Dunn (underlying landholder).

3.1.1 DES Meeting

CCPL and SLR had a PRCP pre-lodgement meeting with the Department of Environment and Science (DES) on 1 June 2021. The primary purpose of the meeting was to confirm what land outcomes are approved in Land Outcome Documents and to agree to a PRCP submission date. The outcomes of the meeting include:

- The Curragh Project has pre-approved residual voids as Non-Use Management Areas;
- CCPL will update the Residual Void study to provide clarification on previously identified voids and to include any voids within the new MLs; and
- A proposed combined PMLU of grazing and native habitat was agreed upon.

The other key outcome of the meeting was that the PRCP for Curragh would be due to DES on 21st October 2022.

3.1.2 Traditional Owners

CCPL has a quarterly meeting with the local indigenous group, Gaangalu Nation People, to discuss a number of matters as they arise. At the meeting in May 2022, SLR provided a presentation on the PRCP process and how this relates to the Curragh Complex. The key discussion items included:

- Explanation of the PRCP process and purpose and presentation of a PowerPoint which includes a description of the consultation process;
- Where the rehabilitation seeds come from and potential for supply by local Indigenous supplier;
- An overview of the nature of PRCP being progressive and reiterative as the mine life continues;
- Possibility of Curragh looking to complete fauna surveys as evidence of return of totemic species and to further support the suitability of rehabilitation;
    - Curragh requested a list of target species that can be targeted in fauna surveys; and

- Potential for returning artefacts to the land, however, will need to be a conversation with the native title applicants and consider what the post mining use will be.

It is the intention that this forum will be used for future updates on the PRCP process.

3.1.3 Underlying Landholder

On 9th August 2022, CCPL and SLR had a one-on-one meeting with an underlying landholder (property manager of Mourallyn) at Curragh North. The purpose of the meeting was to discuss the PRCP framework and how it relates to Curragh Complex. SLR provided a presentation on the PRCP process, the proposed post-mining land uses at Curragh and the community consultation process. Key discussion points from the meeting included:

- Conversation with the landholder about how a 'grazing' land use is assessed. The landholder's advice is that this should focus on management requirements and not specific parameters such as stocking rates given that these change with changing conditions (e.g. weather, condition of pasture, etc.);
- Some of the key queries regarding the closure of Curragh for the landholder included:
    - Responsibility of final voids;
    - How the land will be managed for grazing;
    - Importance of an ongoing relationship between the landholder and CCPL;
    - Erosion of the land;
    - Potential for the retainment of infrastructure including areas of bare land;
- Peter was happy for consultation to occur as required and was interested in attending larger community events and site visits; and
- It was reiterated that the land should be rehabilitated with the final land user in mind and that there should be no surprises at the time of surrender.

Peter offered to provide some guidance on grazing management strategies that he would recommend for incorporation into the rehabilitation strategy.

4 Post-Mining Land Uses

A post-mining land use (PMLU) is defined under section 112 of the EP Act as the purpose for which the land will be used after all relevant activities for the PRC plan carried out on the land have ended. A PMLU must meet the definition of stable condition. Land is in a stable condition if:

a) The land is safe and structurally stable; and

b) There is no environmental harm being caused by anything on or in the land; and

c) The land can sustain a PMLU.

The proposed land outcomes for Curragh Project are shown in **Figure 4-1**. As shown, CCPL is proposing to have a PMLU of Light Grazing and Open Woodland as a combined use as well as proposing Non-Use Management Areas for their pit lakes and highwalls.

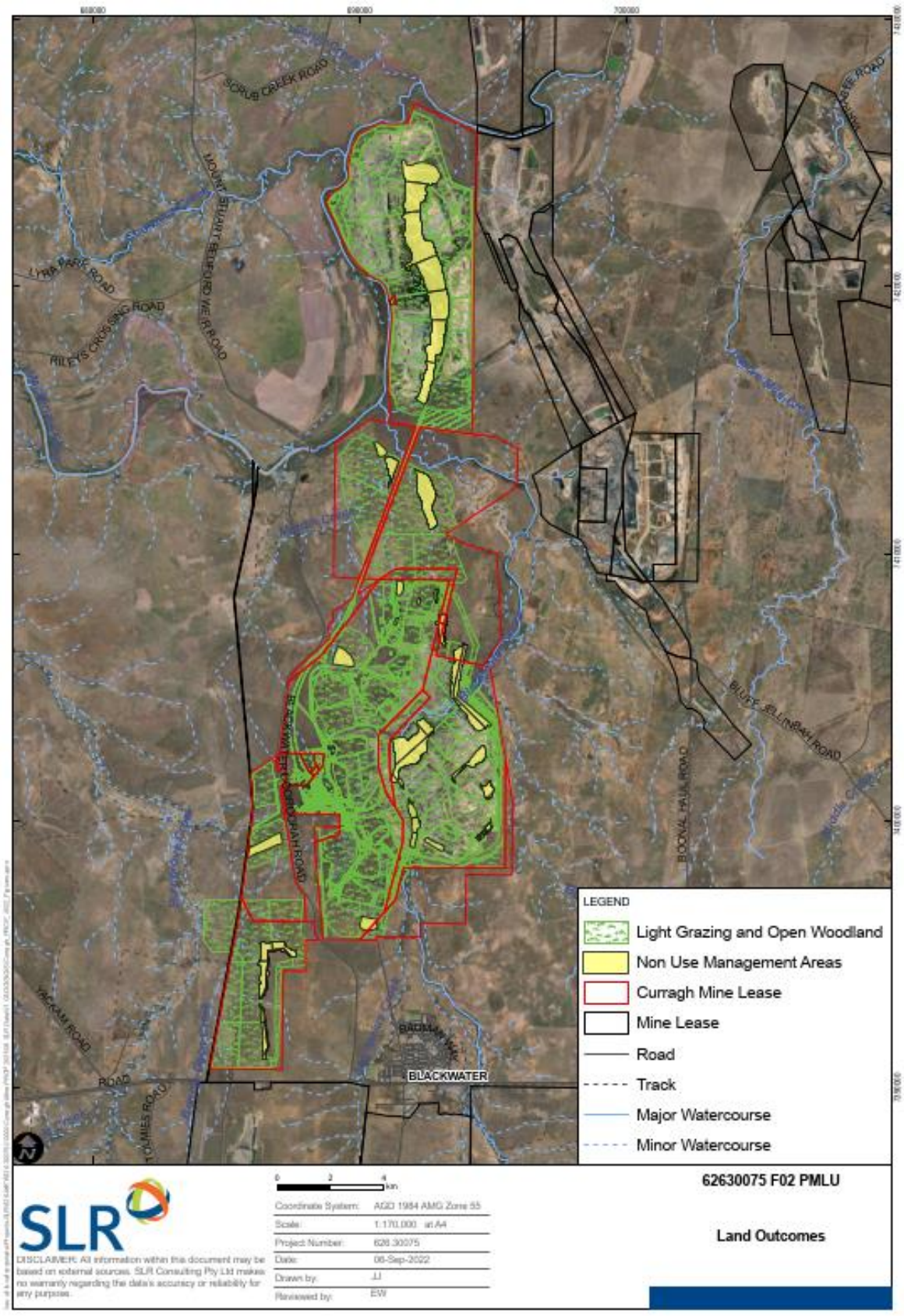


Figure 4-1 Proposed Land Outcomes

4.1 Pre-approved PMLUs

Under the transitional provisions of the EP Act, existing approved PMLUs are able to be transitioned into the PRCP without further assessment or public notification. Existing approvals must be included in a land outcome document. Land outcome documents are listed in section 750 of the EP Act and include:

a. An EA;

b. A document made under a condition of an EA that:

   i. Relates to the management or rehabilitation of land (e.g., rehabilitation and closure plan or residual void management plan);

   ii. Was provided to the administering authority, and had not been superseded, before 30 November 2018; and

   iii. Before 15 January 2019, the administering authority had not notified the EA holder that the document was insufficient.

c. A document made under a condition of an EA that:

   i. Relates to the management or rehabilitation of land (e.g., rehabilitation and closure plan or residual void management plan);

   ii. Was provided to the administering authority between 20 November 2019 and 30 November 2021; and

   iii. Within 20 business days after receiving the document, the administering authority had not notified the EA holder that the document was insufficient.

d. A report evaluating an EIS under section 34D of the *State Development and Public Works Organisation Act 1971* (SDPWO Act);

e. An EIS assessment report; and

f. A written agreement between the EA holder and the State that is in force on 30 November 2018.

The Land Outcome Documents associated with Curragh Project, in order of hierarchy, include:

- Environmental Authority EPML00643713 (**Appendix B**);
- Concept Residual Voids Assessment made under Condition G14 of the EA and submitted to the administering authority prior to November 2018 (AECOM, 2012);
- Rehabilitation Management and Monitoring Plan created under Condition G18 of the EA and submitted prior to November 2018 (Coronado Curragh, 2018);
- Blackwater Creek Diversion Monitoring and Maintenance Plan referred to in Condition G17 of the EA (Coronado Curragh, 2019a) (**Appendix C**);
- Concept Residual Voids Assessment updated under Condition G14 of the EA (SLR, 2021) (**Appendix D**);
- Rehabilitation Management and Monitoring Plan updated under Condition G18 of the EA (Coronado Curragh, 2021) (**Appendix E**); and
- Curragh North EIS Report (2003).

Please note that the Concept Residual Voids Assessment and Rehabilitation Monitoring and Maintenance Plan were updated in late 2021 to provide further clarity of the rehabilitation outcomes and to include additional planned disturbance since the 2012 versions. Although the earlier versions of these documents are considered higher in the LOD hierarchy, the updated versions will be used for transitioning land outcomes as they are substantially the same and provide additional information / disturbance areas.

The EA doesn't include specific land outcomes but does include a number of relevant conditions including:

G10 All areas significantly disturbed by mining activities must be rehabilitated to a stable landform with a self-sustaining vegetation cover.

G13 Residual voids must comply with the following rehabilitation outcomes:

a) Residual voids must not cause any serious environmental harm to land, surface waters or any recognised groundwater aquifer, other than the environmental harm constituted by the existence of the residual void itself and subject to any other condition within this environmental authority.

In a pre-lodgement meeting with DES in June 2021, DES officers stated that the EA conditions provide for the option of having residual voids and that Condition G10 was not intended to apply to pit lake areas.

The Conceptual Residual Voids Assessment focuses on voids that are proposed as NUMAs and discussed further in **Section 5** of this report.

The Rehabilitation Management and Monitoring Plan (2021) focuses on all areas with the exception of voids proposed as NUMAs. The post mining land use for all areas in the RMMP is identified as having a mixed use of Light Grazing and Open Woodland.

4.2 Proposed PMLUs

CCPL is proposing to transition the post-mining land use in the RMMP, Light Grazing and Open Woodland, into the PRCP Schedule.

Conversations with the underlying landholder and local grazier has helped provide further clarification on how grazing of the land would occur. It is seen that the rehabilitated land would not be used to fatten cattle or as a long term are of use. It would be more appropriate for pulse grazing and using grazing as a land management practice.

Proposed PMLUs must meet the PRCP objectives and performance outcomes outlined in Schedule 8A of the EP Regulation-

Each post-mining land use-

a) Is viable, having regard to the use of land in the surrounding region; and

b) Satisfies at least 1 of the following-

i. The use is consistent with how the land was used before a mining activity was carried out on the land;

ii. The use is consistent with a development approval relating to the land;

iii. The use is consistent with a use of the land, other than a use that is mining, permitted under a State or Commonwealth Act, including, for example, a planning instrument under the Planning Act;

iv. The use will deliver, or is aimed at delivering, a beneficial environmental outcome.

The PMLU of Light Grazing and Open Woodland is viable with consideration of the surrounding land uses. One of the underlying land holders is a grazier who intends to graze the land once it is rehabilitated. Areas that have already been rehabilitated demonstrate that the joint land use of Light Grazing and Open Woodland is achievable. The land before mining was grazing land with sparse to moderate tree coverage, therefore the proposed PMLU is consistent with the land use prior to mining.

The stable embankments will require rock mulch for the slope facing the watercourse in order to ensure erosional stability (further information in **section 6.1.1**). The stable embankment as a whole will provide a PMLU of Light Grazing and Open Woodland with the slope that is rock mulched providing an additional secondary use of fauna habitat. There are a number of reptiles recorded to occur on site as per the Wild Net Species List for ML1878 (Queensland Government, 2022):

- Spotted Python;
- Brown Tree Snake;
- Orange-naped Snake;
- Eastern Brown Snake;
- Burton's Legless Lizard;
- Eastern Blue-tongued Lizard.

There are a number of studies (Michael et al., 2008; Michael et al., 2012; Wolfe et al., 2018) that identify rocky habitat as an important landscape for reptiles especially where grazing has caused mass clearing of areas. Therefore, the rock mulched slope will be able to support a use in addition to the general landscape use of Light Grazing and Open Woodland.

At the moment, there are no landholder agreements for the retainment of infrastructure, however in stakeholder consultation a desire to retain certain infrastructure and laydown areas was expressed. This will continue to be pursued by CCPL over the life of mine.

CCPL are the underlying landholders of majority of the site. Advice from the underlying landholder and grazier is that the land needs three key things to be used for grazing – water, fencing and feed. To support the PMLU of light grazing one of the requirements is to have available water sources; therefore, CCPL are proposing to retain all raw water dams. The raw water dams to be retained will have the sediment removed then be allowed to naturally fill again. The water is expected to be of a stock watering quality in accordance with ANZECC Guidelines.

4.2.1 Community Consultation

CCPL has actively engaged with Traditional Owners and an underlying landholder about the proposed PMLUs. Neither party raised any issues with the proposed PMLU and were generally supportive. The underlying landholder was very interested in having the land returned to a landform suitable for light grazing and has provided advice on how to achieve this. Relevant stakeholders will continue to be consulted over the life of the mine to ensure communication of the PMLU and expectations are managed appropriately.

4.2.2 Plans and Strategies

Section 126C of the EP Act requires the PRCP to state the extent to which the PMLU is consistent with any strategies or plans for the land of a local government, the State, or the Commonwealth. Relevant plans and strategies have been identified below.

Water Resources (Fitzroy Basin) Plan 2011

The Water Plan (Fitzroy Basin) 2011 (current as of 2 September 2017) provides a framework for sustainably managing water and taking water from overland flows and Groundwater while considering existing water users including the environment. Mine closure planning including final landforms and drainage (e.g., water diversions) has considered the protection of flows (e.g., prevention of impounding waters, connection of base flows, etc.), water quality and groundwater recovery for surrounding ecosystems and users in accordance with this plan.

The Queensland Plan

The Queensland Plan is an aspirational 30-year community vision with nine foundation areas which include the following relevant areas to mine closure planning for this project: Regions – building thriving communities, Environment – achieving balance, and Infrastructure – being connected. Mine closure planning is required to consider goals of capitalising on unique regional opportunities and assets, environmental protection, effective natural resource management, and connectivity and accessibility across the state.

Central Highlands Regional Council Planning Scheme 2016

The Central Highlands Regional Council (CHRC) Planning Scheme 2016, which is currently operating under amendment no.6 (May 2022), was developed as a planning instrument under the Planning Act 2016 (Queensland Government). The CHRC Planning Scheme aims to manage growth of the region through the regulation of existing land use and new development to reflect community aspirations. The land on which Curragh Project is situated is zoned for Rural land use which supports the propose PMLU of Light Grazing and Open Woodland.

4.2.3 Final Milestone Criteria

Completion criteria for the different domains within the proposed PMLU is identified in the RMMP. This criterion has been further built upon with the outcomes of the PRCP technical studies and is shown in section 9.3 of this report.

5 Non-Use Management Areas

A Non-use Management Area (NUMA) is defined in section 112 of the EP Act as an area of land the subject of a PRCP that cannot be rehabilitated to a stable condition after all relevant activities for the PRCP carried out on the land have ended. A NUMA can only be proposed due to one of the following reasons:

a) carrying out rehabilitation of the land would cause greater risk of environmental harm than not carrying out the rehabilitation; or

b) both of the following apply:

   a. The risk of environmental harm as a result of not carrying out rehabilitation of the land is confined to the area of the relevant resource tenure.

   b. The applicant considers, having regard to each public interest consideration, that it is in the public interest for the land not to be rehabilitated to a stable condition.

5.1 Pre-approved NUMAs

As mentioned above in section 4.2, land outcomes are able to be transitioned from Land Outcome Documents in accordance with the transitional provisions in the EP Act. The Conceptual Residual Void Assessment (CRVA) is the LOD which identifies voids as NUMAs.

The CRVA (AECOM, 2012) is higher on the LOD hierarchy and identifies a total of 1,742 ha as pit area. The updated CRVA (SLR, 2021) refined this for the purpose of maximising areas which can support a PMLU while also adding in extra mining areas and identified a total area proposed as a NUMA of 1,499 ha. The NUMAs identified in the CRVA (SLR, 2021) is shown in **Figure 5-1**.

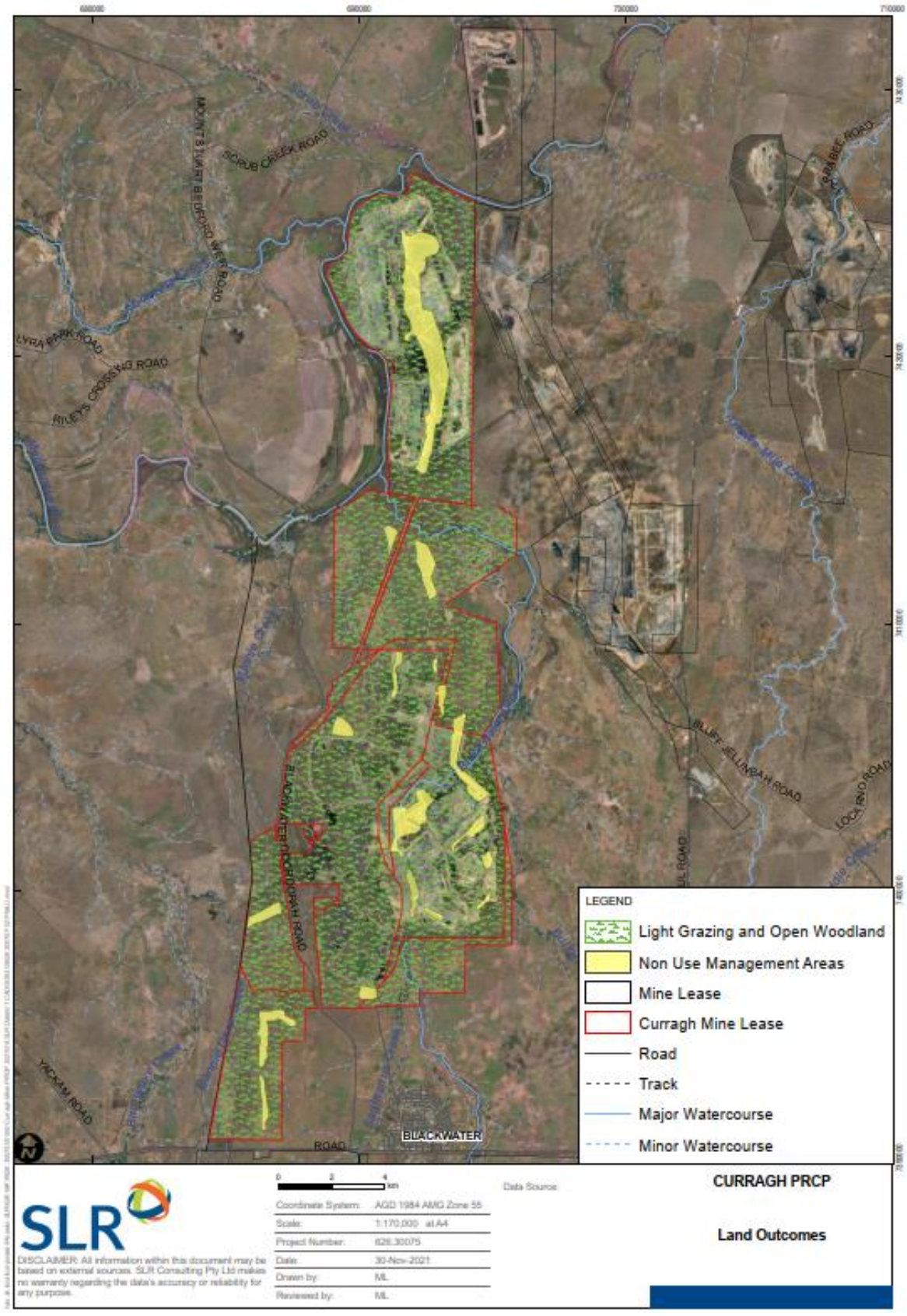


Figure 5-1 Land Outcomes from CRVA (SLR, 2021)

5.2 Proposed NUMAs

CCPL are proposing the transition the pre-approved NUMAs from the updated CRVA (SLR, 2021) into the PRCP Schedule with some minor changes. Following the update to the CRVA, mine planning changes were made and therefore the proposed final landform was amended. The void water balance modelling was also updated to identify any changes to the pit lakes. Two additional pit lakes were identified (referred to as Main Other and Pit X West 2). The Main Other pit lake is located within an area of existing rehabilitation, and it was originally thought that this water would be suitable to support a PMLU; however, water modelling has shown that over time the water will become highly saline.

In order to maintain the same area of NUMA approved in the CRVA (2021), CCPL has amended the NUMA locations to ensure no additional area has been included. Pit I has been reassessed to remove some of the area originally identified as NUMA. **Figure 4-1** shows the proposed locations of NUMAs for this PRCP.

Table 5-1 shows a comparison of the 2012 proposed residual voids, the 2021 preliminary NUMA areas and the final proposed NUMA areas. This shows that the area which could be interpreted as a NUMA in the PRCP has been reduced in this version of the CRVA and proposed PRCP schedule. This was achieved by reviewing the parameters of what is considered a 'NUMA' and optimising the PMLU for the low wall and Tertiary highwall.

Table 5-1 Residual Voids / NUMA Areas 2012 vs 2021 vs Proposed

Domain	2012 CRVA Residual Void Area (ha)	2021 CRVA NUMA Area (ha)	Final proposed NUMA Area (ha)
Curragh Main	1,096	561	546
Curragh North	646	637	637
Pit X	-	125	141
Pit Y	-	48	48
Pit Z	-	128	128
Total	**1,742**	**1,499**	**1,500**

This change in location is insignificant and has been undertaken to align with the main objectives for characterising a residual void as a NUMA; that being that the highwall slope is over 16% and there is permanent hypersaline water present.

The flood model, residual void water modelling and numerical groundwater model have all be revisited to identify any potential environmental harm which may result from the residual voids being left in their proposed location. There was no difference in potential harm identified in these studies. Therefore, CCPL would consider the proposed NUMAs to still be 'substantially similar' to those proposed in the CRVA (2021) in accordance with section 754(3) of the EP Act.

5.2.1 Plans and Strategies

The Central Highlands Regional Council Planning Scheme identified the Curragh Project lease area as 'rural.' It is acknowledged that mining and exploration activities occur within this planning zone. Therefore, the final land use of final void/water containment is consistent with the current planning scheme for the area.

5.2.2 Community Consultation

CCPL has actively engaged with Traditional Owners and an underlying landholder about the proposed NUMAs. Neither stakeholder had any strong objections to the proposed NUMAs. The underlying land holder had questions about the quality of the void water and responsibility of the voids post-surrender.

5.2.3 Final Milestone Criteria

SLR have developed completion criteria for the proposed NUMAs (**Table 5-2**) using the technical studies undertaken and detailed above. It should be noted that this criterion is only applicable to the Permian Highwall and maximum void water level.

Table 5-2 NUMA Criteria

Objective	Criteria	Justification
Safe for humans, livestock and native fauna	Static Factor of Safety >1.5 Dynamic Factor of Safety >1.1	Factor of safety design criteria is recommended in the Geotechnical Report.
	Certification from an appropriately qualified person that the residual void is safe to humans and livestock	Example from PRCP Guideline.
	Installation of fencing and signage where required.	The installation of fencing and signage would be confirmed in the PRCP once the final landform has been finalised.
Geotechnically and erosionally stable	The final landform does not form rill erosion of >30 cm.	This is a standard criteria for demonstrating erosional stability.
	Permian highwalls battered to a geotechnically stable slope.	As recommended in Geotechnical Report. Where fault related rock mass shearing and/or adversely orientated structures are interpreted or inferred final walls may have to be constructed as softwalls at 22 degrees.
	Certification from an appropriately qualified person that the residual void is geotechnically and erosionally stable.	Example from PRCP Guideline.
Does not cause serious environmental harm to land, surface waters or any recognised groundwater aquifer, other than the environmental harm constituted by the existence of the residual void itself	Construction of a stable, long-term embankment which prevents the ingress of flood water into the residual voids.	The embankment will protect the voids from interacting with the floodplain. The Flood Model Report provides the minimum height for the embankment based on very conservative flood modelling. This height may be reviewed based on more detailed flood modelling recommended as part of the PRCP.

Objective	Criteria	Justification
	Saline void water will not spill or seep into the surrounding environment at a concentration that will cause environmental harm.	The void water balance modelling shows that the voids are highly unlikely to spill. Groundwater modelling demonstrates that the voids are likely to act as sinks and not contaminate the surrounding environment.
	Certification from an appropriately qualified person that the residual void does not cause serious environmental harm to land, surface waters or any recognised groundwater aquifer, other than the environmental harm constituted by the existence of the residual void itself.	Similar example from PRCP Guideline.

6 Rehabilitation/Management Methodologies

6.1 Rehabilitation/Management Studies

6.1.1 Landform

Overburden

The overburden dumps have been designed to have a maximum slope of 16%, although majority of the slopes are lower than this. There are three different types of spoil material at Curragh Project Permian, Quaternary and Tertiary. The dumping method will aim at having Permian or Quaternary material on the surface with any Tertiary spoil buried as it has a higher dispersivity.

Highwalls

The void highwalls have been designed in the Conceptual Final Landform to the lowest angles proposed in the Geotechnical Assessment (Raine Associates, 2021). While CCPL will endeavour to keep the void highwalls as steep as possible while achieving long term stability, the final landform has incorporated the lowest slopes proposed for the highwall as a worst case scenario for the total area of the NUMAs. A steeper slope would result in a reduced NUMA footprint. Further information on the highwall angles is provided in **section 6.1.9**.

Stable Embankment

As Curragh Project is located on a floodplain, an indicative cross section of the long-term stable embankment has been designed to prevent flood water ingress into the residual voids. The embankment design has been based on the B Pit embankment section developed from the B Pit Tailings Storage Facility Design Plan (Golders, 2017). A conceptual embankment design is shown in **Figure 6-1** with parameters outlined in **Table 6-1**. Stable embankments based on this concept and constructed to heights to provide freeboard to protect residual voids against the 0.1% AEP flood event are being incorporated into the final landform design for Curragh.

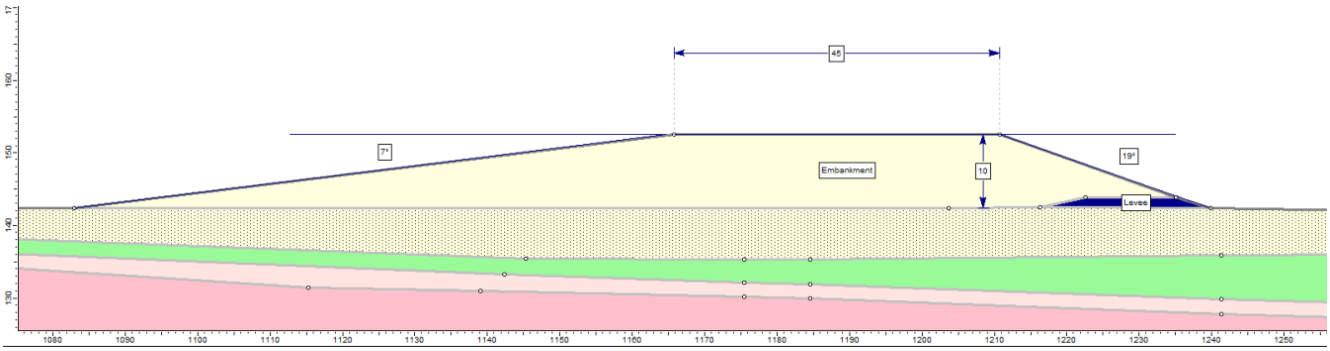


Figure 6-1 Stable Embankment Conceptual Design (Raine Associates, 2021)

Table 6-1 Indicative Stable Embankment Standard Parameters

Parameter	Value
Height	10 m (actual will be 0.1% AEP plus 1 m freeboard)
Top width	45 m (actual to be determined during design)

Parameter	Value
Water facing slope	<19° (actual to be long term stable to erosion and flood scour)
Residual void facing slope	7° (actual to be long term stable to erosion)

The outcomes of the flood model have been incorporated into the conceptual landform design for the PRCP to ensure flood water does not enter residual voids.

Conceptual Final Landform

The conceptual final landform and proposed slope gradients are shown in **Figure 6-2**, **Figure 6-3** and **Figure 6-4**.

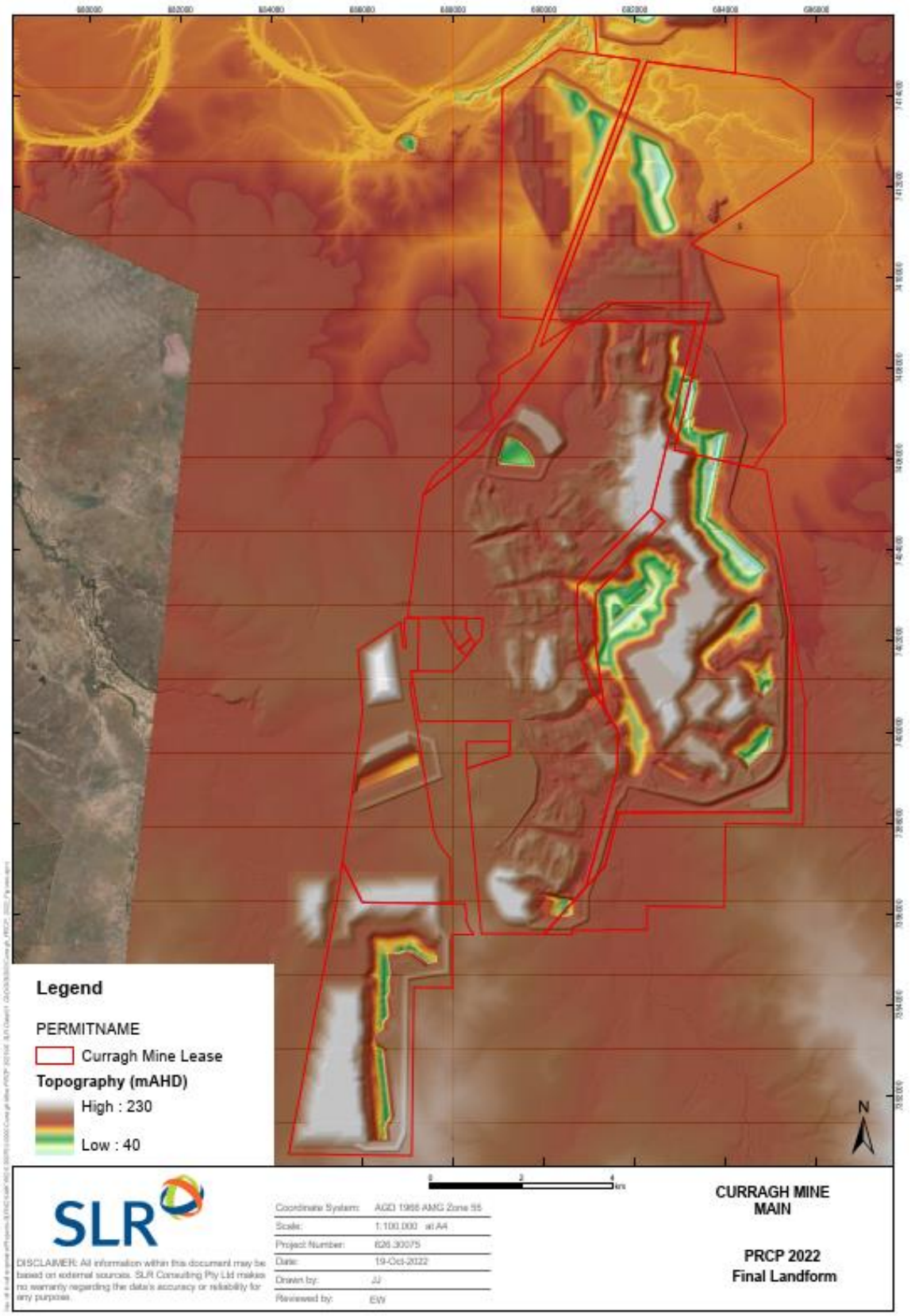


Figure 6-2 Conceptual Final Landform

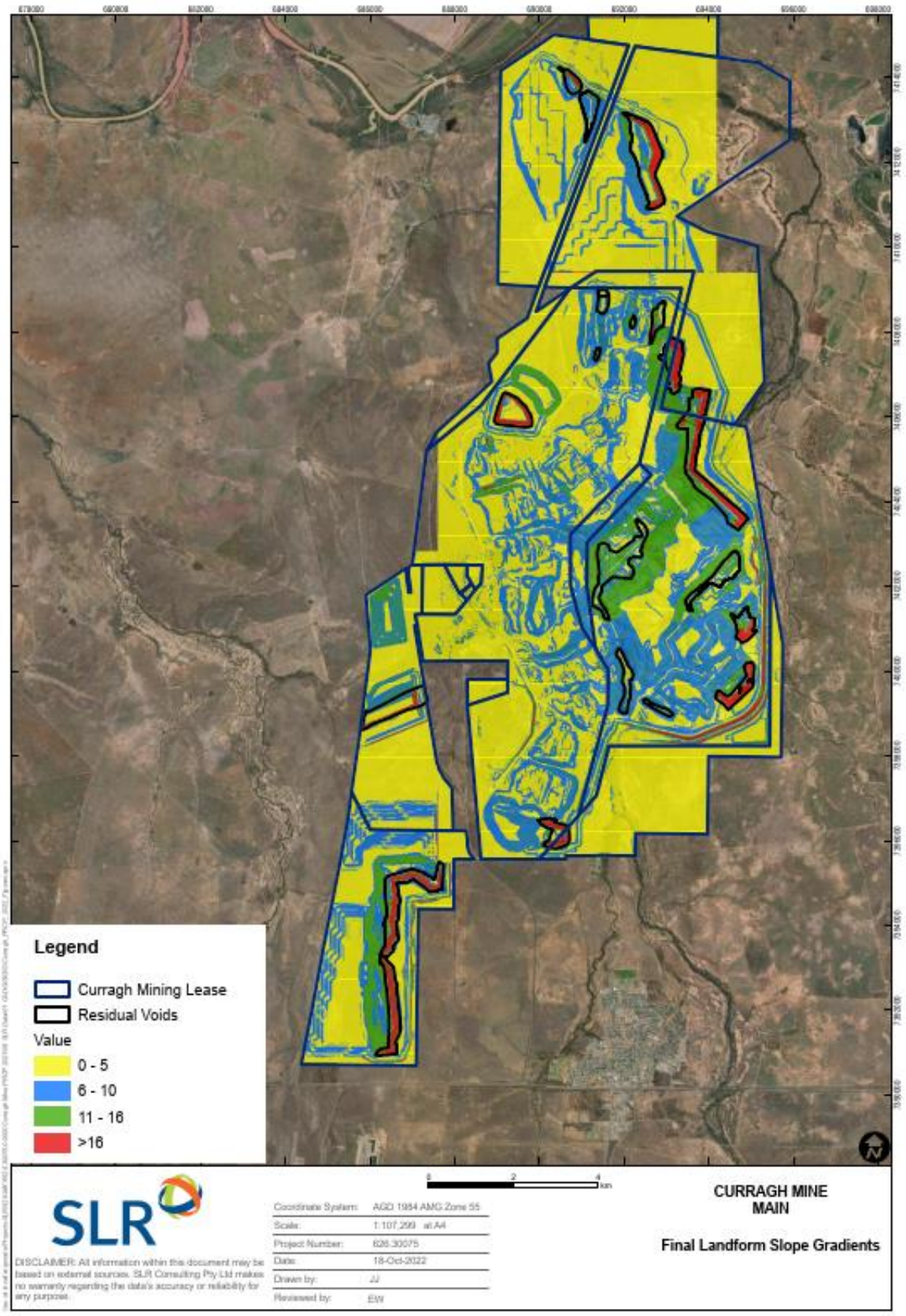


Figure 6-3 Curragh Main Final Landform Slope Gradients (%)

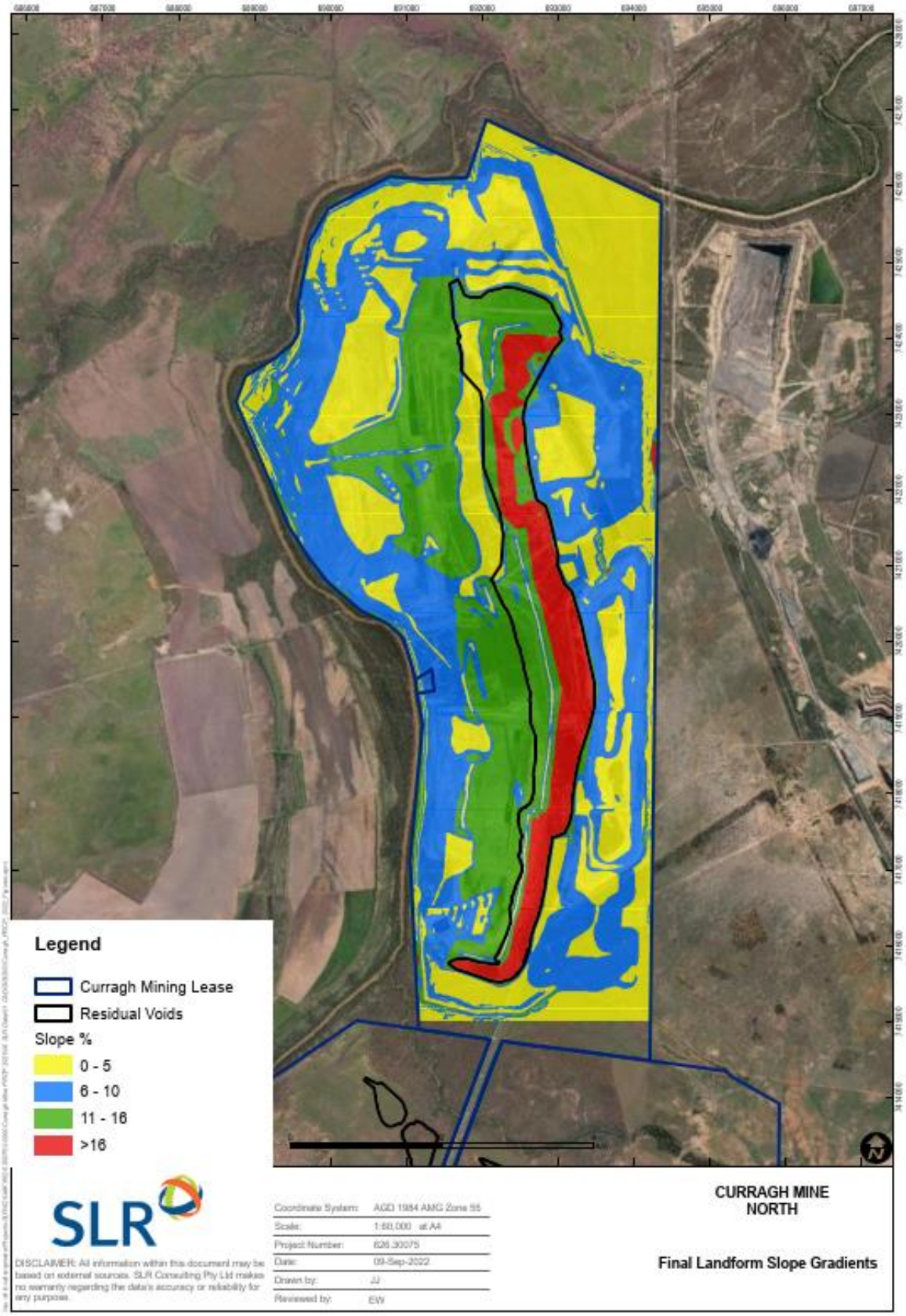


Figure 6-4 Curragh North Final Landform Slope Gradients (%)

6.1.1.1 Erosion Assessment

An erosion assessment of the conceptual final landform was undertaken by SLR (2022) (**Appendix F**). The erosion assessment used the revised universal soil loss equation (RUSLE) to calculate the potential soil loss from the conceptual landform. This method was used as an early indicator into whether the proposed slopes would be erosionally stable.

Topsoil and spoil samples were taken from across the site and analysed in a laboratory in order to provide input for the RUSLE calculations. A number of different cover methods were assessed including different levels of grass cover, the application of hydromulch, a cover crop with straw mulch and a cover crop with stone.

There is currently no broad agreement on what constitutes an 'acceptable rate of erosion' on a rehabilitated landform. Spatial data available from CSIRO (2020) provide estimates of broad scale and in situ soil erosion in Australia. The soil erosion estimate provided for the Curragh site range from 0.026 to 31.4 t/ha/y. SLR have used the Food and Agricultural Organisation (FAO) soil loss classes for assessing an acceptable soil loss criterion at Curragh Project, as shown in **Table 6-2**.

Table 6-2 FAO soil loss classes after Bergma et al (1991)

Soil loss (ton/ha/yr)	Class
< 5	very low
5 – 12	low
12 – 25	moderate
25 – 60	high
60 – 150	very high
> 150	extremely high

The results of the RUSLE calculations are provided in **Table 6-3** for Permian, Quaternary and Tertiary spoil and **Table 6-4** for topsoil from Curragh North and Curragh Main. The results indicate the following:

- Stable 16% slope gradients can be achieved on all spoil types by applying hydromulch;
- Permian and Quaternary spoil with 16% slope gradients will be stable once 50% cover is established;
- Tertiary spoil will only be stable when at least 80% cover is established;
- Spoil stability is increased as a result of stone fragments which provide additional cover;
- Stone cover offer the best protection against erosion with soil losses classified as very low to low where this is applied;
- Topsoil from Curragh North is less erodible and will reach a low annual soil loss once 60% cover is established; and
- Topsoil from Curragh Main is more erodible and gentler slopes should be considered.

Table 6-3 Soil loss (t/ha/yr) for Spoil at Curragh Project

Lithology			Slope angle (%)	35%	25%	18%	16%	14%	12%	10%	8%	6%
			Slope length (m)	31m	45m	45m	55m	70m	80m	90m	105m	115m
	Cover management					Calculated annual soil loss (t/ha/yr)						
Permian	Newly established grass cover no canopy	0		219.0	204.9	116.9	110.4	106.1	88.0	69.6	52.3	38.2
		20		98.6	92.2	52.6	49.7	47.7	39.6	31.3	23.5	17.2
		40		43.8	41.0	23.4	22.1	21.2	17.6	13.9	10.5	7.6
		50		32.9	30.7	17.5	16.6	15.9	13.2	10.4	7.8	5.7
		60		21.9	20.5	11.7	11.0	10.6	8.8	7.0	5.2	3.8
		80		6.6	6.1	3.5	3.3	3.2	2.6	2.1	1.6	1.1
	Hydromulch			15.3	14.3	8.2	7.7	7.4	6.2	4.9	3.7	2.7
	Cover crop with 2.5 t/ha straw mulch			43.8	41.0	23.4	22.1	21.2	17.6	13.9	10.5	7.6
	Cover crop with 3.8 t/ha straw mulch			26.3	24.6	14.0	13.2	12.7	10.6	8.4	6.3	4.6
	Cover crop with 330 t/ha stone			11.0	10.2	5.8	5.5	5.3	4.4	3.5	2.6	1.9
	Cover crop with 600 t/ha stone			4.4	4.1	2.3	2.2	2.1	1.8	1.4	1.0	0.8
Quaternary	Newly established grass cover no canopy	0		148.9	139.4	79.5	75.1	72.1	59.9	47.4	35.6	26.0
		20		67.0	62.7	35.8	33.8	32.5	26.9	21.3	16.0	11.7
		40		29.8	27.9	15.9	15.0	14.4	12.0	9.5	7.1	5.2
		50		22.3	20.9	11.9	11.3	10.8	9.0	7.1	5.3	3.9
		60		14.9	13.9	7.9	7.5	7.2	6.0	4.7	3.6	2.6
		80		4.5	4.2	2.4	2.3	2.2	1.8	1.4	1.1	0.8
	Hydromulch			10.4	9.8	5.6	5.3	5.0	4.2	3.3	2.5	1.8
	Cover crop with 2.5 t/ha straw mulch			29.8	27.9	15.9	15.0	14.4	12.0	9.5	7.1	5.2
	Cover crop with 3.8 t/ha straw mulch			17.9	16.7	9.5	9.0	8.7	7.2	5.7	4.3	3.1
	Cover crop with 330 t/ha stone			7.4	7.0	4.0	3.8	3.6	3.0	2.4	1.8	1.3
	Cover crop with 600 t/ha stone			3.0	2.8	1.6	1.5	1.4	1.2	0.9	0.7	0.5
Tertiary	Newly established grass cover no canopy	0		236.5	221.3	126.3	119.2	114.6	95.1	75.2	56.5	41.3
		20		106.4	99.6	56.8	53.7	51.6	42.8	33.8	25.4	18.6
		40		47.3	44.3	25.3	23.8	22.9	19.0	15.0	11.3	8.3
		50		35.5	33.2	18.9	17.9	17.2	14.3	11.3	8.5	6.2
		60		23.7	22.1	12.6	11.9	11.5	9.5	7.5	5.7	4.1
		80		7.1	6.6	3.8	3.6	3.4	2.9	2.3	1.7	1.2
	Hydromulch			16.6	15.5	8.8	8.3	8.0	6.7	5.3	4.0	2.9

Lithology	Slope angle (%)	35%	25%	18%	16%	14%	12%	10%	8%	6%
	Slope length (m)	31m	45m	45m	55m	70m	80m	90m	105m	115m
	Cover management			Calculated annual soil loss (t/ha/yr)						
	Cover crop with 2.5 t/ha straw mulch	47.3	44.3	25.3	23.8	22.9	19.0	15.0	11.3	8.3
	Cover crop with 3.8 t/ha straw mulch	28.4	26.6	15.2	14.3	13.7	11.4	9.0	6.8	5.0
	Cover crop with 330 t/ha stone	11.8	11.1	6.3	6.0	5.7	4.8	3.8	2.8	2.1
	Cover crop with 600 t/ha stone	4.7	4.4	2.5	2.4	2.3	1.9	1.5	1.1	0.8

Table 6-4 Soil loss (t/ha/yr) for Topsoil at Curragh Project

Lithology	Slope angle (%)		35%	25%	18%	16%	14%	12%	10%	8%	6%
	Slope length (m)		31	45m	45m	55m	70m	80m	90m	105m	115m
	Cover management				Calculated annual soil loss (t/ha/yr)						
Curragh North	Percentage newly established grass cover no canopy	0	184.0	172.1	98.2	92.7	89.1	73.9	58.5	43.9	32.1
		0.2	82.8	77.5	44.2	41.7	40.1	33.3	26.3	19.8	14.5
		0.4	36.8	34.4	19.6	18.5	17.8	14.8	11.7	8.8	6.4
		0.5	27.6	25.8	14.7	13.9	13.4	11.1	8.8	6.6	4.8
		0.6	18.4	17.2	9.8	9.3	8.9	7.4	5.8	4.4	3.2
		0.8	5.5	5.2	2.9	2.8	2.7	2.2	1.8	1.3	1.0
	Hydromulch		12.9	12.1	6.9	6.5	6.2	5.2	4.1	3.1	2.2
	Cover crop with 2.5 t/ha straw mulch		36.8	34.4	19.6	18.5	17.8	14.8	11.7	8.8	6.4
	Cover crop with 3.8 t/ha straw mulch		22.1	20.7	11.8	11.1	10.7	8.9	7.0	5.3	3.9
	Cover crop with 330 t/ha stone		9.2	8.6	4.9	4.6	4.5	3.7	2.9	2.2	1.6
	Cover crop with 600 t/ha stone		3.7	3.4	2.0	1.9	1.8	1.5	1.2	0.9	0.6
Curragh Main	Percentage newly established grass cover no canopy	0	245.3	229.5	130.9	123.7	118.8	98.6	78.0	58.6	42.8
		0.2	110.4	103.3	58.9	55.6	53.5	44.4	35.1	26.4	19.3
		0.4	49.1	45.9	26.2	24.7	23.8	19.7	15.6	11.7	8.6
		0.5	36.8	34.4	19.6	18.5	17.8	14.8	11.7	8.8	6.4
		0.6	24.5	23.0	13.1	12.4	11.9	9.9	7.8	5.9	4.3
		0.8	7.4	6.9	3.9	3.7	3.6	3.0	2.3	1.8	1.3
	Hydromulch		17.2	16.1	9.2	8.7	8.3	6.9	5.5	4.1	3.0
	Cover crop with 2.5 t/ha straw mulch		49.1	45.9	26.2	24.7	23.8	19.7	15.6	11.7	8.6
	Cover crop with 3.8 t/ha straw mulch		29.4	27.5	15.7	14.8	14.3	11.8	9.4	7.0	5.1
	Cover crop with 330 t/ha stone		12.3	11.5	6.5	6.2	5.9	4.9	3.9	2.9	2.1
	Cover crop with 600 t/ha stone		4.9	4.6	2.6	2.5	2.4	2.0	1.6	1.2	0.9

6.1.2 Hydrogeology

SLR have reviewed the existing groundwater, climate, geology, surface water and topography data available for Curragh Project and developed a Groundwater Technical Report (**Appendix G**) to support this PRCP. The objectives of the hydrogeological assessment are to understand the post-closure groundwater regime around the mine and specifically to:

1. Present an understanding of the hydrogeological setting of the mine including potential groundwater receptors;

2. Simulate the post mining groundwater level recovery using the final landform (mine void backfill levels) developed by CCPL to understand whether the final voids act as groundwater sinks or sources; and

3. Understand the long-term effect of the proposed post mining landform on local groundwater levels i.e. the residual drawdown, and post-mining groundwater flux.

Section 2 of the Groundwater Technical Report presents information on the hydrogeological setting of the Curragh mine and the Conceptional Hydrogeological Model (CHM) including:

- Topography, climate and hydrology;
- Geology and hydrostratigraphy;
- Groundwater monitoring data (quality, levels, local Water Quality Objectives); and
- Groundwater values (Groundwater Dependant Ecosystems and local groundwater use).

The surface geology across the study area (based on 1:100,000 published mapping), is presented in **Figure 2-6** and the regional (solid) geology is presented in **Figure 2-7.**

Cross-sections showing the geology of the study area have been developed using the geological model for the site together with LiDAR (current and pre mining), and the final landform.

The locations of all cross-sections presented in the groundwater technical appendix (**Appendix X**) are shown on **Figure 2-7**, and selected cross sections are reproduced here including the north-south long section (A-A' **Figure 6-5**), and east-west sections (C-C' **Figure 6-6**, E-E' **Figure 6-7**, and G-G' **Figure 6-8**).

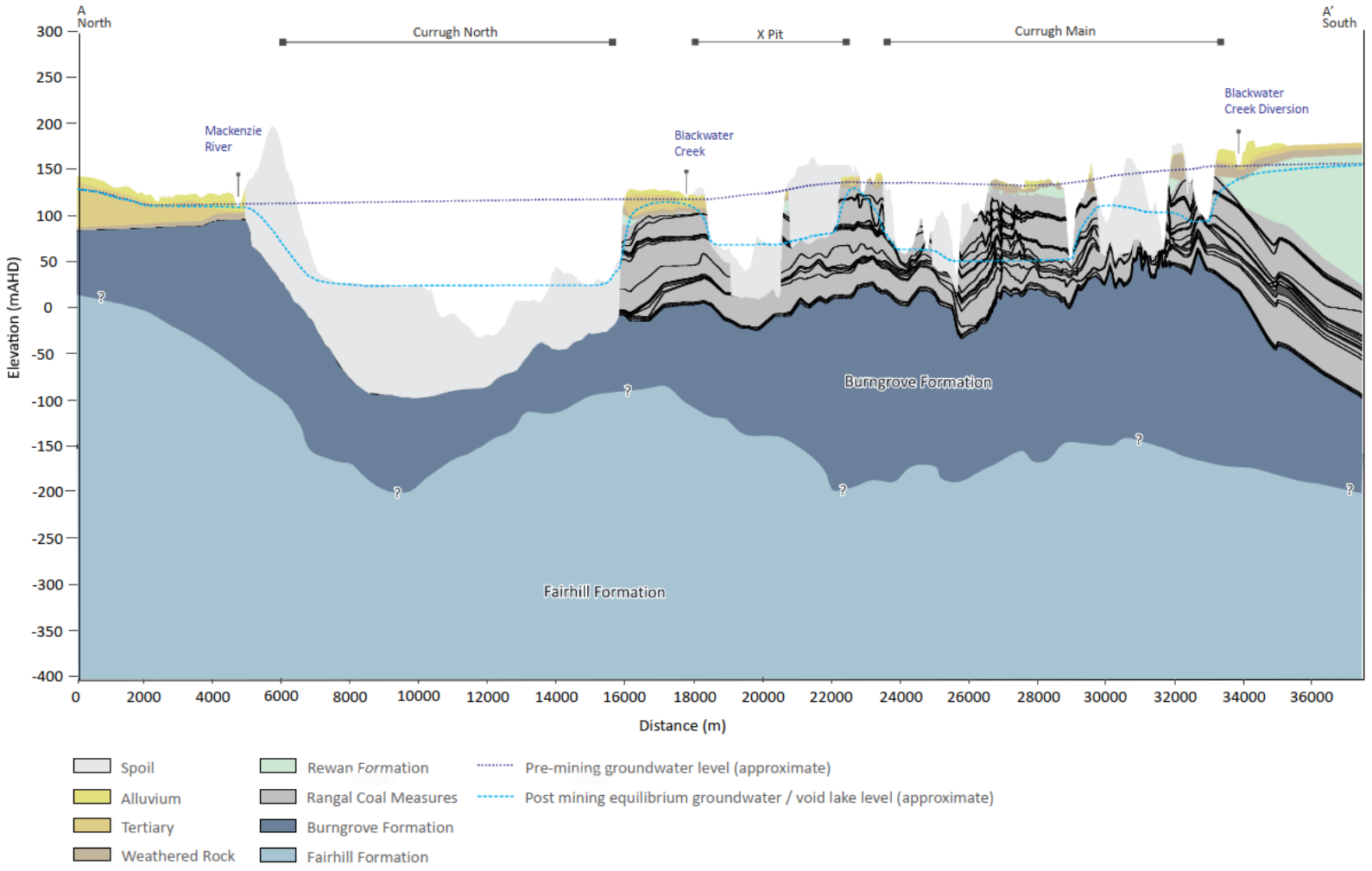


Figure 6-5 Conceptual geological cross-section A-A' (PB, 2016)

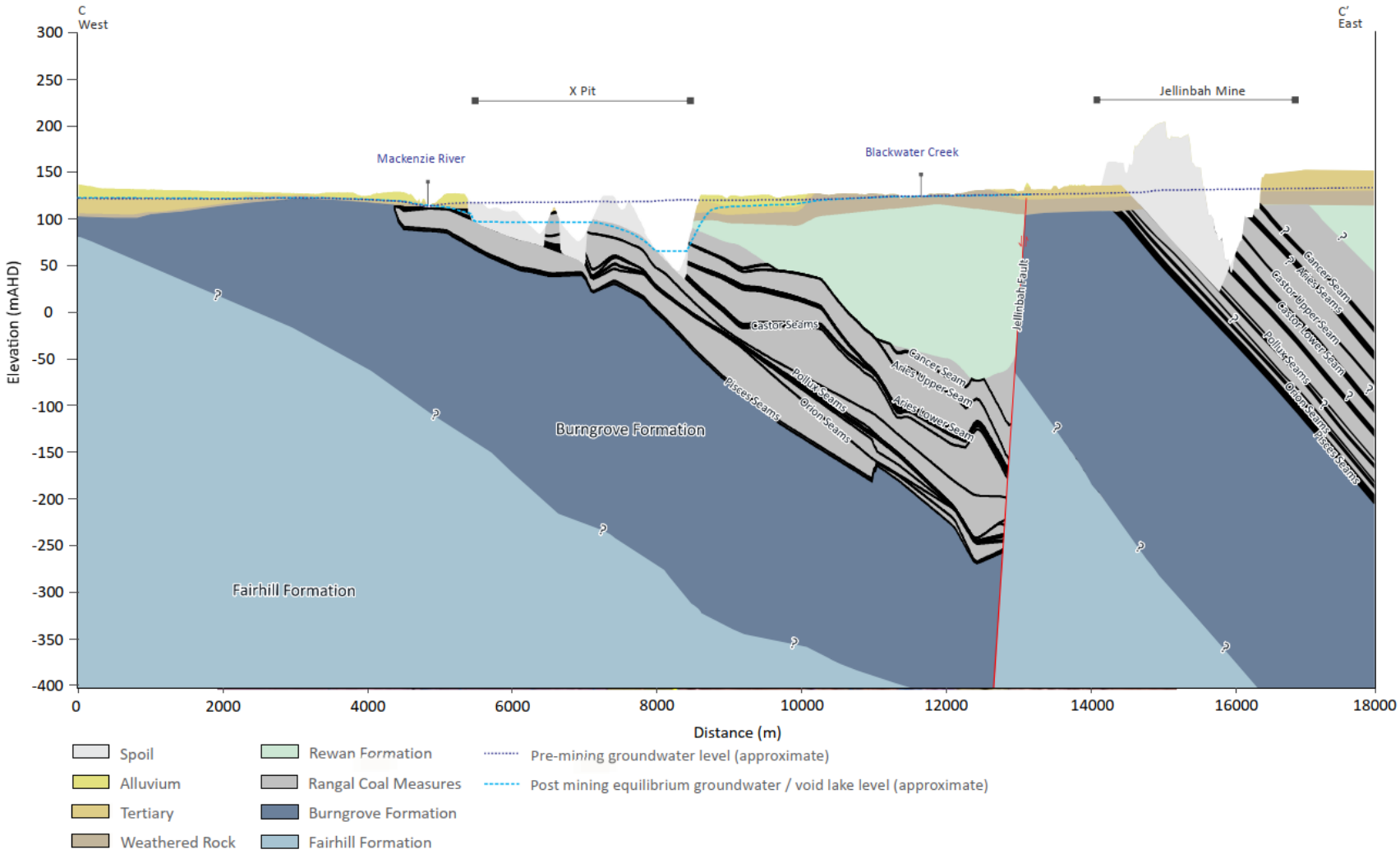


Figure 6-6 Geological cross-section C-C' of Curragh project showing final landforms/voids and groundwater levels

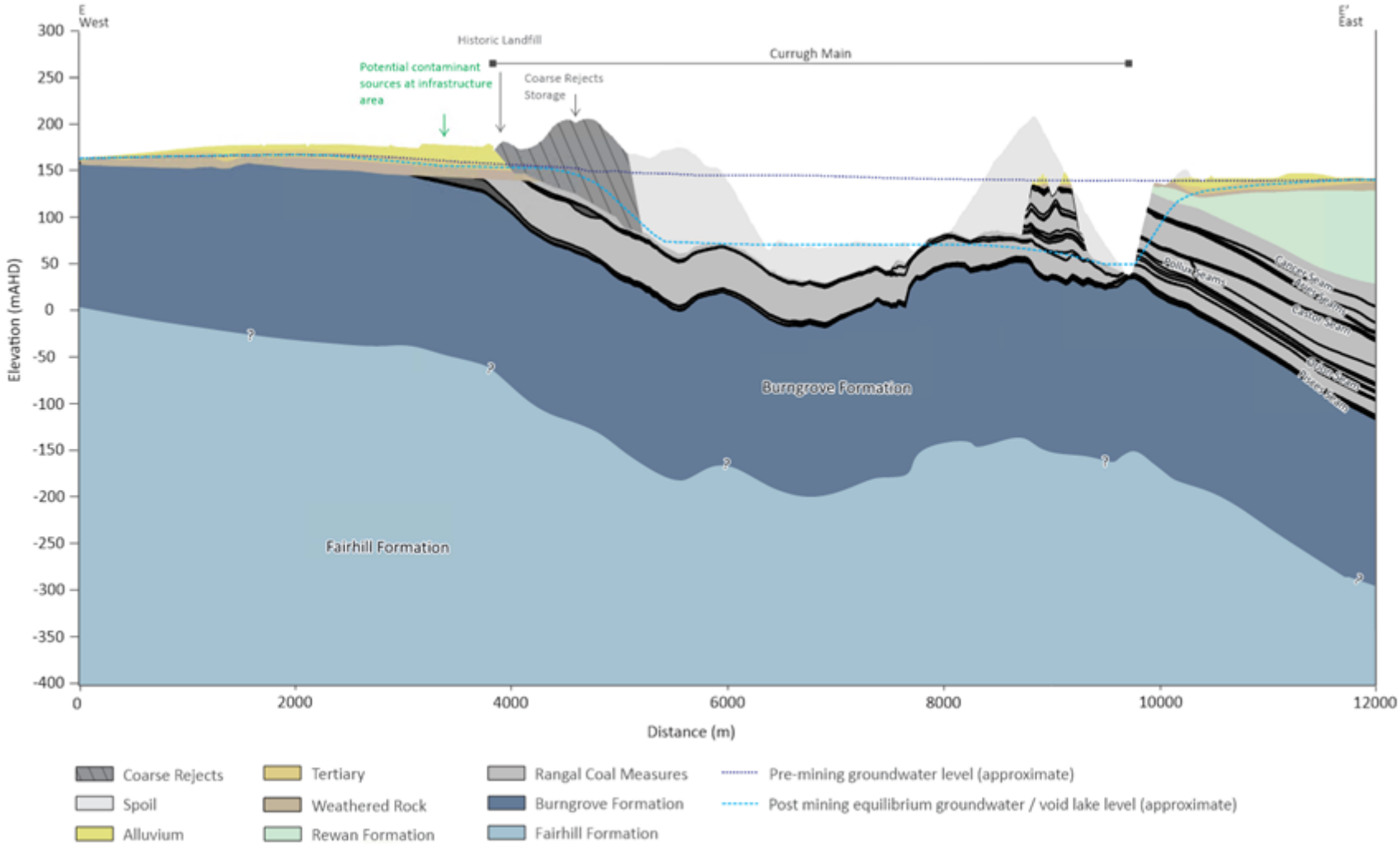


Figure 6-7 Geological cross-section E-E' of Curragh project showing final landforms/voids and groundwater levels

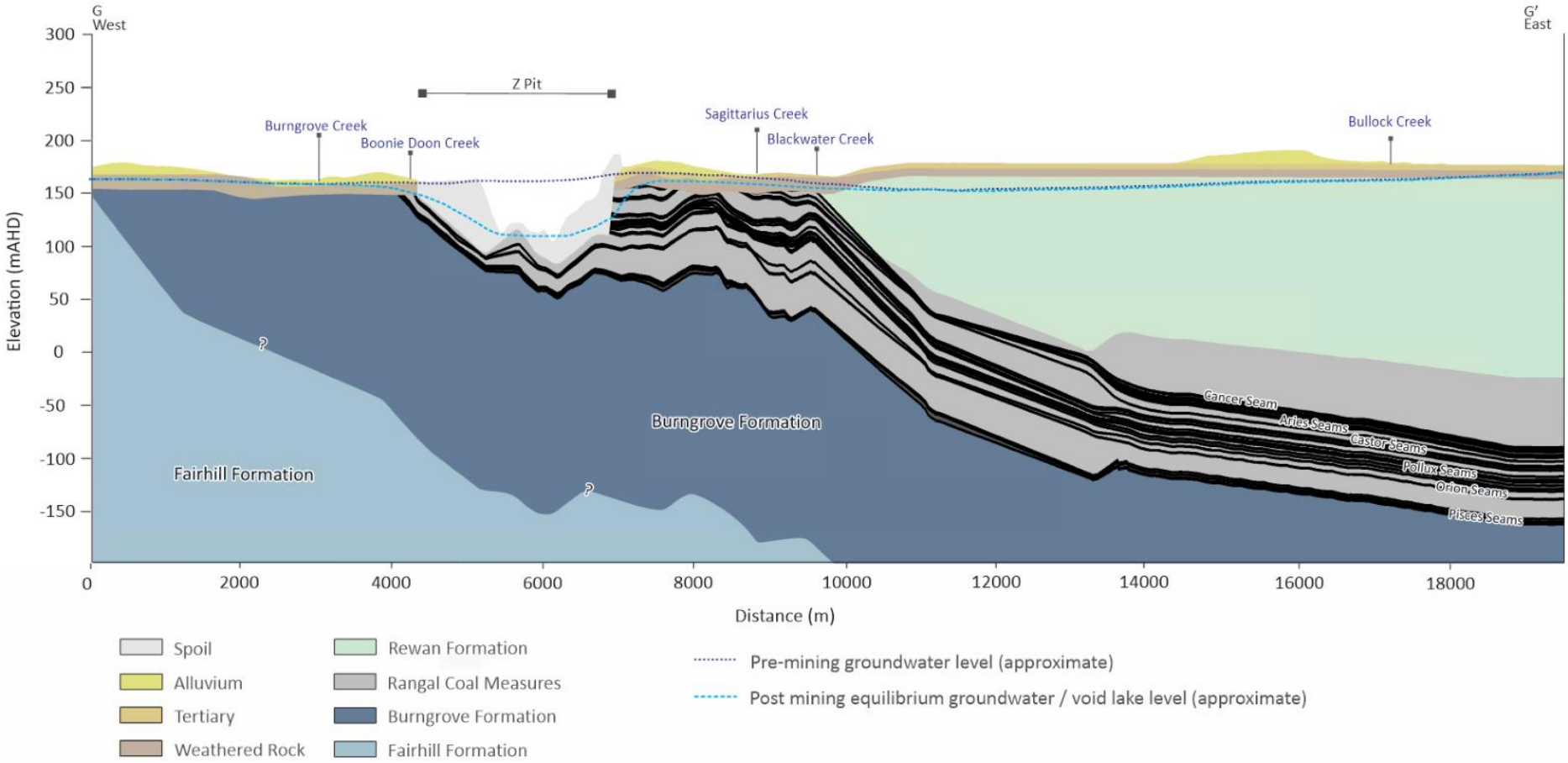


Figure 6-8 Geological cross-section G-G' of Curragh Project showing final landforms/voids and groundwater levels

An updated model has been constructed by SLR to assess the recovery of the groundwater system after mine closure. The key changes to the model design from that reported for the 2021 CRVA model (SLR, 2021) include:

- Model extent and grid – extended model domain, unstructured Voronoi grid with refinement in key areas;
- Model layers – constructed layers to capture significant displacement faults within Curragh Mine area and incorporate the most recent geological model for the Curragh Mine Complex;
- Boundary conditions – set model boundary conditions with revised grid and regional flows;
- Stresses – model inputs updated with recent and site-specific data;
- Calibration – the new model has been calibrated with an updated calibration data set.

The key objectives of the modelling exercise were to:

- Develop a calibrated model with mine progression, final voids, tailings storages in line with the current closure landform design developed by Coronado;
- Simulate the post-mining groundwater level recovery to assess whether the final voids will generally act as groundwater sinks or sources; and;
- Understand the long-term effect of the proposed post-mining landform on local groundwater levels by comparing the long-term post closure case to a null case (no mining scenario).

Further information on the numerical model is provided in **Appendix G**.

Post mining impacts were investigated with a recovery model, commencing at the end of active mining. A preliminary transient recovery model was developed initially to assess the relationship between the final voids' lake elevations and groundwater inflow. The relationship between groundwater inflows to the voids and void lake level was extracted from the preliminary recovery model and incorporated into the site water balance model (WBM). The WBM predicts the equilibrium lake levels for each void and these levels were then used in the final groundwater recovery model.

The final recovery model uses the MODFLOW river package (RIV) to simulate increasing void lake elevations in each of the final voids over the recovery period, with stage elevations vs time applied according to the WBM predictions for each void, up to the predicted equilibrium lake levels. The WBM predicted water levels in the final voids to reach equilibrium conditions after approximately 50 to 80 years, dependent on void structure and interaction with the regional groundwater system

The simulated average groundwater takes at the end of recovery (December 2132) at each of the site areas are presented in **Table 6-5.** The net groundwater flux has been calculated as a cumulative void flux for each area at Curragh Project (Curragh North, X Pit, Curragh Main, Ramp 9, Y Pit and Z Pit) (**Figure 6-9**) to account for interaction between the adjacent voids within each area. The groundwater fluxes to the final voids are total fluxes, including throughflow from spoil (higher recharge over the spoil and drainage into the final void), and groundwater inflow from the Rangal Coal Measures (RCM).

An equilibrium groundwater flux of 6.09 ML/day was predicted at Curragh North, where the minimum elevation of the final landform is 74.6 m lower than the other voids. The relative depth of the residual void at Curragh North is likely accountable for the higher predicted groundwater flux to the void in this area. Equilibrium total groundwater flux to the voids in X Pit, Curragh Main, Ramp 9, Y Pit and Z Pit are predicted to be 0.56, 0.67, 0.01, 0.08 and 0.64 ML/day respectively, indicating all simulated voids are predicted to be groundwater sinks with net groundwater flow into the voids.

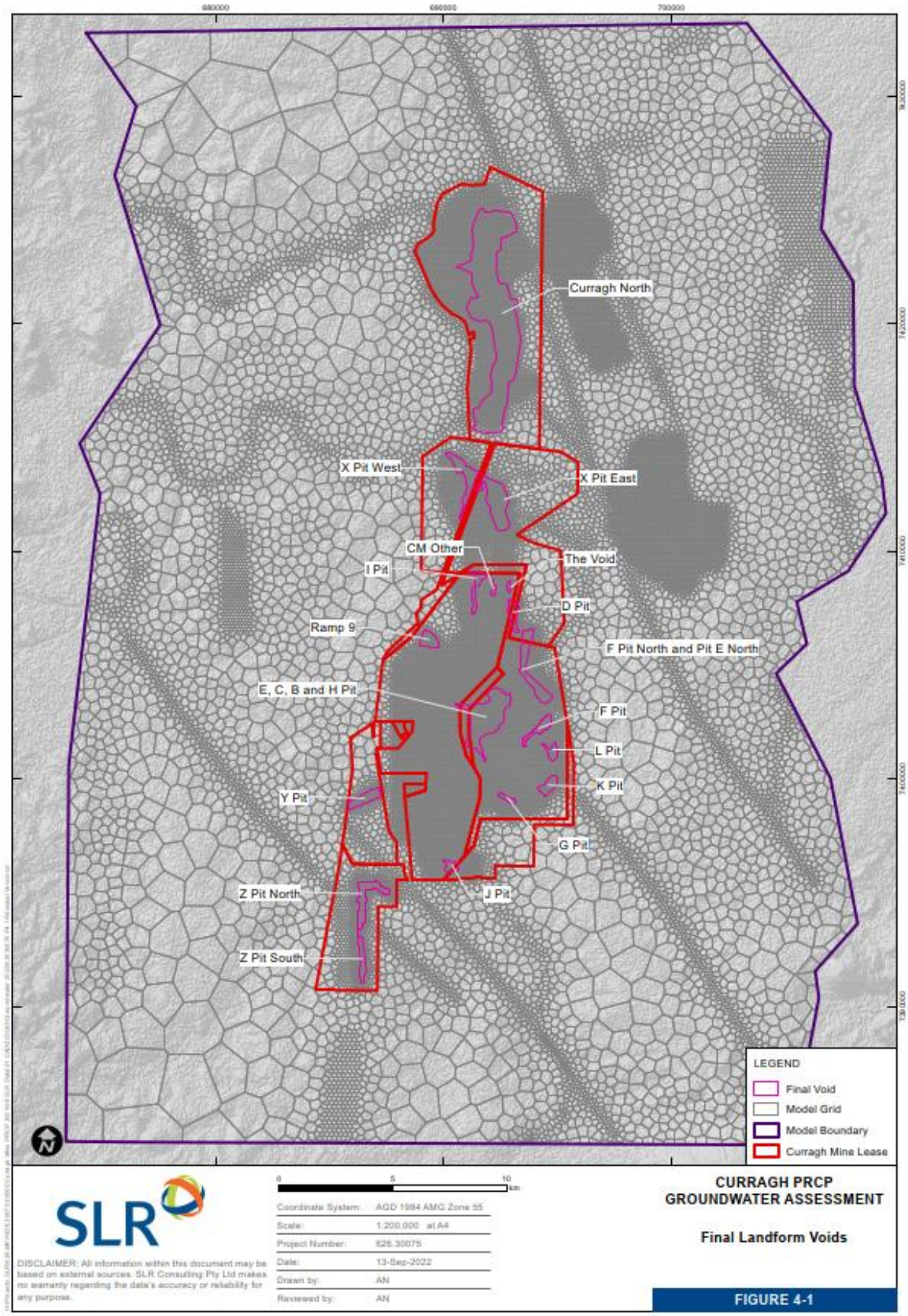


Figure 6-9 Hydrogeologic Residual Void Groups

Table 6-5 Post-mining equilibrium residual void summary

Curragh Area:		Curragh N	X Pit		Curragh Main										Ramp 9	Y Pit	Z Pit	
Residual Void[1]:		**UTS**	**X West**	**X East**	**I Pit**	**Main Other**	**The Void**	**D Pit**	**F Pit**	**F Pit North & E Pit**	**L Pit**	**K Pit**	**ECBH Pits**	**G Pit**	**J Pit**			**Z Pit North**	**Z Pit South**
Final landform minimum elevation (mAHD)		-48	78.373	33.503	133.1	120	93	29.13	91.6	26.6	64.6	63.11	40.6	130.1	92.6	77.1	116	78.1	87.11
Post-mining equilibrium void lake level (mAHD)*		23.1	98.2	67.3	134.3	127.4	125.7	62.2	110.5	49.3	102.3	77.1	70.3	136.4	111.2	131.4	123.2	107.8	104.6
Approximate base of weathering (mAHD)**		75	110	105	130	130	130	125	125	130	140	135	130	140	145	125	155	155	160
Void lake salinity (uS/cm), as predicted by the water balance model.[2]	~10 years	13,900	19,200	15,600	171,200	11,700	10,200	16,500	18,200	27,500	13,800	28,400	15,700	40,700	23,300	17,300	40,600	19,800	23,400
	~30 years	20,100	39,600	27,500	319,000	25,700	15,600	28,800	38,600	55,400	24,200	67,800	33,700	121,700	49,300	25,600	121,800	37,600	48,500
	~200 years	99,400	259,200	181,700	520,900	123,500	83,900	165,200	25,2500	276,500	150,200	416,900	228,600	484,800	324,800	99,800	500,700	237,800	317,000
Net groundwater flux to void at equilibrium (ML/day)***		6.14	0.57		1.44											0.02	0.08	0.64	

Notes:

1 The residual voids have been grouped where a void may act as a source of water to an adjacent void, but where collectively they act as a groundwater sink.

2 532,836 µS/cm is the maximum salinity limit set in the surface water balance model (SLR 2022)

* Final lake levels were derived from the surface water model.

** Approximate elevation of base of weathering estimated from available data.

*** Total flux including inflow draining from the spoil and groundwater inflow from the RCM

The predicted post-mining water table at equilibrium (end of recovery) is shown in **Figure 6-10**. Hydraulic gradients at equilibrium indicate an overall flow direction toward residual voids at Curragh Main and Curragh North. All residual voids show hydraulic heads decreasing with proximity to the void, indicating all voids are predicted to act as local groundwater sinks.

Predicted drawdown figures (**Figure 6-11** and **Figure 6-12**) show where residual drawdown impacts are predicted to exceed 1 m. **Figure 6-11** presents the residual drawdown just within the alluvium only at post-mining equilibrium. Predicted recovered heads in the alluvium west of Curragh North show residual drawdowns of 1 to 2 m extending up to 4 km from mined pits at Curragh North although drawdowns at the very edge of the voids are higher (10-20 m). **Figure 6-12** presents the residual drawdown of the water table at post-mining equilibrium.

To investigate the potential movement of groundwater to or from the voids and spoil at post-mining equilibrium, the post-mining water table predicted for the end of recovery was used to infer potential flow pathways in and around the spoil at each area of mining. Particle tracking was used together with the post-mining water table to predict groundwater movement relative to the voids and areas of spoil. Particles are “dropped” on the post mining equilibrium water table and allowed to track down hydraulic gradient from their starting position. **Figure 6-13** shows the inferred flow pathways around the residual voids interpreted from the particle tracking simulation at post-mining equilibrium. shows the inferred flow pathways around the residual voids interpreted from the particle tracking simulation at post-mining equilibrium. The flow paths from the outer edges of the voids or spoil dumps informed by the recovered head levels indicate groundwater flow is toward the residual voids hence none of the voids are likely to act as sources to the groundwater system. Particle tracking also indicates that indicates that groundwater in the vicinity of the TSFs and sources of potential groundwater contamination (infrastructure area, landfills) would move into towards the final voids rather than migrate off site

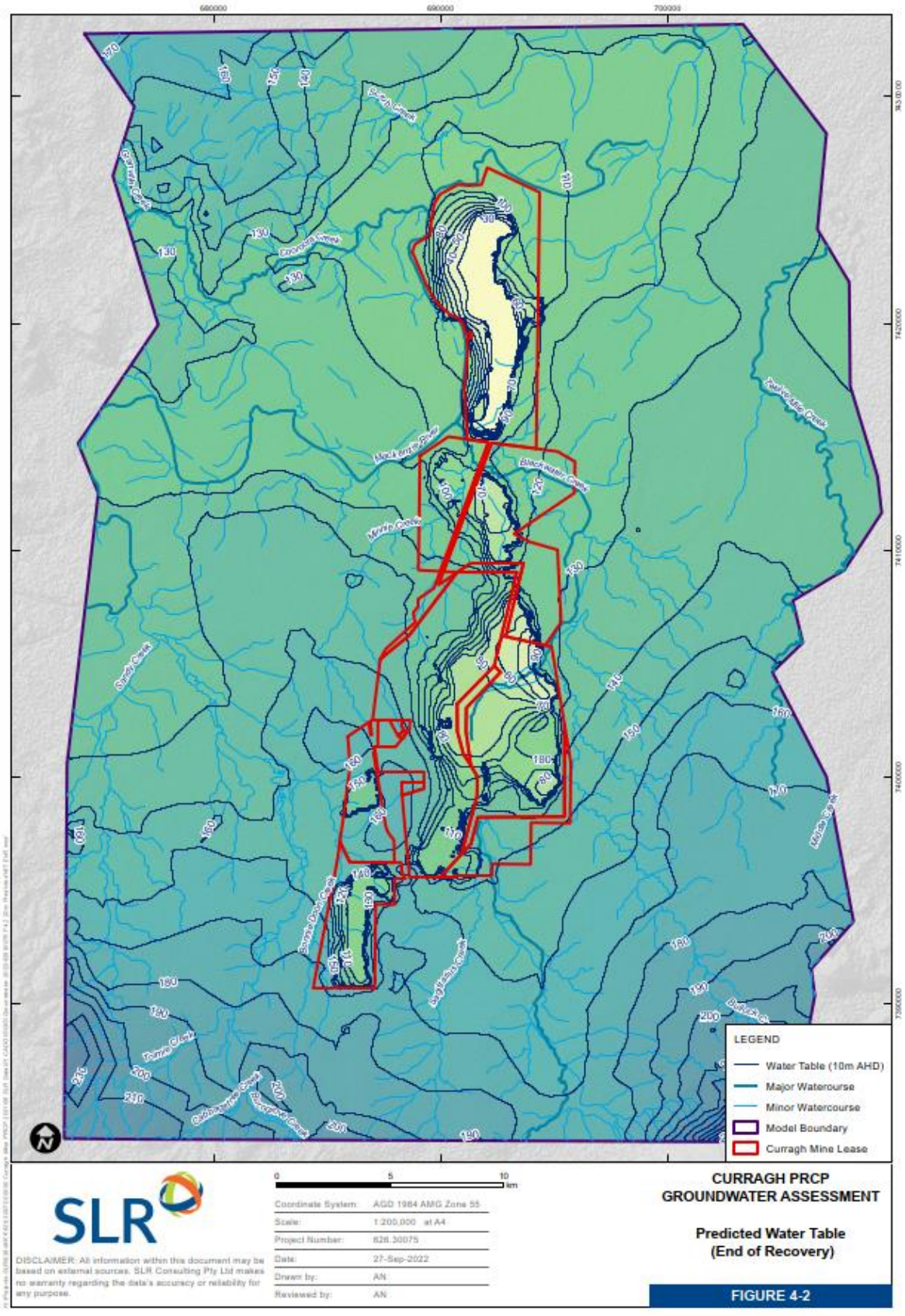


Figure 6-10 Predicted Water Table at End of Recovery

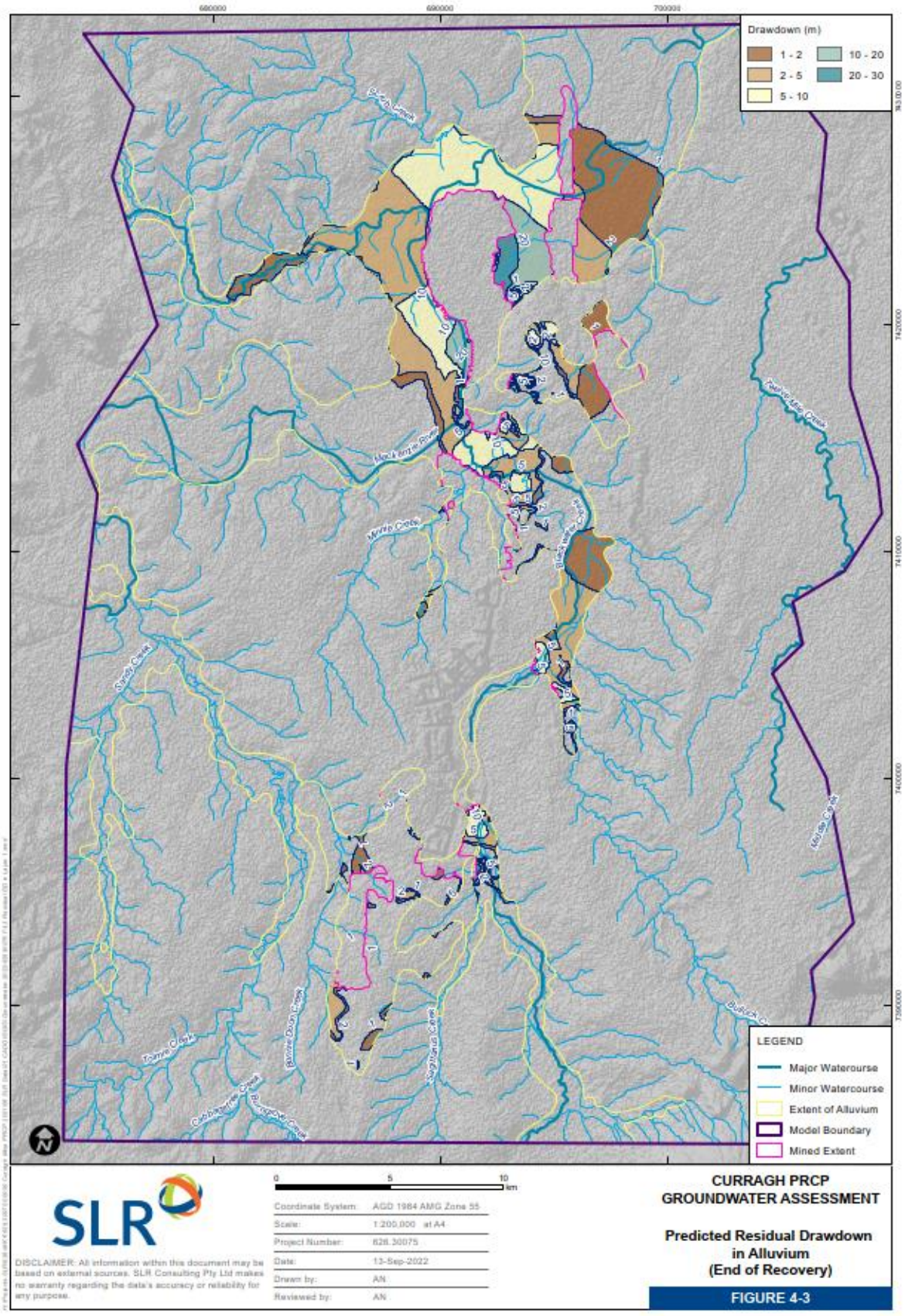


Figure 6-11 Predicted Residual Drawdown in Alluvium at End of Recovery

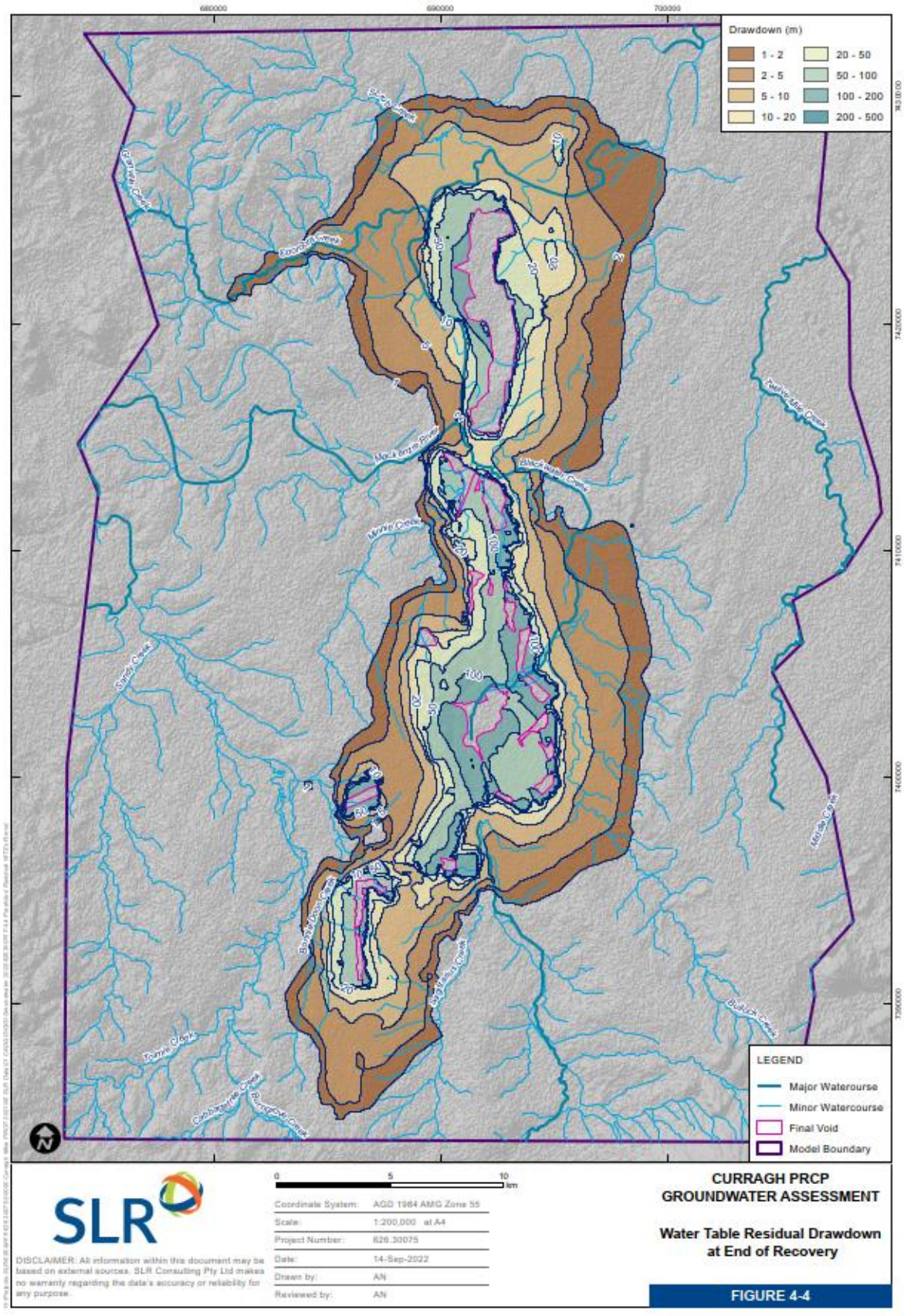


Figure 6-12 Predicted Residual Water Table Drawdown at End of Recovery

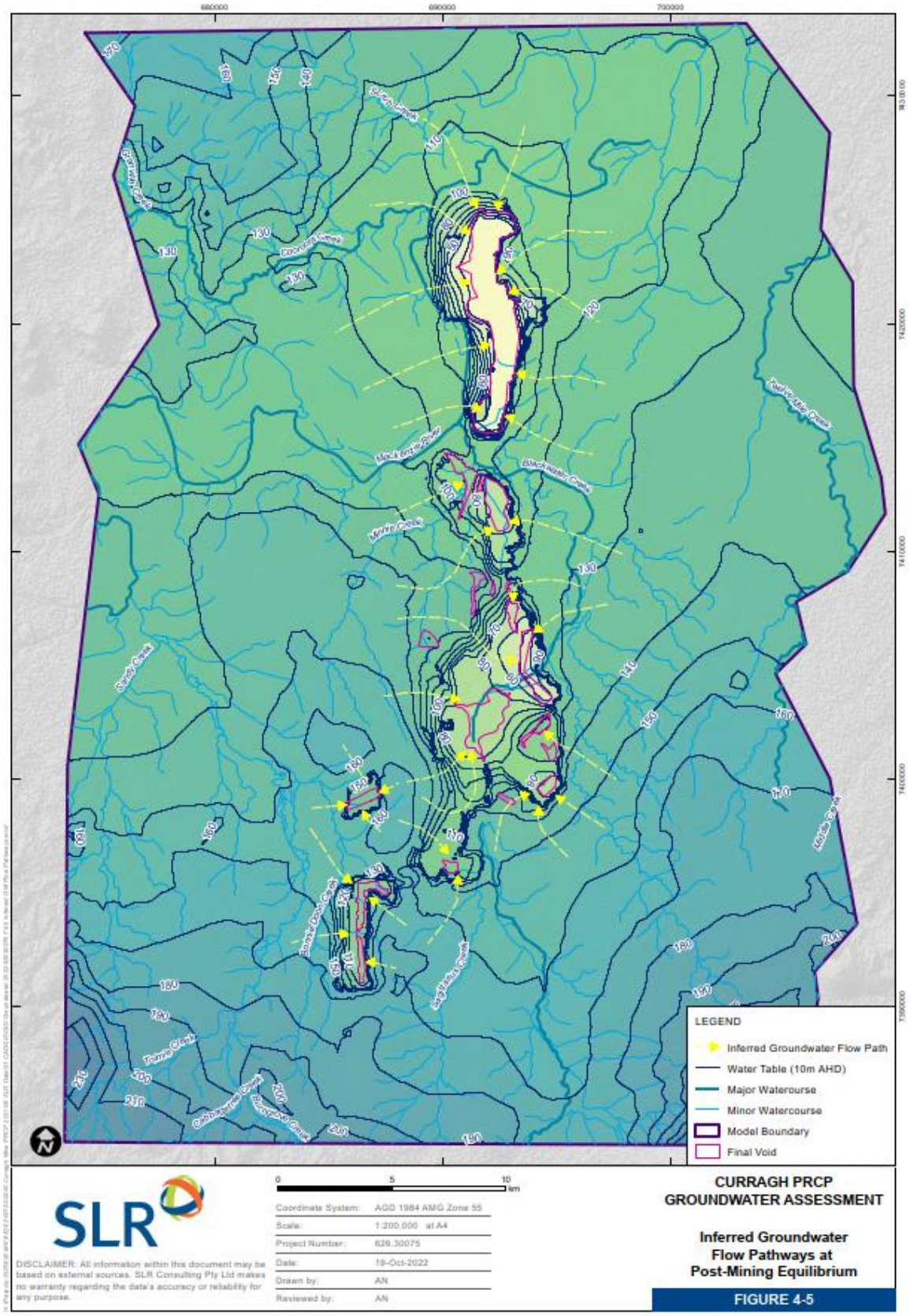


Figure 6-13 Inferred Groundwater Flow Pathways at post-mining Equilibrium

The following key conclusions are drawn from the numerical modelling assessment of the post-mining groundwater environment at the Curragh Mine Complex:

- The numerical modelling indicates that lakes will form within the final voids of the proposed post-mining landform. These lakes will act as local groundwater 'sinks' with groundwater within mining disturbed areas (including the TSFs, CRS and shallow groundwater at the location of potential sources of contamination) migrating towards these sinks.
- Post-mining residual drawdown in the Mackenzie River Alluvium to the west of Curragh North will generally be in the order of 1-2m (but up to 20m near the mine voids), noting that the Mackenzie River is regarded as a "losing" watercourse with pre-mining groundwater levels in the alluvium 3-5 m below the river stage in the vicinity of the mine.
- Based on the geological data reviewed for this assessment, it appears that equilibrium void lake levels are generally below the level of alluvium and base of weathering (potential preferential pathways for outward seepage of water from the void lakes). Where the minimum base of weathering elevation is potentially exceeded by the predicted equilibrium void lake levels at Ramp 9 and Pit G, particle tracking shows that any seepage from these voids will migrate to adjacent voids with lower void lake levels.
- Post-mining, the total estimated "groundwater" inflow to all voids is approximately 8.89 ML/d although the majority of this is water derived from infiltration to the spoil and drainage into the void lake rather than inflow from the Rangal Coal Measures or Alluvium.

6.1.3 Material Assessment

Topsoil Management

Topsoil is managed in accordance with the site Topsoil Management Procedure which outlines stripping methods, topsoil storage and topsoil placement.

Topsoil depth as determined from the soil mapping will provide a guide as to the depth of topsoil to be removed. All preferable topsoil shall be removed to the correct depth prior to mining. EMS PROC 1.3 Topsoil Management Procedure together with the EMS PROC 1.2 Permit to Disturb Procedure governs the removal of topsoil along with conditions and controls required for vegetation management.

Curragh's topsoil management program targets a stockpile surplus that is capable of ensuring that:

- Topsoil strips unable to sustain vegetation cover (e.g. through drought conditions) can be re-topsoiled if necessary;
- Bare spoil strips unable to sustain vegetation cover can be topsoiled where appropriate;
- If topsoil quality deteriorates in some areas of stockpile, there is sufficient volume of suitable quality to ensure that topsoiling needs are met; and
- Topsoil inventory reconciliations are undertaken regularly by the Curragh Survey team based on surveyed volumes.

Where suitably prepared areas are not yet ready for topsoil placement, topsoil shall be stockpiled to a maximum height of two lifts with rear dump trucks or scrapers to a height of about four metres to limit soil degradation. Procedures for the management of Topsoil are found in EMS PROC 1.3 Topsoil Management Procedure.

Topsoil replacement at Curragh Project is carried out in accordance with the following procedures EMS PROC 1.3 Topsoil Management Procedure and EM PLAN 1.3 Rehabilitation Management and Monitoring Plan.

Topsoil Inventory

CCPL (2020) has undertaken a topsoil quality assessment which includes information on the volumes and quality of topsoil stockpiles within the Curragh Project. Topsoil is currently stripped in advance of mining activities and stockpiled for utilisation in planned rehabilitation activities. As each new topsoil stockpile is created it is included into the topsoil inventory in its specific zone and allocated the next numerical number available. Therefore, the lower the stockpile ID number the older the topsoil stockpile is. However, as mining progresses some of the old topsoil stockpiles are required to be relocated. As this occurs comments are made in the topsoil inventory to indicate that a topsoil stockpile has been relocated to a new location, and whether it has kept its original number or had a new number allocated.

Topsoil stockpile zones are allocated as a new active mining pit or overburden dump location are created. Topsoil stockpiles are surveyed by the Curragh Survey Team for topsoil volume as they are generated, or at the end of each month with the aerial LIDAR process. Topsoil stockpile volume and location reconciliations are conducted by the Curragh Survey and Environmental Teams regularly and are saved in both a mapping layer for visual representation and an inventory list for volumetric analysis.

Topsoil stockpile locations and topsoil zones for Curragh Main and Curragh North are shown in **Figure 6-14** and **Figure 6-15** respectively, with current stockpiled topsoil volumes, by topsoil zone, provided in **Table 6-6**.

Table 6-6 Topsoil Inventory June 2022

Location Description		Volume m^3	Total m^3
Curragh Main	Zone 1	893,942	5,620,304
	Zone 2	70,284	
	Zone 3	533,081	
	Zone 4	255,829	
	Zone 5	626,809	
	Zone 5	433,939	
	Zone 7	955,893	
	Zone 8	785,359	
	Zone 9	1,065,168	
Curragh North	Zone 10	56,461	7,294,292
	Zone 11	119,893	
	Zone 12	134,156	
	Zone 13	856,792	
	Zone 14	849,045	
	Zone 15	4,180,573	
	Zone 16	1,097,372	
Total			**12,914,596**

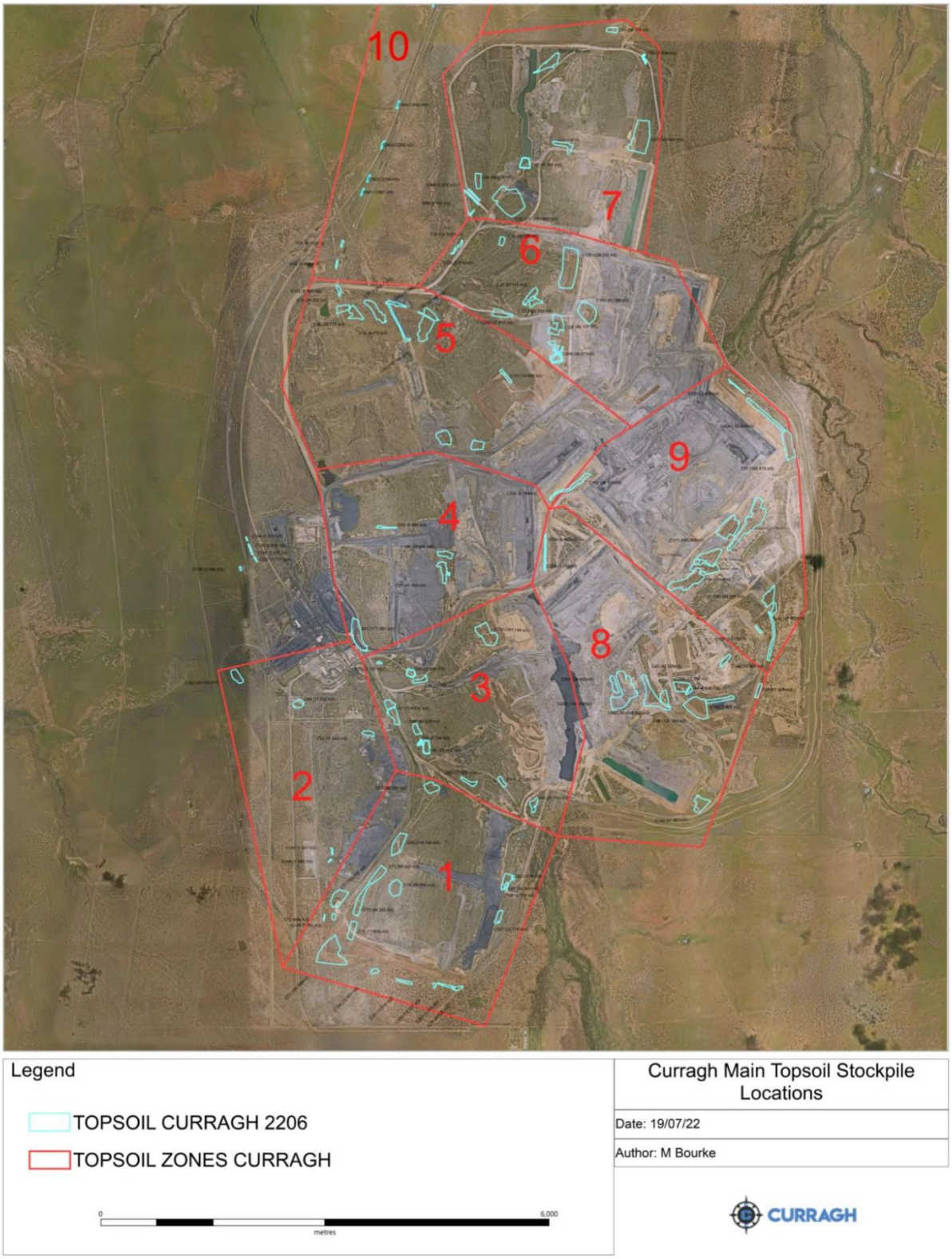


Figure 6-14 Curragh Main Topsoil Stockpile Locations by Zone

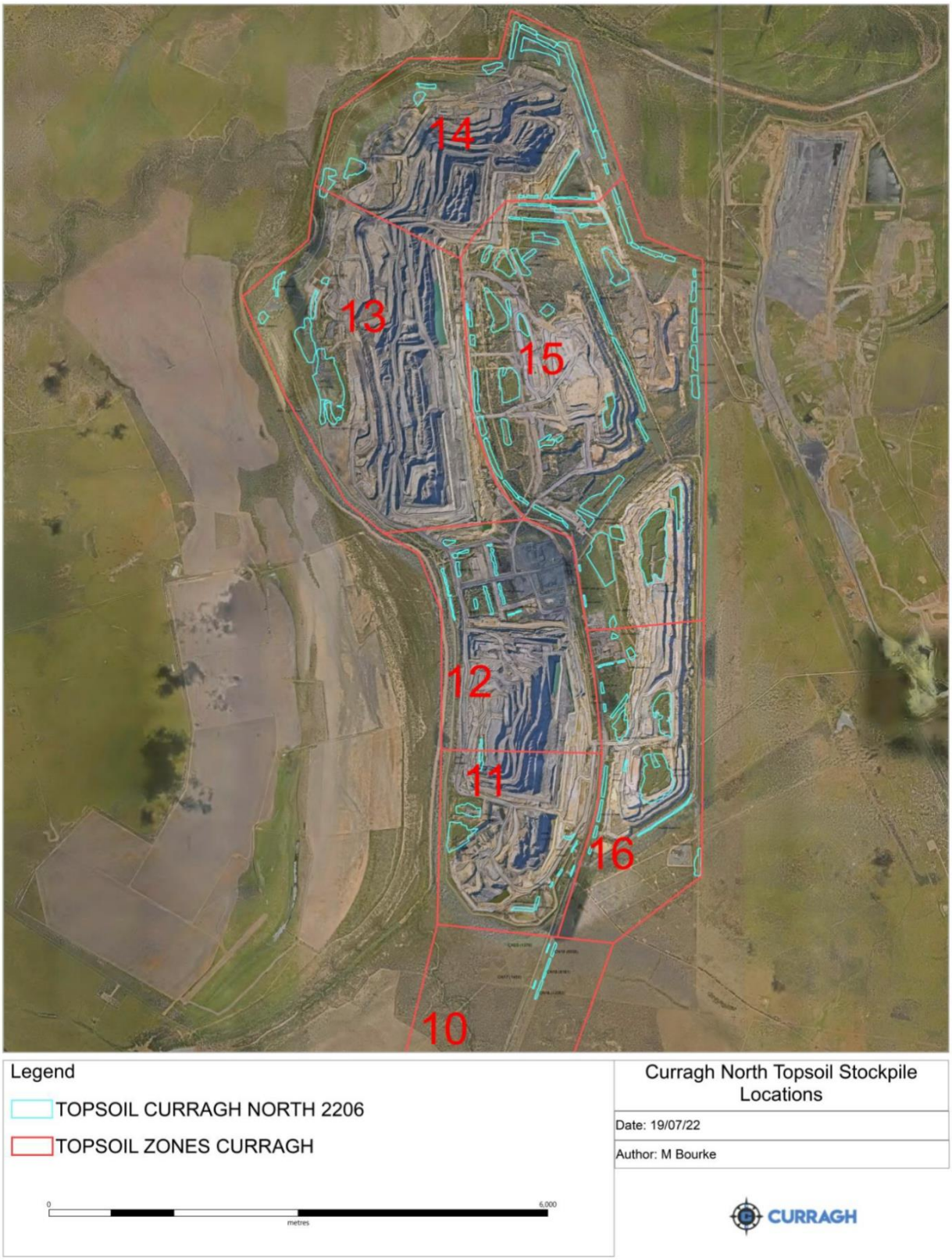


Figure 6-15 Curragh North Topsoil Stockpile Locations by Zone

Topsoil Quality

In 2020, CCPL conducted topsoil sampling program which included at least one stockpile from each zone (**Appendix H**). Zones with a collective volume of greater than 650,000m^3 of topsoil, were required to have two stockpiles from each zone sampled. Zones with a collective volume of less than 650,000m^3 were required to have only one stockpile from each zone sampled. Stockpile locations within each zone were chosen after a spatial assessment of all stockpile locations, taking into consideration adjacent zones.

Two composite samples, consisting of four grab samples each, were taken within every assessed stockpile. Each composite sample was collected in a north / south or east / west cross section dependent on the form and location of the stockpile.

The sampling strategy resulted in 23 stockpiles being sampled and a total of 45 individual samples being collected. The samples were taken by the Curragh environment personnel and sent to an Australian Laboratory Services (ALS) Laboratory for analysis of physical and chemical properties.

Both field and laboratory analysis were undertaken. The field observations recorded included, but was not limited to:

- Vegetation cover;
- Soil surface;
- Erosion impacts present;
- Soil colour; and
- Inclusion of waste or foreign objects.

All of the samples were sent to an ALS laboratory for analysis of the below parameters:

- ADMC at 40°C;
- pH plus EC 1:5;
- Total N, Nitrate, Nitrite, Ammonia;
- Bicarbonate Ext P (Oslen - Alkaline Soils);
- Organic Matter Content;
- Exchangeable Cations (Ca, Mg, K, Na), CEC, Ca/Mg ratio, ESP;
- Metals (Mn, Cu, Fe, Zn, B, Al);
- Sulphur (Total as S); and
- Chloride.

The following tables (**Table 6-7**, **Table 6-8** and **Table 6-9**) were used as the basis for the infield assessment of all soil samples.

The results of the infield assessments are presented in **Table 6-10** and indicate that of the 45 samples taken across 23 stockpiles on site, 32 samples or 71% place within the suitable range for field dispersion, 32 or 71% place within the suitable range for slaking behaviour and 45 or 100% of the samples place within the suitable range for dispersive behaviour.

Table 6-7 Field Dispersion Analysis

Score	Field analysis
0	Very stable soil
1 2 / 3	Stable soil, will resist dispersion after tillage Soil is prone to compaction and hard setting
4 /5	Soil will disperse if cultivated wet
6	Soil disperses strongly if cultivated wet
7 / 8	May benefit from stubble retention. If complete dispersion is observed within both initial wetting and remoulded aggregate tests, it is likely that dispersive attributes of the soil may require soil amelioration and provide a poor environmental for plant growth. Laboratory analysis will assist with further analysis.

Table 6-8 Field Slaking Scores

Score	Slaking Behaviour	Field analysis
0	If the aggregate remains intact	This soil is stable to wetting. This is typical of pasture soils. No action is needed
1	if the aggregate collapses around the edges but remains mainly intact	
2	If the aggregate collapses into angular pieces	This is typical of self-mulching clays. If the soil does not disperse no action is necessary.
3	If the aggregate collapses into small (less than 2 mm diameter) rounded pieces, forming a cone	Surface may form a crust. However, this is only a problem in non-swelling
4	If the aggregate collapses into single grains (you can see sand grains).	This soil is very likely to crust and hard-set (sands and loams). Reduced cultivation, stubble retention and more frequent irrigations may be necessary on these soils.

Table 6-9 Dispersive Behaviour

Score	Dispersive Behaviour
0	Nil dispersion
1	Slight dispersion, recognised by slight milkiness of water adjacent to the aggregate
2	Moderate dispersion with obvious milkiness
3	Strong dispersion with considerable milkiness and about half of the original volume of the aggregate dispersed outwards
4	Complete dispersion, leaving only sand grains in a cloud of clay

Table 6-10Curragh North Field Dispersion and Slaking Behaviour

Topsoil Stockpile #	Zone #	Volume (m^3)	Dominant Texture	Field Dispersion Score	Field Slaking Score	Dispersive Behaviour
CN364_1	11	305,894	Clay, loam sandy	2 - 3	3	0
CN364_2	11	305,894	Clayey sand	2 - 3	1	0
CN385_1	11	26,135	Clayey sand	4 - 5	1	1
CN385_2	11	26,135	Clayey sand	4 - 5	3	2
CN387_1	11	51,624	Clayey sand	4 - 5	3	2
CN387_2	11	51,624	Sandy loam	4 - 5	3	0
CN212_1	12	22,240	Clay loam	1	2	0
CN212_2	12	22,240	Clay loam	1	2	0
CN413_1	13	420,158	Sandy clay loam	1	1	1
CN413_2	13	420,158	Sandy clay loam	4 - 5	3	0
CN55_1	13	38,570	Clay loam	1	1	1
CN55_2	13	38,570	Clay loam	1	1	2
CN326_1	14	46,764	Light medium clay	1	1	1
CN326_2	14	46,764	Light clay	2 - 3	1	0
CN400_1	14	66,387	Clay loam	1	4	0
CN400_2	14	66,387	Clay loam	1	4	0
CN93_1	15	328,172		2 - 3	1	0
CN93_2	15	328,172	Medium Clay	2 - 3	1	2
CN225_1	16	17,600	Medium heavy clay	4 - 5	3	0

CN225_2	16	17,600	Medium clay	4 - 5	1	0
CN414_1	16	28,087	Sand	4 - 5	0	1
CN414_2	16	28,087	Sand	4 - 5	4	1

General topsoil stockpile categorisation values can be assigned to each stockpile based on the overall presence of vegetation and percentage of uncontaminated material observed as per the categories defined in **Table 6-11**.

Table 6-11 Stockpile Quality Category

Topsoil Stockpile Category	Value Description
A	High value. Low levels of contaminated material. Uncontaminated soil content at least 70% of the stockpile. Quality topsoil.
B	Moderate value. Soil purity 50-70%. Higher levels of contamination and variable quality. Useable topsoil value but preferable in lower sloping areas or as 'subsoil' material or capping.
C	Marginal. Significant levels of contamination present (>50%). Quality better than most spoil present but only useful a capping / subsoil material in rehabilitation.
D	Unsuitable. No better that spoil material present.

In total 23 Stockpiles were sampled during the study and the categories assigned to the stockpiles show a 50:50 split of Category A and Category B stockpiles, with 48% and 52% respectively. At Curragh Main the results split was 58%:42% for Category A and Category B stockpile qualities. With Curragh North stockpiles had 41% assigned a stockpile quality Category A and 59% assigned a Category B.

The laboratory results have also been assessed using categories for primary parameters tested.

Soil pH is important as it affects the ability of nutrients in soil. Ensuring the pH of the soil is as close as possible to the neutral range as indicated below in **Table 6-12** will ensure satisfactory results when the topsoil is used for planned rehabilitation activities.

Table 6-12 pH Rating

Rating	pH
Acidic	5.6–6.5
Neutral	6.6–7.5
Mild Alkalinity	7.6–8.5
Alkaline	>8.5

The laboratory results of all pH (1:5 soil/water) samples show soil pH within the 7.3 – 9.2 range. Topsoil at Curragh Main ranges from 7.6 – 8.4 with the average value of 8.13. Topsoil at Curragh North ranges from 8.4 – analysed is shown in

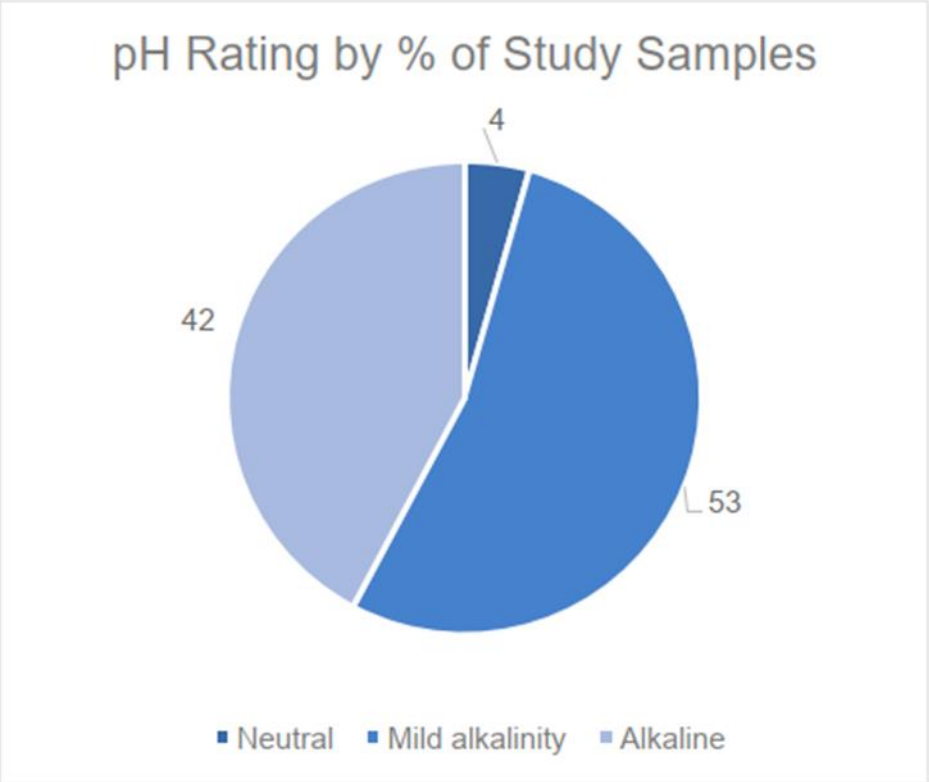


Figure 6-16.

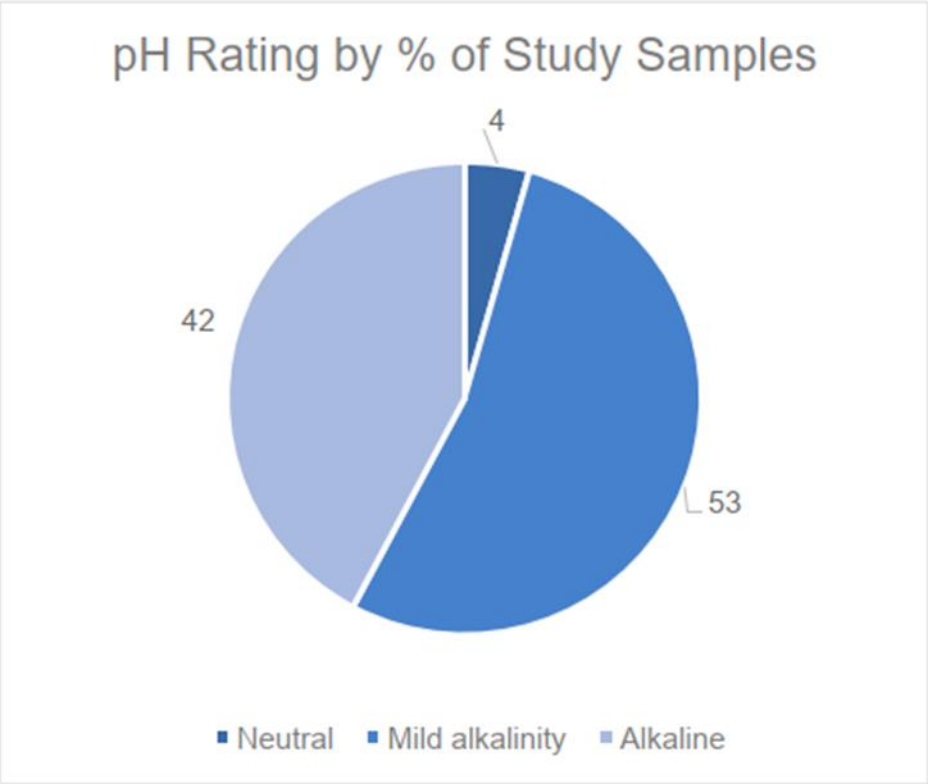


Figure 6-16 pH Rating by % of Study Samples

Cation Exchange Capacity (CEC) is the measurement used to assess the overall nutrient holding capability of soil. The stockpiled topsoil has been surface soil stripped and placed into stockpiles predominantly using scrapers. The samples sent for laboratory analysis were all taken from within a depth of 300mm of the stockpile surfaces and results interpreted in accordance with **Table 6-13**.

Table 6-13 Cation Exchange Capacity Rating and Results

Rating	CEC/ECEC (meq/100 g of soil)	# of samples	% of study area
very low	<5	3	7
low	5–15	11	24
moderate	15–25	25	56
high	25–40	6	13
very high	>40	0	0

The results of all CEC samples indicate a range of results regarding cation exchange (nutrient holding) capacity. The results indicated 13% of samples were in the moderate CEC range and 31% in the low to very low range with the higher results coming from the Curragh Main area and the lower results from the Curragh North area. The average CEC for Curragh Main is 20.26meg/100g soil and Curragh North is 13.96meg/100g soil.

Exchangeable sodium percentage (ESP) is used to assess the relative abundance of exchangeable sodium. Where high levels of exchangeable sodium are present relative to other cations the soil material physical property is deemed to be of a sodic nature. **Table 6-14** provides the rating table used for analysis of the sample results. Soils with a high exchangeable sodium percentage disperse readily.

Table 6-14 Exchangeable Sodium Percentage Rating

Rating	Exchangeable Sodium Percentage (%)
non-sodic (low)	<6
sodic (moderate)	6–15
strongly sodic (high)	15–20
extremely sodic (very high)	>20

Calcium Magnesium ratio provides a guide to the relative abundance of the two major cations (Calcium and Magnesium) and is useful when used in conjunction with Exchangeable Sodium Percentage to predict soil physical behaviour. Soils with a high Calcium dominance, as described by the rating in **Table 6-15**, will counteract the dispersive nature of the ESP.

Table 6-15 Calcium Magnesium Ratio Rating

Rating	Ca/Mg ratio	Comments
very low	<0.10	Mg is >10 times more dominant than Ca
low	0.10–0.50	Mg is 5–10 times more dominant than Ca
moderate	0.51–1.0	Ca and Mg becoming co-dominant
high	1.1–2	Ca more dominant than Mg
very high	>2	Ca >2 times more dominant than Mg

The laboratory results of both the ESP and calcium/magnesium ratio indicate majority of soils across site (80%) rated as non-sodic with 18% being sodic and 2% (one sampled stockpile) with a strongly sodic rating. The strongly sodic stockpile is located at Curragh North. Correspondingly, of the soils sampled across site, 88% and 12% identify as having a very high and high dominance of calcium resulting in majority (80-100%) of soils across site physical property being non dispersive.

Bicarbonate Extractable Phosphorus is the current measurement for the assessment of relative differences in soil fertility. Using the rating table adapted from Ahern provided in McCann, R (2019) (**Table 6-16**), 46.7% of the samples taken during the assessment returned a moderate or higher soil fertility rating. 37.8% returned a low fertility rating and 15.6% returned a very low soil fertility rating. On average Curragh North samples indicated almost two times greater soil fertility than Curragh Main with the reading being 15.8ppm and 8.31ppm respectively. Curragh North samples ranged from 1ppm to 48.2ppm, whilst Curragh Main samples ranged for 1ppm to 26.7ppm.

Table 6-16 Bicarbonate Extractable Phosphorus Rating

Rating	Bicarb. extr. P (ppm)
very low	<5
low	6-9
moderate	10-15
high	16-40
very high	>40

Total Organic Carbon is generally used to assess surface soil fertility. All topsoil stockpiles on the mine site are surface topsoil stripped and placed in stockpiles. Therefore, the assessment of total organic carbon is relevant to each stockpile in its entirety.

Using the rating table from Bruce and Rayment (1982) (**Table 6-17**) the Laboratory results for Total Organic Carbon indicate that 44% of the samples taken during the assessment returned a moderate or higher soil fertility. 53% returned a low fertility rating and 2% a very low rating. Curragh Main samples were on average higher than Curragh North samples, with average values of 1.9% and 1.1% respectively. Curragh Main results ranged from 1% to 4.2%, whilst Curragh North results ranged from 0.5% to 2.4%.

Table 6-17 Organic Carbon Rating

Rating	Organic Carbon (%)[1]
Very Low	<0.5
Low	0.5-1.5
Moderate	1.6-2.5
High	2.6-5.0
Very High	>5.0

1 – Categories from Bruce and Rayment (1982)

This topsoil quality assessment study conducted in 2020 has shown most of the stockpiled topsoil at both Curragh Main and Curragh North is of acceptable physical and chemical quality and will not require amelioration during planned rehabilitation activities. With selective placement of topsoil depending on its quality and proposed location, any potential negative effects from poorer soil quality can be further mitigated.

The overall stockpiled topsoil quality is rated as an A or B, based of field observations, indicating high purity and relatively uncontaminated high value topsoil. The results from the topsoil quality assessment indicate a similar quality to that which has historically been found within Brigalow and Eucalypt Scrub plains at Curragh and Curragh Main (McCann, R, 2019).

Amelioration could be considered if rehabilitation of an area is required to be established prior to an upcoming unfavourable weather event such as drought or a severe wet season. Inclusion of amelioration would improve the speed in which the vegetative cover establishes and provide protection from environmental impacts. Similarly, the use of a hydromulch or other materials could be considered in such circumstances.

Topsoil Rehabilitation Strategy

The majority of the site has a post-mining land use of Light Grazing and Open Woodland. Topsoil placement will be prioritised where a more concentrated grazing outcome is desired as topsoil promotes grass growth. Topsoil is proposed to be placed at a depth of 0.2 m to the following areas:

- Infrastructure areas;
- Miscellaneous activities (rehabilitated roads and tracks, ROM Pad, etc.);
- 65% of overburden dumps; and
- Tailings Storage facility.

A topsoil inventory of the areas requiring topsoil as of June 2022 is provided in **Table 6-18**.

Table 6-18 Topsoil Required for Rehabilitation as of June 2022

Domain	Topsoil Required (m^3)
Infrastructure Areas	1,109,204
Miscellaneous activities	183,086

Domain	Topsoil Required (m^3)
65% Overburden Dumps	7,010,498
Tailings Storage Facility	640,330
Total	**8,943,118**

Only 65% of the overburden dumps are proposed to be topsoiled using a spoil strip and topsoil rehabilitation strip method. This method involves planting native tree and shrub species directly into the overburden. The topsoil areas provide immediate grass coverage and act as a source of grass seeds to occupy the overburden areas once the native trees have established. Therefore, overcoming the issue of the introduced grass species outcompeting the native trees and shrubs (Australian Government, 2016). This method allows both grass and tree and shrub species to establish and therefore provide for the mixed land use of Light Grazing and Open Woodland.

WSP (2019) completed a Progressive Rehabilitation Certification Report with the purpose of identifying potential areas suitable for progressive certification under the EP Act. One of the recommendations of this report was to continue using the spoil/topsoil strip method as it has proven to promote tree and shrub growth and support the post-mining land use towards certification readiness.

Material Balance

A topsoil materials balance has been developed showing the material available and material requirements for rehabilitation as of June 2022 (**Table 6-19**). The materials balance shows that there is a current surplus in material available for use in rehabilitation. It is CCPL's objective to have a surplus of material to account for possible losses or deterioration of topsoil quality. If any surplus exists at the time of final closure, then topsoil will be applied at a greater depth or it will be used for maintenance of existing rehabilitation.

Table 6-19 Topsoil Balance as of June 2022

Inventory	Topsoil Amount (m^3)
Topsoil Available	12,914,596
Topsoil Required for Rehabilitation	8,943,118
Topsoil Balance	**Surplus 3,971,478**

This material balance will be updated throughout the life of mine as mining and rehabilitation progress.

6.1.4 Waste Characterisation

A review of existing documentation has been undertaken to assess the types of mine waste present at Curragh the percentages of material present and to propose a suitable rehabilitation treatment for spoil. This review includes Curagh Main, Curragh East and Curragh North. Given that Curragh West and the Curragh Extension Project have not yet commenced there is no existing waste characterisation to assess; however, a preliminary indicative waste characterisation program has been outlined for collecting future data in these areas.

The key outcomes identified in the review include:

- Overburden is characterised by a low propensity for acid generation and acid and metalliferous drainage (AMD) is unlikely to develop to be a management issue;

- Sodicity levels for the overburden material are sufficiently high to warrant placement of overburden below the root zone; and
- Salinity levels are not sufficiently high to adversely affect plant growth.

Although the AMD risk is very low, it has been adjusted to account for a small number of samples at Curragh North that have some acid generating potential, thus between 90-95% NAF waste across Curragh Mine, 5% PAF waste at Curragh North and an overall 5% uncertainty to account for areas that may not have been fully represented in the sampling programmes.

Curragh Mining Complex

Stuart Miller & Associates (1984, 1980) and Emmerton (1993) carried out spoil characterisation studies to provide physical and chemical data for dragline spoil throughout the mine. Emmerton encountered some acidity and potential acidity in the Ramp 11 to Ramp 12 area, but quantities of these materials were not large.

Stuart Miller and Associates (1984) completed field and laboratory investigation to characterise overburden and identify management techniques that may be required to maximise rehabilitation success and preserve water quality. This report focuses on overburden samples taken from Pits C and E (formerly known as Pit E East) as well parts of Pits B and D.

The results show that:

- The total sulphur content of samples ranged from 0.03 to 2.8%;
- The ANC is high in all samples – and hence sufficient to neutralise acid produced by oxidation of sulphur;
- The thin (<0.5m) interburden layer between the Aries/Castor and Pollux seams is acid forming in places but shouldn't prove problematic in rehabilitation, provided that this strata is mixed with other layers;
- Spoils were moderately to highly saline and were highly sodic; and
- Coal seams are potentially acid forming and hence rejects generated from this area may be acidic in nature.

Land Reclamation Service completed a survey of dragline dumped spoil in 1993, 81 grab samples were analysed for pH and EC, with results from these samples used to select 41 samples for further analysis. The in-situ and laboratory results have shown that:

- The majority of spoil is saline and sodic:
- Of the 81 grab samples only 6 returned an acidic pH with;
    - One of these samples came from coal reject material;
    - Four samples contained oxidised coal material;
    - One clay and grey shale material with slight acidity was found between ramps 7 and 8.

In addition to the dragline spoil sampling, Land Reclamation Services also completed analysis of overburden chips from 5 drill holes within the mining lease. The samples were analysed for pH and EC (1:5) and results show that:

- In general, weathered materials (ranging from 333 to 2270 µS/cm) appear to have higher salinities than unweathered materials (EC between 293 and 945 µS/cm); and
- The majority of the chip samples were strongly alkaline with the exception being some near surface clay samples from the northern area of the mining lease.

HLA-Envirosciences completed pH and NAG analysis on 20 samples from 5 bore holes in March 1998. Of the twenty samples only two had an acidic pH and a NAG of >0.1. The details of these two samples are shown below:

- Sample 98137-13100 was taken from between the base of weathering and the Aries roof, a pH of 3.4 and NAG of 12.9 kg/t was recorded; and
- Sample 98143-13118 was taken between Aries floor and Caster roof, a pH of 2.9 and NAG of 4.5kg.

The above was summarised in the 2002 EMOS as follows: “NAG testing was also undertaken during 1998 in conjunction with the highwall drilling program, i.e. west of Blackwater Creek to identify any adverse material that would need to be ameliorated. A total of 20 soil sampled were analysed by an independent NATA registered laboratory. The results indicated that the spoil being removed was non-acid forming.

Curragh East Mining Complex

As part of the Curragh East Project, Environmental Geochemistry International (EGI) was commissioned to investigate the Acid Forming Potential (AFP) and environmental geochemistry of the overburden in the Curragh East project area. Curragh Mine personal supplied the EGI laboratory with 119 samples from varying depths within 16 drill holes. All samples were analysed for total sulphur content and ANC with subsequent calculations to determine NAPP being made. Selected samples then underwent Net Acid Generation NAG testing and a multi element analysis. From the analysis the following conclusions were drawn:

- All samples had low sulphur contents (<0.01 to 0.36%), the samples with the greater than 0.15% Sulphur were almost exclusively from the roof or floor of the Aries and Castor seams;
- ANC were typically moderate to high, and generally increased with sample depth;
- In most cases the ANC is at least 20-times the acid production potential;
- NAPP results were all negative and therefore all samples are classified as non-acid forming;
- Overburden is slightly to moderately enriched with Silver, Arsenic and Selenium, however concentrations are below levels which would limit rehabilitation of the overburden after mining;
- Spoil was found to be generally sodic in nature; and
- The potential for generation of acidic leachates in all types of spoil from the Curragh East area is extremely low.

The above was summarised in the 2002 EMOS as follows: “East of Blackwater Creek, 119 samples of overburden and interburden were tested for acid formation potential (EGI, 1993). Eleven of these were selected for Net Acid Generation (NAG) testing. All 119 samples had low sulphur contents and highly negative Net Acid Producing Potential (NAPP) and NAG testing confirmed an excess of acid neutralising capacity (ANC), hence little likelihood of acid generation by spoil during or after mining.”

Curragh North Mining Complex

Spoil characterisation studies were carried out during the feasibility analysis for Curragh North (Wesfarmers Curragh Pty Ltd, 2003). All overburden samples analysed were non-saline, while the pH and Net Acid Producing Potential results have indicated that the overburden characterised demonstrates a low propensity for acid generation.

More specific information on the types of overburden, with regards to PAF is provided in Austral Asian Resource Consultants (1999) in MinServe Pisces Coal Project - Environmental Management Overview Strategy (Draft) indicating the following:

- Median ANC values for alluvium and Permian overburden were 10 and 12 kg/t respectively;
- Median acid producing potential (APP) for alluvium and Permian material were 0.5 kg/t and 1 kg/t respectively. Six of the 36 samples displayed a positive NAPP. All of these were Permian, fine grained mudstone and siltstones. Acid leachate will not be a concern in the context of future spoil heaps; and
- All samples tested were alkaline however, alluvium has slightly lower pH results.

Geochemical analysis of spoil material at Curragh North (undertaken during 2002 and 2004 for the Curragh North EIS and updated in 2009) indicates that most of the overburden demonstrates a low propensity for acid generation, and all the overburden materials contain sufficient acid neutralising capacity (ANC) to neutralise any acid that may be generated. Additionally, there are no known incidents of acid mine drainage from the site.

The geochemical properties of the overburden to be placed on the raised dumps will be the same as currently stockpiled. As such, increasing the height of the spoil dumps is not expected to increase the risk of environmental harm. This is based on the:

- Known characteristics of the overburden (little likelihood of acid generation by spoil during or post mining); and
- On-site mine water management system (which collects and retains mine affected water on-site).

Overburden characterisation was undertaken by AustralAsian Resource Consultants Pty Ltd (AARC) for the Curragh North EIS. This characterisation used analytical results from 33 overburden samples to identify and evaluate potential management issues associated with the handling of overburden material.

The samples were analysed for:

- Acid leach potential pH, Net Acid Producing Potential (NAPP);
- Salinity (electrical conductivity - EC);
- Sodicity/dispersity – exchangeable sodium percentage (ESP);
- Activity – cation exchange capacity (CEC), major cations;
- Soil aluminium toxicity; and
- Heavy metals – arsenic, selenium.

The outcomes from this work are summarised in **Table 6-20**.

Table 6-20 Summary of Results from Geochemical Analysis of Overburden

Analysis	Summary of Results
Acid producing potential	pH: • all samples tested were neutral to strongly alkaline (pH ranging from 7.3 to 10.1) • Permian material tended to be more strongly alkaline • elevated pH results indicate that aluminium toxicity is unlikely to be of management concern NAPP: • ranged from -295.6 kg/t to 5 kg/t • only 6 of the 33 samples displayed a positive NAPP, all of which were Permian, fine-grained mudstone and siltstones • the overburden demonstrated a moderate neutralising capacity (average acid neutralising capacity (ANC) 35 kg/t)

Analysis	Summary of Results
Sodicity	• pH for the overburden is moderately to highly sodic (ESP 5 – 35) indicating an increased potential for dispersion and erosion, surface crusting, impermeability and poor aeration • the magnesium/calcium ratio suggests that isolated Tertiary alluvium samples display a greater susceptibility to dispersion than Quaternary or Permian material • Tertiary material and much of the fine-grained Permian material will not be desirable as subsoil and should where practical be placed below the root zone.
Salinity	• all overburden samples analysed were non-saline with EC values ranging between 80 µS/cm and 1180 µS/cm, with an average EC of 352 µS/cm • the highest EC result was present in Permian sandstone material and fall well below that likely to affect plant growth.

Based on these characterisation results it was concluded that:

- pH and NAPP results - indicate that the overburden is characterised by a low propensity for acid generation and acid and metalliferous drainage (AMD) is unlikely to develop to be a management issue;
- Sodicity levels for the overburden material are sufficiently high to warrant placement of overburden below the root zone; and
- Salinity levels are not sufficiently high to adversely affect plant growth.

Curragh, Curragh East and Curragh North

Further sampling of mine spoil from Curragh, Curragh East and Curragh North was undertaken during 2009 by Curragh Mine site personnel. As outlined in the Curragh Project Rehabilitation Management and Monitoring Plan (EM PLAN 1.3), sampling used an experimental process which involved measuring field pH (pHF) and field pH peroxide (pHFOX) on sub-samples of mine spoil. The Guidelines for Sampling an Analysis of Lowland Acid Sulfate Soils in Queensland (Ahern et al. 1998) were also used to interpret the experimental results. Based on the Ahern (1998) guideline, a combination of three factors was applied to describe a positive field sulfide identification:

- A reaction with hydrogen peroxide;
- A much lower pH_{FOX} than field pH_F (ΔpH); and
- Actual value of pH_{FOX}.

In addition to field investigations, 11 samples were sent to a NATA accredited laboratory for further analysis.

The results from the field and laboratory analysis are summarised in **Table 6-21**.

Table 6-21 Results of Overburden Sampling (On-site 2009)

Parameter	Field assessment	Laboratory Analysis (11 samples)
pH	pH_F: 7.4 to 9.4 Note: one sample from Permian material on the Curragh North Eastern spoil dump returned a pH_F of 6.3.	pH: 7.8 to 9.4
pH_{FOX} / △pH	Only two samples returned an acidic pH_{FOX} (Tertiary and Permian materials from the Curragh North Eastern spoil dump). Permian material on the Curragh North Eastern spoil dump has the highest acid sulfate soil (PASS) potential, with pH_{FOX} of 2.7 and ΔpH of 3.6.	As per the field assessment two samples returned an acidic pH_{OX} these samples were the two samples from the Curragh North Eastern spoil dump.

Parameter	Field assessment	Laboratory Analysis (11 samples)
	Three samples had a ΔpH > 1 they were from mine spoils located on the Curragh North Eastern spoil dump (both Tertiary and Permian material) and the Curragh North levee access road.	
Net acid generation (NAG)	N/a	<0.5 kg (H_2SO_4)/tonne for all except one sample, Curragh North Eastern spoil dump 2 (Permian material) had a NAG of 3.5 kg (H_2SO_4)/tonne
ANC	N/a	6.1 to 67 kg (H_2SO_4)/tonne for all 11 samples.
NAPP	N/a	Negative for all samples, suggesting that the samples have enough ANC to prevent acid generation.

The results suggested that if isolated areas of PASS are discovered, future spoil sampling may be required to facilitate successful spoil placement (WSP, 2019).

Summary

Using the available information on overburden characterisation, from studies between 1980 to 2019 the overall indication is that overburden at the Curragh Mine is predominantly alkaline, with a low sulphur content and has no or very little acid producing potential. Due to the extremely low potential for PAF at Curragh East and Curragh Mine, material was considered to be 0% PAF, 95% NAF with 5% uncertainty to allow for areas that may have not have been represented in the sampling programme. At Curragh North a very small number of samples tested positive for NAPP but NAG testing confirmed an excess of ANC, hence acid mine drainage potential is very low. However, this isolated and small potential has been taken into account and for Curragh North material were considered to be 5% PAF, 90% NAF with 5% uncertainty, the latter to account for areas that may not have been represented in the sampling programme.

Table 6-22 Summary of Waste Characterisation at Curragh Project

Waste material	PAF %	NAF %	Uncertain%
Curragh	0	95	5
Curragh East	0	95	5
Curragh North	5	90	5

2022 Sampling

A total of 20 waste rock samples were collected from the Curragh WRD. These samples were sent to a certified laboratory for geochemical analysis. SLR has summarised the results in a technical memorandum (**Appendix I**).

The characterisation of 20 waste rock samples from the Curragh WRD (**Figure 6-17** and **Table 6-23**) suggests that 17 of 20 samples are non-acid forming (NAF). Two sample are classified as Uncertain and one sample was classified as potentially acid generating (PAF). The net acid producing potential (NAPP) of all 20 samples ranges from positive 6.7 to negative 88.8 kg/H_2SO_4/tonne. Combined with the mostly alkaline NAG pH (16 of 20 samples) the overwhelming negative NAPP indicates a strong and available alkaline buffering capacity. Given this strong and available buffering capacity, the bulk waste rock is very unlikely to develop acid generating characteristics.

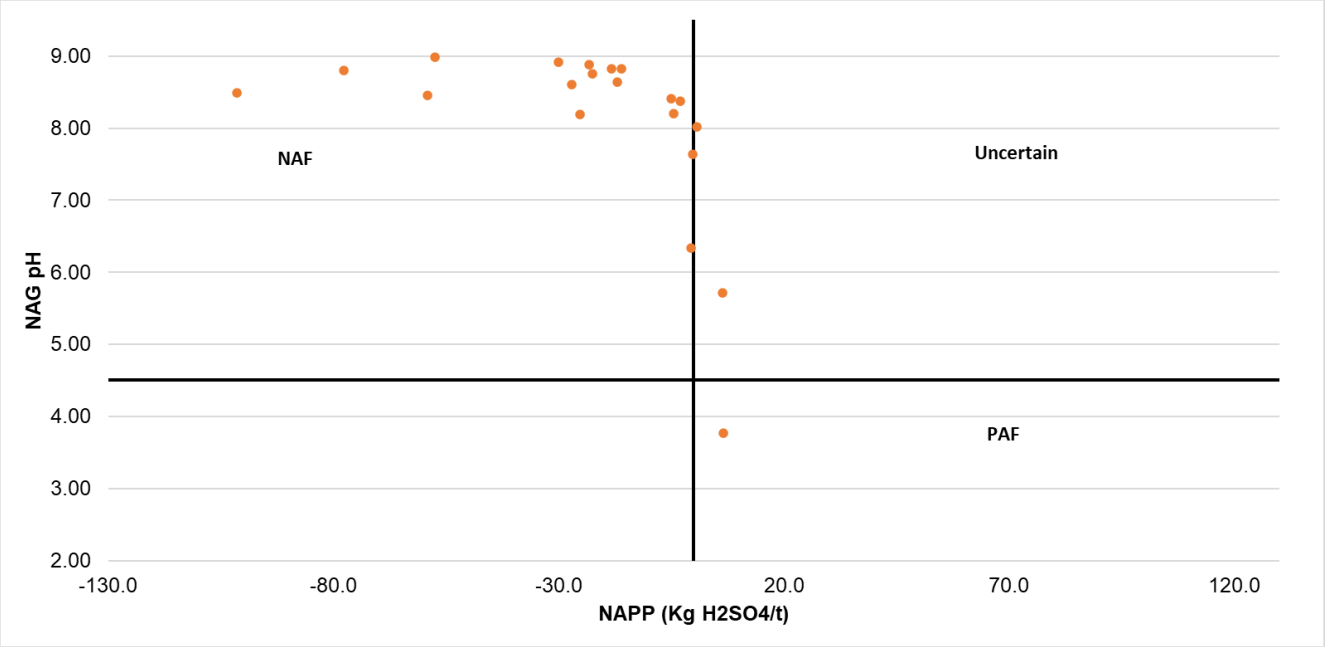


Figure 6-17 AMD Characteristics of total 20 samples collected

Table 6-23 Summary of test results for 20 Curragh waste rock samples collected

Sample	NAG pH	MPA kg H_2SO_4/t based on total S	ANC kg H_2SO_4/t	NAPP kg H_2SO_4/t based on total S
SP-CN-C418	8.64	1.348	18.3	-23.8
SP-CN-C16	7.64	0.980	1.1	-0.1
SP-CM-C07	8.91	0.980	31.0	-30.1
SP-CM-C10	8.49	0.858	102.4	-88.8
SP-CM-C126	8.02	3.461	2.9	-6.5
SP-CM-C042	8.98	1.041	58.4	-61.1
SP-CM-C152	8.82	1.776	17.9	-30.7
SP-CM-C100	8.41	1.807	6.8	-10.7
SP-CM-C38/38	8.75	2.266	24.7	-54.8
SP-CM-C077	8.82	1.960	20.3	-38.6
SP-CN-C369/370	5.72	7.656	1.2	-1.8
SP-CN-CN93	8.20	1.378	5.9	-6.9
SP-CN-CN320	6.34	1.011	1.7	-0.7
SP-CN-CN342	3.77	6.584	0.0	6.7
SP-CN-CN413	8.19	1.439	26.7	-37.7
SP-CN-CN334	8.37	5.114	8.0	-36.8
SP-CN-CN364	8.88	1.807	25.0	-44.4

Sample	NAG pH	MPA kg H_2SO_4/t based on total S	ANC kg H_2SO_4/t	NAPP kg H_2SO_4/t based on total S
SP-CM-C051	8.60	1.348	28.5	-37.9
SP-CN-CN223	8.46	1.256	60.4	-76.3
SP-CM-C142	8.80	0.858	78.5	-67.9

The geochemical assessment of 20 additional waste rock samples from Curragh confirmed the results of previous waste rock assessments by URS in 2005 and 2015. The waste rock collected is in its entirety non-acid generating and has significant buffering capacity. Metal concentrations of the waste rock, represented through the GAI, are very low. Showing that the sedimentary sequences forming the waste rock are depleted with regards to most metals. As a result of the high buffering capacity and relatively low metal concentrations of the solid waste rock future metal leaching from the waste rock will be low. Compared to available guideline values for freshwater, several ASLP metal concentrations, particularly aluminium and vanadium, are in exceedance. Such exceedances are unlikely at the reported leachate pH and are thought to be the result of colloid transport through the 0.45µm filter membrane.

Future Waste Characterisation Sampling Program

CCPL proposes that a waste characterisation sampling program be conducted in active pits as the opportunity arises in existing planned holes, and preferably some at least within the next 12 months. Data collection would be ongoing as mining progresses in future mining areas.

Figure 6-18 and **Table 6-24** summarises the proposed program, samples numbers and approximate timing of sampling.

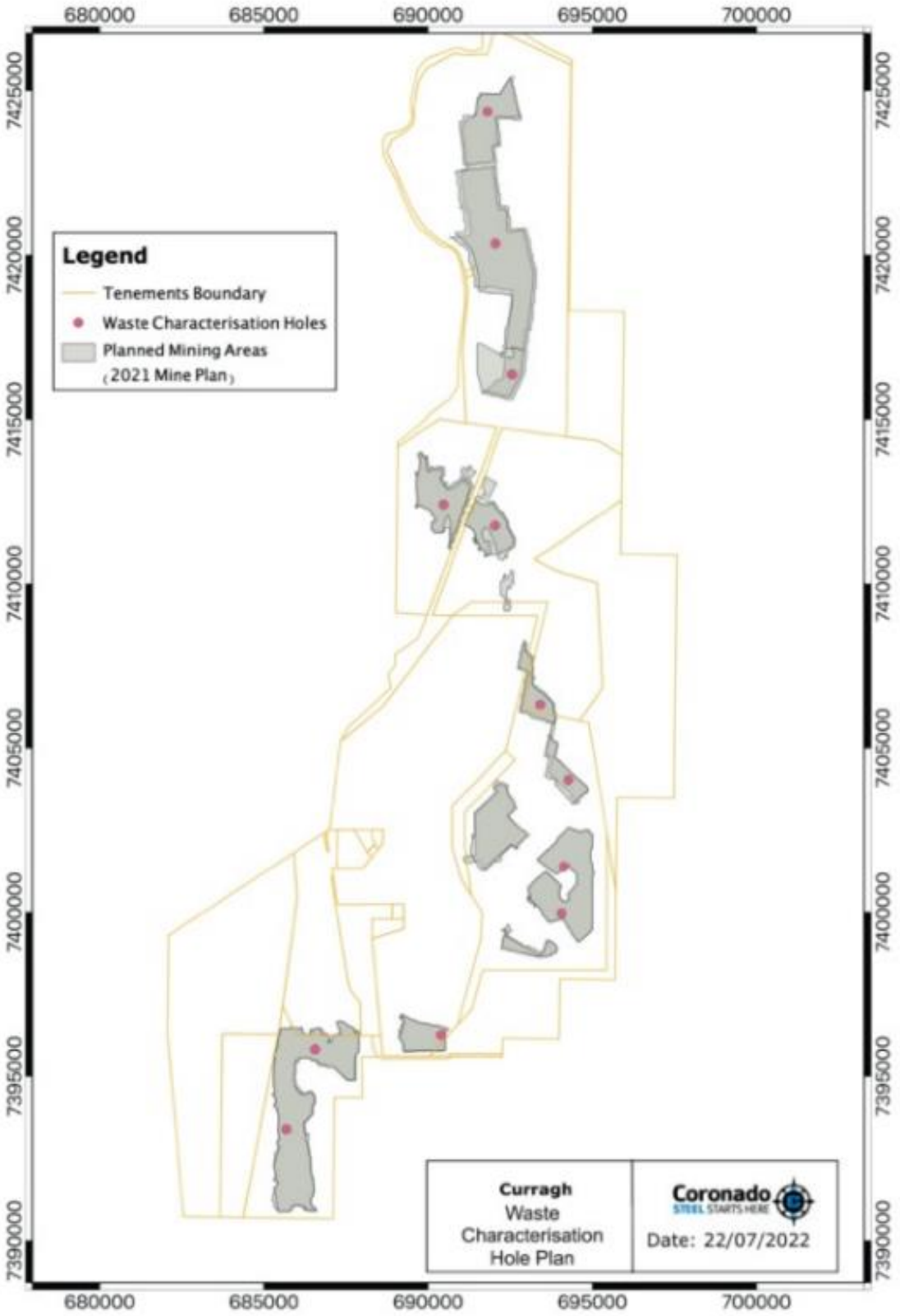


Figure 6-18 Proposed Waste Characterisation Holes

Table 6-24 Planned Waste Characterisation Holes

Site_ID	Easting	Northing	Year	Samples
L11_GC_GC259	694135	7401386	FY23	30
K18_GC_GC190	694062	7399964	FY23	30
UEX35_GC_GC11	691804	7424367	FY23	30
J4_GTGC133	690388	7396256	FY25	30
PITT_WC1	692053	7420345	FY24	30
PITSSTH_WC1	692553	7416370	FY24	30
PITX_WC2	690464	7412406	FY30	30
PITX_WC1	692044	7411763	FY30	30
PITE_WC	693422	7406318	FY23	30
PITZ_WC1	686558	7395823	FY24	30
PITZ_WC2	685677	7393388	FY24	30
FNTH_WC	694273	7404027	FY24	30
TOTAL				380

Proposed analytes in the sampling program are:

- pH;
- Conductivity (EC);
- NAPP Suite (aged pH 1:2, Aged EC 1:2, Sulfate SHCl, Total Sulphur, TOS Tot S – SO_4, ANC, Acid Base Accounting;
- NAG;
- Total Metals (As, Al, B, Be, Cd, Co, Cr, Cu, Fe, Mo, Mn, Ni, Pb, Sn, V, Zn); and
- Dissolved Metals (As, Al, B, Be, Cd, Co, Cr, Cu, Fe, Mo, Mn, Ni, Pb, Sn, V, Zn).

6.1.5 Flooding

SLR has undertaken flood modelling of the floodplain surrounding the Curragh Project to assist in design levels for the concept flood barriers for proposed residual voids. The Preliminary Flood Model Report has been provided in **Appendix J**.

The flood modelling was undertaken to estimate a 0.1% Annual Exceedance Probability (AEP) flood event for the relevant watercourses which impact the Curragh Project. The intent of the assessment is to understand the locations and dimensions of the flood barrier (long-term stable embankment) required to protect the nominated residual voids from flood influx. For planning purposes, the model has adopted a high level of conservatism by using the most conservative (i.e. largest) flow estimate derived from the flood frequency analysis (FFA).

Modelling showed that all residual voids within the Curragh Project are not subject to flood inundation (0.1% AEP event) due to the current diversion of Blackwater Creek and the stable embankments defined as part of the proposed final landform (**Figure 6-19**). The modelled results show that a residual void landform can effectively use spoil dumps and long-term stable embankments to protect the residual voids from flood ingress. SLR adjusted the provided residual void landform along the existing Blackwater Creek diversion and between X Pit and Curragh North to provide additional protection. Modelled results for the 0.1% AEP flood event show that no voids are inundated, however inundation of Curragh North, X Pit West, X Pit East, E Pit, C Pit, B Pit, H Pit, and J Pit occurs in the PMF event.

Based on the results of the flood modelling undertaken, the main outcomes are:

- All pits are not inundated in events up to and including the 0.1% AEP, as required by PRCP guidelines;
- Scour and erosion potential of landforms is unlikely for the 1% AEP, as high shear stresses and velocities occur in localised areas within the existing watercourses;
- Inundation of Curragh North, X Pit West, X Pit East, E Pit, C Pit, B Pit, H Pit, and J Pit occurs in the PMF event (Note there are no requirements that pits be flood free in a PMF event);
- High velocities and bed shear stress are predicted within the Blackwater Creek diversion, which may require ongoing monitoring in accordance with legislative requirements; and
- High velocities and bed shear stress are predicted in the 0.1% AEP and PMF events north of Curragh North.

It should be noted that the flood assessment undertaken was unable to include adjacent mining disturbance by other companies due to limited public information. It is recommended that flood modelling be reassessed over the life of the mine as changes to the catchment occur around Curragh Project.

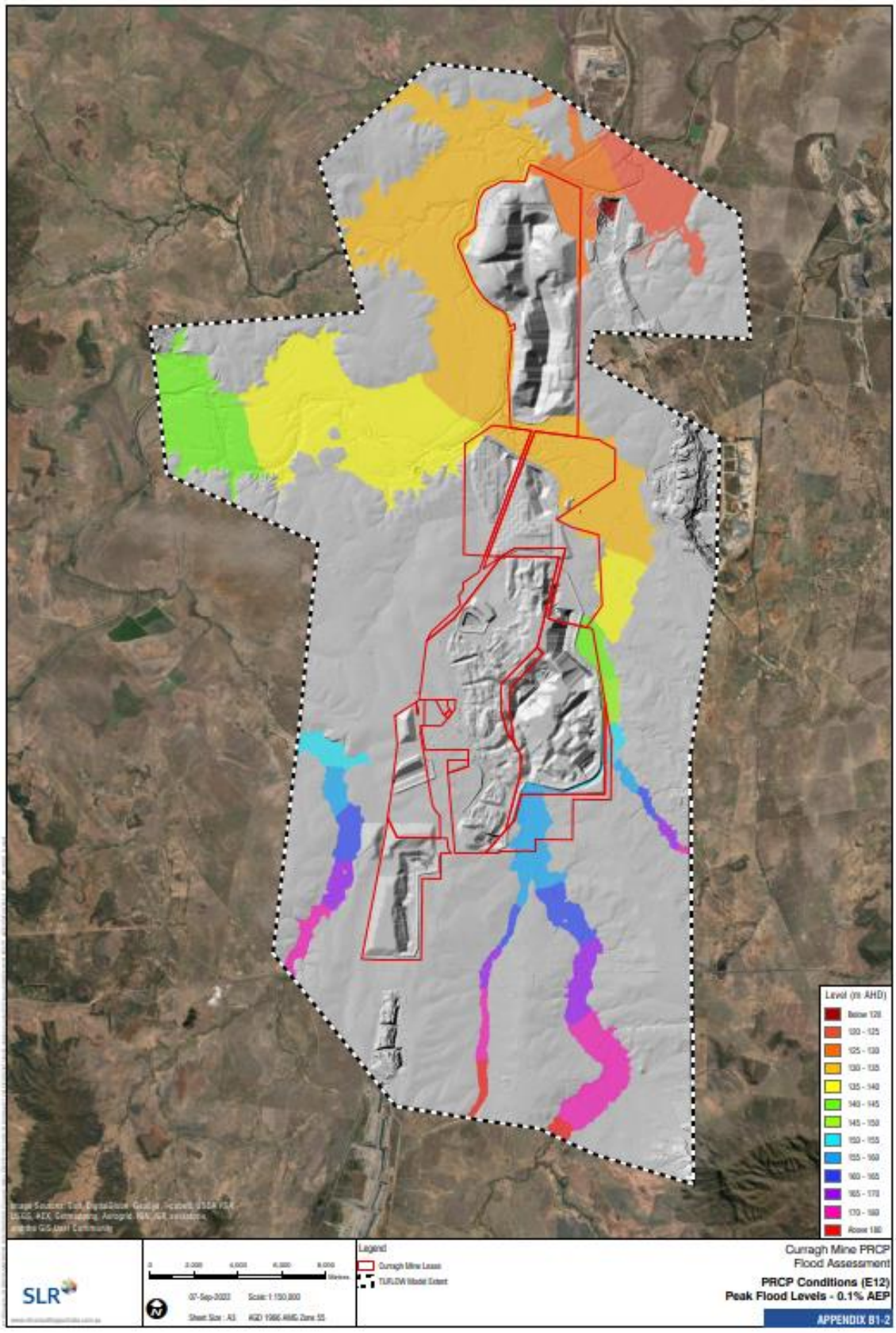


Figure 6-19 Flood extent for 0.1% AEP Event

6.1.6 Final Voids

SLR developed a void water balance model to assess the predicted void water levels and salinity concentration (**Appendix K**). Following closure of the mine, 19 residual void areas are expected to remain. The arrangement of these voids for the purpose of the Water Balance Model (WBM) to determine void water volume, quality and spill frequency is listed below with multiple pits grouped where hydrologically linked:

- Curragh North;
- Curragh Main: Pit I; Curragh Main Other; The Void; D Pit; F Pit North and Pit E North; E, C, B and H Pits; E, C, B and H Tailings; F Pit; L Pit; K Pit; G Pit; Ramp 9; J Pit; and
- Expansion Areas: X Pit (East and West), Y Pit, J Pit, Z Pit (North and South).

A WBM was developed using the Goldsim software package to assess the long-term water level and water quality was of the residual voids following closure of CCPL.

The model simulates daily changes in the volumes of stored water in response to inflows (rainfall, groundwater) and outflows (evaporation and controlled releases/overflows). The WBM was run for daily time step over 200-year simulation period, represented by 500 climate sequences, allowing the model to assess long term water levels, quality and risk of overflow for each void.

The water balance model was developed to include a high-level salt balance to track both the quantity and quality of water on-site. The salt balance tracks the water quality in all of the inflows into the voids and subsequent effects from evaporation and releases on the storage water quality. The water quality values are presented in **Table 6-25**. These adopted values are consistent with those adopted for other Queensland mine sites.

Based on groundwater monitoring data at the mine, an EC of 12,500 µS/cm was adopted as the average salinity concentration of groundwater inflows. Salinity parameters for surface runoff were determined based on prior experience in the area.

Table 6-25 Adopted Salinity Generation Parameters

Inflow	Salinity (EC) (µS/cm)
Void	3000
Rehabilitation	250
Groundwater Inflow	12,500

The above salinity values are converted to a concentration in milligrams per litre using an average multiplication factor of 0.67 (Measuring Salinity DERM, June 2007) to quantify the mass of salt transferred in the model.

The WBM was predicted to stabilise after approximately 100 years to the approximate levels for the median condition shown in **Table 6-26**. It is noted that some individual voids within the WBM reached equilibrium level in less than 20 years.

Table 6-26 Residual Void Water Level Summary

Void	Residual Void Level (50%ile) (mAHD)	Depth (m)	Surface Area (ha)
Curragh North	23	71	197
I Pit	135	1	5
Curragh Main Other	135	15	2
The Void	100	7	1
D Pit	62	33	12
F Pit North and Pit E North	49	23	24
E, C, B and H Pits	70	30	45
Pit B	112	4	13
F Pit	111	19	12
L Pit	103	38	6
K Pit	77	14	8
G Pit	137	7	6
Ramp 9	132	54	39
J Pit	111	18	8
X Pit East	67	33	39
X Pit West	98	20	19
Y Pit	123	8	8
Z Pit North	108	30	27
Z Pit South	105	17	13

The relative size of external catchment to the void footprint results in water levels that stabilise well below the indicative spill level with evaporative losses balancing inflows into the voids. A similar trend in water level is seen across all the residual voids. Water depths range from 1 m to 71 m within the voids for median conditions (50th percentile). During dry climatic conditions (5th percentile) water levels are approximately 0.1 m to 6 m lower. During very wet (99th percentile) climatic conditions the water level increases by 0.4 m to 9 m depending on the void and generally causes greater fluctuation in the equilibrium water level. Median final water levels range from 11 m to 109 m below the indicative spill levels and are not expected to overtop.

Water within the residual voids becomes highly saline throughout the simulation. This was not unexpected due to the high salinity of groundwater in the region and the assumption that the only loss from the system is evaporation (through which no salt is lost). Within the WBM, salinity is capped at a maximum EC of 532,836 µS/cm, which is equivalent to the point where the concentration of salt becomes high enough that the solution is saturated and any additional salt will precipitate out of solution. All voids are expected to exceed hypersaline EC levels (>50,000 µS/cm) within approximately 120 years of closure, with some exceeding this value within 30 years.

The average salinity of the voids throughout the simulation period are provided in **Table 6-27**.

Table 6-27 Average Stage Salinity (EC µS/cm)

Void	Year 10	Year 30	Year 200
Curragh North	13,900	20,100	>50,000
I Pit	>50,000	>50,000	>50,000
Curragh Main Other	11,700	25,700	>50,000
The Void	10,200	15,600	>50,000
D Pit	16,500	28,800	>50,000
F Pit North and Pit E North	27,500	>50,000	>50,000
E, C, B and H Pits	15,700	33,700	>50,000
B Pit	>50,000	>50,000	>50,000
F Pit	18,200	38,600	>50,000
L Pit	13,800	24,200	>50,000
K Pit	28,400	>50,000	>50,000
G Pit	40,700	>50,000	>50,000
Ramp 9	17,300	25,600	>50,000
J Pit	23,300	49,300	>50,000
X Pit East	15,600	27,500	>50,000
X Pit West	19,200	39,600	>50,000
Y Pit	40,600	>50,000	>50,000
Z Pit North	19,800	37,600	>50,000
Z Pit South	23,400	48,500	>50,000

At Curragh Complex the median residual void water levels are expected to range from 23 mAHD to 137 mAHD with water depths of 1 m to 71 m . The results indicate that the mine is not a net accumulator of water after approximately 100 years when the equilibrium water levels are reached. The final water levels remain below the spill level and the voids are unlikely to overtop in the 99th percentile climate scenario.

A significantly high concentration of salt is expected to accumulate within the residual voids. The elevated salinity of the groundwater inflows input a high level of salt into the voids which is not lost from the system via evaporation. The salinity of the voids is expected to exceed that of the groundwater and form highly concentrated solution. Although poor quality, water within the voids is not expected to interact with surrounding surface water given the final water levels.

6.1.7 Tailings/Rejects

There are currently five tailings/rejects disposal facilities on site: Out-of-pit Tailings Storage Facility, Pit A, Pit B, Ramp 8 and Ramp 3 (**Figure 6-20**). Only Pit B is in use with all other storages at capacity or no longer planned to receive additional material. Pit B is anticipated to provide tailings storage for the rest of the mine life.

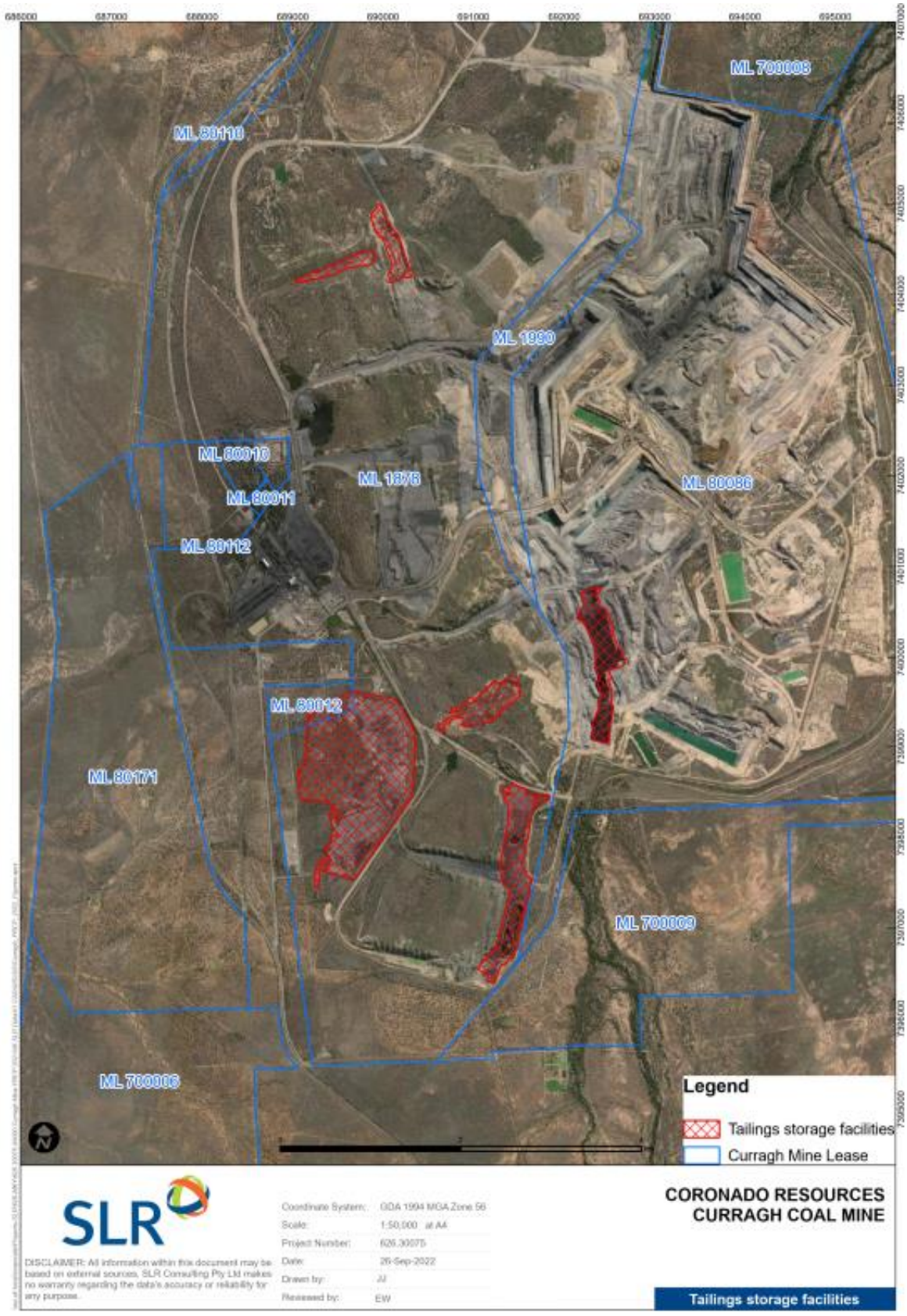


Figure 6-20 Curragh Project Tailings Storage Facilities

Tailings/Rejects Characterisation

Tailings samples were collected from Pit A in July 2022, including 6 samples taken from 10 cm depth and 7 samples from 40 cm depth. All samples were analysed by ALS Laboratory for a plant growth suite including pH, Electrical Conductivity (EC), and Sulfur content (both as soluble major anions and total Sulfur content). Samples collected from a 40 cm depth were also analysed for sample Particle sizing, and soil classification (based on particle size).

Key findings from the analysis of the 40 cm depth samples include:

- Majority of the samples were predominantly sand (>63 µm particle size);
- pH ranged from 7.6 to 8.7, with sample one an outlier at 3.5 pH;
- EC ranged from 1,100 to 3,020 µS/cm; with Sample 7 recording 8,590 µS/cm;
- Moisture content ranged from 5.2 – 15.4% with an average of 8.9%; and
- Total Sulfur for Samples 2-7 ranged from 810 – 6,470 mg/kg with an outlier of 23,000 mg/kg recorded in Sample 1.

Key findings from the analysis of the 10 cm depth samples include:

- pH ranged from 5.5 – 8.6 pH for Samples 2-6 with Sample 1 recording 2.4 pH;
- EC ranged from 2,080 to 7,080 µS/cm;
- Moisture content ranged from 6.6 to 15.1% with an average of 11.33%; and
- Total Sulfur for Samples 2-6 ranged from 5,500 – 11,300 mg/kg with an outlier recorded in Sample 1 at 38,900 mg/kg.

The results suggest that the majority of material has a low EC and Sulfur content with a few samples identified as outliers. The moisture content from both sampling depths is relatively low and therefore indicates that the surface is well crusted and dry. However, further sampling would be required to determine trafficability.

Golders (2017) summarised Curragh's geotechnical tailings physical and geochemical characteristics in **Table 6-28** and **Table 6-29**, respectively.

Table 6-28 Tailings Physical Characteristics

Parameter	Value	Unit	Source
Annual production rate	1,040,000	tpa	Curragh
Particle size	≤0.5	mm	Sedgman
Particle density	1.65	t/m^3	Curragh
Solids concentration – m/m	37.4	%	Curragh
Solids concentration – v/v	26.5	%	Curragh
Slurry density	1.17	t/m^3	Curragh
Tailings initial settled dry density	0.8	t/m^3	Golder
Tailings beaching angle			
Above water	0.5	%	Golder
Below water	3.0	%	Golder

Table 6-29 Tailings Geochemical Properties (CHPP Data for Tailings Liquor 2013)

Date	pH		EC (µS/cm)	
	CHPP1	CHPP2	CHPP1	CHPP2
24/09/2013	8.22	8.25	4,630	756
27/09/2013	7.38	7.89	1,656	650
30/09/2013	8.49	8.08	3,950	2,050
14/10/2013	7.66	8.21	4,750	4,000

A summary of other tailings/rejects characterisation available is provided in **Table 6-30**.

Table 6-30 Tailings Characterisation Summary

Tailings Facility	Source	Tailings Characteristics
Old Tailings Dam	Parsons Brinkerhoff (2016)	Laboratory results indicate that the tailings is of medium to high plasticity and is predominantly silt sized. Moisture contents generally increase with depth
Old Tailings Dam – Core Samples	Mitra PTS (2019)	• 100% passing 1mm • Ash 30-48% • Relative density 1.63 - 1.78 t/m^3 • Exposed tailings dry on surface 0-3m (13-20% free moisture) • Damp 1-9m (24-26% free moisture) • Wet below 9 (26-30% free moisture)
Old Tailings Dam	FDP Mining (2020)	Particle Size Distribution analysis indicated an average of approximately 60% at < 38µ
Pit A tailings	ALS (2022) EB2220646	• Predominately neutral to alkaline, EC (1:5) 1100 to 8590, Soluble Sulfur as S (mg/kg) 770 to 6970

Tailings Facility	Source	Tailings Characteristics
Pit A Tailings	ALS (2022) EB22003071	• Organic Sulphur <0.02 – 1.00% • Inorganic Sulphur 0.39 – 3.86% • % less than 1mm 98.7 – 99.9% • Dominant fractions 0.25 – 0.5mm and <0.038mm)
Tailings (General)	Curragh (2015)(Appendix I)	• pH (average) = 8.02 • EC (average) = 3,000 µS/cm

6.1.8 Cover Design

6.1.8.1 Old Tailings Dam Capping Strategy

Parsons Brinckerhoff completed a Geotechnical Investigation and Assessment for Capping for the Out of Pit Tailings area in 2016 (**Appendix L**).

Capping material and layer thickness

Capping material is to comprise coarse reject material or inert well-graded granular mine spoil with boulders greater than 500 mm removed to reduce the likelihood of a punching failure. The capping material will need to have a low moisture content (i.e. not saturated) prior to placement and will need to be placed in accordance with approval requirements regarding minimum cover. Capping material should be dumped short of the leading edge of the advancing cap and pushed into position by a dozer. Dumping of the capping material directly onto the tailings surface should be avoided until additional geotechnical testing is carried out across the tailings surface.

Rate of construction

The geotechnical analysis indicates that the tailings profile tested was of sufficient shear strength to support a capping thickness up to 1.0 m and dozer. Some additional strength gain might also be expected with time following capping placement. Block tipping may be possible over the capping layer as it progresses but will require a minimum offset to be maintained from the leading edge. Larger vehicles and increased block tipping limits may be possible after some measured strength gain within the tailings.

Water management

The existing tailings surface should be kept free of water until such time as the entire tailings surface is capped. The placed capping layer should generally be graded in a south direction towards the spillway.

Testing

As construction of the capping layer progresses, testing of the tailings should be carried out in front of the advancing layer. Geotechnical investigation including test pitting by mini excavator and shear vane testing at to assess the tailings profile within capped areas to verify the shear strength for access by larger dump trucks

Capping construction

Given the size of Old Tailings Dam works area may be defined for placement of capping material in a single shift which will allow working on multiple fronts. Placement of capping in these areas would then be on a round-robin basis. Equipment sizes should be kept to a minimum. In the above analysis, a ground pressure applied by the equipment has been limited to 100 kPa. Where dump trucks are used for the placement of material over tailings consideration should be given to offset distances (e.g. 50/30 m rules). These should be maintained while working on the capping to limit the interaction of dynamic loads. Further investigation of the underlying tailings shear strength is required following the placement of the initial cap prior to placement of subsequent layers or accessing by larger construction vehicles than analysed.

Final landform earthworks

As part of mine rehabilitation, additional earthworks are required to tie the capping layers in to the surrounding landform. Future capping layers should be placed from the north of the storage towards the south to promote the drainage of surface water runoff and prevent areas of ponding. The final capped surface should tie in with the surrounding landform in accordance with mine approvals. Further geotechnical advice is required prior to the placement of subsequent capping layers to confirm the strength of the underlying tailings to support the additional capping material and advise on allowable construction load limits for future rehabilitation

6.1.8.2 B Pit TSF Closure Strategy

Golders Associates completed a Design Plan for the B Pit Tailings Storage facility in 2017 (**Appendix M**). A conceptual cover design is included in the Design Plan.

The final surface cover of the TSF will be subject to investigation works and detailed assessment in the years prior to closure and would typically include an assessment of the geochemistry and leaching of the tailings material which would be used in conjunction with detailed cover analysis in determination of the preferred capping philosophy, whilst achieving the overall objectives as outlined below. Typical cover design options to be considered may include a barrier/low hydraulic conductivity cover or a store-and-release cover. Notwithstanding the above, the following provides a conceptual strategy for the closure of the B Pit TSF, with the final cover system including all or a subset of the cover components as described below.

The typical objectives to be adopted for rehabilitation of the TSF would be to create a landform that is:

- Stable and sustainable;
- Compatible with the surrounding landform; and
- Of minimum long term environmental impact (i.e. non-polluting).

Based on these objectives, a concept for the TSF is as follows:

Landform development

It is envisaged that the final TSF landform would reach a level below any Quaternary surface water tables to enable the tailings to be confined within the tight Permian highwall strata. The final landform will be free draining. This may therefore necessitate a final campaign of tailings deposition at the southern end of the TSF to infill any significant depression. The TSF will be capped and final drainage installed.

Tailings surface capping

A tailings surface cap would serve the following purposes:

- Facilitate ongoing free drainage and prevent ponding;
- Stabilise the surface to mitigate against potential ongoing erosion;
- Produce a substrate capable of plant growth and a grazing land use; and
- Reduce potential rainfall infiltration into the tailings as recharge to seepage.

The cap would comprise the following components as described below to meet these performance standards. This configuration assumes that the tailings would remain geochemically benign.

Tailings surface stabilisation layer

To provide a geotechnical competent surface over the surface of the tailings, a stabilization layer may be necessary to provide a competent subgrade or bridging layer for capping. The area most likely to require stabilisation would be the decant pond surface, due to the likely extent of saturated slimes materials and this being the natural accumulation point for surface water. The stabilisation layer would typically comprise a rock mattress (the rock comprising competent and durable material) or subject to the bearing capacity and shear strength of the tailings, may comprise a geotextile layer.

Sealing layer

Given the benign nature (to plant growth as evidenced by results and in-situ tailings vegetation) and low hydraulic conductivity of the tailings, low rainfall and the construction of a capping layer, a specific sealing layer for the tailings is unlikely to be required.

Surface protection layer

To protect the tailings surface from erosion and exposure deterioration (through wetting and drying), a surface protection/capping layer would be required. This cap could also be utilized as a rooting zone for vegetation depending on the proposed end land use. This layer would be formed typically using select mine overburden. The thickness of this layer would be selected to not only maintain drainage, but also to compensate for settlement within the underlying tailings. A more detailed assessment of a suitable capping configuration would need to be completed, subject to more data being available with respect to the physical and geochemical characteristics of the tailings. In particular, geochemical compatibility between the tailings and capping materials must be confirmed to ensure the integrity of the capping horizon is not compromised.

6.1.8.3 Proposed Cover Design for all In-Pit TSFs

Given that only conceptual work has been undertaken on Pit B TSF, CCPL is proposing to use the low risk TSF cover design from the ERC Calculator. As demonstrated in section 6.1.7, the tailings deposited in these facilities has low to moderate salinity and is of moderate strength and therefore a low risk cover design was proposed and accepted in the latest Estimated Rehabilitation Cost application. The low risk cover design includes:

- 1 m of rock/overburden cover; and
- 0.15 m of growth media cover.

6.1.9 Geotechnical

Raine Associates (2021) undertook a geotechnical stability assessment of the residual voids (**Appendix N**). Final landform designs were geotechnically assessed using deterministic slope stability analysis, using two-dimensional limit equilibrium methods and Rocscience's proprietary software SLIDE 2.0 (SLIDE). Nine (9) selected cross-section locations through the supplied final landform designs were analysed.

The following assumptions, comments and qualifications are made in relation to the analyses completed:

- Static and dynamic scenarios have been considered. To consider the potential impacts of earthquakes (i.e. dynamic scenarios) a peak ground acceleration (g) of 0.02 has been applied, equivalent to an event with an exceedance probability of 2% in 50 years (refer to Section 2.3).
- For design acceptance criteria, a minimum factor of safety (FoS) of 1.5 for static conditions and 1.1 for dynamic conditions have been adopted for these analyses;
- The Spencer method has been adopted for these analyses;
- The Path Search method has been adopted for these analyses;
- The slope stability analysis considers Global Stability of the slope;
- For the purpose of these analyses a slope angle of 7-degrees in the soil materials has been assumed. It is understood that this is to help prevent and minimise surface erosion, rather than to maintain long term stability of the relevant final landform slopes;
- A Disturbance (D) Factor of 0.7 has been applied when determining Hoek-Brown material parameters for a blast affect Permian rock mass;
- A Disturbance (D) Factor has been applied to a width equal to approximately half the bench height, where the final landform comprises final excavated pitwall geometries in the Permian rock;
- The analysis of final excavated pitwall geometries in the Permian rock only considers potential failures through the rock mass and does not consider the potential impact(s) of individual fault planes, fault orientation(s) and fault interaction(s); and
- Groundwater and surface water can have a significant and adverse impact on the stability of pitwalls and must therefore be appropriately understood and considered. Limited groundwater and/or hydrogeological information is available.
    - The Steady State FEA tool provided in SLIDE has been utilised to model groundwater movement and hydrostatic pressures through the materials based on the adopted ground models, for the assumed water levels and adopted material hydraulic conductivities (Table 5-7).
    - Flood levels have been adopted as per Section 6.1.5. A 1m freeboard was added to the provided flood levels for the presented analysis. Values were converted to the CCPL mine grid coordinate system prior to use.
    - The final voids have been assumed to be dry for the presented analyses.
    - Perched water tables have not been considered

Slope Stability Analysis Results The analysis results for the critical failure surfaces analysed are provided in **Table 6-31**.

Table 6-31 Critical Failure Surfaces of Final Landform Options

Pit	Scenario	Estimated Static Factor of Safety	Estimated Dynamic Factor of Safety
U Pit	Planned Final Landform Option - Highwall Side	1.8	1.7
S Pit South	Planned Final Landform Option - Highwall Side	1.8	1.7
	Planned Final Landform Option - Lowwall Side	1.7	1.6
X Pit	Planned Final Landform Option - Highwall Side	1.8	1.7
D Pit	Planned Final Landform Option - Highwall Side	2.4	2.3
	Alternative Final Landform Option - Highwall Side	3.2	2.7
	Alternative Final Highwall Re-Shaped Final Slope Option - Highwall Side	1.6	1.5
F Pit South	Planned Final Landform Option - Highwall Side	1.9	1.8
	Alternative Final Highwall Re-Shaped Final Slope Option - Highwall Side	1.8	1.7
	Planned Final Landform Out Board Slope	1.7	1.6
	Planned Final Landform Option - Lowwall Side	2.9	2.6
K Pit	Planned Final Landform Option - Highwall Side	2.5	2.4
	Alternative Final Landform Option - Highwall Side	3.2	3.1
	Alternative Final Highwall Re-Shaped Final Slope Option - Highwall Side	1.7	1.6
J Pit	Planned Final Landform Option - Highwall Side	1.7	1.6
	Planned Final Highwall Re-Shaped Final Slope - Highwall Sid	1.6	1.5
Y Pit	Planned Final Landform Option - Highwall Side 2.7 2.5	2.7	2.5
	Planned Final Highwall Re-Shaped Final Slope - Highwall Side	2.0	1.9
Z Pit	Planned Final Landform Option - Highwall Side	1.8	1.7
	Planned Final Highwall Re-Shaped Final Slope - Highwall Sid	1.6	1.5

Deterministic analysis results for the final landform designs, based on the adopted ground models and analysis methodology and assumptions, indicate that the final landform designs meet the adopted design acceptance criteria (a minimum factor of safety (FoS) of 1.5 for static conditions and 1.1 for dynamic conditions).

Past pitwall performance at Curragh indicates that geological structures are a key factor requiring consideration as part of the design process and CPS. The analysis of sections that include remnant pitwalls in the Permian rock only considers potential failures through the rock mass and does not consider the potential impact(s) of individual fault planes, fault orientation(s) and fault interaction(s). Where adverse fault orientations and interactions, relative to pitwall geometries and locations are present, the planned final pitwall geometries (as provided) may not be appropriate for CCPLs long-term final landform stability requirements. In such cases alternative design options such as the construction of softwalls in blasted Permian rock may be required. Due to potential surface erosion mitigation requirements and in order to meet the adopted design acceptance criteria for long-term slope stability, it may be necessary to re-shape softwalls to reduce slope angles. A re-shaped slope angle of approximately 22-degrees has been considered in the analysis undertaken for ground models that consider re-shaping of softwalls constructed in blasted Permian rock. The associated cut-fill balance of these options is to be further investigated as detailed design works are completed.

The ability to identify geological fault locations and geometries accurately for the final pitwall is limited by existing data coverage and density. Fault interpretations and geotechnical ground models for final pitwalls are to be developed as mining progresses and/or additional geology and geotechnical data is collected and obtained.

To consider the provided flood levels for X-Pit the proposed final landform has been raised by approximately 10 m for the purpose of these analyses.

6.1.10 Revegetation

The objective of revegetation is threefold:

- To stabilise the re-contoured ground, and/or;
- To fit in and complement the surrounding flora and habitat, and/or;
- To enhance or increase diversity.

Revegetation is predominantly carried out by seeding a combination of pasture grasses and native tree seed. Previous applications using tube stock planting has resulted in a high mortality rate, and direct seeding appears to yield more robust outcomes. However, should favourable conditions present themselves Curragh may engage in tube stock planting for target areas or stock.

Through previous experience on site and at other mines deep ripping of the spoil/topsoil is undertaken after shaping has been completed to improve rainfall infiltration and decrease erosion. Deep ripping is undertaken by a specifically designed winged tyne (**Figure 6-21**) to loosen the subsoil profile immediately prior to seeding.

Deep ripping is carried out to a depth of 60–75 cm with the rip-lines oriented across the slope at a gradient of 0.5% (1h: 200v) off the contour. The machine operator uses the graded banks, which are also at 0.5% gradient, for alignment guidance. Deep ripping is carried out in conjunction with the seeding operation.

The seed mix employed at Curragh Project will vary from year to year depending on environmental and operational factors. Rehabilitation monitoring records show that 13 to 23 native tree and shrub species are seeded on the bare spoil strips and between 6 to 9 grass and legume species are seeded in the topsoil strips. A typical seed mix is provided in **Table 6-32** this is subject to availability and may change.

Figure 6-21 Winged tyne used at Curragh



Table 6-32 Typical Seed Mix

Acacias	*Acacia bancroftii* *Acacia complanata* *Acacia cretata* *Acacia harpophylla* *Acacia holosericea*	*Acacia macradenia* *Acacia salicina* *Acacia saligna* *Acacia stenophylla*
Eucalyptus	*Eucalyptus camaldulensis* *Eucalyptus cambageana* *Eucalyptus citriodora* *Eucalyptus crebra* *Eucalyptus drepanophylla*	*Eucalyptus longirostrata* *Eucalyptus populnea* *Eucalyptus punctata* *Eucalyptus tereticornis* *Eucalyptus thozetiana*
Native Grasses	*Digitaria didactyla* *Cynodon dactylon* *Heteropogon contortus*	*Dicanthium serecium* *Astrebla lappacea* *Themeda australis* *Paspalidium caespitosum*
Legumes	*Clitoria ternatea* *Chamaecrista rotundifolia* *to be reviewed in 2020	*Stylosanthes hamata* *Stylosanthes scabra*
Introduced / Exotic Grasses	*Cenchrus ciliaris* *Chloris gayana* *Urochloa mosambicensis*	*Panicum coloratum* *Panicum maximum*
Other Trees/Shrubs	*Atalaya hemiglauca* *Brachychiton rupestris* *Senna artemisioides*	*Casuarina crista* *Lysiphyllum carronii* *Senna notabilis*

Normally, 50% of the Acacia seed (except *A. harpophylla*) is scarified and 50% is left un-scarified. Scarification enhances early establishment of Acacias following the first rain after seeding. The remaining un-scarified seed will germinate at a longer period. This arrangement provides a backup in the event of the initial seeds perishing due to minimal follow up rain.

6.1.10.1 Amelioration

The Curragh topsoil management plan (Curragh, 2020) provides information on soil baseline studies undertaken from 1990 to 2015. The study with the MLs associated with the respective studies are outlined in **Table 6-33** and shown in **Figure 6-22.**

Table 6-33 Land resource assessments conducted at Curragh Project

Year	Author	Curragh sites	MLs associated with study
1990	Land Reclamation Services	Curragh Main	ML1878, ML 1990, ML80010, ML80011, ML80012
1998	Environment Health and Safety Systems	Curragh Main	ML80086
2003	Australasian Resource Consultants Pty Ltd	Curragh North	ML80110, ML80123
2011	Parsons Brickenhoff	Curragh Main, Section of area associated with Pit Y	ML80171
2015	SLR	Curragh Main, Sections of areas associated with Pit X and Pit Z	ML700006, ML700007, ML700008, ML700009

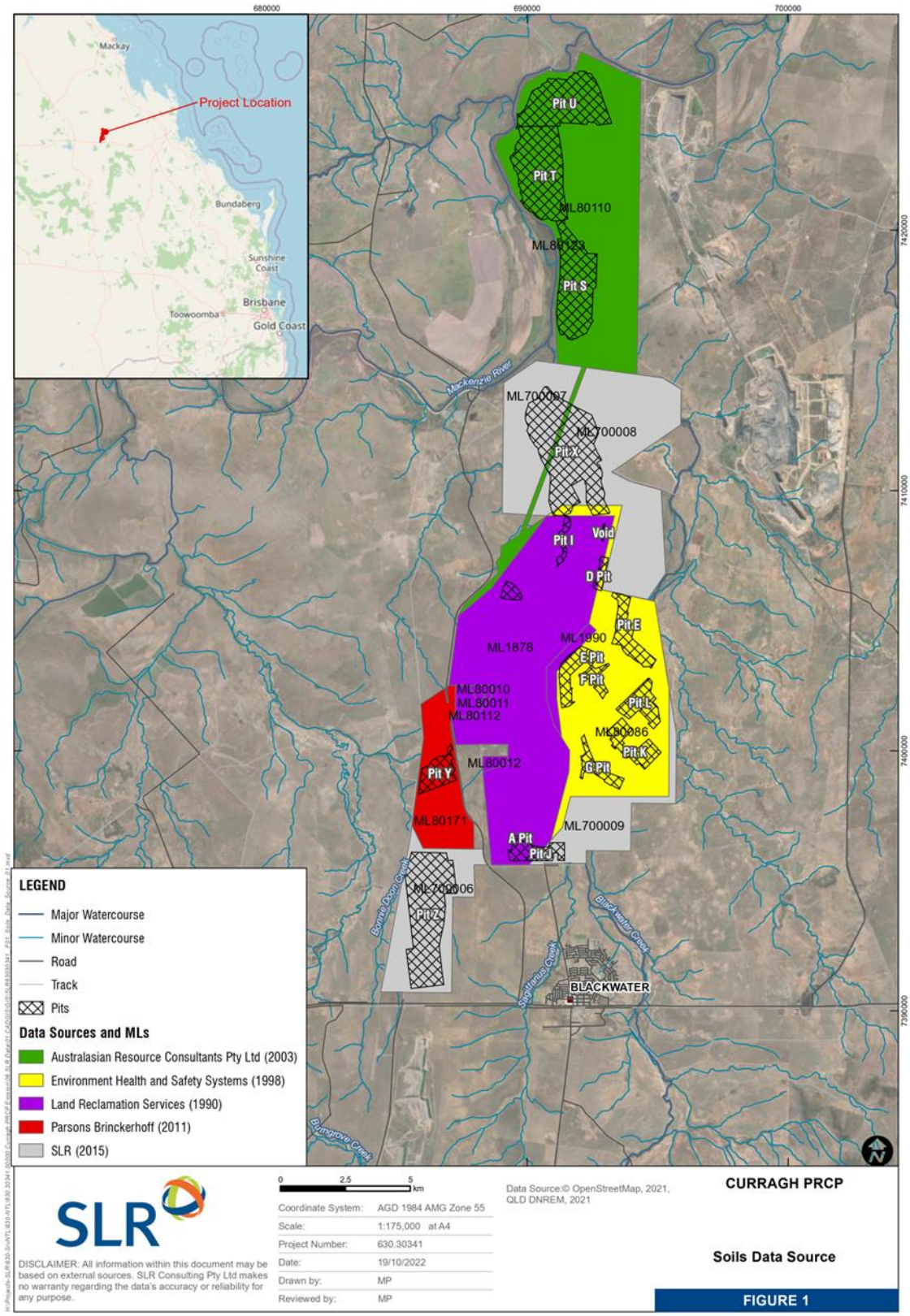


Figure 6-22 Curragh Soil baseline Data Available

Site Investigation

Based on observations on site and the desktop review, SLR provided Curragh personnel with guidance to complete a sampling program (SLR, 2022). Curragh collected topsoil and spoil samples under advice from SLR. The samples were collected during late July to August 2022. The site number names, material type and sample dates are listed in **Table 6-34.** Site numbers provide the following information:

- Material type: SP (spoil) or TS (topsoil)
- Location: CN (Curragh North) or CM (Curragh Main)
- Stockpile or location name is provided as the third code in the sample number (e.g., C042 in site number SP-CM-C042).

Sample logs and photographs for the sites are provided in **Appendix F.**

Samples were submitted to NATA accredited laboratory, Environmental Analytical Laboratory (EAL) at the Southern Cross University in Lismore. Certificates of analysis are provided in **Appendix F**. Samples were submitted for the following analytical suites:

- **Growth medium:** Typical soil analysis associated with plant growth including pH, electrical conductivity, nitrate nitrogen, plant extractable phosphorus and particle size analysis to inform proposed ameliorant or treatment requirements to assist with vegetation establishment and long-term growth on steeper slopes
- **Propensity for dispersion:** Analysis of the propensity for dispersion by Emerson aggregate test and analysis of exchangeable sodium percentage

Table 6-34 Curragh North and Curragh Main topsoil and spoil samples collected for cover material investigation

Curragh Main			Curragh North		
Material type	Site No.	Date	Material type	Site No.	Date
Spoil	SP-CM-C042	01-08-2022	Spoil	SP-CN-C16	02-08-2022
Spoil	SP-CM-C051	02-08-2022	Spoil	SP-CN-C369/370	02-08-2022
Spoil	SP-CM-C07	02-08-2022	Spoil	SP-CN-C418	02-08-2022
Spoil	SP-CM-C077	01-08-2022	Spoil	SP-CN-CN223	02-08-2022
Spoil	SP-CM-C10	01-08-2022	Spoil	SP-CN-CN320	04-08-2022
Spoil	SP-CM-C100	01-08-2022	Spoil	SP-CN-CN334	03-08-2022
Spoil	SP-CM-C126	01-08-2022	Spoil	SP-CN-CN342	04-08-2022
Spoil	SP-CM-C142	05-08-2022	Spoil	SP-CN-CN364	02-08-2022
Spoil	SP-CM-C152	01-08-2022	Spoil	SP-CN-CN413	04-08-2022
Spoil	SP-CM-C38/38	01-08-2022	Spoil	SP-CN-CN93	04-08-2022
Topsoil	TS-CM-C042	01-08-2022	Topsoil	TS-CN-C16	02-08-2022
Topsoil	TS-CM-C051	02-08-2022	Topsoil	TS-CN-CN223	02-08-2022
Topsoil	TS-CM-C07	02-08-2022	Topsoil	TS-CN-CN320	04-08-2022
Topsoil	TS-CM-C077	01-08-2022	Topsoil	TS-CN-CN334	03-08-2022
Topsoil	TS-CM-C10	01-08-2022	Topsoil	TS-CN-CN342	04-08-2022
Topsoil	TS-CM-C100	01-08-2022	Topsoil	TS-CN-CN364	02-08-2022
Topsoil	TS-CM-C126	01-08-2022	Topsoil	TS-CN-CN369/370	02-08-2022
Topsoil	TS-CM-C142	05-08-2022	Topsoil	TS-CN-CN413	04-08-2022

Curragh Main			Curragh North		
Material type	Site No.	Date	Material type	Site No.	Date
Topsoil	TS-CM-C152	01-08-2022	Topsoil	TS-CN-CN93	04-08-2022
Topsoil	TS-CM-C38/38	01-08-2022			

SLR also included amelioration rates for topsoil stockpiles sampled by Curragh in 2020 under guidance from the *Topsoil Training, Assessment and Sampling* guideline developed by GT Environmental in 2019.

Twenty-three topsoil stockpiles were sampled and a total of 45 samples were submitted for analysis to ALS laboratory. The samples were analysed at ALS for similar parameters to the samples collected during the current investigation with the exclusion of Emerson aggregate tests (EAT) and particle size analysis (PSA). Soil texture was determined by Curragh personnel in the field and not included in the analytical suite. Results of the analysis was reported in the 2020 and 2022 reports titled *Topsoil Quality Assessment Report* (Curragh, 2020) and (Curragh, 2022)).

Results

The laboratory results for the sites are summarised in **Table 6-36** with analyte thresholds outlined in **Table 6-35.**

Certificates of analysis are provided in **Appendix F**. Samples were collected and bulked at each stockpile site. The results indicate the following:

Organic matter (OM) is marginal to across most of the spoil sites and at good levels for the majority of the topsoil sites. Amelioration with composted organic matter at all sites where OM is marginal will improve plant establishment.

Nitrate nitrogen levels are typically deficient across most sites and will require amelioration to improve nitrogen levels. Nitrogen is to be applied as DAP or Urea,

- Colwell extractable phosphorous is typically deficient across most sites and will require amelioration. Phosphorus to be applied as MAP or DAP.
- pH is generally strongly alkaline to very strongly alkaline at the spoil sites. Site SP-CN-C369/370 is moderately acidic while SP-CN-CN342 is very strongly acidic and both will require amelioration towards neutral with lime. Very high pH can be overcome during plant establishment by utilising zinc coated MAP or DAP.
- Salinity (ECe) ranges from non-saline to extremely saline at spoil sites, with levels are generally low at topsoil sites, ranging from non-saline to slightly saline. Sites with ECe above 2 dS/m will require amelioration with composted organic matter.
- Sodicity (ESP) varies between sites, with the majority of topsoil stockpiles being non-sodic. Most of the spoil samples are marginally sodic to strongly sodic and will require amelioration with gypsum.
- Emerson aggregate test (EAT) values of 3 or 4 were reported at the majority of topsoil sites, indicating minimal dispersion potential. Most spoil sites mostly had values of 2 indicating potential dispersion, which can be ameliorated with gypsum.
- Calcium to magnesium ratio (Ca:Mg) is typically low (less than 3) across most sites and will require amelioration. Gypsum or lime will provide adequate calcium to increase the Ca:Mg.
- Zinc (Zn) levels are typically low, due to the elevated pH across most sites and can be ameliorated with zinc coated MAP or DAP.

Table 6-35 Analyte Thresholds

OM	Nitrate N	P (Colwell)	Zn	Mn	Fe	Cu	B	ESP	EAT	Ca:Mg	pH	ECe
%	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	%	Score	Ratio	H20	Value
>2.0	>10.0	≥35	>0.7	4.0 – 50.0	4.0 – 50.0	>0.4	≥0.8	<5	4, 6, 7	>3.0	≥6.0	<2.0
≤2	7-10	<35	≤0.7	<4.0 or >50	<4.0 or >50	≤0.4	>0.8	≥5	2, 3	2-3	≤6.0	2-8
<1	<7.0	<20	<0.5	N/A	N/A	N/A	>1.5	>15	1, 5	<2	≤5.5	>8.0

Analytes thresholds are derived from the following sources:

- The Grazier's Guide to Pastures (DPI, 2003)
- Soil Sense: Soil Management for North Coast Farmers (Lines-Kelly, 1995)
- Soil Analysis: An Interpretation Manual (Peverill, Sparrow, & Reuter, 1999)

Table 6-36 Soil sample analysis & threshold ratings 2022 sites

Site	Material	OM	Nitrate N	P (Colwell)	Zn	Mn	Fe	Cu	B	ESP	EAT	Ca:Mg
SP-CN-C418	Spoil	1.0	0.8	10.5	0.9	3.3	17.6	3.0	0.2	6.9	2	1.2
SP-CN-C16	Spoil	0.4	0.8	4.9	<0.5	0.5	2.3	0.2	1.2	20.4	2	0.8
SP-CM-C07	Spoil	0.6	9.6	5.6	<0.5	4.1	2.7	0.4	1.9	30.2	2	2.1
SP-CM-C10	Spoil	3.6	6.6	8.2	<0.5	1.5	3.3	0.4	1.0	19.2	2	1.8
SP-CM-C126	Spoil	3.7	9.6	8.2	19.3	2.6	8.4	8.7	0.8	45.5	2	0.7
SP-CM-C042	Spoil	2.2	0.8	5.9	<0.5	0.2	0.6	0.1	0.4	8.2	2	1.0
SP-CM-C152	Spoil	0.8	7.1	6.2	<0.5	0.3	<0.5	<0.1	1.2	45.5	2	1.1
SP-CM-C100	Spoil	0.4	0.8	10.5	<0.5	1.3	1.9	0.2	0.5	17.4	2	1.4
SP-CM-C38/38	Spoil	2.4	1.4	5.6	0.8	1.6	4.1	0.2	0.3	19.0	2	1.6

Site	Material	OM	Nitrate N	P (Colwell)	Zn	Mn	Fe	Cu	B	ESP	EAT	Ca:Mg
SP-CM-C077	Spoil	1.7	24.5	9.2	<0.5	1.6	2.4	0.5	0.8	18.0	2	2.6
SP-CN-C369/370	Spoil	29.6	0.8	38.4	0.6	18.0	19.8	0.9	0.3	1.8	4	0.9
SP-CN-CN93	Spoil	0.4	0.7	20.0	<0.5	2.5	3.4	0.4	0.7	11.0	2	1.8
SP-CN-CN320	Spoil	0.3	<0.1	6.9	<0.5	0.9	1.8	0.2	<0.1	9.0	2	0.9
SP-CN-CN342	Spoil	0.5	<0.1	12.5	1.0	7.8	16.1	0.1	0.3	2.0	4	1.6
SP-CN-CN413	Spoil	2.0	0.7	6.9	2.7	2.3	8.7	2.5	0.2	3.3	2	1.6
SP-CN-CN334	Spoil	27.7	0.8	20.0	5.8	12.4	30.4	3.2	0.2	17.4	2	1.4
SP-CN-CN364	Spoil	1.8	6.3	13.4	3.5	7.5	15.7	2.1	0.3	18.1	2	1.7
SP-CM-C051	Spoil	4.5	9.1	20.7	<0.5	0.1	<0.5	<0.1	0.9	16.0	2	1.7
SP-CN-CN223	Spoil	1.5	4.7	15.4	0.7	0.8	2.3	0.2	0.4	9.6	2	1.3
SP-CM-C142	Spoil	1.5	1.3	6.9	<0.5	3.6	4.6	0.2	0.2	1.8	4	5.7
TS-CM-C077	Topsoil	2.3	9.6	11.8	<0.5	6.2	8.5	1.6	0.6	4.2	3	3.9
TS-CM-C142	Topsoil	10.5	1.8	7.2	<0.5	4.3	3.3	0.7	0.4	1.4	4	3.9
TS-CM-C100	Topsoil	1.8	25.6	17.1	<0.5	4.8	9.0	1.3	1.0	9.4	2	3.1
TS-CM-C051	Topsoil	4.8	95.7	13.1	<0.5	3.5	6.8	0.7	0.3	1.2	4	14.3
TS-CM-C042	Topsoil	2.9	11.0	8.5	<0.5	3.0	6.7	1.2	0.5	1.5	4	4.4
TS-CM-C07	Topsoil	2.6	4.2	8.2	<0.5	5.3	10.7	1.3	0.7	5.3	3	3.3
TS-CM-C10	Topsoil	2.6	3.8	6.9	<0.5	5.8	7.0	2.0	0.6	1.4	4	2.9
TS-CM-C38/38	Topsoil	2.2	4.2	10.5	<0.5	4.9	6.6	1.1	0.9	4.3	3	5.1
TS-CM-C152	Topsoil	2.0	3.1	7.9	<0.5	8.0	4.6	1.0	0.5	0.8	4	4.4
TS-CN-C16	Topsoil	2.8	2.7	26.9	<0.5	3.7	7.0	1.1	1.0	3.2	4	3.3
TS-CN-CN364	Topsoil	0.8	1.3	8.2	<0.5	2.7	11.9	0.4	0.3	1.5	3	7.0
TS-CN-CN223	Topsoil	1.5	81.4	38.0	<0.5	6.0	11.6	0.5	0.4	3.7	4	3.1
TS-CN-CN342	Topsoil	2.1	10.0	58.4	<0.5	6.0	9.4	0.8	0.4	1.9	3	2.4

Site	Material	OM	Nitrate N	P (Colwell)	Zn	Mn	Fe	Cu	B	ESP	EAT	Ca:Mg
TS-CN-CN413	Topsoil	1.3	3.5	40.7	<0.5	3.7	4.4	0.5	0.3	1.2	3	4.6
TS-CN-CN334	Topsoil	2.2	5.7	48.9	<0.5	5.5	10.5	0.9	1.0	3.9	3	2.3
TS-CN-CN93	Topsoil	3.3	0.7	25.6	0.6	2.4	6.1	1.1	0.8	4.7	3	1.9
TS-CN-CN320	Topsoil	2.1	0.9	58.1	<0.5	5.1	11.0	0.9	0.7	2.6	3	2.3
TS-CN-CN369/370	Topsoil	0.7	1.2	16.1	<0.5	4.6	7.6	0.4	0.3	2.5	3	2.3
TS-CM-C26	Topsoil	1.9	4.4	19.7	<0.5	4.8	8.8	1.2	1.4	9.6	2	2.8

Table 6-37 Soil Sample Analysis & Threshold Ratings for pH and EC 2022 sites

Site	Material	pH	Rating	Texture*	ECe**	Rating
SP-CN-C418	Spoil	9.5	Very Strongly Alkaline	Silty Loam	1.4	Non-Saline
SP-CN-C16	Spoil	8.9	Strongly Alkaline	Medium Clay	1.3	Non-Saline
SP-CM-C07	Spoil	8.7	Strongly Alkaline	Medium Clay	14.8	Highly Saline
SP-CM-C10	Spoil	9.5	Very Strongly Alkaline	Light-Medium Clay	4.3	Moderately Saline
SP-CM-C126	Spoil	8.3	Moderately Alkaline	Silty Clay Loam	23.0	Extremely Saline
SP-CM-C042	Spoil	9.8	Very Strongly Alkaline	Clay Loam	1.9	Non-Saline
SP-CM-C152	Spoil	8.8	Strongly Alkaline	Clay Loam	27.7	Extremely Saline
SP-CM-C100	Spoil	9.4	Very Strongly Alkaline	Clay Loam	1.0	Non-Saline
SP-CM-C38/38	Spoil	10.0	Very Strongly Alkaline	Loam	4.0	Slightly Saline
SP-CM-C077	Spoil	9.2	Very Strongly Alkaline	Silty Clay Loam	6.3	Moderately Saline
SP-CN-C369/370	Spoil	5.7	Moderately Acidic	Silty Clay	1.0	Non-Saline
SP-CN-CN93	Spoil	9.2	Very Strongly Alkaline	Clay Loam	1.5	Non-Saline
SP-CN-CN320	Spoil	9.2	Very Strongly Alkaline	Sandy Loam	0.5	Non-Saline
SP-CN-CN342	Spoil	3.4	Very Strongly Acidic	Sandy Clay Loam	12.7	Highly Saline
SP-CN-CN413	Spoil	9.3	Very Strongly Alkaline	Loam	1.2	Non-Saline

Site	Material	pH	Rating	Texture*	ECe**	Rating
SP-CN-CN334	Spoil	9.5	Very Strongly Alkaline	Silty Clay Loam	2.3	Slightly Saline
SP-CN-CN364	Spoil	9.7	Very Strongly Alkaline	Clay Loam	3.7	Slightly Saline
SP-CM-C051	Spoil	9.1	Very Strongly Alkaline	Silty Clay Loam	6.0	Moderately Saline
SP-CN-CN223	Spoil	9.5	Very Strongly Alkaline	Clay Loam	1.7	Non-Saline
SP-CM-C142	Spoil	9.1	Very Strongly Alkaline	Clay Loam	0.9	Non-Saline
TS-CM-C077	Topsoil	8.9	Strongly Alkaline	Heavy Clay	1.0	Non-Saline
TS-CM-C142	Topsoil	8.5	Strongly Alkaline	Medium Clay	0.6	Non-Saline
TS-CM-C100	Topsoil	8.9	Strongly Alkaline	Heavy Clay	2.2	Slightly Saline
TS-CM-C051	Topsoil	8.4	Moderately Alkaline	Light-Medium Clay	2.6	Slightly Saline
TS-CM-C042	Topsoil	8.8	Strongly Alkaline	Heavy Clay	0.8	Non-Saline
TS-CM-C07	Topsoil	8.9	Strongly Alkaline	Light-Medium Clay	1.1	Non-Saline
TS-CM-C10	Topsoil	8.8	Strongly Alkaline	Heavy Clay	0.8	Non-Saline
TS-CM-C38/38	Topsoil	9.1	Very Strongly Alkaline	Light Clay	1.3	Non-Saline
TS-CM-C152	Topsoil	8.8	Strongly Alkaline	Light Clay	0.9	Non-Saline
TS-CN-C16	Topsoil	8.9	Strongly Alkaline	Heavy Clay	0.9	Non-Saline
TS-CN-CN364	Topsoil	8.8	Strongly Alkaline	Sandy Loam	0.9	Non-Saline
TS-CN-CN223	Topsoil	7.5	Mildly Alkaline	Sandy Clay Loam	2.5	Slightly Saline
TS-CN-CN342	Topsoil	7.6	Mildly Alkaline	Clay Loam	0.7	Non-Saline
TS-CN-CN413	Topsoil	8.4	Strongly Alkaline	Sandy Clay Loam	0.7	Non-Saline
TS-CN-CN334	Topsoil	8.3	Moderately Alkaline	Heavy Clay	0.5	Non-Saline
TS-CN-CN93	Topsoil	8.9	Strongly Alkaline	Silty Clay	1.1	Non-Saline
TS-CN-CN320	Topsoil	8.1	Moderately Alkaline	Heavy Clay	0.5	Non-Saline
TS-CN-CN369/370	Topsoil	7.7	Mildly Alkaline	Sandy Loam	0.5	Non-Saline
TS-CM-C26	Topsoil	9.0	Very Strongly Alkaline	Heavy Clay	1.5	Non-Saline

Table 6-38 Soil sample analysis and threshold ratings 2020 sites

Site	TOC	Nitrate N	P (Olsen)	ESP	Ca:Mg	pH	Rating	Texture*	ECe**	Rating
C07_1	1.7	8.8	1.7	1.0	3.0	8.4	Moderately Alkaline	Medium Clay	0.8	Non-Saline
C07_2	1.9	12.0	2.6	1.5	2.7	8.4	Moderately Alkaline	Medium Clay	0.8	Non-Saline
C122_1	0.9	19.4	10.7	12.0	2.2	8.4	Moderately Alkaline	Light clay	8.5	Highly Saline
C122_2	1.0	45.1	16.4	5.3	3.3	8.2	Moderately Alkaline	Silty Clay Loam	2.5	Slightly Saline
C125_1	1.4	23.9	1.5	11.7	3.0	8.9	Strongly Alkaline	Silty loam	3.2	Slightly Saline
C125_2	1.2	17.8	1.7	9.8	3.1	8.9	Strongly Alkaline	Silty loam	2.1	Slightly Saline
C142_1	1.0	5.7	2.4	<0.2	5.1	8.5	Strongly Alkaline	Loamy Sand	1.8	Non-Saline
C142_2	2.0	3.3	<1.0	0.9	3.9	8.4	Moderately Alkaline	Loamy Sand	1.6	Non-Saline
C149_1	1.3	16.8	14.8	1.3	2.6	8.5	Strongly Alkaline	Silty Clay Loam	1.3	Non-Saline
C149_2	1.4	42.4	11.8	0.1	2.4	8.4	Moderately Alkaline	Light Clay	1.5	Non-Saline
C17_1	2.8	10.9	5.8	0.1	3.0	8.5	Strongly Alkaline	Medium Clay	0.9	Non-Saline
C17_2	2.4	7.1	1.3	0.1	3.8	8.5	Strongly Alkaline	Medium Clay	0.8	Non-Saline
C31_1	1.5	23.7	8.8	0.1	2.2	7.4	Mildly Alkaline	Loamy Sand	3.2	Slightly Saline
C46_1	1.5	34.7	11.4	3.8	2.5	8.2	Moderately Alkaline	Sand	4.3	Moderately Saline
C46_2	1.2	11.7	21.9	0.1	3.5	7.6	Mildly Alkaline	Sand	1.7	Non-Saline
C51_1	1.9	21.4	4	1.1	3.0	8.5	Strongly Alkaline	Light Clay	1.2	Non-Saline
C51_2	4.2	78.6	4.2	0.1	4.0	8.0	Moderately Alkaline	Light Clay	2.1	Slightly Saline
C60_1	2.1	29.7	26.7	0.1	3.3	8.2	Moderately Alkaline	Light Clay	1.2	Non-Saline
C60_2	1.9	33.1	12.7	0.1	2.3	8.5	Strongly Alkaline	Light Clay	1.4	Non-Saline
C71_1	2.1	11.9	3.3	0.1	3.6	8.3	Moderately Alkaline	Silty Clay Loam	1.2	Non-Saline
C71_2	2.8	22.5	4	0.1	2.9	8.2	Moderately Alkaline	Medium Clay	1.2	Non-Saline
C81_2	3.1	56.5	14.1	0.1	2.4	8.3	Moderately Alkaline	Light Clay	1.5	Non-Saline

Site	TOC	Nitrate N	P (Olsen)	ESP	Ca:Mg	pH	Rating	Texture*	ECe**	Rating
CN212_1	1.7	5.4	26.1	0.1	2.3	7.9	Moderately Alkaline	Light Clay	1.5	Non-Saline
CN212_2	1.7	14.8	35.8	0.1	3.4	8.5	Strongly Alkaline	Clay Loam	1.0	Non-Saline
CN225_1	1.0	48.8	4.4	12.8	2.5	7.8	Mildly Alkaline	Clay Loam	0.6	Non-Saline
CN225_2	1.1	43.3	4.6	15.4	2.1	8.6	Strongly Alkaline	Medium Clay	6.8	Moderately Saline
CN326_1	1.0	1.9	15.5	3.6	1.6	8.8	Strongly Alkaline	Medium Clay	5.0	Moderately Saline
CN326_2	0.9	1.4	10	4.8	1.7	8.6	Strongly Alkaline	Light clay	0.7	Non-Saline
CN364_1	0.8	4.7	4.6	8.5	1.9	9.0	Strongly Alkaline	Light clay	0.8	Non-Saline
CN364_2	0.7	9.5	6.5	0.1	2.4	9.1	Very Strongly Alkaline	Sandy Loam	1.7	Non-Saline
CN385_1	0.6	2.1	<1.0	0.1	2.4	8.8	Strongly Alkaline	Sand	2.0	Slightly Saline
CN385_2	0.6	5.4	2.9	0.1	1.9	8.7	Strongly Alkaline	Sand	1.7	Non-Saline
CN387_1	<0.5	6.5	1.8	11.4	2.6	8.2	Moderately Alkaline	Sand	1.1	Non-Saline
CN387_2	0.8	6.6	6.4	0.1	4.7	9.2	Very Strongly Alkaline	Sand	2.9	Slightly Saline
CN400_1	1.1	36.7	18	4.6	2.3	8.4	Moderately Alkaline	Sandy loam	0.7	Non-Saline
CN400_2	1.2	9.7	30.2	3.5	2.5	8.0	Moderately Alkaline	Clay Loam	1.8	Non-Saline
CN413_1	1.6	41.5	17.7	7.0	2.7	8.0	Moderately Alkaline	Clay Loam	0.8	Non-Saline
CN413_2	0.9	26.6	16.2	11.2	1.9	8.7	Strongly Alkaline	Sandy Clay Loam	3.0	Slightly Saline
CN414_1	0.8	21.4	6.4	0.1	1.9	9.0	Strongly Alkaline	Sandy Clay Loam	2.8	Slightly Saline
CN414_2	0.8	3.6	5.4	0.1	1.8	7.8	Mildly Alkaline	Sand	1.4	Non-Saline
CN55_1	2.4	11.6	48.2	0.4	2.9	8.3	Moderately Alkaline	Sand	0.8	Non-Saline
CN55_2	1.8	19.4	38.7	1.6	3.3	7.3	Neutral	Clay Loam	0.5	Non-Saline
CN93_1	2.2	24.7	24	0.1	2.5	8.3	Moderately Alkaline	Clay Loam	0.8	Non-Saline
CN93_2	1.9	13.9	23.2	0.1	2.3	8.0	Moderately Alkaline	Medium Clay	1.0	Non-Saline

Table 6-39 Soil sample analysis and threshold ratings 2020 sites

Site	TOC	Nitrate N	P (Olsen)	ESP	Ca:Mg
C07_1	1.7	8.8	1.7	1.0	3.0
C07_2	1.9	12.0	2.6	1.5	2.7
C122_1	0.9	19.4	10.7	12.0	2.2
C122_2	1.0	45.1	16.4	5.3	3.3
C125_1	1.4	23.9	1.5	11.7	3.0
C125_2	1.2	17.8	1.7	9.8	3.1
C142_1	1.0	5.7	2.4	<0.2	5.1
C142_2	2.0	3.3	<1.0	0.9	3.9
C149_1	1.3	16.8	14.8	1.3	2.6
C149_2	1.4	42.4	11.8	0.1	2.4
C17_1	2.8	10.9	5.8	0.1	3.0
C17_2	2.4	7.1	1.3	0.1	3.8
C31_1	1.5	23.7	8.8	0.1	2.2
C46_1	1.5	34.7	11.4	3.8	2.5
C46_2	1.2	11.7	21.9	0.1	3.5
C51_1	1.9	21.4	4	1.1	3.0
C51_2	4.2	78.6	4.2	0.1	4.0
C60_1	2.1	29.7	26.7	0.1	3.3
C60_2	1.9	33.1	12.7	0.1	2.3
C71_1	2.1	11.9	3.3	0.1	3.6
C71_2	2.8	22.5	4	0.1	2.9
C81_2	3.1	56.5	14.1	0.1	2.4
CN212_1	1.7	5.4	26.1	0.1	2.3
CN212_2	1.7	14.8	35.8	0.1	3.4
CN225_1	1.0	48.8	4.4	12.8	2.5
CN225_2	1.1	43.3	4.6	15.4	2.1
CN326_1	1.0	1.9	15.5	3.6	1.6
CN326_2	0.9	1.4	10	4.8	1.7
CN364_1	0.8	4.7	4.6	8.5	1.9
CN364_2	0.7	9.5	6.5	0.1	2.4
CN385_1	0.6	2.1	<1.0	0.1	2.4
CN385_2	0.6	5.4	2.9	0.1	1.9
CN387_1	<0.5	6.5	1.8	11.4	2.6
CN387_2	0.8	6.6	6.4	0.1	4.7
CN400_1	1.1	36.7	18	4.6	2.3
CN400_2	1.2	9.7	30.2	3.5	2.5
CN413_1	1.6	41.5	17.7	7.0	2.7

Site	TOC	Nitrate N	P (Olsen)	ESP	Ca:Mg
CN413_2	0.9	26.6	16.2	11.2	1.9
CN414_1	0.8	21.4	6.4	0.1	1.9
CN414_2	0.8	3.6	5.4	0.1	1.8
CN55_1	2.4	11.6	48.2	0.4	2.9
CN55_2	1.8	19.4	38.7	1.6	3.3
CN93_1	2.2	24.7	24	0.1	2.5
CN93_2	1.9	13.9	23.2	0.1	2.3

Dispersive soils

Soils with EAT indices of 1-3 will disperse if water is allowed to pond on them. Thus, the soils tested are prone to dispersion, hardsetting or the development of a surface crust when dry. This is also indicated by the exchangeable sodium percentage measured at the sites.

It is critical that on-site management includes measures that provide for protection and treatment of sodic and dispersive soils so as to limit the potential for erosion and generation of turbid water. Turbid water from construction areas also needs to be treated on site, as once clays are in suspension and turbid water runs off into waterways, it is very difficult to remove from the water.

Vegetated swales and wetlands along waterways will assist with stormwater treatment and entrapment of silt and sand fractions but are unlikely to be effective in removing dispersed clay from suspension. Treatment of water collected in sedimentation basins may be required to remove suspended clays from water, prior to discharge of water into waterways. Water collected in sedimentation basins may be treated with a flocculant and involve the use of cyclones to improve water quality, prior to entering waterways.

The management of water flows over and through dispersive soils is a key tool in control of detrimental effects. Approaches may include:

- Diversion of water flows away from these materials. This is not always possible due to the extensive distribution of these dispersive soils
- Minimising potential convergence and/or ponding of surface flows, particularly on disturbed soils
- Development of appropriate cover/protection of dispersive soils (i.e. creation of stable linings that a resistant to rainfall erosion and runoff)
- Soil chemical ameliorants are recommended for short-term stabilisation of dispersive soils on construction sites. Three primary soil ameliorants and their uses for stabilising dispersive soils on construction sites are:
  - Natural or recycled gypsum ($CaSO_4$) primarily for stabilising dispersive topsoil or subsoil
  - Hydrated lime ($Ca(OH)_2$) stabilises soil cations by supply of calcium and increasing soil strength
  - Agricultural lime ($CaCO_3$) will provide minor soil stability.

Salinity

Most topsoil sites have a low or very low salinity risk and meet the rehabilitation criterion milestone ‘a leaching profile has developed, or is likely to, and EC values are sufficiently low to allow survival and growth of the plant species present’. Four spoil samples are considered to have extreme salinity (EC) risk and may not meet this criterion milestone. Amelioration for salinity with compost is recommended at sites as outlined in **Table 6-40**.

pH levels

pH levels at sites that were acidic and where material with pH ≤6 was present may not currently meet the criterion milestone 'levels of pH are within the range required to allow plant growth' and will require amelioration towards neutral pH levels at the rehabilitation sites. Amelioration recommendations with lime are outlined in **Table 6-40**. Where pH is very strongly alkaline (>9) zinc coated MAP or DAP should be considered to ensure zinc levels are adequate for pasture establishment.

Nutrients

The calcium magnesium ratio (Ca:Mg) is typically low across all sites and may not meet the criterion milestone 'levels of soil macro and micro nutrients are likely to be sufficient to ensure that trees do not experience nutrient deficiencies'. It is recommended that gypsum or lime application is undertaken across all sites which are marginal or deficient. Use of gypsum or lime will be determined according to pH and/or ESP status (**Table 6-40**). Gypsum and lime will increase the Ca:Mg towards more desirable levels for increase soil stability and pasture growth, with gypsum having the added benefit of supplying a source of sulfur. If "recycled" gypsum is to be sourced, then these rates should be increased by 20%. The gypsum can be broadcast directly over the top of the pasture and incorporated by rainfall.

At sites where organic matter (OM) levels were deficient to marginal, compost can be applied to ameliorate organic carbon content as outlined in **Table 6-40**.

Nitrate N levels are typically marginal to deficient across most sites and requires amelioration to improve plant available nitrogen with DAP as outlined in **Table 6-40**. Mono-ammonium phosphate (MAP) and di-ammonium phosphate (DAP) will also address phosphorous deficiencies across identified sites.

Recommendations

Recommendations for ameliorants are summarised in **Table 6-40** and **Table 6-41.** Ameliorant recommendations listed in **Table 6-40** are for samples collection in July/August 2022 by Curragh and analysed as outlined in the *Curragh Topsoil and Spoil Sampling Program* proposed by SLR in 2022. Ameliorant recommendations listed in **Table 6-41** are for samples collection in 2020 by Curragh and analysed as outlined in the *Topsoil Training, Assessment and Sampling* guideline by GT Environmental (2019).

Table 6-40 Ameliorant Recommendations for sample collection in July/August 2022

Site	Potential Stockpile Use	Gypsum	Lime	Compost	MAP + Zn	DAP +Zn	Urea
		t/ha	t/ha	m³/ha	kg/ha	kg/ha	kg/ha
SP-CN-C418	Native Topsoil	5	Nil	2	Nil	200	Nil
SP-CN-C16	Native Topsoil	10	Nil	2	Nil	200	Nil
SP-CM-C07	Subsoil	10	Nil	15	Nil	200	Nil
SP-CM-C10	Native Topsoil	10	Nil	5	Nil	200	Nil
SP-CM-C126	Subsoil	10	Nil	20	Nil	200	Nil
SP-CM-C042	Native Topsoil	10	Nil	Nil	Nil	200	Nil
SP-CM-C152	Subsoil	10	Nil	20	Nil	200	Nil
SP-CM-C100	Native Topsoil	10	Nil	2	Nil	200	Nil
SP-CM-C38/38	Native Topsoil	10	Nil	5	Nil	200	Nil
SP-CM-C077	Native Topsoil	10	Nil	5	Nil	200	Nil
SP-CN-C369/370	Subsoil	10	5	10	50	Nil	100

Site	Potential Stockpile Use	Gypsum	Lime	Compost	MAP + Zn	DAP +Zn	Urea
		t/ha	t/ha	m³/ha	kg/ha	kg/ha	kg/ha
SP-CN-CN93	Native Topsoil	5	Nil	2	Nil	150	Nil
SP-CN-CN320	Native Topsoil	5	Nil	2	Nil	200	Nil
SP-CN-CN342	Native Topsoil	2	10	15	Nil	200	Nil
SP-CN-CN413	Native Topsoil	2	Nil	Nil	Nil	200	Nil
SP-CN-CN334	Native Topsoil	10	Nil	10	Nil	150	Nil
SP-CN-CN364	Native Topsoil	10	Nil	5	Nil	200	Nil
SP-CM-C051	Native Topsoil	10	Nil	5	Nil	150	Nil
SP-CN-CN223	Native Topsoil	5	Nil	2	Nil	200	Nil
SP-CM-C142	Native Topsoil	Nil	Nil	2	Nil	200	Nil
TS-CM-C077	Pasture Topsoil	Nil	Nil	Nil	Nil	200	Nil
TS-CM-C142	Pasture Topsoil	Nil	Nil	Nil	Nil	200	Nil
TS-CM-C100	Pasture Topsoil	5	Nil	5	150	Nil	Nil
TS-CM-C051	Pasture Topsoil	Nil	Nil	10	200	Nil	Nil
TS-CM-C042	Pasture Topsoil	Nil	Nil	Nil	200	Nil	Nil
TS-CM-C07	Pasture Topsoil	5	Nil	Nil	Nil	200	Nil
TS-CM-C10	Pasture Topsoil	Nil	Nil	Nil	Nil	200	Nil
TS-CM-C38/38	Pasture Topsoil	Nil	Nil	Nil	Nil	200	Nil
TS-CM-C152	Pasture Topsoil	Nil	Nil	Nil	Nil	200	Nil
TS-CN-C16	Pasture Topsoil	Nil	Nil	Nil	Nil	150	Nil
TS-CN-CN364	Pasture Topsoil	Nil	Nil	2	Nil	200	Nil
TS-CN-CN223	Pasture Topsoil	2	Nil	5	50	Nil	Nil
TS-CN-CN342	Pasture Topsoil	2	Nil	Nil	50	Nil	100
TS-CN-CN413	Pasture Topsoil	Nil	Nil	2	50	Nil	100
TS-CN-CN334	Pasture Topsoil	2	Nil	Nil	50	Nil	100
TS-CN-CN93	Pasture Topsoil	2	Nil	Nil	Nil	150	Nil
TS-CN-CN320	Pasture Topsoil	2	Nil	Nil	50	Nil	100
TS-CN-CN369/370	Pasture Topsoil	2	Nil	2	Nil	200	Nil
TS-CM-C26	Pasture Topsoil	5	Nil	2	Nil	200	Nil

Table 6-41 Ameliorant Recommendations for sample collection in 2020

Site	Potential Stockpile Use	Gypsum	Lime	Compost	MAP + Zn	DAP +Zn	Urea
		t/ha	t/ha	m³/ha	kg/ha	kg/ha	kg/ha
C07	Pasture Topsoil	Nil	Nil	2	Nil	200	Nil
C122	Pasture Topsoil	5	Nil	10	200	Nil	Nil
C125	Pasture Topsoil	5	Nil	5	200	Nil	Nil
C142	Pasture Topsoil	Nil	Nil	2	Nil	200	Nil
C149	Pasture Topsoil	2	Nil	2	200	Nil	Nil
C17	Pasture Topsoil	Nil	Nil	Nil	Nil	200	Nil
C31	Pasture Topsoil	2	Nil	5	200	Nil	Nil
C46	Pasture Topsoil	2	Nil	5	200	Nil	Nil
C51	Pasture Topsoil	Nil	Nil	5	200	Nil	Nil
C60	Pasture Topsoil	2	Nil	2	200	Nil	Nil

Site	Potential Stockpile Use	Gypsum	Lime	Compost	MAP + Zn	DAP +Zn	Urea
		t/ha	t/ha	m³/ha	kg/ha	kg/ha	kg/ha
C71	Pasture Topsoil	2	Nil	Nil	200	Nil	Nil
C81	Pasture Topsoil	2	Nil	Nil	200	Nil	Nil
CN212	Pasture Topsoil	Nil	Nil	2	Nil	150	Nil
CN225	Pasture Topsoil	5	Nil	5	200	Nil	Nil
CN326	Pasture Topsoil	2	Nil	5	Nil	200	Nil
CN364	Pasture Topsoil	5	Nil	5	Nil	200	Nil
CN385	Pasture Topsoil	2	Nil	5	Nil	200	Nil
CN387	Pasture Topsoil	5	Nil	5	Nil	200	Nil
CN400	Pasture Topsoil	2	Nil	2	Nil	200	Nil
CN413	Pasture Topsoil	5	Nil	5	200	Nil	Nil
CN414	Pasture Topsoil	2	Nil	5	Nil	200	Nil
CN55	Pasture Topsoil	2	Nil	Nil	150	Nil	Nil
CN93	Pasture Topsoil	2	Nil	Nil	150	Nil	Nil

Notes:

- Where multiple samples were taken at the same site, amelioration recommendations were made on the "worst" results to achieve the best outcome
- Trace elements were analysed using a methodology which determines concentration of total elements and not DTPA extractable concentration
- ECe and amelioration rates are based on field texture as lab determined particle size analysis was not undertaken

The majority of spoil stockpiles are recommended for use as topsoil for establishment of native woodland. The four spoil stockpiles recommended for use as subsoil is due to high salinity and/or sodicity. If these four stockpiles are utilised as subsoil no amelioration is recommended. Similarly, if any other stockpiles are utilised as subsoil amelioration is not required. All topsoil stockpiles are recommended for use as topsoil for establishment of grass pasture or grassy woodland.

Soil improvers selected for use in the amelioration program are as follows:

- Gypsum provides calcium, sulfur and reduces dispersion – if recycled gypsum is used the application rate needs to be increased by 20%.
- Agricultural lime provides calcium and increases pH towards neutral.
- Compost provides organic carbon, increases water holding capacity, permeability and decreases salinity.
- MAP + Zinc provides phosphorus and some nitrogen (22P, 10N) and trace element zinc.
- DAP + Zinc provides phosphorus and nitrogen (20P, 18N) and trace element zinc.
- Urea provides nitrogen only (46N).

Soil re-spreading and seedbed preparation

Where topsoil resources allow, topsoil should be spread to a nominal depth of 0.15 m on all re-graded land. Topsoil should be spread, treated with gypsum and seeded in one consecutive operation to reduce potential for topsoil loss to wind and water erosion. Soil respreading on steep slopes at depths exceeding 0.15 m can be deleterious because of the sponge effect which can cause slippage of the topsoil from the slope. Flat areas should be topsoiled at a nominal depth of 0.2 m.

Thorough seedbed preparation should be undertaken to ensure optimum establishment and growth of vegetation. All topsoiled areas should be lightly contour ripped (after topsoil spreading) to create a "key" between the soil and underlying material. Best results will be obtained by ripping when soil is moist and when undertaken immediately prior to sowing. The respread topsoil surface should be scarified prior to or during seeding to reduce runoff and increase infiltration.

6.1.11 Water Management

Water Infrastructure Post Closure

CCPL is proposing to leave all raw water dams in order to support the PMLU of light grazing and open woodland. In order to successfully graze the land stock water sources are required. CCPL will remove sediment from any dams to be retained then allow them to naturally fill again. The water in these dams will be required to meet stock watering requirements as outlined in ANZEEC Guidelines.

Processing dams will be decommissioned and rehabilitated to the proposed PMLU. A land contamination study will be undertaken for all processing dams then the dam will be rehabilitated by battering in the dam walls, topsoiling, ripping and seeding to establish the land to the surrounding land use.

Erosion and Sediment Control

CCPL will continue to produce a landform design that, where possible, will emulate the natural drainage and slopes in the mining area. Landform design will incorporate natural and engineered structures to minimise erosion.

Where required, erosion and sediment control structures will be implemented where required in accordance with the EM Plan 2.1 Erosion and Sediment Control Management Plan.

Contour banks may be constructed in areas of steep slopes or long slope lengths to manage runoff during rehabilitation and closure. Contour banks are earthen structures constructed at intervals down the slope to intercept run off and safely channel it into stable waterways.

Contour bank design parameters include:

- Low gradient design of 0.5% along the flow alignment;
- Flow velocities below 1.0 m/sec (for nil vegetation case);
- Spoil construction, covered by 200 mm of topsoil;
- Bank invert left bare, no topsoil; and
- Up slope bank face at 1:2, down slope face at 1:3.

Contour banks less than 400 m long are built to a standard dimension of 1 m high of spoil, plus a 200 mm topsoil cover. Contour banks effectively minimise erosion on slopes but tend to produce concentrated high velocity flows at their discharge end. Contour banks are therefore arranged to discharge into a strategically placed energy dissipation basin or waterway.

Some waterways may require rock armouring due to the high flow velocities encountered. At the Curragh Project, the Ishbash equation has been used to determine optimum rock size and all rehabilitation waterways are designed to a 50-year ARI.

Several rock lined waterways have been constructed in the rehabilitation areas and are working efficiently. The rock size grading is specified according to the steepness of the channel and the subsequent velocities experienced.

Hydraulic jump basins will be used at the bottom of the slope to dissipate energy and therefore limit the length of the waterway.

If contour banks are left to remain in the longer term, after the establishment of a vegetative cover, they may increasingly be at risk of overtopping. This failure could cause a concentration of flow to occur and commencement of gully erosion. Consequently, after establishment of adequate vegetative cover, the potential will be assessed as to whether the contour banks will be removed to avoid that possibility.

Removal could be carried out by a variety of methods depending on the height of the bank and its manner of construction. These methods may include:

- Grading out the bank material up and down slope;
- Complete removal by scraper;
- The area of the removed bank will be re-seeded and where necessary, re-topsoiled.

Blackwater Creek Diversion

In 2008 Wesfarmers Curragh Pty Ltd received approval to divert a 9.4 km section of Blackwater Creek to allow the extension of mine operations to the east. The Blackwater Creek Diversion (BWCD) has a constructed length of 10.2 kms and consists of a meandering low flow channel, high flow channel, batter banks and terraces that all required rehabilitation and revegetation.

The intent of the rehabilitation is to provide a comprehensive strategy that facilitates the re-establishment of in-stream and ex-stream ecological processes within the channel. The aim of the rehabilitation is to create as much as possible, a self-sustaining system that requires minimal management in the short to medium term and no future management beyond the cessation of the mining operations. The BWCD will result in a permanent, stable and sustainable creek alignment that will provide an important ecological corridor over the entire length of the diversion.

The diversion channel has been designed to imitate the bed grade, channel plan form, cross-section form, and other geomorphic and habitat features of the reaches of the natural channel that the diversion will replace. Essentially the functional design aims to recreate a “natural” reach of channel that will be self-sustaining over the long term, well beyond the cessation of mining operations.

To achieve this the design aims to recreate a system as close as possible to, within the limits posed by the engineering design requirements of the diversion, the naturally occurring in stream and riparian zones in undisturbed parts of Blackwater Creek. This will aid in the establishment of natural in stream habitat, riparian and near riparian zones (riverine zones) featuring as far as practicable, locally occurring native plant species that include groundcovers, shrubs and trees.

Restoration of a diverse physical structure within the stream, and a diverse floristic structure, will see a corresponding increase in habitat diversity and an increase in faunal activity, diversity and dispersal.

A geometrically engineered diversion channel was designed by Parsons Brinckerhoff which included both low flow and high flow components divided into zones that reflect the profile attributes of the diversion.

The mandatory elements that were incorporated into the design were:

- Variations in the longitudinal and latitudinal section of the floor of stream form; and
- Strategic location of vegetation to increase habitat values and maximise bank stability.

Some amendments were made to the original rehabilitation design that was assessed as ongoing improvements and adaptations to achieve the desired outcomes.

The rehabilitation zones are referred to as:

- Channel: low flow channel;
- Zone A: low flow channel batter (1V:3H);
- Zone B1: high flow terrace extending up to Zone B2;
- Zone B2: high flow terrace extending up to Zone C; and
- Zone C: high flow batters (batters of 1V:3H), levees and drains extending to natural ground.

Rehabilitation success criteria for diverting Blackwater Creek were that the diversion must achieve a minimum of 75% groundcover and have weediness not greater than 5%.

The establishment of adequate vegetative groundcover was deemed necessary to achieve acceptable scour resistance within the range of velocity, shear and stream power characteristics predicted. The criteria and staged response are outlined in **Table 6-42**. These assigned parameters aligned with the time intervals proposed for the formal assessment monitoring.

Due to the acceleration of the project, cover and weediness were still the target values which had to be achieved at the opening stage. These are considered to be the Primary Success Criteria.

Table 6-42 Rehabilitation Success Criteria for Practical Completion

Parameter	3 months	6 months	12 months	18 months	24 months
Cover / m^2 - Groundcover – Hydromulch Zones A, B2 & C	30%	50%	75%	75%	75%
Weediness	15%	10%	5%	5%	5%

Biodiversity Success Criteria were not necessary for Practical Completion but are considered necessary for proving reinstatement of biodiversity performance. **Table 6-43** details the long-term biodiversity outcomes.

Table 6-43 Long Term Biodiversity Outcomes

Parameter	3 months	6 months	12 months	18 months	24 months
Cover / m^2 - Groundcover – Hydromulch Zones A, B2 & C	30%	50%	75%	75%	75%
Diversity - Groundcover – Hydromulch Zones A, B2 & C	≥3 species	≥3 species	≥4 species	≥5 species	≥6 species
Height (Median) - (Direct Planting cells and continuous planting in Zone B1)	20cm	40cm	75cm	100cm	125cm
Diversity** - (Direct Planting cells and continuous planting in Zone B1)	≥5 species	≥5 species	≥7 species	≥10 species	≥10 species

It is the intention that the diversion will be maintained post-opening to ensure that it complies with the long-term diversity criteria.

Other Watercourse Diversions

There are two other permanent watercourse diversions proposed to occur as part of the Curragh Extension project; Minnie Creek Diversion and Bonnie Doon Creek Diversion (**Figure 6-23**).

The western portion of Curragh Central intersects with Minnie Creek. An approximately 6.9 km long diversion of Minnie Creek is proposed around the western perimeter of Curragh Central and discharging into the Blackwater Creek.

A portion of the mine vehicle haul road along the western perimeter of Curragh South crosses and traverses Bonnie Doon Creek. An approximately 1.1 km long diversion of Bonnie Doon Creek is proposed on the western side of the mine vehicle haul road.

These diversions have not yet been designed or constructed. Prior to construction a certified design plan in accordance with the EA conditions must be submitted to the administering authority. ‘As Constructed’ drawings and specifications must also be submitted at least 60 days after the construction of a diversion.

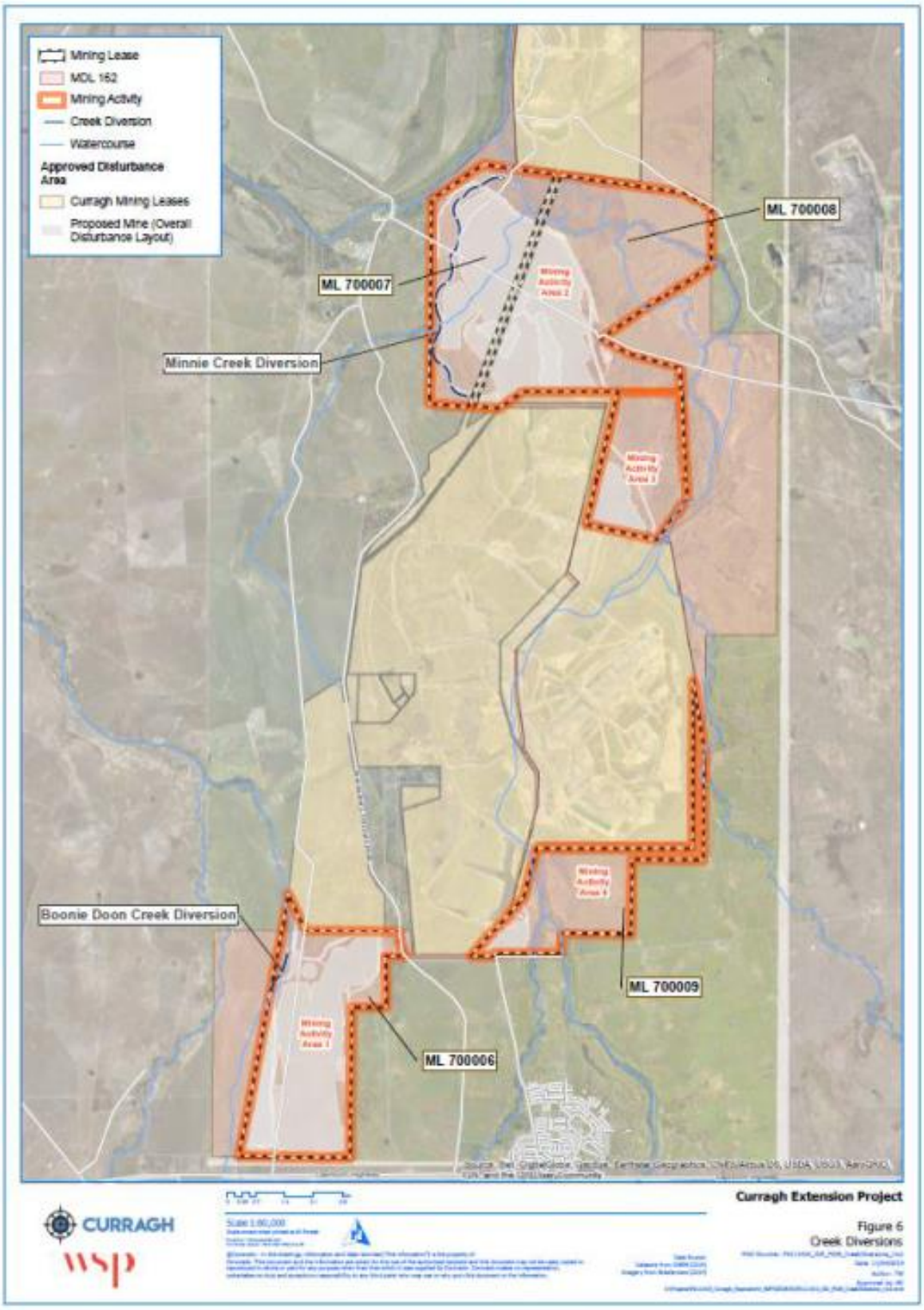


Figure 6-23 Proposed Watercourse Diversions

6.2 Rehabilitation/Management Strategy

The rehabilitation objectives for the Curragh Project are:

i. To achieve a self-sustaining open pasture and woodland, capable of supporting both native fauna and pasture for light intensity grazing that requires minimal on-going maintenance;

ii. To ensure the land disturbed by mining activities will be made stable; and

iii. Maintain downstream water quality at an acceptable standard consistent with ambient water quality conditions.

To avoid land degradation, grazing should be of a light intensity only. Light grazing is a condition with less than 30% grass utilization to produce slaughter steers. A 30% pasture utilization is considered the maximum to maintain land condition without degradation (Bowen and Chudleigh, 2017).

The basic elements essential to the attainment of these objectives are landform stability, topsoil management, revegetation, and the control of run-off water.

The rehabilitation strategy is built around five benchmarks as follows:

- Areas re-contoured (reshaped to final grade);
- Areas topsoiled;
- Areas seeded (ripped and seeded, irrespective of germination success);
- Areas established (vegetation has established, although minor reseeding/ erosion repairs may be necessary); and
- Areas successfully rehabilitated and certified (compliance with rehabilitation success criteria).

6.2.1 Infrastructure

The decommissioning and final rehabilitation will occur on a staged basis over several years. Where written agreement has not been obtained with stakeholders for infrastructure to remain, the rehabilitation will include:

- The removal of buildings and structures;
- The breaking up and covering of concrete slabs and or/coal stockpile areas with a suitable depth of inert material; and
- The removal of redundant roads by removal of contaminated material before ripping and seeding.

Haul roads and hardstand areas will be rehabilitated by removal of contaminated material and ripping of compacted areas, topsoiling and seeding.

6.2.2 Water Management Infrastructure

CCPL is proposing to leave all raw water dams in order to support the PMLU of light grazing and open woodland. In order to successfully graze the land stock water sources are required. CCPL will remove sediment from any dams to be retained then allow them to naturally fill again. The water in these dams will be required to meet stock watering requirements as outlined in ANZEEC Guidelines.

Processing dams will be decommissioned and rehabilitated to the proposed PMLU. A land contamination study will be undertaken for all processing dams then the dam will be rehabilitated by battering in the dam walls, topsoiling, ripping and seeding to establish the land to the surrounding land use.

6.2.3 Overburden Dumps

The overburden dumps will be reshaped in accordance with the proposed final landform. Landform morphology will be developed and implemented to ensure an integrated final landform. Water and erosion will be managed though use of the appropriate water management structures e.g. contour banks, rock lining on waterways.

Topsoil will be applied in strips to approximately 65% of the area in order to allow tree and shrub growth without the competition of grasses which prefer topsoiled areas.

Deep ripping of spoil/topsoil in conjunction with seeding will be utilised to minimise erosion. Revegetation will be surveyed on a regular basis and maintenance will be carried out to meet rehabilitation success criteria. Revegetation will be carried out predominantly using a seeder to broadcast seed.

6.2.4 Tailings

The Out-of-pit tailings storage facility will be rehabilitated in accordance with the Parson Brinckerhoff (2016) Design report. Once the cover design is installed and signed off by a RPEQ qualified person, the area will be topsoiled and seeded with predominantly grass species.

The in pit tailings disposal areas will be covered in at least 1 m of inert rock as part of the reshaping of the overburden dumps and low walls. The area will then be topsoiled within at least 0.2 m of growth media, ripped then seeded.

6.2.5 Final Voids

The final voids will be reprofiled in accordance with the geotechnical report based on the rock material assessed prior to rehabilitation occurring. The geotechnical report summarised in section 6.1.9, outlines the different scenarios shown for each pit. Once the pit wall is reprofiled a bund will be constructed to limit access to the highwall. Fencing and signage haven't been proposed as these require ongoing maintenance and are unsustainable in the long-term.

The voids will be allowed to fill with water which has been modelled to show that it will not interact with the surrounding environment.

6.2.6 Stable Embankments

The stable embankments will be formed when the voids are mined to their final location and the area is rehabilitated. The embankments will be constructed using Permian or Quaternary spoil. Rock mulch will be applied to the watercourse side slope (19°) to provide erosional stability. The full extent of the stable embankment will support a use of Light Grazing and Open Woodland with the slope rock mulched providing a secondary use of fauna habitat. The rest of the stable embankment will be seeded to support the Light Grazing and Open Woodland use.

7 Risk Assessment

7.1 Principles and Methodology

The key steps to the risk assessment process were:

- **Establish the Context:** Consideration should be given to both the internal and external environment, the limits within the risk assessment are valid, the activity being assessed and the cross section of people contributing to the risk management process;
- **Identification of Hazards:** Risk identification refers to the process of identifying risks against a pre-defined set of business objectives, taking into account the context, the previous risk assessments, incidents and the findings of audits performed onsite;
- **Risk Analysis:** each potential consequence should be analysed separately, and existing or current controls should be identified and their effectiveness and efficiency taken into account.
- **Risk Evaluation:** to assist in making decisions, and to define which risks need treatment and the priority for treatment implementation; and
- **Risk Treatment:** selecting control options for modifying risks and implementing those controls to reduce residual risk factors to a level as low as is reasonably achievable (ALARA). Costs and efforts of the controls versus the benefits derived should be reviewed. Reduction of the risks should be according to the hierarchy of controls:
    - Elimination;
    - Substitution;
    - Engineering controls;
    - Administrative controls; and
    - Personal protective equipment.

A PRCP Closure Risk Workshops were facilitated by SLR over two days 6th and 7th June 2022. Attendees were as per **Table 7-1**.

Table 7-1 Risk Assessment Attendees

Name	Employer	Department	Date of Attendance
Mark Stokes	Coronado Curragh	Development	06/06/2022 07/06/2022
Margaret Stewart	Coronado Curragh	Development	06/06/2022 07/06/2022
Brad Radloff	SLR Consulting	Environmental Approvals and Management	06/06/2022 07/06/2022
Emma Williams	SLR Consulting	Environmental Approvals and Management	06/06/2022 07/06/2022
Kim Tuart	Coronado Curragh	Technical Services	06-06-2022
Madeline Bourke	Coronado Curragh	Technical Services	06-06-2022

Name	Employer	Department	Date of Attendance
Kelly Smith	Coronado Curragh	Technical Services	06-06-2022
Amanda Dawson-Evenhuis	Coronado Curragh	Technical Services	06-06-2022
Connor Jacklin	Coronado Curragh	Technical Services	06-06-2022
Liz Blythe	Coronado Curragh	HR and Social	07-06-2022
Anne Palmer	Coronado Curragh	HR and Social	07-06-2022
Tania Fitzgerald	Coronado Curragh	HR and Social	07-06-2022
Danny Millers	Coronado Curragh	Mine Planning	07-06-2022
Brett Mason	MineOp Consulting	Mine Planning	07-06-2022
Eugene Cooper	Coronado Curragh	Mine Planning	07-06-2022
Anthony De Domenico	Coronado Curragh	Management	06/06/2022 07/06/2022
Scott Weatherall	Coronado Curragh	Mine Planning	07-06-2022
Eaton Sheridan	Coronado Curragh	Mine Planning	07-06-2022

7.2 Risk Matrix

A risk matrix was used to assess the level of risk with certain events. The risk matrix considers the consequence and likelihood of each event. The consequence and likelihood categories have been developed based on the criteria from the Integrated Mine Closure Good Practice Guide, 2nd Edition (ICMM, 2019). The risk matrix is shown in **Table 7-2**.

Table 7-2 Risk Matrix

Likelihood		Consequence				
		1 - Insignificant	2 - Minor	3 - Moderate	4 - Significant	5 - Major
		No lasting rehabilitation impact, no remediation required, no rehabilitation delivery impacts	Minor rehabilitation impact requiring minor remediation or repair, delivery impact of <6 months	Moderate rehabilitation impact requiring moderate remediation or repairs, delivery impact of <2 years	Significant rehabilitation impact requiring significant remediation or repairs, delivery impact of <10 years	Major rehabilitation impact requiring major remediation or repairs, delivery impact of >10 years
5 - Almost Certain	Greater than 90% likelihood of occurring Has happened, will probably happen during the mine life/closure and there is no reason to suspect it won't happen	**11 - Medium**	**16 - Significant**	**20 - Significant**	**23 - High**	**25 - High**
4 - Likely	Likelihood of occurring is equal to or more than 30% and less than 90% This consequence is not uncommon in the mining and metals industry/area	**7 - Medium**	**12 - Medium**	**17 - Significant**	**21 - High**	**24 - High**
3 - Possible	Likelihood of occurring is equal to or more than 10% and less than 30% There is a possibility of this risk occurring as it has occurred before (albeit infrequently) in the mining and metals industry/area	**4 - Low**	**8 - Medium**	**13 - Significant**	**18 - Significant**	**22 - High**
2 - Unlikely	Likelihood of occurring is more than or equal to 3% and less than 10% There are no specific circumstances to suggest this could happen	**2 - Low**	**5 - Low**	**9 - Medium**	**14 - Significant**	**19 - Significant**
1 - Rarely	Likelihood of occurring is less than 3% it would require a substantial change in circumstances to create an environment for this to occur, and even then, this is a rare occurrence	**1 - Low**	**3 - Low**	**6 - Medium**	**10 - Medium**	**15 - Significant**

7.3 Summary of Key Closure Risks

The risk assessment outcomes are outlined in **Appendix O**. A total of 30 risks were identified and assessed. No high risks, 11 significant risks, 13 medium risks and 6 low risks were classified in accordance with the risk matrix.

The 11 significant risks identified include:

- Changes to mine planning resulting in non-compliance with PRCP schedule.
- Change in mining methods.
- Changes in infrastructure requirements over mine life (e.g. tailings/rejects storage).
- Incorrect placement of materials resulting in erosion and/or geotechnical instability.
- Waste characterisation inadequate.
- Grass competition results in insufficient woodland development.
- Inadequate monitoring data to support relinquishment.
- Drought impacting rehabilitation success.
- Uncontrolled bushfire damaging rehabilitation.
- Stakeholder support of post-mining land uses change.
- Potential changes to regulator rehabilitation expectations / interpretation impacting PRCP schedule amendments.

7.4 Risk Treatment Plan

A Risk Treatment Plan (**Appendix O**) has been developed for the risks identified in the risk assessment. The Risk Treatment Plan includes the following:

- Proposed treatments for each risk;
- Reason for the proposed treatment;
- Performance measures and constraints;
- Reporting and monitoring requirements;
- Potential corrective actions;
- Resources requirements;
- Timing; and
- Responsibility.

The outcomes of the risk treatment plan assessment are linked with the monitoring and maintenance programs to ensure that all actions necessary are undertaken to ensure risks are mitigated and minimised.

7.5 Rehabilitation Trials

7.5.1 Heightened Spoil Dumps at Curragh North

Issues and risks that may affect the success and performance of revegetation on increased slope angles include:

- Soil erosion and landform stability;
- Adequacy of current species mixes for final landform and land use; and
- Vegetation establishment on steeper slopes >16%.

Consequently, the following measures will be trialled for rehabilitation of the steeper slopes associated with the heighted Curragh North spoil dumps.

Contour banks / slope breaks

On the steeper slopes associated with the heighted spoil dumps at Curragh North, the regularity of contour banks and/or slope breaks will be increased (to approximately 55m apart for vegetated slopes up to 20%). The adequacy of these additional contour banks and slope breaks for maintaining erosion and landform stability, will be assessed through erosion and landform stability monitoring as outlined below.

Erosion analysis

For the heighted spoil dumps at Curragh North, field-based erosion monitoring will be undertaken at the same time as rehabilitation monitoring. Evidence of erosion will be assessed in accordance with the Australian Soil and Land Survey Field Handbook (National Committee on Soil and Terrain 2009) and includes:

a. type of erosion (wind, water, scald, sheet, rill, gully, tunnel and mass movement)
b. state of erosion (active, partially stabilised or stabilised)
c. severity of erosion (dependent upon type of erosion present – present/absent and if present either minor, moderate, severe or very severe)
d. for gullies - the depth and width of erosion
e. opportunistic identification of all areas of significant erosion encountered outside of the assessment areas.

Landform stability

Landform stability of the rehabilitation on the heightened spoil dumps will be assessed using current Light Detection and Ranging (LiDAR) data and remote sensing software to generate 1 m digital elevation models (DEMs) of the landform. DEMs from previous years will be compared to assess stability as it relates to identifying areas of settlement, deposition, subsidence and erosion.

The DEM slope analysis will also be used to assess the as built landform against the landform design criteria with a maximum slope of 16% for the out of pit (OoP) dump slope tying into the final landform and with in-pit dump slopes of up to 27% for the internal rehabilitation batters.

Annual erosion and landform stability monitoring will enable early detection of instability of rehabilitated slopes >16%, particularly areas that may be developing deep rills or gullies and/or areas that are either subsiding or where run off is settling. Early detection will enable targeted rework as required to maintain overall landform stability.

Species mix

The following measures will be implemented to improve rehabilitation success on steeper slopes associated with the heightened spoil dumps at Curragh North:

- Establishment of additional vegetation reference sites in surrounding vegetation communities on steep slopes (i.e. > 16%) to improve species data and vegetation data to inform rehabilitation on the steeper slopes;
- Tree, shrub and grass species representative of the surrounding vegetation will be included in the species mix for steeper slopes; and
- To establish short-term groundcover, a cover crop such as millet or oats will be included with the revised native tree, shrub and grass seed mix.

Vegetation establishment on steeper slopes

The current rehabilitation method includes deep ripping, with the use of a winged tyne and direct seeding. For steeper slopes, (>16%) there is an increased risk of erosion. To reduce this risk, rehabilitation is focused on establishing a high ground cover to reduce rainfall impact on soils and on establishing deeper roots to stabilise slopes. To improve native tree and shrub establishment on steeper slopes all areas of rehabilitation that have been adequately topsoiled are seeded with the revised native species mix (outlined above).

In areas of rehabilitation lacking suitable topsoil, consideration will be given to hydro mulching slopes >16% to improve vegetation establishment to achieve >50% cover with revised species mix in less than one year to reduce the risk of erosion.

When preparing the soils for direct seeding, consideration will be given to the constraints associated with the material below the depth of ripping (i.e. poor structure from sodicity or subsoil salinity). The addition of soil ameliorants such as lime or gypsum or alternatively a calcium based soil conditioner in combination with recalcitrant carbon-based soil conditioner, a biologically active fertiliser blend including soil bacteria and mycorrhizal fungi developed for rehabilitation, and a soil binder product may be required to stabilise the soil prior to direct seeding and ripping.

8 Monitoring and Maintenance

8.1 Monitoring Program

The overall aim of the rehabilitation monitoring program is to provide Curragh Project with accurate information about the performance and development of its rehabilitation over time. Within this broad aim there are number of specific objectives:

- To measure the density, richness and condition of canopy, shrub (overstorey) and shrub (understory) woody species established on rehabilitated land using plot-based methods, and to benchmark the results against completion criteria;
- To measure species richness in the rehabilitation and compare against completion criteria.
- To accurately assess vegetation success against completion criteria;
- Assessment of slope stability, erosion ‘hotspots’ or slumping across the site using LiDAR (or similar); and
- To determine if any relationships exist between biophysical parameters, such as substrate quality, soil moisture and rainfall patterns at the time of sowing, and rehabilitation success.

Table 8-1 Rehabilitation Monitoring Program

Monitoring Activity	Year 1-3	Year 5	Year 7	>Year 10	Milestone Criteria
Inspections of Highwalls	Annual	Once	Once	Every five years until certification	• Static Factor of Safety >1.5 and Dynamic Factor of Safety >1.1. • Installation of fencing and signage as required. • Highwall slopes maximum of 65°. • Bund highwall area.
Event Inspection	Wet season	As required	As required	As required	• No maintenance actions required.
Erosion monitoring	Annual	Once	Once	Every five years until certification	• Absence of rill/gully erosion >0.3 m.
Surface water quality monitoring	Annual	Once	Once	Every five years until certification	• Surface water quality meets the water quality characteristics outlined in the EA.
Groundwater monitoring	Annual	Once	Once	Every five years until certification	• Groundwater quality meets the limits outlined in the EA.
Soil quality monitoring	Annual	Once	Once	Every five years until certification	• Soil salinity content is <800 dS/m, pH is between 5.5-9 and exchangeable sodium percentage is <15%.
Topsoil depth	After topsoil spreading				• Topsoil spread to >200 mm. • Topsoil strips spread to >200 mm over approximately 65% of overburden dump area.
Ecological monitoring /LFA	Annual	Once	Once	Every five years until certification	• Presence of at least 1 Eucalyptus species and at least 2 Acacia species. • Mean vegetative groundcover is >50%.

Monitoring Activity	Year 1-3	Year 5	Year 7	>Year 10	Milestone Criteria
					• 60% of native species present in the reference sites are present in rehabilitation • >100 stems/ha of native tree and shrub species
Diversion monitoring	After 2018, every two years until relinquishment.				• Blackwater Creek Diversion criteria

8.1.1 Inspection and certification of highwalls

To ensure the structural stability and integrity of the void highwalls sign off from an appropriately qualified person should be undertaken post any reshaping. Annual inspections should then occur to report on evidence of:

- Cracking or slumping;
- Erosion;
- Water runoff; and
- Void creep.

8.1.2 Surface Water Monitoring

Surface water monitoring will take place in accordance with methodology to be outlined in the Receiving Environment Monitoring Program (REMP). The REMP will outline the surface water quality monitoring to be undertaken at locations across the Curragh site. To ensure that milestone criteria are met, surface water monitoring will take place throughout the wet season, annually. However, the climate of the region is generally dry, resulting in periods when surface water is not present, and monitoring is not possible.

8.1.3 Groundwater Monitoring

Groundwater quality and water levels will be monitored in accordance with the locations and frequencies outlined in the EA. Table C12 of Schedule C outlines the groundwater monitoring locations and frequencies and appendix 5 outlines the groundwater monitoring locations for quality characteristics identified in **Table C13 – groundwater contaminant trigger levels**. The EA states the groundwater quality limits and that groundwater is to be measured at least every 6 months.

8.1.4 Revegetation Monitoring

A modified transect-based approach is used at Curragh to provide continuity with previous monitoring of rehabilitation on site and to inform remotely sensed imagery interpretation. The assessment focuses on collecting data suitable for comparison against the rehabilitation success criteria.

Sites less than one year old

For sites less than one year old the following are recorded:

- plant species richness – native, pasture species and weeds;
- percentage cover; and
- rill and gully erosion.

A walk through of the site is undertaken to record all native and weed species observed across representative area of the site, ensuring variation across the site is assessed, e.g. areas of woodland species, pasture grasses, weedy areas and any area where there are obvious differences in vegetation cover. Following this, a representative location towards the centre of the site is chosen and a 1m x 1m quadrat is randomly placed in the four compass directions (north, east, south and west).

The species assemblage (including declared weeds) and the following groundcover percentages within the quadrats are recorded. Rill and gully formation are also noted and where significant gullies are forming a GPS waypoint is recorded so that gully stability can be assessed over time.

This assessment is undertaken for each site with a minimum of four quadrat samples per 10 hectares provided the site is relatively homogeneous. If there is substantial variation in vegetation cover across a site, the site will be stratified so that an additional four quadrats will be sampled for each strata, e.g. high cover areas, low cover areas, weed dominated areas.

For each quadrat the following are recorded:

- Native grasses;
- Non-native grasses;
- Native forbs and others;
- Woody species (saplings);
- Non-native forbs and others; and
- Bare ground/rock.

Sites greater than one year old

At each new site, three transects of 50m x 14m running downslope will be established and permanently marked for future re-assessment. At each (new and established) transect assessments are undertaken in 50m x 14m, 50m x 8m, 50m x 4m and in 1m x 1m quadrats (listed in Table 9), with the following parameters assessed:

- Species richness – total number of different species in each life form layer as described in the BioCondition Methodology (Eyre et al., 2015);
- Coarse woody debris – total length in metres of all woody debris over 0.5m length and 0.1m diameter; and
- Tree species recruitment – regeneration of canopy and sub-canopy species.

Table 8-2 Data Attributes Collected in Different Quadrants

50m x 4m quadrats	1m x 1m quadrats
Canopy cover, sub-canopy cover and shrub layer cover using the line intercept method along the transect centre line. Cover is recoded for each layer where it intercepts the tape measure laid out along the centre line	Native perennial grass cover, native other grass, native forbs and other species (non-grass), native shrubs
stem counts identified into groupings – Eucalypt/Corymbia, Acacia, Other (tree), Shrub based on final life form, i.e. a young Eucalypt in the shrub layer is still recorded as a tree	
estimate of the mean height of the sub-canopy and shrub layer based on field measurements	
number of large trees. A large tree will be determined based on comparison with the relevant reference sites and measured against a DBH threshold	

8.1.5 Soil Sampling

Soil sampling (0-10 cm) at both ends of the transect on newly revegetated sites (or problem sites) across topsoil / spoil media for analysis of EC, pH and nutrient characteristics.

8.1.6 Erosion Monitoring

Erosion data will be collected from a 50 m cross-section along the centre of each LFA transect. Data collected will include:

- Type of erosion;
- Length and width of each site of erosion;
- Erosion depth and
- Stability of erosion.

This information will be used to estimate the scale and current activity of erosion at each monitoring site. The information will be reported in the Rehabilitation Monitoring Report with the LFA status of each monitoring site. Where erosion gullies are greater than 400 mm deep and active rill erosion less than 300 mm deep, action to mitigate erosion including:

- The repair of any contour drains;
- The addition of minor contour drains to disburse and distribute water;
- The installation of sediment fencing and
- The re-establishment of vegetation where required.

8.1.7 Blackwater Creek Diversion

The Blackwater Creek Diversion will be monitored and maintained in accordance with the EMS Plan 1.4 Blackwater Creek Diversion Monitoring and Maintenance Plan (**Appendix C**).

8.2 Maintenance Plan

A range of maintenance and management activities may be required in rehabilitated areas to facilitate achievement of defined success criteria. Rehabilitation areas should be monitored at an early stage and results compared to success criteria. Areas that do not meet the defined success criteria should have maintenance or management activities completed to facilitate achievement of the success criteria. These activities are outlined below (**Table 8-3**).

Table 8-3 Maintenance and Management Program

Aspect	Management Action	Maintenance Action
Vegetation	• Identify vegetation cover and compare with success criteria or natural bare areas. • Fence off areas to control grazing.	• Apply follow-up fertiliser where specified or based on soil analysis. • Re-seed areas by hand if soil quality is addressed. • Re-seed with selected species if diversity is not acceptable.

Aspect	Management Action	Maintenance Action
	• Utilise (grazing) areas to prevent overgrazing, i.e., correct stocking ration / rotational system depending on maturity of system. • Check for dormancy. • Vegetation assessment to determine if success criteria (cover, diversity, vitality, etc.) are met.	• Stimulate growth with controlled grazing. • Increase roughness of surface or mulch layer to trap seeds. • All vegetation established including tree species was effective with seeding and re-planting of trees are not needed.
Erosion	• Monitor extent and severity of erosion and determine causes – do not repair erosion if activity will cause excessive additional disturbance – allow another season to monitor the progression or stabilisation of small-scale erosion. • Identify footpath creation during utilisation of area. • Identify unwanted concentration of runoff over large areas.	• Small rill erosion – selected branch or rock packing. • Gullies – backfill where needed by borrowing from surrounds or use small earthworks equipment (e.g., TLB); use coarse material for backfilling. • Large gullies – import material to backfill from stockpiles or borrow pits or construct structures (e.g., silt fences, etc.). • Reinstate / upgrade water control structures. • Spread runoff where concentration occurs. • Improve vegetation cover.
Sediment Control	• Monitor and inspect sediment control structures that were constructed. • Evaluate the need for de-silting in view of stabilisation of rehabilitated areas and buffer capacity of sediment control structures. • Inspect sediment control structures especially after intense rain events and increased erosion.	• De-silt sediment control structures where capacity has been compromised – place silt on areas that is not subject to erosion, ameliorate and vegetate. • Construct new sediment control structures where needed. • Re-route runoff based on evaluation of drainage pattern after rehabilitation. • Repair upstream erosion. • Improve vegetation cover.
Water Control Structures (e.g., berms, graded banks)	• Identify reduced capacity due to sedimentation. • Check for vertical alignment, i.e., uneven settlement or consolidation causing low areas. • Check for long-term stability, e.g., scouring.	• Remove sediment from sediment traps. • Repair damages to berms or channels.

Aspect	Management Action	Maintenance Action
	• Check condition of low-lying areas that were constructed on the top of dumps and other flat areas.	• Revisit Surface Water Management Plan after evaluation of drainage pattern after rehabilitation and construct additional structures where needed or remove is no longer required/functional.
Weed Management	• Continue with weed control programme.	• Annual weed inspections and mapping. • Weed control with selected herbicides appropriate to area concerned (e.g., rehabilitated areas vs. firebreaks). • Bush encroachment control follow up on previously cleared areas. • Thin out undesirable species where it may impact/affect grass cover. • Mowing/slashing periodically as removing biomass repeatedly causes reduced vigour in many weed species. Use in combination with herbicides. • Weed removal using a weed wrench or root talon.
Feral Animal Management	• Identify feral animals that can affect rehabilitated areas.	• Implement feral animal control plan. • Liaise with neighbouring stakeholders, where needed, to address the cause of the problem.
Fire Management	• Maintain firebreaks.	• Maintaining firebreaks on boundaries. • Vegetation control along firebreaks. • Clear firebreaks mechanically where needed.
Land Stability	• Monitor land stability.	• Erosion and sediment control structures are appropriately maintained.

9 PRCP Schedule

The PRCP Schedule has been provided as a pdf and excel format as per the DES template (**Appendix P**).

9.1 Final Landform Design

The final site design is shown in Error! Reference source not found. and delineates the following:

- The maximum disturbance footprint;
- Mining lease boundaries;
- The PMLUs and NUMAs for the area; and
- 0.1% AEP flood extent.

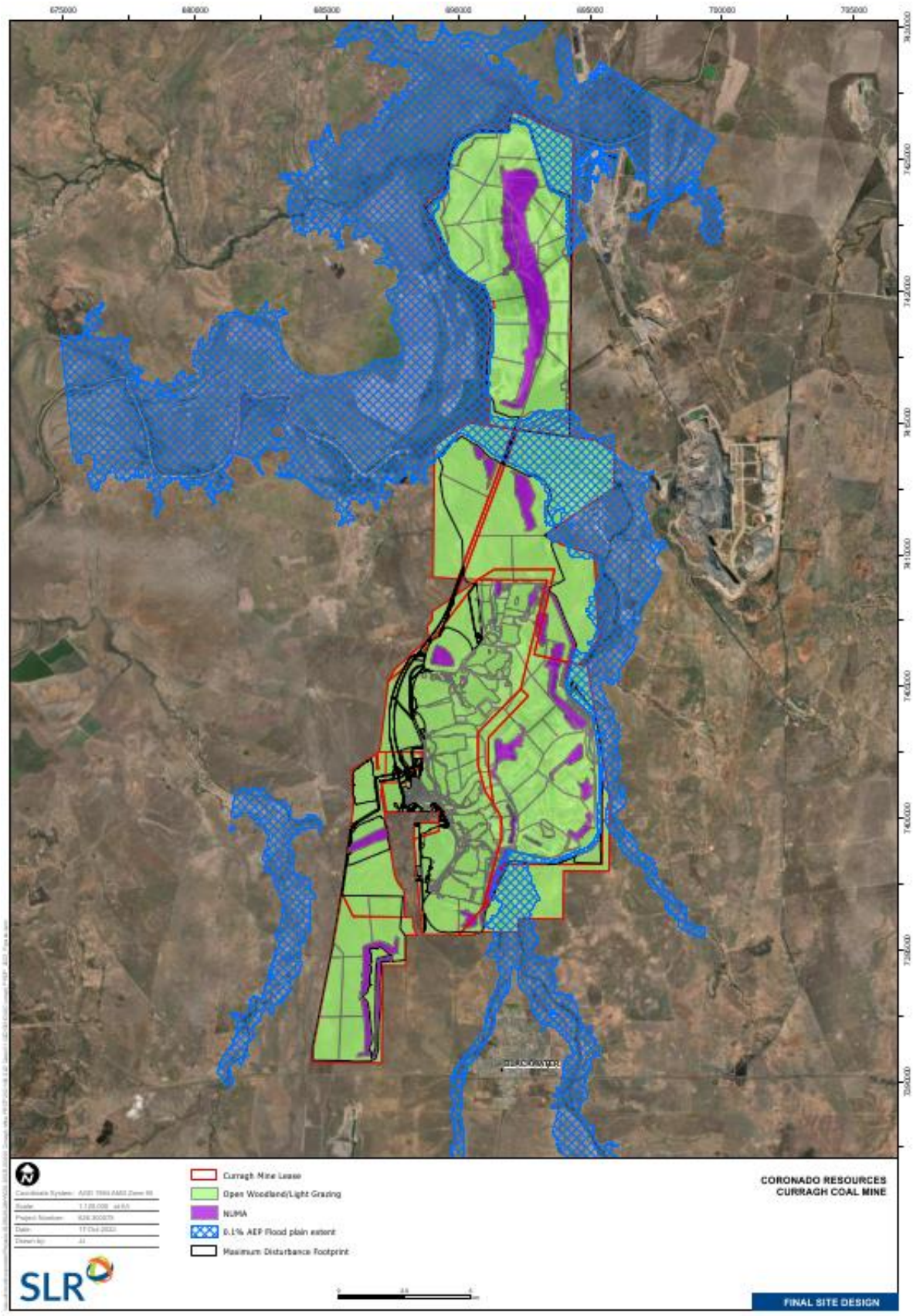


Figure 9-1 Curragh Project - Final Site Design

9.2 Rehabilitation/Improvement Areas

A Rehabilitation Area (RA) is defined in the EP Regulation as an area of land in the post-mining land use to which a rehabilitation milestone for the post-mining land use relates. The Curragh Project only has one PMLU of Light Grazing and Open Woodland. The residual voids are proposed as NUMAs. The applicable rehabilitation methodology/milestones have been used to identify different rehabilitation areas.

The proposed rehabilitation areas are detailed in **Table 9-1** and shown in **Figure 9-2, Figure 9-3, Figure 9-4** and **Figure 9-5**.

Table 9-1 Proposed Rehabilitation and Improvement Areas

Rehabilitation Area / Improvement Area	Description	Total Size (ha)	Post-mining Land Use
RA1	Overburden Dumps, Ramps, In Pit Tailings	11,253	Light Grazing and Open Woodland
RA2	Infrastructure activities requiring a land contamination study	128	Light Grazing and Open Woodland
RA3	Miscellaneous Activities	542	Light Grazing and Open Woodland
RA4	Blackwater Creek Watercourse Diversion	185	Light Grazing and Open Woodland
RA5	Water Infrastructure	65	Light Grazing and Open Woodland
RA6	Out-of-pit Tailings Storage Facility	185	Light Grazing and Open Woodland
RA7	Stable Embankments	331	Open Woodland and Fauna Habitat
IA1	Residual Voids	1,499	NUMAs

The approximate total rehabilitation area for Curragh Project is 14,188 ha.

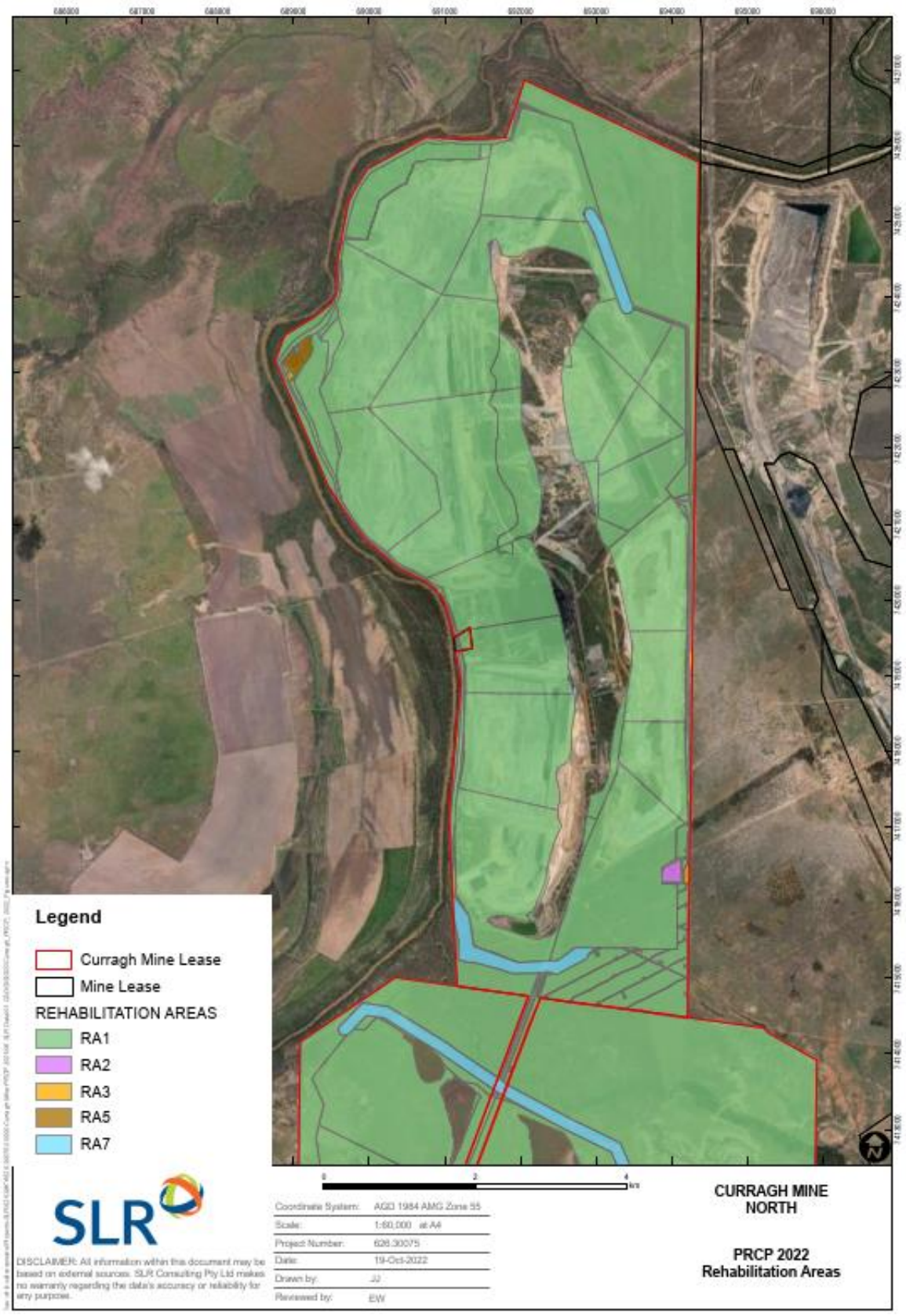


Figure 9-2 Curragh North Rehabilitation Areas



Figure 9-3 Curragh North Improvement Areas

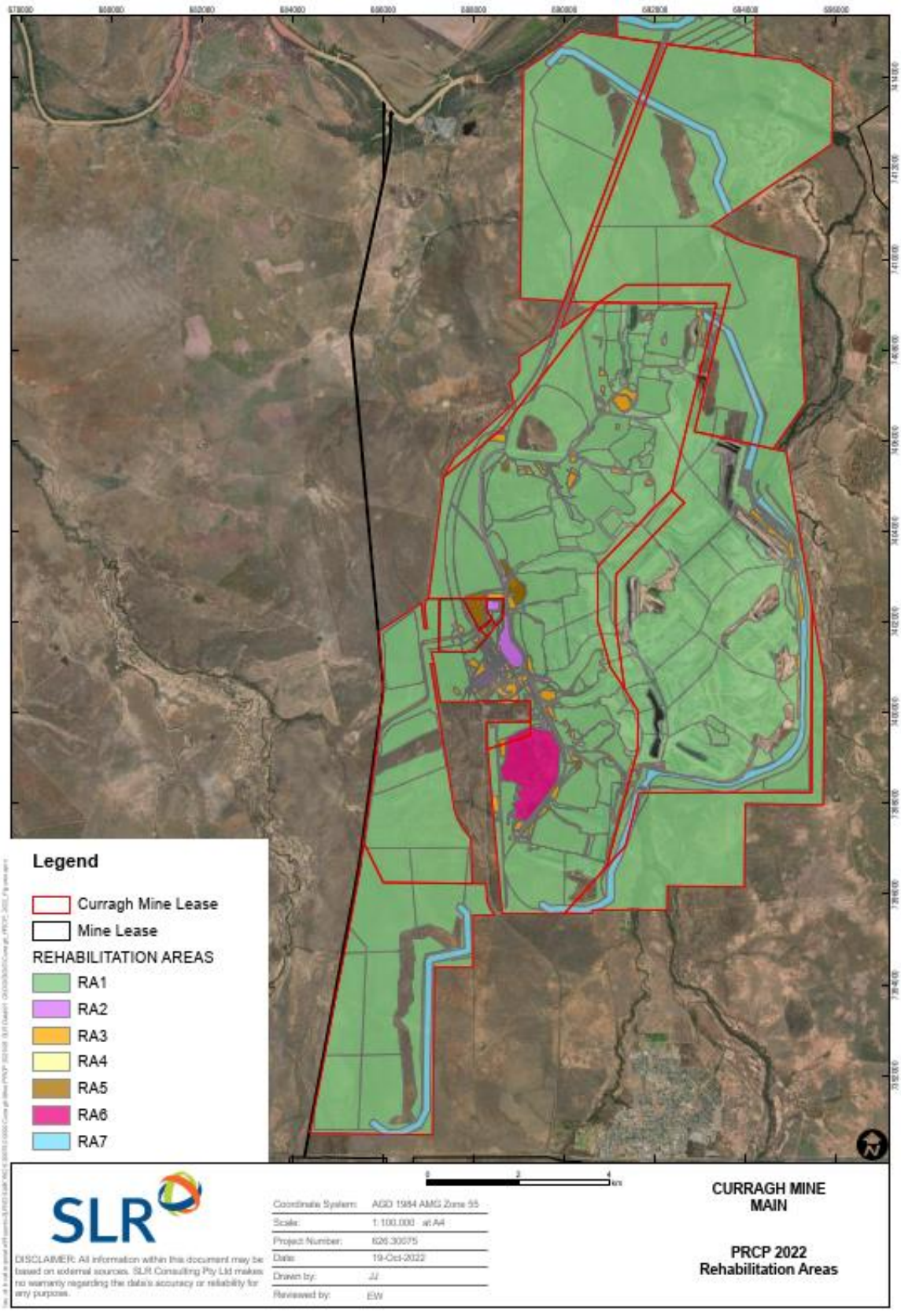


Figure 9-4 Curragh Main Rehabilitation Areas

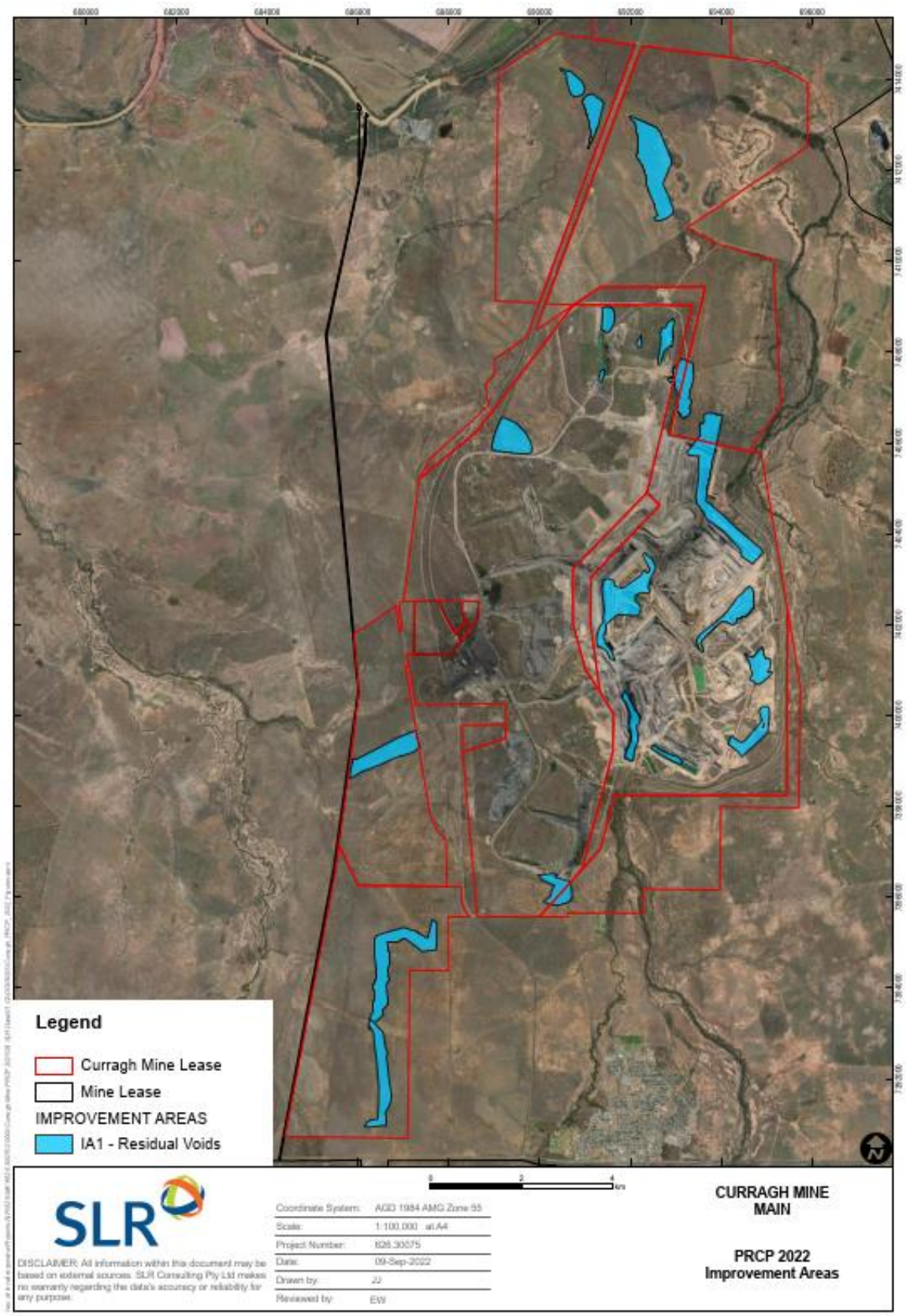


Figure 9-5 Curragh Main Improvement Areas

9.3 Available for Rehabilitation

Available for rehabilitation is defined in section 126D of the EP Act as land that is no longer being mined, unless:

a) The land is being used for operating infrastructure or machinery for mining, including, for example, a dam or water storage facility;

b) The land is identified in the proposed PRCP schedule as containing a resource to be mined within 10 years after the land would otherwise have become available for rehabilitation;

c) The land is required for the mining of a probable or proved ore reserve mentioned in paragraph (b); or

d) The land contains permanent infrastructure identified in the proposed PRCP schedule as remaining on the land for a PMLU.

Rehabilitation areas at Curragh Project will progressively become available throughout the life of the mine and once mining on site has ceased. CCPL has developed a rehabilitation schedule for the overburden dumps and voids in accordance with the current mine plan and availability of resources. This schedule has been used to develop the timeframes in the PRCP Schedule.

Other rehabilitation areas will commence rehabilitation after mining has ceased. The Out-of-pit TSF is proposed to be rehabilitated in 2044. While the TSF is technically available for rehabilitation now, there are potential plans to reprocess the tailings and therefore reduce the disturbance associated with the area. Hence, the rehabilitation of this area will be delayed allowing these plans to be finalised and actioned.

Infrastructure areas will be rehabilitated in 2049 as infrastructure will be required for the rehabilitation of overburden dumps and voids. Once these areas have completed active rehabilitation activities (reshaping, topsoil, ripping and seeding) all other areas will commence rehabilitation.

9.4 Milestones and Milestone Criteria

Rehabilitation milestones and the associated criteria have been developed using the information presented in this PRCP. These milestones have been reflected in the proposed PRCP schedule and are shown in **Table 9-2**.

Table 9-2 Proposed Milestones and Milestone Criteria

Milestone reference	Rehabilitation milestone	Milestone criteria	Justification
RM1	Infrastructure Decommissioning and Removal	1. All infrastructure has been decommissioned and removed from site. 2. All roads, where not being retained, have been removed. 3. Any infrastructure retained has a written agreement from the post mining landholder or owner. 4. All demolition and hazardous waste have been treated and disposed of. 5. All services have been disconnected and terminated. 6. Machinery and equipment not required for rehabilitation have been removed.	The criteria proposed for this milestone is consistent with the steps undertaken as part of the infrastructure decommissioning process. While CCPL does not currently have any landholder agreements, it has been raised by landholders as an area of further interest and therefore the possibility of these agreements has been allowed for in the criteria.

Milestone reference	Rehabilitation milestone	Milestone criteria	Justification
RM2	Landform Development and reshaping/reprofiling	1. All major earthworks completed. 2. Maximum slope of 16%. 3. Installation of erosion and sediment control systems to design and certified by an appropriately qualified person. 4. In pit tailings will be covered with at least 1 m of inert rock cover.	The maximum slope of 16% has been transitioned from the RMMP. It is noted that majority of the area will be under 14% but there is approval for 16% given the material and surface conditions support this slope without erosion occurring.
RM3	Surface Preparation	1. Topsoil strips spread to >200 mm over approximately 65% of overburden dump area. 2. Topsoil applied to >200 mm will be applied to all other areas including in pit tailings. 3. Ripping to a depth of 600-750 mm has been completed. 4. Amelioration products have been applied where appropriate and required.	Topsoil will be applied in strips to 65% of the overburden dumps as per the rehabilitation methodology. All other areas will be 100% of the area topsoiled. Amelioration will only be applied if required. Soil testing will occur before topsoil is applied.
RM4	Revegetation	1. Completed seeding at same time as ripping. 2. Application of fertiliser where required.	The criteria for revegetation don't include seed mix specifications due to the fact that seed mixes can vary due to availability and seasonality.
RM5	Achievement of Surface Requirements	1. Mean vegetative groundcover is ≥30%. 2. Native tree and shrub abundance >100 stems/ha	This milestone is used as a check in point between seeding and reaching stable condition. Therefore, the criteria has been developed with the purpose of showing progress towards final completion.
RM6	Achievement of Open Woodland and Light Grazing	1. Presence of at least 1 Eucalyptus species and at least 2 Acacia species. 2. Mean vegetative groundcover is ≥50%. 3. 60% of native species present in the reference sites are present in rehabilitation. 4. Presence of native grass and pasture species. 5. Fauna presence and habitat evident. 6. Soil salinity content is <800 dS/m, pH is between 5.5-9 and exchangeable sodium percentage is <15%. 7. Factor of Safety ≥1.2. 8. ≤16 % slope. 9. Absence of rill/gully erosion >0.3 m. 10. Groundwater quality in accordance with EA limits. 11. Surface water quality in accordance with EA limits. 12. Water storages meet the water quality requirements for stock watering under the ANZEEC Guidelines.	Majority of this criteria has been transitioned from the RMMP. There isn't any specific grazing criteria based on advice from underlying landholder that head of cattle or weight gains isn't useful for how the land will be managed. The mean vegetative cover has come from the recommendations of the Erosion Assessment. The factor of safety has been transitioned from the Geotechnical Study. The maximum slope criterion has been transitioned from the RMMP. Groundwater and surface water quality will be required to continue compliance with the EA conditions as this is demonstrated to not cause environmental harm. The last criterion has been added for retained water storages providing available water sources for stock.

Milestone reference	Rehabilitation milestone	Milestone criteria	Justification
RM7	Remediation of Contaminated Land	1. Completion of a contaminated land investigation. 2. Certification that all measures required by the preliminary land investigation have been implemented.	A contaminated land investigation will be required for certain land. The remediation actions can't be predicted and therefore the criteria relates to getting certification at the time of remediation occurring.
RM8	Maintenance of Diversion	1. Meets design criteria. 2. Absence of active rill/gully erosion.	This milestone refers to the ongoing maintenance of the diversion until surrender.
RM9	Achievement of Open Woodland and Light Grazing (Watercourse)	1. Groundcover is ≥75%. 2. Weed coverage is <5%. 3. Groundcover diversity is ≥ 6 species.	This criterion is transitioned from the Blackwater Diversion Monitoring Plan.
RM10	Rehabilitation of Dams	1. Dam walls battered in for all dams to be decommissioned. 2. Sediment removed from all raw water dams to be retained.	This criterion is specific to the rehabilitation methodology required.
RM11	Installation of cover system / cap	1. Cover system constructed to Detailed Design specifications. 2. Certification from RPEQ that the cover system has been constructed to design.	The Old TSF will have a cover design installed to design criteria with an RPEQ signoff as per best practice.
RM12	Stable Embankment Development	1. Stable embankment is built to a height suitable to keep 0.1% AEP flood event from infiltrating residual voids. 2. The watercourse side slope is built to a maximum of 19° and is applied with rock mulch.	These criterion reflect the objective of the stable embankment and the design criteria.
MM1	Landform Development and reshaping/reprofiling	1. Highwall slopes maximum of 65°.	The maximum highwall slope as per the Geotechnical Study is 65°. The highwalls will be constructed to the suitable slope based on geology type.
MM2	Achievement of sufficient improvement	1. Static Factor of Safety ≥1.5 and Dynamic Factor of Safety ≥1.1. 2. The final landform does not form rill erosion >30 cm. 3. Groundwater meets the requirements in the EA. 4. Bund highwall area.	This criterion has been transitioned from the CRVA.

9.5 Timeframes

To determine the completion dates for the milestones in the PRCP schedule, some general guidance regarding the timing of milestones to complete have been developed (Table 9-3). These rules have been adapted in the PRCP schedule with consideration to overall delivery.

Table 9-3 Milestone completion dates

Milestone Reference	Rehabilitation Milestone	Approximate timeframe for completion	Comments
RM1	Infrastructure decommissioning and Removal	2 Years	The removal and decommissioning of all infrastructure and services are included in this timeframe. Landholder consultation will take place to ensure that any Infrastructure to be retained is identified. This time allows for interruptions due to weather and limited workforce.
RM2	Landform development and reshaping/reprofiling	1 -5 Years	Earthworks associated with overburden dumps will occur in accordance with the rehabilitation schedule developed by CCPL which considers mine plan and available resources (e.g. equipment). Other areas which are smaller and simpler in size will be completed quicker.
RM3	Surface Preparation	2 Years	This timeframe allows for the spreading of topsoil, ripping and amelioration (if required) prior to seeding. Some time as a contingency has been allowed for testing of soil and to coordinate with seeding.
RM4	Revegetation	2 Years	Seeding will take place directly after topsoil application. This timeframe ensures that seeding takes place during the correct time of year and accounts for re-seeding, if required.
RM5	Achievement of Surface Requirements	3 Years	This timeframe has been allocated to ensure the correct monitoring and maintenance can be undertaken.
RM6	Achievement of Stable Condition (Light Grazing and Open Woodland)	3-5 Years	To ensure successful rehabilitation has been established, a monitoring program of 5 years (additional to any other monitoring and maintenance) has been suggested.
RM7	Remediation of Contaminated Land	2 Years	This timeframe allows for a suitably qualified person to visit site and conduct preliminary contaminated land investigations. This includes any sampling and analysis of material, as well as to action any required works.
RM8	Maintenance of Diversion	Life of project	The diversion has already been constructed to design and is
RM9	Achievement of Stable Condition (Diversion)	Completion at surrender	Final signoff.
RM10	Rehabilitation of Dams	1 Year	This timeframe accounts for any climatic delays in undertaking the work.
RM11	Installation of cover system / cap	2 Years	It will take approximately 2 years to complete the cover design with an additional year for RPEQ signoff.
MM1	Landform Development and reshaping/reprofiling	1-5 Years	Earthworks associated with pits will occur in accordance with the rehabilitation schedule developed by CCPL which considers mine plan and available resources (e.g. equipment).
MM2	Achievement of sufficient improvement	5 Years	To ensure successful improvement has been established, a monitoring program of 5 years (additional to any other monitoring and maintenance) has been suggested.

Please note that the above has been used only as general guidance for completing the PRCP schedule. The timing of when these milestones will be achieved must also be considered for rehabilitation to be completed effectively and efficiently. For example, seeding should take place at the end of the year before the wet season and ideally is done soon after the application of topsoil. Milestones should also be aligned to maximise efficiency, where possible.

10 References

Austral Asian Resource Consultants (1999*) MinServe Pisces Coal Project -*

Austral Asian Resource Consultants (2003) *Curragh North Project - Environmental Impact Statement*

Austral Asian Resource Consultants (1998), *Environmental Management Overview Strategy*

Australian Government, (2016), *Mine Rehabilitation – Leading Practice Sustainable Development Program for the Mining Industry.*

Bureau of Meteorology (BOM). (2021), *Map of Climate Zones Australia*. Retrieved August 20, 2021, from http://www.bom.gov.au/climate/how/newproducts/images/zones.shtml

CMLR, (2002-2016), *Curragh Coal Mine Rehabilitation Monitoring Reports 2002-2016. University of Queensland*.

CMLR, (2011*), Curragh Mine – Vegetation Monitoring Assessment – The Establishment and Monitoring of Native Analogue Sites. University of Queensland*

Coronado Curragh (2019), *Blackwater Creek Diversion Monitoring and Maintenance Plan*

Coronado Curragh (2021), *EM Plan 1.3 Rehabilitation Management and Monitoring Plan*

Coronado Global Resources (2019), *Statement of Coal Resources and Reserves for the Curragh Coal Mine – Bowen Basin – Queensland, Australia*

Curragh Mine (2002), *Environmental Management Overview Strategy PJ80028*

DRNME (2019), *Vegetation Management Supporting Map* (DRNME, 2019)

Environment Health and Safety Systems (1998).

Environmental Geochemistry International (1993), *Curragh Queensland Mining – Curragh East Development Area: Geochemistry of Overburden and Implications for its Disposal*

Golder Associates (2017), *Out Tailings Storage Facility Design Plan*

Golders Associates (2017) *B pit Tailings Storage Facility Design Plan*

HLA-Envirosciences (1998) *Soil Analysis: Net Acid Generation and pH Curragh Mine Queensland*

Isbell (1996) *Australian Soil Classification*

Land Reclamation Services (1990) *Curragh Mine Soil Survey*

Land Reclamation Services (1993) *Characterisation of Dragline Dumped Spoil – Curragh Mine*

Lanyonscapes (2019), *Blackwater Creek Diversion*, available at: Blackwater Creek Diversion | Lanyonscapes, accessed on: 31 August 2022

McCann, R (2019), *Topsoil Training, Assessment and Sampling Coronado Global Resources Inc. v2.*

Michael et al. (2008), *A forgotten habiat? Gransite inselbergs conserve reptile diversity in fragmented agricultural landscapes*, Journal of Applied Ecology, 45, 1742-1752

Michael et al. (2012), *Comparative use of active searches and artificial refuges to survey reptiles in temperate eucalypt woodlands*, Wildlife Research, 39, 149-162

Parsons Brinckerhoff, (2004), *Curragh North Coal Mine – Hydrology, Flooding and Groundwater Report*

Parsons Brinckerhoff (2015)*, Curragh Extension Supporting Info – 2172652G-ENV-REP-001 Rev C*

Parsons Brinckerhoff (2016) *Old Tailings Dam Rehabilitation – Geotechnical Investigation and Assessment for Capping.*

Parsons Brinckerhoff (2016), *Curragh Extension Project – Groundwater Technical Report (2172652H-WAT-REP-002 RevB)*

Queensland Government, 2022, WildNet Records – Species List, accessed 20 October 2022 from Environmental reports online | Environment, land and water | Queensland Government (www.qld.gov.au)

SLR (2021), *Concept Residual Voids Assessment*

SLR (2021a)*, Voids in Floodplain Modelling*

SLR (2021b), *Concept Residual Void Assessment - Groundwater Technical Appendix*

Stuart Miller and Associates (1984), *Curragh Queensland Mining Limited, Waste Management and Rehabilitation Studies Overburden Geochemical Investigations*

Wesfarmers Curragh Pty Ltd (2003), *Curragh North Project, Volume 4, Environmental Management Overview Strategy*

Wolfe et al. (2018), *Impacts of translocation on a large urban-adapted venomous snake*, Wildlife Research, 45, 316-324

WSP (2019) *Curragh North Dump Height Increase – Environmental Impact Assessment*

WSP (2019), *Progressive Rehabilitation Certification Report*

WSP (2020), *Groundwater Monitoring Program – WSP, 2020*

WSP (2021), *Curragh 2020 Rehabilitation Monitoring Report*

WSP (2022), *DRAFT Curragh 2021 Rehabilitation Monitoring Report*

APPENDIX A

Community Consultation Plan

COMMUNITY CONSULTATION PLAN

Curragh Project

Prepared for:

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BASIS OF REPORT

This report has been prepared by SLR Consulting Australia Pty Ltd (SLR) with all reasonable skill, care and diligence, and taking account of the timescale and resources allocated to it by agreement with Coronado Curragh Pty Ltd (the Client). Information reported herein is based on the interpretation of data collected, which has been accepted in good faith as being accurate and valid.

This report is for the exclusive use of the Client. No warranties or guarantees are expressed or should be inferred by any third parties. This report may not be relied upon by other parties without written consent from SLR.

SLR disclaims any responsibility to the Client and others in respect of any matters outside the agreed scope of the work.

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1 Introduction

Community and stakeholder consultation and engagement is an important aspect of mine closure planning. In order to gain community and stakeholder support and consider community feedback in closure planning, early and frequent engagement will be undertaken by Coronado Curragh Pty Ltd (CCPL).

The purpose of this Community Consultation Plan is to plan, outline and record CCPL's consultation undertaken with the community and stakeholders with regard to mine closure at Curragh. This Plan will be submitted with the Progressive Rehabilitation and Closure Plan (PRCP) and meets the requirements of section 126C(1)(c)(iii) and (iv) in the *Environmental Protection Act 1994* (EP Act).

This plan includes the following:

- Objectives of consultation;
- Identification of community and stakeholders;
- Consultation methodologies;
- A future consultation plan including what information will be provided and how frequently; and
- A Consultation Register.

1.1 Relevant Regulations

There are multiple regulations and requirements that relate to the potential impact of mining on the surrounding community. The key legislation includes:

- Queensland Environmental Protection Act 1994;
- Commonwealth Environmental Protection and Biodiversity Act 1999;
- Queensland Coal Mining Safety and Health Act 1999 and the Coal Mining Safety and Health Regulation 2017;
- Commonwealth Fair Work Act 2009;
- Queensland Water Act 2000;
- Queensland Vegetation Management Act 1999;
- Queensland Nature Conservation Act 1992;
- Commonwealth Native Title Act;
- Queensland Heritage Act 1992;
- Queensland Aboriginal Cultural Heritage Act 2003 and Torres Strait Islander Cultural Heritage Act 2003; and
- Queensland Regional Planning Interests Act 2014.

2 Consultation Objectives

The objectives of this Plan and are to:

- Improve CCPL's understanding of the socio-economic impacts regarding closure and rehabilitation through engagement with the community and other stakeholders;
- Collaborate with the community to unlock ongoing value regarding mine closure opportunities and constraints through meaningful discussions on final landform, land use and infrastructure outcomes;
- Understand community issues for consideration in closure planning;
- Provide potential solutions to key closure and rehabilitation risks, perceptions and opportunities that exist in the local community;
- Share awareness of the Curragh Project and the proposed closure outcomes with the community;
- Assist and prepare the community for mine closure;
- Transition employees and contractors post mine closure;
- Manage stakeholder expectations;
- Provide a flatform for comments and feedback from the community and other stakeholders; and
- Develop a plan for how future engagement should be undertaken.

3 Community Profile

3.1 Location

The Curragh Project is located within the Central Highlands Regional Council, approximately 6 km north of the town of Blackwater and approximately 200 km west of Rockhampton (**Figure 1**). The total mining lease area is approximately 19,650 ha.

PRCP consultation will focus on the social risks and impacts that are likely to be experienced by the communities surrounding Curragh Project and will consider both positive and negative as well as direct, indirect and cumulative risks and impacts. Therefore, the area of influence includes, but is not limited to:

- Blackwater;
- Middlemount;
- Emerald;
- Rockhampton;
- Gladstone;
- Mackay; and
- Brisbane.

Given that Blackwater is the closest town and where residential and temporary (drive in and drive out (DIDO), fly in fly out (FIFO)) accommodation is located, Blackwater will be town most directly affected by the closure of the Curragh Project.

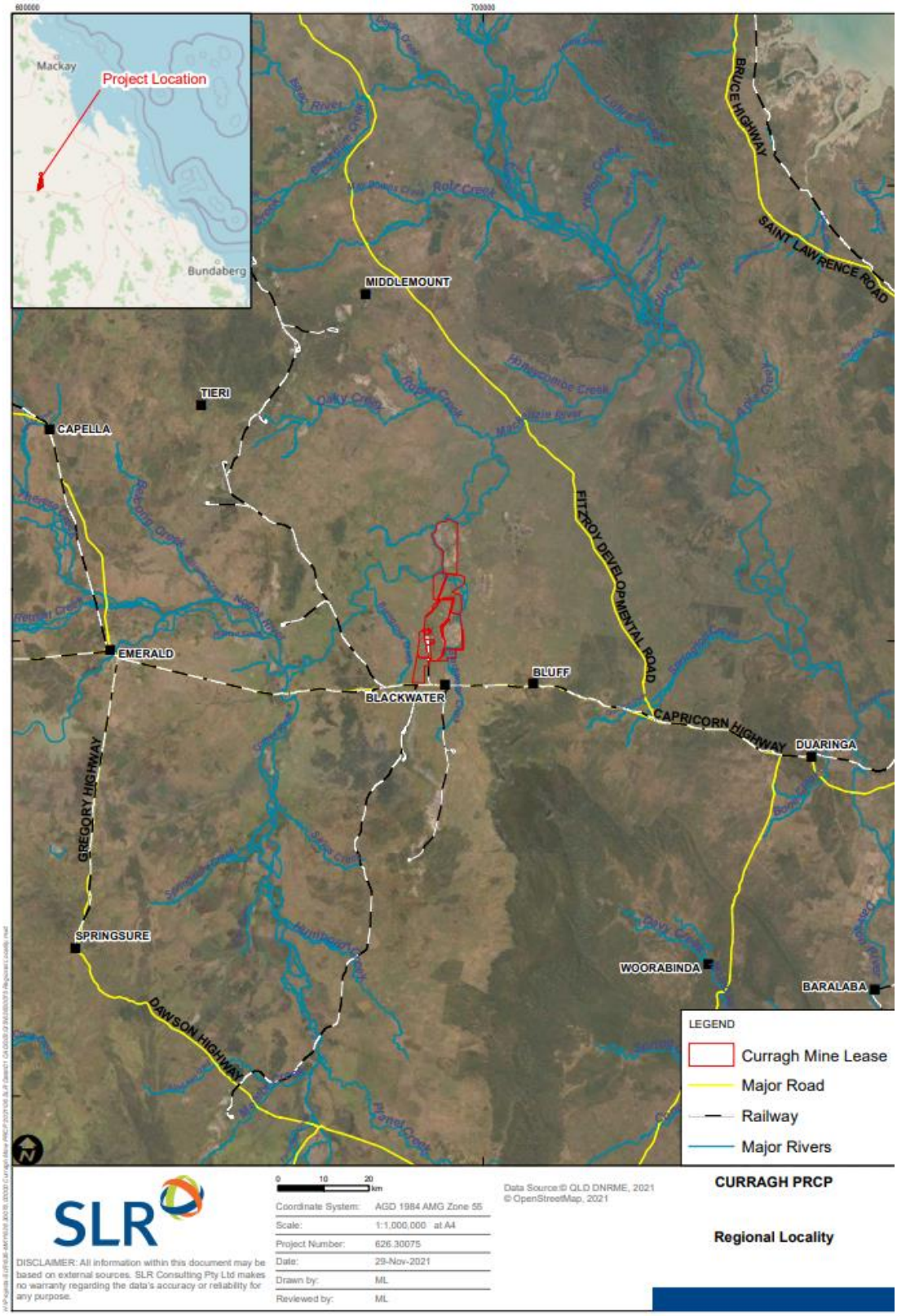


Figure 1 Curragh Mine Regional Locality

3.2 Blackwater Community

In the 2016 Census, there were 4,749 people in Blackwater with 54.9% male and 45.1% female (ABS, 2017). Aboriginal and/or Torres Strait Islander people made up 7.5% of the population. Of the employed people in Blackwater, 47.2% worked in Coal Mining.

The Blackwater settlement began with the 1877 extension of the Great Western railway line from Rockhampton and the town was gazetted in 1886 (Centre for the Government of Queensland, 2018). In the 1920s the population was approximately 80; however, coal mining sparked growth in the town.

In 1967 the first of several open-cut coal mines began production south of Blackwater, followed by the Cook Colliery in 1970 (Centre for the Government of Queensland, 2018). Gregory and Oaky Creek mines north of Blackwater began in 1979, and the Curragh Project opened in 1983. Branch railway lines serve the mines, transporting coal to Hay Point (near Mackay) or to Gladstone.

The International Coal Centre and Australian Coal Mining Museum is located at Blackwater. Besides the mining industry, Blackwater has one of the finest Japanese Gardens in the state and is located within 55 km of the Blackdown Tableland National Park (Tourism & Events Queensland, 2022).

4 Key Community and Stakeholders

The Department of Environment and Science (DES) have released an information sheet *Community consultation for Progressive Rehabilitation and Closure Plans* (ESR/2019/5101) which provides guidance on the community consultation requirements for the PRCP and the definition of 'community'. The information sheet states that members of the community must have a genuine interest in the underlying, adjacent or surrounding land where the mine is located. The information sheet provides the following examples of genuine interest:

- Direct impact interest (e.g. underlying and adjacent landholders);
- Cultural interest (e.g. Indigenous communities, Traditional Owners including Native Title holders);
- Heritage interest (e.g. State or Local government or relevant community groups);
- Environmental interest (e.g. State or Local government or relevant community groups);
- Recreational interest (e.g. community groups);
- Land use interest (e.g. overlapping tenure holders, agricultural entities or Local government); or
- Health interest (e.g. State or Local government, community groups).

Based on the above definition of 'community' for the purpose of the PRCP, the stakeholders relevant to the Curragh Project have been identified. A summary of the stakeholder type, organisation name and key interests has been provided in Table 1.

SLR has also assessed at what level each stakeholder requires engagement. The Spectrum of Public Participation (IAP2, 2018) is a wide used tool used to assist with the selection of the level of participation for a consultation process. The spectrum is shown below (**Figure 2**) and includes five different levels of participation.

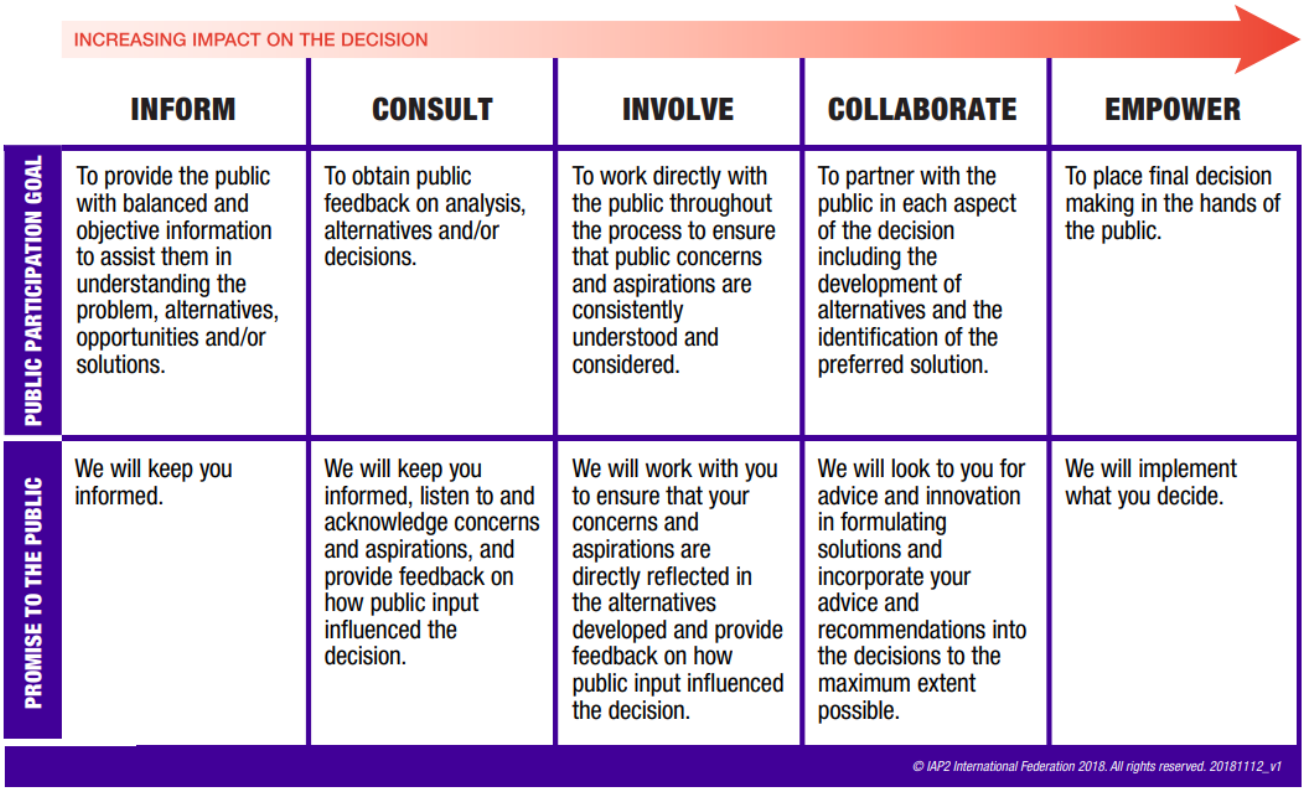


Figure 2 IAP2 Spectrum of Public Participation (Source https://iap2.org.au/wp-content/uploads/2020/01/2018_IAP2_Spectrum.pdf)

Table 1 Relevant Community and Stakeholders

Type of Stakeholder	Organisation Name	Key Interests	Level of Participation
Federal Government	Commonwealth Department of Climate Change, Energy, the Environment and Water	- Matters of National Environmental Significance - Post-mining land uses - Compliance with approvals - Impacts to local industry	Inform
State Government	Department of Environment and Science	- Environmental outcomes - Safe, stable, non-polluting landforms with an agreed post-mining land use	Inform, Consult and Involve
	Department of Resources	- Maximise utilisation of the resource - Compliance with Mining Lease conditions	Inform
	Department of Transport and Main Roads	- Impacts on rail and road network during and following closure	Inform
Local Government	Central Highlands Regional Council	- Impact on local and regional employment - Social impacts of population change - Future sustainability of Blackwater township and associated services - Effective transition of workforce and economy - Post-mining land uses - Consistency/impacts on local planning schemes	Inform
Private Landholders	A & N Goodwin	- Condition of post mining land use - Impact on water resources - Ongoing management requirements - Use of remaining/permanent infrastructure	Inform and Consult
	T & M Goodwin		
	A & J Acton		
	P Dunne		
	I & A Davidson		

Type of Stakeholder	Organisation Name	Key Interests	Level of Participation
	L & N Phillipson		
	J Atkinson		
	J & R Warren		
Community Groups and Non-Government Organisations	Fitzroy Basin Association Lock the Gate Alliance Environmental Defenders Office	- Impact on water resources - Net positive impact on water quality post closure - Environmental impact - Post-mining land uses	Inform
Local Indigenous Groups and Cultural Heritage Groups	Nghally Ghungalu Thoonieda Aboriginal Corporation	- Connection to country - Management of cultural heritage - Post mining land uses	Inform and Consult
	Ghungalou Aboriginal Corporation		
	Gaangalu Nation People		
Key Suppliers	Queensland Rail, Electricity, Port Operator and Local Suppliers	- Timeline for closure - Impact on their business - Ongoing workforce	Inform
Employees	Mine employees and nominated contractors	- Current and future employment (e.g. implementing closure) - Remaining mine life - Redundancy and benefits - Workforce transition - Housing - Future of community services	Inform, Consult and Involve

5 Past Stakeholder Consultation

5.1 Curragh North EIS (2001-2003)

During the Curragh North EIS process, which concluded in 2004, a Stakeholder Consultation Plan was developed. Consultation was initially undertaken by Stanmore and continued by Wesfarmers after the sale of the Project. The consultation involved engaging multiple stakeholders including:

- Surrounding Landholders;
- Government departments;
- Local Council;
- Traditional Owners; and
- General members of the community.

A Consultation Database was established to comprehensively detail consultation undertaken, issues raised, issue topics, responses to issues, and follow-up action to address the issue.

A copy of the Stakeholder Consultation Plan and Consultation Database is provided in **Appendix A**.

Community Consultation and Environmental Report

A community Consultation and Environmental Report was prepared and distributed in April 2001. The report was provided to the Queensland Environmental Protection Agency (QEPA) for review and comment as well as key stakeholders and advisory bodies including surrounding landholders and Duaringa Shire Council. The Report included a Response Form for feedback, for requesting regular updates on the Project and for requesting to be placed on an Employment and Business Register.

Only three completed Response Forms were sent back to AustralAsian Resource Consultants (AARC). Two forms were from businesses primarily requested to be placed on the Employment and Business Register, and one form was from a surrounding landholder. An issue raised by two of the three respondents was concern about the loss of potential economic benefits by accommodating staff at a mine village on site instead of at Blackwater.

Draft Terms of Reference

An amended Draft TOR was submitted to the QEPA in June 2001. The Draft TOR was distributed to advisory bodies and stakeholders. In July 2001 the QEPA prepared and published a Terms of Reference Notice for public notification of the Draft TOR, and Stanwell Corporation Limited (SCL) provided copies of the Terms of Reference Notice to all identified affected and interested persons. At the same time the Draft TOR was made available for viewing or downloading from the Project web-site, which was linked to the QEPA web-site, so that people could access the Project web-site from the QEPA web-site.

The Draft TOR exhibition period was from Monday 9 July to Monday 20 August 2001 and comments on the Draft TOR from advisory bodies, stakeholders and other interested persons were lodged with the QEPA. In total, 14 separate submissions were received from advisory bodies, stakeholders and affected persons, and 278 issues were entered on the Consultation Database from these submissions. After the close of the exhibition period the Draft TOR comments were provided to SCL by the QEPA. SCL and AARC prepared a written summary of the comments, responses to the comments, and amended the draft TOR as a result of the comments received.

Summary of Key Issues Raised

As of February 2002, issues had been raised on 98 different topics. The issues relating specifically to rehabilitation and closure included:

- Final/Post mining-land use (raised 21 times);
- Final/Post-mining landform (raised 14 times);
- Final voids (raised 6 times);
- Final rehabilitation strategy (raised 14 times);
- Final voids – water quality (raised once);
- Rehabilitation monitoring (raised three times);
- Post-mining agricultural productivity (raised once); and
- Maintenance and stability of post-mining landforms (raised three times).

Consultation with Traditional Owners

The below local indigenous groups were also consulted:

- Nghally Ghungalu Thoonieda Aboriginal Corporation for the Ghungalu traditional owners; and
- The Ghungalou Aboriginal Corporation as representatives of the Kangalou traditional owners.

Discussions have also been held with the Birri Gubba Guntha Bimbi Sacred Sites Aboriginal Corporation for the Kabalbarra traditional owners, who claim traditional ownership to the west side of the Mackenzie River which does not form part of the Project site.

6 Initial PRCP Consultation

6.1 DES Meeting

CCPL and SLR had a PRCP pre-lodgement meeting with the DES on 1 June 2021. The primary purpose of the meeting was to confirm what land outcomes are approved in Land Outcome Documents and to agree to a PRCP submission date. The outcomes of the meeting include:

- The Curragh Project has pre-approved residual voids as Non-Use Management Areas;
- CCPL will update the Residual Void study to provide clarification on previously identified voids and to include any voids within the new Mining Leases (MLs); and
- A proposed combined Post-Mining Land Use (PMLU) of light grazing and open woodland was agreed upon.

The other key outcome of the meeting was that the PRCP for the Curragh Project would be due to DES on 21st October 2022.

6.2 Traditional Owners

CCPL has a quarterly meeting with the local indigenous group, Gaangalu Nation People, to discuss a number of matters as they arise. At the meeting in May 2022, SLR provided a presentation on the PRCP process and how this relates to the Curragh Complex. The key discussion items included:

- Explanation of the PRCP process and purpose and presentation of a PowerPoint which includes a description of the consultation process;
- Where the rehabilitation seeds come from and potential for supply by local Indigenous supplier;
- An overview of the nature of PRCP being progressive and reiterative as the mine life continues;
- Possibility of CCPL looking to complete fauna surveys as evidence of return of totemic species and to further support the suitability of rehabilitation;
  - CCPL requested a list of target species that can be targeted in fauna surveys; and
- Potential for returning artefacts to the land, however, this will involve a conversation with the native title applicants and consideration of what the post-mining land use will be.

It is the intention that this forum will be used for future updates on the PRCP process.

6.3 Underlying Landholder

On 9th August 2022, CCPL and SLR had a one-on-one meeting with an underlying landholder (property manager of Mourallyn) at Curragh North. The purpose of the meeting was to discuss the PRCP framework and how it relates to the Curragh Complex. SLR provided a presentation on the PRCP process, the proposed post-mining land uses at Curragh and the community consultation process. Key discussion points from the meeting included:

- Conversation with the landholder about how a 'grazing' land use is assessed. The landholder's advice is that this should focus on management requirements and not specific parameters such as stocking rates given that these change with changing conditions (e.g. weather, condition of pasture, etc.);
- Some of the key queries regarding the closure of Curragh included:
  - Responsibility of final voids;
  - How the land will be managed for grazing;
  - Importance of an ongoing relationship between landholders and CCPL;
  - Erosion of the land;
  - Potential for the retainment of infrastructure including areas of bare land;
- The landholder was happy for consultation to occur as required and was interested in attending larger community events and site visits; and
- It was reiterated that the land should be rehabilitated with the final land user in mind and that there should be no surprises at the time of surrender.

Peter offered to provide some guidance on grazing management strategies that he would recommend for incorporation into the rehabilitation strategy.

7 Consultation Plan

It is well understood that consultation and engagement relating to rehabilitation and mine closure should be undertaken over the life of the project. It is best to communicate and manage mine closure expectations so that there are no surprises when it comes time to relinquish the site. Ongoing consultation can also be used to identify opportunities such as retaining infrastructure for future use, transitioning the workforce and organising rehabilitation trials.

The PRCP Guideline requires mines to plan for when and how consultation should occur in the future. Consultation should always be meaningful and not used to simply tick a box. Some situations where consultation is recommended to occur include:

- Significant mine planning changes that result in the delay of rehabilitation or relinquishment;
- Changes to approved post-mining land uses and non-use management areas;
- When new areas of disturbance are proposed;
- Significant changes to rehabilitation methodologies;
- Large legislative changes that may impact/influence rehabilitation and closure; and
- When there may be opportunities for collaboration on rehabilitation objectives.

7.1 Consultation Processes

CCPL will utilise existing consultation processes wherever suitable to discuss mine closure and rehabilitation matters. However, in some cases consultation outside of these existing processes may be required. **Table 2** outlines recommended consultation processes and frequency for each stakeholder in accordance with their level of participation as per **Table 1**.

7.1.1 Near Neighbours Meetings

CCPL hold a bi-annual near neighbours meeting for adjacent and underlying land holders. This meeting provides an opportunity for CCPL to provide an update on relevant projects and changes as well as an opportunity for near neighbours to raise any concerns or feedback. CCPL has already used this forum to introduce the concept of PRCPs and will continue to use it for updates on rehabilitation and closure where appropriate.

7.1.2 Coordinating Committee Meetings

Coordinating Committee Meetings are held generally every quarter between the Gaangalu Nation People and CCPL. These meetings are used to raise any issues or concerns from the Gaangalu Nation People as well as CCPL to provide an update on projects. CCPL has already used this forum to introduce the concept of PRCPs and will continue to use it for updates on rehabilitation and closure where appropriate.

7.1.3 Coronado Global Resources Website

The Coronado Global Resources website is another existing resource that may be used to publish information about the rehabilitation of the Project site. The website already contains general information about the Curragh Project, surrounding community and environmental performance.

Table 2 Consultation Plan

Type of Stakeholder	Organisation Name	Level of Participation	Consultation Methods	Frequency	Information to be Provided
Federal Government	Commonwealth Department of Climate Change, Energy, the Environment and Water	Inform	1. One-on-one meetings 2. Website 3. Information Sheets	1. As required 2. All year round 3. As required	• Any impacts to MNES • Project description • Life of mine schedule
State Government	Department of Environment and Science	Inform, Consult and Involve	1. One-on-one meetings (e.g. pre-lodgement meetings) 2. Website 3. Information Sheets 4. Site visits 5. Review of Draft documentation	1. As required 2. All year round 3. As required 4. As required 5. As required	• Draft amendment applications • Any impacts to MSES • Project description • Life of mine schedule • Existing rehabilitation tours • Rehabilitation success • Post-mining land uses
	Department of Resources	Inform	1. One-on-one meetings 2. Website 3. Information Sheets	1. As required 2. All year round 3. As required	• Project description • Life of mine schedule • ML details

Type of Stakeholder	Organisation Name	Level of Participation	Consultation Methods	Frequency	Information to be Provided
	Department of Transport and Main Roads	Inform	1. One-on-one meetings 2. Website 3. Information Sheets	1. As required 2. All year round 3. As required	• Project description • Life of mine schedule • Impacts to roads
Local Government	Central Highlands Regional Council	Inform	1. One-on-one meetings 2. Website 3. Information Sheets 4. Community Events	1. As required 2. All year round 3. As required 4. As required	• Project description • Life of mine schedule • Post-mining land uses • How to provide feedback
Private Landholders	A & N Goodwin	Inform and Consult	1. One-on-one meetings 2. Website 3. Information Sheets 4. Site visits 5. Community Events 6. Near Neighbour Meetings 7. Community Newsletters	1. As required 2. All year round 3. As required 4. As required 5. As required 6. Bi-Annually 7. Monthly	• Project description • Life of mine schedule • Rehabilitation success • Retention of infrastructure • Rehabilitation trials • How to provide feedback
	T & M Goodwin				
	A & J Acton				
	P Dunne				
	I & A Davidson				
	L & N Phillipson				
	J Atkinson				
	J & R Warren				

Type of Stakeholder	Organisation Name	Level of Participation	Consultation Methods	Frequency	Information to be Provided
Community Groups and Non-Government Organisations	Fitzroy Basin Association Lock the Gate Alliance Environmental Defenders Office	Inform	1. Website 2. Information Sheets 3. Community Events	1. All year round 2. As required 3. As required	• Project description • Life of mine schedule • Rehabilitation success • How to provide feedback
Local Indigenous Groups and Cultural Heritage Groups	Nghally Ghungalu Thoonieda Aboriginal Corporation Ghungalou Aboriginal Corporation Gaangalu Nation People	Inform and Consult	1. Coordinating Committee Meetings 2. Information Sheets 3. Site visits 4. Community Events	1. Quarterly 2. As required 3. As required 4. As required	• Project description • Life of mine schedule • Rehabilitation success • Cultural Heritage • How to provide feedback
Key Suppliers	Queensland Rail, Electricity, Port Operator and Local Suppliers	Inform	1. Website 2. Information Sheets 3. Community Events	1. All year round 2. As required 3. As required	• Project description • Life of mine schedule
Employees	Mine employees and nominated contractors	Inform, Consult and Involve	1. Employee meetings 2. Website 3. Information Sheets 4. Workplace Events 5. Workplace Newsletters 6. Workshops	1. As required 2. All year round 3. As required 4. As required 5. Monthly 6. As required	• Project description • Life of mine schedule • Workplace transition

8 Community Consultation Register

A record of all closure and rehabilitation consultation undertaken must be kept in the Community Consultation Register. The register records the following information:

- Consultation date(s);
- Stakeholder or Community member name(s);
- Consultation method;
- Information provided;
- Issues raised by stakeholders/community;
- How issues have been or are intended to be considered;
- Any decisions/outcomes of the consultation; and
- Any commitments made.

A copy of the register has been provided in **Appendix B**.

9 References

Australian Bureau of Statistics, 2017, 2016 Census QuickStats: Blackwater, accessed on 16 February 2022, available at 2016 Census QuickStats: Blackwater (abs.gov.au).

Centre for the Government of Queensland, 2018, Blackwater, accessed on 16 February 2022, available at Blackwater | Queensland Places.

IAP2, 2018, IAP2 Spectrum of Public Participation, accessed on 17 August 2022, available at https://iap2.org.au/wp-content/uploads/2020/01/2018_IAP2_Spectrum.pdf

Tourism & Events Queensland, 2022, Blackwater, accessed on 16 February 2022, available at Blackwater (queensland.com).

APPENDIX A

COMMUNITY CONSULTATION PLAN (2001)

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1.0 INTRODUCTION

This Consultation Report has been prepared as an Appendix to the Curragh North Project Environmental Impact Statement (EIS) prepared by AustralAsian Resource Consultants (AARC) for Wesfarmers Curragh Pty. Ltd. Community consultation for the Pisces Project was commenced by Stanwell Corporation Limited (SCL) in January 2001 and included the development of the Draft Terms of Reference for the EIS. Curragh signed an agreement with SCL on the 24th of January 2003 for Curragh to apply for a Mining Lease and develop the Project. Curragh has committed to continue the voluntary EIS process commenced by SCL and to complete an EIS consistent with the Terms of Reference finalised by the Queensland Environmental Protection Agency (QEPA) and forwarded to SCL on the 23rd November 2001. This report provides an outline of the aims, methodology and the results, of consultation to date by both SCL and Curragh for the Curragh North Project.

2.0 AIMS

The aims of the community consultation are presented below:

- To provide stakeholders with information on the Project, the EIS process and the role of consultation/public comment in that process.
- To identify key concerns of stakeholders and advisory bodies.
- To work with stakeholders to develop control strategies for key concerns.
- To incorporate control strategies into Project design, to mitigate potential adverse effects of the Project and capitalise on positive opportunities identified.

3.0 METHODOLOGY

A key component of the EIS preparation process has been the involvement of various advisory bodies and other stakeholders. Advisory body and stakeholder consultation included meeting key stakeholders and affected persons one-on-one, and addressing meetings of interested groups. Significant formal input was received through responses to the Draft TOR.

3.1 STANWELL METHODOLOGY

A Stakeholder Consultation Plan was developed and presented to the QEPA for review and comment in April, 2001.

The consultation strategy, as presented in the Stakeholder Consultation Plan, utilised the following methodologies:

- Numerous one-on-one meetings with landholders, stakeholders, interested persons and relevant advisory bodies;
- Presentations to meetings of stakeholders and other interested groups, including the Fitzroy Basin Association, and Central Queensland Mine Rehabilitation Group;
- Preparation and distribution of a Community Consultation and Environmental Report, which included a response form for feedback, to key stakeholders and advisory bodies;

- Preparation and distribution of a Project Fact Sheet; and
- Establishment and maintenance of a Project web-site with options for downloading the Terms of Reference (TOR) and Project Fact Sheet, and options for providing feedback to the Project Team, asking questions of the Project Team, and registering interest in receiving Project updates via email. The Project web-site address was www.aarc.net.au/pisces.

These activities were undertaken in addition to fulfilling all relevant requirements of the *Environmental Protection Act 1994* (EP Act) and policies or requirements of the QEPA, related to the TOR process, such as providing notices to affected persons.

Copies of consultation materials, including the Project Fact Sheet and a print out of the Project web-site (as at February 2002) are presented in Attachment 1.

3.2 CURRAGH METHODOLOGY

Community consultation was undertaken and will continue to be carried out to allow the community the opportunity to:

- Become fully informed of the Project status and the likely impacts of any development prior to approval;
- Express any concerns regarding current or planned Project activities and their environmental impacts; and
- Discuss, review and contribute to the formulation of the strategies proposed for the Project to mitigate of any potential adverse impacts that may arise.

The following strategies are used in community consultation:

1) Conduct consultation meetings as appropriate and evaluate feedback from such meetings.

2) Implement company procedures covering:

   - operation of the site; and
   - a complaints recording and investigation system.

3) Utilise local services and skilled personnel where appropriate.

4) Curragh has utilised the output from SCL's community consultation process and has focussed its activities on the documented feedback.

5) Curragh has incorporated comments from the Terms of Referrence process in the development of the EIS.

3.3 SUMMARY OF KEY ISSUES

As at February 2002, issues had been raised on nearly 100 different specific topics in response to the Draft Terms of Reference. A summary of the topics raised, the number of times each topic was raised by stakeholders during the consultation process, and where the topic is addressed in the EIS is presented in Attachment 1.

3.4 ONGOING CONSULTATION

After the close of the EIS submission period public comments will be forwarded to Curragh by the QEPA. Curragh will formulate a written summary of the comments, responses to the comments, and amend the EIS as a result of the comments received. Responses to the submission comments will be provided to the stakeholders and discussed with stakeholders during follow-up meetings and/or discussions.

Curragh will continue ongoing consultation with stakeholders at key stages of the Project life where there is any significant progress or change with Project activities. Curragh will continue consultation during Project operation and final rehabilitation of the Project using the following methods:

- One-on-one meetings with landholders, stakeholders, interested persons and relevant advisory bodies;
- Presentations to meetings of stakeholders and other interested groups;
- Maintenance of a website linked to the Wesfarmers web page with options for downloading the TOR, EIS (when available) and the latest Project Fact Sheet.
- Feedback from consultation will continue to be entered into the Consultation Database. Issues raised through EIS submissions will be addressed by amending the EIS and/or Project plans as required, and/or through consultation. After the EIS has been approved and the Project is commissioned, feedback from the consultation to be undertaken as outlined above, will be entered onto the Consultation Database and then provided to the relevant Project team member for action and implementation of appropriate mitigation strategies where required. This will ensure that mitigation strategies are developed for potential adverse environmental and socio-economic impacts identified through consultation.

Existing stakeholders have been identified through discussions with government departments and surrounding landholders. The methods to be used for ongoing consultation outlined above, particularly methods that include feedback options, will assist in identifying new and additional stakeholders.

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4.0 CONSULTATION ACTIVITIES AND RESULTS

This section describes the consultation activities undertaken and a summary of the results of consultation activities.

A Consultation Database was established to comprehensively detail consultation undertaken, issues raised, issue topics, responses to issues, and follow-up action to address the issue. The Consultation Database is structured such that each issue raised from each consultation is entered on the database as a stand-alone record. That is, one consultation may arise in several entries on the database. This method allows the database to be sorted by issue, thus making it more useful for assessing key issues. For Draft TOR submissions, each issue in each submission was given a unique reference number, which was added to the database. This system was used to assist the EPA in reviewing the summary table of comments on the Draft TOR, responses to those comments and proposed Draft TOR amendments. In total, the communication database recorded 353 entries from 65 separate consultations or communications.

The aim of the Consultation Database is to demonstrate to the QEPA and advisory bodies that the consultation process was effective and that feedback from consultation influenced the final Project design. The Consultation Database is presented in Attachment 2 of this Report, and key issues raised and outcomes from consultation are summarised below.

4.1 COMMUNITY CONSULTATION AND ENVIRONMENTAL REPORT

A Community Consultation and Environmental Report was prepared and distributed in April 2001. This report was provided to QEPA Brisbane for review and comment. Copies of the Community Consultation and Environmental Report were provided by SCL to key stakeholders and advisory bodies including surrounding landholders and Duaringa Shire Council. Additional copies were provided to Duaringa Shire Council for public display.

The Community Consultation and Environmental Report included a Response Form for feedback, for requesting regular updates on the Project, and for requesting to be placed on an Employment and Business Register.

Only three completed Response Forms were sent back to AARC. Two forms were from businesses primarily requested to be placed on the Employment and Business Register, and one form was from a surrounding landholder. The full details of issues raised in the Response Forms are presented in the Consultation Database. An issue raised by two of the three respondents was concern about the loss of potential economic benefits by accommodating staff at a mine village on site instead of at Blackwater.

4.2 DRAFT TERMS OF REFERENCE

SCL submitted an amended Draft TOR to the QEPA in June 2001. Multiple copies of the Draft TOR were provided to the QEPA for distribution to advisory bodies and stakeholders. In July 2001 the QEPA prepared and published a Terms of Reference Notice for public notification of the Draft TOR, and SCL provided copies of the Terms of Reference Notice to all identified affected and interested persons. At the same time the Draft TOR was made available for viewing or downloading from the Project web-site, which was linked to the QEPA web-site, so that people could access the Project web-site from the QEPA web-site.

The Draft TOR exhibition period was from Monday 9 July to Monday 20 August 2001 and comments on the Draft TOR from advisory bodies, stakeholders and other interested persons were lodged with the QEPA. In total, 14 separate submissions were received from advisory bodies, stakeholders and affected persons, and 278 issues were entered on the Consultation Database from these submissions. After the close of the exhibition period the Draft TOR comments were provided to SCL by the QEPA. SCL and AARC prepared a written summary of the comments, responses to the comments, and amended the draft TOR as a result of the comments received. The summary of comments, responses to the comments and proposed amendments to the Draft TOR were included on the Consultation Database. All comments, responses and TOR amendments were provided to the QEPA in October 2001 as required under the EP Act. Responses to stakeholder comments were provided to the stakeholders and in many cases discussed with stakeholders during follow-up meetings or discussions.

4.3 SUMMARY OF KEY ISSUES RAISED

As at February 2002, issues had been raised on 98 different topics. A summary of the topics raised and the number of times each topic was raised by stakeholders during the consultation process is presented in Table 1. The section of the EIS where the topic is addressed is also presented in Table 1.

Table 1
Summary of Key Topics Raised

Topic	Number
Impacts on infrastructure and transport	3
Impacts on facilities and services	5
Health and safety	12
Cumulative impacts of mining in the area	1
Existing wetlands	4
Baseline soils information	8
Baseline land capability information	1
Baseline land suitability assessment	5
Economic impacts on relocated landholders	1
Final/Post-mining land use	21
Project alternatives	5
Final/Post-mining landform	14
Final voids	6
Approvals required	4
Impacts of levees on local hydrology	7
Riparian buffer zones	10
Air quality impacts	21
Impacts on adjacent agricultural land/production, including economic impacts	5
Social impacts	5
Final rehabilitation strategy	14
Description of nearest residences	1
Waste disposal	1
Water treatment	1
Vector control	1
Workforce requirements	1
Existing groundwater users	1
Groundwater impacts	1
Protection of remnant vegetation	1

Topic	Number
Impacts on stability of Mackenzie River	2
Final voids – water quality	1
Impacts on traditional owners	1
Noise impacts	2
Hazardous wastes	1
MDL 306 development	2
Ongoing community consultation	5
Community involvement in project	2
Rehabilitation monitoring	3
Ongoing monitoring	4
Impacts of mining on a floodplain	1
Recovery of resources	2
Resource sterilisation	1
Post-mining agricultural productivity	1
Existing land use	1
Past land use	1
Maintenance and stability of post-mining landforms	3
Training and employment opportunities for locals and indigenous peoples.	5
Mine waste management	2
Requests for documents	2
Lot 17 management	2
Registered business interest	2
Mine village – potential loss of economic benefits	6
Mine access road flooding	1
Haul road location	5
Haul road location and impacts on stock movement	1
Water allocation and usage	3
Water quality impacts	6
Impacts on fauna – Wallaroos	1
Impacts and management of Mackenzie River riparian zone	3
Impacts on geomorphology	3
Air quality impacts – terrestrial and aquatic flora and fauna	2
Impacts on terrestrial fauna	1
Impacts on flora	1
Visual impacts	1
Weed management	3
EIS format and presentation	5
Information on proponent	1
Subcontractor arrangements	1
EIS scope	1
Details on how to make submissions	1
Size of MLA areas	1
Mining methodology	1
Mine layout – location of stockpiles	1
Mine layout – location of crushers	1
Rail infrastructure	1
Transport routes	1
Recovery of sand and gravel resources	2
Baseline geomorphology	4
Existing groundwater hydrology	1
Typographical	17
Flood hydrology	1
Baseline flora assessment	12

Topic	Number
Baseline fauna assessment	6
Inclusion of Environmentally Sensitive Areas	1
Inclusion of Environmental Resilience	1
Cultural heritage study methodology	12
Cultural heritage management plan	8
Proposed infrastructure – haul roads	1
Flood risks and management	1
MLA application requirements	1
Baseline air quality	1
Vegetation Management Act	2
Location of levees	2
Flood modelling	1
EIS and MLA approval process and timing	1
Flood risk management/protection during mining	2
Impacts of dust on neighbouring properties	5
Impacts of dust on crops and pasture	2

4.4 CONSULTATION WITH TRADITIONAL OWNERS

Apart from advisory bodies, other stakeholders who have been consulted include the landowners and Aboriginal groups who assert a traditional affiliation with the area. These groups are:

- Nghally Ghungalu Thoonieda Aboriginal Corporation for the Ghungalu traditional owners; and
- The Ghungalou Aboriginal Corporation as representatives of the Kangalou traditional owners.

Discussions have also been held with the Birri Gubba Guntha Bimbi Sacred Sites Aboriginal Corporation for the Kabalbarra traditional owners, who claim traditional ownership to the west side of the Mackenzie River which does not form part of the Project site.

This consultation has provided the advisory bodies, landholders and Aboriginal groups with the opportunity to:

- Become fully informed of the Project status and the likely impacts of any development prior to approval;
- Express any concerns regarding current or planned Project activities and their environmental impacts; and
- Discuss, review and contribute to the formulation of the strategies proposed for the Project for mitigation of any potential adverse impacts which may arise.

ATTACHMENT 1: Response to the Draft Terms of Reference

PISCES COAL PROJECT				
DRAFT TERMS OF REFERENCE				
SUMMARY OF COMMENTS AND PROPONENT RESPONSE				
LEGEND				
DTOR	Draft terms of Reference			
EIS	Environmental Impact Statement			
GQAL	Good Quality Agricultural Land			
SCL	Stanwell Corporation Limited			

PISCES COAL PROJECT - DRAFT TERMS OF REFERENCE
SUMMARY OF COMMENTS AND PROPONENT RESPONSE

NAME	ORGANISATION	DATE OF CONTACT	FORM OF CONTACT	ISSUES RAISED	REFERENCE	ISSUE TOPIC	RESPONSE	PROPOSED FOLLOW UP ACTION	DETAILS OF ACTION TAKEN/TASKS AND RESPONSIBILITIES
Neil Hoy, Nigel Homes	EPA, Rockhampton	22/01/2001	Meeting with Claire Avenell (SCL), and Peter Macey (AARC).	Notify EPA Project Officer of intention to pursue ML grant. Seek feedback on proposed consultation plan and stakeholder list.	-	General meeting to discuss progress, no issues raised requiring SCL response.	No issues raised requiring response.	No issues raised requiring response.	No issues raised requiring response.
Peter Dunne & A. Palmer	Landholder – "Mourallyn" and legal representative from Rees R. & Sydney Jones.	22/01/2001	Meeting with Claire Avenell (SCL), Russell Brown (Taylor Byrne-Valuers), Peter Macey (AARC).	To re-open negotiations between SCL and Mr Dunne for purchase of part Lot 6, LR94 ("Mourallyn"). To address Mr Dunne's specific concerns on Project and invite open communication with SCL throughout future phases of project.	-	General meeting to discuss progress, no issues raised requiring SCL response.	No issues raised requiring response.	No issues raised requiring response.	No issues raised requiring response.
Central Qld Mine Rehabilitation Group	-	14/02/2001	Presentation on Pisces – Project Overview & Environmental Issues, to CQMRG workshop attendees from Claire Avenell.	-	-	General meeting to discuss progress, no issues raised requiring SCL response.	No issues raised requiring response.	No issues raised requiring response.	No issues raised requiring response.
Kerry Marler	DNRM, Rockhampton	22/02/2001	Meeting with Claire Avenell (SCL), Roger Pattison (PPK), Brad Tite (PPK).	General feedback on EIS draft section on hydrology, hydrogeology, flood modelling and flood mitigation measures proposed.	-	Hydrology	PPK to review and update hydrology and flood modelling report as required.	PPK to review and update hydrology and flood modelling report.	
Scott Fanshawe	Customer Service Manager, SunWater, Emerald.	20/03/2001	Meeting with Claire Avenell (SCL), Nev Turner (SCL).	Ascertain availability of water for mining activities & determine correct procedure for seeking water allocation for Pisces.	-	Water allocation and usage.	SCL to submit tender for water allocation.	SCL to submit tender for water allocation.	
Scott McGhie	Landholder, "Minnie Plains"	20/03/2001	Meeting with Claire Avenell (SCL), Nev Turner (SCL).	Provide plans of proposed haulroute – seek feedback.	-	Haul road location	SCL and TMG to finalise haul route options and reasons for selected option and present in EIS. Haul route will be influenced by flora, fauna and cultural heritage issues and therefore can't be finalised until all flora, fauna and cultural heritage field work is completed.	Haul route and reasons for selecting to be addressed in EIS.	
Tom Hall, Derm Stower	Mayor and CEO, Duaringa Shire Council.	20/03/2001	Meeting with Claire Avenell (SCL), Nev Turner (SCL).	Provided four copies of Community Consultation & Environmental Report to DSC for display at Blackwater Administration Building, Duaringa Shire Council office, Blackwater Library and Duaringa Library. Advise of SCL's intention to submit a Mining Lease Application.	-	General meeting to discuss progress, no issues raised requiring SCL response.	No issues raised requiring SCL response.	No issues raised requiring SCL response.	No issues raised requiring SCL response.
Sibson, Philipson & Wight families, "Jellinbah Station"	Landholders, "Jellinbah Station"	20/03/2001	Meeting with Claire Avenell (SCL), Nev Turner (SCL).	Informal dinner meeting to advise on Pisces Project status; discuss fencing, road access and land management issues.	-	General meeting to discuss progress, no issues raised requiring SCL response.	No issues raised requiring SCL response.	No issues raised requiring SCL response.	No issues raised requiring SCL response.
Dr Bill Dixon, John Bywater	EPA, Brisbane	27/03/2001	Meeting with Claire Avenell (SCL), and Peter Macey (AARC).	Supplied three copies of Voluntary Application for Submission of EIS & Draft Terms of Reference document for EPA informal review.	-	General meeting to discuss progress, no issues raised requiring SCL response.	No issues raised requiring SCL response.	No issues raised requiring SCL response.	No issues raised requiring SCL response.
CEO, Duaringa Shire Council	Duaringa Shire Council	29/03/2001	Letter from Peter Schmidt, Production Manager – SCL	Formal request for Council approval for Pisces ML application; application to Council for temp/permanent road closure of affected portions of Bluff-Jellinbah Road.	-	No issues raised requiring SCL response.	No issues raised requiring SCL response.	No issues raised requiring SCL response.	No issues raised requiring SCL response.
Peter Dunne	Landholder – "Mourallyn"	5/04/2001	Meeting with Russell Brown (Taylor Byrne Agribusiness) during site inspection of Lot 16.	Lot 16 management - weeds from Lot 16 infest neighbouring properties. Discussions with Peter Dunne regarding a Remedial Program for Lot 16, which may involve local LandCare group.	-	Lot 16 Management	SCL commissioned AARC and Taylor Byrne Agribusiness to prepare a Land Management Plan for Lot 16. Surrounding landholders and other stakeholders reviewed draft Plan and provided input to Plan during meetings and discussions held in December 2001. Following feedback from this consultation the Plan was finalised in January 2002.	Prepare and implement a Land management Plan for Lot 16.	In early 2002, SCL commenced implementation of the Lot 16 Land Management Plan (e.g. weed control).
Scott McGhie	Landholder "Minnie Plains"	6/04/2001	Meeting with Russell Brown (Taylor Byrne Agribusiness) during site inspection of "Minnie Plains".	Concerned about the haul road limiting the movement of stock from east to west across his property. Would like a copy of the design of the crossing points.	-	Haul road route and impacts stock movements	Haul road route and impacts on stcok movements, and control strategies to mitigate these impacts, is included in DTOR and will be addressed in EIS.	To be addressed in EIS.	

NAME	ORGANISATION	DATE OF CONTACT	FORM OF CONTACT	ISSUES RAISED	REFERENCE	ISSUE TOPIC	RESPONSE	PROPOSED FOLLOW UP ACTION	DETAILS OF ACTION TAKEN/TASKS AND RESPONSIBILITIES
Scott McGhie	Landholder "Minnie Plains"	6/04/2001	Meeting with Russell Brown (Taylor Byrne Agribusiness) during site inspection of "Minnie Plains".	Concerned that the mine access road along the river will flood.		Mine Access Road flooding.	Details of Mine Access Road route, any feasible alternatives, and justification for selection of proposed route to be provided in EIS.	To be addressed in EIS.	
Scott McGhie	Landholder "Minnie Plains"	6/04/2001	Meeting with Russell Brown (Taylor Byrne Agribusiness) during site inspection of "Minnie Plains".	Concerned about impacts of dust on crops and pasture.		Impacts of dust on crops and pasture	Impacts of dust on crops and pasture and control strategies to mitigate these impacts is included in DTOR and will be addressed in EIS.	To be addressed in EIS.	
Jennifer Roche	J&R Mowing and Maintenance	4/05/2001	Completed and faxed to AARC "Response Form" from "Community Consultation and Environmental Report".	Registered business interest. Concerned about the mine village. "Mining Village - Blackwater and Emerald benefit from additional people living in their towns and the flow on effect in services. By providing a mine village for workers, it does not encourgae families to live in the area, instead compounding the existing problem of families remaining at the coast and hence the financial and economic benefit flows back to those areas instead. Blackwater has an abundance of housing - would it not make sense to come to an arrangement with regard to existing housing and bus them out to the site rather than creating an additional facility which would bring less economic benefit to the area when there is an opportunity to provide for families and address an excess housing issue in the area. Would your employees ever be given this option?".		Registered business interest, Mine village	Details added to business register. Details of accommodation arrangements, feasible alternatives considered and reason for selecting final option will be detailed in EIS.	Details added to business register. To be addressed in EIS.	Details added to business register. To be addressed in EIS.
Peter Dunne	"Wallbury" Duaringa. Landholder "Mourallyn"	19/06/2001	Completed and faxed to AARC "Response Form" from "Community Consultation and Environmental Report".	No fly-in fly-out. When final EMOS and mine plan is realised I will be able to make a more informed comment.		Mine village	Details of accommodation arrangements, feasible alternatives considered and reason for selecting final option will be detailed in EIS.	To be addressed in EIS.	To be addressed in EIS.
Roger Pattison	PPK	25/07/2001	Attended Advisory Bodies TOR meeting in Rockhampton	Advisory bodies submitted formal responses to draft Terms of Reference	-	-	-	-	-
Rebecca Powlett	DNRM Rockhampton	25/07/2001	Attended Advisory Bodies TOR meeting in Rockhampton	Advisory bodies submitted formal responses to draft Terms of Reference	-	-	-	-	-
Noel Barker	DNRM Rockhampton	25/07/2001	Attended Advisory Bodies TOR meeting in Rockhampton	Advisory bodies submitted formal responses to draft Terms of Reference	-	-	-	-	-
John Milne	DNRM Rockhampton	25/07/2001	Attended Advisory Bodies TOR meeting in Rockhampton	Advisory bodies submitted formal responses to draft Terms of Reference	-	-	-	-	-
Ken Day	DNRM Rockhampton	25/07/2001	Attended Advisory Bodies TOR meeting in Rockhampton	Advisory bodies submitted formal responses to draft Terms of Reference	-	-	-	-	-
Scott Fanshawe	SunWater	25/07/2001	Attended Advisory Bodies TOR meeting in Rockhampton	Advisory bodies submitted formal responses to draft Terms of Reference	-	-	-	-	-
Lisa Bricknell	Qld Health, Rockhampton	25/07/2001	Attended Advisory Bodies TOR meeting in Rockhampton	Advisory bodies submitted formal responses to draft Terms of Reference	-	-	-	-	-
Neil Hoy	EPA, Rockhampton	25/07/2001	Attended Advisory Bodies TOR meeting in Rockhampton	Advisory bodies submitted formal responses to draft Terms of Reference	-	-	-	-	-
Steve Elson	EPA, Rockhampton	25/07/2001	Attended Advisory Bodies TOR meeting in Rockhampton	Advisory bodies submitted formal responses to draft Terms of Reference	-	-	-	-	-
Nigel Holmes	EPA, Rockhampton	25/07/2001	Attended Advisory Bodies TOR meeting in Rockhampton	Advisory bodies submitted formal responses to draft Terms of Reference	-	-	-	-	-
Lyle Mitchell	Qld Police	25/07/2001	Attended Advisory Bodies TOR meeting in Rockhampton	Advisory bodies submitted formal responses to draft Terms of Reference	-	-	-	-	-
Cynthia Rowan	Department of Families, Rockhampton	25/07/2001	Attended Advisory Bodies TOR meeting in Rockhampton	Advisory bodies submitted formal responses to draft Terms of Reference	-	-	-	-	-
Peter Macey	AARC	25/07/2001	Attended Advisory Bodies TOR meeting in Rockhampton	Advisory bodies submitted formal responses to draft Terms of Reference	-	-	-	-	-
Clair Avenell	SCL	25/07/2001	Attended Advisory Bodies TOR meeting in Rockhampton	Advisory bodies submitted formal responses to draft Terms of Reference	-	-	-	-	-

PISCES COAL PROJECT - DRAFT TERMS OF REFERENCE
SUMMARY OF COMMENTS AND PROPONENT RESPONSE

NAME	ORGANISATION	DATE OF CONTACT	FORM OF CONTACT	ISSUES RAISED	REFERENCE	ISSUE TOPIC	RESPONSE	PROPOSED FOLLOW UP ACTION	DETAILS OF ACTION TAKEN/TASKS AND RESPONSIBILITIES
Steve Elson	EPA	25/07/2001	Attended Advisory Bodies TOR meeting in Rockhampton	Advisory bodies submitted formal responses to draft Terms of Reference	-	-	-	-	-
David Coffey	DNRM	26/07/2001	Attended Advisory Bodies TOR meeting in Brisbane	Advisory bodies submitted formal responses to draft Terms of Reference	-	-	-	-	-
Peter Dunne	Landcare/Fitzroy Basin Association	26/07/2001	Attended Advisory Bodies TOR meeting in Brisbane	Advisory bodies submitted formal responses to draft Terms of Reference	-	-	-	-	-
Craig Smith	Department of Treasury	26/07/2001	Attended Advisory Bodies TOR meeting in Brisbane	Advisory bodies submitted formal responses to draft Terms of Reference	-	-	-	-	-
Peter McDonald	EPA, Brisbane	26/07/2001	Attended Advisory Bodies TOR meeting in Brisbane	Advisory bodies submitted formal responses to draft Terms of Reference	-	-	-	-	-
Bruce Shay	Voith Hydraulics and Pneumatics	16/08/2001	Completed and faxed to AARC "Response Form" from "Community Consultation and Environmental Report".	Registered business interest. No other issues.	-	Registered business interest	Details added to business register.	Add details to business register	Details added to business register.
Jim Bell, Chief Surveyor	DME, Brisbane	2/10/2001	Meeting with Claire Avenell (SCL), Richard Hoskings (The Minserve Group), Paul Stewart (The Minserve Group)	DME's requirements with respect to surveying & pegging of Pisces MLA areas.	-	MLA application requirements			
Jellinbah Station landholders	-	13/10/2001	Meeting with Claire Avenell (SCL), Barry Saunders (QGS)	Fencing requirements for Lot 16; general update on project status		Lot 16 Management			
Joanne Gardiner – Tech Services Manager	Curragh Mine	13/10/2001	Meeting with Claire Avenell (SCL), Roger Pattison (PPK)	Haulroute proposals to provide Pisces with access to Curragh load out and washplant.		Haul road location			
Mr Rod Jarro, Representative	Kangoulu Native Title Claimant Group	7/11/2001	Letter from AARC	Provided three copies of Voluntary EIS Application and Draft TOR and three copies of 2000 cultural heritage survey carried out on the proposed Pisces Coal Project site by Mr Tim Spencer.		Provided copies of reports			
Mr Brett Mackie, Manager Native Title	Gurang Land Council	12/11/2001	Letter from AARC	TOR and two copies of 2000 cultural heritage survey carried out on the proposed Pisces Coal Project site by Mr Tim Spencer.		Provided copies of reports			
Ms Patricia Leisha	Nghally Ghungalu Thooneida A/C (Ghungalu Native Title Claimant Group)	12/11/2001	Letter from AARC	Provided two copies of Voluntary EIS Application and Draft TOR and three copies of 2000 cultural heritage survey carried out on the proposed Pisces Coal Project site by Mr Tim Spencer.		Provided copies of reports			
Mr Alister Hughes	Landholder "Woodleigh"	29?/11/2001	P/call from Claire Avenell (SCL).	Concerned about proposed access to Lot 16, as "Woodleigh" is currently unfenced along the Bluff-Jellinbah Road which is currently used for access to Lot 16.		Mine Access Road route and impacts.	To be addressed through ongoin consultation and in EIS.	Address issue through ongoing consultation with landholder	
Mr Neil Hoy	EPA Rockhampton	29/11/2001	Letter from AARC	Provided a copy of SCL responses to EPA comments on DTOR and arranged a meeting to discuss TOR comments.	-	Provided copies of reports	Arranged meeting for 10/12/01	Meet with EPA to discuss tOR comments	Meeting held 10/12/01
Mr John Grimes	Department of Primary Industries (DPI), Rockhampton	30/11/2001	Letter from AARC	Provided a copy of SCL responses to DPI comments on DTOR and arranged a meeting to discuss TOR comments.	-	Provided copies of reports	Arranged meeting for 10/12/01	Meet with EPA to discuss tOR comments	Meeting held 10/12/01
Mr Ken Day	Department of Natural Resources and Mines (DNRM), Rockhampton	30/11/2001	Letter from AARC	Provided a copy of SCL responses to DNRM Rockhampton comments on DTOR and arranged a meeting to discuss TOR comments.	-	Provided copies of reports	Arranged meeting for 10/12/01	Meet with EPA to discuss tOR comments	Meeting held 10/12/01
Ms Cynthia Rowan	Department of Families	30/11/2001	Email from Dept Families to AARC in response to draft TOR.	attached our response to the draft TOR with attachments. I recall from the meeting with the proponents on 25th July 2001, that the issues was raised in regards to the impact of access to suitable accommodation for sub-contractors or contractors of the project. During our discussion it was noted that most motel and caravan park accommodation was booked to contractors working on various projects in the Blackwater area. This in effect whilst beneficial to small business - effectively, reduced the capacity to accommodate tourists. The suggestion was to lease houses from other mining companies that are experiencing a downturn. This		Social Impacts	To be addressed in EIS.	To be addressed in EIS.	

NAME	ORGANISATION	DATE OF CONTACT	FORM OF CONTACT	ISSUES RAISED	REFERENCE	ISSUE TOPIC	RESPONSE	PROPOSED FOLLOW UP ACTION	DETAILS OF ACTION TAKEN/TASKS AND RESPONSIBILITIES
Neil Hoy	EPA Rockhampton	10/12/2001	Meeting with Claire Avenell (SCL), Peter Macey (AARC) and Robyn Mountford (AARC), at EPA office in Rockhampton.	EIS must consider Vegetation Management Act.		Flora impacts	Included in Final TOR. To be addressed in EIS.	To be addressed in EIS.	
Neil Hoy	EPA Rockhampton	10/12/2001	Meeting with Claire Avenell (SCL), Peter Macey (AARC) and Robyn Mountford (AARC), at EPA office in Rockhampton.	Suggested SCL undertake ambient dust levels, as this will be a key issue.		Baseline air quality, air quality impacts	Baseline dust monitoring to be undertaken. Impacts of dust, and mitigation strategies, are included in TOR and will be addressed in EIS.	Baseline dust monitoring to be undertaken.	Baseline dust monitoring commenced 15/2/02.
Neil Hoy	EPA Rockhampton	10/12/2001	Meeting with Claire Avenell (SCL), Peter Macey (AARC) and Robyn Mountford (AARC), at EPA office in Rockhampton.	EPA Rockhampton require 3 hard copies of EIS.		Request for copies of EIS	3 copies of EIS to be provided to EPA Rockhampton	3 copies of EIS to be provided to EPA Rockhampton	
Neil Hoy	EPA Rockhampton	10/12/2001	Meeting with Claire Avenell (SCL), Peter Macey (AARC) and Robyn Mountford (AARC), at EPA office in Rockhampton.	Ensure that the correct protocol for cultural heritage studies is followed, with respect to publishing cultural heritage information. That is, the Cultural Heritage Management Plan is not to be included in the EIS. However, EPA personnel are authorised to review the cultural heritage study results.		Cultural heritage report	Correct protocal for publishing results of cultural heritage study will be followed.	Correct protocal for publishing results of cultural heritage study will be followed.	
John Grimes	DPI Rockhampton	10/12/2001	Meeting with Claire Avenell (SCL), Peter Macey (AARC) and Robyn Mountford (AARC), at DPI office in Rockhampton.	After reviewing SCL responses to DPI commenst on DTOR, DPI is satisfied with SCL responses and accepts that DPI's issues will be addressed in the EIS.		-	DPI issues will be addressed in EIS	DPI issues will be addressed in EIS	
John Grimes	DPI Rockhampton	10/12/2001	Meeting with Claire Avenell (SCL), Peter Macey (AARC) and Robyn Mountford (AARC), at DPI office in Rockhampton.	Any works that impede water flow and fish movement need to be approved under the Fisheries Act.		Approvals required	Already addressed in DTOR. S 3.4 of the Draft TOR states that necessary approvals for the project will be identified in the EIS (in the section dealing with regulatory framework).	Addressed in DTOR. To be considered when describing necessary approvals in EIS.	
John Grimes	DPI Rockhampton	10/12/2001	Meeting with Claire Avenell (SCL), Peter Macey (AARC) and Robyn Mountford (AARC), at DPI office in Rockhampton.	Use the definition of "watercourse" from *The Water Act 2000*.		Approvals required	Already addressed in DTOR. S 3.4 of the Draft TOR states that necessary approvals for the project will be identified in the EIS (in the section dealing with regulatory framework).	Addressed in DTOR. To be considered when describing necessary approvals in EIS.	
John Grimes	DPI Rockhampton	10/12/2001	Meeting with Claire Avenell (SCL), Peter Macey (AARC) and Robyn Mountford (AARC), at DPI office in Rockhampton.	DPI Rockhampton require 2 hard copies of EIS.		Request for copies of EIS	2 copies of EIS to be provided to DPI Rockhampton	2 copies of EIS to be provided to DPI Rockhampton	
John Grimes	DPI Rockhampton	10/12/2001	Meeting with Claire Avenell (SCL), Peter Macey (AARC) and Robyn Mountford (AARC), at DPI office in Rockhampton.	DPI policy recommends a separation distance of 50m to freshwater waterways and wetlands. However, this is a guideline only. The width of the selected buffer zone needs to be justified.		Riparian buffer zones	Comment to be addressed in design of buffer zones and addressed in EIS.	Comment to be addressed in design of buffer zones and addressed in EIS.	
Ken Day, Rebecca Powlett, Kerry Marler	DNRM Rockhampton	10/12/2001	Meeting with Claire Avenell (SCL), Peter Macey (AARC) and Robyn Mountford (AARC), at DNRM office in Rockhampton.	The project is exempt to provisions of Fitzroy Basin Water Moratorium because it will be on a Mining Lease.		Water allocation	-	-	
Ken Day, Rebecca Powlett, Kerry Marler	DNRM Rockhampton	10/12/2001	Meeting with Claire Avenell (SCL), Peter Macey (AARC) and Robyn Mountford (AARC), at DNRM office in Rockhampton.	The distance from the levees to the river are not covered by the Water Resources Act and the levees will not be required to be licenced. However, this does not detract from the obligation under the local authorities for levee bank management.		Location of levees	The distance of the levees from the Mackenzie River will be justified in the EIS. SCL will attempt to abide by Water Resources Act as a guideline, even if it is not necessary	To be addressed in EIS.	
Ken Day, Rebecca Powlett, Kerry Marler	DNRM Rockhampton	10/12/2001	Meeting with Claire Avenell (SCL), Peter Macey (AARC) and Robyn Mountford (AARC), at DNRM office in Rockhampton.	DNRM seek assurance that consultation will be ongoing and that outcomes of consultation will be incorporated in project planning and operation. In particular changes to flood flows need to be communicated to neighbours.		Ongoing consultation.	To be addressed in ongoing consultation. Commitment to ongoing consultation and details of consultation process to be addressed in EIS and EMOS	To be addressed in ongoing consultation. Commitment to ongoing consultation and details of consultation process to be addressed in EIS and EMOS	

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Ken Day, Rebecca Powlett, Kerry Marler	DNRM Rockhampton	10/12/2001	Meeting with Claire Avenell (SCL), Peter Macey (AARC) and Robyn Mountford (AARC), at DNRM office in Rockhampton.	Soils map in EIS should be at a scale of 1:5000 as per former QDME guidelines for Land Suitability Assessment Techniques. Copies should be provided to Ken Day for review.		Baseline soils assessment	To be addressed in EIS and EMOS/EA conditions. Production of small scale maps and provision to DNRM is likely to be an EA condition. The scale of the maps will be dictated by requirements of the Advisory Bodies.	To be addressed in EIS and EMOS/EA Conditions.	
Ken Day, Rebecca Powlett, Kerry Marler	DNRM Rockhampton	10/12/2001	Meeting with Claire Avenell (SCL), Peter Macey (AARC) and Robyn Mountford (AARC), at DNRM office in Rockhampton.	Commitment to research final void quality should be included in EIS.		Final Void Quality	To be addressed in EIS and EMOS commitments/EA conditions.	To be addressed in EIS and EMOS/EA Conditions.	
Ken Day, Rebecca Powlett, Kerry Marler	DNRM Rockhampton	10/12/2001	Meeting with Claire Avenell (SCL), Peter Macey (AARC) and Robyn Mountford (AARC), at DNRM office in Rockhampton.	Draft Flood Modelling Report can be reviewed by DNRM, to ensure it meets DNRM requirements, prior to submission of EIS.		Flood modelling	Flood modelling reports provided to Bill Dixon EPA in January 2002, for distribution to appropriate Advisory Bodies for review.	Flood modelling reports to be provided to Bill Dixon EPA in January 2002, for distribution to appropriate Advisory Bodies for review.	Flood modelling reports to be provided to Bill Dixon EPA in January 2002, for distribution to appropriate Advisory Bodies for review. Response from DNRM on flood modelling report received from Bill Dixon EPA in February 2002 and distributed to Pisces Project Team.
Ken Day, Rebecca Powlett, Kerry Marler	DNRM Rockhampton	10/12/2001	Meeting with Claire Avenell (SCL), Peter Macey (AARC) and Robyn Mountford (AARC), at DNRM office in Rockhampton.	Erosion control for levee banks needs to be considered.		Levee - erosion control	Included in TOR and to be addressd in EIS.	Included in TOR and to be addressd in EIS.	
David and John Chapman	Landowners "Cooroorah". Cooroorah Farming and Grazing Company.	11/12/2001	Jones Offices in Rockhampton at 10.45 am. Attended by David and John Chapman, Andrew Palmer (solicitor - Rees R and Sydney Jones), Claire Avenell (SCL), Alistair Henderson (Taylor Byrne Agribusiness), Craig	Chapmans want to see current mine plan and alternative development options considered by SCL.		Project alternatives	The EIS will include details of all alternative mining methods and infrastructure and justification for selection of preferred option. EIS could be provided to Andrew Palmer soon after EPA accepts final version.		
David and John Chapman	Landowners "Cooroorah". Cooroorah Farming and Grazing Company.	11/12/2001	Meeting at Rees R and Sydney Jones Offices in Rockhampton at 10.45 am. Attended by David and John Chapman, Andrew Palmer (solicitor - Rees R and Sydney Jones), Claire Avenell (SCL), Alistair Henderson (Taylor Byrne Agribusiness), Craig McKiernan (AARC).	Concerned about development of MDL306 and affect on forward sales, and any further development on "Cooroorah". Requested copy of MDL documents and maps. Enquired about opportunities for compensation. Concerned about lack of information on MDL 306 development so that they can plan their farming activities.		Development of MDL 306, Impact on adjacent agricultural lands, impacts of dust on crops and pasture.	SCL has no intererest in including MDL306 in Pisces MLA. MDL306 does contain a mineable resource, however SCL is still considering development options for this portion. MDL306 may be pursued as a separate MLA at some future time. The likelihood of development on MDL 306 being permitted is not high given that its on the lower bank of the Mackenzie River and possibly at greater flood risk. MDL306 is viewed by SCL as a "holding" MDL. SCL to provide map of MDL 306 to Chapmans. SCL management to be made aware that clearer information on MDL 306 is to be provided to Chapmans.	MDL306 map to Chapmans. Clearer information to Chapmans on MDL306 plans.	????
David and John Chapman	Landowners "Cooroorah". Cooroorah Farming and Grazing Company.	11/12/2001	Jones Offices in Rockhampton at 10.45 am. Attended by David and John Chapman, Andrew Palmer (solicitor - Rees R and Sydney Jones), Claire Avenell (SCL), Alistair Henderson (Taylor Byrne Agribusiness), Craig	What is the cost of the EIS document. Will there be an opportunity to have input into the EIS. What is the expected approval time for the ML and EA. Is final TOR available.		EIS and MLA approval process and timing.	EIS is generally provided free to affected persons. Opportunities for input to EIS, EIS and MLA process and timing will be detailed in EIS.	Provide Final TOR to Chapmans.	????
Peter Dunne	Landholder – "Mourallyn"	13/12/2001	Meeting with Claire Avenell (SCL), Craig McKiernan (AARC) and Alastair Henderson (Taylor Byrne) to discuss Lot 16 Land Management Plan.	Suggested that creating a series of staged mining cells would provide better flood protection during mining.		Flood protection during mining,.	Strategies for flood protection during mining are included in Final TOR and are to be addressed in EIS.	To be addressed in EIS.	
Peter Dunne	Landholder – "Mourallyn"	13/12/2001	Meeting with Claire Avenell (SCL), Craig McKiernan (AARC) and Alastair Henderson (Taylor Byrne) to discuss Lot 16 Land Management Plan.	Suggested that backfilled areas and overburden dumps be covered with 1m of topsoil during rehabilitation and returned to cropping post mining.		Final rehabilitation strategy post-mining land use.	Final land use and rehabilitation strategies are included in Final TOR and are to be adressed in EIS.	To be addressed in EIS.	
Peter Dunne	Landholder – "Mourallyn"	13/12/2001	Meeting with Claire Avenell (SCL), Craig McKiernan (AARC) and Alastair Henderson (Taylor Byrne) to discuss Lot 16 Land Management Plan.	Concerned about impacts of dust on neighbouring properties and Mackenzie River water quality. Option of in-pit crushing should be investigated, in order to reduce air quality impacts.		Impacts of dust on neighbouring properties, impacts of dust on Mackenzie River water	Impacts of dust on neighbouring properties and land use, and mitigation strategies, to be addressed in EIS. Impacts of dust on Mackenzie River water quality, and mitigation strategies, to be adressed in EIS. Option of in-pit crushing to be included in project alternatives.	To be addressed in EIS.	

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Peter Dunne	Landholder – "Mourallyn"	13/12/2001	Meeting with Claire Avenell (SCL), Craig McKiernan (AARC) and Alastair Henderson (Taylor Byrne) to discuss Lot 16 Land Management Plan.	Option of in-pit crushing should be investigated, in order to reduce air quality impacts.		Impacts of dust on neighbouring properties, impacts of dust on Mackenzie River water	Impacts of dust on neighbouring properties and land use, and mitigation strategies, to be addressed in EIS. Option of in-pit crushing to be included in project alternatives.	To be addressed in EIS.	
Peter Dunne	Landholder – "Mourallyn"	13/12/2001	Meeting with Claire Avenell (SCL), Craig McKiernan (AARC) and Alastair Henderson (Taylor Byrne) to discuss Lot 16 Land Management Plan.	Erosional stability of final void in a flood situation.		Erosional stability of final landform	Erosional stability of final void during flooding to be adressed in EIS.	To be addressed in EIS.	
Arthur Goodwin	Landholder - "New Caledonia".	13/12/2001	Meeting with Claire Avenell (SCL), Craig McKiernan (AARC) and Alastair Henderson (Taylor Byrne) to discuss Lot 16 Land Management Plan.	Flood protection during mining, particularly the ability of the levees to prevent flooding from flow along the Mackenzie between the north and south pits.		Flood protection.	Strategies for flood protection during mining are included in Final TOR and are to be addressed in EIS.	To be addressed in EIS.	
Arthur Goodwin	Landholder - "New Caledonia".	13/12/2001	Meeting with Claire Avenell (SCL), Craig McKiernan (AARC) and Alastair Henderson (Taylor Byrne) to discuss Lot 16 Land Management Plan.	The stability of the levee during flooding.		Stability of final landforms	Levee stability is included in the TOR and is to be addressed in the EIS.	To be addressed in EIS.	
Arthur Goodwin	Landholder - "New Caledonia".	13/12/2001	Meeting with Claire Avenell (SCL), Craig McKiernan (AARC) and Alastair Henderson (Taylor Byrne) to discuss Lot 16 Land Management Plan.	Concerned about impacts of dust on neighbouring properties.		Impacts of dust on neighbouring properties.	Impacts of dust on neighbouring properties and land use, and mitigation strategies, to be addressed in EIS.	To be addressed in EIS.	
Ian Barnes Davison	Landholder - "Barnet".	12/12/2001	Meeting with Claire Avenell (SCL), Craig McKiernan (AARC) and Alastair Henderson (Taylor Byrne) to discuss Lot 16 Land Management Plan.	Concerned about impacts of levees on flood levels on his property "Barnet".		Impact of levee on local hydrology	Impacts of levees on flood levels is included in final TOR and is to be addressed in EIS.	To be addressed in EIS.	
Ian Barnes Davison	Landholder - "Barnet".	12/12/2001	Meeting with Claire Avenell (SCL), Craig McKiernan (AARC) and Alastair Henderson (Taylor Byrne) to discuss Lot 16 Land Management Plan.	Concerned about impacts of dust on neighbouring properties, particularly residence on his property across the river from the crushing plant.		Impacts of dust on neighbouring properties.	Impacts of dust on neighbouring properties and land use, and mitigation strategies, to be addressed in EIS.	To be addressed in EIS.	
Wayne McGuire	Landholder - "Scrubee".	12/12/2001	Meeting with Claire Avenell (SCL), Craig McKiernan (AARC) and Alastair Henderson (Taylor Byrne) to discuss Lot 16 Land Management Plan.	No specific concerns.	-	General meeting to discuss progress, no issues raised requiring SCL response.	No issues raised requiring response.	No issues raised requiring response.	
Brett Cuskopf, Coordinator, Capricorn Conservation Council	Capricorn Conservation Council	11/12/2001	Letter from AARC	Provided copy of Voluntary EIS Application and Final TOR and offered AARC and SCL to meet Capricorn Conservation Council in Rockhampton.	-	Provided copies of report	-	-	-
Mr Michael Bent	Fitzroy Basin Association	19/12/2001	Email from AARC	Provided a copy of SCL responses to FBA comments on DTOR	-	Provided copies of report	-	Meet with FBA to discuss TOR and provide project update.	Claire Avenell (SCL) and Peter Macey (AARC) gave presentation to FBA at their February meeting on 8/2/02 in Yeppoon.
Mr John Chapman	Landholder "Coorooorah"	12/02/2002	Phone call from AARC regarding set up of dust gauges. Permission given to set up gauges. Gauges installed on 15/2/02 by Mark Sanders and Lisa Kiddell with the assistance of Ian Ferguson (station manager)..	-	-	-	-	Dust gauges set up on 15/2/02	-

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Ian Barnes Davison	Landholder - "Barnet".	15/02/2002	Brief site meeting with Lisa Kiddell and Mark Sanders regarding location of houses on property	No specific concerns.	-	-		Location of residence to be shown in EIS.	
John and Barry Chapman, and Palmer	Landholder - "Cooroorah"	2/05/2002	Meeting with Claire Avenell (SCL), John and Barry Chapman and Palmer (owners) at "Cooroorah"	Dust monitoring on his property, concerned he wasn't properly consulted about this.	Air quality	Impacts of dust on their property, plus not being consulted about dust monitoring			
Consultation by Wesfarmers Curragh									
	Stanwell Corporation	24-Jan-03	Signing of coal supply agreement	Agreement for Wesfarmers Curragh to assume the responsibility for the mining lease application, EIS and community consultation	EIS		Curragh to complete EIS and apply for mining lease Curragh to apply for Prospecting Permit to allow Mining Lease application to proceed.		In progress. Completion expected 2003.
Ian Ogden	Duaringa Shire Council	30-Jan-03	Meeting with Murray Bailey, General Manager of Curragh Mine.	Curragh's agreement with Stanwell and Curragh's intention to apply for a Mining Lease.					
John and David Chapman	Landowners "Cooroorah". Cooroorah Farming and Grazing Company.	31-Jan-03	Don Henderson (Curragh) and Darren Fooks (Clayton Utz) Meeting with John and David Chapman, Andrew Palmer from Rees R. & Sydney Jones and Stanwell Corportation	Curragh's plans for the development of the mine.		Environmental issues.	Curragh described time table for development and agreed to meet again with the Chapmans.	Agreed to meet again.	Met again 14-March-2003.
Noel Barker, Paul O'Sullivan, Jim Grundy, Russel Dann,	Deparment of Natural Resources and Mines, Rockhampton	31-Jan-03	Don Henderson (Curragh) and Darren Fooks (Clayton Utz)Meeting with DNRM and Stanwell Corporation	Curragh's agreement with Stanwell and Curragh's intention to apply for a Mining Lease.Curragh's mining plans.		Timing, process		Prospecting Permit	In progress, Permit to be lodged June 2003.
Peter Dunne	Landholder,"Mourallyn"	3-Feb-03	Don Henderson and Kevin Smith (Curragh) meeting with Peter Dunne.	Curragh's agreement with Stanwell and Curragh's plans for developing Curragh North.		Environmental issues.		Will be kept informed of development	Meeting 16th April 2003.
Alan Acton	Landholder, "Minnie Plains"	3-Feb-03	Don Henderson and Kevin Smith (Curragh) meeting with Alan Acton.	Curragh's agreement with Stanwell and Curragh's plans for developing Curragh North.		Transport corridor, environmental issues.	Curragh to look at alternatives to prefered haul route following the Ergon 66kv poweline.	Will be kept informed of development	Meeting 9-April-2003
Barney Davison	Landholder, "Barnett"	4-Feb-03	Don Henderson and Kevin Smith (Curragh) meeting with Barney Davison	Curragh's agreement with Stanwell and Curragh's plans for developing Curragh North		Environmental Issues.		Will be kept informed of development	Meeting 10-June-2003
Dr. Bill Dixon, Glen Schulz, David Trezise	QEPA, Brisbane	6-Feb-03	Don Henderson and Kevin Smith (Curragh) and Peter Macey (AARC).	Curragh's agreement with Stanwell and Curragh's plans for developing Curragh North		Timing, process and concepts		Development of an EIS	Proposed lodgement June 2003
John and David Chapman	Landholder, "Cooroorah"	20-Feb-03	Don Henderson (Curragh) and Kevin Smith (Curragh)	Environmental issues.		Environmental issues.		To meet 14-March-2003	Meeting held 14 March 2003
John and David Chapman	Landholder, "Cooroorah"	14-Mar-03	Don Henderson (Curragh) and Darren Fooks (Clayton Utz) and Stanwell Corporation meeting with Chapman's and Andrew Palmer from Rees R. & Sydney Jones	Environmental issues.		Environmental issues.	Further discussions when EIS is complete		
Noeleen Porter, Rod Jarro, Cliff Kina, Des Hamilton, Pat Leisha, Marie Kemp, Margaret Kemp	Nghally Ghungalu Thooneida A/C and the Ghungalou A/C	23-Mar-03	Joanne Gardiner, Lloyd Jensen and Lynell Collins (Curragh) meeting with the indigenous groups and Peter Poynton (Counsel) and Luke Godwin (CQCHM) in Rockhampton, .	Cultural Heritage investigation and Cultural Heritage Management		Cultural Heritage	To negotiate a Cultural Heritage investigation and management agreement.	Meeting to formalise CHIMA	Meeting held 10-May-2003
Paul Inches	DNRM, Brisbane	26-Mar-03	T. Kuzman and Don Henderson (Curragh)	Curragh's plans for the development of the mine		Timing and plans		Development of an EIS	Proposed lodgement June 2003
Alan Acton	Landholder, "Minnie Plains"	9-Apr-03	Don Henderson (Curragh). John Grady (Parsons Brinckerhoff) and Alan Acton	Location of transportation corridor		Transport corridor, environmental issues.	Further analysis of options	Will be kept informed of development	Meeting 16-April-2003

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Alan Acton	Landholder, "Minnie Plains"	16-Apr	Don Henderson and Lloyd Jensen (Curragh), and Alan Acton	Location of transport corridor		Transport corridor, environmental issues.	Further analysis of options	Will be kept informed of development	Meeting held 13-May-2003
Peter Dunne	Landholder "Mourallyn"	16-Apr	Don Henderson and Lloyd Jensen (Curragh), and Peter Dunne	Progress in mine planning and EIS		Environmental issues.	Further discussions	Will be kept informed of development	Meeting 9-May-2003
Mark Palmer, Anthony Loveday	Ergon Energy	7-May	Don Henderson, Stephen Downs, Murray Bailey, Mac Adlam (Curragh)	Supply of power to Curragh North		Power supply	Further discussions	Will be kept informed of development	Ongoing consultation with Ergon Energy as mine plan is developed.
Peter Dunne	Landholder "Mourallyn"	9-May-03	Don Henderson, Murray Bailey, Kevin Smith (Curragh) and Peter Dunne	Progress in mine planning.		Environmental issues.	Further discussions	Will be kept informed of development	Meetings to be held as required
Noeleen Porter, Rod Jarro, Cliff Kina, Pat Leisha, Marie Kemp, Margaret Kemp, Kim Dale	Nghally Ghungalu Thooneida A/C and the Ghungalou A/C	10-May-03	Lloyd Jensen, Don Henderson and Lynell Collins (Curragh) ,meeting with the indigenous groups and Peter Poynton (Counsel) and Luke Godwin (CQCHM) in Brisbane, .	Cultural Heritage investigation and cultural heritage management		Draft CHIMA	Negotiation of the CHIMA.	Expect to agree CHIMA conditions at next meeting	Meeting held 7-June-2003 CHIMA signed.
Alan Acton	Landholder "Minnie Plains"	13-May-03	Don Henderson, Kevin Smith (Curragh) and Alan Acton	Location of transportation corridor		Environmental issues.	Further discussions	Will be kept informed of development	Meeting to be held at a later date.
Craig Thamm Sara Cooke	QEPA Emerald	13-May-03	Don Henderson and Kevin Smith met with QEPA in Emerald	Progress in mine planning and EIS, changes to Stanwell concept, and Curragh timetable		Environmental issues.	Further discussions	Writing of EIS and EMOS	Lodgement June 2003
Ruth Kerr	Native Title Services, DNRM, Brisbane	15-May-03	Don Henderson (Curragh) and Darren Fooks (Clayton Utz) meeting in Brisbane	Native Title		Native Title	Meetings as required	Meetings as required	
Glen Schulz	Glen Schulz	19-May-03	Don Henderson (Curragh)	Progress in EIS, timing issues, process for lodgement of EIS.		Environmental issues.	Further discussions and information	Will be kept informed of development	Logement June 2003
Mike Mckee	Yarrabee Mine	22-May-03	Mac Adlam, Murray Bailey	Overview of Curragh North development		Mine site development	Will be kept informed of development	Will be kept informed of development	Will meet as required
Arthur Goodwin	Landholder New Caledonia	24-May-03	Mac Adlam, Kevin Smith	Overview of Curragh North development		Environmental issues.	Will be kept informed of development	Will be kept informed of development	Will meet as required
Ian Ogden and Dom Carroll	Duaringa Shire Council	26-May-03	Murray Bailey, Don Henderson, Mac Adlam (Curragh) met with DSC in Blackwater	Progress of EIS		EIS development	Further discussions and information	Will be kept informed of development	Meeting will be held as planning progresses
John Warren	Curragh Mine Landuser	27-May-03	Mac Adlam, Murray Bailey	Overview of Curragh North development		Mine site development	Will be kept informed of development	Will be kept informed of development	Will meet as required
Dan Cawte	Jellinbah Mine	4-Jun-03	Mac Adlam, Murray Bailey	Overview of Curragh North development		Mine site development	Will be kept informed of development	Will be kept informed of development	Will meet as required
Ian Davidson	Landholder, "Barnett"	10-Jun-03	Murray Bailey, Kevin Smith	Mine site development		Environmental issues.	Will be kept informed of development	Will be kept informed of development	Will meet as required

ATTACHMENT 2: CONSULTATION DATABASE

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NAME	ORGANISATION	DATE OF CONTACT	FORM OF CONTACT	ISSUES RAISED	REF.	ISSUE TOPIC	RESPONSE	DETAILS OF ACTION TAKEN/TASKS AND RESPONSIBILITIES	
JF, GF, SH, DJ, BD and RM Chapman	Proprietors "Cooroorah", Blackwater.	19/09/2001	Letter. Response to Draft TOR	The property covered by MDL 306 has been operated as producing cotton farm for some years and my clients are extremely concerned by the location of the proposed mining leases on the eastern side of the McKenzie River and the development of an integrated project which would include a mining lease over the area covered by MDL 306.	1.1	Impact on adjacent agricultural lands covered by MDL 306	No change to DTOR required.	MDL 306 is not part of the Project and is not covered by this EIS.	
JF, GF, SH, DJ, BD and RM Chapman	Proprietors "Cooroorah", Blackwater.	19/09/2001	Letter. Response to Draft TOR	The impact the Project will have on the cotton growing areas of properties which are adjacent to the McKenzie River and immediately opposite lot 16 (part of "Jellinbah"), "Mouralyan" and Minnie Plains".	1.2	Impact on adjacent agricultural lands	Already addressed in DTOR. S 6.1.1 of the Draft TOR states that potential environmental harm on adjacent areas used for agriculture should be described. S 6.10.6 of the DTOR states that potential impacts on land use on adjoining sites resulting from the project should be identified. No change to DTOR required.	Potential impacts from air emissions and the potential impacts to adjacent agricultural areas are discussed in Appendix 0 (Volume 4 - Air Quality) and in Section 4.5 of Volume 1 of the EIS. 4.1.10 of Volume 1 of the EIS describes Agricultural Impacts. Impacts from potential increased inundation are discussed in Section 4.2.1.1.	
JF, GF, SH, DJ, BD and RM Chapman	Proprietors "Cooroorah", Blackwater.	19/09/2001	Letter. Response to Draft TOR	The Draft TOR should be expanded in relation to sec 5.09 (air quality) to include a consideration of properties outside of the proposed mining leases in the same way that clause 5.10 (noise environment) considers noise sensitive areas outside the proposed mining lease area.	1.3	Air quality	S 5.9 of the DTOR states that air quality of "surrounds" and "air shed" will be described. This does not restrict description to MLA area. The FTOR states that the scope of the region to be potentially affected be discussed in Section 4.7 of the FTOR.	Section 4.5 of volume 1 of the EIS describes potential impacts from dust on surrounding areas. Appendix O also describes potential impacts of dust on surrounding areas.	
JF, GF, SH, DJ, BD and RM Chapman	Proprietors "Cooroorah", Blackwater.	19/09/2001	Letter. Response to Draft TOR	My clients also have a great concern as to the impact of the proposed mining lease on the amenity of the area particularly with noise and dust pollution, the potential for discharge of hazardous waste and the consequent adverse impact on neighbouring properties. The terms of reference should be expanded to specifically make reference to consideration of these aspects outside the area of the proposed mining leases.	1.4	Noise, Air quality, Hazardous wastes	AIR - S 6.6 DTOR requires a description of emissions, potential impacts on and mitigation strategies for surrounding receivers — Section 3.9 of the Final TOR was amended to state that a description of the existing air shed should be provided having regard for particulates and that the potential impacts on air quality on surrounding residences including "Coorooorah" and "Minnie" Plains homesteads will be assessed. NOISE - S 6.8 of the DTOR states that noise levels at noise sensitive receivers	Section 4.5 of volume 1 of the EIS describes potential impacts from dust on surrounding areas. Appendix O also describes potential impacts of dust on surrounding areas. Potential noise impacts are described in Section 4.8 including the impacts on surrounding sensitive receivers. 2.3.6 of Volume 1 of the EIS describes hazardous waste management.	
JF, GF, SH, DJ, BD and RM Chapman	Proprietors "Cooroorah", Blackwater.	19/09/2001	Letter. Response to Draft TOR	Requested copy of Final TOR	1.5	-	EPA provide a copy of Final TOR to all people who provided submissions to the DTOR.	EPA to provide final TOR to all submitters.	
Mr Ron Weatherall, Regional Director	Department of Families, Central Queensland Region.	24/09/2001	Letter. Response to Draft TOR	The meeting of the 25/07/01 was informed that the construction and operation of the coal mine would be sub-contracted. The contract between the proponent and sub-contractor should include identified components to reduce or mitigate social impacts on the local community and traditional owners during construction and operation of the coal mine.	2.1	Social Impacts associated with the engagement of contractors including impacts on Traditional Owners	S 6.10 of the DTOR describes social impact issues to be addressed in the EIS. Social and environmental impact mitigation strategies will be incorporated as EMOS commitments and consequently EA conditions. Wesfarmers as the EA holder will be required under the EP Act 1994 to ensure that any person (including contractors) carrying out mining activities under the EA comply with all EA conditions are complied with. Wesfarmers will include compliance with EA conditions in contractual agreements with sub-contractors.	CHIMA has been signed. 3.9 and 4.4 in the EIS details cultural heritage. 3.13 and 4.10 details the social and economic environment. The EMOS contains proposed social EA conditions and cultural heritage management strategies. Wesfarmers is required to ensure that any contractors comply with the EMOS and EA. This issue will be addressed by Wesfarmers internally when drafting contractor agreements.	

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Dave Mason, Acting Executive Director	Minerals and Petroleum Division, Department of Natural Resources and Mines, Brisbane.	10/09/2001	Letter. Response to Draft TOR	Concern that the recovery of coal resources from the deposit is maximised and that other of the State's mineral resources are not adversely affected or sterilised by the proposed project or its associated infrastructure. -It is suggested that the proponent could incorporate data pertaining to resources as well as any related comments and analysis of this information into the section dealing with "Resources and Mining Process" including data on and due consideration of coal seam adjacent to the target Pisces Seam (i.e. stratigraphically higher or lower) that are not planned to be mined as part of this project.	3.1	Maximisation Recovery of resources, Resource sterilisation	S 4.2 and 4.3 of DTOR state that resources and mining methodology will be described in EIS, but does not include specifically efficient recovery of resources and resource sterilisation. S 2.2 in the Final TOR has been ammended to state that a full description of the target resource, adjacent coal resources and resources other than coal within the excavation area and the significance of those resources will be discussed. Furthermoreline 149 in S 2.2 was added in to the Final TOR and states that a justification of the location of excavation with respect to optimal recovery of recources and discussion of constraints to maximising recovery of the coal resource.	2.2 of the EIS details available resources and economically recoverable coal and provides justification for locations of excavations to achieve optimal recovery of resources taking into account the constraints of the immediate and surrounding environment.	
Dave Mason, Acting Executive Director	Minerals and Petroleum Division, Department of Natural Resources and Mines, Brisbane.	10/09/2001	Letter. Response to Draft TOR	Impact on the groundwater resources with particular emphasis on the interconnectivity between the proposed operation and the Mackenzie River.	3.2	Hydrology and Water Quality	S 6.3.2 of DTOR amended to include assessment of interconnectivity between river and pit. Specifically, lines 913, 914 and 915 in S4.4.2 of the Final TOR state that an assessment of the impacts of groundwater resoucres should include an assessment of the potential hydraulic connection between pit waters and the river system.	4.2 and specifically 4.2.2.2 describe the potential connectivity of the Mackenzie and groundwater resources and potential impacts on groundwater quality.	
Dave Mason, Acting Executive Director	Minerals and Petroleum Division, Department of Natural Resources and Mines, Brisbane.	10/09/2001	Letter. Response to Draft TOR	The proponent should adopt a rehabilitation strategy that employs conventional shaping of spoil and accepted revegetation principles.	3.3	Final rehabilitation strategy	Rehabilitation already covered in DTOR - S 6.1.1 of the Draft TOR states that rehabilitation techniques should be described. No change to DTOR required.	4.1.11 and 4.1.6 details rehabilitation for the Project. Rehabilitation commitments are made in the EMOS.	
Athol Backhouse, District Manager	Capricorn District, Department of Natural Resources and Mines, Rockhampton	20/08/2001	Letter. Response to Draft TOR	A description of the various alternative ways of carrying out the project should be provided in the EIS, and reasons for selecting the preferred mine plan should be related to information provided on potential impacts in Section 6 of the EIS.	4.1	Project Alternatives	S 3.5 of the DTOR already states that the decision making process for the project should be included in the EIS, that alternatives to various aspects of the Project should be reviewed and discussed and that reasons for selecting the preferred options and courses of action in terms of technical, commercial social and environmental aspects. Issue already addressed in DTOR. No change to DTOR required.	Project alternatives are discussed in 1.3.3 and 1.6 of the EIS.	
Athol Backhouse, District Manager	Capricorn District, Department of Natural Resources and Mines, Rockhampton	20/08/2001	Letter. Response to Draft TOR	Given the high agricultural value of the subject land and adjacent properties, and close proximity of the proposal to the Mackenzie River, discussion of post-mining land use options should occur at an early stage during the public consultation process (Section 3.3.4).	4.2	Community Consultation, Final Land Use	Details of Community consultation not relevant for inclusion in DTOR, no changes to be made to DTOR. Discussions of post-mining land use to be included in Stakeholder Consultation Plan which is to be detailed in EIS.	4.1 of the EIS discusses post mining landform and land use changes and post mine land use options.	
Athol Backhouse, District Manager	Capricorn District, Department of Natural Resources and Mines, Rockhampton	20/08/2001	Letter. Response to Draft TOR	The outcome of public consultation process should be taken into account when proposing post-mining land use, which in turn will influence the mine plan and the land rehabilitation program.	4.3	Community Consultation, Final Land Use	S 6.10.1 of DTOR amended to include statement that the EIS should provide details of the outcomes of community and stakeholder consultation, and specific commitments resulting from community and stakeholder consultation. Details of how the Stakeholder Consultation Plan is to be used as a vehicle for ongoing communications should be described in the EIS.	The outcome of community and stakeholder consultation is addressed in Volume 2 of the EIS in Appendix B. The EMOS (Volume 4) further describes community consultation commitments.	
Athol Backhouse, District Manager	Capricorn District, Department of Natural Resources and Mines, Rockhampton	20/08/2001	Letter. Response to Draft TOR	Change heading of S 6 to "Environmental, Social and Economic IMAPCTS AND Management Strategies"	4.4	Typographical	In the Final TOR the heading for S 4 is "Environmental, Social and Economic Impacts and Management Strategies"	None required.	
Athol Backhouse, District Manager	Capricorn District, Department of Natural Resources and Mines, Rockhampton	20/08/2001	Letter. Response to Draft TOR	S 5.2 - Reference to physical and chemical properties of the soils that influence the potential agricultural productivity of the land is also required.	4.5	Baseline soils information, Post-mining agricultural productivity	Change made to DTOR. S 3.21 of the Final TOR states that the agricultural use potential of soils (including potential for cropping) will be addressed.	3.2.3 (Volume 1) describes topsoil characteristics as does Appendix H (Volume 4)	
Athol Backhouse, District Manager	Capricorn District, Department of Natural Resources and Mines, Rockhampton	20/08/2001	Letter. Response to Draft TOR	S 5.2 – A more detailed scale such as 1:5000 is required for the areas to be disturbed	4.6	Baseline soils information	S 5.2 of DTOR states that soils are to be mapped at a "suitable scale", but does not specify scales. No change was made to the FTOR		
Athol Backhouse, District Manager	Capricorn District, Department of Natural Resources and Mines, Rockhampton	20/08/2001	Letter. Response to Draft TOR	S 5.2 – In relation to the intention to appraise the depth and quality of useable soil for rehabilitation, it is suggested that the outcome of this appraisal be reported in the EIS through the development of a Topsoil Management Plan to support the rehabilitation program and post-mining land use.	4.7	Baseline soils information	S 5.2 of DTOR does not specify that Topsoil Management Plan is to be prepared. In s 3.2 of the Final TOR it states that a soil management plan is to be prepared and incorporated into the EIS.	The Soil Management Plan is detailed Volume 1 section 4.1.3 of the EIS and in the EMOS (Volume 4).	

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Athol Backhouse, District Manager	Capricorn District, Department of Natural Resources and Mines, Rockhampton	20/08/2001	Letter. Response to Draft TOR	S 5.3 – The description of land use on the subject land and adjacent properties should include the location and extent of land which is either currently used or has been used in the past for dryland and irrigated cropping.	4.8	Existing Land Use, past land use	Change made to DTOR. S 3.3 lines 459, 461 and 462 of the Final TOR state that past land use will be described including the location and extent of land used for dryland and irrigated cropping.	2.1.3 and 3.3 (Volume 1) describes the properties underlying the Project and adjacent to the Project.	
Athol Backhouse, District Manager	Capricorn District, Department of Natural Resources and Mines, Rockhampton	20/08/2001	Letter. Response to Draft TOR	S 6 – Potential impacts that could occur after mining has ceased should be predicted and management strategies developed.	4.9	Post-mining impacts	Change made to DTOR. S 4.2 of the Final TOR states that the stability of the final landform under post-mining land use should be addressed. Additionally any limitations to the return of the land to a landform suitable for agricultural production will be discussed. Line 800 S 4.2 states that the potential environmental harm caused by the project , over the mine life and post-mining on the agricultural production from adjacent areas currently used for agriculture should be described	Section 4.1 (Volume 1) of the EIS describes post mining land form and land use changes and details the rehabilitation strategy.	
Athol Backhouse, District Manager	Capricorn District, Department of Natural Resources and Mines, Rockhampton	20/08/2001	Letter. Response to Draft TOR	S 6 – The future maintenance of all rehabilitated areas and constructed levees should be addressed. This assumes that levees will be left in place after mine decommissioning.	4.1	Maintenance and stability of post-mining landforms, Final rehabilitation strategy	FTOR requires rehabilitation monitoring be addressed	Post mine rehabilitation monitoring is addressed in 4.1.12 of the EIS and the EMOS (Volume 4). 4.2.11 details flood levee construction impacts.	
Athol Backhouse, District Manager	Capricorn District, Department of Natural Resources and Mines, Rockhampton	20/08/2001	Letter. Response to Draft TOR	S 6.1 – The EIS should investigate and report on the acid generating potential of all mine spoil/waste rock and propose strategies to ensure that impacts on the quality of water leaving the site are minimised.	4.11	Mine waste management	Change made to S 6.1 of DTOR. In S 4.1 lines 758 to 762 it states that the potential acid forming characteristics of mine waste should be estimated and presented in the EIS and that management strategies for watse should also be described if appropriate.	4.1.1 (Volume 1) describes the acid forming potential of spoil. Mitigation strategies are detailed in the EMOS (Volume 4).	
Athol Backhouse, District Manager	Capricorn District, Department of Natural Resources and Mines, Rockhampton	20/08/2001	Letter. Response to Draft TOR	S 6.1.1 – DNRM expects that the five-class land suitability classification system will be used in making pre-mine and post-mine comparisons.	4.12	Post-mining Land Use, Baseline land suitability assessment	Change made to DTOR. S 4.2 line 784 in the Final TOR states that the land suitability should be described according to the five class land suitability classification systems.	3.2.4 of the EIS describes the land suitability classes, and are detailed in the EMOS. 3.2.5 assesses the post mining and land use options using the land capability classification.	
Athol Backhouse, District Manager	Capricorn District, Department of Natural Resources and Mines, Rockhampton	20/08/2001	Letter. Response to Draft TOR	S 6.1.1 - In order to make valid pre-and post-mine comparisons it is also recommended that soil and landform limitation subclasses assigned to map units to derive the land suitability classes to be reported in the EIS.	4.13	Baseline land suitability assessment	Changemade to DTOR. S 4.2 lines 785 to 787 state that the soil and landform limitation subclasses assigned to map units to derive that land suitability classes should be included.	Figure 3.3 and 3.4 (Volume 1) of the EIS details land suitability classes	
Athol Backhouse, District Manager	Capricorn District, Department of Natural Resources and Mines, Rockhampton	20/08/2001	Letter. Response to Draft TOR	S 6.1.1 – The proposed pre-mine and post-mine land suitability should include areas considered from the pre-mining assessment to be Good Quality Agricultural Land and how such land can be returned to agricultural use.	4.14	Post-mining Land Use	S 6.1.1 of the DTOR states that post-mining land use options and suitability for use as agriculture, and description of post-mining land use, as well as rehabilitation techniques will be provided in EIS. DTOR-amended to be more specific in terms of identification and post-mining land use of GQAL.	3.2.4 of the EIS describes the land suitability classes, and are detailed in the EMOS. 4.1.5 of the EIS assesses the post mining land use options using the land capability classification. The agricultural impacts and rehabilitation strategy are detailed in 4.1.11 and 4.1.12 of the EIS.	
Athol Backhouse, District Manager	Capricorn District, Department of Natural Resources and Mines, Rockhampton	20/08/2001	Letter. Response to Draft TOR	S 6.1.1 – The pre-mine and post-mine land suitability should include a description the overall impact of the proposed project on agricultural production from land adjacent to the mining lease applications over the life of the mine and post-mining (implied in Section 6.10.6).	4.15	Post-mining Land Use	S 6.1.1 of the Draft TOR states that potential environmental harm on adjacent areas used for agriculture should be described.	3.2.4 of the EIS describes the land suitability classes, and are detailed in the EMOS. 4.1.5 of the EIS assesses the post mining land use options using the land capability classification. The agricultural impacts and rehabilitation strategy are detailed in 4.1.11 and 4.1.12 of the EIS.	
Athol Backhouse, District Manager	Capricorn District, Department of Natural Resources and Mines, Rockhampton	20/08/2001	Letter. Response to Draft TOR	S 6.1.1 – The pre-mine and post-mine land suitability should include a description of alternative strategies to the proposal to leave voids after mining in terms of the affect of their presence on the usefulness of the land for long-term agriculture use, and reasons for choosing the preferred alternative.	4.16	Post-mining Land Use, Project alternatives, Post-mining landforms, Final voids	S 3.5 of DTOR to be amended to specifically include final landforms (voids) reasons for choosing preferred alternative. S 6.1.1 DTOR amended to include a description of any final voids and their role in the proposed final land use. S 1.5 states that all feasible and prudent alternatives including final landforms should be fully reviewed and discussed.	3.2.3 and 3.2.4 (Volume 1) of the EIS describes the land suitability classes, and are detailed in the EMOS (Volume 4). 4.1.5 of the EIS assesses the post mining land use options using the land capability classification. The agricultural impacts and rehabilitation strategy are detailed in 4.1.11 and 4.1.12 of the EIS.	
Athol Backhouse, District Manager	Capricorn District, Department of Natural Resources and Mines, Rockhampton	20/08/2001	Letter. Response to Draft TOR	S 6.1.1 - Proposed erosion protection measures for constructed levees.	4.17	Levees -erosion protection	S 2.8.2 entitled Flood Protection Infrastructure has been added in to the Final TOR and states that details on the construction of the levees, including erosion protection and design criteria of the levees in terms of erosion protection should be discussed.	4.1.12 details rehabilitation strategies which include levees. 4.2 addresses flood levee construction impacts, erosion and stability levees	
Athol Backhouse, District Manager	Capricorn District, Department of Natural Resources and Mines, Rockhampton	20/08/2001	Letter. Response to Draft TOR	S 6.1.1 - Criteria to be used in assessing success of overall rehabilitation program and the proposed maintenance of rehabilitation areas should be described.	4.18	Rehabilitation monitoring	S 4.2 lines 810 and 811 in the Final TOR states that the proposed methods for assessing rehabilitation success should be described.	4.1.12-details rehabilitation monitoring and success criteria.	
Athol Backhouse, District Manager	Capricorn District, Department of Natural Resources and Mines, Rockhampton	20/08/2001	Letter. Response to Draft TOR	S 6.3.1 – The assessment should also include any potential impact of the proposed project on the integrity of existing watercourses on or adjacent to the land subject to the mining lease applications. This includes the potential impact of proposed levees on the integrity and stability of the Mackenzie River.	4.19	Hydrology, Impacts of levees	S 6.3.1 of the DTOR states that the potential impact on flow and quality of surface waters in the catchment area of the site should be assessed. S4.4.1 in the Final TOR has bee edited to include an extensive assessment of the potential impacts of proposed levees on the integrity and stability of the Mackenzie River.	4.2.1 (Volume 1) of the EIS describes potential impacts on surrounding watercourses.	
Athol Backhouse, District Manager	Capricorn District, Department of Natural Resources and Mines, Rockhampton	20/08/2001	Letter. Response to Draft TOR	S 6.3.1 – Any proposed levee, stream diversions or works on watercourses, whether temporary or for the mine life, should be described in sufficient detail in the EIS to allow a determination of whether such works will require licensing under the Water Resources Act 1989.	4.2	Hydrology, Approvals required	S4.4.1 in the Final TOR states that an assessment should be made of the likely effects on the catchment area of the site from any temporary diversion or bunding of exsiting water courses.	No mention of levee licensing at this point.	

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Athol Backhouse, District Manager	Capricorn District, Department of Natural Resources and Mines, Rockhampton	20/08/2001	Letter. Response to Draft TOR	S 6.3.1 – The EIS should specifically address the affects of the proposed levees on increased flood height and flood velocity on the land subject to mining leases and surrounding land including impact on the stability of the Mackenzie river and justification for the width of the riparian zone.	4.21	Hydrology, Stability of Mackenzie River	AFFECT OF LEVEES: S 6.3.1 of the DTOR states that details of changes to the flow regime of surface waters resulting from the alteration of drainage networks should be provided in the EIS. S 4.5 of the Final TOR states that any obligations imposed by relevant State or Commonwealth legislation or policy with respect to buffer zones should be disscussed. The proposed width of any buffer zones should be justified.	Section 4.2.1 (Volume 1) describes potential impacts on surface waters.	
Athol Backhouse, District Manager	Capricorn District, Department of Natural Resources and Mines, Rockhampton	20/08/2001	Letter. Response to Draft TOR	S 6.3.1 – Flood protection afforded by the proposed levees for all mine infrastructure, including potential spoil dumps.	4.23	Hydrology	S 2.8.2 entitled Flood Protection Infrastructure has been added in to the Final TOR and states that a detailed description of the required flodd protection infrastructure is to be provided	4.2.1.1 and 2.8.2 (Volume 1) describes flood protection of levee and potential impacts associated with the levee.	
Athol Backhouse, District Manager	Capricorn District, Department of Natural Resources and Mines, Rockhampton	20/08/2001	Letter. Response to Draft TOR	S 6.3.1 – Water quality in the proposed final voids in terms of proposed post-mining land use.	4.24	Final voids - water quality	S 4.4.1 in the Final TOR states that the risk of the final void water inpacting on potential post-mining land uses will be discussed.	4.2.1.4 describes the water management of final voids.	
Athol Backhouse, District Manager	Capricorn District, Department of Natural Resources and Mines, Rockhampton	20/08/2001	Letter. Response to Draft TOR	S 6.3.2 - Impacts of the project on existing groundwater resources.	4.25	Groundwater impacts	S 6.3.2 in the DTOR states that an assessment of the potential environmental harm casused by the Project to local groundwater resources be included.	4.2.2.1 describes existing groundwater users.	
Athol Backhouse, District Manager	Capricorn District, Department of Natural Resources and Mines, Rockhampton	20/08/2001	Letter. Response to Draft TOR	S 6.4 – Any obligations for the protection of remnant native vegetation under the Vegetation Management Act 1999.	4.26	Protection of remnant vegetation	S3.6 line 536 states that any obligations for the protection of remnant vegetation under the Vegetation Management Act 1999, should be discussed.	3.6.1.7 describes the remnant native vegetation on the Project site as per the Vegetation Mangement Act.	
Brad Carter, Director	State Development Centre Rockhampton, State Development, Rockhampton.	25/07/2001	Letter. Response to Draft TOR	The project in terms of providing reliable and cost effective access to coal resources to fuel the Stanwell Power Station. This access subsequently impacts on the supply of electricity to process industries in the region, and in particular, supports the global competitiveness of the Stanwell Energy Park. In addition, and in light of the recent coal mine closures, the project would be expected to have a positive impact on the local Blackwater and Central Highlands community.	5.1	Project need	No change to final TOR necessary.	None required	
Gavin McCullagh, Policy Officer	Department of Emergency Services, Brisbane	21/09/2001	Letter. Response to Draft TOR	S 6.10.4 –Impact on existing emergency services.	6.1	Impact on emergency services	S 4.11.4 states that the project's impacts on the emergency services will be discussed	4.10.4 describes impacts on community services. We note that the impact on emergency services is not specifically addressed.	
Gavin McCullagh, Policy Officer	Department of Emergency Services, Brisbane	21/09/2001	Letter. Response to Draft TOR	S 6.11 – It is recommended that an analysis be made of safety matters related to other on-site accidents and also definition of the plans for responding to medical emergencies, injuries due to accidents and entrapment of personnel.	6.2	Health and safety	No change to final TOR necessary.	Addressed in 4.11 (Volume 1) of the EIS and the Curragh Mine Safety Management system and Safety Policy. policies and procedures as stated in the EIS.	
Gavin McCullagh, Policy Officer	Department of Emergency Services, Brisbane	21/09/2001	Letter. Response to Draft TOR	S 6.11 - It is also recommended that an all hazard risk assessment of natural hazards be undertaken.	6.3	Health and safety	S 4.12 of the Final TOR states that the EIS should include an assessment of bushfire and flood risks and precautions taken to reduce these risks. In addition details of disaster management planning should also be provided in the EIS	Addressed in 4.13 of the EIS and Curragh Mine Safety Management System and Safety Policy.	
Dr R. L Miles, Director	Regional Services (Central), Department of Primary Industries	10/09/2001	Letter. Response to Draft TOR	S 3.5 - The TORs should be considering the cumulative impacts of mining in the proposed location.	7.1	Cumulative impacts of mining in the.	S 6.0 of the DTOR states that impact assessment should account for cumulative effects. Already addressed in DTOR, no change to DTOR required.	3.3 is Land use and tenure. One mining lease is proposed as described in 3.3. The assessment of the Project is based on a description of the existing environment in section 3.0 of the EIS.	
Dr R. L Miles, Director	Regional Services (Central), Department of Primary Industries	10/09/2001	Letter. Response to Draft TOR	S 5.1 A description of the proposed site in relation to the catchment system and any waterways or wetlands on or near the site is required.	7.2	Existing wetlands	S3.1 of the Final TOR states that a description of the proposed site in relation to the catchment system and any waterways or wetlannds or lagoons on or near the site is required.	3.4.1.2 and 4.2 (Volume 1) provides a description of surface waters, wetlands are not found on the Project site.	
Dr R. L Miles, Director	Regional Services (Central), Department of Primary Industries	10/09/2001	Letter. Response to Draft TOR	S 5.2 – A description and map (at a suitable scale) is required that covers areas to be disturbed, with particular reference to those physical and chemical properties of the soils and mine spoil/waste rock which may influence erosion potential, agricultural use potential, a rehabilitation program, or the quality of water leaving the site	7.3	Baseline soils information, Baseline land capability information.	S 3.2 of the Final TOR states a description and map (at a suitable scale) is required that covers areas to be disturbed, with particular reference to those physical and chemical properties of the soils and mine spoil/waste rock which may influence erosion potential, agricultural use potential, a rehabilitation program, or the quality of water leaving the site	Where are these issues addressed in the EIS?	
Dr R. L Miles, Director	Regional Services (Central), Department of Primary Industries	10/09/2001	Letter. Response to Draft TOR	S 5.4 - A description of the environmental values of the surface waterways or wetlands of the Project site and surrounding land is required.	7.4	Existing wetlands	S 3.4 lines 498 and 499 state that a description of the environmental values of the surface waterways or wetlands of the Project site and surrounding land is required.	4.2 provides a description of surface waters. Wetlands are not found on the Project site.	
Dr R. L Miles, Director	Regional Services (Central), Department of Primary Industries	10/09/2001	Letter. Response to Draft TOR	S 5.4 – Physical integrity, fluvial processes and morphology of watercourses or wetlands, including riparian zone vegetation and form.	7.5	Surface Waters	S 3.4 lines 502 and 503 state that the physical integrity, fluvial processes and morphology of watercourses or wetlands, including riparian zone vegetation and form.	3.4 describes hydrology and water quality. There are no wetlands on the Project site.	

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Dr R. L Miles, Director	Regional Services (Central), Department of Primary Industries	10/09/2001	Letter. Response to Draft TOR	S 5.12 – This section should discuss the pre-mining economic value of the land and the numbers of people living on the properties proposed to be mined that will need to be relocated and where the services used by these people currently are accessed.	7.6	Economic impacts on relocating landholders, Impacts on services	S 3.12 in the Final TOR states that the pre-mining economic value of the land to be mined, the numbers of people living on the land proposed to be mined, and where the services used by these people are assessed be described.	4.10 and 4.12 (Volume 1) address social infrastructure, accommodation and economic impacts associated with the Project.	
Dr R. L Miles, Director	Regional Services (Central), Department of Primary Industries	10/09/2001	Letter. Response to Draft TOR	S 6.1 – The effects of any intended land disposal of wastes on the subsequent potential uses of the land in question should be discussed.	7.7	Waste Management, Post-mining land use	Post mining land use is detailed in the FTOR as is waste management, inlcuding overburden.	3.3 and 4.1 (Volume 1) address waste management strategies and post mining land uses. Waste commitments are detailed in the EMOS (Volume 4).	
Dr R. L Miles, Director	Regional Services (Central), Department of Primary Industries	10/09/2001	Letter. Response to Draft TOR	S 6.1.1 – DPI wishes to see included in the TORs, an alternative proposal for land rehabilitation whereby the levees are removed and the voids backfill.	7.8	Project Alternatives, Voids, final landform	S 3.5 of the DTOR states that alternatives to various aspects of the Project should be reviewed and discussed and that reasons for selecting the preferred options and courses of action will be discussed in terms of technical, commercial social and environmental aspects. Therefore, an assessment of alternatives is already included in the DTOR and no changes to the DTOR are required. S 6.1.1 of the DTOR also states that rehabilitation techniques and post-mine land use suitability (that is rehabilitation standards) should be described in the EIS. Rehabilitation standards are already addressed in the DTOR and no changes to the DTOR are required.	4.1.12 details rehabilitation strategies which include levees. 4.1.5 addresses post mining land use options.	
Dr R. L Miles, Director	Regional Services (Central), Department of Primary Industries	10/09/2001	Letter. Response to Draft TOR	S 6.3.1 – The requirement for approval under the Fisheries Act 1994 to undertake waterway barrier works should be specifically identified.	7.9	Approvals required	Already addressed in DTOR. S 3.4 of the Draft TOR states that necessary approvals for the project will be identified in the EIS (in the section dealing with regulatory framework).	Statutory approvals are detailed in Appendix C.	
Dr R. L Miles, Director	Regional Services (Central), Department of Primary Industries	10/09/2001	Letter. Response to Draft TOR	S 6.3.1 - Potential impacts of the levee banks on accelerated erosion and possible river/stream realignment, with particular reference to the gap between the northern system (on "Jellinbah") and the southern system (on "Mourallyn").	7.1	Hydrology, Impacts of levee on Mackenzie River hydrology	S 6.3.1 of the DTOR states that details of changes to the flow regime of surface waters resulting from the alteration of drainage networks should be provided in the EIS.	Appendix G (Volume 3) describes the potential hydrological impacts and 4.2.1 (Volume 1)	
Dr R. L Miles, Director	Regional Services (Central), Department of Primary Industries	10/09/2001	Letter. Response to Draft TOR	S 6.4 - Provisions of buffer zones and movement corridors as strategies to minimise environmental harm should be discussed.	7.11	Riparian buffer zones	S 4.5 in the paragraph starting at line 960 states that buffer zones and any legislative obligations should be discussed including a justification of the proposed width of the buffer.	The existing riparian zone is to remain largely intact.	
Dr R. L Miles, Director	Regional Services (Central), Department of Primary Industries	10/09/2001	Letter. Response to Draft TOR	S 6.6 - Impacts of dust from coal loading facilities on the project site, traffic movement within site and to Curragh Mine and the deposition of coal dust from uncovered transport vehicles within and beyond the site.	7.12	Air quality	S 4.7 of the Final TOR dot point two states that these issues will be discussed as part of the EIS.	4.5.4 (Volume 1) details potential sources of emissions and associated potential impacts are described in 4.5.1. The EMOS (Volume 4) details further mitigation strategies.	
Dr R. L Miles, Director	Regional Services (Central), Department of Primary Industries	10/09/2001	Letter. Response to Draft TOR	S 6.10 – Impacts of the proposal on existing and potential agricultural production.	7.13	Impact on adjacent agricultural land use.	S 6.1.1 of the DTOR states that post-mining land use options and suitability for use as agriculture, description of post-mining land use, and restrictions to land use will be provided in EIS. S 6.1.1 of the Draft TOR also states that potential environmental harm on adjacent areas used for agriculture should be	4.1.11 (Volume 1) details potential agricultural impacts.	
Dr R. L Miles, Director	Regional Services (Central), Department of Primary Industries	10/09/2001	Letter. Response to Draft TOR	S 6.12 - Potential impacts on the existing rural community and flow-on effects to the wider community in terms of services that are currently used.	7.14	Social Impacts, Impacts on current services	S 6.10.4 states that impacts on services and facilities should be discussed. Already addressed in DTOR.	Section 1.3.4, 4.10, 4.12 (Volume 1) covers social and economic benefits and potential impacts.	
David Strain, Assistant Manager	Central Public Health Unit Network, Queensland Health, Rockhampton	26/07/2001	Letter. Response to Draft TOR	Part A1.1 - the EIS document should be produced in electronic (PDF) format made available on the internet-and text/graphics should be produced in an appropriate resolution.	8.1	EIS format	FTOR covers submissions and availability of the EIS.	The EIS will be available in PDF from the Wesfarmer's webpage. Section 1.4.4.1 details the web address.	
David Strain, Assistant Manager	Central Public Health Unit Network, Queensland Health, Rockhampton	26/07/2001	Letter. Response to Draft TOR	Part B 4.1 - The description of the proposed site should also include details of the nearest occupied dwellings and larger settlements	8.4	Description of existing environment - nearest residences	S 2.1 line128 in the Final TOR states that a the description of the nearest occupied dwellings and larger settlements should be discussed.	Section 2.1 (Volume 1) details the Project location and surrounding land tenure.	
David Strain, Assistant Manager	Central Public Health Unit Network, Queensland Health, Rockhampton	26/07/2001	Letter. Response to Draft TOR	Part B 4.6 - Add the following: "Wastes from village accommodation and methods of removal and/or onsite treatment e.g. composting, recycling, recycling, landfill".	8.5	Waste disposal	S2.6 paragraph beinning at line 236 states that wastes from village accommodation and methods of removal and/or onsite treatmentwill be discussed.	Waste management is detailed in Section 2.6 (Volume 1). There will not be an accommodation village at the Project site.	
David Strain, Assistant Manager	Central Public Health Unit Network, Queensland Health, Rockhampton	26/07/2001	Letter. Response to Draft TOR	Part B 4.6 - Add the following: "Proposed methods of treatment of potable water and monitoring of quality".	8.6	Water treatment	s 2.7 of the FTOR states that any proposed potable water treatment methods and proposed monitoring of potable water quality.	Potable water infrastructure is detailed in Section 2.7.8 (Volume 1) and treatment is detailed in the EMOS (Volume 4).	
David Strain, Assistant Manager	Central Public Health Unit Network, Queensland Health, Rockhampton	26/07/2001	Letter. Response to Draft TOR	Part B 4.6 - Add the following: "Proposed methods of vector control, particularly mosquito breeding, in effluent pond".	8.7	Vector control	FTOR states information should be provided on accommodation, facilities for food preparation, ablutions and vector control (Paraphrased from Section 2.9 of the FTOR).	Workforce will be housed in Blackwater and no specific vector control methods are in place at the Project Site.	
David Strain, Assistant Manager	Central Public Health Unit Network, Queensland Health, Rockhampton	26/07/2001	Letter. Response to Draft TOR	Part B 4.9 - information on the size and type of accommodation, facilities for food preparation and storage, ablution facilities, vector control (with respect to vermin control and insect screening), and indoor air quality should be required under this heading.	8.8	Workforce requirements	FTOR states information should be provided on accommodation, facilities for food preparation, ablutions and vector control (Paraphrased from Section 2.9 of the FTOR).	Workforce will be housed in Blackwater, Section 2.10 (Volume 1) details the workforce requirements for the Project.	

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David Strain, Assistant Manager	Central Public Health Unit Network, Queensland Health, Rockhampton	26/07/2001	Letter. Response to Draft TOR	Part B 5.9 - Baseline data with respect to ambient levels of pollutants, airborne particulates and meteorology should be collected at receptor points such as the nearest properties and settlements to the proposed site. These sites should also be utilised as monitoring points once the mine is operational	8.9	Air quality	FTOR states in section 3.9 that background levels and sources of suspended particulates and any other major constituent of the ari environmenta must be discussed.	3.10 (Volume 1) describes the existing air quality. Appendix O (Volume 3) also describes background air quality.	
David Strain, Assistant Manager	Central Public Health Unit Network, Queensland Health, Rockhampton	26/07/2001	Letter. Response to Draft TOR	Part B 5.12 - add: "Services such as ambulance, hospital, police and Council".	8.1	Impacts on services, Impacts on facilities.	FTOR states to provide information on the Project's impact on services such as medical, emergency, law enforcement, education and social facilities.	Section 4.10.4(Volume 1) details government and community services.	
David Strain, Assistant Manager	Central Public Health Unit Network, Queensland Health, Rockhampton	26/07/2001	Letter. Response to Draft TOR	Part B 5.12 - Any discussion relating to the effect of the project on existing local and state labour markets.	8.11	Social Impacts	Not specifically addressed in the FTOR	3.13 (Volume 1) describes the existing social and economic environment and Section 1.3.3 (Volume 1) describes economic benefits of the Project.	
David Strain, Assistant Manager	Central Public Health Unit Network, Queensland Health, Rockhampton	26/07/2001	Letter. Response to Draft TOR	Part 6.31 - Identify areas of poor drainage , site runoff, ponding and potential for mosquito breeding.	8.12	Health and safety	Site hydrology is detailed in the FTOR	2.7(Volume 1) describes the water management system. Vector control is not specifically identified as there will be no accommodation village on the Project site.	
David Strain, Assistant Manager	Central Public Health Unit Network, Queensland Health, Rockhampton	26/07/2001	Letter. Response to Draft TOR	Part B 5.12 - Add: "Details and location of local residents using groundwater for drinking, stock or irrigation".	8.13	Existing groundwater use	S 3.4 of the Final TOR states that details will be provioded on the location of surrounding residents using the groundwater for drinking, stock watering or irrigation purposes.	4.2.2.1 (Volume 1) describes the potential impacts on existing groundwater users.	
David Strain, Assistant Manager	Central Public Health Unit Network, Queensland Health, Rockhampton	26/07/2001	Letter. Response to Draft TOR	Part B 6.6 - the first dot point under this heading should include odours, airborne particulates and dusts as examples of emissions.	8.14	Air quality	S 4.7 of the Final Tor dot point one states that examples of emissions will include odours,airborne particulates and deposited dust.	4.5.4 (Volume 1) details potential air emissions including sources and types (dust).	
David Strain, Assistant Manager	Central Public Health Unit Network, Queensland Health, Rockhampton	26/07/2001	Letter. Response to Draft TOR	Part B 6.6 - Define the scope of the potentially affected region, including one or more remote residences/settlements/towns potentially affected emissions from operations. Concern also raised as to the air modelling to be undertaken.	8.15	Air quality	S 4.7 of the Final TOR dot point one states that the scope will define the region to be potentially affected by emissions from the project activities, including residences, settlements and towns.	4.5.1 (Volume 1) details the region potetially affected. Air quality impacts and mitigation strategies are discussed in Section 4.5 (Volume 1) and the EMOS (Volume 4).	
David Strain, Assistant Manager	Central Public Health Unit Network, Queensland Health, Rockhampton	26/07/2001	Letter. Response to Draft TOR	Part B 6.10.4 - Law enforcement/policing and local government services should be included under this heading.	8.21	Community Services and facilities	S 4.11.4 of the Final TOR states thatimpacts of the Project on law enforcement and policing are to be discussed	4.10 (Volume 1) discusses potential social impacts including government and community services.	
David Strain, Assistant Manager	Central Public Health Unit Network, Queensland Health, Rockhampton	26/07/2001	Letter. Response to Draft TOR	Part B 6.10.5 - Impact on the community and services with respect to road transport injury should be described under this heading.	8.22	Transportation and infrastructure impacts	S4.11.5 of the Final TOR paragraph one has been editied to include the impacts of road safety and accidents and other impacts.	4.11 (Volume 1) details health and safety.	
David Strain, Assistant Manager	Central Public Health Unit Network, Queensland Health, Rockhampton	26/07/2001	Letter. Response to Draft TOR	Part B 6.11 - An environmental health risk assessment is necessary.	8.23	Health and safety	S4.12 of the Final TOR states that this section should include an assessment of health and safety risks.	4.11 (Volume 1) details health and safety.	
David Strain, Assistant Manager	Central Public Health Unit Network, Queensland Health, Rockhampton	26/07/2001	Letter. Response to Draft TOR	Part B 6.11 - Details of disaster management planning should also be required under this heading.	8.24	Health and safety	S4.12 line 1204 of the Final TOR states thatdetails of disaster management planning should also be provided in the EIS.	4.11 (Volume 1) details health and safety.	
W. S. McReight, District Director (Emerald)	Department of Main Roads, Central Region, Emerald.		Letter. Response to Draft TOR	Draft TOR in terms of road transport issues is satisfactory.	9.1	-	-	None required	
Jack Cembalisty, Environmental Officer	Queensland Rail, Brisbane		Letter. Response to Draft TOR	Draft TOR satisfactory	10	-	-	None required	
Gordon Webley, Chief Executive Officer	Broadsound Shire Council		Letter. Response to Draft TOR	Draft TOR satisfactory	11	-	-	None required	
Micahel Bent, Action Planner	Fitzroy Basin Association	20/09/2001	Letter. Response to Draft TOR	Opportunities should be pursued to link the project with local catchment planning and on-ground action projects.	12.1	Community involvement in project, Catchment Management	Community involvement in the project has been and will continue to be included in ongoing Stakeholder Consultation Plan proposed final land use and rehabilitation design and rehabilitation maintenance strategy. S4.4.1 line 873 states that how the water management system will conform to the relevant	Comments considered in Community and Stakeholder Consultation program and final land use design, which are dealt with in 4.12.1 and 4.1 (Volume 1) of the EIS respectively. Community involvement is covered in the EMOS (Volume 4).	
Micahel Bent, Action Planner	Fitzroy Basin Association	20/09/2001	Letter. Response to Draft TOR	The Environmental Monitoring Plan should be considered in relation to the water quality targets being developed as part of the National Action Plan for Salinity and Water Quality	12.2	Monitoring	S 5.2 on the Final TOR states that any obligations or requirements for monitoring and monitoring targets imposed by national or state policy or legislation (e.g. the National Action Plan for Salinity and Water Quality) should be detailed.	5.2 covers environmental monitoring.	
Micahel Bent, Action Planner	Fitzroy Basin Association	20/09/2001	Letter. Response to Draft TOR	S 3.3.4 - The issues associated with mining a major river floodplain.	12.3	Mining on a floodplain	As detailed in several places in the DTOR, the impacts of this mining Project on the Mackenzie River floodplain will be described fully in the EIS. No amendments to the DTOR were necessary.	4.2 (Volume 1) details potential impacts on surface water and groundwater including the floodplain.	
Micahel Bent, Action Planner	Fitzroy Basin Association	20/09/2001	Letter. Response to Draft TOR	S 3.5 - Alternative sources of coal from existing mines should be discussed.	12.4	Project Alternatives	S 1.5 line 108 of the Final TOR states that the option of obtaining coal from existing mines should also be discussed as a project alternative.	1.3.3 and 1.6 (Volume 1) discuss alternatives to the Project including sourcing from other sources in Queensland.	

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Micahel Bent, Action Planner	Fitzroy Basin Association	20/09/2001	Letter. Response to Draft TOR	S 4.9 - Opportunities to target youth and indigenous unemployment from local communities should be pursued.	12.5	Employment opportunities for locals	The Final TOR states that the opportunities to target youth and indigenous unemployment from local communities should be pursued. (Paraphrase from S 4.11.2 paragraph 2)	4.10 discusses potential social impacts including employment and training opportunities created by the Project. Curragh continues to be an equal opportunity employer.	
Micahel Bent, Action Planner	Fitzroy Basin Association	20/09/2001	Letter. Response to Draft TOR	S 5.1 A Description of wetlands/lagoons should also be included.	12.6	Wetlands	There are no wetlands/lagoons on the Project site - no amendments to the DTOR are required.	There are no wetlands or lagoons on the Project site.	
Micahel Bent, Action Planner	Fitzroy Basin Association	20/09/2001	Letter. Response to Draft TOR	S 5.2 Discussion of Good Quality Agricultural Land should include its Agricultural Potential re: crops	12.7	Agricultural Potential of land	S 3.2 of the Final TOR states that a description of th soils and agricultural use potential (including potential for cropping) should be provided. (paraphrase from parahraph one S 3.2 of the Final TOR)	4.1.10 details potential impacts on agricultural	
Micahel Bent, Action Planner	Fitzroy Basin Association	20/09/2001	Letter. Response to Draft TOR	S 5.4 - A risk assessment on the water quality at Bingegang Weir needs to be included.	12.8	Water Quality	S 3.4 paragraph two of the Final TOR states that an assessment is required of the existing water quality in surface water likely to be affected by the project, including Bingegang Weir.	3.4.1 and 4.2 (Volume 1) details existing surface water quality and potential impacts. Water quality if further discussed in Appendix I (Volume 3). Water quality protection commitments are made in the EMOS (Volume 4)	
Micahel Bent, Action Planner	Fitzroy Basin Association	20/09/2001	Letter. Response to Draft TOR	S 5.6 - Locally significant populations of animals (Wallaroo) should be identified and their migratory path assessed and incorporated into the mine plan.	12.9	Fauna	DTOR to be amended to include assessment of a local colony of Wallaroos. DTOR already states that impacts of alterations to the surface environment and provision of movement corridors should be discussed in the EIS.	Existing fauna environment is discussed in 3.6.1.9 (Volume 1). Wallaroos are specifically addressed in Section 3.6.1.9.5 . A complete Flora and Fauna Report is available in Appendix J (Volume 2).	
Micahel Bent, Action Planner	Fitzroy Basin Association	20/09/2001	Letter. Response to Draft TOR	S 5.7 - The Mackenzie River from both sides of the high bank should be considered an Environmentally Sensitive Area because impacts on one side of the river will also impact the other side.	12.1	Riparian Management	No change needed to the DTOR	3.8.1 describes environmentally sensitive areas in accordance with the requirements under the *Environmental Protection Act 1994* .	
Micahel Bent, Action Planner	Fitzroy Basin Association	20/09/2001	Letter. Response to Draft TOR	S 6.1.1 - With respect to good quality agricultural lands, areas which have land slopes less than 1% and soil depths exceed 1 meter (L.R.S. 21 - C.S.I.R.O. 1968), would be Class I. This appears to cover the bulk of the proposed mine site on both Mourallyn and Jellinbah.	12.11	Baseline land Suitability Assessment	Base line land suitability is detailed in the FTOR, as is a soil management plan.	3.2.34 describes the land suitability classes. 4.1.6 and 4.1.11 and the EMOS deal with land suitability and agricultural impacts. and are detailed in the EMOS.	
Micahel Bent, Action Planner	Fitzroy Basin Association	20/09/2001	Letter. Response to Draft TOR	S 6.1.1 - The final voids should progressively be filled as mining proceeds in preference to using pits spoil dumps.	12.12	Post-mining landform	FTOR details mining methodology and final landform.	Mining methodology is described in Section 2.3 (Volume 1). Final Landform is discussed in Section 4.1 (Volume 1).	
Micahel Bent, Action Planner	Fitzroy Basin Association	20/09/2001	Letter. Response to Draft TOR	S 6.1.1 - It should be specified that pre-mining soil structure be restored by ensuring the full depth of alluvial soil be replaced (using lazer level scrapers) on top of the contaminated soil/landfill used in lower sections of the voids.	12.13	Final Rehabilitation strategy	DTOR amended to include soil management strategy for returning post-mining land form to nominated land use capability. S 6.1.1. Of the DTOR states that rehabilitation techniques should be described in EIS.	3.2 (Volume 1) details soil properties which are further discussed in Appendix H (Volume 3). A soil management plan is discussed in Section 4.1.3 (Volume 1) and overburden placement is discussed in Section 2.3.1 (Volume 1)	
Micahel Bent, Action Planner	Fitzroy Basin Association	20/09/2001	Letter. Response to Draft TOR	S 6.1.1 - Post-mining use of the land should include being immediately farmed to cropping.	12.14	Post-mining Land Use	The Final TOR states that a detailed discussion of post-mining landuse options, including the suitability of the area mined to be used for agriculture.	2.3.4 and 2.3.5 (Volume 1) describe Land Suitability and Capability. Final land uses are discussed in Section 4.1 (Volume 1). Rehabilitation commitments are detailed in the EMOS (Volume 4) and in 4.1 (Volume 1).	
Micahel Bent, Action Planner	Fitzroy Basin Association	20/09/2001	Letter. Response to Draft TOR	S 6.1.1 - It needs to be established in the draft report that levee banks and all other topographical alterations made in preparation and during mining be removed.	12.15	Post-mining Land Use	S 4.2 states that a post-mining land use discussion will include a description of any final voids and their role in the proposed final land use.	4.1 (Volume 1) describes post mining land form and rehabilitation strategies. Further post mining commitments are detailed in the EMOS (Volume 4).	
Micahel Bent, Action Planner	Fitzroy Basin Association	20/09/2001	Letter. Response to Draft TOR	S6.1.1 - State planning for extractive industries should be consulted with regard to river gravel extraction. River gravel is a commodity and should be stored separately.	12.16	Resources	S 4.2 of DTOR amended to include identification, management and potential sterilisation of resources other than coal.	2.2.1.3 (Volume 1) describes other resources including sand and gravel.	
Micahel Bent, Action Planner	Fitzroy Basin Association	20/09/2001	Letter. Response to Draft TOR	S 6.1 - Reject tailings should be replaced in the bottoms of pits as mining progresses to avoid copious piles of contaminated material and expansive voids in the landscape.	12.17	Tailings management	Tailings not detailed in FTOR. Tailings not to be disposed of at the Project site	None required	
Micahel Bent, Action Planner	Fitzroy Basin Association	20/09/2001	Letter. Response to Draft TOR	S6.2.1 - Change in water flow may result in relocation of existing areas of sediment drop, and/or accelarated erosion activity and washing.	12.18	Hydrology/ Geomorphology	S 4.4.1 line 847 to 848 state that any changes to sediment drop both in waterways and on the floddplain due to any proposed changes in flow will be discussed.	4.2 (Volume 1) describes potential impacts to surface water quality. Further details on hydrology and geomorphology are included in Appendix G (Volume 3).	
Micahel Bent, Action Planner	Fitzroy Basin Association	20/09/2001	Letter. Response to Draft TOR	S6.2.1 - There is also the primary concern of the increased probability of levee bank failure.	12.2	Hydrology	S 4.4.1 line 853 to 855 state that an assessment of the stability of any proposed flood protection infrastructure, the risk of failure of flood protection infrastructure and potential impacts arising from such failure will be discussed.	4.2.1 and 2.7.1 describes levee construction	
Micahel Bent, Action Planner	Fitzroy Basin Association	20/09/2001	Letter. Response to Draft TOR	S6.2.1 - The land between the "Jellinbah" homestead and the Mackenzie River should be excluded from mine site. A lagoon presently lies between the homestead and the Mackenzie River and it adopts the role of being the main watercourse during times of flood. The present crusher plant site and western dump should be excluded from mine site. Other lagoons on lease area should be identified.	12.21	Hydrology	There are no wetlands/lagoons on the Project site - no amendments to the DTOR are required.	Section 2.2.1.4 (Volume 1) details the location of site infrastructure. However, there are no lagoons or wetlands on the Project MLA and are therefore not discussed in the EIS. The potential impacts on Three Mile and Five Mile lagoon, which are not on the Project MLA are discussed in Section 4.2.1.1 (Volume 1).	

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Micahel Bent, Action Planner	Fitzroy Basin Association	20/09/2001	Letter. Response to Draft TOR	S6.2.1 - A geomorphologist should be consulted on the possibility of river realignment.	12.22	Hydrology/ Geomorphology	DTOR amended to include realignment.	2.2.1.1 (Volume 1) discusses the potential impacts of the levee, which includes minimising the potential realignment of the Mackenzie River. Further details are found in Appendix G (Volume 3).	
Micahel Bent, Action Planner	Fitzroy Basin Association	20/09/2001	Letter. Response to Draft TOR	S 6.3 - Raw coal dust from trucks and crushing plant as well as run off sediment from roads may contaminate pounds, gullies etc and have detrimental effects on the associated aquatic and terrestrial life in the vicinity. Plant species in the immediate and nearby areas may also be adversely affected because of decreased photosynthesis activity resulting from excessive coatings of coal dust on their leaves.	12.23	Impacts of dust on terrestrial and Aquatic Fauna	DTOR amended to include assessment of impacts of sedimentation on aquatic and terrestrial flora and fauna. S 6.4 of DTOR already addresses issue of impacts of dust and other emissions on flora and fauna.	Impacts on the Mackenzie River and riparian vegetation are discussed in Section 4.6 (Volume 1) and further detailed in Appendix O (Volume 3).	
Micahel Bent, Action Planner	Fitzroy Basin Association	20/09/2001	Letter. Response to Draft TOR	S 6.3 - Potential displacement of terrestrial fauna.	12.24	Terrestrial Fauna	No changes necessary to final TOR .	4.3.1 (Volume 1) describes potential impacts and mitigation strategies for terrestrial fauna.	
Micahel Bent, Action Planner	Fitzroy Basin Association	20/09/2001	Letter. Response to Draft TOR	S 6.3 - Concern regarding the use of invasive plant and tree species in environmental buffer zones.	12.25	Final Rehabilitation strategy	No changes necessary to final TOR .	4.1 (Volume 1) details rehabilitation monitoring and success criteria. The EMOS (Volume 4) further details rehabilitation.	
Micahel Bent, Action Planner	Fitzroy Basin Association	20/09/2001	Letter. Response to Draft TOR	S 6.4 - Appropriate training in mining procedures should be made available to indigenous people well in advance of the anticipated commencement of mining activities.	12.26	Indigenous employment	The Final TOR states that the opportunities to target youth and indigenous unemployment from local communities should be pursued. (Paraphrase from S 4.11.2 paragraph 2)	4.10 (Volume 1) describes social impacts including equal opportunity employment.	
Micahel Bent, Action Planner	Fitzroy Basin Association	20/09/2001	Letter. Response to Draft TOR	S 6.6 - Potential impacts on the aquatic flroa and fauna, in particular associated with air impacts.	12.27	Air Quality	S 6.4 of DTOR already addresses issue of impacts of dust and other emissions on flora and fauna.	There are no known terrestrial species associated with the Mackenzie River. 4.6 (Volume 1) details potential air quality impacts on aquatic flora and fauna. Further details are found in Appendix O (Volume 3).	
Micahel Bent, Action Planner	Fitzroy Basin Association	20/09/2001	Letter. Response to Draft TOR	S 6.8 - If/when a new "Mourallyn" homestead is constructed in close proximity, it must be included in the list of homesteads to take into consideration. The "Scrubby" homestead was omitted from the list mentioned in the draft regarding this section, this needs to be amended by including it among the list to be taken into consideration.	12.28	Noise Impacts	FTOR requires details of sensitive receivers.	3.11 (Volume 1) details the requirements for noise modelling including homestead locations and 4.10 discusses predicted noise levels and potential impacts at homesteads. Noise monitoring commitments are detailed in the EMOS (Volume 4) and will be ammended should the new Mourallyn homestead be constructed in close proximity to the Project.	
Micahel Bent, Action Planner	Fitzroy Basin Association	20/09/2001	Letter. Response to Draft TOR	S 6.9 - Attention should be given to the development of an environmental buffer around the mine site.	12.29	Visual Amenity/Buffers	DTOR already addresses issue of buffers. No changes to draft TOR necessary.	The construction of the levee will act as a buffer around the Project. Design criteria are detailed in Section 2.8.2 (Volume 1).	
Micahel Bent, Action Planner	Fitzroy Basin Association	20/09/2001	Letter. Response to Draft TOR	S 6.10.1 - The long term viability of community and social impacts is not addressed.	12.3	Social impacts, Ongoing consultation	S 6.10 of DTOR amended to include assessment of social impacts throughout all phases of the project, including post-mining.	Section 1.3.4 (Volume 1) details social benefits. Social impacts are also discussed in Section 4.10 (Volume 1)	
Micahel Bent, Action Planner	Fitzroy Basin Association	20/09/2001	Letter. Response to Draft TOR	S 6.10.1 - The impact of the project on the environmental and productive values of the floodplain.	12.31	Ongoing consultation	Falls under several different aspects of the FTOR	Issue is dealt with in the Community Stakeholder Consultation Plan. Appendix B describes community consultation processes. Impacts on floodplain fall under several sections of Section 4 of the EIS (Volume 1)	
Micahel Bent, Action Planner	Fitzroy Basin Association	20/09/2001	Letter. Response to Draft TOR	S 6.10.2 - Training and employment opportunities for youth includi,ng indigenous youth.	12.32	Employment and training opportunities	The Final TOR states that the opportunities to target youth and indigenous unemployment from local communities should be pursued. (Paraphrase from S 4.11.2 paragraph 2)	4.11 describes social impacts including equal opportunity employment	
Micahel Bent, Action Planner	Fitzroy Basin Association	20/09/2001	Letter. Response to Draft TOR	S 6.10.3 - Workforce should be housed in the Blackwater township, not on site.	12.33	Workforce Accommodation	It states that details should be provided on housing and accomodation requirements including the location of workforce accommodation. (Paraphase from S 4.11.3 of the Final TOR)	4.12.3 deal with workforce accommodation and states that all Curragh employees will be offered accommodation in Blackwater. There will be no on site workforce accommodation.	
Micahel Bent, Action Planner	Fitzroy Basin Association	20/09/2001	Letter. Response to Draft TOR	S 6.10.5 - The Haul Road should not be located close to the Mackenzie River due to impacts on wildlife (road kill), noise (birds) and air and water quality. The Road should be located on the eastern portion of the mine site, and the option of integrating the mine transport infrastructure with existing mine (Jellinbah and Yarrabee) haul roads should be evaluated.	12.34	Haul Road Location	Site infrastructure a requirement of FTOR	2.2.1.4 details infrastructure location.	
Micahel Bent, Action Planner	Fitzroy Basin Association	20/09/2001	Letter. Response to Draft TOR	S 6.10.6 - The sediment drop on the flood plain adjoining the proposed mining lease may be different to current alluvial soils on the flood plain, due to the velocity of water.	12.35	Impacts and adjacent land use, geomorphology.	S 4.4.1 line 847 to 848 state that any changes to sediment drop both in waterways and on the floddplain due to any proposed changes in flow will be discussed.	4.2.1 describes surface water quality and existing alluvial soils in the floodplain.	
Micahel Bent, Action Planner	Fitzroy Basin Association	20/09/2001	Letter. Response to Draft TOR	S 6.12 - The loss of agricultural production has not been addressed	12.36	Economic Impacts	S 4.2 states that a decription should be provided of the pre-mine land capaility during which good quality agricultural land should be idenitifed. Addtionally post-mine land capailities should be discussed.	4.1.11 details agricultural impacts. Rehabilitation is discussed in Section 4.1 (Volume 1) and includes the possibility of returning to grazing. Land suitability and capability are discussed in Section 3.2.4 and 3.2.5 (Volume 1).	
Micahel Bent, Action Planner	Fitzroy Basin Association	20/09/2001	Letter. Response to Draft TOR	S 7.2 - Opportunities to integrate environmental monitoring, data sharing, and reporting, in particular water quality, with public State Government monitoring via Natural Resources and Mines or community based Waterwatch.	12.37	Environmental Monitoring	Environmental Monitoring included in FTOR	5.2 details environmental monitoring and legislative requirements.	
Peter Dunne	"Wallbury" Duaringa	20/09/2001	Letter. Response to Draft TOR	What material is between the surface and the coal seam to be used during production	13.1	Resources	S 4.2 of DTOR amended to include discussion of resources present on the project site and how they will be managed and the potential for sterilisation of resources other than coal.	2.8.2 (Volume 1) describes the use of spoil in the construction of levees.	
Peter Dunne	"Wallbury" Duaringa	20/09/2001	Letter. Response to Draft TOR	Why is there a need to mine between the high banks of the river.	13.2	Resources	S 4.2 of the DTOR states that location of excavations will be identified. DTOR amended to include justification of location of proposed excavations.	There is no mining between the high banks of the Mackenzie River.	

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Peter Dunne	"Wallbury" Duaringa	20/09/2001	Letter. Response to Draft TOR	S 3.1 - The bulk of the proposed mine site is Class 1 (CSIRO LRS21) and should be Class 1 post mining.	13.3	Post-mining Land Capability	FTOR states that post mining land capability be discussed.	4.2 describes post mining land use options	
Peter Dunne	"Wallbury" Duaringa	20/09/2001	Letter. Response to Draft TOR	S3.1 - "Concern that-'final voids' may be used as watering points".	13.4	Final landform, voids	DTOR amended to specifically include final landforms in Project alternatives and post-mining land use. DTOR amended to include a description of any final voids and their role in the proposed final land use	4.2.1.4 (Volume 1) describes final voids.	
Peter Dunne	"Wallbury" Duaringa	20/09/2001	Letter. Response to Draft TOR	S 3.1 - What are the specification for "top soil"?	13.5	Post-mining Land Capability	DTOR amended to include a soil management plan which details depth and quality of soil to be stockpiled as topsoil.	4.1.3 details soil management plan. Land capability and suitability are discussed in Section 3.2.4 and 3.2.5.	
Peter Dunne	"Wallbury" Duaringa	20/09/2001	Letter. Response to Draft TOR	S 3.2.1.1 - There appears to be conflict between the riparian zone and the Water Act 2000 which states "high bank".	13.6	Riparian buffer zone	S 6.4 of DTOR amended to include discussion of legislative and policy obligations with respect to buffer zones.	Appendix C details the legislative requirements for the Project.	
Peter Dunne	"Wallbury" Duaringa	20/09/2001	Letter. Response to Draft TOR	S3.2.1.1 - Parthenium and Parkinsonia are both declared weed species and need to be eradicated on-site at all times.	13.7	Weed Management	FTOR require a weeds be detailed	4.3.2 deals with potential impacts of weeds and control strategies. A weed survey report is detailed in Appendix L (Volume 3).	
Peter Dunne	"Wallbury" Duaringa	20/09/2001	Letter. Response to Draft TOR	S 3.2.1.3 - If this were rehabilitated to the full high bank zone and then 200 metres the river would not receive the expected dust from the haul road and mine site. There is significant evidence that the western side of the haul road to 'Jellinbah' is experiencing such an effect.	13.8	Impacts on and management of riparian Zone, Dust impacts on terrestrial flora	s 6.6 of DTOR amended to include air quality impacts on waterways.	The likely impact of dust on riparian vegetation and on Mackenzie river water quality is dealt with in 4.6.2 and 4.6.3 of the EIS.	
Peter Dunne	"Wallbury" Duaringa	20/09/2001	Letter. Response to Draft TOR	The bulk of the Project area should be returned to Class 1 (agricultural land).	13.9	Final land form, final land use	Amend DTOR to be more specific and include discussion of final land form.	4.1 details final landform including land use changes and final landform stability. Land suitability and land capability are discussed in Section 3.2.4 and 3.2.5.	
Cliff Jones, Acting District Manager	Environmental Protection Agency, Rockhampton	21/09/2001	Letter. Response to Draft TOR	It is unclear why there is no commitment to house all workers in Blackwater to bring more benefits to the Duaringa Shire.	14.1	Mine village, Housing and Accommodation		4.11 (Volume 1) deals with social impacts, including housing and accommodation and states that all Curragh employees will be offered accommodation in Blackwater instead of the previously proposed on-site village accommodation.	
Cliff Jones, Acting District Manager	Environmental Protection Agency, Rockhampton	21/09/2001	Letter. Response to Draft TOR	The assumption that workforce will be able to be sourced locally has not been substantiated.	14.2	Employment and Training	S 6.10.2 of DTOR states that recruitment of the workforce should be described in the EIS.	4.11 describes social impacts including equal opportunity employment and training. 3.13 includes an employment profile of the locality.	
Cliff Jones, Acting District Manager	Environmental Protection Agency, Rockhampton	21/09/2001	Letter. Response to Draft TOR	Reference to Blackwater community groups should be included including the irrigators across the Mackenzie River.	14.3	Community involvement in project.	Local community detailed in FTOR	3.13. (Volume 1) describes the existing community.	
Cliff Jones, Acting District Manager	Environmental Protection Agency, Rockhampton	21/09/2001	Letter. Response to Draft TOR	The proposed and alternative rehabilitation strategies should be discussed in the EIS as well as the proposed EMOS inlcluding post mine capacility and landform stability .	14.5	Rehabilitation, Post Mining Landuse	FTRO details rehabilitation and research into new methods.	4.1 (Volume 1) details rehabilitation strategies, monitoring and success criteria. Land suitability and capability are discussed in Section 3.2.4 and 3.2.5 (Volume 1).	
Cliff Jones, Acting District Manager	Environmental Protection Agency, Rockhampton	21/09/2001	Letter. Response to Draft TOR	Maps provided do not reflect the suggestion that the haul road will connect with Curragh Mine internal haul roads - it appears to skirt Curragh mine and duplicate existing internal and main roads.	14.8	Haul Road Location	Map specifications not included in FTOR	Figure 1.2 shows the transportation corridor and proximity to Curragh Mine.	
Cliff Jones, Acting District Manager	Environmental Protection Agency, Rockhampton	21/09/2001	Letter. Response to Draft TOR	General directions were have been provided by the EPA in relation to the format and presentation of the EIS. These general directions do not require any amendment tobe made tothe draft TOR.	14.9	Maps and Diagrams	No amendment required.	None required	
Cliff Jones, Acting District Manager	Environmental Protection Agency, Rockhampton	21/09/2001	Letter. Response to Draft TOR	S 3 Line 335 - Add "…Project proponent and how this proposal complements their core business activities.".	14.17	Project proponent	How the proposal complements core business activities of Wesfarmers is not considered relevant to the EIS. No change to the draft TOR necessary.	None required	
Cliff Jones, Acting District Manager	Environmental Protection Agency, Rockhampton	21/09/2001	Letter. Response to Draft TOR	If the proponent is not proposing to conduct the mining then the proposed arrangements for the operation of the mine should be included.	14.18	Arrangements with subcontractor	Arrangements with the contractor is not considered relevant to the EIS. Wesfarmers is required as the holder of the EA to ensure that any contractors comply with the conditions of the EA. This issue will be dealt with internally by Wesfarmers. No change to the draft TOR is necessary.	Proponent is conducting the mining of the Project.	
Cliff Jones, Acting District Manager	Environmental Protection Agency, Rockhampton	21/09/2001	Letter. Response to Draft TOR	Statutory requirements for activities outside of the mining lease.	14.21	Statutory requirements	S 3.3.1 of DTOR amended to include statutory requirements of an EIS.	Legislative requirements for the Project are detailed in Appendix C.	
Cliff Jones, Acting District Manager	Environmental Protection Agency, Rockhampton	21/09/2001	Letter. Response to Draft TOR	Recommendation: Amend S 3.3.2 to be consistent with the draft generic TOR.	14.22	Submissions	DTOR-amended as requested.	None required	
Cliff Jones, Acting District Manager	Environmental Protection Agency, Rockhampton	21/09/2001	Letter. Response to Draft TOR	S 3.3.4 Line 370 - Add "…identify broad and specific issues…interested persons and document how these concerns were addressed.".	14.23	Typographical, minor	DTOR-amended as requested.	None required	

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Cliff Jones, Acting District Manager	Environmental Protection Agency, Rockhampton	21/09/2001	Letter. Response to Draft TOR	S 4.1 Line 407 - Add "…proposed site, historic, present and potential agricultural land uses…".	14.24	Typographical, minor	DTOR amended as requested. What does this change relate to? If typographical then it should be left out.	None required	
Cliff Jones, Acting District Manager	Environmental Protection Agency, Rockhampton	21/09/2001	Letter. Response to Draft TOR	Dust impacts in the existing locality.	14.26	Air Quality	Air quality impacts and mitigation strategies already addressed in DTOR.	3.10 deals with the existing air quality environment and 4.5 and 4.6 deal with potential air quality impacts.	
Cliff Jones, Acting District Manager	Environmental Protection Agency, Rockhampton	21/09/2001	Letter. Response to Draft TOR	The size of the proposed mining leases should be justified.	14.27	Jusitification of size of MLA areas	What actual amendments were made to the final TOR, if any?	1.6.4 provides justification of size of mining lease and final voids.	
Cliff Jones, Acting District Manager	Environmental Protection Agency, Rockhampton	21/09/2001	Letter. Response to Draft TOR	S 4.2 Line 417 - If land controlled by the proponent is to be used to mitigate the mining impacts then it should be formalised as a nature refuge agreement or similar tenure	14.28	Final land use	Details of final land use and specific impact management strategies already dealt with in DTOR.	4.1 deals with final land use including post mining land use options and conflict assessment, rehabilitation strategies and monitoring.	
Cliff Jones, Acting District Manager	Environmental Protection Agency, Rockhampton	21/09/2001	Letter. Response to Draft TOR	S 4.2 Line 425 - add "…any final void and the basis relied upon for such void to be left…". What does this mean? A general statement of the change requested would be better here.	14.3	Final voids	S 3.5 DTOR amended to include justification of final voids in discussion of justification of Project and assessment of Project alternatives	1.6.4 provides justification of size of mining lease and final voids.	
Cliff Jones, Acting District Manager	Environmental Protection Agency, Rockhampton	21/09/2001	Letter. Response to Draft TOR	S 4.3 Line 426 - As this site has the potential for deep alluvial soils, measures should be described that will maximise the selected handling of top soil and alluvial subsoils so that the production of prime agricultural land is maximised (eg. Topsoiling of waste dumps).	14.31	Final rehabilitation straategy, post-mining land use	S 6.1 of DTOR-amended to include description soil management techniques required for maximising opportunity of returning land to nominated post-mining land use.	4.1 deals with final land use and landforms, rehabilitation strategies and includes a soil management plan.	
Cliff Jones, Acting District Manager	Environmental Protection Agency, Rockhampton	21/09/2001	Letter. Response to Draft TOR	Records and local knowledge/evidence, of actual historic and recent flood events at the site should be discussed and mapped where possible.	14.35	Baseline geomorphology, Flood hydrology	S 4.3 of DTOR already states that reasons for the preferred operational option should be made clear. DTOR amended to require specification of the location of coal stockpiles and and crushers and mitigation strategies dor dust emissions from traffic and coal transport.	2.3.1.5 details coal handling Alternative methods for mining are considered in 1.6.3 of the EIS.	
Cliff Jones, Acting District Manager	Environmental Protection Agency, Rockhampton	21/09/2001	Letter. Response to Draft TOR	Material that is suitable for extractive industries (sand and gravel) should be separated during spoiling to minimise demand for this material from sensitive creek and river beds.	14.42	Recovery of Sand and Gravel Resources	S 4.2 and 4.3 of DTOR amended to include identification and management of resources other than coal in proposed excavation areas.	2.2.1.3 details other resources	
Cliff Jones, Acting District Manager	Environmental Protection Agency, Rockhampton	21/09/2001	Letter. Response to Draft TOR	S 4.9 Line 574 - Add "…also be stated. The proposed shift lengths and arrangements should be stated and reviewed with respect to current community concerns regarding fatigue management and family well-being associated with other mining projects in this state."	14.44	Health and Safety	If DTOR already deal with these issues - this should be stated.	4.12 details health and safety including the Curragh Safety Management System and Safety Management Policy.	
Cliff Jones, Acting District Manager	Environmental Protection Agency, Rockhampton	21/09/2001	Letter. Response to Draft TOR	The flooding history should be described using aerial photographs and remote sensed images to demonstrate alluvial patterns and a review of local knowledge of flood levels.	14.46	Baseline geomorphology, baseline soils information	EPA added "Flooding history" to final TOR.	3.4.2.4 details flood analysis, 4.2.1 details potential flood levee impacts and control strategies, and 4.1.8 details post mine flood protection. Further hydrology details are included in Appendix G (Volume 3).	
Cliff Jones, Acting District Manager	Environmental Protection Agency, Rockhampton	21/09/2001	Letter. Response to Draft TOR	The soils on the flood plain should be mapped for surface soil texture to confirm proposed river velocity models and should be considered in final land use.	14.47	Baseline geomorphology, baseline soils information. Final land use.	s 5.2 of DTOR states that soil texture should be included in EIS.	Geology and soils are addressed in 3.2 and 4.1.3. Post mining land use is discussed in 4.1.	
Cliff Jones, Acting District Manager	Environmental Protection Agency, Rockhampton	21/09/2001	Letter. Response to Draft TOR	S 5.2 the geomorphology of the river and flood plains should be investigated to describe the history of the channel movements and identify the risks of future river re-alignments.	14.49	Baseline geomorphology, baseline soils information	s6.3.1 of DTOR amended to include discussion of risk of river realignment.	3.4.2.4 details flood analysis, 4.2.1 details potential flood levee impacts and control strategies, and 4.1.8 details post mine flood protection. Further hydrology details are included in Appendix G (Volume 3).	
Cliff Jones, Acting District Manager	Environmental Protection Agency, Rockhampton	21/09/2001	Letter. Response to Draft TOR	The role of ana-branches in fluvial process should be interpreted by qualified geomorphologist.	14.5	Hydrology/ Geomorphology	s6.3.1 of DTOR amended to include discussion of floodplain geomorphology.	3.4.2.4 details flood analysis, 4.2.1 details potential flood levee impacts and control strategies, and 4.1.8 details post mine flood protection. Further hydrology details are included in Appendix G (Volume 3).	
Cliff Jones, Acting District Manager	Environmental Protection Agency, Rockhampton	21/09/2001	Letter. Response to Draft TOR	Old flow channels should be identified for potential hydraulic connection with the river or for the storage of groundwater reserves or potential leakage of pit waters back to the river system.	14.51	Existing groundwater hydrology	s 6.3.2 of DTOR-amended to include assessment of groundwater impacts with respect to potential interconnectivity between river and pit.	3.4.2 details Groundwater assessment.	
Cliff Jones, Acting District Manager	Environmental Protection Agency, Rockhampton	21/09/2001	Letter. Response to Draft TOR	Concern that final land use will provide for agriculture.	14.53	Final land use	DTOR amended to include provision for maximising suitability for nominated land use.	4.1 (Volume 1) details rehabilitation strategies post mining land uses, and agriculture impacts. Land suitability and capability are discussed in Section 3.2.4 and 3.2.5 (Volume 1).	
Cliff Jones, Acting District Manager	Environmental Protection Agency, Rockhampton	21/09/2001	Letter. Response to Draft TOR	Records and local knowledge/evidence, of actual historic and recent flood events at the site should be discussed and mapped where possible.	14.56	Baseline geomorphology, Flood hydrology	FTOR does not refer specifically to historic flood events. Flood studies are required.	Historical hydrological data is discussed in Appendix G (Volume 3)	

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Cliff Jones, Acting District Manager	Environmental Protection Agency, Rockhampton	21/09/2001	Letter. Response to Draft TOR	Location and extent of vegetation types.	14.57	Baseline flora assessment	DTOR amended to include commitment to providing description of methodology used in vegetation assessment in EIS to using standard methods adopted by Queensland Herbarium.	3.6 details flora surveys.	
Cliff Jones, Acting District Manager	Environmental Protection Agency, Rockhampton	21/09/2001	Letter. Response to Draft TOR	Fauna survey methodology should be stated and should be consistent with current best practice. The survey should identify species listed as rare, vulnerable or endangered under the Nature Conservation Act or the EPBC Act (including locally significant colony of Wallaroos).	14.65	Baseline flora assessment	FTOR requires that flora and fauna methodologies are described.	3.6 details fauna surveys. 4.3 details potential impacts on fauna. Further details of fauna surveys are included in Appendix J (Volume 2).	
Cliff Jones, Acting District Manager	Environmental Protection Agency, Rockhampton	21/09/2001	Letter. Response to Draft TOR	The condition of in-stream and riparian habitat, changes to natural hydrology and water quality and any other impacting or threatening processes should be discussed	14.71	Baseline fauna assessment, baseline flora assessment	This is stated in the FTOR.	3.6 details riparian vegetation. 4.3 details potential impacts on flora.	
Cliff Jones, Acting District Manager	Environmental Protection Agency, Rockhampton	21/09/2001	Letter. Response to Draft TOR	Address health and safety issues including the potential for Dawson River Sandfly plague.	14.72	Health and Safety	S 6.11 of DTOR amended to include assessment impacts of pooled waters and any mitigation strategies.	4.12 deals with Health and safety. Specifically the Dawson Sandfly Plauge is not discussed. The Project will not affect or create breeding habitat and there are provision	
Cliff Jones, Acting District Manager	Environmental Protection Agency, Rockhampton	21/09/2001	Letter. Response to Draft TOR	Environmentally Sensitive Areas and Environmental Resilience	14.73	Environmentally sensitive Areas, Environmental Resilience	S3.7 of the FTOR requires an assessment of environmentally senstive areas and environmental resilience.	3.8 deals with environmentally sensitive areas and environmental resilience.	
Cliff Jones, Acting District Manager	Environmental Protection Agency, Rockhampton	21/09/2001	Letter. Response to Draft TOR	Liaison with relevant Indigenous and non-Indigenous community/communities including representatives from the Ghungalu and Kangoulu Native Title Claimant Groups is required. A cultural heritage survey and report of the Project Area is also required. A permit must be obtained to carry out the survey.	14.76	Cultural Heritage	Cultural heritage is a requirement of the FTOR	CHIMA has been signed. 3.9 and 4.4 (Volume 1) details cultural heritage, the EMOS (Volume 4) further details cultural heritage.	
Cliff Jones, Acting District Manager	Environmental Protection Agency, Rockhampton	21/09/2001	Letter. Response to Draft TOR	An historic search should be undertaken to determine if any places within the proposed development area are affected by the provisions of the Queensland Heritage Act 1992. A report on historic heritage is required.	14.81	Queensland Heritage	Cultural heritage is a requirement of the FTOR	CHIMA has been signed. 3.9 and 4.4 in the EIS details cultural heritage. 3.13 and 4.11 details the social and economic environment. The EMOS contains proposed social EA conditions and cultural heritage management strategies.	
Cliff Jones, Acting District Manager	Environmental Protection Agency, Rockhampton	21/09/2001	Letter. Response to Draft TOR	A study of the existing product and climatic influences controlling the generation and distribution of dust in the locality is required (including PM10 and TSP). Baseline studies should be conducted in consultation with landholders who have experienced dust problems in the past.	14.85	Air quality impacts	s3.9 of the FTOR covers background air quality.	Baseline air quality studies are detailed in 3.10.2. Further details on background air quality are found in Appendix O (Volume 3) 3.5 details climate and meteorology.	
Cliff Jones, Acting District Manager	Environmental Protection Agency, Rockhampton	21/09/2001	Letter. Response to Draft TOR		14.86	Air quality impacts	Already addressed in DTOR in a general way. However DTOR to be amended to include PM 10 particle and deposited dust, and comments to be considered during assessment of baseline air quality and air quality impacts to be detailed in EIS.		
Cliff Jones, Acting District Manager	Environmental Protection Agency, Rockhampton	21/09/2001	Letter. Response to Draft TOR	Proposals for continuous monitoring of weather conditions across the site should be described.	14.87	Air quality, ongoing monitoring	Continous climatology monitoring is not included in the FTOR.	3.5 details climate and meteorology which is continuously monitored.	
Cliff Jones, Acting District Manager	Environmental Protection Agency, Rockhampton	21/09/2001	Letter. Response to Draft TOR	Final land use and impacts on agriculture need to be addressed (including GQAL).	14.88	Final Land use	USA rehabilitation literature is not considered to be relevant. However DTOR to be amended to state that "Any limitations to the return of the land to a landform suitable for agricultural production should be discussed with reference to local landcare and mining practices and relevant literature".	4.1 (Volume 1) details land resources including agricultural impacts and final rehabilitation.	
Cliff Jones, Acting District Manager	Environmental Protection Agency, Rockhampton	21/09/2001	Letter. Response to Draft TOR	Rehabilitation strategies need to address staging in accordance with progress of mining, the extent of changes to natural hydrology and the stability of the final land form to flooding under likely post-mining land use.	14.91	Hydrology, Post-mining landform, Rehabilitation strategies	s 4.2 covers rehabilitation in the FTOR, including flooding.	4.1.11 detail rehabilitation strategies.	
Cliff Jones, Acting District Manager	Environmental Protection Agency, Rockhampton	21/09/2001	Letter. Response to Draft TOR	S6.1.1 Line 806 - The site could be mapped using electromagnetic induction technology to identify stored salts in the soil profile and this used to design rehabilitation to agricultural land. A soil profile needs to be undertaken and considered in the rehabilitation strategies.	14.93	Baseline land suitability assessment, soil profile rehabilitation	Rehabilitation strategies are required under s4.2 of the FTOR. Soil profiling is not sepcifically addressed.	3.2 and 4.1 (Volume 1) details soil profiles and rehabilitation. Land use capabilities are discussed in Section 3.2.5 (Volume 1).	
Cliff Jones, Acting District Manager	Environmental Protection Agency, Rockhampton	21/09/2001	Letter. Response to Draft TOR	Selectively stripped alluvial soils should be returned to a profile acceptable for agriculture	14.94	Final rehabilitation strategy	S 6.1 of DTOR amended to include description soil management techniques required for maximising opportunity of returning land to nominated post-mining land use.	Top soil management plan and rehabilitation is detailed in the EMOS (Volume 4) and in 4.1 details rehabilitation	
Cliff Jones, Acting District Manager	Environmental Protection Agency, Rockhampton	21/09/2001	Letter. Response to Draft TOR	Rehabilitation success criteria should include agricultural production.	14.95	Post-mining land use, Final rehabilitation strategy	DTOR amended to include success criteria.	4.1.11 details rehabilitation strategies which includes success criteria. Rehabilitation is expected to be to native habitat and not agriculture.	
Cliff Jones, Acting District Manager	Environmental Protection Agency, Rockhampton	21/09/2001	Letter. Response to Draft TOR	Post mining land form and land use changes need to be addressed (including agricultural impacts).	14.96	Post-mining landform	DTOR amended to include discussions on any limitations to the return of the land to a landform suitable for agricultural production.	4.1 details post mining land form, agricultural impacts and rehabilitation strategies including success criteria.	
Cliff Jones, Acting District Manager	Environmental Protection Agency, Rockhampton	21/09/2001	Letter. Response to Draft TOR	Mine plans should be designed so that voids progressively reduce in size and can be refilled to minimise out of pit dumps and disruption to the landscape	14.98	Post-mining landform, final voids	DTOR-amended to specifically include final landforms in Project alternatives and post-mining land use. DTOR to be amended to include a description of any final voids and their role in the proposed final land use	Mining methodology is discussed in Section 2.3 (Volume 1). 4.1.8 (Volume 1) details final voids and 2.6.1.1 details dumps.	

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Cliff Jones, Acting District Manager	Environmental Protection Agency, Rockhampton	21/09/2001	Letter. Response to Draft TOR	Bunding should be planned for removal following extraction of coal so that disruption to the natural flow of floodwaters can be minimised.	14.99	Post-mining landform	Details of final landform not relevant for inclusion in DTOR. However, comments to be considered when designing final landform design and considered as a Project alternative, which are to be detailed in EIS. DTOR to be amended to specifically include final landforms in Project alternatives and post-mining land use.	The rehabilitated levee with be part of the final landform which is discussed in Section 4.1. The hydrology of the levee is discussed in Section 4.2.1.1 (Volume 1)	
Cliff Jones, Acting District Manager	Environmental Protection Agency, Rockhampton	21/09/2001	Letter. Response to Draft TOR	The proposed 10m lifts on dumps are excessive and dumps should be redesigned to maximise return to agricultural land.	14.1	Post-mining landform	DTOR amended to include discussions on any limitations to the return of the land to a landform suitable for agricultural production.	2.6.1.1 details dumps and 4.1. details final land form and rehabilitation.	
Cliff Jones, Acting District Manager	Environmental Protection Agency, Rockhampton	21/09/2001	Letter. Response to Draft TOR	Any dumps required should be aligned with the flow of floods so that bunds can be removed and there is minimal increase in flood water velocity.	14.101	Post-mining landform	Specifically, this is not addressed in the FTOR. There is a requirements for the potential impacts on the integrity ans stability of watercourses.	The rehabilitated levee with be part of the final landform which is discussed in Section 4.1. Dumps are discussed in Section 2.6.1.1	
Cliff Jones, Acting District Manager	Environmental Protection Agency, Rockhampton	21/09/2001	Letter. Response to Draft TOR	The changes to natural hydrology resulting from the project during mining and post-mining should be defined in terms of impacts such as; Frequency of flow events defining river geomorphology; Frequency of flow events impacting on adjacent land use; and Velocity of flow events at sensitive locations on the floodplain.	14.102	Impacts on local hydrology	FTOR details flooding impacts in 4.4.1	Potential impacts on surface water are addressed in 4.2.1.Further details on hydrology are included in Appendix G (Volume 3).	
Cliff Jones, Acting District Manager	Environmental Protection Agency, Rockhampton	21/09/2001	Letter. Response to Draft TOR	The environmental values of surface waters potentially affected by the project should be identified.	14.104	Water quality	FTOR details surface water impacts in 4.4.1	3.4.1 details surface water quality, including environmental values. Water quality is further discussed in Appendix I (Volume 2).	
Cliff Jones, Acting District Manager	Environmental Protection Agency, Rockhampton	21/09/2001	Letter. Response to Draft TOR	The effect of surface runoff and planned and unplanned discharge of waters from the site should be discussed.	14.105	Water quality	Surfacewater environmental values are required under section 4.4.1 of the FTOR	3.4.1 details surface water quality. Discharge criteria is discussed in the EMOS (Volume 4).	
Cliff Jones, Acting District Manager	Environmental Protection Agency, Rockhampton	21/09/2001	Letter. Response to Draft TOR	Management strategies should be adequately detailed to demonstrate best practice management and that environmental values (with associated water quality objectives) will be maintained.	14.106	Water quality	Management strategies are required under 4.4.1 of the FTOR	4.2 (Volume 1) details the potential impacts on surface water quality. The EMOS (Volume 4) details water quality monitoring and water quality commitments.	
Cliff Jones, Acting District Manager	Environmental Protection Agency, Rockhampton	21/09/2001	Letter. Response to Draft TOR	Where possible the natural land surface should be retained in lieu of total recovery of the potential resource	14.107	Post-mining landform, Resource recovery	s 4.2 of DTOR amended to include justification of mine excavation(s) boundaries, and justification of location of excavation with respect to optimal recovery of resources and discussion of constraints to maximising recovery of coal resource.	Section 2.2.1.2 details the justification of excavation including areas of coal not mined for environmental reasons.	
Cliff Jones, Acting District Manager	Environmental Protection Agency, Rockhampton	21/09/2001	Letter. Response to Draft TOR	Bunding should not encroach on the lower banks as shown on plans and should be separated from the river by the buffer strips. Lower flood ana-branches should not be impacted by bunds or other mining activities.	14.109	Location of levees, Impacts of levees on hydrology	All watercourse works including levees are required to be detailed in s 2.8.2 of the FTOR.	Section 2.2.1.4 details site infrastructure location. The impacts of the construction of the flood levee is detailed in Section 4.2.1.1	
Cliff Jones, Acting District Manager	Environmental Protection Agency, Rockhampton	21/09/2001	Letter. Response to Draft TOR	Haul roads should be directed away form the river inside bunded areas not along bund walls.	14.11	Haul roads routes, Mine Layout		The transportation corridor travels on the east side of the Project. The location of the transportation corridor is found in Section 2.8.	
Cliff Jones, Acting District Manager	Environmental Protection Agency, Rockhampton	21/09/2001	Letter. Response to Draft TOR	A risk assessment should be conducted on the potential for sediment for waste dumps or other mining activities to be transported into the impoundment of the Bingegang Weir downstream	14.111	Water quality	Sediments are a requirement of the FTOR	Water monitoring is detailed in the EMOS (Volume 4) and water management system are detailed in section 2.7.3 (Volume 4).	
Cliff Jones, Acting District Manager	Environmental Protection Agency, Rockhampton	21/09/2001	Letter. Response to Draft TOR	A water balance for the operation, particularly inside the bunded area should be described and validated for test rainfall events such as for the rains from Cyclone Joy.	14.112	Water Usage	s 4.7 of DTOR-amended to include water balance and assessment of capacity of on site water storage for various storm events.	2.7.5 (Volume 1) details the Project water balance assessment.	
Cliff Jones, Acting District Manager	Environmental Protection Agency, Rockhampton	21/09/2001	Letter. Response to Draft TOR	Acid mine drainage: The potential for the generation of sulphate (either acid or neutral) should be described.	14.113	Waste management	S 6.1 of DTOR to be amended.	3.2.2 details potential acid mine drainage. Control strategies are detailed in the EMOS (Volume 4).	
Cliff Jones, Acting District Manager	Environmental Protection Agency, Rockhampton	21/09/2001	Letter. Response to Draft TOR	There should be a salt balance for the operation described, any potential need for discharges justified in the context of cumulative impacts on the water quality in the Fitzroy Basin.	14.114	Water quality	S 6.3.1 of DTOR to be amended to include description of properties of discharge waters and their impact.	Water monitoring is detailed in the EMOS (Volume 4) as are potential discharge criteria which will be in compliance with agreed Environmental Authority conditions.	
Cliff Jones, Acting District Manager	Environmental Protection Agency, Rockhampton	21/09/2001	Letter. Response to Draft TOR	Describe strategic and operational measures to establish and maintain the management pest plants and animals consistent with current best land care practice.	14.115	Pest and weed management	FTOR requires that pest control stategies be detailed, inlcuding plants and feral animals.	4.3 details weed management and pest animal control. Further details are found in Appendix J (Volume 2).	
Cliff Jones, Acting District Manager	Environmental Protection Agency, Rockhampton	21/09/2001	Letter. Response to Draft TOR	Potential impacts on the stability of banks should be avoided by avoiding disturbance of vegetation on the lower levees of the river. Set-backs (buffers around 200m) from the river should be incorproated and managed to enhance the natural values and hence stability of the bank.	14.118	Riparian buffer zone	Buffer zone justification is detailed in s 4.5 of the FTOR	4.3.1.1 describes potential flora impacts and control strategies.	
Cliff Jones, Acting District Manager	Environmental Protection Agency, Rockhampton	21/09/2001	Letter. Response to Draft TOR	The~~re~~ balance between tree and ground cover (such as endemic Lignum bush) should be managed to maximise soil protection from erosion	14.12	Riparian buffer zone	Not specifically addressed in FTOR.	4.3.1.2 describes flora impact strategies.	
Cliff Jones, Acting District Manager	Environmental Protection Agency, Rockhampton	21/09/2001	Letter. Response to Draft TOR	A process of consultation with riparian neighbours, commit to fence both banks of the river to exclude cattle and provide off-stream watering points.	14.121	Riparian buffer zone, riparian zone management	DTOR amended to include identification of opportunities for neighbours and community groups to become involved in riparian zone management.	Community consultation is detailed in Appendix B.	
Cliff Jones, Acting District Manager	Environmental Protection Agency, Rockhampton	21/09/2001	Letter. Response to Draft TOR		14.134	Air quality, Ongoing monitoring	Details of proposed monitoring is not relevant for inclusion in EIS. However comments to be considered when designing air quality monitoring plan which as stated in S 7.2 will be detailed in EIS.	3.10 deals with the existing air environment and 4.5 deals with potential impacts and costs/strategies. Air quality monitoring is detailed in the EMOS.	

NAME	ORGANISATION	DATE OF CONTACT	FORM OF CONTACT	ISSUES RAISED	REF.	ISSUE TOPIC	RESPONSE	DETAILS OF ACTION TAKEN/TASKS AND RESPONSIBILITIES	
Cliff Jones, Acting District Manager	Environmental Protection Agency, Rockhampton	21/09/2001	Letter. Response to Draft TOR	S 6.6 Line 912 - Add: Standards for monitoring of dust from the site in sensitive locations such as along the Mackenzie River and also along haul routes should be proposed using conventional and ecological methods (impact on vegetation/fauna?)	14.135	Air quality, Ongoing monitoring		4.5 (Volume 1) details potential air quality impacts.	
Cliff Jones, Acting District Manager	Environmental Protection Agency, Rockhampton	21/09/2001	Letter. Response to Draft TOR	The Stakeholder Consultation plan should have documented outcomes and specific commitment proposals presented in the EIS based on information collected to date - as well as being an ongoing vehicle for communication.	14.137	Stakeholder Consultation Plan, Ongoing community consultation	s 4.11.1 requires that a stakeholder consultation plan be developed with ongoing opportunities.	Community consultation is detailed in Appendix B and the EMOS.	
Cliff Jones, Acting District Manager	Environmental Protection Agency, Rockhampton	21/09/2001	Letter. Response to Draft TOR	The strategy for sourcing of workforce personnel locally mentioned in the introduction (line 180) should be discussed and quantified.	14.14	Employment of locals	S 6.10.2 of DTOR already states that recruitment of the workforce should be described in the EIS.	4.11 (Volume 1) details social impacts including employment	
Cliff Jones, Acting District Manager	Environmental Protection Agency, Rockhampton	21/09/2001	Letter. Response to Draft TOR	Measures to address current community concerns about fatigue management and the impact of family units associated with mining project should be detailed.	14.141	Health and safety	Not sepcifically addressed in FTOR.	4.12.2 details health and safety	
Cliff Jones, Acting District Manager	Environmental Protection Agency, Rockhampton	21/09/2001	Letter. Response to Draft TOR	The location of existing and proposed additional housing and other accommodation facilities for the project must be specified and the potential to bring more benefits to the local shire should be discussed.	14.142	Mine village, Housing and Accommodation	Housing and accommodation alternatives considered and reason for choosing preferred alternative will be addressed in Project needs and alternatives section of EIS.	4.11 details housing, 1.3.4.2 details social benefits and 4.12 details other social impacts.	
Cliff Jones, Acting District Manager	Environmental Protection Agency, Rockhampton	21/09/2001	Letter. Response to Draft TOR	The specific option to upgrade the sealed road to the Bedford Weir for the hauling of coal to Curragh should be discussed.	14.143	Transportation, Infrastructure	DTOR provide for alternatives to be discussed.	1.6 deals with project alternatives and 2.7 deals with mine infrastructure.	
Cliff Jones, Acting District Manager	Environmental Protection Agency, Rockhampton	21/09/2001	Letter. Response to Draft TOR	Provide an overview of management strategies and control measures to be used to minimise the risk of incident on site and to conditions.	14.145	Flood risks and management, Health and Safety	The DTOR amended to include an assessment flood risks and precautions taken to reduce these risks	4.13.12 details health and safety including safety management procedures and policies. Further control strategies are provided in the EMOS (Volume 4).	
Cliff Jones, Acting District Manager	Environmental Protection Agency, Rockhampton	21/09/2001	Letter. Response to Draft TOR	Detail the monitoring programs implemented or proposed to ensure that the pre- and post-mining management of the site reflects current best practice for Land Care. Detail specific research programs to evaluate the return of mined land to agricultural production.	14.149	Rehabilitation, monitoring	S 7.2 of DTOR to be amended to state that rehabilitation monitoring should be detailed in this section and should include a description of program for monitoring and assessment of post-mining land suitability and capability of rehabilitated areas.	Rehabilitation monitoring is detailed in 5.0 (Volume 1) of the EIS the EMOS (Volume 4). Rehabilitation monitoring is detailed in 4.1.13 of the EIS.	

APPENDIX B

COMMUNITY CONSULTATION REGISTER

Date	Stakeholders	Consultation type	Information provided	Issues raised/discussed	How issues were considered	Decisions/outcomes	Commitments
14/10/2022	Department of Environment and Science	Pre-lodgement meeting	SLR and CCPL provided a presentation on the work undertaken for the PRCP.	• Stable embankments land use • Objectives of the cover design • Hydrogeology technical modelling report • NUMA location change	CCPL and SLR have taken away the comments made by DES and are making small changes to the PRCP to address this feedback.	The PRCP will be submitted by 21st October 2022.	The PRCP will be submitted by 21st October 2022.
09/08/2022	Underlying Landholder	One-on-one meeting with CCPL and SLR	Presentation on PRCP framework, proposed post-mining land uses and ongoing engagement process	• Rehabilitating for the final land use of grazing • Final voids responsibility • Erosion • Retention of Infrastructure • Potential grazing trials for management techniques	Peter has offered to provide information on this recommended grazing management that can be incorporated into the rehabilitation strategy at Curragh.	• Peter to provide grazing management advice • CCPL to continue to engage with Peter on updates • SLR and CCPL to focus on the final land user when developing PRCP • Noted that the PRCP would have all infrastructure to be removed with the purpose of continuing to engage on this aspect	• CCPL will continue to engage with Peter on rehabilitation and closure • Further discussion on the retainment of infrastructure post-closure to occur • Peter to provide grazing management advice
07/06/2022	Department of Environment and Science	Site visit	Tour of site and update on PRCP progress	• Availability of tailings data and capping design for PRCP	Discussion with DES on weather impacting opportunities to take tailings sampling.	• DES advised CCPL to try looking at historical imagery for deposition times • Provide as much information as possible in PRCP	No commitments made.
10/05/2022	Gaangalu Nation People	Quarterly Coordinating Committee Meeting	Presentation on PRCP framework, proposed post-mining land uses and ongoing engagement process	• Rehabilitation seed collection and potential for supply by local indigenous supplier • Interest in CCPL completing fauna surveys as evidence of species use of area and suitability of rehabilitation • Potential for returning artefacts to the land	Further discussion required for the rehabilitation monitoring and return of artefacts to the land.	• CCPL asked for a list of target species for potential fauna surveys • CCPL will need to discuss the return of artefacts with native title applicants and consider the post-mining land use	• CCPL will provide the Rehabilitation Monitoring Report • An update on the PRCP and return of artefacts will be provided in the next meeting
17/11/2021	Near Neighbours	Near Neighbours Meeting	Provided presentation including an introduction to PRCPs.	No issues raised.	No issues raised.	Engagement for information purposes.	No rehabilitation/closure commitments made.
01/06/2021	Department of Environment and Science	PRCP Pre-lodgement Meeting	• Site background information • CCPL's interpretation of Land Outcome Documents • PRCP Delivery Schedule	• Pre-approved NUMAs • Inclusion of new areas as pre-approved NUMAs • Combined PMLUs • PRCP Delivery	• DES acknowledged that the EA allowed for the presence of voids as NUMAs • The Residual Void study will need to be updated to include any additional areas • DES had no issue with the combined use of open woodland and grazing	• CCPL will update the Residual Void study and submit it prior to 30 November 2021 • The PRCP due date of 21st October 2022 was decided	• DES to send formal transition notice in 2-4 weeks
19/02/2020	Near Neighbours	Near Neighbours Meeting	• Overview of the Curragh Extension Project and Exploration Program • Drill site rehabilitation	No issues raised.	No issues raised.	Engagement for information purposes.	No rehabilitation/closure commitments made.
30/08/2019	Gaangalu Nation People	Quarterly Coordinating Committee Meeting	• Discussion on rehabilitation and cultural material • Established rehabilitation areas	No issues raised.	No issues raised.	Engagement for information purposes.	No rehabilitation/closure commitments made.
2001 - 2003	• Landholders • Traditional Owners • Duaringa Shire Council • DNRM, Sunwater and the QEPA	• Meetings with local landholders • Meetings with Traditional Owners • Ongoing negotiations with Council • Discussions and meetings with DNRM, Sunwater and the QEPA	• Community Consultation and Environmental Report • Draft ToR • EIS	Please see Appendix A for the full details of all consultation and feedback received. Items relating to mine closure and rehabilitation have been highlighted in yellow for ease of reading.			

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APPENDIX B

Environmental Authority EPML00643713

Permit

Environmental Protection Act 1994

Environmental authority EPML00643713

This environmental authority is issued by the administering authority under Chapter 5 of the Environmental Protection Act 1994.

Environmental authority number: EPML00643713

Environmental authority takes effect on 1 August 2022

The anniversary date of this environmental authority is 31 May each year.

The anniversary date of this environmental authority is the same day each year as the take effect date. The payment of the annual fee will be due each year on this day.

An annual return will be due each year on 01 April.

Environmental authority holder(s)

Name(s)	Registered address
CORONADO CURRAGH PTY LTD	Level 31, Central Plaza One 345 Queen Street BRISBANE CITY QLD 4000

Environmentally relevant activity and location details

Environmentally relevant activity/activities	Location(s)
Schedule 3 13: Mining black coal	ML1878, ML1990, ML700006, ML700007, ML700008, ML700009, ML80010, ML80011 ML80012, ML80086, ML80110, ML80112, ML80123, ML80171
Ancillary 08 - Chemical Storage 2: Storing 50t or more of chemicals of dangerous goods class 6, division 6.1 under subsection (1)(b)	ML1878, ML1990, ML700006, ML700007, ML700008, ML700009, ML80010, ML80011 ML80012, ML80086, ML80110, ML80112, ML80123, ML80171
Ancillary 31 - Mineral processing 2: Processing, in a year, the following quantities of mineral products, other than coke (b) more than 100,000t	ML1878, ML1990, ML700006, ML700007, ML700008, ML700009, ML80010, ML80011 ML80012, ML80086, ML80110, ML80112, ML80123, ML80171

Environmentally relevant activity/activities	Location(s)
Ancillary 60 - Waste disposal 2: Operating a facility for disposing of, in a year, the following quantity of waste mentioned in subsection (1)(b) (b) more than 2000t but not more than 5000t	ML1878, ML1990, ML700006, ML700007, ML700008, ML700009, ML80010, ML80011 ML80012, ML80086, ML80110, ML80112, ML80123, ML80171
Ancillary 63 - Sewage Treatment 1: Operating sewage treatment works, other than no-release works, with a total daily peak design capacity of (b-ii) more than 100 but not more than 1500EP otherwise	ML1878, ML1990, ML700006, ML700007, ML700008, ML700009, ML80010, ML80011 ML80012, ML80086, ML80110, ML80112, ML80123, ML80171

Additional information for applicants

Environmentally relevant activities

The description of any environmentally relevant activity (ERA) for which an environmental authority (EA) is issued is a restatement of the ERA as defined by legislation at the time the EA is issued. Where there is any inconsistency between that description of an ERA and the conditions stated by an EA as to the scale, intensity or manner of carrying out an ERA, the conditions prevail to the extent of the inconsistency.

An EA authorises the carrying out of an ERA and does not authorise any environmental harm unless a condition stated by the EA specifically authorises environmental harm.

A person carrying out an ERA must also be a registered suitable operator under the *Environmental Protection Act 1994* (EP Act).

Contaminated land

It is a requirement of the EP Act that an owner or occupier of contaminated land give written notice to the administering authority if they become aware of the following:

- the happening of an event involving a hazardous contaminant on the contaminated land (notice must be given within 24 hours); or
- a change in the condition of the contaminated land (notice must be given within 24 hours); or
- a notifiable activity (as defined in Schedule 3) having been carried out, or is being carried out, on the contaminated land (notice must be given within 20 business days)

that is causing, or is reasonably likely to cause, serious or material environmental harm.

For further information, including the form for giving written notice, refer to the Queensland Government website www.qld.gov.au, using the search term ‘duty to notify’.

Take effect

Please note that, in accordance with section 200 of the EP Act, an EA has effect:

a) if the authority is for a prescribed ERA and it states that it takes effect on the day nominated by the holder of the authority in a written notice given to the administering authority-on the nominated day; or

b) if the authority states a day or an event for it to take effect-on the stated day or when the stated event happens; or

c) otherwise- one the day the authority is issued.

However, if the EA is authorising an activity that requires an additional authorisation (a relevant tenure for a resource activity, a development permit under the *Planning Act 2016* or an SDA Approval under the *State Development and Public Works Organisation Act 1971*), this EA will not take effect until the additional authorisation has taken effect.

If this EA takes effect when the additional authorisation takes effect, you must provide the administering authority written notice within 5 business days of receiving notification of the related additional authorisation taking effect.

If you have incorrectly claimed that an additional authorisation is not required, carrying out the ERA without the additional authorisation is not legal and could result in your prosecution for providing false or misleading information or operating without a valid environmental authority.



Alisha Stewart
Department of Environment and Science
Delegate of the administering authority
Environmental Protection Act 1994

Date Issued*:* 1 August 2022

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Privacy statement

Pursuant to section 540 of the EP Act, the Department is required to maintain a register of certain documents and information authorised under the EP Act. A copy of this document will be kept on the public register. The register is available for inspection by members of the public who are able take extracts, or copies of the documents from the register. Documents that are required to be kept on the register are published in their entirety, unless alteration is required by the EP Act. There is no general discretion allowing the Department to withhold documents or information required to be kept on the public register. For more information on the Department's public register, search 'public register' at www.qld.gov.au. For queries about privacy matters please email privacy@des.qld.gov.au or telephone 13 74 68.

Obligations under the *Environmental Protection Act 1994*

In addition to the requirements found in the conditions of this environmental authority, the holder must also meet their obligations under the EP Act, and the regulations made under the EP Act. For example, the holder must comply with the following provisions of the Act:

- general environmental duty (section 319)
- duty to notify environmental harm (section 320-320G)
- offence of causing serious or material environmental harm (sections 437-439)
- offence of causing environmental nuisance (section 440)
- offence of depositing prescribed water contaminants in waters and related matters (section 440ZG)
- offence to place contaminant where environmental harm or nuisance may be caused (section 443)

Other permits required

This permit only provides an approval under the *Environmental Protection Act 1994*. In order to lawfully operate you may also require permits / approvals from your local government authority, other business units within the department and other State Government agencies prior to commencing any activity at the site. For example, this may include permits / approvals with your local Council (for planning approval), the Department of Transport and Main Roads (to access state controlled roads), the Department of Resources (to clear vegetation), and the Department of Agriculture and Fisheries (to clear marine plants or to obtain a quarry material allocation).

Conditions of environmental authority:

The environmentally relevant activity(ies) conducted at the location as described above must be conducted in accordance with the following site-specific conditions of approval.

This environmental authority consists of the following Schedules and Appendices:

Schedule A	General
Schedule B	Air
Schedule C	Water
Schedule D	Regulated structures
Schedule E	Noise and vibration
Schedule F	Waste
Schedule G	Land
Schedule H	Watercourse diversions
Figure 1	Release points (RP) and monitoring points (MP) on Blackwater Creek
Figure 2	Release points (RP) and monitoring points (MP) on the Mackenzie River
Figure 3	Curragh Mine Onsite Landfill Facility
Figure 4	Approved Disturbance Area and Mine Activity Areas
Figure 5	Prescribed environmental matters
Figure 6	Watercourse Diversions

Conditions of environmental authority:

Agency interest: General	
Condition number	**Condition**
A1	The environmental authority authorises environmental harm referred to in the conditions. Where there is no condition or this environmental authority is silent on a matter, the lack of a condition or silence does not authorise environmental harm.
A2	In carrying out coal mining, disturbance of land is limited to the areas marked "Approved Disturbance Area and Mine Activity Areas" in **Figure 4**. Note: *This condition relates to disturbance of land within ML700006, ML700007, ML700008 and ML700009 only*.
A3	**Prevent and /or minimise likelihood of environmental harm** In carrying out the environmentally relevant activities, you must take all reasonable and practicable measures to prevent and / or to minimise the likelihood of environmental harm being caused. Any environmentally relevant activity, that, if carried out incompetently, or negligently, may cause environmental harm, in a manner that could have been prevented, shall be carried out in a proper manner in accordance with the conditions of this authority.
A4	**Maintenance of measures, plant and equipment** The environmental authority holder must ensure: a) install all measures, plant and equipment necessary to ensure compliance with the conditions of this environmental authority b) maintain such measures, plant and equipment in a proper and efficient condition c) operate such measures, plant and equipment in a proper and efficient manner d) ensure all instruments and devices used for the measurement or monitoring of any parameter under any condition of this environmental authority are properly calibrated.
A5	**Monitoring and records** Except where specified otherwise in another condition of this environmental authority, all monitoring records or reports required by this environmental authority must be kept for a period of not less than **five** (**5) years**.
A6	Where monitoring is a requirement of this environmental authority, ensure that a competent person(s) conducts all monitoring.
A7	**Notification of emergencies, incidents and exceptions** The holder of this environmental authority must notify the administering authority by written notification within **twenty-four (24) hours**, after becoming aware of any emergency or incident which results in the release of contaminants not in accordance, or reasonably expected to be not in accordance with, the conditions of this environmental authority.

A8	Within **ten (10) business days** following the initial notification of an emergency or incident, or receipt of monitoring results, whichever is the latter, further written advice must be provided to the administering authority, including the following: a) results and interpretation of any samples taken and analysed b) outcomes of actions taken at the time to prevent or minimise unlawful environmental harm c) proposed actions to prevent a recurrence of the emergency or incident.
A9	**Complaints** The holder of this environmental authority must record all environmental complaints received about the mining activities including: a) name, address and contact number for of the complainant b) time and date of complaint c) reasons for the complaint d) investigations undertaken e) conclusions formed f) actions taken to resolve the complaint g) any abatement measures implemented h) person responsible for resolving the complaint.
A10	The holder of this environmental authority must, when requested by the administering authority, undertake relevant specified monitoring within a reasonable timeframe nominated or agreed to by the administering authority to investigate any complaint of environmental harm. The results of the investigation (including an analysis and interpretation of the monitoring results) and abatement measures, where implemented, must be provided to the administering authority within **ten (10) business days** of completion of the investigation, or no later than **ten (10) business days** after the end of the timeframe nominated by the administering authority to undertake the investigation.
A11	**Coal Extraction** The environmental authority holder is approved for a coal extraction rate of up to **eighteen (18) million tonnes per annum (Mtpa)** of run-of-mine (ROM) coal by means of open cut mining (including highwall mining).
A12	**Exploration** Exploration activities on ML700006, ML700007, ML700008 and ML700009 must be conducted in accordance with the standard conditions in the document titled '*Eligibility criteria and standard conditions for exploration and mineral development projects - Version 2*' (ESR/2016/1985).

Agency interest: Air	
Condition number	**Condition**
B1	**Determining Air Quality for ML700006, ML700007, ML700008 and ML700009** The holder of the environmental authority must carry out a study to determine air quality background at least **six (6) months** prior to coal mining taking place on ML700006, ML700007, ML700008 and ML700009.
B2	**Dust Monitoring Plan** A dust monitoring plan is to be submitted to the administrating authority at least **six (6) months** prior to coal mining taking place on ML700006, ML700007, ML700008 and ML700009. This plan will include: a) proposed monitoring sites for ML700006, ML700007, ML700008 and ML700009 b) dust monitoring sites associated with existing operations c) align with monitoring methods outlined in condition **B4**.
B3	**Dust nuisance** The release of dust or particulate matter or both resulting from the mining activities must not cause an environmental nuisance, at any sensitive or commercial place.

B4	**Dust and particulate matter monitoring** The Proponent shall ensure all reasonable and feasible avoidance and mitigation measures are employed so that the dust and particulate matter emissions generated by the mining activities do not cause exceedances of the following levels when measured at any sensitive place or commercial place. The environmental authority holder will respond within **twenty-eight (28) days** to any validated air quality complaints with a dust monitoring campaign, as agreed with the administrating authority, that assesses the level of nuisance with reference to the following air quality levels: a) Dust deposition of 120 milligrams per square metre per day, averaged over one month, when monitored in accordance with the most recent version of Australian Standard *AS3580.10.1 Methods of sampling and analysis of ambient air – Determination of particulate matter - Deposited matter - Gravimetric method*. b) A concentration of particulate matter with an aerodynamic diameter of less than 10 micrometres (PM_{10}) suspended in the atmosphere of 50 micrograms per cubic meter over a 24-hour averaging time, for no more than five exceedances recorded each year, when monitored in accordance with the most recent version of either: *1.* Australian Standard *AS3580.9.6 Methods for sampling and analysis of ambient air - Determination of suspended particulate matter – PM10 high volume sampler with size - selective inlet - Gravimetric method*, or *2.* Australian Standard *AS3580.9.9 Methods for sampling and analysis of ambient air - Determination of suspended particulate matter - PM(sub)10(/sub)low volume sampler - Gravimetric method*, or 3. Beta attenuation monitoring (BAM) method used to calculate mass concentration of PM10 volume as per Australian Standard *AS3580.9.11Methods for sampling and analysis of ambient air – Determination of suspended particulate matter – PM10 beta attenuation matters.* c) A concentration of particulate matter suspended in the atmosphere of 90 micrograms per cubic metre over a 1 year averaging time, when monitored in accordance with the most recent version of *AS/NZS3580.9.3:2003 Methods for sampling and analysis of ambient air - Determination of suspended particulate matter - Total suspended particulate matter (TSP) - High volume sampler gravimetric method*.
B5	**Odour nuisance** The release of noxious or offensive odour(s) or any other noxious or offensive airborne contaminant(s) resulting from the mining activity must not cause an environmental nuisance at any sensitive or commercial place.
B6	When requested by the administering authority, odour monitoring must be undertaken within a reasonable and practicable timeframe nominated by the administering authority to investigate any complaint (which is neither frivolous nor vexatious nor based on mistaken belief in the opinion of the authorised officer) of environmental nuisance at any sensitive or commercial place, and the results must be notified within ten business days to the administering authority following completion of monitoring.

Agency interest: Water	
Condition number	**Condition**
C1	**Contaminant release** Contaminants that will, or have the potential to cause environmental harm must not be released directly or indirectly to any waters except as permitted under the conditions of this environmental authority.
C2	Unless otherwise permitted under the conditions of this environmental authority, the release of mine affected water to waters must only occur from the release points specified in **Table C1** and depicted in **Figure 1** and **Figure 2** attached to this environmental authority.
C3	The release of mine affected water to internal water management infrastructure that is installed and operated in accordance with a water management plan that complies with conditions **C33** to **C38** inclusive is permitted.
C4	The release of mine affected water to waters in accordance with condition **C2** must not exceed the release limits stated in **Table C2** when measured at the monitoring points specified in **Table C1** for each quality characteristic.

Table C1 (Mine Affected Water Release Points, Sources and Receiving Waters)

Release Point (RP)	Latitude (decimal degree, GDA94)	Longitude (decimal degree, GDA94)	Mine Affected Water Source and Location	Monitoring Point	Receiving waters description
RP 1	-23.5130	148.8753	Dam RD1	Dam	Blackwater Creek
RP 2	-23.5098	148.8868	Various sources – release outlet to diversion channel	End of pipe	Blackwater Creek
RP 3	-23.2837	148.8478	Dam CN3	Release channel downstream of pipe outlet	Mackenzie River
RP 4	-23.3588	148.8717	Dam CN5	Release channel downstream of pipe outlet	Mackenzie River
RP 5	-23.4522	148.9011	Various sources. Outlet pipe through plug on the former Blackwater Creek channel.	Release channel downstream of pipe outlet	Blackwater Creek
RP 6	-23.2615	148.8763	Various sources. Outlet pipe through Mackenzie River levee	End of pipe	Mackenzie River
RP 7	-23.3072	148.8565	Various sources. Release outlet to Mackenzie River on pipe network	End of pipe	Mackenzie River
RP8	-23.3167	148.8675	Various sources, predominantly S pit. Outlet pipe through Mackenzie River levee.	Standing water at pipe inlet	Mackenzie River
RP9	-23.2834	148.8936	Various sources. Pumped from behind the levee to the Mackenzie	End of pipe	Mackenzie River

Table C2 (Mine Affected Water Release Points, Sources and Receiving Waters)

Quality Characteristic	Release Limits	Monitoring frequency	Comment
Electrical conductivity (µS/cm)	Release limits specified in **Table C4** for variable flow criteria.	Daily during release (the first sample must be taken within 2 hours of commencement of release)	
pH (pH Unit)	6.5 (minimum) 9.0 (maximum)	Daily during release (the first sample must be taken within 2 hours of commencement of release)	
Suspended Solids (mg/L)		Daily during release* (first sample within 2 hours of commencement of release)	Suspended solids are required to measure the performance of sediment and erosion control measures.
Turbidity (NTU)	Mackenzie River release points 182 NTU or Blackwater Creek release points 629 NTU	Daily during release* (first sample within 2 hours of commencement of release)	Turbidity is required to assess ecosystems impacts and can provide instantaneous results

*Note: *Limit for suspended solids can be omitted if turbidity limit is included. Limit for turbidity not required if suspended solids limit included.*

C5	a) The release of mine affected water to waters from the release points must be monitored at the locations specified in **Table C1** for each quality characteristics and at the frequency specified in **Table C2** and **Table C3**. *Note: the administering authority will take into consideration any extenuating circumstances prior to determining an appropriate enforcement response in the event condition **C5** is contravened due to a temporary lack of safe or practical access. The administering authority expects the environmental authority holder to take all reasonable and practicable measures to maintain safe and practical access to designated monitoring locations.* b) The holder of the environmental authority must ensure that there are no adverse impacts to the ecosystem or wetlands through overland flow for RP9.

Table C3 (Release Contaminant Trigger Investigation Levels, Potential Contaminants)

Quality Characteristic	Trigger Levels (µg/L)	Comment on Trigger Level	Monitoring Frequency
Aluminium	55	*For aquatic ecosystem protection, based on SMD guideline*	Commencement of release and thereafter weekly during release
Arsenic	13	*For aquatic ecosystem protection, based on SMD guideline*	
Cadmium	1	*Based on LOR*	
Chromium	1	*For aquatic ecosystem protection, based on SMD guideline*	
Copper	4	*80th percentile value for reference sites*	
Iron	300	*For aquatic ecosystem protection, based on low reliability guideline*	
Lead	4	*For aquatic ecosystem protection, based on SMD guideline*	
Mercury	0.2	*For aquatic ecosystem protection, based on LOR for CV FIMS*	
Nickel	11	*For aquatic ecosystem protection, based on SMD guideline*	
Zinc	8	*For aquatic ecosystem protection, based on SMD guideline*	
Boron	370	*For aquatic ecosystem protection, based on SMD guideline*	
Cobalt	90	*For aquatic ecosystem protection, based on low reliability guideline*	
Manganese	1900	*For aquatic ecosystem protection, based on SMD guideline*	
Molybdenum	34	*For aquatic ecosystem protection, based on low reliability guideline*	
Selenium	10	*For aquatic ecosystem protection, based on LOR for ICPMS*	
Silver	1	*For aquatic ecosystem protection, based on LOR for ICPMS*	
Uranium	1	*For aquatic ecosystem protection, based on LOR for ICPMS*	
Vanadium	11	*80th percentile value for reference sites*	
Ammonia	900	*For aquatic ecosystem protection, based on SMD guideline*	
Nitrate	1100	*For aquatic ecosystem protection, based on ambient Qld WQ Guidelines (2006) for TN*	
Petroleum hydrocarbons (C6-C9)	20		
Petroleum hydrocarbons (C10- C36)	100		
Fluoride (total)	2000	*Protection of livestock and short term irrigation guideline*	
Sodium	180,000	*Australian Drinking Water Guideline*	
Sulphate	200,000	*Drinking water environmental values from NHMRC 2006 guidelines or ANZECC*	

Note:

1. All metals and metalloids must be measured as total (unfiltered) and dissolved (filtered). Trigger levels for metal/metalloids apply if dissolved results exceed trigger.

2. The quality characteristics required to be monitored as per Table C3 can be reviewed once the results of two years monitoring data is available, or if sufficient data is available to adequately demonstrate negligible environmental risk, and it may be determined that a reduced monitoring frequency is appropriate or that certain quality characteristics can be removed from Table C3 by amendment.

3. SMD – slightly moderately disturbed level of protection, guideline refers ANZECC & ARMCANZ (2000).

4. LOR – typical reporting for method stated. ICPMS/CV FIMS – analytical method required to achieve LOR.

C6	If quality characteristics of the release exceed any of the trigger levels specified in **Table C3** during a release event, the environmental authority holder must compare the downstream results in the receiving waters to the trigger values specified in **Table C3** and: 1. where the trigger values are not exceeded then no action is to be taken; or 2. where the downstream results exceed the trigger values specified **Table C3** for any quality characteristic, compare the results of the downstream site to the data from background monitoring sites and; a) if the result is less than the background monitoring site data, then no action is to be taken; or b) if the result is greater than the background monitoring site data, complete an investigation in accordance with the ANZECC & ARMCANZ 2000 methodology, into the potential for environmental harm and provide a written report to the administering authority in the next annual return, outlining: (i) details of the investigations carried out; and (ii) actions taken to prevent environmental harm. Note: *Where an exceedance of a trigger level has occurred and is being investigated, in accordance with C6 2(b) of this condition, no further reporting is required for subsequent trigger events for that quality characteristic.*
C7	If an exceedance in accordance with condition **C6 2(b)** is identified, the holder of the authority must notify the administering authority in writing within **one (1) business day** of receiving the result.
C8	**Mine Affected Water Release Events** The holder must ensure a stream flow gauging station/s is installed, operated and maintained to determine and record stream flows at the locations and flow recording frequency specified in **Table C4**.
C9	Notwithstanding any other condition of this environmental authority, the release of mine affected water to waters in accordance with condition **C2** must only take place during periods of natural flow events in accordance with the receiving water flow criteria for discharge specified in **Table C4** for the release point(s) specified in **Table C1**.

Table C4 (Mine Affected Water Release during Flow Events)

Receiving waters/ stream	Release Point (RP)	Gauging station	Gauging Station Latitude (decimal degree, GDA94)	Gauging Station Longitde (decimal degree, GDA94)	Receiving Water Flow Recording Frequency	Receiving Water Flow Criteria for discharge (m^3/s)	Maximum release rate (for all combined RP flows)	Electrical Conductivity and Sulphate Release Limits
Mackenzie River	RP 3 RP 4# RP 6 RP 7 RP 8 RP 9	Bingegang tailwater gauge MP14 (Sunwater)	-23.0737	149.0319	Continuous (minimum daily	**Low flow** > 1 m^3/s for a period of 30 days after natural flow events that exceed 30 m^3/s	≤ 0.5 m^3/s	Electrical conductivity ≤ 310 µS/cm Sulphate $(SO_4)^{2-}$ ≤ 200 mg/L
						Medium Flow > 30 m^3/s	≤0.18 m^3/s	Electrical conductivity ≤ 3,500 µS/cm Sulphate (SO_4^{2-}) ≤ 500 mg/L
							≤ 0.10 m^3/s	Electrical conductivity ≤ 6,000 µS/cm Sulphate (SO_4^{2-}) ≤ 750 mg/L
						High flow > 80 m^3/s	Release rate not to exceed 350 (natural) to 1 (mine affected water) dilution of the flow rate at Bingegang tailwater gauge	Electrical conductivity ≤ 7,000 µS/cm (≤ 6000 µS/cm for RP4) Sulpate (SO_4^{2-}) ≤ 750 mg/L
Blackwater Creek	RP 1 RP 2 RP 5	MP 1	-23.5122	149.0319	Continuous (minimum daily)	**Low Flow** <0.5 m^3/s for a period of 4 weeks after natural flow events that exceed 1 m^3/s	≤ 0.5 m^3/s	Electrical conductivity ≤ 680 µS/cm Sulpate (SO_4^{2-}) ≤ 250 mg/L
						Medium Flow > 2.5 m^3/s	≤ 0.16 m^3/s	Electrical conductivity ≤ 6,000 µS/cm Sulpate (SO_4^{2-}) ≤ 500 mg/L
						High Flow > 5 m^3/s	≤ 0.18 m^3/s	Electrical conductivity ≤ 10,000 µS/cm Sulphate (SO_4^{2-}) ≤ 1000 mg/L

Note:
 # Release of mine affected water from RP4 under high flow conditions (Mackenzie River) must not exceed 6,000 (µS/cm).

C10	The release of mine affected water to waters in accordance with condition **C2** must not exceed the Electrical Conductivity and Sulphate release limits or the Maximum Release Rate (for all combined release point flows) for each receiving water flow criteria for discharge specified in **Table C4** when measured at the monitoring points specified in **Table C1**.
C11	The daily quantity of mine affected water released from each release point must be measured and recorded at the monitoring points in **Table C1**.
C12	Releases to waters must be undertaken so as not to cause erosion of the bed and banks of the receiving waters, or cause a material build up of sediment in such waters.
C13	**Notification of Release Event** The environmental authority holder must notify the administering authority as soon as practicable and no later than **twenty-four (24) hours** after commencing to release mine affected water to the receiving environment. Notification must include the submission of written advice to the administering authority of the following information: a) release commencement date/time; b) expected release cessation date/time; c) release point/s; d) release volume (estimated); e) receiving water/s including the natural flow rate; and f) any details (including available data) regarding likely impacts on the receiving water(s). Note: *Notification to the administering authority must be addressed to the Manager and Project Manager of the local Administering Authority via email or facsimile.*
C14	The environmental authority holder must notify the administering authority as soon as practicable (nominally within **twenty-four (24) hours** after cessation of a release event) of the cessation of a release notified under condition **C13** and within **twenty-eight (28) days** provide the following information in writing: a) release cessation date/time; b) natural flow volume in receiving water; c) volume of water released; d) details regarding the compliance of the release with the conditions of Agency Interest: Water of this environmental authority (i.e. contamination limits, natural flow, discharge volume); e) all in-situ water quality monitoring results; and f) any other matters pertinent to the water release event. Note: *Successive or intermittent releases occurring within twenty-four (24) hours of the cessation of any individual release can be considered part of a single release event and do not require individual notification for the purpose of compliance with conditions C13 and C14, provided the relevant details of the release are included within the notification provided in accordance with conditions C13 and C14.*
C15	**Notification of Release Event Exceedance** If the release limits defined in **Table C2** are exceeded, the holder of the environmental authority must notify the administering authority within **twenty-four (24) hours** of receiving the results.

C16	The authority holder must, within **twenty-eight (28) days** of a release that exceeds the conditions of this authority, provide a report to the administering authority detailing: a) the reason for the release; b) the location of the release; c) all water quality monitoring results; d) any general observations; e) all calculations; and f) any other matters pertinent to the water release event.
C17	**Monitoring of Water Storage Quality** Water storages stated in **Table C5** which are associated with the release points must be monitored for the water quality characteristics specified in **Table C6** at the monitoring locations and at the monitoring frequency specified in **Table C5**.
C18	In the event that waters storages defined in **Table C5** exceed the contaminant limits defined in **Table C6**, the holder of the environmental authority must implement measures, where practicable, to prevent access to waters by all livestock.

Table C5 (Water Storage Monitoring)

Water Storage Description	Latitude (decimal degree, GDA94)	Longitude (decimal degree, GDA94)	Monitoring Location	Frequency of Monitoring
Dam RD1	-23.5130	148.8753	Mixed sample taken from bank or pontoon if available	Quarterly
Dam CN3	-23.2877	148.8492	Mixed sample taken from bank or pontoon if available	Quarterly
Dam CN5	-23.3552	148.8776	Mixed sample taken from bank or pontoon if available	Quarterly
T Pit	-23.3047	148.8613	Mixed sample taken from bank or pontoon if available	Quarterly

Table C6 (Onsite water storage contaminant limits)

Quality Characteristic	Test Value	Contaminant Limit
pH (pH unit)	Range	Greater than 4, less than 9[2]
EC (µS/cm)	Maximum	5970[1]
Sulphate (mg/L)	Maximum	1000[1]
Fluoride (mg/L)	Maximum	2[1]
Aluminium (mg/L)	Maximum	5[1]
Arsenic (mg/L)	Maximum	0.5[1]
Cadmium (mg/L)	Maximum	0.01[1]
Cobalt (mg/L)	Maximum	1[1]
Copper (mg/L)	Maximum	1[1]
Lead (mg/L)	Maximum	0.1[1]
Nickel (mg/L)	Maximum	1[1]
Zinc (mg/L)	Maximum	20[1]

Note:

[1] Contaminant limit based on ANZECC & ARMCANZ (2000) stock water quality guidelines.

[2] Page 4.2-15 of ANZECC & ARMCANZ (2000) "Soil and animal health will not generally be affected by water with pH in the range of 4–9". Note: Total measurements (unfiltered) must be taken and analysed

C19	**Receiving environment monitoring and contaminant trigger levels** The quality of the receiving waters must be monitored at the locations specified in **Table C8** and shown in **Figure 1** and **Figure 2** for each quality characteristic and at the monitoring frequency stated in **Table C7**.

Table C7 (Receiving Waters Contaminant Trigger Levels)

Quality Characteristic	Trigger Level	Monitoring Frequency
pH	Blackwater Creek 6.5 – 9.0 Mackenzie River 6.5 - 8.5	Daily during the release
Electrical Conductivity (μS/cm)	Blackwater Creek 720 μS/cm Mackenzie River 400 μS/cm	
Suspended solids (mg/L)	Blackwater Creek 690 mg/L Mackenzie River 200 mg/L	
Sulphate (SO_4^{2-}) (mg/L)	Blackwater Creek 250 mg/L Mackenzie River 200 mg/L	
Sodium (mg/L)	Blackwater Creek 180 mg/L Mackenzie River 50 mg/L	

C20	If quality characteristics of the receiving water at the downstream monitoring points exceed any of the trigger levels specified in **Table C7** during a release event the environmental authority holder must compare the downstream results to the upstream results in the receiving waters and: a) where the downstream result is the same or a lower value than the upstream value for the quality characteristic then no action is to be taken; or b) where the downstream results exceed the upstream results complete an investigation into the potential for environmental harm and provide a written report to the administering authority in the next annual return, outlining: 1. details of the investigations carried out; and 2. actions taken to prevent environmental harm. Note: *Where an exceedance of a trigger level has occurred and is being investigated, in accordance with C20(2) of this condition, no further reporting is required for subsequent trigger events for that quality characteristic.*

Table C8 (Receiving Water Upstream Background Sites and Downstream Monitoring Points)

Monitoring Points	Receiving Waters Location Description	Latitude (decimal degree, GDA94)	Longitude (decimal degree, GDA94)
Upstream Background Monitoring Points			
Monitoring Point 1	Blackwater Creek 800 metres upstream of RP 1	-23.5190	148.8773
Monitoring Point 12	Bedford Weir Tailwater Mackenzie River 3,400 metres upstream of RP 4	-23.3721	148.8414
Downstream Monitoring Points			
Monitoring Point 4	Blackwater Creek 6,000 metres downstream of RP 5	-23.4061	148.9158
Monitoring Point 11 (access permitting)	Mackenzie River 4,700 metres downstream of RP6	-23.2631	148.9014
Monitoring Point 13	Mackenzie River downstream of RP4.	-23.3160	148.8678
Monitoring Point 14 (alternative)	Bingegang Weir Headwater Mackenzie River approx. 40 kilometres downstream of RP 6	-23.0737	149.0319

Notes:

a) *The upstream monitoring point should be within 4 km the release point.*

b) *The downstream point should not be greater than 45 km from the release point.*

c) *The data from background monitoring points must not be used where they are affected by releases from other mines.*

C21	**Receiving Environment Monitoring Program (REMP)** The environmental authority holder must develop and implement a REMP to monitor, identify and describe any adverse impacts to surface water environmental values, quality and flows due to the authorised mining activity. This must include monitoring the effects of the mine on the receiving environment periodically (under natural flow conditions) and while mine affected water is being discharged from the site.

C22	The REMP must: a) Assess the condition or state of receiving waters, including upstream conditions, spatially within the REMP area, considering background water quality characteristics based on accurate and reliable monitoring data that takes into consideration temporal variation (e.g. seasonality); and b) Be designed to facilitate assessment against water quality objectives for the relevant environmental values that need to be protected; and c) Include monitoring from background reference sites (e.g. upstream or background) and downstream sites from the release (as a minimum, the locations specified in **Table C8**); and d) Specify the frequency and timing of sampling required in order to reliably assess ambient conditions and to provide sufficient data to derive site specific background reference values in accordance with the *Queensland Water Quality Guidelines* 2006. This should include monitoring during periods of natural flow irrespective of mine or other discharges; and e) Include monitoring and assessment of dissolved oxygen saturation, temperature and all water quality parameters listed in **Table C2 and C3**; and f) Include, where appropriate, monitoring of metals/metalloids in sediments (in accordance with ANZECC & ARMCANZ 2000, BATLEY and/or the most recent version of AS5667.*1 Guidance on Sampling of Bottom Sediments*); and g) Include, where appropriate, monitoring of macro-invertebrates in accordance with the AusRivas methodology, and h) Apply procedures and/or guidelines from ANZECC & ARMCANZ 2000 and other relevant guideline documents; and i) Describe sampling and analysis methods and quality assurance and control; and j) Incorporate stream flow and hydrological information in the interpretations of water quality and biological data.
C23	A report outlining the findings of the REMP, including all monitoring results and interpretations in accordance with conditions **C21** and **C22** must be prepared annually and made available on request to the administrating authority. This must include an assessment of background reference water quality, the condition of downstream water quality compared against water quality objectives, and the suitability of current discharge limits to protect downstream environmental values.
C24	**Water Reuse** Mine affected water may be piped or trucked or transferred by some other means that does not contravene the conditions of this environmental authority and deposited into artificial water storage structures, such as farm dams or tanks, or used directly at properties owned by the environmental authority holder or a third party for the purpose of: i) supplying stock water subject to compliance with the quality release limits specified in **Table C9**; or ii) supplying irrigation water subject to compliance with quality release limits in **Table C10**; or iii) supplying water for construction and/or road maintenance in accordance with the conditions of this environmental authority.

Table C9 (Stock water release limits)

Quality characteristic	Units	Minimum	Maximum
pH	pH units	6.5	8.5
Electrical Conductivity	µS/cm	N/A	5000

Table C10 (Irrigation Water Release Limits)

Quality characteristic	Units	Minimum	Maximum
pH	pH units	6.5	8.5
Electrical Conductivity	µS/cm	N/A	Site specific value to be determined in accordance with ANZECC & ARMCANZ (2000) Irrigation Guidelines

C25	Mine affected water may be piped or trucked or transferred by some other means that does not contravene the conditions of this environmental authority and deposited into artificial water storage structures, such as dams or tanks, for the purpose of supplying water to Jellinbah Mine. The volume, pH and electrical conductivity of water transferred to Jellinbah Mine must be monitored and recorded.
C26	If the responsibility for mine affected water is given or transferred to another person in accordance with conditions **C25** or **C26:** a) the responsibility for the mine affected water must only be given or transferred in accordance with a written agreement (the third party agreement); and b) the third party agreement must include a commitment from the person utilising the mine affected water to use it in such a way as to prevent environmental harm or public health incidents and specifically make the persons aware of the General Environmental Duty (GED) under section 319 of the *Environmental Protection Act 1994,* environmental sustainability of the water disposal and protection of environmental values of waters; and c) the third party agreement must be signed by both parties to the agreement.
C27	**Water General** All determinations of water quality and biological monitoring must be: a) performed by a person or body possessing appropriate experience and qualifications to perform the required measurements; b) made in accordance with methods prescribed in the latest edition of the *Monitoring and Sampling Manual*; Note: *Condition C28 requires the Monitoring and Sampling Manual to be followed and where it is not followed because of exceptional circumstances this should be explained and reported with the results.* c) collected from the monitoring locations identified within this environmental authority, within forty-eight (48) hours of each other where possible; d) carried out on representative samples; and e) analysed at a laboratory accredited (e.g. NATA) for the method of analysis being used.

C28	The release of any contaminants as permitted by this environmental authority, directly or indirectly to waters, other than internal water management infrastructure that is installed and operated in accordance with a water management plan that complies with conditions **C31** to **C36** inclusive: a) must not produce any visible discolouration of receiving waters; and b) must not produce any slick or other visible or odorous evidence of oil, grease or petrochemicals nor contain visible floating oil, grease, scum, litter or other objectionable matter.
C29	**Annual water monitoring reporting** The following information must be recorded in relation to all water monitoring required under the conditions of this environmental authority and submitted to the administering authority in the specified format with each annual return: a) the date on which the sample was taken; b) the time at which the sample was taken; c) the monitoring point at which the sample was taken; d) the measured or estimated daily quantity of the contaminants released from all release points; e) the release flow rate at the time of sampling for each release point; f) the results of all monitoring and details of any exceedances with the conditions of this environmental authority; and g) water quality monitoring data must be provided to the administering authority in the specified electronic format upon request.
C30	**Temporary interference with waterways** Temporarily destroying native vegetation, excavating, or placing fill in a watercourse, lake or spring necessary for and associated with mining operations must be undertaken in accordance with the latest edition of the *Guideline - Activities in a watercourse, lake or spring associated with a resources activity or mining operations.*
C31	**Water Management Plan** A Water Management Plan must be implemented.
C32	The Water Management Plan must: a) provide for effective management of actual and potential environmental impacts resulting from water management associated with the mining activity carried out under this environmental authority; and b) be developed in accordance with the guideline *Preparation of water management plans for mining activities (EM324)* and include: i. a study of the source of contaminants; ii. a water balance model for the site; iii. a water management system for the site; iv.measures to manage and prevent saline drainage; v.measures to manage and prevent acid rock drainage; vi.contingency procedures for emergencies; and iv. a program for monitoring and review of the effectiveness of the water management plan.

C33	The Water Management Plan must be reviewed each calendar year and a report prepared by an appropriately qualified person. The report must: a) assess the plan against the requirements under condition **C32**; b) include recommended actions to ensure actual and potential environmental impacts are effectively managed for the coming year; and c) identify any amendments made to the water management plan following the review.
C34	The holder of this environmental authority must attach to the review report required by condition **C33**, a written response to the report and recommended actions, detailing the actions taken or to be taken by the environmental authority holder on stated dates: a) to ensure compliance with this environmental authority; and b) to prevent a recurrence of any non-compliance issues identified.
C35	The review report required by condition **C33** and the written response to the review report required by condition **C34** must be submitted to the administering authority with the subsequent annual return under the signature of the appointed signatory for the annual return.
C36	A copy of the Water Management Plan must be provided to the administering authority on request.
C37	**Saline drainage** The holder of this environmental authority must ensure proper and effective measures are taken to avoid or otherwise minimise the generation and/or release of saline drainage.
C38	**Acid rock drainage** The holder of this environmental authority must ensure proper and effective measures are taken to avoid or otherwise minimise the generation and/or release of acid rock drainage.
C39	**Stormwater and water sediment controls** An Erosion and Sediment Control Plan must be developed by an appropriately qualified person and implemented for all stages of the mining activities on the site to minimise erosion and the release of sediment to receiving waters and contamination of stormwater.
C40	**Stormwater, other than mine affected water, is permitted to be released to waters from:** a) erosion and sediment control structures that are installed and operated in accordance with the Erosion and Sediment Control Plan required by condition **C39**; and b) water management infrastructure that is installed and operated, in accordance with a Water Management Plan that complies with conditions **C31** to **C36** inclusive, for the purpose of ensuring water does not become mine affected water.
C41	The maintenance and cleaning of any vehicles, plant or equipment must not be carried out in areas from which contaminants can be released into any receiving waters.
C42	Any spillage of wastes, contaminants or other materials must be cleaned up as quickly as practicable to minimise the release of wastes, contaminants or materials to any stormwater drainage system or receiving waters.
C43	**Sewage effluent** The daily operation of the sewage treatment plant and pollution control equipment must be carried out by a person(s) with appropriate experience and/or qualifications to ensure the effective operation of that treatment system and control equipment.

C44	Pipelines and fittings associated with the sewage treatment system must be clearly identified.
C45	All treated effluent released from the sewage treatment facilities must be monitored at the frequency and for the parameters specified in **Table C11.**

Table C11 (Sewage effluent quality targets)

Quality characteristics	Release limit	Units	Limit type	Monitoring frequency
5 day Biochemical Oxygen Demand	20	mg/L	max	Monthly
pH	6.0 to 9.0	pH Units	range	Monthly
Free Chlorine Residual	3	mg/L	max	Monthly
Faecal coliforms	<1000	Cfu/100mL[2]	max	Monthly

C46	Treated effluent used directly from the sewage treatment facilities for dust suppression or irrigation must not exceed sewage effluent release limits defined in **Table C11**.
C47	Treated effluent used for dust suppression or irrigation must not cause spray drift or over spray to any sensitive or commercial place.
C48	Treated effluent from the sewage treatment plant must only be discharged from the authorised discharge location.
C49	Treated effluent must not be used for dust suppression or reused for irrigation so as to create a likelihood of contact or exposure to persons.
C50	Treated effluent must not be released from the site to any waters or the bed and banks of any waters.
C51	**Groundwater** The holder of this environmental authority must not release contaminants to groundwater.
C52	All determinations of groundwater quality monitoring must be performed by a suitably qualified person.
C53	The holder of the environmental authority must implement a groundwater monitoring program which has been developed by a suitably qualified person. The program must be able to detect a significant change to groundwater quality values and standing water levels (consistent with the current suitability of the groundwater for domestic and agricultural use) due to activities that are part of this mining project.
C54	The holder of the environmental authority must report the results and analysis of groundwater monitoring to the administering authority on request.
C55	Groundwater affected by the mining activities must be monitored at compliance bores within the nominated geologies and minimum frequencies defined in **Table C12**.

Table C12 (Groundwater monitoring locations and frequency)

Geology	Minimum number of monitoring locations	Minimum Monitoring Frequency
Alluvium	7	6 monthly
Rangal Coal Measures	4	6 monthly
Burngrove	2	6 monthly

C56	If the groundwater contaminant trigger levels defined in **Table C13** are exceeded then the environmental authority holder must complete an investigation into the potential for environmental harm and notify the administering authority within **twenty-eight (28) days** of receiving the analysis results. An action plan to mitigate potential harm must be developed by a suitably qualified person.

Table C13 (Groundwater contaminant trigger levels)

Parameter	Unit	Trigger Levels			Limit Type
		Alluvium	Rangal coal measures	Burngrove	
Groundwater Level	RL AHD (m)	Greater than 2 metre drawdown from the background level.			Maximum
pH	pH Units	6.5 - 9.0	6.5 - 9.0	6.5 - 9.0	Minimum/Maximum
Electrical Conductivity	µS/cm	TBA	TBA	TBA	Maximum
Total Dissolved Solids	mg/L	TBA	TBA	TBA	Maximum
Calcium*	mg/L	TBA	TBA	TBA	Maximum
Magnesium*	mg/L	TBA	TBA	TBA	Maximum
Sodium*	mg/L	TBA	TBA	TBA	Maximum
Potassium*	mg/L	TBA	TBA	TBA	Maximum
Chloride*	mg/L	TBA	TBA	TBA	Maximum
SO_4*	mg/L	TBA	TBA	TBA	Maximum
CO_3*	mg/L	TBA	TBA	TBA	Maximum
HCO_3*	mg/L	TBA	TBA	TBA	Maximum
PO4	mg/L	TBA	TBA	TBA	Maximum
NO3	mg/L	TBA	TBA	TBA	Maximum
Iron	mg/L	TBA	TBA	TBA	Maximum
Aluminium	mg/L	TBA	TBA	TBA	Maximum
Arsenic	mg/L	TBA	TBA	TBA	Maximum
Mercury	mg/L	TBA	TBA	TBA	Maximum
Total Petroleum Hydrocarbons					
TPH (C6-C9)	mg/L	TBA	TBA	TBA	Maximum
TPH (C10-C14)	mg/L	TBA	TBA	TBA	Maximum
TPH (C15-C28)	mg/L	TBA	TBA	TBA	Maximum
TPH (C28-C36)	mg/L	TBA	TBA	TBA	Maximum

*means these cations and anions are to be monitored once/year

C57	**Determining contaminant trigger level and limit type** The background groundwater quality for each geology must be determined from hydraulically isolated background bore(s) that have not been affected by any mining activities. The groundwater contaminant trigger levels and limit type as per **Table C13** must be determined and submitted to the administering authority by **1 February 2023**.
C58	**Bore construction and maintenance and decommissioning** The construction, maintenance and management of groundwater bores (including background and compliance groundwater monitoring bores) must be undertaken in a manner that prevents or minimises impacts to the environment and ensures the integrity of the bores to obtain accurate monitoring. For all bores constructed after February 2015 construction and decommissioning must be in accordance with the *Manual for Minimum Construction Standard for Water Bores in Australia*.

Agency interest: Regulated Structures	
Condition number	**Condition**
D1	**Assessment of consequence category** The consequence category of any structure must be assessed by a suitably qualified and experienced person in accordance with the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (EM635) a*t the following times: a) prior to the design and construction of the structure, if it is not an existing structure; or b) prior to any change in its purpose or the nature of its stored contents.
D2	A consequence assessment report and certification must be prepared for each structure assessed and the report may include a consequence assessment for more than one structure.
D3	Certification must be provided by the suitably qualified and experienced person who undertook the assessment, in the form set out in the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (EM635)*.
D4	**Design and construction[1] of a regulated structure** Conditions **D5** to **D9** inclusive do not apply to existing structures. Note [1] : *Construction of a dam includes modification of an existing dam—refer to the definitions.*
D5	All regulated structures must be designed by, and constructed [2] under the supervision of, a suitably qualified and experienced person in accordance with the requirements of the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (EM635)*. Note [2]: *Certification of design and construction may be undertaken by different persons.*
D6	Construction of a regulated structure is prohibited unless the holder has submitted a consequence category assessment report and certification to the administering authority has been certified by a suitably qualified and experienced person for the design and design plan and the associated operating procedures in compliance with the relevant condition of this authority.
D7	Certification must be provided by the suitably qualified and experienced person who oversees the preparation of the design plan in the form set out in the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (EM635)*, and must be recorded in the Regulated Dams/Levees register.
D8	**Regulated structures** must: a) be designed and constructed in accordance with and conform to the requirements of the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (EM635);* b) be designed and constructed with due consideration given to ensuring that the design integrity would not be compromised on account of: i) floodwaters from entering the regulated dam from any watercourse or drainage line; and ii) wall failure due to erosion by floodwaters arising from any watercourse or drainage line. c) have the floor and sides of the dam designed and constructed to prevent or minimise the passage of the wetting front and any entrained contaminants through either the floor or sides of the dam during the operational life of the dam and for any period of decommissioning and rehabilitation of the dam.

D9	Certification by the suitably qualified and experienced person who supervises the construction must be submitted to the administering authority on the completion of construction of the regulated structure, and state that: a) the 'as constructed' drawings and specifications meet the original intent of the design plan for that regulated structure; b) construction of the regulated structure is in accordance with the design plan.
D10	Operation of a regulated structure, except for an existing structure, is prohibited unless: a) the holder has submitted to the administering authority: i) one paper copy and one electronic copy of the design plan and certification of the 'design plan' in accordance with condition **G6**; ii) a set of 'as constructed' drawings and specifications; iii) certification of those 'as constructed drawings and specifications' in accordance with condition **G9**; iv) where the regulated structure is to be managed as part of an integrated containment system for the purpose of sharing the DSA volume across the system, a copy of the certified system design plan; v) the requirements of this authority relating to the construction of the regulated structure have been met; vi) the holder has entered the details required under this authority, into a Register of Regulated Structures; and vii) there is a current operational plan for the regulated structures.
D11	For existing structures that are regulated structures: a) where the existing structure that is a regulated structure is to be managed as part of an integrated containment system for the purpose of sharing the DSA volume across the system, the holder must submit to the administering authority within **twelve (12) months** of the commencement of this condition a copy of the certified system design plan including that structure; and b) there must be a current operational plan for the existing structures.
D12	Each regulated structure must be maintained and operated, for the duration of its operational life until decommissioned and rehabilitated, in a manner that is consistent with the current operational plan and, if applicable, the current design plan and associated certified 'as constructed' drawings.
D13	Conditions **D14** – **D17** inclusive only apply to Regulated Structures which have not been certified as low consequence category for 'failure to contain – overtopping'.
D14	The Mandatory Reporting Level (the MRL) must be marked on a regulated dam in such a way that during routine inspections of that dam, it is clearly observable.
D15	The holder must, as soon as practical and within **forty-eight (48) hours** of becoming aware, notify the administering authority when the level of the contents of a regulated dam reaches the MRL.
D16	The holder must, immediately on becoming aware that the MRL has been reached, act to prevent the occurrence of any unauthorised discharge from the regulated dam.
D17	The holder must record any changes to the MRL in the Register of Regulated Structures.

D18	**Design storage allowance** The holder must assess the performance of each regulated dam or linked containment system over the preceding November to May period based on actual observations of the available storage in each regulated dam or linked containment system taken prior to **1 July** of each year.
D19	By **1 November** of each year, storage capacity must be available in each regulated dam (or network of linked containment systems with a shared DSA volume), to meet the Design Storage Allowance (DSA) volume for the dam (or network of linked containment systems).
D20	The holder must, as soon as possible and within **forty-eight (48) hours** of becoming aware that the regulated dam (or network of linked containment systems) will not have the available storage to meet the DSA volume on **1 November** of any year, notify the administering authority.
D21	The holder must, immediately on becoming aware that a regulated dam (or network of linked containment systems) will not have the available storage to meet the DSA volume on **1 November** of any year, act to prevent the occurrence of any unauthorised discharge from the regulated dam or linked containment systems.
D22	Each regulated structure must be inspected each calendar year by a suitably qualified and experienced person.
D23	At each annual inspection, the condition and adequacy of all components of the regulated structure must be assessed and a suitably qualified and experienced person must prepare an annual inspection report containing details of the assessment and include recommended actions to ensure the integrity of the regulated structure.
D24	The suitably qualified and experienced person who prepared the annual inspection report must certify the report in accordance with the Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (EM635).
D25	The holder must: a) Within **twenty (20) business days** of receipt of the annual inspection report, provide to the administering authority: i) The recommendations section of the annual inspection report; and ii) If applicable, any actions being taken in response to those recommendations; and b) If, following receipt of the recommendations and (if applicable) actions, the administering authority requests a full copy of the annual inspection report from the holder, provide this to the administering authority within **ten (10) business days** of receipt of the request.
D26	**Transfer arrangements** The holder must provide a copy of any reports, documentation and certifications prepared under this authority, including but not limited to any Register of Regulated Structures, consequence assessment, design plan and other supporting documentation, to a new holder on transfer of this authority.

D27	**Decommissioning and rehabilitation** Dams must not be abandoned but be either: a) decommissioned and rehabilitated to achieve compliance with condition **D28**; or b) be left in-situ for a beneficial use(s) provided that: i) it no longer contains contaminants that will migrate into the environment; and ii) it contains water of a quality that is demonstrated to be suitable for its intended beneficial use(s); and iii) the administering authority, the holder of the environmental authority and the landholder agree in writing that the dam will be used by the landholder following the cessation of the environmentally relevant activity(ies).
D28	After decommissioning, all significantly disturbed land caused by the carrying out of the environmentally relevant activity(ies) must be rehabilitated to meet the following final acceptance criteria: a) the landform is safe for humans and fauna; b) the landform is stable with no subsidence or erosion gullies for at least **three (3) years**; c) any contaminated land (e.g. contaminated soils) is remediated and rehabilitated; d) not allowing for acid mine drainage; or e) there is no ongoing contamination to waters (including groundwater); f) rehabilitation is undertaken in a manner such that any actual or potential acid sulfate soils on the area of significant disturbance are treated to prevent or minimise environmental harm in accordance with the Instructions for the treatment and management of acid sulfate soils (2001); g) all significantly disturbed land is reinstated to the pre-disturbed soil suitability class; h) for land that is not being cultivated by the landholder: i) groundcover, that is not a declared pest species is established and self-sustaining ii) vegetation of similar species richness and species diversity to pre-selected analogue sites is established and self-sustaining, and iii) the maintenance requirements for rehabilitated land is no greater than that required for the land prior to its disturbance caused by carrying out the petroleum activity(ies). i) for land that is to be cultivated by the landholder, cover crop is revegetated, unless the landholder will be preparing the site for cropping within **three (3) months** of petroleum activities being completed.
D29	**Register of Regulated Structures** A Register of Regulated Structures must be established and maintained by the holder for each regulated structure.
D30	The holder must provisionally enter the required information in the Register of Regulated Structures when a design plan for a regulated structure is submitted to the administering authority.
D31	The holder must make a final entry of the required information in the Register of Regulated Structures once compliance with condition **D10** and **D11** has been achieved.
D32	The holder must ensure that the information contained in the Register of Regulated Structures is current and complete on any given day.

D33	All entries in the Register of Regulated Structures must be approved by the chief executive officer for the holder of this authority, or their delegate, as being accurate and correct.
D34	The holder must, at the same time as providing the annual return, supply to the administering authority a copy of the records contained in the Register of Regulated Structures, in the electronic format required by the administering authority.
D35	**Transitional arrangements** All existing structures that have not been assessed in accordance with either the Manual or the former Manual for Assessing Hazard Categories and Hydraulic Performance of Dams must be assessed and certified in accordance with the Manual within **6 months** of amendment of the authority adopting this schedule.
D36	All existing structures must subsequently comply with the timetable for any further assessments in accordance with the Manual specified in **Table D1**, depending on the consequence category for each existing structure assessed in the most recent previous certification for that structure.
D37	**Table D1** ceases to apply for a structure once any of the following events has occurred: a) It has been brought into compliance with the hydraulic performance criteria applicable to the structure under the Manual; or b) It has been decommissioned; or c) It has been certified as no longer being assessed as a regulated structure.
D38	Certification of the transitional assessment required by condition **D35** and **D36** (as applicable) must be provided to the administering authority within **6 months** of amendment of the authority adopting this schedule.

Table D1 (Transitional Hydraulic Performance Requirements for Existing Structures)

Transition period required for existing structures to achieve the requirements of the *Manual for Assessing Consequence Categories and Hydraulic Performance of Dams*			
Compliance with Criteria	**High**	**Significant**	**Low**
90% and a history of good compliance performance in last 5 years	No transition required	No transition required	No transitional conditions apply. Review consequence assessment every 7 years.
>70%-≤90%	Within 7 years, unless otherwise agreed with the administering authority, based on no history of unauthorised releases.	Within 10 years, unless otherwise agreed with the administering authority, based on no history of unauthorised releases.	No transitional conditions apply. Review consequence assessment every 7 years.
>50-≤70%	Within 5 years unless otherwise agreed with the administering authority, based on no history of unauthorised releases.	Within 7 years unless otherwise agreed with the administering authority, based on no history of unauthorised releases.	Review consequence assessment every 7 years.
≤50%	Within 5 years or as per compliance requirements (e.g. TEP timing)	Within 5 years or as per compliance requirements (e.g. TEP timing)	Review consequence assessment every 5 years.

Agency interest: Noise and vibration	
Condition number	**Condition**
E1	**Noise limits** The holder of this environmental authority must ensure that noise generated by the mining activities does not cause the criteria in **Table E1** to be exceeded at a sensitive place or commercial place.
E2	The environmental authority holder will respond within **twenty-eight (28) days** to any validated noise limit complaints with a noise monitoring campaign, as agreed with the administrating authority that assesses the level of nuisance with reference to the **Table E1** criteria.

Table E1 (Noise limits)

Noise level dB(A)	**7am - 6pm**	**6pm - 10pm**	**10pm - 7am**
	Noise measured at a 'Sensitive place'		
$L_{A10, adj, 10 mins}$	46	46	41
$L_{A1, adj, 10 mins}$	55	51	45
	Noise measured at a 'Commercial place'		
$L_{A10, adj, 10 mins}$	51	N/A	N/A

E3	**Determining Noise limits for ML700006, ML700007, ML700008 and ML700009** The holder of the environmental authority must carry out a study to determine noise limits as per **Table E2**, at least **six (6) months** prior to coal mining taking place on ML700006, ML700007, ML700008 and ML700009.

Table E2 (Noise limits)

Sensitive place						
Noise level dB(A) measured as:	**Monday to Saturday**			**Sunday and public holidays**		
	7am to 6pm	**6pm to 10pm**	**10pm to 7am**	**9am to 6pm**	**6pm to 10pm**	**10pm to 9am**
$L_{Aeq, adj, 15 mins}$	TBA	TBA	TBA	TBA	TBA	TBA
$L_{A1, adj, 15 mins}$	TBA	TBA	TBA	TBA	TBA	TBA
Commercial place						
Noise level dB(A) measured as:	**Monday to Saturday**			**Sunday and public holidays**		
	7am to 6pm	**6pm to 10pm**	**10pm to 7am**	**9am to 6pm**	**6pm to 10pm**	**10pm to 9am**
$L_{Aeq, adj, 15 mins}$	TBA	TBA	TBA	TBA	TBA	TBA

E4	**Airblast overpressure limits** The holder of this environmental authority must ensure that blasting does not cause the limits for peak particulate velocity and air blast overpressure in **Table E3** to be exceeded at a sensitive place or commercial place.
E5	The holder of the environmental authority must develop and implement a blast monitoring program to monitor compliance with **Table E3** criteria.
E6	The environmental authority holder will respond within **twenty-eight (28) days** to any validated blasting limit complaints with a blast monitoring campaign, as agreed with the administrating authority, that assesses the level of nuisance with reference to the **Table E3** criteria.

Table E3 (Blasting noise limits)

Blasting noise limits	**Sensitive or commercial blasting noise limits**	
	7am – 6pm	**6pm – 7am**
Airblast overpressure	115dB (Linear) Peak for 9 out of 10 consecutive blasts initiated and not greater than 120dB (Linear) Peak at any time	No blasting impacts to occur
Ground vibration peak particulate velocity	5mm/second peak particle velocity for 9 out of 10 consecutive blasts and not greater than 10mm/second peak particle velocity at any time.	No blasting impacts to occur

E7	**Monitoring and reporting** Noise monitoring and recording must include the following descriptor characteristics and matters: a) LAN,T (where N equals the statistical levels of 1, 10 and 90 and T = time) b) background noise LA90 c) the level and frequency of occurrence of impulsive or tonal noise and any adjustment and penalties to statistical levels d) atmospheric conditions including temperature, relative humidity and wind speed and directions e) effects due to any extraneous factors such as traffic noise f) location, date and time of monitoring g) if the complaint concerns low frequency noise, Max LpLIN,T and one third octave band measurements in dB(LIN) for centre frequencies in the 10 – 200 Hz range.
E8	The method of measurement and reporting of airblast overpressure levels must comply with the current edition of the administering authority's *Noise Measurement Manual*.

Agency interest: Waste	
Condition number	**Condition**
F1	**Storage of tyres** Scrap tyres stored awaiting disposal or transport for take-back and recycling, or waste-to-energy options must be stored in stable stacks and at least 10 metre from any other scrap tyre storage area, or combustible or flammable material, including vegetation.
F2	All reasonable and practicable fire prevention measures must be implemented, including removal of grass and other materials within a 10 metre radius of the scrap tyre storage area.
F3	Disposing of scrap tyres resulting from the authorised activities in spoil emplacements is acceptable, provided tyres are placed as deep in the spoil as reasonably practicable.
F4	Scrap tyres resulting from the mining activities disposed within the operational land must not impede saturated aquifers or compromise the stability of the consolidated landform.
F5	**Waste management** A Waste Management Plan, in accordance with the *Waste Reduction and Recycling Act 2011,* must be implemented and must cover: a) describe how Curragh Coal Mine recognise and apply the waste and resource management hierarchy (*Waste Reduction and Recycling Act 2011)*; b) identify characterisations of wastes generated from the project and general volume trends over the past 3 years; c) a program for safe recycling or disposal of all wastes- reusing and recycling where possible; d) waste commitments with auditable targets to reduce, reuse and recycle; e) the waste management control strategies must consider: i. the type of wastes; ii. segregation of the wastes; iii. storage of the wastes; iv. transport of the wastes; v. monitoring and reporting matters concerning the waste; vi. emergency response planning; and vii. disposal, reused and recycling options. f) identify the potential adverse and beneficial impacts of the wastes generated; g) detail the hazardous characteristics of the waste generated (if any); h) cover a disposal procedure for hazardous wastes; i) outline the process to be implemented to allow for continuous improvement of the waste management systems; j) identify responsible staff (positions) for implementing, managing and reporting the Waste Management Plan; and k) cover a staff awareness and induction program that encourages re-use and recycling.

F6	Unless otherwise permitted by the conditions of this environmental authority or with prior approval from the administering authority and in accordance with a relevant standard operating procedure, waste must not be burnt.
F7	General waste must only be disposed of into the waste disposal trench facility of ML1878 and identified in **Figure 3**.
F8	The holder of this environmental authority may burn vegetation cleared in the course of carrying out extraction activities provided the activity does not cause environmental harm at any sensitive place or commercial place.
F9	Records must be kept for five years, and must include the following information: a) date of pickup of waste; b) description of waste; c) cross reference to relevant waste transport documentation; d) quantity of waste; e) origin of the waste; f) destination of the waste; and g) intended fate of the waste, for example, type of waste treatment, reprocessing or disposal. Note: Records of documents maintained in compliance with a waste tracking system established under the *Environmental Protection Act 1994* or any other law for regulated waste will be deemed to satisfy this condition.
F10	Records of trade and regulated wastes or material leaving the mining lease for recycling or disposal, including the final destination and method of treatment, must be in accordance with the *Waste Reduction and Recycling Act 2011.*
F11	All regulated waste received at and removed from the site must be transported by a person who holds a current authority to transport such waste under the provisions of the *Environmental Protection Act 1994*.
F12	Except as otherwise provided by the conditions of this authority, all waste removed from the site must be taken to a facility that is lawfully allowed to accept such waste under the provisions of the *Environmental Protection Act 1994*.

Agency interest: Land	
Condition number	**Condition**
G1	**Topsoil** Topsoil must be strategically stripped ahead of mining in accordance with a Topsoil Management Plan.
G2	**Preventing contaminant release to land** Contaminants must not be released to land in manner which constitutes nuisance, material or serious environmental harm.
G3	**Chemicals and flammable or combustible liquids** All flammable and combustible liquids, chemicals, explosives, corrosive substances, toxic substances, gases and dangerous goods must be contained within an on-site containment system and controlled in a manner that prevents environmental harm and maintained in accordance with the current version of the relevant Australian Standard.
G4	Spillage of all flammable and combustible liquids, chemicals, explosives, corrosive substances, toxic substances, gases and dangerous goods must be controlled in a manner that prevents environmental harm (other than trivial harm).
G5	All chemicals and flammable or combustible liquids stored on site that have the potential to cause environmental harm must be stored in or serviced by an effective containment system that is impervious to the materials stored and managed to prevent the release of liquids to waters or land. Where no relevant Australian Standard is available, the following must be applied: a) storage tanks must be bunded so that the capacity and construction of the bund is sufficient to contain at least 110% of a single storage tank or 100% of the largest storage tank plus 10% of the second largest storage tank in multiple storage areas; and b) drum storages must be bunded so that the capacity and construction of the bund is sufficient to contain at least 25% of the maximum design storage volume within the bund.
G6	**Spill kit** An appropriate spill kit, personal protective equipment and relevant operator instructions/emergency procedure guides for the management of wastes, chemicals and flammable and combustible liquids associated with the activity must be kept at the site.
G7	**Infrastructure** All infrastructure, constructed by or for the environmental authority holder during the licensed activities including water storage structures, must be removed from the site prior to surrender, except where agreed in writing by the post mining land owner / holder. Note: *This is not applicable where the landowner / holder is also the environmental authority holder.*
G8	**Acid rock drainage and leachate management** Subject to the release limits defined in Department Interest: Water, all reasonable and practicable measures must be implemented to prevent hazardous leachate being directly or indirectly released or likely to be released as a result of the activity to any groundwater or water course.

G9	**Rehabilitation landform criteria** All areas significantly disturbed by mining activities must be rehabilitated to a stable landform with a self-sustaining vegetation cover.
G10	Progressive rehabilitation must commence within three years when areas become available within the operational land.
G11	**Residual void outcome** Residual voids must comply with the following rehabilitation outcomes: residual voids must not cause any serious environmental harm to land, surface waters or any recognised groundwater aquifer, other than the environmental harm constituted by the existence of the residual void itself and subject to any other condition within this environmental authority.
G12	The rehabilitation of disturbed areas and residual void investigation reports, submitted to the administrating authority in June 2012, are to be updated to incorporate rehabilitated landform criteria and residual void outcomes for ML700006, ML700007, ML700008, ML700009, **six (6) months** prior to coal mining occurring on these ML's. The rehabilitated landform criteria and residual void outcomes from these reports must be reviewed every three years, or if any amendments occur and re-submitted to the administering authority.
G13	**Erosion** Rehabilitated land must: a) not have a rate of soil loss that exceeds that present in representative unmined areas within the mining leases that have the same chemical and physical characteristics including slope, slope length and fire regime; and b) not exhibit any signs of continued erosion greater than that exhibited on representative unmined areas within the mining leases.
G14	**Weed control** Class 1 and Class 2 declared plants as listed under the Land Protection Pest and Stock Route Management Act 2002 and subordinate legislation must not be present in the rehabilitation in densities that prevent the revegetation criteria from being achieved.
G15	**Rehabilitation of Blackwater Creek diversion** Rehabilitation of the Blackwater Creek diversion works must be conducted in accordance with the document EM Plan 1.4 Blackwater Creek Diversion Monitoring and Maintenance Plan.
G16	**Rehabilitation monitoring program** The holder of the environmental authority must conduct a Rehabilitation Monitoring Program on a yearly basis, which must include sufficient spatial and temporal replication to enable statistically valid conclusions as established under the rehabilitation program.
G17	**Post closure management plan** A post closure management plan for the site must be prepared at least **eighteen (18) months** prior to the final coal processing on site and implemented for a nominal period of: a) at least **thirty (30) years** following final coal processing on site; or b) a shorter period if the site is proven to be geotechnically and geochemically stable and it can be demonstrated to the satisfaction of the administering authority that no release of contaminants from the site will result in environmental harm.

G18	The post closure management plan must include the following elements: a) operation and maintenance of: i. wastewater collection and reticulation systems; ii. wastewater treatment systems; iii. the groundwater monitoring network; iv. final cover systems; and v. vegetative cover. b) monitoring of: i. surface water quality; ii. groundwater quality; iii. seepage rates; iv. erosion rates; v. the integrity and effectiveness of final cover systems; and vi. the health and resilience of native vegetation cover.
G19	**Biodiversity offsets** Significant residual impacts to prescribed environmental matters, other than if the impacts were authorised by an existing authority issued before the commencement of the *Environmental Offsets Act 2014*, are not authorised under this environmental authority or the *Environmental Offsets Act 2014* unless the impacts are specified in **Table G2 – Authorised impacts to prescribed environmental matters** in the locations shown in **Figure 5 – Prescribed Environmental Matters**. *Note: This condition relates to disturbance of land within Mine Activity Area 1 (ML700006 – Pit Z), Mine Activity Areas 2 (ML700007 and part ML700008 – Pit X) Mine Activity Area 3 (part ML700008 – Pit D) and Mine Activity Area 4 (ML700009 – Pit J).*
G20	Records demonstrating that each impact to a prescribed environmental matter not listed in **Table G2 - Authorised impacts to prescribed environmental matters** did not, or is not likely to, result in a significant residual impact to that matter must be: a) completed by an appropriately qualified person; and b) kept for the life of the environmental authority.
G21	An environmental offset made in accordance with the *Environmental Offsets Act 2014* and Queensland Environmental Offsets Policy, as amended from time to time, must be undertaken for the maximum extent of impact to each prescribed environmental matter authorised in **Table G2 - Authorised impacts to prescribed environmental matters**, unless a lesser extent of the impact has been approved in accordance with condition **G24** for staged offsets.

Table G2 (Authorised impacts to prescribed environmental matters)

Prescribed environmental matter	Maximum extent of impact	Environmental offset required	Maximum Extent of Impact – Stage 1	Maximum Extent of Impact – Stage 2	Maximum Extent of Impact – Stage 3	Maximum Extent of Impact – Stage 4
*Endangered regional ecosystem – 11.3.1**	*0.8ha*	*No*	*0*	*0.7*	*0*	*0.1*
*Endangered regional ecosystem - 11.4.7**	*10.1ha*	*No*	*6.6*	*3.5*	*0*	*0*
*Of concern regional ecosystem – 11.3.3**	*79ha*	*Yes*	*0*	*79.0*	*0*	*0*
*Remnant vegetation within a defined distance from the defining banks of a relevant watercourse***	*30.8ha*	*Yes*	*0*	*30.8*	*0*	*0*
Essential habitat for Ornamental snake	*1.3ha*	*Yes*	*0*	*1.3*	*0*	*0*
*Connectivity area***	*44.8ha*	*Yes*	*0*	*44.8*	*0*	*0*
Plants that are endangered wildlife - Solanum elachophyllum	*18.3ha*	*No*	*0*	*7.2*	*0*	*11.1*
*Habitat for an animal that is vulnerable wildlife – Yakka skink (Egernia rugosa)**	*10.9ha*	*No*	*6.6*	*4.2*	*0*	*0.1*
*Habitat for an animal that is vulnerable wildlife – Ornamental snake (Denisonia maculata)**	*79.9ha*	*No*	*0*	*79.8*	*0*	*0.1*
*Habitat for an animal that is vulnerable wildlife – Dunmall's snake (Furina dunmalli)**	*93.8ha*	*No*	*7.2*	*36.1*	*0*	*50.5*
*Habitat for an animal that is vulnerable wildlife – Eastern long-eared bat (Nyctophilus corbeni)**	*180.3ha*	*No*	*8.75*	*121*	*0*	*50.6*
*Habitat for an animal that is vulnerable wildlife- Large-eared pied bat (Chalinolobus dwyeri)**	*180.3ha*	*No*	*8.75*	*121*	*0*	*50.6*
*Habitat for an animal that is vulnerable wildlife – Squatter pigeon – (Geophaps scripta scripta)**	*97.4ha*	*No*	*8.2*	*89.1*	*0*	*0.1*
*Habitat for an animal that is vulnerable wildlife – Australian painted snipe (Rostratula australis)**	*75.9ha*	*No*	*0*	*75.9*	*0*	*0*

**These prescribed environmental matters duplicate MNES values and will be conditioned for offsets by the Commonwealth*

*** Offsets for remnant vegetation within a defined distance from the defining banks of a relevant watercourse &/ or connectivity areas may be co-located within an offset site for other prescribed environmental matters or MNES values conditioned for offsets by the Commonwealth, provided the site meets the offset requirements for each matter.*

G22	The significant residual impacts to a prescribed environmental matter authorised in condition **G19** for which an environmental offset is required by condition **G21** may be carried out in stages. An environmental offset can be delivered for each stage of the impacts to prescribed environmental matters.
G23	Prior to the commencement of each stage, a report completed by an appropriately qualified person, that includes an analysis of the following must be provided to the administering authority: a) for the forthcoming stage—the estimated significant residual impacts to each prescribed environmental matter; and b) for the previous stage, if applicable—the actual significant residual impacts to each prescribed environmental matter, to date.
G24	The report required by condition **G23** must be approved by the administering authority before a notice of election for the forthcoming stage, if applicable, is given to the administering authority.
G25	A notice of election for the staged environmental offset referred to in condition **G24**, if applicable, must be provided to the administering authority no less than three months before the proposed commencement of that stage, unless a lesser timeframe has been agreed to by the administering authority.
G26	Within six months from the completion of the final stage of the project, a report completed by an appropriately qualified person, that includes the following matters must be provided to the administering authority: a) an analysis of the actual impacts on prescribed environmental matters resulting from the final stage; and b) if applicable, a notice of election to address any outstanding offset debits for the authorised impacts.

Agency interest: Watercourse diversions	
Condition number	**Condition**
H1	Conditions **H2** to **H7** relate to disturbance associated with coal mining on land within Mine Activity Area 1 (ML700006 – Bonnie Doon Creek diversion) and Mine Activity Area 2 (ML700007 – Minnie Creek diversion) as identified in **Figure 6 – Watercourse Diversions**.
H2	**Permanent watercourse diversions** Permanent watercourse diversion, or the re-establishment of a pre-existing watercourse where a temporary watercourse diversion is being replaced, must be designed and constructed to: a) incorporate natural features (including geomorphic and vegetation) present at the location of the diversion b) maintain the pre-existing hydrologic characteristics of surface water and groundwater systems for the area in which the watercourse diversion is located c) maintain the hydraulic characteristics of the permanent watercourse diversion that are equivalent to other local watercourses and are suitable for the area in which the diversion is located without using artificial structures that require on-going maintenance d) maintain sediment transport and water quality regimes that allow the diversion to be self-sustaining, while minimising any impacts to upstream and downstream water quality, geomorphology or vegetation e) Maintain equilibrium and functionality in all substrate conditions at the location of the diversion.
H3	**Temporary watercourse diversions** Temporary watercourse diversions must be designed and constructed to: a) Maintain the pre-existing hydrologic characteristics of surface water systems for the area in which the watercourse diversion is located b) Maintain the hydraulic characteristics of the watercourse diversion that are equivalent to other local watercourses and are suitable for the area in which the diversion is located. Where structures that require on-going maintenance are used, they must not compromise the equilibrium and performance of the temporary watercourse diversion and adjoining watercourses c) Maintain sediment transport and water quality regimes that minimise any impacts to upstream and downstream.
H4	**Design plan – All diversions** A certified Design Plan that achieves condition **H2** for permanent watercourse diversions (i.e. Bonnie Doon Creek in Mine Activity Area 1 (ML700006) and Minnie Creek in Mine Activity Area 2 (ML700007) as identified in **Figure 6**) and condition **H3** for temporary watercourse diversions must be submitted to the administering authority at least **ten (10) business days** before commencing construction of the diversion.
H5	The certified design plan for any temporary or permanent watercourse diversion (i.e. Bonnie Doon Creek in Mine Activity Area 1 (ML700006) and Minnie Creek in Mine Activity Area 2 (ML700007) as identified on **Figure 6**) must be consistent with the functional design/s that formed a part of the application documents for this authority.

H6	**Construction and operation – All diversions** A certified set of 'as constructed' drawings and specifications must be submitted to the administering authority within **sixty (60) business days** from the completion of construction of the temporary or permanent watercourse diversion, or re-establishment of the pre-existing watercourse. These drawings and specifications must state: a) that the 'as constructed' drawings and specifications meet the original intent of the design plan for the watercourse diversion b) construction of the watercourse diversion is in accordance with the design plan.
H7	**Register – All diversions** The details of watercourse diversions planned and constructed under an environmental authority must be accurately recorded on the Register of Watercourse Diversions kept by the holder of the authority. An electronic copy must be provided to the administering authority on request.

Definitions

Words and phrases used throughout this environmental authority are defined below. Where a definition for a term used in this environmental authority is not provided within this environmental authority, but is provided in the *Environmental Protection Act (EP Act) 1994* or subordinate legislation, the definition in the *EP Act* or subordinate legislation must be used.

Acceptance criteria means the measures by which the actions implemented to rehabilitate the land are deemed to be complete. The acceptance criteria indicate the success of the rehabilitation outcome or remediation of areas which have been significantly been disturbed by the mining activities. Acceptance criteria may include information regarding:

a) vegetation establishment, survival and succession;

b) vegetation productivity, sustained growth and structure development;

c) fauna colonisation and habitat development;

d) ecosystem processes such as soil development and nutrient cycling, and the recolonisation of specific fauna groups such as collembola, mites and termites which are involved in these processes;

e) microbiological studies including recolonisation by mycorrhizal fungi, microbial biomass and respiration;

f) effects of various establishment treatments such as deep ripping, topsoil handling, seeding and fertiliser application on vegetation growth and development;

g) resilience of vegetation to disease, insect attack, drought and fire; and

h) vegetation water use and effects on ground water levels and catchment yields.

Administering authority is the agency that administers the environmental authority provisions under the *Environmental Protection Act 1994*.

AEP means the Annual Exceedance Probability, which is the probability that at least one event in excess of a particular magnitude will occur in any given year.

Airblast overpressure means energy transmitted from the blast site within the atmosphere in the form of pressure waves. The maximum excess pressure in this wave, above ambient pressure is the peak airblast overpressure measured in decibels linear (dBL).

Ambient (or total) noise at a place, means the level of noise at the place from all sources (near and far), measured as the Leq for an appropriate time interval.

Annual inspection report means an assessment prepared by a suitably qualified and experienced person containing details of the assessment against the most recent consequence assessment report and design plan (or system design plan);

a) against recommendations contained in previous annual inspections reports;

b) against recognised dam safety deficiency indicators;

c) for changes in circumstances potentially leading to a change in consequence category;

d) for conformance with the conditions of this authority;

e) for conformance with the ‘as constructed’ drawings;

f) for the adequacy of the available storage in each regulated dam, based on an actual observation or observations taken after **31 May** each year but prior to **1 November** of that year, of accumulated sediment, state of the containment barrier and the level of liquids in the **dam** (or network of linked containment systems);

g) for evidence of conformance with the current operational plan.

ANZECC means the *Australian and New Zealand Guidelines for Fresh Marine Water Quality 2000*

Authority means environmental authority (mining activities) under the *Environmental Protection Act 1994*.

Appropriately qualified person means a person who has professional qualifications, training, skills or experience relevant to the nominated subject matter and can give authoritative assessment, advice and analysis on performance relative to the subject matter using the relevant protocols, standards, methods or literature.

Assessed or **Assess** by a suitably qualified and experienced person in relation to a hazard assessment of a dam, means that a statutory declaration has been made by that person and, when taken together with any attached or appended documents referenced in that declaration, all of the following aspects are addressed and are sufficient to allow an independent audit at any time:

a) exactly what has been assessed and the precise nature of that assessment;

b) the relevant legislative, regulatory and technical criteria on which the assessment has been based;

c) the relevant data and facts on which the assessment has been based, the source of that material, and the efforts made to obtain all relevant data and facts; and

d) the reasoning on which the assessment has been based using the relevant data and facts, and the relevant criteria.

Associated works in relation to a dam, means:

a) operations of any kind and all things constructed, erected or installed for that dam; and

b) any land used for those operations.

Bed and banks for a waters, river, creek, stream, lake, lagoon, pond, swamp, wetland or dam means land over which the water of the waters, lake, lagoon, pond, swamp, wetland or dam normally flows or that is normally covered by the water, whether permanently or intermittently; but does not include land adjoining or adjacent to the bed and banks that is from time to time covered by floodwater.

Beneficial use in respect of dams means that the current or proposed owner of the land on which a dam stands, has found a use for that dam that is:

a) of benefit to that owner in that it adds real value to their business or to the general community,

b) in accordance with relevant provisions of the *Environmental Protection Act 1994*,

c) sustainable by virtue of written undertakings given by that owner to maintain that dam, and

d) the transfer and use have been approved or authorised under any relevant legislation.

Biosolids means the treated and stabilised solids from sewage.

Blasting means the use of explosive materials to fracture:

a) rock, coal and other minerals for later recovery; or

b) structural components or other items to facilitate removal from a site or for reuse.

Bunded means within bunding consistent with Australian Standard 1940.

Certification, certifying or **certified** by an appropriately qualified and experienced person in relation to a design plan or an annual report regarding dams/structures, means that a statutory declaration has been made by that person and, when taken together with any attached or appended documents referenced in that declaration, all of the following aspects are addressed and are sufficient to allow an independent audit at any time:

a) exactly what is being certified and the precise nature of that certification.

b) the relevant legislative, regulatory and technical criteria on which the certification has been based;

c) the relevant data and facts on which the certification has been based, the source of that material, and the efforts made to obtain all relevant data and facts; and

d) the reasoning on which the certification has been based using the relevant data and facts, and the relevant criteria.

Chemical means:

a) an agricultural chemical product or veterinary chemical product within the meaning of the *Agricultural and Veterinary Chemicals Code Act 1994* (Commonwealth), or

b) a dangerous good under the Australian Code for the Transport of Dangerous Goods by Road and Rail approved by the Australian Transport Council, or

c) a lead hazardous substance within the meaning of the *Workplace Health and Safety Regulation 1997*, or

d) a drug or poison in the Standard for the Uniform Scheduling of Drugs and Poisons prepared by the Australian Health Ministers' Advisory Council and published by the Commonwealth, or

e) any substance used as, or intended for use as:

   i) a pesticide, insecticide, fungicide, herbicide, rodenticide, nematocide, miticide, fumigant or related product, or

   ii) a surface active agent, including, for example, soap or related detergent, or

   iii) a paint solvent, pigment, dye, printing ink, industrial polish, adhesive, sealant, food additive, bleach, sanitiser, disinfectant, or biocide, or

   iv) a fertiliser for agricultural, horticultural or garden use, or

   v) a substance used for, or intended for use for mineral processing or treatment of metal, pulp and paper, textile, timber, water or wastewater, or

   vi) manufacture of plastic or synthetic rubber.

Coal mining means to carry on an operation for the purpose of extracting coal from its natural state and disposing of mineral in connection with, or waste substances resulting from, the extraction. This includes processes such as overburden removal, blasting, coal mining, waste rock and tailings disposal, crushing, washing and flotation and the construction activities associated with these processes. It does not include exploration activities.

Commercial place means a work place used as an office or for business or commercial purposes, which is not part of the mining activity and does not include employees accommodation or public roads.

Competent person means a person with the demonstrated skill and knowledge required to carry out the task to a standard necessary for the reliance upon collected data or protection of the environment.

Consequence category means a category, either low, significant or high, into which a dam is assessed as a result of the application of tables and other criteria in the *Manual for assessing consequence categories and hydraulic performance of structures (ESR/2016/1933)*.

Construction or **constructed** in relation to a regulated structure includes building a new regulated structure and lifting or otherwise modifying an existing regulated structure, but does not include investigation and testing necessary for the purpose of preparing a design plan.

Construction or **constructed** in relation to watercourse diversions, is the process of building, or modifying an existing diversion, but does not include investigation and testing necessary for the purpose of preparing a design plan.

Contaminate means to render impure by contact or mixture.

Contaminated means the substance has come into contact with a contaminant.

Contaminant A contaminant can be:

a) a gas, liquid or solid; or

b) an odour; or

c) an organism (whether alive or dead), including a virus; or

d) energy, including noise, heat, radioactivity and electromagnetic radiation; or

e) a combination of contaminants.

Control measure means any action or activity that can be used to prevent or eliminate a hazard or reduce it to an acceptable level.

Cover material means any soil or rock suitable as a germination medium or landform armouring.

Dam means a land-based structure or a void that is designed to contain, divert or control flowable substances - including any substances that are thereby contained, diverted or controlled by that land-based structure or void; but does not mean a fabricated or manufactured tank or container designed to a recognised standard. In case there is any doubt, a levee dyke or bund is a dam.

Design plan (structures which are dams or levees**)** is a document setting out how all identified consequence scenarios are addressed in the planned design and operation of a regulated structure.

Design plan (watercourse diversion**)** is a document that contains the design, operation, monitoring and revegetation criteria of a watercourse diversion that addresses the outcomes stated in conditions on the environmental authority relating to the diversion. The document should include, but not be limited to:

a) required information under a functional design

b) the location, function and description of geomorphic and riparian vegetation features within the proposed watercourse diversion

c) results from hydrologic, hydraulic and sediment transportation modelling used in the design of the diversion

d) a revegetation and vegetation management plan (a revegetation plan) for the diversion

e) engineering drawings depicting the physical attributes and dimensions of the diversion

f) (if relevant) the staged development of a permanent watercourse diversion including the proposed use of temporary watercourse diversions with identified lifespans

g) all investigation and other reports relied on by the design

h) plans and specifications sufficient to complete construction and revegetation in accordance with the design.

Design storage allowance or **DSA** means the minimum storage required in a dam at the first of November each year in order to meet the hydraulic performance requirements.

Development approval means a development approval under the *Integrated Planning Act 1997* in relation to a matter that involves an environmentally relevant activity under the *Environmental Protection Act 1994*.

Disturbance of land includes:

a) compacting, removing, covering, exposing or stockpiling of earth

b) removal or destruction of vegetation or topsoil or both to an extent where the land has been made susceptible to erosion

c) carrying out mining within a watercourse, waterway, wetland or lake

d) the submersion of areas by tailings or hazardous contaminant storage and dam/structure walls

e) temporary infrastructure, including any infrastructure (roads, tracks, bridges, culverts, dam/structures, bores, buildings, fixed machinery, hardstand areas, airstrips, helipads etc) which is to be removed after the mining activity has ceased

f) releasing of contaminants into the soil, or underlying geological strata.

However, the following areas are not included when calculating areas of 'disturbance':

a) areas off lease (e.g. roads or tracks which provide access to the mining lease)

b) areas previously disturbed which have achieved the rehabilitation outcomes

c) by agreement with the administering authority, areas previously disturbed which have not achieved the rehabilitation objective(s) due to circumstances beyond the control of the mine operator (such as climatic conditions)

d) areas under permanent infrastructure. Permanent infrastructure includes any infrastructure (roads, tracks, bridges, culverts, dam/structures, bores, buildings, fixed machinery, hardstand areas, airstrips, helipads etc) which is to be left by agreement with the landowner

e) disturbance that pre-existed the grant of the tenure.

Domestic waste means waste, other than domestic clean-up waste, green waste, recyclable waste, interceptor waste or waste discharged to a sewer, produced as a result of the ordinary use or occupation of domestic premises.

Dwelling means any of the following structures or vehicles that is principally used as a residence:

a) a house, unit, motel, nursing homes or other building or part of a building; or

b) a caravan, mobile home or other vehicle or structure on land; or

c) a water craft in a marina.

Effluent treated waste water discharged from sewage treatment plants.

End of pipe means the location at which water is released to waters or land.

Environmental authority means an environmental authority under Chapter 5 of the *Environmental Protection Act 1994.*

Environmental authority holder means the holder of this environmental authority.

Environmental nuisance is unreasonable interference or likely interference with an environmental value caused by:

a) aerosols, fumes, light, noise, odour, particles or smoke; or

b) an unhealthy, offensive or unsightly condition because of contamination; or

c) another way prescribed by regulation.

Environmental offset has the meaning in section 7 of the *Environmental Offsets Act 2014*.

Equilibrium A state where 'balance' is achieved despite changing variables.

Environmentally relevant activity means an environmentally relevant activity as defined under Section 18 of the *Environmental Protection Act 1994* and listed under Schedule 1 of the *Environmental Protection Regulation 1998.*

Existing structure means a structure that prior to when EA is issued with new dam manual conditions meets any or both of the following, a structure:

a) with a design that is in accordance with the current version of the Manual for Assessing Consequence Categories and Hydraulic Performance of Structures and that is considerably in progress;

b) that is under considerable construction or that is constructed.

Floodwater means water overflowing, or that has overflowed, from waters, river, creek, stream, lake, pond, wetland or dam onto or over riparian land that is not submerged when the watercourse or lake flows between or is contained within its bed and banks.

Flowable substance means matter or a mixture of materials which can flow under any conditions potentially affecting that substance. Constituents of a flowable substance can include water, other liquids fluids or solids, or a mixture that includes water and any other liquids fluids or solids either in solution or suspension.

Foreseeable future is the period used for assessing the total probability of an event occurring. Permanent structures and ecological sustainability should be expected to still exist at the end of a 150 year foreseeable future with an acceptable probability of failure before that time.

Functional design is a document that contains 'conceptual' information about the design, operation and revegetation criteria of a watercourse diversion that addresses the outcomes stated in the conditions on the environmental authority relating to the diversion. The document should include, but not be limited to:

a) geomorphic and vegetation assessment of the existing watercourse

b) hydrologic conditions of the existing watercourse

c) the proposed watercourse diversion route

d) results from hydrologic, hydraulic and sediment transportation modelling used in the design of the diversion.

General waste means waste other than regulated waste.

Hazardous waste means a substance, whether liquid, solid or gaseous that, if improperly treated, stored, disposed of or otherwise managed, is likely to cause environmental harm.

Hazard in relation to a dam as defined, means the potential for environmental harm resulting from the collapse or failure of the dam to perform its primary purpose of containing, diverting or controlling flowable substances.

Hazard category means a category, either low significant or high, into which a dam is assessed as a result of the application of tables and other criteria in 'Manual for Assessing Hazard Categories and Hydraulic Performance of Dams'.

Hydraulic performance means the capacity of a regulated dam to contain or safely pass flowable substances based on the design criteria specified for the relevant consequence category in the *Manual for assessing consequence categories and hydraulic performance of structures (ESR/2016/1933)*.

Infrastructure means water storage dams, roads and tracks, buildings and other structures built for the purpose of mining activities but does not include other facilities required for the long term management of mining impacts or the protection of potential resources. Such other facilities include dams, waste rock dumps, voids, or ore stockpiles and buildings as well as other structures whose ownership can be transferred and which have a residual beneficial use for the next owner of the operational land or the background land owner.

$L_{A10,\ adj,\ 10\ mins}$ means the A-weighted sound pressure level, (adjusted for tonal character and impulsiveness of the sound) exceeded for 10% of any 10-minute measurement period, using Fast response.

$L_{A\ 1,\ adj,\ 10\ mins}$ means the A-weighted sound pressure level, (adjusted for tonal character and impulsiveness of the sound) exceeded for 1% of any 10-minute measurement period, using Fast response

$L_{A,\ max\ adj,\ T}$ means the average maximum A-weighted sound pressure level, adjusted for noise character and measured over any 10 minute period, using Fast response.

Lake includes:

a) lagoon, swamp or other natural collection of water, whether permanent or intermittent; and

b) the bed and banks and any other element confining or containing the water.

Land in the **land schedule** of this document means land excluding waters and the atmosphere, that is, the term has a different meaning from the term as defined in the *Environmental Protection Act 1994*. For the purposes of the *Acts Interpretation Act 1954*, it is expressly noted that the term 'land' in this environmental authority relates to physical land and not to interests in land.

Land capability as defined in the *DME 1995 Technical Guidelines for the Environmental Management of Exploration and Mining in Queensland*.

Land suitability as defined in the *DME 1995 Technical Guidelines for the Environmental Management of Exploration and Mining in Queensland*.

Land use means the selected post mining use of the land, which is planned to occur after the cessation of mining operations.

Landfill means land used as a waste disposal site for lawfully putting solid waste on the land.

Levee means an embankment that only provides for the containment and diversion of stormwater or flood flows from a contributing catchment, or containment and diversion of flowable materials resulting from releases from other works, during the progress of those stormwater or flood flows or those releases; and does not store any significant volume of **water** or **flowable substances** at any other times.

Mandatory reporting level or **MRL** means a warning and reporting level determined in accordance with the criteria in the *Manual for assessing consequence categories and hydraulic performance of structures (ESR/2016/1933)* published by the administering authority.

Manual means the *Manual for assessing consequence categories and hydraulic performance of structures (ESR/2016/1933)* published by the administering authority, as amended from time to time.

Maximum extent of impact means the total, cumulative, residual extent and duration of impact to a prescribed environmental matter that will occur over a project's life after all reasonable avoidance and reasonable on-site mitigation measures have been, or will be, undertaken.

Measures includes any measures to prevent or minimise environmental impacts of the mining activity such as bunds, silt fences, diversion drains, capping, and containment systems.

mg/L means milligrams per litre.

Mineral means a substance which normally occurs naturally as part of the earth's crust or is dissolved or suspended in water within or upon the earth's crust and includes a substance which may be extracted from such a substance, and includes—

a) clay if mined for use for its ceramic properties, kaolin and bentonite;

b) foundry sand;

c) hydrocarbons and other substances or matter occurring in association with shale or coal and necessarily mined, extracted, produced or released by or in connection with mining for shale or coal or for the purpose of enhancing the safety of current or future mining operations for coal or the extraction or production of mineral oil therefrom;

d) limestone if mined for use for its chemical properties;

e) marble;

f) mineral oil or gas extracted or produced from shale or coal by in situ processes;

g) peat;

h) salt including brine;

i) shale from which mineral oil may be extracted or produced;

j) silica, including silica sand, if mined for use for its chemical properties;

k) rock mined in block or slab form for building or monumental purposes;

But does not include—

a) living matter;

b) petroleum within the meaning of the *Petroleum Act 1923*;

c) soil, sand, gravel or rock (other than rock mined in block or slab form for building or monumental purposes) to be used or to be supplied for use as such, whether intact or in broken form; or

d) water.

'Mine affected water':

a) means the following types of water:

i) pit water, tailings dam water, processing plant water

ii) water contaminated by a mining activity which would have been an environmentally relevant activity under Schedule 2 of the *Environmental Protection Regulation 2008* if it had not formed part of the mining activity

iii) rainfall runoff which has been in contact with any areas disturbed by mining activities which have not yet been rehabilitated, excluding rainfall runoff discharging through release points associated with erosion and sediment control structures that have been installed in accordance with the standards and requirements of an Erosion and Sediment Control Plan to manage such runoff, provided that this water has not been mixed with pit water, tailings dam water, processing plant water or workshop water

iv) groundwater which has been in contact with any areas disturbed by mining activities which have not yet been rehabilitated

v) groundwater from the mine's dewatering activities

vi) a mix of mine affected water (under any of paragraphs i)-v) and other water.

b) does not include surface water runoff which, to the extent that it has been in contact with areas disturbed by mining activities that have not yet been completely rehabilitated, has only been in contact with:

i) land that has been rehabilitated to a stable landform and either capped or revegetated in accordance with the acceptance criteria set out in the environmental authority but only still awaiting maintenance and monitoring of the rehabilitation over a specified period of time to demonstrate rehabilitation success, or

ii) land that has partially been rehabilitated and monitoring demonstrates the relevant part of the landform with which the water has been in contact does not cause environmental harm to waters or groundwater, for example:

- areas that are been capped and have monitoring data demonstrating hazardous material adequately contained with the site
- evidence provided through monitoring that the relevant surface water would have met the water quality parameters for mine affected water release limits in this environmental authority, if those parameters had been applicable to the surface water runoff, or

iii) both.

Minimise is to reduce to the smallest possible amount or degree.

Mining operations means mining activities carried out on land over which there is a mineral development licence or mining lease under the *Mineral Resources Act 1989*.

Modification or modifying (see definition of 'construction')

NATA means National Association of Testing Authorities, Australia.

Natural flow means the flow of water through waters caused by nature.

Nature includes:

a) ecosystems and their constituent parts; and

b) all natural and physical resources; and

c) natural dynamic processes.

Notice of election has the meaning in section 18(2) *Environmental Offsets Act 2014*.

Noxious means harmful or injurious to health or physical well being.

Offensive means causing reasonable offence or displeasure; is disagreeable to the sense; disgusting, nauseous or repulsive, other than trivial harm.

Operational land means the land associated with the project for which this environmental authority has been issued.

Operational plan means a document that amongst other things sets out procedures and criteria to be used for operating a dam during a particular time period. The operational plan as defined herein may form part of a otherwise required in legislation.

Palletised means stored on a movable platform on which batteries are placed for storage or transportation.

Peak particle velocity (ppv) means a measure of ground vibration magnitude which is the maximum rate of change of ground displacement with time, usually measured in millimetres/second (mm/s).

Permanent watercourse diversion is a man-made structure that incorporates the geomorphologic, hydraulic, hydrologic and ecological components of a local watercourse and is designed, constructed, operated and maintained according to an engineering standard that ultimately achieves a self-sustaining watercourse able to function without features or characteristics that rely on ongoing maintenance or that impose a financial or other burden on the proponent, government or the community.

Pre-existing watercourse is the section of watercourse from which the flow of water will be diverted as a result of the construction and operation of a watercourse diversion.

Prescribed environmental matters has the meaning in section 10 of the *Environmental Offsets Act 2014*, limited to the matters of State environmental significant listed in schedule 2 of the Environmental Offsets Regulation 2014.

Protected area means – a protected area under the *Nature Conservation Act 1992*, or

a) a marine park under the Marine Parks Act 1992, or
b) a World Heritage Area.

Progressive rehabilitation means rehabilitation (defined below) undertaken progressively or a staged approach to rehabilitation as mining operations are ongoing.

Process water means water used or produced during the mineral development activities.

Receiving waters means the waters into which this environmental authority authorises releases of mine affected water.

Recycled water means appropriately treated effluent and urban stormwater suitable for further use.

Reference site (or analogue site) may reflect the original location, adjacent area or another area where rehabilitation success has been completed for a similar biodiversity. Details of the reference site may be as photographs, computer generated images and vegetation models etc.

Register of Regulated Structures includes**:**

a) Date of entry in the register;
b) Name of the structure, its purpose and intended/actual contents;
c) The consequence category of the dam as assessed using the *Manual for assessing consequence categories and hydraulic performance of structures (ESR/2016/1933)*;
d) Dates, names, and reference for the design plan plus dates, names, and reference numbers of all document(s) lodged as part of a design plan for the dam;
e) Name and qualifications of the suitably qualified and experienced person who certified the design plan and 'as constructed' drawings;
f) For the regulated dam, other than in relation to any levees –

i) The dimensions (metres) and surface area (hectares) of the dam measured at the footprint of the dam;

ii) Coordinates (latitude and longitude in GDA94) within five metres at any point from the outside of the dam including its storage area

iii) Dam crest volume (megalitres);

iv) Spillway crest level (metres AHD).

v) Maximum operating level (metres AHD);

vi) Storage rating table of stored volume versus level (metres AHD);

vii) Design storage allowance (megalitres) and associated level of the dam (metres AHD);

viii) Mandatory reporting level (metres AHD);

g) The design plan title and reference relevant to the dam;

h) The date construction was certified as compliant with the design plan;

i) The name and details of the suitably qualified and experienced person who certified that the constructed dam was compliant with the design plan;

j) Details of the composition and construction of any liner;

k) The system for the detection of any leakage through the floor and sides of the dam;

l) Dates when the regulated dam underwent an annual inspection for structural and operational adequacy, and to ascertain the available storage volume for 1 November of any year;

m) Dates when recommendations and actions arising from the annual inspection were provided to the administering authority;

n) Dam water quality as obtained from any monitoring required under this authority as at 1 November of each year.

Regulated dam means any dam in the significant or high hazard category as assessed using the *Site Water Management Technical Guideline for Environmental Management of Exploration and Mining in Queensland (DME 1995)*.

Regulated structure means any structure in the significant or high consequence category as assessed using the *Manual for assessing consequence categories and hydraulic performance of structures (ESR/2016/1933)* published by the administering authority. A regulated structure does not include:

a) a fabricated or manufactured tank or container, designed and constructed to an Australian Standard that deals with strength and structural integrity of that tank or container;

b) a sump or earthen pit used to store residual drilling material and drilling fluid only for the duration of drilling and well completion activities;

c) a flare pit.

Regulated waste means non-domestic waste mentioned in schedule 7 of the *Environmental Protection Regulation 1998* (whether or not it has been treated or immobilised), and includes –

a) for an element – any chemical compound containing the element; and

b) anything that has contained the waste.

Rehabilitation the process of reshaping and revegetating land to restore it to a stable landform.

Release event means a surface water discharge from mine affected water storages or contaminated areas on the licensed place.

Representative means a sample set which covers the variance in monitoring or other data either due to natural changes or operational phases of the mining activities.

Residual void means an open pit resulting from the removal of ore and/or waste rock which will remain following the cessation of all mining activities and completion of rehabilitation processes.

Revegetation is the re-establishment of vegetation[1] of a species and density of cover similar to surrounding undisturbed areas or the landform that existed before mining activities on soil surfaces associated with the construction or rehabilitation of a watercourse diversion.

Saline drainage The movement of waters, contaminated with salts, as a result of the mining activity.

Self sustaining means not requiring on-going intervention and maintenance to maintain functional riverine processes and characteristics

Sensitive place means:

a) a dwelling, residential allotment, mobile home or caravan park, residential marina or other residential premises; or

b) a motel, hotel or hostel; or

c) an educational institution; or

d) a medical center or hospital; or

e) a protected area under the *Nature Conservation Act 1992*, the *Marine Parks Act 1992* or a World Heritage Area; or

f) a public park or gardens.

Note: The definition of 'sensitive place' and 'commercial place' is based on Schedule 1 of EPP Noise. That is, a sensitive place is inside or outside on a dwelling, library and educational institution, childcare or kindergarten, school or playground, hospital, surgery or other medical institution, commercial & retail activity, protected area or an area identified under a conservation plan under Nature Conservation Act 1992 as a critical habitat or an area of major interest, marine park under Marine Parks Act 2004, park or garden that is outside of the mining lease and open to the public for the use other than for sport or organised entertainment. A commercial place is inside or outside a commercial or retail activity.

A mining camp (i.e., accommodation and ancillary facilities for mine employees or contractors or both, associated with the mine the subject of the environmental authority) is not a sensitive place for that mine or mining project, whether or not the mining camp is located within a mining tenement that is part of the mining project the subject of the environmental authority. For example, the mining camp might be located on neighbouring land owned or leased by the same company as one of the holders of the environmental authority for the mining project, or a related company. Accommodation for mine employees or contractors is a sensitive place if the land is held by a mining company or related company, and if occupation is restricted to the employees, contractors and their families for the particular mine or mines which are held by the same company or a related company.

For example, a township (occupied by the mine employees, contractors and their families for multiple mines that are held by different companies) would be a sensitive place, even if part or all of the township is constructed on land owned by one or more of the companies.

Sewage means the used water of person's to be treated at a sewage treatment plant.

Spillway means a weir, channel, conduit, tunnel, gate or other structure designed to permit discharges from the dam, normally under flood conditions or in anticipation of flood conditions.

Stable in relation to land, means land form dimensions are or will be stable within tolerable limits now and in the foreseeable future. Stability includes consideration of geotechnical stability, settlement and consolidation allowances, bearing capacity (trafficability), erosion resistance and geochemical stability with respect to seepage, leachate and related contaminant generation.

Stormwater means all surface water runoff from rainfall.

Structure means dam or levee.

Suitably qualified and experienced person means a person who is a Registered Professional Engineer of Queensland under the provisions of the *Professional Engineers Act 2002*, who has an **appropriate level of expertise** in the structures, geomechanics, hydrology, hydraulics and environmental impact of watercourse diversions.

An ***appropriate level of expertise*** includes:

- demonstrable competency, experience and expertise in:
    - investigation, design or construction of watercourses
    - diversions operation and maintenance of watercourse
    - geomechanics with particular emphasis on channel equilibrium, geology and geochemistry
    - hydrology with particular reference to flooding, estimation of extreme storms, water management or meteorology
    - hydraulics with particular reference to sediment transport and deposition and erosion control
    - hydrogeology with particular reference to seepage and groundwater
    - solute transport processes and monitoring thereof, or
- sufficient knowledge and experience to certify that where the **suitably qualified and experienced person** has relied on advice and information provided by other **persons with relevant expertise***:
    - they consider it reasonable to rely on that advice and information
    - the expert providing the advice and information has knowledge, competency, suitable experience and demonstrated expertise in the matters related to watercourse diversions.

Persons with relevant expertise include:

- Geomorphologist: person who has demonstrated competency and relevant experience in stream geomorphology and watercourse diversions.
- Geotechnical Expert: person who has demonstrated competency and relevant experience in geotechnical assessment of soil characteristics suitable for watercourse diversions.
- Vegetation Expert: person who has demonstrated competency and relevant experience in the identification, role and function of vegetation with watercourses and adjoining floodplains, and has demonstrated competency and relevant experience in revegetation of watercourse diversions and adjoining floodplains. .
- Groundwater Expert: person who has demonstrated competency and relevant experience in groundwater systems.
- Surface Water Expert: person who has demonstrated competency and relevant experience in hydrology.

- Engineer: person who is a Registered Professional Engineer of Queensland (RPEQ) under the provisions of the *Professional Persons Act 2002* or has similar qualifications under a respected professional registration association, and has demonstrated competency and relevant experience in design and construction of watercourse diversions.
- Soils Expert: person who has demonstrated competency and relevant experience in soil classification including the physical, chemical and hydrologic analysis of soil.

Suitably qualified and experienced person in relation to regulated structures means a person who is a Registered Professional Engineer of Queensland (RPEQ) under the provisions of the *Professional Engineers Act 2002*, and has demonstrated competency and relevant experience:

- for regulated dams, an RPEQ who is a civil engineer with the required qualifications in dam safety and dam design
- for regulated levees, an RPEQ who is a civil engineer with the required qualifications in the design of flood protection embankments.

Note: It is permissible that a suitably qualified and experienced person obtain subsidiary certification from an RPEQ who has demonstrated competence and relevant experience in either geomechanics, hydraulic design or engineering hydrology.

System design plan means a plan that manages an integrated containment system that shares the required DSA and/or ESS volume across the integrated containment system.

Temporary watercourse diversion is a man-made structure that may incorporate geomorphologic, hydraulic, hydrologic and ecological components of a local watercourse and is designed, constructed, operated and maintained to an engineering standard that ensures the diversion does not compromise the equilibrium and performance of the diversion and adjoining watercourses. A temporary diversion is replaced by a permanent diversion, or the re-establishment of the pre existing watercourse, within the timeframe specified in the design plan.

The Act means the *Environmental Protection Act 1994*.

Trivial harm means environmental harm which is not material or serious environmental harm and will not cause actual or potential loss or damage to property of an amount of, or amounts totalling more than $5,000.

Tolerable limits means a range of parameters regarded as being sufficient to meet the objective of protecting relevant environmental values. For example, a range of settlement for a tailings capping, rather than a single value, could still meet the objective of draining the cap quickly, preventing pondage and limiting infiltration and percolation.

Void means any man-made, open excavation in the ground.

Waste as defined in section 13 of the *Environmental Protection Act 1994*.

Waste and resource management hierarchy – has the meaning provided in section 9 of the *Waste Reduction and Recycling Act 2011* and is the following precepts, listed in the preferred order in which waste and resource management options should be considered—

a) AVOID unnecessary resource consumption
b) REDUCE waste generation and disposal
c) RE-USE waste resources without further manufacturing
d) RECYCLE waste resources to make the same or different products
e) RECOVER waste resources, including the recovery of energy

f) TREAT waste before disposal, including reducing the hazardous nature of waste

g) DISPOSE of waste only if there is no viable alternative.

Waste and resource management principles – has the meaning provided in section 4(2)(b) of the *Waste Reduction and Recycling Act 2011* and means the:

a) polluter pays principle

b) user pays principle

c) proximity principle

d) product stewardship principle.

Water is defined under Schedule 4 of the *Water Act 2000.*

Watercourse has the meaning in Schedule 4 of the *Environmental Protection Act 1994* and means:

a) a river, creek or stream in which water flows permanently or intermittently—

i) in a natural channel, whether artificially improved or not; or

ii) in an artificial channel that has changed the course of the watercourse.

b) Watercourse includes the bed and banks and any other element of a river, creek or stream confining or containing water.

Waste water means used water from the activity, process water or contaminated storm water.

Water quality means the chemical, physical and biological condition of water.

Waters includes all or any part of a river, stream, lake, lagoon, pond, swamp, wetland, unconfined surface water, unconfined water in natural or artificial watercourses, bed and banks of a watercourse, dams, non-tidal or tidal waters (including the sea), stormwater channel, stormwater drain, roadside gutter, stormwater run-off, and groundwater.

Weediness includes weeds that are declared plants as defined under the *Land Protection (Pest and Stock Route Management) Act 2002*.

µg/L means micrograms per litre

µS/cm means micro siemens per centimetre

Figure 1 - Release points (RP) and monitoring points (MP) on Blackwater Creek



Figure 2 - Release points (RP) and monitoring points (MP) on the Mackenzie River

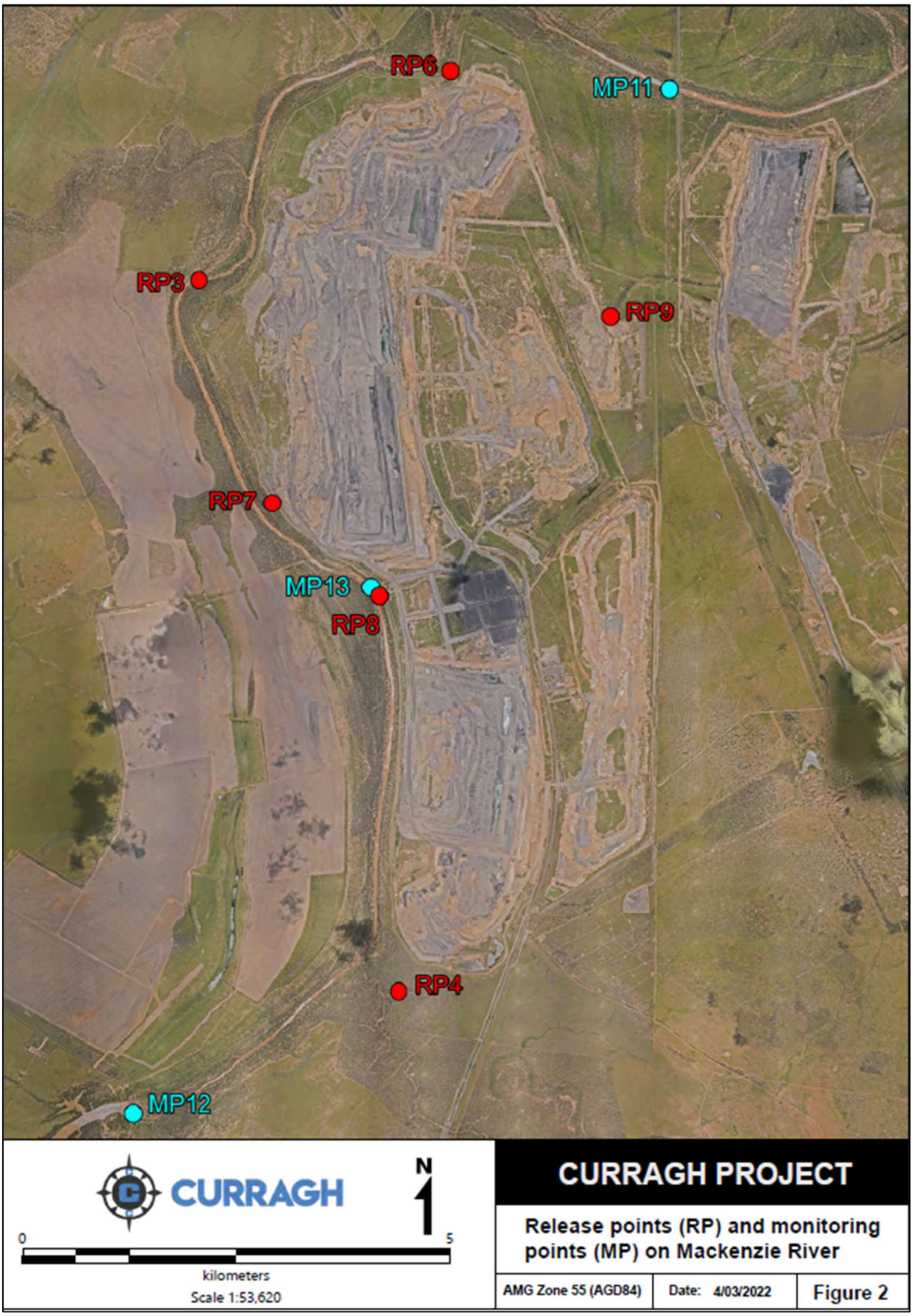


Figure 3 – Curragh Mine Onsite Landfill Facility



Figure 4 – Approved Disturbance Area and Mine Activity Areas

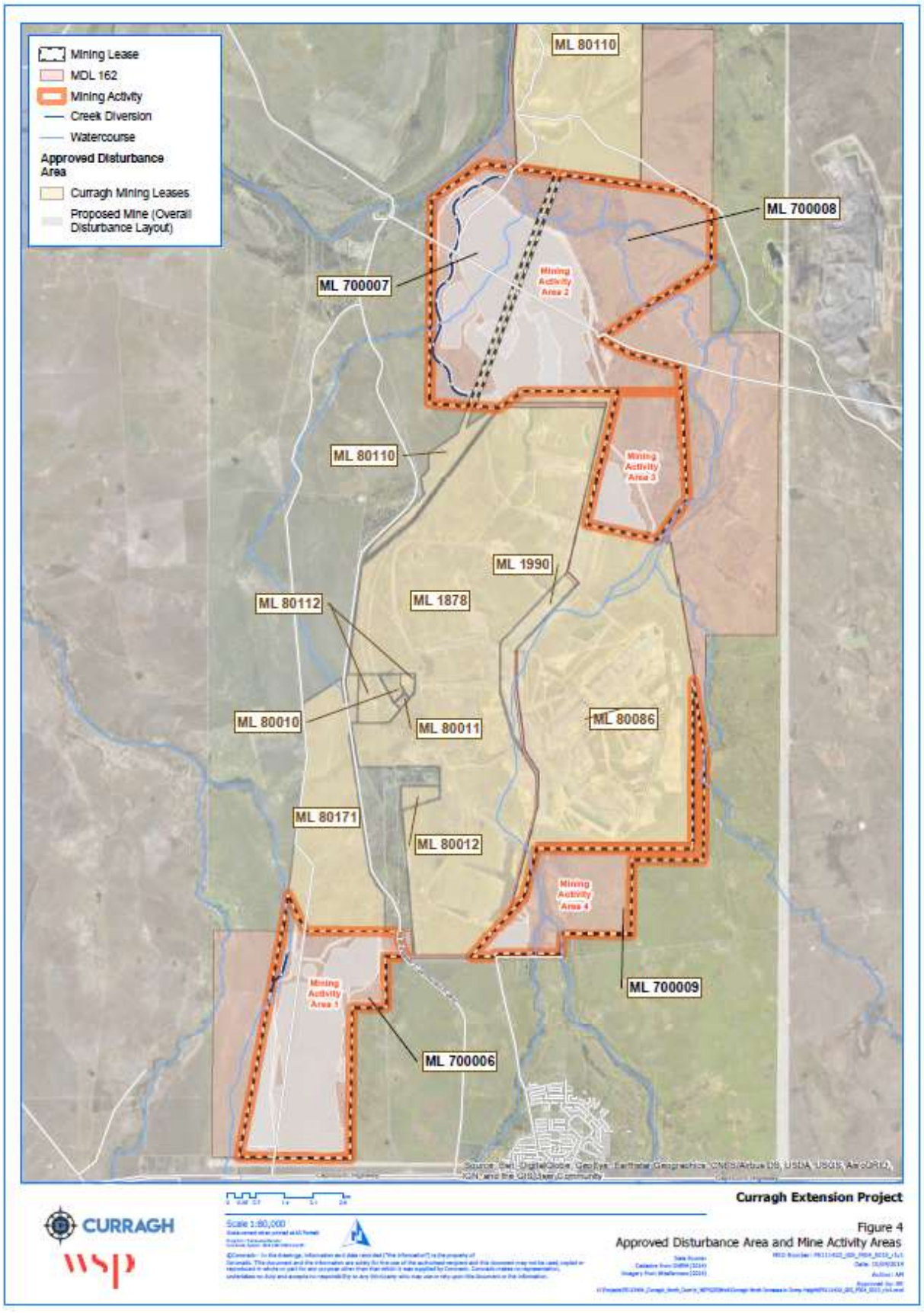


Figure 5 – Prescribed environmental matters

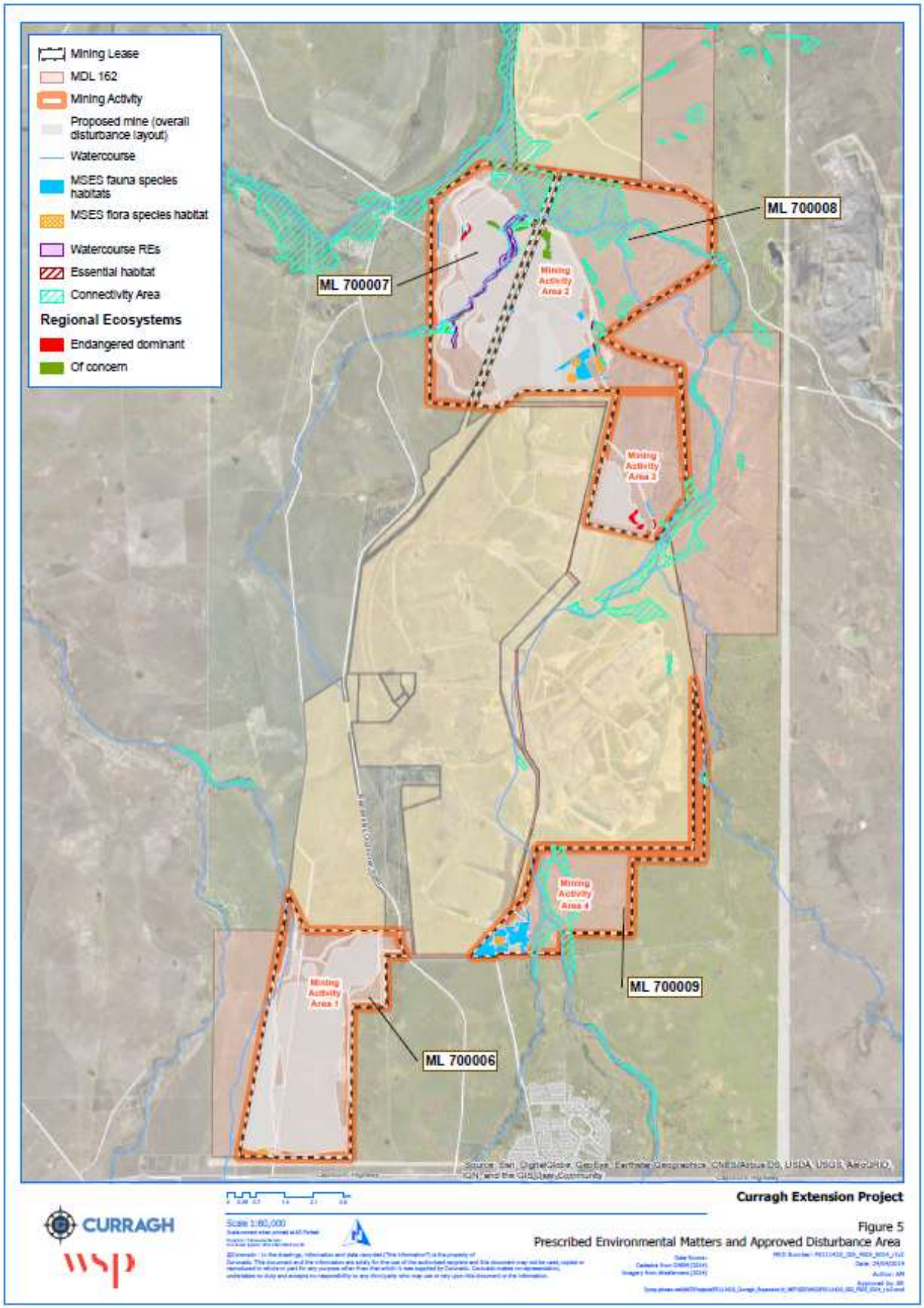
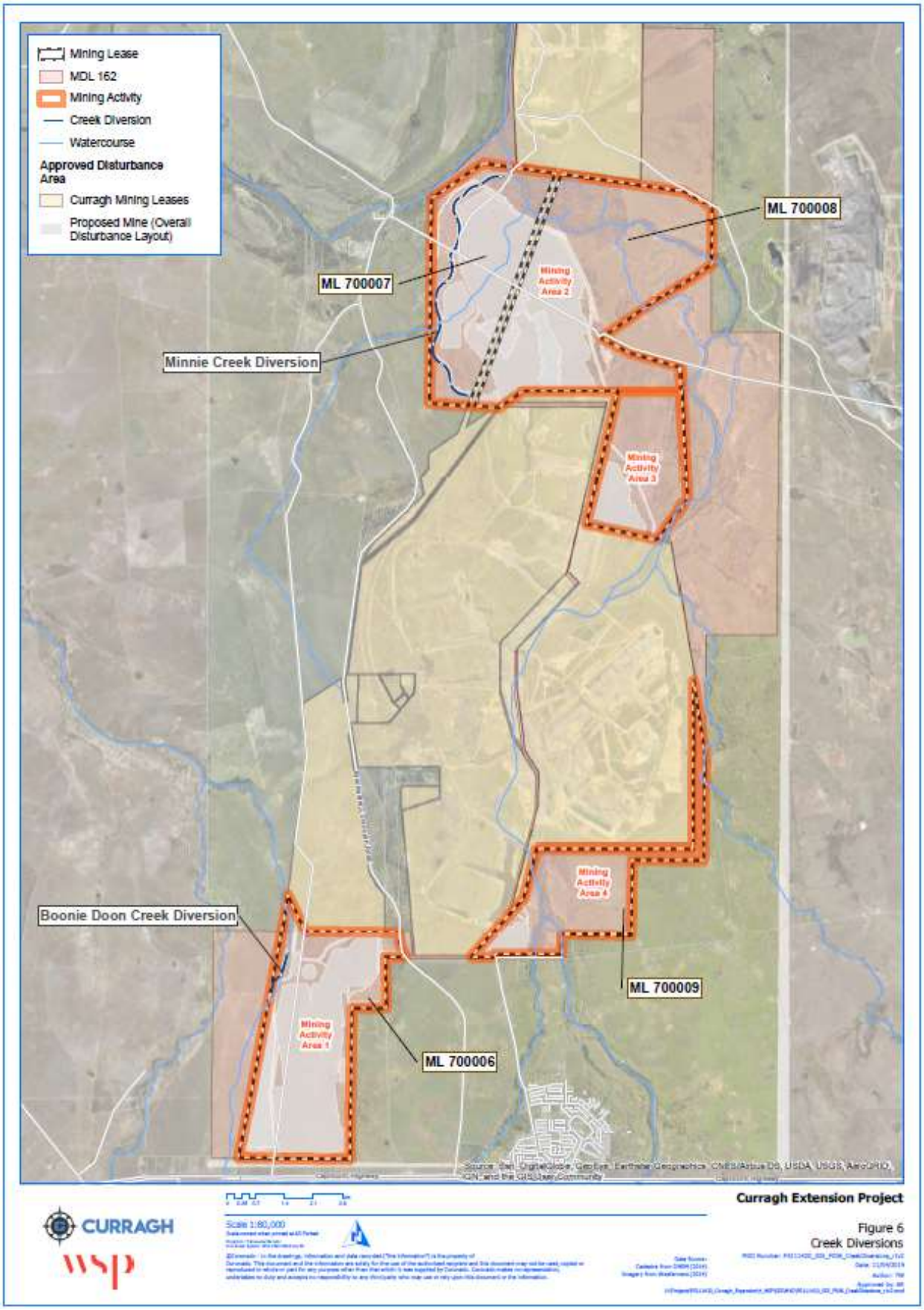


Figure 6 – Watercourse Diversions



END OF PERMIT

APPENDIX C

Blackwater Creek Diversion Monitoring and Maintenance Plan

BLACKWATER CREEK DIVERSION MONITORING AND MAINTENANCE PLAN

Document No:	EMS PLAN 1.4	**Version:**	6
Applies to:	TS	**Work Groups:**	Environment Section
RELEVANT LEGISLATION	Environmental Protection Act 1994, Biosecurity Act 2014		
	Environmental Authority EPML00643713: G17		

KEY RELATED DOCUMENTS

Plans	Procedures	Forms
EM PLAN 1.0	EMS PROC 1.1	EMS FORM 1.5
EM PLAN 1.3		EMS FORM 1.6
EM PLAN 1.5		EMS FORM 1.7

DOCUMENT CONTROL

	Title	Name	Signature
Prepared by:	Environmental Specialist	Kim Tuart	Tuart, Kim | Approved | 29/04/2019 3:16 PM
Approved by:	Superintendent Environment	Elmien Ballot	Ballot, Elmien | Approved | 29/04/2019 3:38 PM
Document Owner:	Manager Technical Services	David Thomasson	Thomasson, David | Approved | 2/05/2019 12:36 PM
Next Review Date:	**This document is scheduled for review 3 years from the Approval Date**		

REVISION HISTORY

Revision	Description	Date	Prepared by	Approved by
1	Creation of Document	20/01/2014	A Dawson-Evenhuis	E Ballot
2	Organisational changes	30/09/2014	S Hansen	E Ballot
3	Update to encompass EA Amendment changes	27/08/2015	K Reibel	E Ballot
4	Organisational Changes	12/04/2016	H Cooke	E Ballot
5	EA Amendment and Staff Changes	28/06/2016	H Cooke	E Ballot
6	Scheduled review	13/03/2019	K Tuart	E Ballot

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1. PURPOSE

The purpose of this Maintenance and Monitoring Plan is to provide ongoing management of the Blackwater Creek Diversion (BWCD) post completion to ensure it continues to perform and meet the success criteria through to its relinquishment in 2025.

2. INTRODUCTION

2.1 Background

In 2008 approvals were granted to Wesfarmers Curragh Pty Ltd by the Department of Environment and Science (DES; previously Department of Environment and Heritage Protection, DEHP) to divert a 9.4 kilometre section of Blackwater Creek to allow the extension of mine operations to the east. The BWCD provides access to an additional 47 million tonnes of low strip coal suitable for processing into hard coking coal for export. The constructed diversion length is 10.2 kilometres and it consists of a meandering low flow channel, high flow channel, batter banks and terraces that all required rehabilitation and revegetation.

The intent of the rehabilitation is to provide a comprehensive strategy that facilitates the re-establishment of in-stream and ex-stream ecological processes within the channel. The aim of the rehabilitation is to create as much as possible, a self-sustaining system that requires minimal management in the short to medium term and no future management beyond the cessation of the mining operations. The BWCD will result in a permanent, stable and sustainable creek alignment that will provide an important ecological corridor over the entire length of the diversion.

2.2 Approvals

As part of the approval process several documents were referenced and provide detailed information on both construction and rehabilitation. They also include specific timeframes for reporting and key criteria for measuring success.

- NRW Integrated Planning Act Development Permit 408512 and the Water Act Development Permit 408511(both issued October 2008). Monitoring and evaluation of the performance of works must be carried out in accordance with the following documents:
  - BWCD– Vegetation and Rehabilitation Management Plan EMS-PROC-034
  - Curragh East Coal Mine – BWCD Vegetation and Rehabilitation Documentation Package.
- DERM Environmental Protection Act Environmental Authority (EA) MIN100657807(August 2008)
  - Rehabilitation of the BWCD must be conducted in accordance with the BWCD- Vegetation and Rehabilitation Management Plan EMS-PROC-034

- Rehabilitation of the BWCD must achieve as a minimum, the rehabilitation success criteria defined in the following table

Rehabilitation success criteria for BWCD (based on staged construction phase of 12 months)

Parameter	3 months	6 months	12 months	18 months	24 months (Diversion opening)
Cover / m^2 - Groundcover – Hydromulch Zones A, B & C	30%	50%	75%	75%	75%
Weediness - Zones A, B & C	15%	10%	5%	5%	5%

- DERM Environmental Protection Act EAMIN100657807(amended November 2009)
  - H17: Rehabilitation of the BWCD must be conducted in accordance with the BWCD Revised Specification EMS-PROC-029
  - Rehabilitation of the BWCD must achieve for approval to open the diversion a minimum of seventy-five (75) per cent groundcover and have a weediness of no greater than five (5) per cent
- DEHP Environmental Protection Act EA EPML00643713 (amended November 2011)
  - H17 Rehabilitation of the BWCD Works must be conducted in accordance with BWCD Revised Rehabilitation Plan EMS-PROC-029
- DEHP Environmental Protection Act EA EPML00643713 (amended 20 March 2015)
  - H17 Rehabilitation of the BWCD Works must be conducted in accordance with the document EM PLAN 1.4 Blackwater Creek Diversion Monitoring and Maintenance Plan
- DEHP Environmental Protection Act EA EPML00643713 (amended 31 August 2015; 7 June 2016; 15 January 2019)
  - G17 Rehabilitation of the BWCD works must be conducted in accordance with the document EM Plan 1.4 Blackwater Creek diversion Monitoring and Maintenance Plan

BWCD Revised Rehabilitation Plan refers to the initial rehabilitation of the Diversion under the above conditions including the criteria required to open the diversion through to the current condition as per the EA EPML00643713.

3. DESIGN PRINCIPLES

The diversion channel has been designed to imitate the bed grade, channel plan form, cross-section form, and other geomorphic and habitat features of the reaches of the natural channel that the diversion will replace. Essentially the functional design aims to recreate a "natural" reach of channel that will be self-sustaining over the long term, well beyond the cessation of mining operations.

To achieve this the design aims to recreate a system as close as possible to, within the limits posed by the engineering design requirements of the diversion, the naturally occurring in stream and riparian zones in undisturbed parts of Blackwater Creek. This will aid in the establishment of natural in stream habitat, riparian and near riparian zones (riverine zones) featuring as far as practicable, locally occurring native plant species that include groundcovers, shrubs and trees.

Restoration of a diverse physical structure within the stream, and a diverse floristic structure, will see a corresponding increase in habitat diversity and an increase in faunal activity, diversity and dispersal.

A geometrically engineered diversion channel was designed by Parsons Brinckerhoff which included both low flow and high flow components divided into zones that reflect the profile attributes of the diversion.

The mandatory elements that were incorporated into the design were:

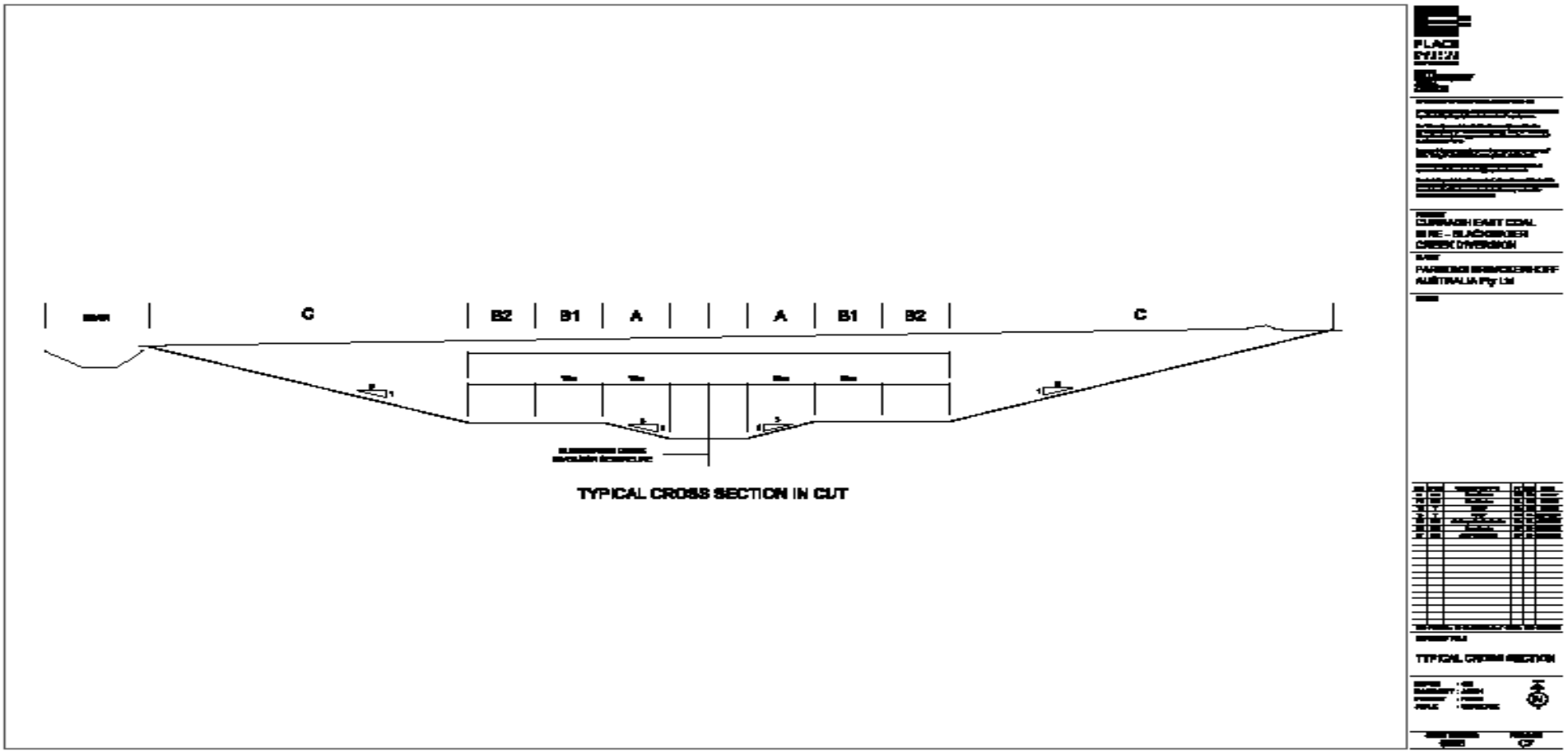
- Variations in the longitudinal and latitudinal section of the floor of stream form; and
- Strategic location of vegetation to increase habitat values and maximise bank stability.

Some amendments were made to the original rehabilitation design that was assessed as ongoing improvements and adaptations to achieve the desired outcomes.

The rehabilitation zones are referred to as:

- **Channel**: low flow channel;
- **Zone A**: low flow channel batter (1V:3H);
- **Zone B1**: high flow terrace extending up to Zone B2;
- **Zone B2**: high flow terrace extending up to Zone C; and
- **Zone C**: high flow batters (batters of 1V:3H), levees and drains extending to natural ground.

Figure 1 Rehabilitation zones



Doc No	Document Name	Version	Date	Doc Owner	Authorised By	Page No
EM PLAN 1.4	Blackwater Creek Diversion Monitoring and Maintenance Plan	6	24/04/2019	Manager Technical Services	Manager Technical Services	6

3.1 Planting Regimes

Zone A – Low Flow Batter

Topsoil depth	150mm
Soil ameliorant	Incorporate soil ameliorant at nominated rates to topsoil. Topsoil to be left with roughened surface before hydromulch application.
Species types	Shallow rooted shrub and grass mix.
Direct planting	Nil
Hydromulch rate	4 t/ha
Hydromulch mix	4t/ha of hydromulch including: 40kg/ha grass seeds as outlined in **Table 1.** 1.5kg/ha native shrubs seeds as outlined in **Table 2.** 4t/ha of sugar cane mulch and associated guar based tackifier.
Irrigate	Irrigate hydromulch for grass establishment following placement, the amount of water to be applied subject to an ongoing trial and is dependent on rainfall.

Zone B1 – High Flow Channel Terrace

Topsoil depth	300mm
Soil ameliorant	Incorporate soil ameliorant at nominated rates to topsoil. Topsoil to be left with roughened surface before hydromulch application.
Species types	Shrubs, trees and grasses.
Direct planting	Install 90 x 50mm native shrub and tree **(Table 4)** for the entire area of Zone B1 @ one plant per 10m^2 as per planting matrix Zone B1 (including application of Terracottem in the base of each planting hole).
Hydromulch rate	4 t/ha
Hydromulch mix	Install 4t/ha of hydromulch including: 4kg/ha native tree and shrubs seeds as outlined in **Table 3** 4t/ha of sugar cane mulch and associated guar based tackifier.
Irrigate	Irrigate hydromulch for establishment. Install header tanks, pumps, drip tube and sprinklers for tubestock watering; and Irrigate planted tubestock to field capacity and keep plant root zone soil moisture between wilting point and field capacity.

Zone B2 – High Flow Channel Terrace

Notes	Zone B2 is the second section of the high flow terrace area.
Topsoil depth	300mm
Soil ameliorant	Incorporate soil ameliorant at nominated rates to topsoil. Topsoil left with roughened surface before hydromulch application.
Species types	Shrubs, trees and grasses.
Direct planting	Install 80 tubestock 90 X 50mm native shrub **(Table 4)** in each of 71 planting cells (800m^2).
Hydromulch rate	4 t/ha
Hydromulch mix	Install 4t/ha of hydromulch outside the planting cells including: 40kg/ha cover crop, pasture grass, and native grass seed as outlined in **Table 1**. 4kg/ha native tree and shrubs seeds as outlined in **Table 3** (only in Chainage 8500-10250 and Chainage 0-1700). 4t/ha of sugar cane mulch and associated guar based tackifier. Install 4t/ha of hydromulch in the planting cells including: 4kg/ha native shrubs and tree seeds as outlined in **Table 3**. 4t/ha of sugar cane mulch and associated guar based tackifier.
Irrigate	Irrigate hydromulch for establishment. Install header tanks, pumps, drip tube and sprinklers for tubestock watering; and Irrigate planted tubestock to field capacity and keep plant root zone soil moisture between wilting point and field capacity.

Zone C – High Flow Batters

Topsoil depth	150mm
Soil ameliorant	Incorporate soil ameliorant at nominated rates to topsoil. Topsoil to be left with roughened surface before hydromulch application.
Species types	Shrubs, trees and grasses.
Direct Planting	Install 80 tubestock 90 X 50mm native trees and shrubs **(Table 4)** in each of 65 planting cells 800m^2.
Hydromulch rate	4 t/ha

Hydromulch mix	Install 4t/ha of hydromulch outside the planting cells including: 40kg/ha cover crop, pasture grass, and native grass seed, outlined in **Table 1**. 4t/ha of sugar cane mulch and associated guar based tackifier. Install 4t/ha of hydromulch in the planting cells including: 4kg/ha native shrubs and tree seeds as outlined in **Table 3**. 4t/ha of sugar cane mulch and associated guar based tackifier.
Erosion control	Install Jute Mesh with 150mm pins over entire zone surface.
Irrigate	Irrigate hydromulch for establishment. Install header tanks, pumps, drip tube and sprinklers for tubestock watering; and Irrigate planted tubestock to field capacity and keep plant root zone soil moisture between wilting point and field capacity.

Zone C – Levees

Topsoil depth	150mm
Soil ameliorant	Supply and incorporate soil ameliorant at nominated rates to topsoil. Topsoil to be left with roughened surface before hydromulch application.
Species types	Grass.
Direct planting	Nil
Hydromulch rate	4 t/ha
Hydromulch mix	Supply and install 4t/ha of hydromulch including: 40kg/ha cover crop, pasture grass, and native grass seed as outlined in **Table 1** on levee batters. 4t/ha of sugar cane mulch and associated guar based tackifier.
Erosion controls	Install Jute Mesh on the inside & outside batter of the levee.

Table 1: Grass Seeding Mix (via hydromulching)

Species	Common Name	Seed Mix kg/ha
Bothriochloa ewartiana	Desert bluegrass	5
	Forest bluegrass	4
Astrebla lappacea	Curly mitchell grass	4
Heteropogon contortus	Black spear grass	5
**Cynodon dactylon*	Green couch	5
**Chloris gayana*	Rhodes grass	10
**Echinochloa esculenta*	Jap millet/Wimmera ryegrass	7
TOTAL		40

Table 2: Shrub Species Mix for Zone A (via hydromulching)

Species	Common Name	Seed Mix kg/ha
Acacia bidwillii (scarified)	Corkwood	0.2
Acacia bancroftiorum (scarified)	Bancroft's Wattle	0.2
Acacia holosericea (scarified)	Soapbush	0.2
Acacia macradenia (scarified)	Zigzag wattle	0.2
Atalaya hemiglauca	Whitewood	0.1
Carrisa ovata	Klunkerberry	0.1
Eremophila maculata	Fuschia Bush	0.2
Lysiphyllum hookerii	White flowered bauhinia	0.2
Senna notabilis	Cockroach Bush	0.1
TOTAL		1.5

Table 3: Shrub and Tree Species Mix (via hydromulching)

Species	Common Name	Seed Mix kg/ha
Acacia bidwillii (scarified)	Corkwood	0.1
Acacia harpophylla	Brigalow	0.3
Acacia salicina (scarified)	Sally wattle	0.3
Atalaya hemiglauca	Whitewood	0.1
Casaurina cristata	Bellah	0.2
Cassia brewsterii	Leichhardt bean	0.3
Corymbia tessellaris	Moreton Bay Ash	0.2
Eremophila maculate	Fuschia bush	0.1
Eucalyptus crebra	Narrow-leafed ironbark	0.3
E. coolabah	Coolibah	0.3
E. populneus	Poplar box	0.2
E. tereticornis	Forest red gum	0.3
Geijera parviflora	Wilga	0.1
Lysiphyllum hookerii	White flowered bauhinia	0.1
Melaleuca bracteata	River tea tree	0.1
Owenia Acidula	Emu apple	0.1
Erythrina vespertilio	Bats Wing Coral	0.1
Petalostigma pubscens	Quinnine	0.2
Brachychiton australis	Kurrajong	0.1
Lomandra longifolia	Spiny headed mat-rush	0.3
Melaleuca leucadendra	Broad-leafed paperbark	0.1
Alphitonia excels	Red Ash	0.1
TOTAL		4.0

Table 4: Tubestock Plant Species (direct planting)

Canopy	Mid Strata	Shrubs	Grasses
Zone B1 Planting Cells			
Brigalow	Ironwood	Bancroft Wattle	Mat Rush
Sally Wattle	Quinine Berry	Corkwood Wattle	Umbrella Grass
Mountain Coolibah	Sandpaper Fig	Cockroach Bush	
Broad-leaved Bottle Tree	Scrub Leopard Wood		
Leichardt Bean	Yellow Berry Bush		
Morton Bay Ash	Broad Leaved Brush Wilga		
Poplar Box	Sandlewood		
Queensland Blue Gum	Red Flowered Bauhinia		
Yellow Wood	White Flowered Bauhinia		
	River Tea Tree		
	Ebony Tree		
	Emu Apple		
Zone B2 Wetlands			
Brigalow	Soft Aclypha	Bancroft Wattle	Mat rush
Sally Wattle	Quinine Berry	Corkwood Wattle	Umbrella grass
Coolibah	Bitter Bark	Soapbush	
Broad-leaved Bottle Tree	Lolly bush	Klunkerberry	
Poplar Box	Yellow Berry Bush		

Canopy	Mid Strata	Shrubs	Grasses
Queensland Blue Gum	Creek Wilga		
Yellowwood	False Sandalwood		
	Red Flowered Bauhinia		
	White Flowered Bauhinia		
	River Tea Tree		
	Ebony Tree		
	Peach Bush		
Zone B2 Planting Cells			
Brigalow	Ironwood	Soapbush	
Sally Wattle	Quinine Berry	Corkwood Wattle	
Mountain Coolibah	Bitter Bark	Whitewood	
Broad-leaved Bottle Tree	Lolly bush	Klunkerberry	
Leichardt Bean	Creek Wilga		
Morton Bay Ash	Yellow Berry Bush		
Poplar Box	False Sandalwood		
Queensland Blue Gum	Sandlewood		
Yellow Wood	Red Flowered Bauhinia		
Narrow-leaved Red Ironbark	White Flowered Bauhinia		
	Ebony Tree		

Canopy	Mid Strata	Shrubs	Grasses
Zone C Planting Cells			
Brigalow	Quinine Berry	Soapbush	
Sally Wattle	Bitter Bark	Fuschia Bush	
Queensland Bottle Tree	Lolly bush	Whitewood	
Morton Bay Ash	Creek Wilga	Klunkerberry	
Poplar Box	False Sandalwood		
Narrow-leaved Red Ironbark	Yellow Berry Bush		
	Scrub Leopard Wood		
	Sandlewood		
	Red Flowered Bauhinia		
	Ebony Tree		

3.2 Accelerating Construction and Revegetation Program

Construction of the diversion and its rehabilitation was originally estimated to take 24 months. Due to operational reasons it was decided to advance the construction to just over 12 months. Earthworks began in November 2008 and most works were completed by October 2009. Revegetation commenced in April 2009 and completed around late November 2009. Final works were completed in February 2010 when the original creek line was sealed via the completion of the bund adjacent to Pit B.

4. SUCCESS CRITERIA

Rehabilitation success criteria for diverting Blackwater Creek were that the diversion must achieve a minimum of 75% groundcover and have weediness not greater than 5%.

The establishment of adequate vegetative groundcover was deemed necessary to achieve acceptable scour resistance within the range of velocity, shear and stream power characteristics predicted. The criteria and staged response are outlined in **Table 5**. These assigned parameters aligned with the time intervals proposed for the formal assessment monitoring.

Due to the acceleration of the project, cover and weediness were still the target values which had to be achieved at the opening stage. These are considered to be the Primary Success Criteria.

Table 5: Rehabilitation Success Criteria for Practical Completion

Parameter	**3 months**	**6 months**	**12 months**	**18 months**	**24 months**
Cover / m^2 - Groundcover – Hydromulch Zones A, B2 & C	30%	50%	75%	75%	75%
Weediness	15%	10%	5%	5%	5%

Biodiversity Success Criteria were not necessary for Practical Completion but are considered necessary for proving reinstatement of biodiversity performance. **Table 6** details the long-term biodiversity outcomes.

Table 6: Long Term Biodiversity Outcomes

Parameter	3 months	6 months	12 months	18 months	24 months
Cover / m^2 - Groundcover – Hydromulch Zones A, B2 & C	30%	50%	75%	75%	75%
Diversity - Groundcover – Hydromulch Zones A, B2 & C	≥3 species	≥3 species	≥4 species	≥5 species	≥6 species
Height (Median) - (Direct Planting cells and continuous planting in Zone B1)	20cm	40cm	75cm	100cm	125cm
Diversity** - (Direct Planting cells and continuous planting in Zone B1)	≥5 species	≥5 species	≥7 species	≥10 species	≥10 species

It is the intention that the diversion will be maintained post-opening to ensure that it complies with the long-term diversity criteria.

4.1 Monitoring Assessment

Three methodologies, performed concurrently, were undertaken during the construction period. Post completion monitoring is to continue utilising the primary methodology to collect and assess data relating to the ongoing success of the revegetation programme.

Assessment Methodology

Primary Monitoring Assessment

This assessment type provides the basis for quantifying the success of the rehabilitation and achievement of milestones. This technique requires the establishment of permanent monitoring quadrates (400m^2) with the data generated to determine the success of the diversion revegetation.

Detailed quantification and qualification of rehabilitation success is then assessed and documented prior to completion and to determine if the criteria have been met for practical completion.

The opening criteria is based on a calculated average of 75% groundcover and <5% weediness, measured in monitoring quadrats along the diversion. These quadrats were randomly located in hydromulch areas in Zone A, Zone B2 and Zone C.

Rehabilitation success criteria to open the diversion for the hydromulched sections of each stage of the diversion are outlined in **Table 7 and 8** and the long-term rehabilitation criteria for biodiversity in both planting cells and hydromulched areas post-opening are outlined in **Table 6.**

Table 7: Monitoring of Hydromulch Seeding Areas

Hydromulch Seeding Areas	
Item	**Observations to note**
Quadrats	Random quadrats of 400m^2 shall be staked and appropriately flagged within the hydromulched areas outside the direct planting cells. One (40m x 10m) quadrat every kilometre in **Zone A** and one (20m x 20m) quadrats every kilometre in both **Zone B2** and **Zone C**. These shall be assessed against opening criteria and long-term Biodiversity Outcomes (**Table 11**).
Photos	Three photos will be taken at each quadrat. All details will be recorded on a "*Primary Monitoring Assessment Template*" which will be utilised for the production of monthly reports by the Contractor to the Principal.
Cover	Within nominated quadrats a straight length of measuring tape will be laid flat upon the ground for 40m. The tape will be positioned adjacent to the centre-line of the plot. For groundcover any hydromulch which is visible beneath the tape is considered as a negative (e.g. 24.56m of hydromulch visible beneath the tape equates to 38.6% vegetative cover).
Weediness	Within each quadrat, weed cover will be expressed as a percentage of overall cover.

Table 8: Monitoring of Direct Planting Cells

Direct Planting Cells	
Item	**Observations to note**
Quadrats	Quadrats of 400m^2 shall be staked and appropriately flagged within the direct planting cells. One (40m x 10m) quadrats every kilometre in **Zone B1** and one (20m x 20m) quadrat every kilometre in both **Zone B2** and **Zone C**. These shall be assessed against the long-term Biodiversity Outcomes (**Table 12**).
Height	All direct planting cells will be initially staked prior to planting. The stake in the southwest corner of nominated planting cells shall be greater than 1,400mm in length and protrude exactly 1,000mm above the natural ground level and be painted or "flagged" in a different colour to nominate heights along the stake (e.g. 100mm, 500mm and 1000mm). This stake will be used to assess growth rates during the maintenance and monitoring periods.
Cover	Within quadrat a straight length of measuring tape will be laid flat upon the ground for 40m. The tape will be positioned adjacent to the centre-line of the plot. The cover of planted trees across the tape is to be recorded (e.g. 17.54m of tape occluded from the sky because of canopy cover is equivalent to 43.85% cover). Note: canopy is considered as an opaque, intact polygon. Gaps between leaves and branches of the same plant are to be acknowledged as complete cover. Similarly, groundcover will be measured. Here, any hydromulch which is visible beneath the tape is considered as a negative (e.g. 24.56m of hydromulch visible beneath the tape equates to 38.6% vegetative cover).
Weediness	Within each quadrat, weed cover will be expressed as a percentage of overall cover.
Attrition	Failure of planted tube-stock will be documented.
Photos	Three photos will be taken at each nominated quadrat. All details will be recorded on a "*Primary Monitoring Assessment Template Direct Planting Cells"* which will be utilised for the production of monthly reports by the Contractor to the Principal.

Photographic Monitoring Points

Permanent photographic monitoring points have been established at 500m intervals along the diversion in line with the irrigation tanks on the western side of the diversion channel.

Photographs are to be taken with a high-resolution camera at intervals with the first directed northward along the edge of the high flow batter, another taken from the stake toward the base of the channel and another facing toward the south of the diversion. A photo could also be taken from the base of the channel looking toward the stake. A reference number must be visible in all photos.

Timing of Monitoring

Primary Monitoring Assessment has been performed at a stage by stage basis prior to the opening of the diversion with the final assessment undertaken on the 11th to 16th January 2010 for practical completion (*Revegetation Implementation and Practical Completion Monitoring Report* PB Jan 2010). Since the opening of the diversion, primary monitoring has continued on a monthly basis commencing in February 2010 through to September 2011, then quarterly through to September 2013.

Primary Monitoring Assessment will continue on a yearly basis for the next 5 years until 2018 then every second year until relinquishment of the diversion in 2025. To allow for the identification of flora, monitoring will be undertaken at the most appropriate time between the months of September and March.

Tertiary Monitoring Assessment

Tertiary assessments are non-formal, visual assessments based on observing, documenting and ameliorating (or making good) matters that threaten the rehabilitation viability. This type of assessment is designed to expedite a timely and proportionate response to address issues as encountered in between the more formal monitoring process (viz. secondary and primary assessments). Designed for observation of works at commencement, during and post rehabilitation.

Secondary Monitoring Assessment

This methodology provides a framework for regular assessment of rehabilitation progression and enables prompt determination of additional requirements, problematic techniques or methodologies, plant failure or success, weed establishment and cover establishment. An acceptable maintenance action can then be applied and subsequently monitored.

Secondary assessments are formal qualitative assessments of the success of the revegetation works, set to a documented timeline. Refer to **Table 9** for schedule of monitoring activities.

Table 9: Secondary Assessment Monitoring Schedule

Monitoring	Time	Maintenance Action
Presence of Weeds	Fortnightly	Remove weed regrowth to ensure dominance of regenerating native plants. A weed exclusion zone of at least 10 metres should be maintained at the top of the high flow batter. Replace hydromulch/jute matting where necessary
Health of Plants	Fortnightly	Replace dead or dying plants. Sick plants may be an indication of stress or poor soil conditions, low nutrient levels or lack of water.
Signs of Regeneration	Fortnightly	Natural regeneration and new growth in previously weed infested areas is a good sign of recovery and indicates a healthy ecosystem.
Signs of Disturbance	Fortnightly	If a disturbance (e.g. impact from stock, native animals or insects, erosion, nutrient influx, etc.) is affecting > 10% of a revegetation area it is considered a major threat and should be mitigated.
Habitat Values	Annually	The site should be developing food sources (e.g. nectar and seed) and habitat (e.g. leaf litter, nesting sites) for native fauna. Logs, rocks and nest boxes can be utilised to enhance fauna habitat as they become available.
Diversity & Structure	Annually	Replace dead or dying plants. Add additional species if biodiversity is limited. The site should begin to represent a natural system. It should display a diversity of native species and a natural structure incorporating canopy, mid-layer and groundcover.

5. PRACTICAL COMPLETION

Primary monitoring was undertaken between November 2009 and January 2010 to determine if the success criteria had been met. All monitoring was conducted in accordance with the methodology described in 'BWCD Practical Completion and Maintenance Monitoring Sampling Protocol Draft Version B' (refer to APPENDIX A).

For practical completion monitoring and ongoing Maintenance Monitoring, sites were selected on the basis of random selection of cells. The locations were to be uniformly representative of zones, longitudinal grade and to encompass both sides of the diversion channel. The intent of the monitoring methodology was to establish a protocol that was transparent, time/cost efficient and repeatable whilst minimising simple biases which may arise between individuals conducting the sampling.

5.1 Results at Practical Completion

Parameter	3 months	6 months	12 months	Results	18 months	24 months
Height(median)	300mm	500mm	750mm	500mm	1000mm	1250mm
Vegetative Cover (hydromulch)	30%	50%	75%	89%	75%	75%
Weed Cover	<15%	<10%	<5%	<5%	<5%	<5%
Diversity (species No.)	>5	>5	>7	13	>10	>10

6. POST MONITORING AND MAINTENANCE

Primary Monitoring Assessment since the opening of the diversion has continued on a monthly basis commencing in February 2010 through to September 2011, then quarterly through to September 2013. Long term biodiversity provided success criteria to be achieved in successional stages up to 24months. March 2012 marked the 24months since the rehabilitation maintenance and monitoring commenced. This ongoing maintenance programme was an integral element in overcoming the adverse conditions that have affected the project by reducing stress and competition to tubestock, preventing and controlling weed outbreaks and identifying any potential problems before they could hinder the long-term success of the vegetation. Maintenance work during this period included watering, weed control, fertilising, whipper snipping grass in the monitoring plots to reduce the competition on tubestock, flood repairs and other general repairs as required.

6.1 Results after 24 months

Results for the month timeframe can be found in BWCD Rehabilitation Monitoring and Assessment 24-month Compliance Report – March 2012 by Lanyonscapes. A brief summary of the results against the criteria is shown below in the table.

Parameter	3 months	6 months	12 months	18 months	24 months	Results
Height (median)	300mm	500mm	750mm	1000mm	1250mm	1360mm
Vegetative Cover (hydromulch)	30%	50%	75%	75%	75%	96.2%
Weed Cover	<15%	<10%	<5%	<5%	<5%	<5%
Diversity (species no.)	>5	>5	>7	>10	>10	17

6.2 Results after 42 months

Results for the 42-month timeframe can be found in the BWCD Maintenance Progress Report – September 2013 by Lanyonscapes.

A brief summary of the results against the criteria is shown below in the table.

Parameter	24 months	Results at 24 months	Results at 42 months
Height (median)	1250mm	1360mm	1624mm
Vegetative Cover (hydromulch)	75%	96.2%	92%
Weed Cover	<5%	<5%	<5%
Diversity (species no.)	>10	17	17

7. FUTURE MONITORING AND MAINTENANCE

7.1 Timing of Monitoring

Curragh will continue to undertake the Primary Monitoring Assessment annually for the next 5 years till 2018 then every second year until relinquishment of the diversion. To allow for the identification of flora, monitoring will be undertaken at the most appropriate time between the months of September and March. A review of this plan should be conducted within 5 years of its implementation to access the data and to ensure it is performing in a manner that meets its long-term objectives.

Monitoring will continue to use the Primary Monitoring Assessment methodology to provide quantitative data and determine ongoing trends in growth, attrition, species composition and the relationship between these factors. Photo monitoring will also be undertaken at this time.

Pro formas have been developed to record this information and have been used throughout each monitoring phase. The originals are found in **APPENDIX B**.

EMS FORM 1.5 BWCD Formal Rehabilitation Assessment Template - Monitoring Sections; EMS FORM 1.6 BWCD Formal Rehabilitation Assessment Template - Photographic Monitoring; and EMS FORM 1.7 BWCD Visual Rehabilitation Assessment Template are used for ongoing monitoring and maintenance and available from Blackrock.

7.2 Weed treatment

The following species of weeds, as Prohibited Matter and/or Restricted Invasive Plants (Category 3) as listed under the *Biosecurity Act 2014*, will be treated within and immediately adjacent to the diversion corridor.

- *Opuntia stricta* (Prickly Pear) - Prohibited matter
- *Opuntia tomentosa* (Velvety Pear) - Prohibited Matter
- *Eriocereus martinii* (Harrisia Cactus) - Prohibited Matter
- *Bryophyllum delagonese* (Mother-of-millions) - Category 3
- *Parkinsonia aculeata* (Parkinsonia) - Category 3
- *Parthenium hysterophorus* (Parthenium) - Category 3
- *Cryptostegia grandiflora* (Rubber Vine) - Category 3

Other species will be treated in accordance with the general biosecurity obligation under the *Biosecurity Act 2014*.

Appropriate weed hygiene practices will be used to reduce the spread of weed species including washdown of all equipment and vehicles prior to entry and exit from the mine site.

Ongoing and appropriate weed treatment by a qualified specialist will be undertaken as necessary in the diversion. Weeds will be mapped on an annual basis as part of Curragh's Weed Management Plan and activities planned around the treatment of those weeds.

Management of declared weeds within the diversion will be addressed in accordance with the existing protocols outlined in EM PLAN 1.0 Land Management Plan and managed under EMS PROC 1.1 Declared Fauna and Flora Management Procedure.

7.3 Erosion Control and Management

Inspections of the levees and diversion are conduction on a quarterly basis, additional inspections will be required in times of rain or flow events in the creek and throughout scheduled monitoring. These will present opportunities to inspect for erosion within the diversion and implement plans for remediation.

7.4 Access

Cattle and unauthorised personnel & vehicles will be excluded from the revegetation area. Regular inspections will be undertaken for monitoring purpose and as part of site security and safety procedures, all other access will be restricted. Pulse grazing may be considered as part of fire management protocols to manage fuel loads and to stimulate vegetation growth.

7.5 Fire Management

EM PLAN 1.5 Fire Management Plan has been developed for site to manage the impacts of fire both upon infrastructure and sensitive environmental management areas. The fuel load within the diversion can present potential issues as a fire would burn with high intensity amongst the grass and damage the trees which are not all receptive to this type of fire. The management plan provides strategies to control and reduce the risk of fire both within and surrounding the diversion. The fire management plan will be updated regularly and should be referenced when undertaking any control measures.

7.6 Plant monitoring and replacement

Rehabilitation has been conducted according to the EM PLAN 1.3 Rehabilitation Management and Monitoring Plan and will continue to be monitored as per the Primary Monitoring Assessment. An important feature in monitoring the success is the continued growth and biodiversity trends in the data that will be collected. The goal for revegetation is to provide an ecologically sustainable diversion through restoration of midstorey and understorey structure to a condition similar to pre-disturbance conditions. Restoration of a diverse vegetation structure will see a corresponding increase in habitat diversity and result in increased faunal diversity. Assessment of fauna will also be conducted throughout the life of the diversion under the

'*Threatened Species Fauna Management Plan for within Blackwater Creek Clearance Area'* Nov 2009.

As and when the opportunity permits, woody debris will be placed within zones B and C to create additional habitat features. Should the data indicate that areas of the diversion are not performing and there is a higher than anticipated rate of attrition, steps will be taken to re-establish vegetation as per the criteria set out in EM PLAN 1.3 Rehabilitation Management and Monitoring Plan

8. REFERENCE DOCUMENTS

REFERENCE	LOCATION
EMS-PROC-029 Blackwater Creek Diversion Revised Rehabilitation Plan	EMS Archive
EMS-PROC-034 Blackwater Creek Diversion Vegetation and Rehabilitation Management Plan Version E. Prepared for Parsons Brinckerhoff Australia Pty Ltd (March 2008)	EMS Archive
EM PLAN 1.0 Land Management Plan	Blackrock
EM PLAN 1.5 Fire Management Plan	Blackrock
EMS PROC 1.1 Declared Flora and Fauna Management Procedure	Blackrock
Lanyonscapes (March 2012) Blackwater Creek Diversion Rehabilitation Monitoring and Assessment 24-month Compliance Report	GDrive/Environment
Lanyonscapes (Sept 2013) Blackwater Creek Diversion Revegetation Maintenance Progress Report	GDrive/Environment
PLACE (Feb 2010) Revegetation Implementation and Practical Completion Monitoring Report	GDrive/Environment
EMS FORM 1.5 BWCD Formal Rehabilitation Assessment Template - Monitoring Sections	Blackrock
EMS FORM 1.6 BWCD Formal Rehabilitation Assessment Template - Photographic Monitoring	Blackrock
EMS FORM 1.7 BWCD Visual Rehabilitation Assessment Template	Blackrock

APPENDIX A

Blackwater Creek Diversion Practical Completion and Maintenance Monitoring Sampling Protocol Draft Version B'

BLACKWATER CREEK DIVERSION

Practical Completion and Maintenance Monitoring Sampling Protocol

1. Purpose

This document has been created to establish the methods of establishing and measuring success criteria for cover and biodiversity at PRIMARY MONITORING SITES within the Blackwater Creek Diversion (BCD). The intent of the monitoring is establish a protocol that is transparent, time/cost efficient and repeatable and which allows a consistent level of data to be collected by a variety of personnel whist minimising sample biases which *may* arise between individuals.

2. Monitoring Points

2.1 Zonation of the Works

The BCD consists of a number of planting zones namely the low flow batter (**Zone A**), the high flow terrace (**Zone B**) and the high flow batter (**Zone C**).

Planting treatments within these zones include Direct (Tubestock) Planting and Direct Seeding.

Direct (Tubestock) planting has occurred within the BCD in **Zone B1** (a continuous planting zone of trees and shrubs), **Zone B2** (a number of 80m x 20m planting cells) and **Zone C** (a number of 80m x 20m planting cells).

Direct seeding with:

- Grasses has occurred within **Zone B2** and **Zone C**;
- Grasses and shrubs has occurred within **Zone A**; and
- Trees and shrubs has occurred within **Zone B1**.

2.2 Monitoring Sites and Nomenclature

Monitoring points have been developed on the basis of this zonation and indicative sampling numbers provided within the *Blackwater Creek Diversion Revegetation Plan* and *Blackwater Creek Diversion Revised Revegetation Plan*.

For the Practical Completion Monitoring (and ongoing Maintenance Monitoring) sites have been selected on the basis of random selection of cells. Sites are overlapped with Downer Monitoring sites to provide a 'calibration' between the monitoring events to allow data sets to be meaningfully compared.

2.2.1 Direct Seeding Sites

- **Zone A** – 18 sites (4 sites are Downer Monitoring Sites);
- **Zone B2** - 16 sites (5 sites are Downer Monitoring Sites); and
- **Zone C** – 16 site (4 sites are Downer Monitoring Sites).

Sample locations have been selected to be uniformly representative of zones, longitudinal grade of the diversion and left or right side of the diversion (when travelling downstream). They are indicated on the attached plan and described in relation to BCD chainage in **Table 1.** Direct Seeding Sites are prefixed with 'D' and sequentially numbered from chainage 0.0 (inlet end) along the alignment to chainage 10,000 (near the outlet). Contractor monitoring sampling site nomenclature has been retained for those sites.

TABLE 1: Direct Seeding 'D' Sample Sites

Chainage (m)	Zone A	Zone B2	Zone C
0.0 – 1,000	D1	D2	D3
1,001 – 2,000	D5	***B9***	D4
	D38		D39
2,001 – 3,000	D7	***B8***	D6
	A15	D9	D8 / (***C8***)
3,001 – 4,000	D11	***B7***	D10
		D12	D13
4,001 – 5,000	***A11***	D14	***C6***
	D17	D15	D16
5,001 – 6,000	***A10***	D18	D19
	D20		
6,001 – 7,000	D23	D21	D22
	D25	D24	
7,001 – 8,000	D27	***B3***	D26
	A5		D28
8,001 – 9,000	D31	D30	D29
	A2		
9,001 – 10,000	D32	D33	***C1***
	D37	D35	D34
		D36	
Total Sites	**18**	**16**	**16**

Notes:
1. Emboldened number (***B9***) are Downer Monitoring Sites
2. Sample sites on the right bank are shaded red, sample sites on the left bank are shaded green

2.2.2 Direct Planting Sites

- **Zone B1** – 10 sites (2 sites are Downer Monitoring Sites);
- **Zone B2** - 10 sites (2 sites are Downer Monitoring Sites); and
- **Zone C** – 10 site (3 sites are Downer Monitoring Sites).

Sample locations have been selected to be uniformly representative of zones, longitudinal grade of the diversion and left or right side of the diversion (when travelling downstream). They are indicated on the attached plan and described in relation to BCD chainage in **Table 2.** Direct Planting Sites are prefixed with 'P' and sequentially numbered from chainage 0.0 (inlet end) along the alignment to chainage 10,000 (near the outlet). Contractor monitoring sampling site nomenclature has been retained for those sites.

TABLE 2: Tubestock Planting 'P' Sample Sites

Chainage (m)	Zone B1	Zone B2	Zone C
0.0 – 1,000	P1	P2	n/a
1,001 – 2,000	P6	P4	P3
			P5
2,001 – 3,000	P7	P8	P9
3,001 – 4,000	P13	P10	P12
		P11	
4,001 – 5,000	P15	P14	***PC6***
			P16
5,001 – 6,000	***PB4***	***PB5***	D17
6,001 – 7,000	P18	n/a	n/a
7,001 – 8,000	P19	n/a	***PC3***
8,001 – 9,000	P21	P22	P20

			PC2
9,001 – 10,000	P24	P23 ***PB1***	n/a
Total Sites	**10**	**10**	**10**

Notes:
1. Emboldened number (**PB9**) are Downer Monitoring Sites
2. Sample sites on the right bank are shaded red, sample sites on the left bank are shaded green

3. Establishment (Target) Criteria

3.1 Direct Seeded Area

Target criteria (for Practical Completion and Opening of the Diversion) are 75% cover with no more than 5% weediness cover. Weeds consist of declared weeds identified within the *Blackwater Creek Diversion Revegetation Plan*, noxious weeds and any weeds deemed by the Principal to be problematic. They do not include any species endemic to the region that may be considered to be agricultural weeds.

A secondary long-term diversity criteria of 6 or more species also applies.

3.2 Direct (Tubestock) Planting

Target criteria are applied to direct planting area based on the date of planting. For example plants planted in March 2009, measurement of the 24 month targets would occur in March 2011. Target Criteria are outlined in **Table 3.**

TABLE 3: Tubestock Target Criteria ('P' Sites)

Planting Method	Parameter	Months				
		3	6	12	18	24
Tubestock Planting (Direct Planting cells & continuous planting in Zone B1)	Height (Median)	20cm	40cm	75cm	100cm	125cm
	Diversity**	≥5 species	≥5 species	≥7 species	≥10 species	≥10 species

Notes:
1. Source is *Table 11 – Longterm Biodiversity Outcomes* of the of the *Blackwater Creek Diversion Revised Revegetation Plan*

4. Site Establishment and Data Collection

Sampling will occur within 40 m X 10 m or 50 m X 8 m (400m^2) sampling quadrats.

4.1 'D' Sites

Within 'D' sites cover will be assessed by the line intercept method along a transect of 40 m length. Quadrats have been oriented on the attached plans to sample along and across slopes (where practical for reasons such as effective width or length of each zone).

At establishment, permanent pegs will placed to denote the transect location. Pegs will be identified with flagging tape and numbered with the respective sample site (quadrat) number. Pegs will be approximately located with a hand held GPS to facilitate later accurate survey.

In the field, data will be collected and recorded on field record sheets (attached). The following data will be collected:

1. **Botanical data and coverage along the intercept** – individual species and extent of dripline coverage will be recorded cumulatively along the length of the tape (refer **Figure 1**).

Data will be analysed to ascertain total coverage expressed as a percentage (ie 30 m of vegetation coverage along a 40 m intercept is 75% cover); extent of weeds as a percentage of cover; composition of each species expressed as a percentage of cover; and diversity. Should less than 6 species be recorded along the intercept, additional meander searches within the 400 m2 quadrat will be undertaken.

2. **Photographic log** – a photographic record of the condition of the vegetation within and surrounding the quadrat will be undertake. Photographs should be taken from the northern peg of the transect a. along the transect with tape in place; b. 45° to the left and c. 45° to the right.
3. **Incidental Observations** – observations of apparent plant health, erosion/scour in close proximity, lesser vegetation coverage nearby etc.
4. **Planting Age** – The date of direct seeding and date of establishment irrigation will be noted by post field interrogation of planting and watering records.

The field procedure is as follows:

- Record sample site and date on template;
- Pin tape to start of measured area with 150mm Jute Mesh pin;
- Lay tape in direction indicated by sample site locations;
- Measure coverage of vegetation where intercepts tape taking note of vegetation species and distances for that species where possible;
- Record measured intercepts and species types on template;
- Role up tape and remove pin.

4.2 'P' Sites

Within 'P' sites cover will be assessed through establishment of 40 m x 10 m quadrats within planting cells (**Zone B2** and **Zone C**) and the continuous planting zone (**Zone B1**). The corners of each quadrat will be identified with pegs (to remain in-situ), identified with flagging tape and numbered with the respective sample site (quadrat) number. Pegs will be approximately located with a hand held GPS to facilitate later accurate survey.

In the field, data will be collected and recorded on field record sheets (attached). The following data will be collected:

1. **Diversity** – the number of planted tubestock species present will be enumerated.
2. **Height** – Heights of each individual planted tubestock will be measured and related to species (eg 6 x *Eucalyptus tereticornis* Qld blue gum – 125 cm, 101cm, 98, cm, 153cm, 122cm, 125cm).
3. **Photographic log** – a photographic record of the condition of the vegetation within and surrounding the quadrat will be undertake. Photographs should be taken from the north-eastern peg of the transect a. diagonal to the south-western corner; b. 45° to the left and c. 45° to the right.
4. **Incidental Observations** – observations of apparent plant health (eg leaf yellowing, outer tip browning, scorch), erosion/scour in close proximity, lesser vegetation coverage nearby etc.
5. **Planting Age** – The date of direct seeding and date of establishment irrigation will be noted by post field interrogation of planting and watering records.

5. Equipment

Field Equipment required by each team undertaking the field monitoring includes the following:

- 1 x Field herbarium / field keys;
- Jewellers tags for sampling unknown species;

- 1 x Digital camera capable of taking photos >7 megapixels;
- 1 x 40m tape reel;
- 1 x 5 m tape measure;
- 1 x Clipboard;
- Field sampling record sheets;
- Timber stakes (suffient for the number of transects / quadrats if sampling for the first time);
- 1 x mallet;
- 2 x rolls of flagging tape;
- Permanent marker pen
- Pencils and eraser.

6. Data Analysis

6.1 'D' Sites

Data synthesis and analysis will provide the following information for each cell:

- Total cover expressed as a percentage;
- Individual species cover expressed percentage of total cover;
- Total weed cover expressed as a percentage;
- Analysis of dominance of cover or secondary crop;
- Species diversity.

Further analysis will occur to chart the progression of vegetative cover from cover crop to secondary crop dominance.

The total cover for the BCD will be established through identification of the mean percentage cover for all cells of the diversion. Data analysis should also indicate highest cover, lowest cover, number of cells below 75% (expressed as classes<75% but > 60%; <60% but >50%; <50% but >40%; <40%).

Data may also be synthesized and analyzed to assess coverage within individual zones (eg **Zone A, Zone B2** and **Zone C**).

6.21 'P' Sites

Data synthesis and analysis will provide the following information for each cell:

- Median height for each cell;
- Mean height for each species; and
- Species diversity.

Further analysis will occur to identify overall health and performance of individual species.

FIGURES

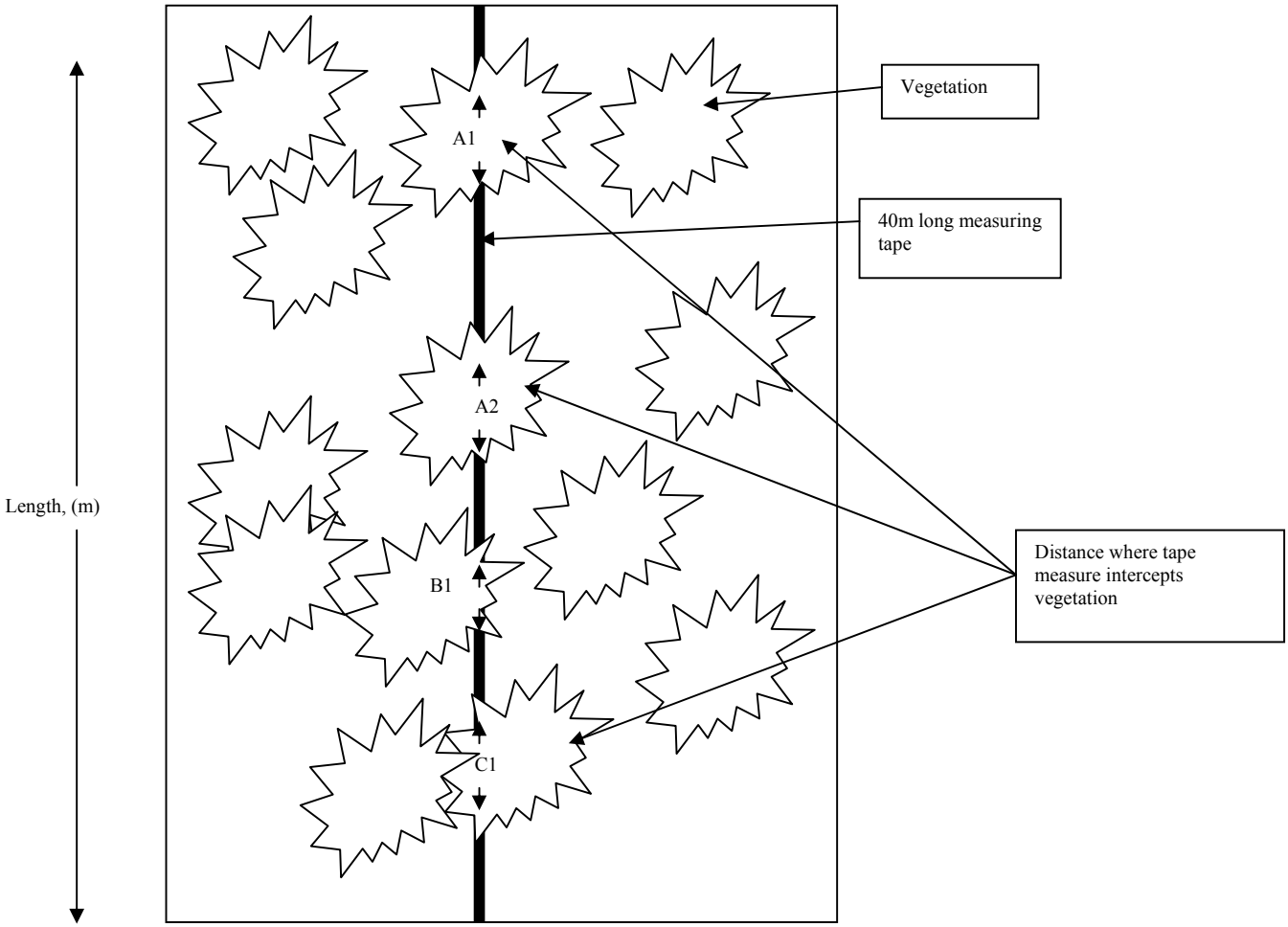


FIGURE 1: Line Intercept Method

The above can be analyzed thus:

Species Diversity: 3 species are present; A, B, C

Total Cover: the sum of the above vegetation intercepts is A1 – 15m + A2 – 5m + B1 – 9m +, C1-1m = 30m. Expressed as percentage of the length of tape is (30/40)*100 = 75%

Species Contribution:

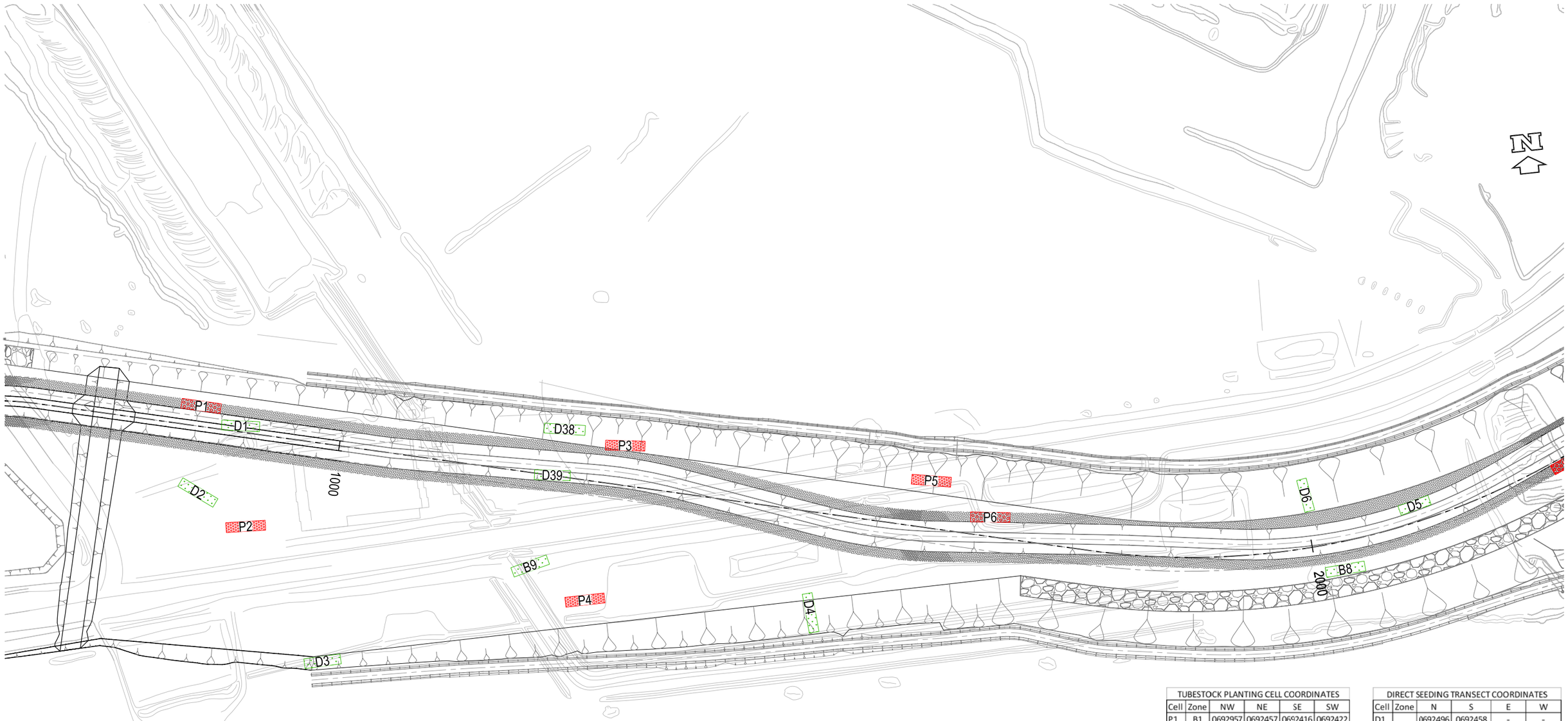
A. Rhodes grass, total line intercept 20m (A1 + A2). Therefore coverage is 50% (20/40*100).
B. Jap millet, total line intercept 7m. Coverage contribution is 22.5% (9/40*100).
C. Weed Species, total line intercept is 3m. Coverage contribution is 2.5% (3/40*100).

Trajectory:

Direct Seeding occurred August 2009. Trajectory is a transition from Cover Crop to dominance by secondary species.

Sample Site Locations

21321105X-SK-0070 (PLACE edit)



TUBESTOCK PLANTING CELL COORDINATES					
Cell	Zone	NW	NE	SE	SW
P1	B1	0692957	0692457	0692416	0692422
		7398606	7398589	7398603	7398614
P2	B2	0692484	0692484	0692450	0692452
		7398487	7398474	7398478	7398486
P3	C	0692880	0692885	0692841	0692845
		7398526	7398509	7398516	7398530
P4	B2	0692825	0692825	0692825	0692789
		7398374	7398364	7398364	7398374
P5	C	0693186	0693184	0693148	0693148
		7398453	7398442	7398452	7398457
P6	B1	0693240	0693240	0693199	0693201
		7398401	7398401	7398405	7398415

DIRECT SEEDING TRANSECT COORDINATES					
Cell	Zone	N	S	E	W
D1		0692496	0692458	-	-
		7398580	7398586	-	-
D2	B2	0692443	0692410	-	-
		7398508	7398533	-	-
D3	C	0692515	0692552	-	-
		7398336	7398337	-	-
D4	C	-	-	0693030	0693032
		-	-	7398333	7398304
D5	A	0693666	0693635	-	-
		7398370	7398361	-	-
D6	C	0693541	0693546	-	-
		7398411	7398378	-	-
D38	C	0692824	0692783	-	-
		7398540	7398547	-	-
D39	A	0692804	0692768	-	-
		7398496	7398501	-	-
B8	B2	0693601	0693550	-	-
		7398317	7398314	-	-
B9	B2	0692772	0692735	-	-
		7398414	07398405	-	-

Cells are shown indicatively on this plan;
for accurate positions, use these grid coordinates (UTM-WGS84 Zone 55s)

All cells 40m x 10m
unless noted otherwise

PLAN
SCALE 1:2000

CONSTRUCTION ISSUE

REV	DATE	DESCRIPTION	DRAWN	CHECK	DESIGN	VERIFY

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DATE RPEQ No.

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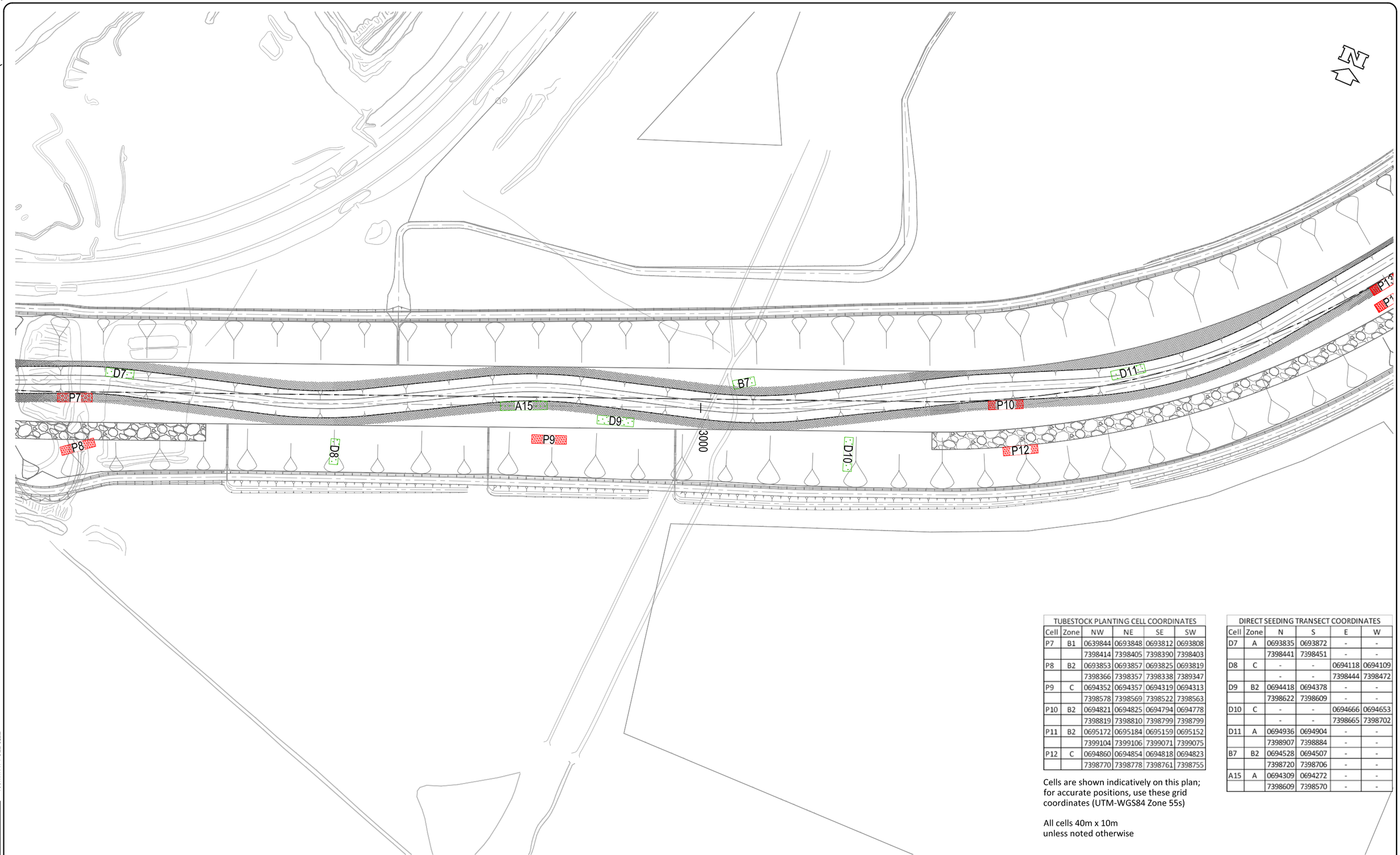
PROJECT
BLACKWATER CREEK DIVERSION
VEGETATION MONITORING LOCATIONS
PLAN
SHEET 1 OF 7

PROJECT No.	DISCIPLINE	NUMBER	REV.
2132105X	SK	0070	

100mm AT FULL SIZE

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2132105X-SK-0071 (PLACE edit)



TUBESTOCK PLANTING CELL COORDINATES

Cell	Zone	NW	NE	SE	SW
P7	B1	0639844	0693848	0693812	0693808
		7398414	7398405	7398390	7398403
P8	B2	0693853	0693857	0693825	0693819
		7398366	7398357	7398338	7389347
P9	C	0694352	0694357	0694319	0694313
		7398578	7398569	7398522	7398563
P10	B2	0694821	0694825	0694794	0694778
		7398819	7398810	7398799	7398799
P11	B2	0695172	0695184	0695159	0695152
		7399104	7399106	7399071	7399075
P12	C	0694860	0694854	0694818	0694823
		7398770	7398778	7398761	7398755

DIRECT SEEDING TRANSECT COORDINATES

Cell	Zone	N	S	E	W
D7	A	0693835	0693872	-	-
		7398441	7398451	-	-
D8	C	-	-	0694118	0694109
		-	-	7398444	7398472
D9	B2	0694418	0694378	-	-
		7398622	7398609	-	-
D10	C	-	-	0694666	0694653
		-	-	7398665	7398702
D11	A	0694936	0694904	-	-
		7398907	7398884	-	-
B7	B2	0694528	0694507	-	-
		7398720	7398706	-	-
A15	A	0694309	0694272	-	-
		7398609	7398570	-	-

Cells are shown indicatively on this plan; for accurate positions, use these grid coordinates (UTM-WGS84 Zone 55s)

All cells 40m x 10m
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PLAN
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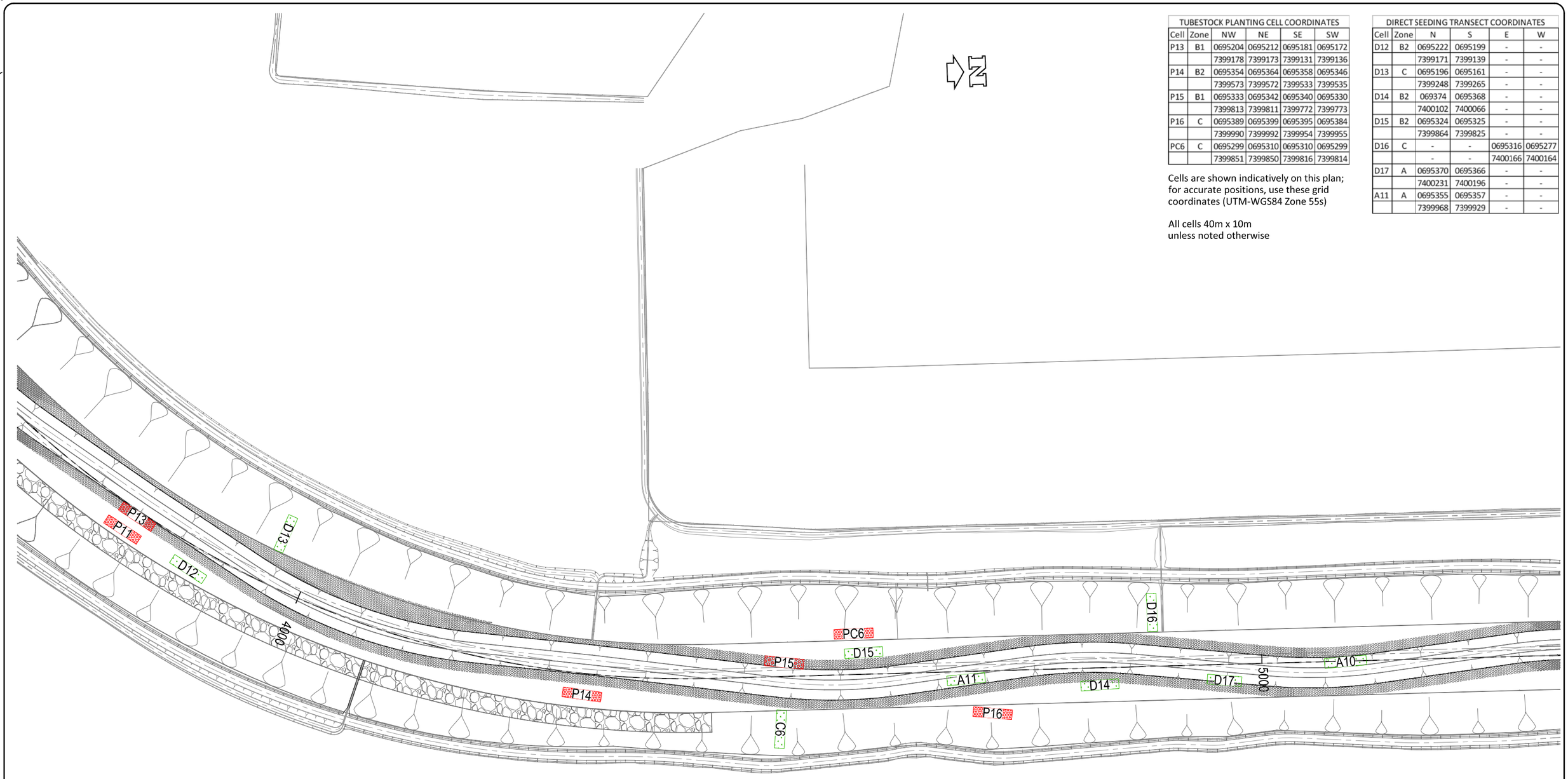
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PROJECT No.	DISCIPLINE	NUMBER	REV.
2132105X	SK	0071	

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2132105X-SK-0072 (PLACE edit)



TUBESTOCK PLANTING CELL COORDINATES

Cell	Zone	NW	NE	SE	SW
P13	B1	0695204	0695212	0695181	0695172
		7399178	7399173	7399131	7399136
P14	B2	0695354	0695364	0695358	0695346
		7399573	7399572	7399533	7399535
P15	B1	0695333	0695342	0695340	0695330
		7399813	7399811	7399772	7399773
P16	C	0695389	0695399	0695395	0695384
		7399990	7399992	7399954	7399955
PC6	C	0695299	0695310	0695310	0695299
		7399851	7399850	7399816	7399814

Cells are shown indicatively on this plan; for accurate positions, use these grid coordinates (UTM-WGS84 Zone 55s)

All cells 40m x 10m unless noted otherwise

DIRECT SEEDING TRANSECT COORDINATES

Cell	Zone	N	S	E	W
D12	B2	0695222	0695199	-	-
		7399171	7399139	-	-
D13	C	0695196	0695161	-	-
		7399248	7399265	-	-
D14	B2	069374	0695368	-	-
		7400102	7400066	-	-
D15	B2	0695324	0695325	-	-
		7399864	7399825	-	-
D16	C	-	-	0695316	0695277
		-	-	7400166	7400164
D17	A	0695370	0695366	-	-
		7400231	7400196	-	-
A11	A	0695355	0695357	-	-
		7399968	7399929	-	-

PLAN
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PROJECT
BLACKWATER CREEK DIVERSION
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SHEET 3 OF 7

PROJECT No.	DISCIPLINE	NUMBER	REV.
2132105X	SK	0072	

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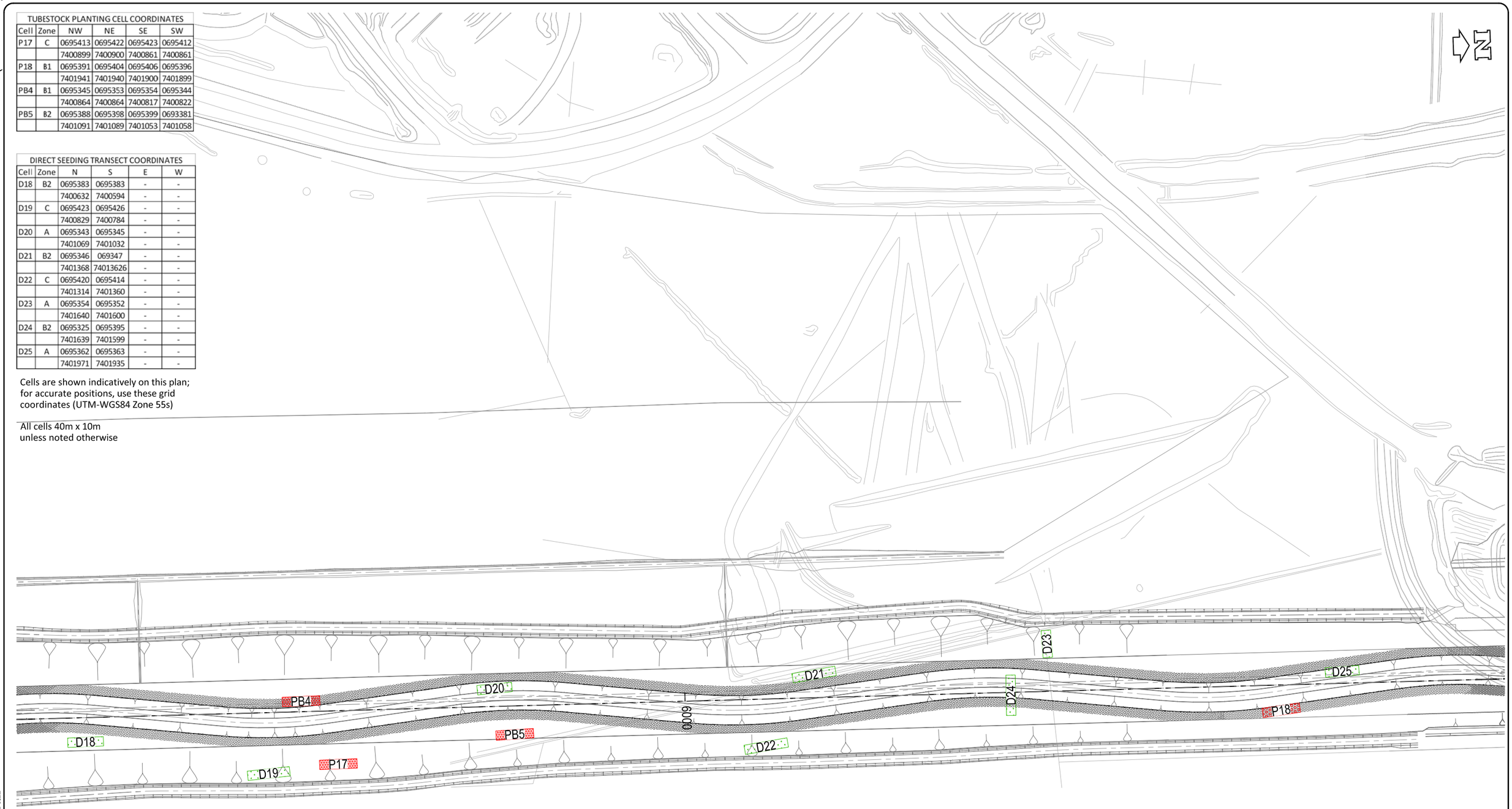
2132105X-SK-0073 (PLACE edit)

TUBESTOCK PLANTING CELL COORDINATES					
Cell	Zone	NW	NE	SE	SW
P17	C	0695413	0695422	0695423	0695412
		7400899	7400900	7400861	7400861
P18	B1	0695391	0695404	0695406	0695396
		7401941	7401940	7401900	7401899
PB4	B1	0695345	0695353	0695354	0695344
		7400864	7400864	7400817	7400822
PB5	B2	0695388	0695398	0695399	0693381
		7401091	7401089	7401053	7401058

DIRECT SEEDING TRANSECT COORDINATES					
Cell	Zone	N	S	E	W
D18	B2	0695383	0695383	-	-
		7400632	7400594	-	-
D19	C	0695423	0695426	-	-
		7400829	7400784	-	-
D20	A	0695343	0695345	-	-
		7401069	7401032	-	-
D21	B2	0695346	069347	-	-
		7401368	74013626	-	-
D22	C	0695420	0695414	-	-
		7401314	7401360	-	-
D23	A	0695354	0695352	-	-
		7401640	7401600	-	-
D24	B2	0695325	0695395	-	-
		7401639	7401599	-	-
D25	A	0695362	0695363	-	-
		7401971	7401935	-	-

Cells are shown indicatively on this plan; for accurate positions, use these grid coordinates (UTM-WGS84 Zone 55s)

All cells 40m x 10m
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PROJECT No.	DISCIPLINE	NUMBER	REV.
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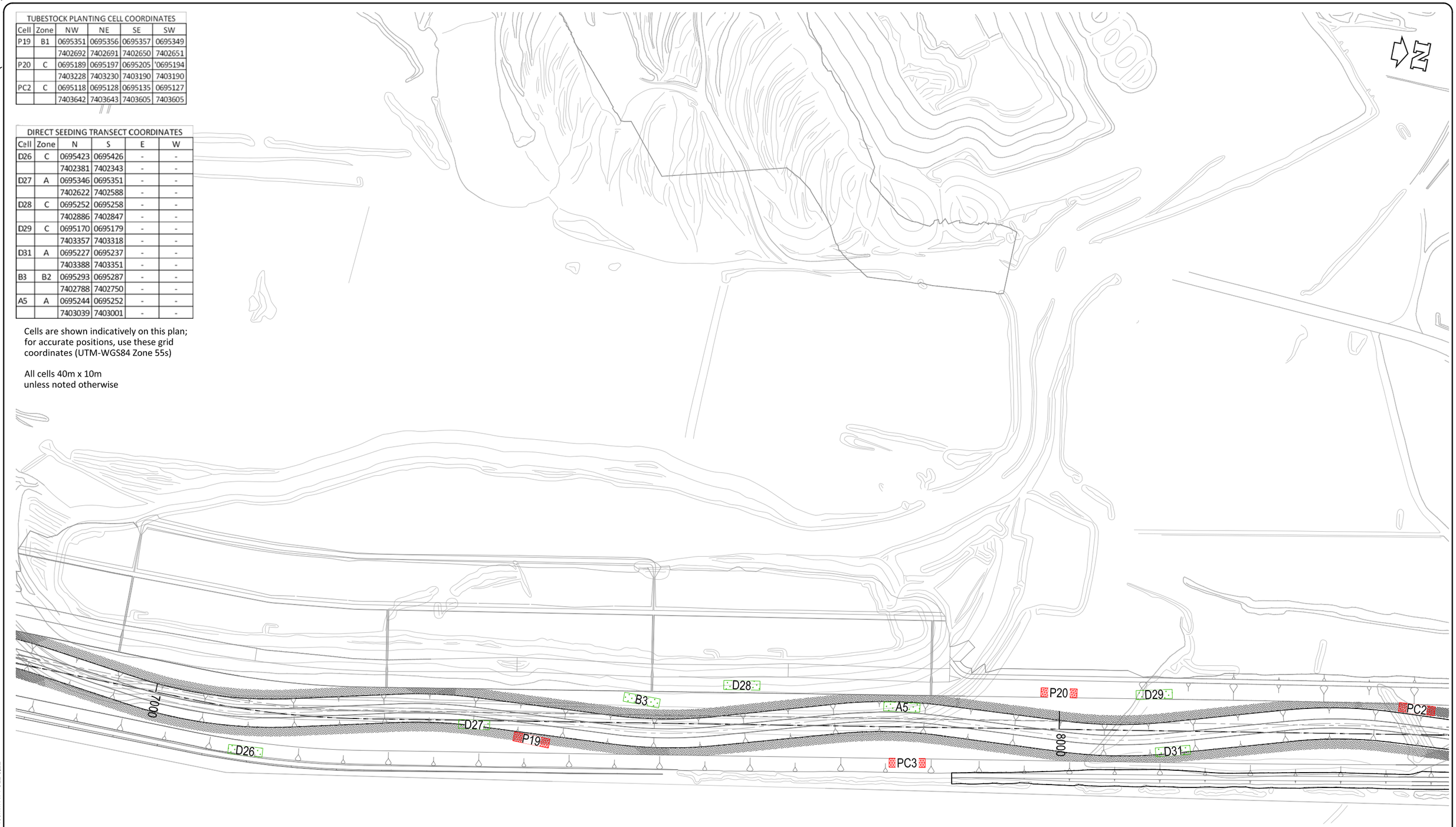
2132105X-SK-0074 (PLACE edit)

TUBESTOCK PLANTING CELL COORDINATES					
Cell	Zone	NW	NE	SE	SW
P19	B1	0695351	0695356	0695357	0695349
		7402692	7402691	7402650	7402651
P20	C	0695189	0695197	0695205	'0695194
		7403228	7403230	7403190	7403190
PC2	C	0695118	0695128	0695135	0695127
		7403642	7403643	7403605	7403605

DIRECT SEEDING TRANSECT COORDINATES					
Cell	Zone	N	S	E	W
D26	C	0695423	0695426	-	-
		7402381	7402343	-	-
D27	A	0695346	0695351	-	-
		7402622	7402588	-	-
D28	C	0695252	0695258	-	-
		7402886	7402847	-	-
D29	C	0695170	0695179	-	-
		7403357	7403318	-	-
D31	A	0695227	0695237	-	-
		7403388	7403351	-	-
B3	B2	0695293	0695287	-	-
		7402788	7402750	-	-
A5	A	0695244	0695252	-	-
		7403039	7403001	-	-

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All cells 40m x 10m
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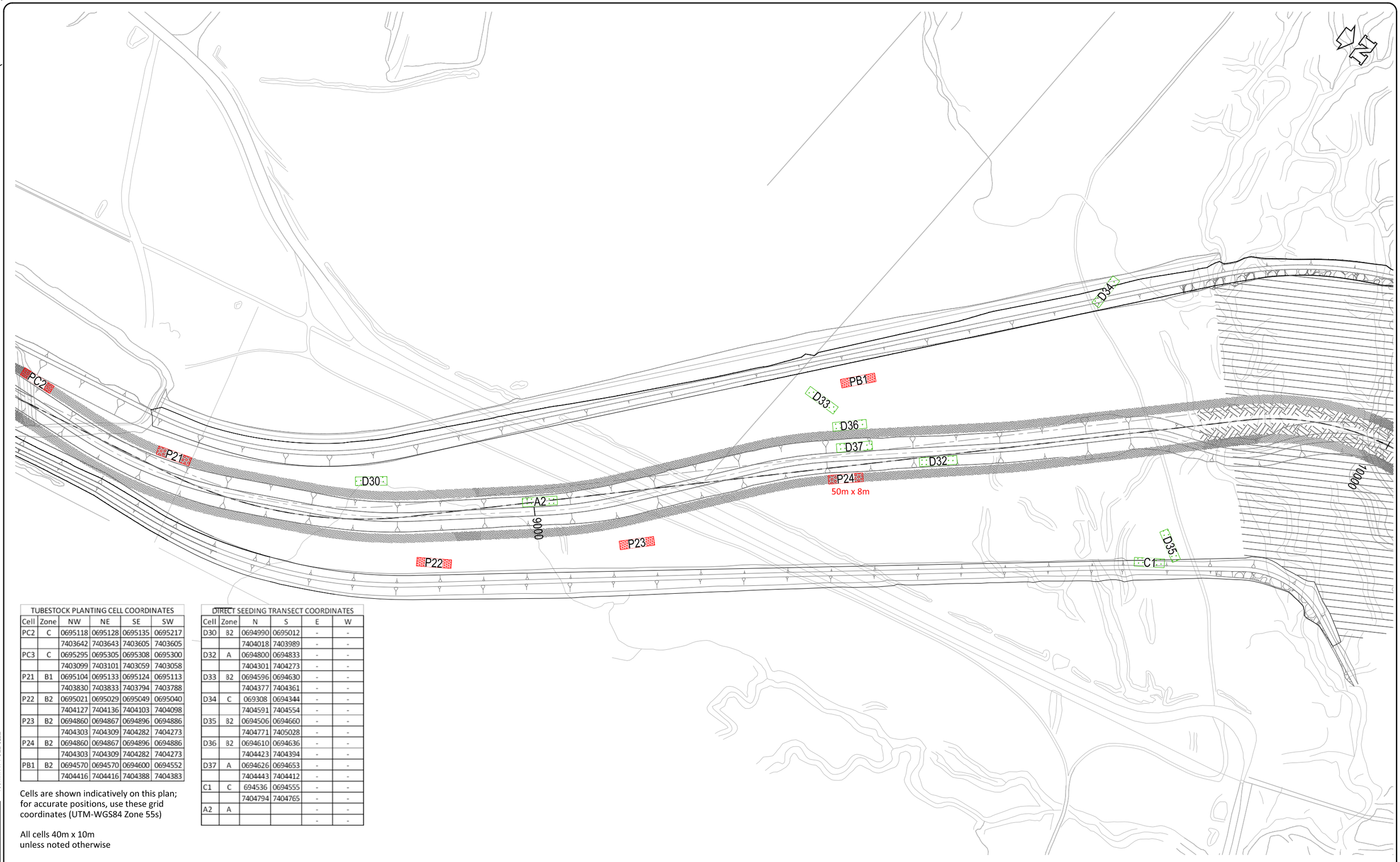
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BLACKWATER CREEK DIVERSION
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PLAN
SHEET 5 OF 7

PROJECT No.	DISCIPLINE	NUMBER	REV.
2132105X	- SK -	0074	

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2132105X-SK-0075 (PLACE edit)



TUBESTOCK PLANTING CELL COORDINATES

Cell	Zone	NW	NE	SE	SW
PC2	C	0695118	0695128	0695135	0695217
		7403642	7403643	7403605	7403605
PC3	C	0695295	0695305	0695308	0695300
		7403099	7403101	7403059	7403058
P21	B1	0695104	0695133	0695124	0695113
		7403830	7403833	7403794	7403788
P22	B2	0695021	0695029	0695049	0695040
		7404127	7404136	7404103	7404098
P23	B2	0694860	0694867	0694896	0694886
		7404303	7404309	7404282	7404273
P24	B2	0694860	0694867	0694896	0694886
		7404303	7404309	7404282	7404273
PB1	B2	0694570	0694570	0694600	0694552
		7404416	7404416	7404388	7404383

DIRECT SEEDING TRANSECT COORDINATES

Cell	Zone	N	S	E	W
D30	B2	0694990	0695012	-	-
		7404018	7403989	-	-
D32	A	0694800	0694833	-	-
		7404301	7404273	-	-
D33	B2	0694596	0694630	-	-
		7404377	7404361	-	-
D34	C	069308	0694344	-	-
		7404591	7404554	-	-
D35	B2	0694506	0694660	-	-
		7404771	7405028	-	-
D36	B2	0694610	0694636	-	-
		7404423	7404394	-	-
D37	A	0694626	0694653	-	-
		7404443	7404412	-	-
C1	C	694536	0694555	-	-
		7404794	7404765	-	-
A2	A			-	-
				-	-

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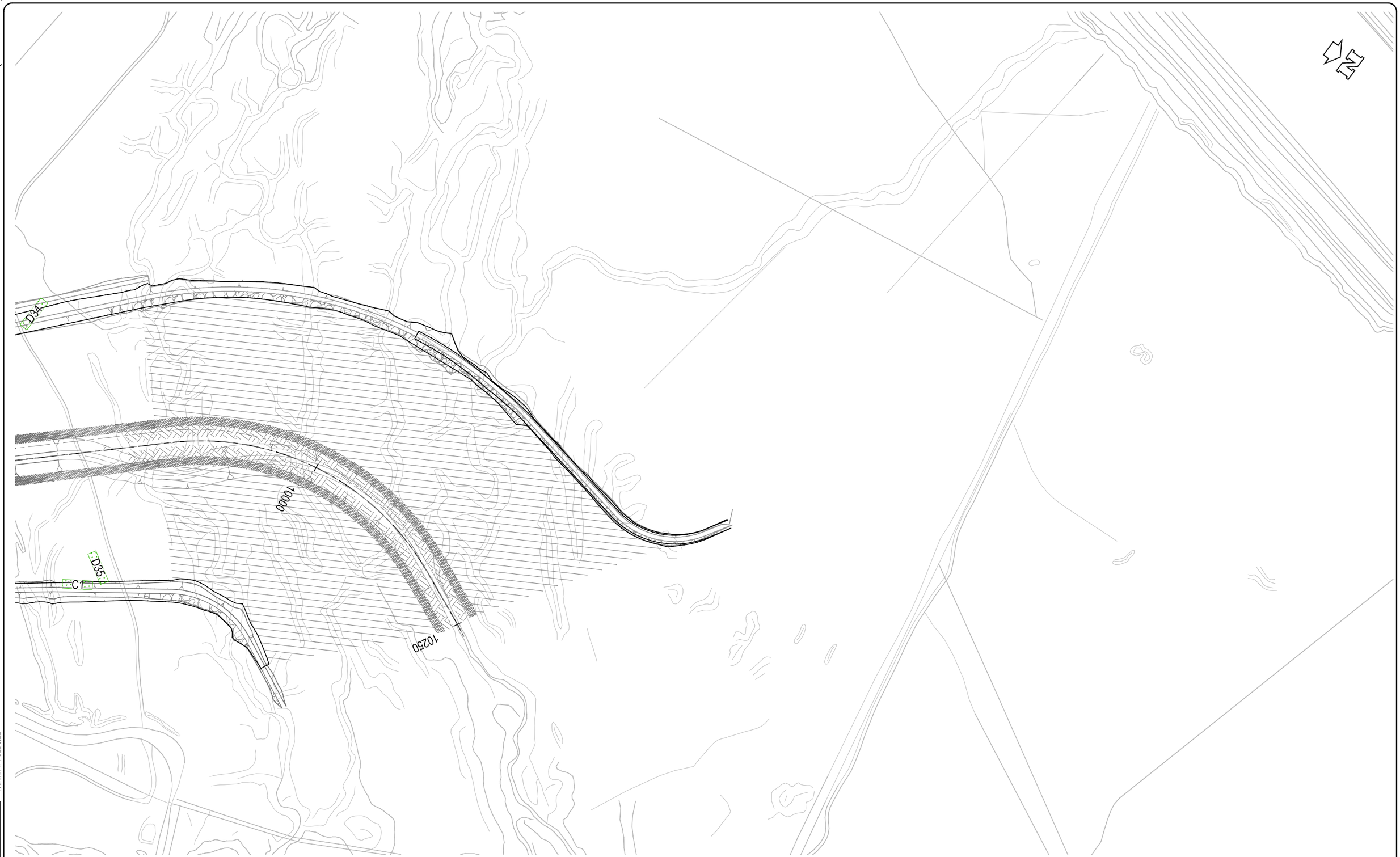
PROJECT
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PLAN
SHEET 6 OF 7

PROJECT No.	DISCIPLINE	NUMBER	REV.
2132105X	SK	0075	

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PROJECT
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SHEET 7 OF 7

PROJECT No.	DISCIPLINE	NUMBER	REV.
2132105X	SK	0076	

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APPENDIX B

Proformas for conducting Primary Monitoring Assessment

Blackwater Creek Diversion
Practical Completion and Maintenance Phase Monitoring Version A

Date:	Chainage:	40 m line intercept: Y / N
Site Number:	Photos:	40 x 10 m quad: Y / N
Samplers:	Zone	L Bank or R bank:*
GPS Co-ordinates (UTM):		

* - view downstream

Vegetation Intercept (cm) *Height (cm)*	**Species**	**Vegetation Intercept (cm) *Height (cm)***	**Species**

Summary

Total Intercept Distance (m)	**Species (Rank in order of dominance)**	**Total Intercept Distance (m)**	**Species**
	1.		11.
	2.		12.
	3.		13.
	4.		14.
	5.		15.
	6.		16.
	7.		17.
	8.		18.
	9.		19.
	10.		20.

Diversity (Additional species) if extended Quadrate is used

1.	6.
2.	7.
3.	8.
4.	9.
5.	10.

Notes:

Weeds:

Dieback / illness

Tree height	Median (m):	Mean (m)
Groundcover:	of 40 m	%
Cover crop:	of 40 m	%
Weeds:	of 40 m	%
Attrition	of 40 m	%

APPENDIX D

Concept Residual Void Assessment

CURRAGH PROJECT

Concept Residual Void Assessment

Prepared for:

Coronado Curragh Pty Ltd



SLR Ref: 626.30075.00000-R01
Version No: -v2.0
November 2021

PREPARED BY

SLR Consulting Australia Pty Ltd
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BASIS OF REPORT

This report has been prepared by SLR Consulting Australia Pty Ltd (SLR) with all reasonable skill, care and diligence, and taking account of the timescale and resources allocated to it by agreement with Coronado Curragh Pty Ltd (the Client). Information reported herein is based on the interpretation of data collected, which has been accepted in good faith as being accurate and valid.

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DOCUMENT CONTROL

Reference	Date	Prepared	Checked	Authorised
626.30075.00000-R01-v2.0	30 November 2021	Emma Williams	Brad Radloff	Brad Radloff
626.30075.00000-R01-v1.0	29 November 2021	Emma Williams	Brad Radloff	

EXECUTIVE SUMMARY

SLR Consulting Australia Pty Ltd (SLR) has been engaged by Coronado Curragh Pty Ltd (CCPL) to update the Conceptual Residual Void Assessment (CRVA) for the Curragh Project. The aim of this report is to satisfy the Environmental Authority (EA) Condition G14 which requires an updated to the CRVA to incorporate rehabilitated landform criteria and residual void outcomes for new mining leases (MLs) ML700006, ML700007, ML700008 and ML700009.

The updated CRVA is being submitted with the intention of being considered a Land Outcome Document (LOD) under the definition in section 750 of the Environmental Protection Act 1994. The Updated CRVA is a document made under a condition of the EA and has been provided to the administering authority on 30 November 2021, if a notice of insufficiency is not received within 20 business days, the updated CRVA will meet the requirements for a LOD.

SLR have developed the following residual void objectives based on relevant legislation and policy, the statutory requirements of the EA and best practice:

1. Safe for humans, livestock and native fauna;
2. Geotechnically and erosionally stable;
3. Does not cause serious environmental harm to land, surface waters or any recognised groundwater aquifer, other than the environmental harm constituted by the existence of the residual void itself; and
4. The extent of residual voids is minimised as much as practicable.

As part of this CRVA update a flood assessment, groundwater assessment, void water balance model and geotechnical stability assessment has been undertaken. The intent of these studies is to assist in defining the final land outcome for residual voids and to provide input into the finalisation of the proposed final landform. The outcomes of the studies are summarised below.

Conservative flood modelling of the 0.1% Annual Exceedance Probability (AEP) event was undertaken for the Curragh Project. The flood modelling shows that with the inclusion of a long-term stable embankment around the residual voids, flood inundation of the voids will not occur. The maximum flood levels from the modelling will be used to further refine the final landform design for the stable embankments.

SLR updated the existing numerical model from Parsons Brinckerhoff in 2016 to be extended over a wider area and to include a post-mining recovery simulation. The preliminary numerical modelling assessment found that the residual voids will act as local groundwater ‘sinks’. The residual drawdown in the Mackenzie River Alluvium to the west of Curragh North will generally be in the order of 1 to 2 m. Based on the geological data reviewed, it appears that the equilibrium void lake levels are generally well below the level of alluvium and the base of weathering which are potential preferential flow paths for seepage.

EXECUTIVE SUMMARY

SLR developed a void water balance model using Goldsim software which includes groundwater inputs from the above study and surface water inputs. The water balance modelling shows that residual void water levels are expected to range from 26 mAHD to 132 mAHD with water depths of 14 m to 74 m. Salinity in all voids increases over time until reaching saturation (37,313 µS/cm) after approximately 20 to 30 years. The results indicate that the mine is not a net accumulator of water after approximately 100 years when the equilibrium water levels are reached. The final water levels remain below the spill level and the voids are unlikely to overtop in the 99th percentile climate scenario.

A Slope Stability Analysis has been undertaken by Raine Associates (RA) for the preliminary final landform provided by CCPL as well as a number of alternative landform options. The factor of safety for all landform options were determined and compared against the acceptable design criteria of >1.5 static factor of safety and >1.1 dynamic factor of safety. All landforms had a factor of safety higher than the design criteria indicating that the final landform is considered safe and geotechnically stable.

The erosional stability of the Tertiary highwall has been assessed against existing rehabilitation trials and literature. Further work is required to determine the final slope angles of the Tertiary highwall and stable embankment with consideration to the outputs of the flood model.

With consideration to all of the above information, SLR recommends that the Permian highwall and maximum void water level be considered a non-use management area and that the void low wall, Tertiary highwall and stable embankment have a post-mining land use of open pasture and woodland.

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1 Introduction

1.1 Purpose

Coronado Curragh Pty Ltd (CCPL) engaged SLR Consulting Australia Pty Ltd (SLR) to update the Concept Residual Void Assessment (CRVA) for Curragh Mine Complex (Curragh Project). The last version of the CRVA was developed in 2012 by AECOM.

The purpose of this CRVA update is to identify the location, and area of all proposed voids, the post-mining land outcome for each of these voids and the work to be undertaken between now and the submission of the Curragh Progressive Rehabilitation and Closure Plan (PRCP). All residual voids are approved with post mining land uses of conservation/grazing post-mining land use for the low walls and a non-use management area for the pit lakes/highwalls.

This assessment will address condition G13 and condition G14 of the Environmental Authority (EA) EPML00643713, outline appropriate outcomes to meet these conditions and demonstrate how these measures can be achieved through ongoing rehabilitation and landform stabilisation at the end of the economic life of each void.

It is intended that this report will be considered a Land Outcome Document (LOD) under the definition in section 750 of the *Environmental Protection Act 1994* (EP Act). The purpose of a LOD is to be able to transition pre-approved land outcomes into the new PRCP framework without further assessment. Under the PRCP Guideline, a LOD includes:

a) An EA;

b) A document made under a condition of an EA that:

   i. Relates to the management or rehabilitation of land (e.g. rehabilitation and closure plan or residual void management plan); and

   ii. Was provided to the administering authority, and had not been superseded, before 30 November 2018; and

   iii. Before 15 January 2019, the administering authority had not notified the EA holder that the document was insufficient.

c) a document made under a condition of an EA that:

   i. Relates to the management or rehabilitation of land (e.g. rehabilitation and closure plan or residual void management plan); and

   ii. Was provided to the administering authority between 20 November 2019 and 30 November 2021; and

   iii. Within 20 business days after receiving the document, the administering authority had not notified the EA holder that the document was insufficient.

d) A report evaluating an EIS under section 34D of the SDPWO Act;

e) An EIS assessment Report; or

f) A written agreement between the EA holder and the State that is in force on 30 November 2018.

It should be noted that LODs are treated in a hierarchy as outlined above. Therefore, the 2012 version of the CRVA would be considered higher on the hierarchy than this updated version as it was provided to the administering authority before 30 November 2018 and did not receive a notice of insufficiency. As mentioned above, the specific purpose of this update to the CRVA is to include five additional pits which were not included in the original version. The land outcomes for the voids identified in the 2012 version have not changed although it is noted that the extent and location of the voids has been updated to account for changes in the landform design and mine planning. This update of the CRVA will provide further clarification on the land outcomes for all planned voids for the Curragh Project.

This updated CRVA has been submitted to DES by 30th November 2021; and therefore, may qualify as a LOD under section 750 of the EP Act. In order to be a sufficient LOD under Condition G14 of the EA, the CRVA must include rehabilitated landform criteria and residual void outcomes both of which are addressed in Section 8 of this report.

1.2 Report Terminology

There have been numerous definitions and interpretations of 'residual void' made in the wider mining industry and therefore SLR would like to clarify the definitions and terminologies used in this report.

For the purposes of this assessment the term 'residual void' refers to the final landform area associated with a mined pit after closure and is not the proposed final land use. The residual void will include the low wall, highwall and pit bottom regardless of the proposed land outcome or use.

The proposed final land use will be referred to as either a post-mining land use (PMLU) or non-use management area (NUMA) in order to be consistent with the PRCP framework terminology and reduce any confusion.

1.3 Project Description

Curragh Project is approved under EA EPML00643713 and operated by CCPL, a wholly owned subsidiary of Coronado Global Resources. The Curragh Project consists of Curragh Main, Curragh East, Curragh West, Curragh Extension and Curragh North mining leases.

Curragh Project is located within the Central Highlands Regional Council, approximately 6 km north of the town of Blackwater and approximately 200 km west of Rockhampton (**Figure 1-1**). The total mining lease area is approximately 19,650 ha.

The mine is an open cut operation producing a variety of coking, PCI and steaming coal products for both export and domestic market. The operation is a mix of dragline and truck and shovel. The annual run of mine (ROM) production is approximately 18 million tonnes per annum (Mtpa).

Operations at Curragh first commenced in 1983. The projected life of the Curragh Project is currently predicted to 2041.

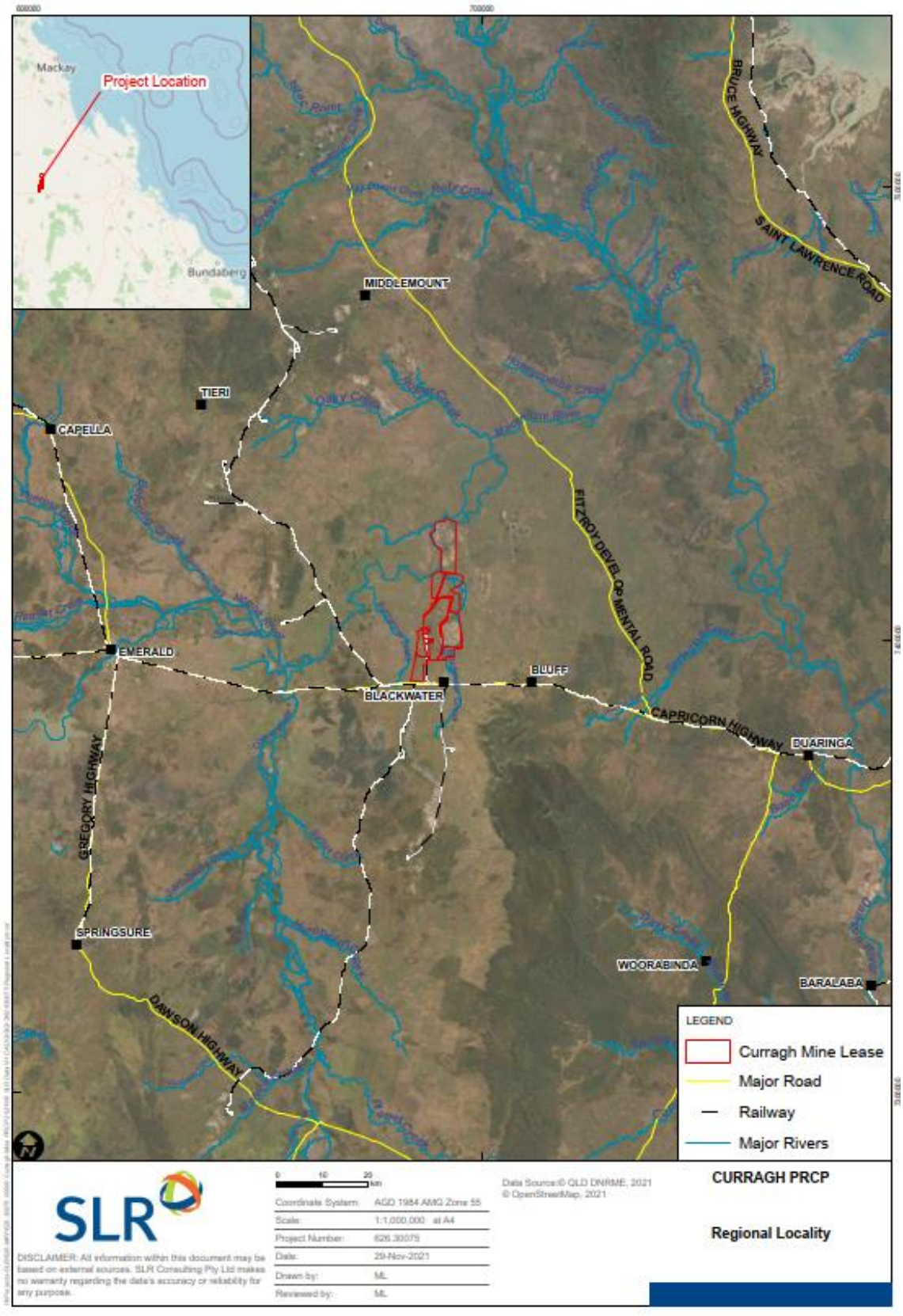


Figure 1-1 Regional Locality

The mine infrastructure and activities on site includes:

- Exploration drilling;
- Clearing vegetation;
- Stripping and stockpiling of topsoil material;
- Explosives;
- Mining;
- Coal processing and stockpiling;
- Tailings and coarse reject disposal;
- Coal stockpiling, train loading and transport via conveyor and rail;
- Rehabilitation of disturbed land;
- Water management;
- Levees and regulated dam management;
- Blackwater Creek Diversion;
- Facilities and Infrastructure;
- Waste management;
- Sewage treatment;
- Mechanical workshops;
- Storage of fuels, oils and chemicals; and
- Village accommodation.

CCPL is required to submit a PRCP for Curragh Project by 21st October 2022.

2 Relevant Legislation, Regulations and Policies

2.1 Environmental Authority

The Curragh Project operates under EA EPML00643713. Conditions G13 and G14 apply to residual voids.

Condition G13 states:

Residual voids must comply with the following rehabilitation outcomes:

(a) residual voids must not cause any serious environmental harm to land, surface waters or any recognised groundwater aquifer, other than the environmental harm constituted by the existence of the residual void itself and subject to any other condition within this environmental authority.

Condition G14 states:

The rehabilitation of disturbed areas and residual void investigation reports submitted to the administrating authority in June 2012 are to be updated to incorporate rehabilitated landform criteria and residual void outcomes for ML700006, ML700007, ML700008, ML700009, six (6) months prior to coal mining occurring on these ML's. The rehabilitated landform criteria and residual void outcomes from these reports must be reviewed every three years, or if any amendments occur and re-submitted to the administering authority.

2.2 Mined Land Rehabilitation Policy

The Mined Land Rehabilitation Policy is a joint departmental policy between the Department of Environment and Science, the Department of Natural Resources and Mines and Queensland Treasury. The Policy presents Queensland Government's position on mine rehabilitation and is the basis of the changes made through the MERFP Act.

The Policy states that, "land disturbed by mining is considered to be rehabilitated when it can be demonstrated it is safe, stable, does not cause environmental harm, and is able to sustain the post-mining land use approved in the PRCP (referred to as 'stable condition'). An area of land that does not sustain a post-mining land use (referred to as a 'non-use management area') may be approved if best practice management can be demonstrated, and:

- Rehabilitating the area would cause greater environmental risk than not rehabilitating, or
- The environmental risks from the area are localised, and the cost of rehabilitation would be so excessive as to not be in the public interest."

The Policy also introduces the prohibition of final voids situated wholly or partly in a floodplain. This Policy is not intended to be applied to residual voids already approved in a LOD.

2.3 Environmental Protection Act 1994

The amendments to the EP Act requiring mines with site-specific EAs to have a PRCP, came into effect on 1 November 2019. The EP Act states the legislative information requirements for the rehabilitation planning part (section 126C) and PRCP schedule (section 126D). The EP Act also details the assessment process for the approval of a proposed PRCP.

The EP Act contains transitional provisions relating to existing site-specific mines. During the three-year transition period, DES will issue notices to existing mines requiring them to develop and submit a proposed PRCP by a specific date (no less than six months from issuing the notice). The transitional provisions also state that existing approvals may be translated into the proposed PRCP without additional assessment or public notification. Final voids approved in a land outcome document are exempt from the prohibition of a final void in a floodplain and the requirement for a public interest evaluation for a NUMA.

2.4 Environmental Protection Regulation 2019

The Environmental Protection Regulation 2019 (EP Regulation) includes PRCP objectives and performance outcomes (schedule 8A) the administering authority must consider when approving a PRCP. The EP Regulation also contains additional requirements for deciding the extent of a floodplain (0.1% Annual Exceedance Probability (AEP)) for the purposes of prohibiting a final void within a floodplain.

2.5 PRCP Guideline

The PRCP Guideline (ESR/2019/4964, V2.00, Effective 17th March 2021) is a statutory guideline made under section 550 of the EP Act and includes additional information requirements the administering authority deems necessary or desirable within a PRCP.

The PRCP Guideline provides information about the assessment process for a PRCP, information requirements for the PRCP, relevant post-approval processes and transitional provisions. The PRCP Guideline stipulates the detailed technical information that is expected to be included in a proposed PRCP.

3 Residual Void Objectives and Locations

3.1 Residual Void Objectives

For residual voids to be relinquished by CCPL, the residual void outcomes describe the key attributes for residual voids at CCPL and thus the underlying principles for closure criteria to be met in a cost effective and timely manner to facilitate relinquishment.

Residual void objectives are described below and the following sections of this report outline how these objectives can be achieved through landform stabilisation and rehabilitation.

The objectives are based on relevant legislation and policy, the statutory requirements of the EA and best practice. The long-term objectives for residual voids are:

1. Safe for humans, livestock and native fauna;
2. Geotechnically and erosionally stable;
3. Does not cause serious environmental harm to land, surface waters or any recognised groundwater aquifer, other than the environmental harm constituted by the existence of the residual void itself; and
4. The extent of residual voids is minimised as much as practicable.

The below sections present the residual void design and describe residual void assumptions and results for landform design and land use studies. Studies undertaken include economic, geotechnical, groundwater and surface water, concept flood barrier / stable embankment design and erosion. Flood modelling and design for the concept flood barrier / stable embankment is presented firstly followed by the detailed studies in the proposed void design.

3.1.1 Factors Affecting Void Behaviour

To understand how the outcomes will be achieved, factors affecting void behaviour must first be understood. The factors which have been considered in this CRVA include:

- Climate;
- Void configuration, including depth, length and spoil landform;
- Topography and catchment areas;
- Effectiveness of rehabilitation, including preventing erosion and regrowth of vegetation;
- Water quality including amount of salts / salinity potential;
- Groundwater inflows and outflows;
- Adjoining land use; and
- Scale of activity.

3.2 Residual Void Locations

The Curragh Project consists of multiple mining leases including:

- ML80110;
- ML700006;
- ML80112;
- ML80011;
- ML80123;
- ML80086;
- ML80171;
- ML80012;
- ML700009;
- ML80010;
- ML1878;
- ML700008;
- ML700007; and
- ML1990.

Condition G14 of the EA requires the residual void investigation report to be updated (this document) to incorporate rehabilitated landform criteria and residual void outcomes for ML700006, ML700007, ML700008 and ML700009 six months prior to coal mining commencing. The proposed voids located with the expansion mining leases are Pit X, Pit Y and Pit Z. All residual voids across the Curragh Project are shown in **Figure 3-1**.

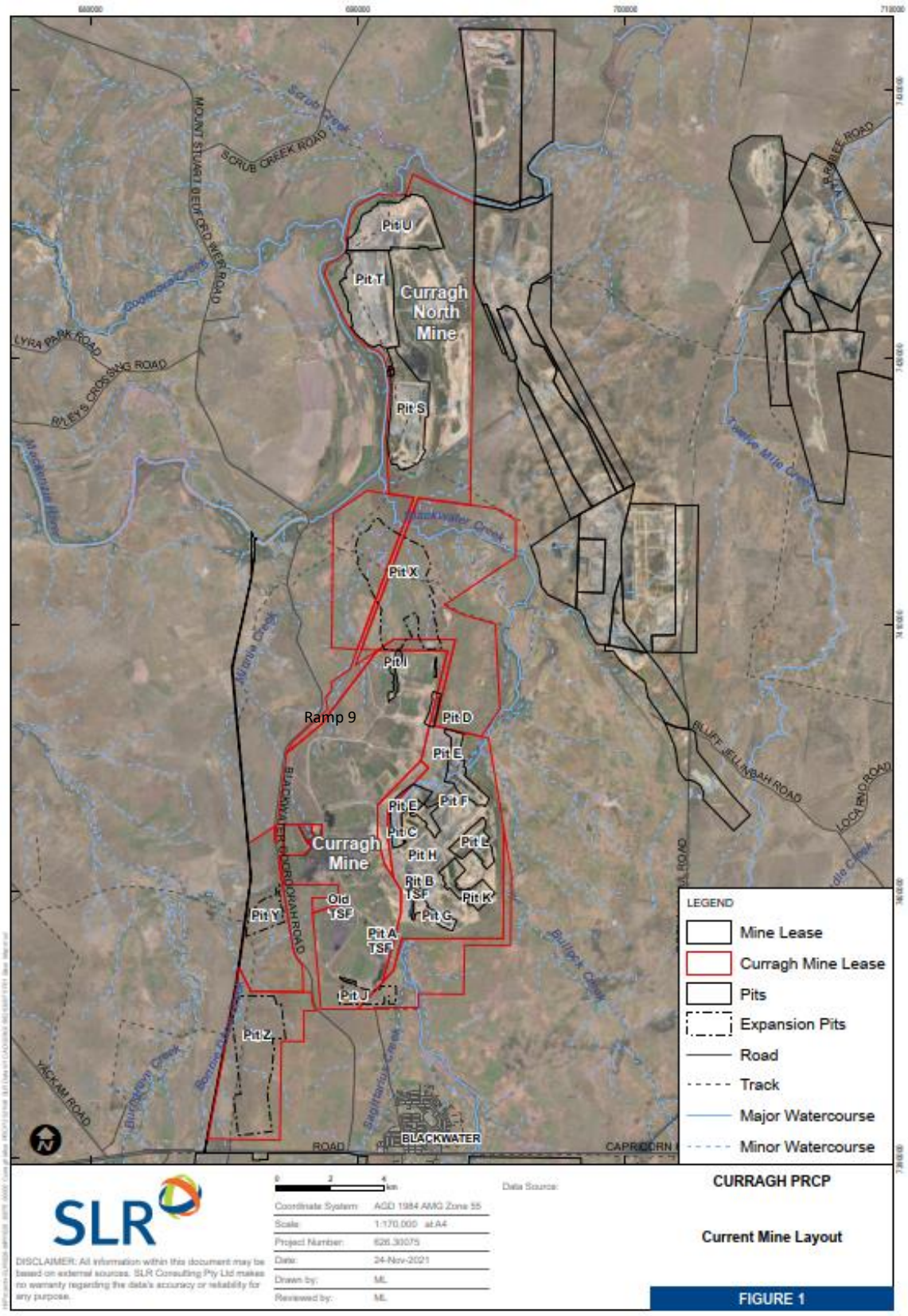


Figure 3-1 Pit Layout at End of Mining

4 Residual Void Flood Assessment

SLR has undertaken preliminary flood modelling of the floodplain surrounding the Curragh Project to assist in design levels for the concept flood barriers for proposed residual voids. The Preliminary Flood Model Report has been provided in **Appendix A**.

The flood modelling was undertaken to estimate 0.1% Annual Exceedance Probability (AEP) flood event for the relevant watercourses which impact the Curragh Project. The intent of the assessment is to understand the locations and dimensions of the flood barrier (long-term stable embankment) required to protect the nominated residual voids from flood influx. For planning purposes, the model has adopted a high level of conservatism by using the most conservative (i.e. largest) flow estimate derived from the flood frequency analysis (FFA). Therefore, the flood modelling results in a conservatively high volume of floodwater over the floodplain rather than stored within the waterway banks providing the worst case flood level estimates.

4.1 Site Hydrology

The mine extends across the floodplain of the Mackenzie River and its tributaries (**Figure 4-1**), the Mackenzie River being the main watercourse in the area and a major tributary of the Fitzroy River. The Mackenzie River forms at the confluence of the Nogoa and Comet rivers, 30km west of Blackwater. The total catchment area of Mackenzie River to Bingegang Weir, 25km downstream of the mine, is approximately 51,000 square km. To the north west of the mine the Mackenzie River floodplain is relatively flat, with the current course of the river meandering through an alluvial tract between approximately 3 km to 8 km in width.

The main tributary of Mackenzie River in the study area is Blackwater Creek, which flows in a northerly direction to the east of Curragh Main via a major diversion around Pits J, K, L, F, and E. Blackwater Creek is naturally ephemeral although at its upstream end, it flows due to intermittent discharge of treated effluent from Blackwater Wastewater Treatment Plant (WTP) into Sagittarius Creek between Blackwater and the mine (PB, 2016).

Blackwater Creek is highly modified having been diverted several times to accommodate mining at Curragh. The current Blackwater Creek diversion is a 9 km long engineered drainage structure made of compacted earth vegetated with grasses and shrubs. The discharge from Blackwater WTP is observed along the extent of the diversion although not north of the diversion (PB, 2016).

Just downstream of the diversion around Curragh Main and to the east of the proposed Pit X Blackwater Creek becomes an ephemeral braided channel system.

Tributaries of Blackwater Creek include Taurus Creek, Sagittarius Creek, Minnie Creek and Bullock Creek, all of which are ephemeral. Minnie Creek flows through the proposed Pit X area and will be subject to a 5.3 km diversion near its confluence with Blackwater Creek plus a 2.9 km diversion of one of its unnamed tributaries around the western side of the pit prior to the commencement of mining in this area (PB, 2016).

Other tributaries of Mackenzie River in the Project area include Burngrove Creek. A tributary of Burngrove Creek is Bonnie Doon Creek, which flows in a northerly direction to the west of proposed Pit Z and will be subject to a diversion. Both Burngrove Creek and Bonnie Doon Creek are ephemeral.

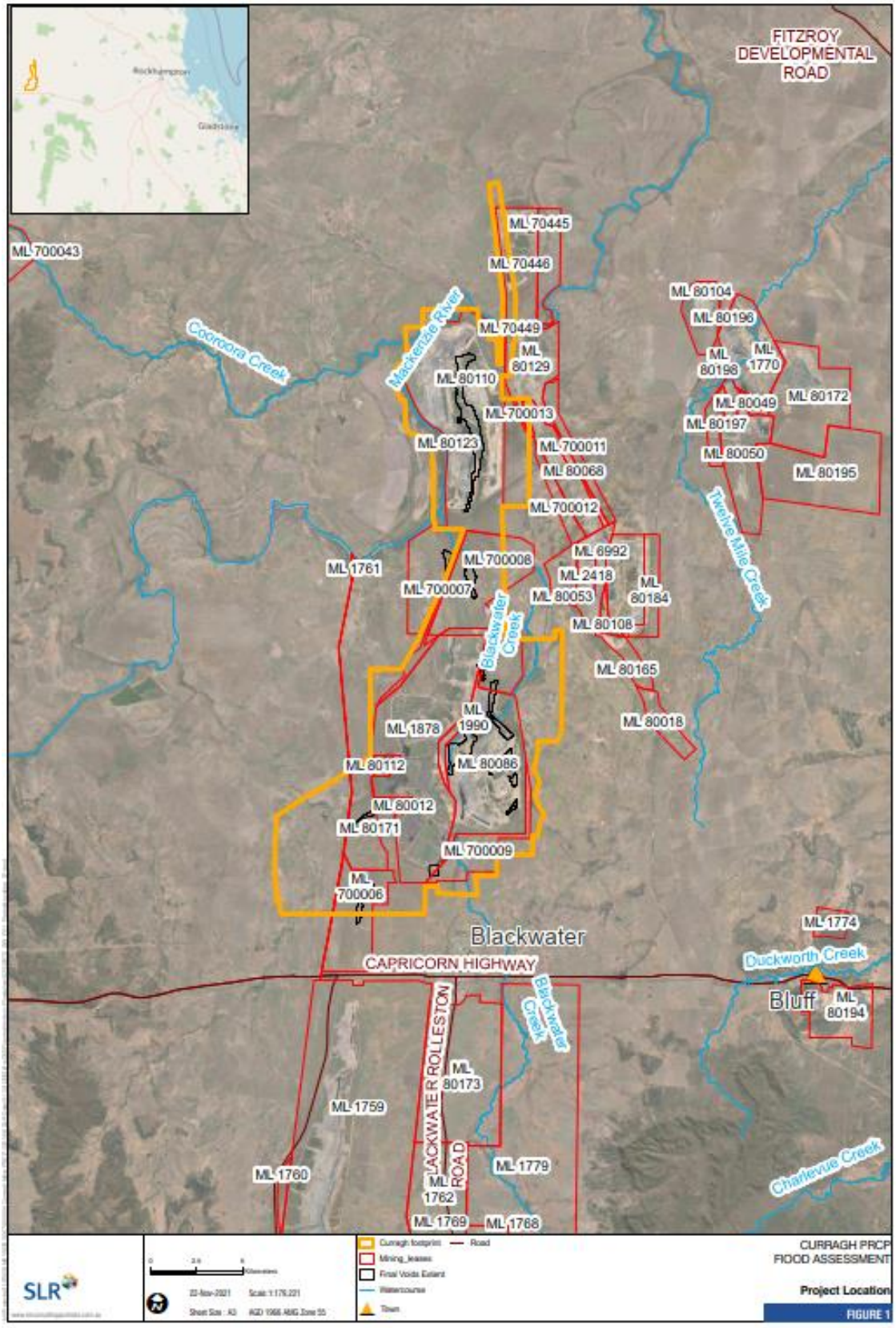


Figure 4-1 Curragh Project Watercourses

4.2 Methodology

A hydrologic assessment was undertaken to provide flow estimates to the hydraulic model. The aim is to estimate the maximum peak flows for 0.1% AEP flood event of various watercourses in relation to the proposed residual voids. To achieve this, a flood frequency analysis (FFA) was undertaken using recorded streamflow data sourced from the Department of Regional Development, Manufacturing and Water (DRDMW). There are no flow gauges in the immediate vicinity of Curragh Project; however, several current and historic gauges are located in the wider catchment. A frequency analysis was undertaken of the annual flood maxima series for each gauge. The details of the FFA are provided in **Appendix A**. The hydrologic inputs for the hydraulic model are:

- For the Mackenzie River immediately upstream of Curragh Project - 1% AEP event of 12,777 m^3/s, and the 0.1% AEP event of 54,393 m^3/s;
- For Blackwater Creek and Minnie Creek - 1% AEP event of 2,702 m^3/s and a 0.1% AEP event of 4,290 m^3/s; and
- For Burngrove Creek - 1% AEP event of 1,182 m^3/s and the 0.1% AEP event of 1,876 m^3/s.

A hydraulic model was developed for the purpose of assessing the post-mining flood extent. The industry standard hydrodynamic modelling software TUFLOW (Build 2020-10-AA) was utilised for the 2D hydraulic modelling. Details of the model setup and methodology are provided in **Appendix A**.

4.3 Assumptions

Broad assumptions in regard to the following elements have been made through the development of the hydraulic model, as follows.

- The flood model has been developed based on inflows derived through a FFA approach. Numerous gauges were used along the Mackenzie River and its tributaries. The assessment shows a lack of convergence in the results. Specifically, the FFA showed estimates of the 0.1% AEP event at each gauge could vary by an order of magnitude. It is thought that this could be due to factors such as floodplain storage, artificial features such as dams and levees, short record lengths and gauge rating curve accuracy. Therefore, the most conservative flow estimate has been adopted. Detailed assessment into the estimate of a 0.1% AEP event for the catchment will be required prior to presentation of results in the PRCP.
- Flow estimates have been applied to the hydraulic model as a steady state inflow. This is a conservative approach as the effects of floodplain storage are removed. The flow estimates were applied as inflows into the model until inflows and outflows were equal.
- Flow estimates for tributaries of the Mackenzie River, such as Blackwater Creek, has been determined through a FFA on donor gauges scaled to the applicable catchment area. As above, the most conservative assessment was applied however this will need to be investigated further prior to understanding flood modelling for the PRCP.
- No assessment of coincident flooding between the Mackenzie River and other tributaries was carried out. Although in reality, flood peaks in Blackwater Creek could potentially occur at a different time to the peak in the Mackenzie River, it was assumed that the flood peak occurred at the same time, providing a conservative approach to estimate the peak water levels.

- The hydraulic model has been largely based on SRTM data due to the limited extent of available Lidar. SRTM data for the site has a vertical accuracy of +/-5-10m. Hydro-enforced SRTM was not used due to the inaccurate representation of waterway cross-sectional area when compared to available LiDAR data. A terrain surface was developed using the residual void landform, 1m Lidar and SRTM with some connectivity along the Mackenzie River provided through the use of artificial terrain manipulation.
- No artificial devices such as weirs were modelled in the hydraulic model.
- No bathymetric data for Mackenzie River was available and therefore not incorporated in the model.
- All roughness values were determined by review of aerial photography. No site visit or verification of the assessment was carried out.
- No infrastructure such as bridges or the like were included in the hydraulic model.

4.4 Results

The results of the TUFLOW model are illustrated for the 0.1% AEP flood event and shown in **Figure 4-2**, **Figure 4-3** and **Figure 4-4**. These figures show that all residual voids within the Curragh Project are not subject to flood inundation due to the current diversion of Blackwater Creek and the stable embankments defined as part of the proposed final landform.

The modelled results show that a residual void landform can effectively use spoil dumps and long-term stable embankments to protect the residual voids from flood ingress. SLR adjusted the provided residual void landform along the existing Blackwater Creek diversion and between X Pit and Curragh North to provide additional protection. Modelled results for the 0.1% AEP flood event show:

- Landform heights of up to 141 mAHD plus freeboard are likely to be required North of X Pit; and
- Blackwater Creek diversion should allow for flood levels up to 162.5 mAHD.

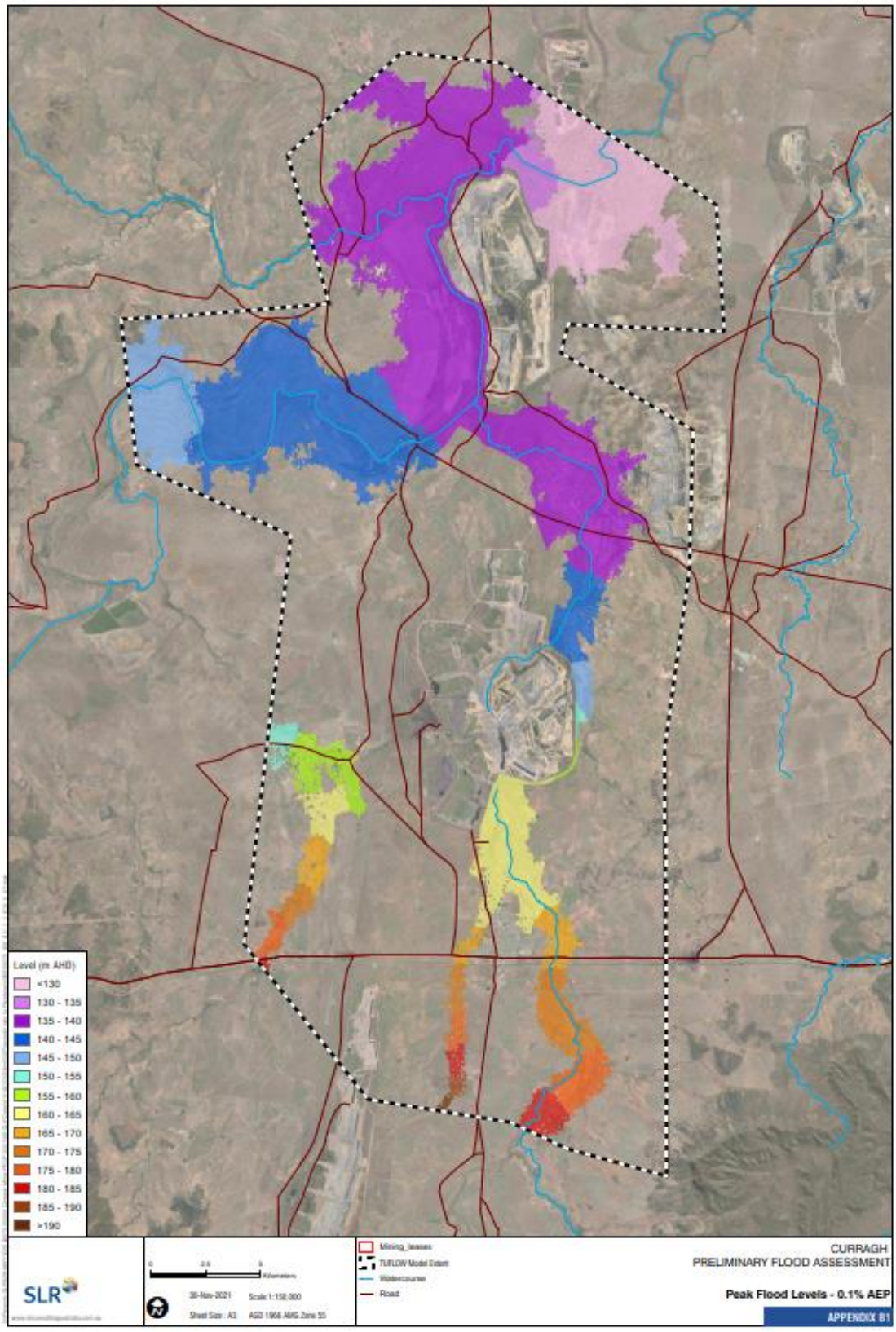


Figure 4-2 Peak Flood levels 0.1% AEP event

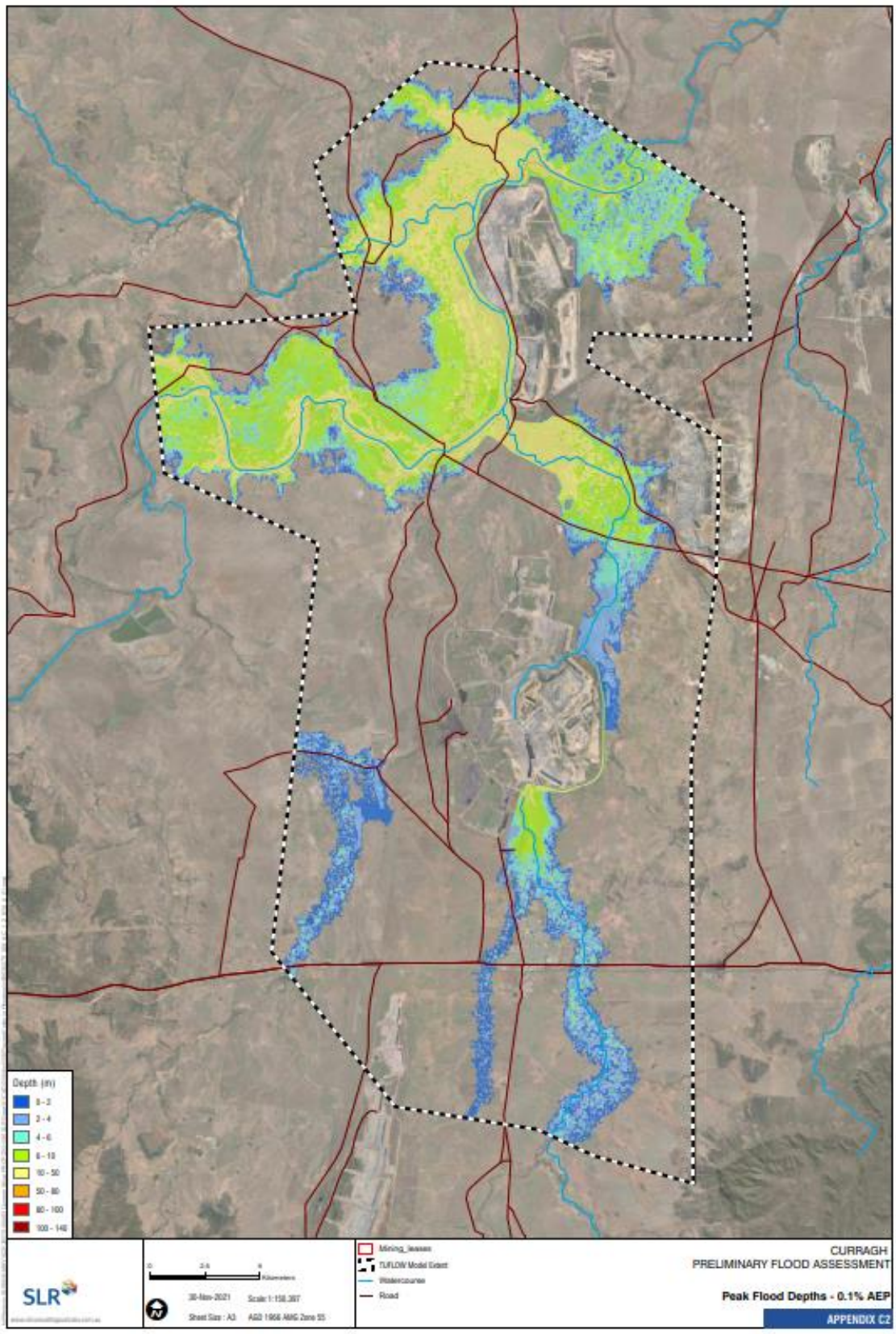


Figure 4-3 Peak flood depths 0.1% AEP event

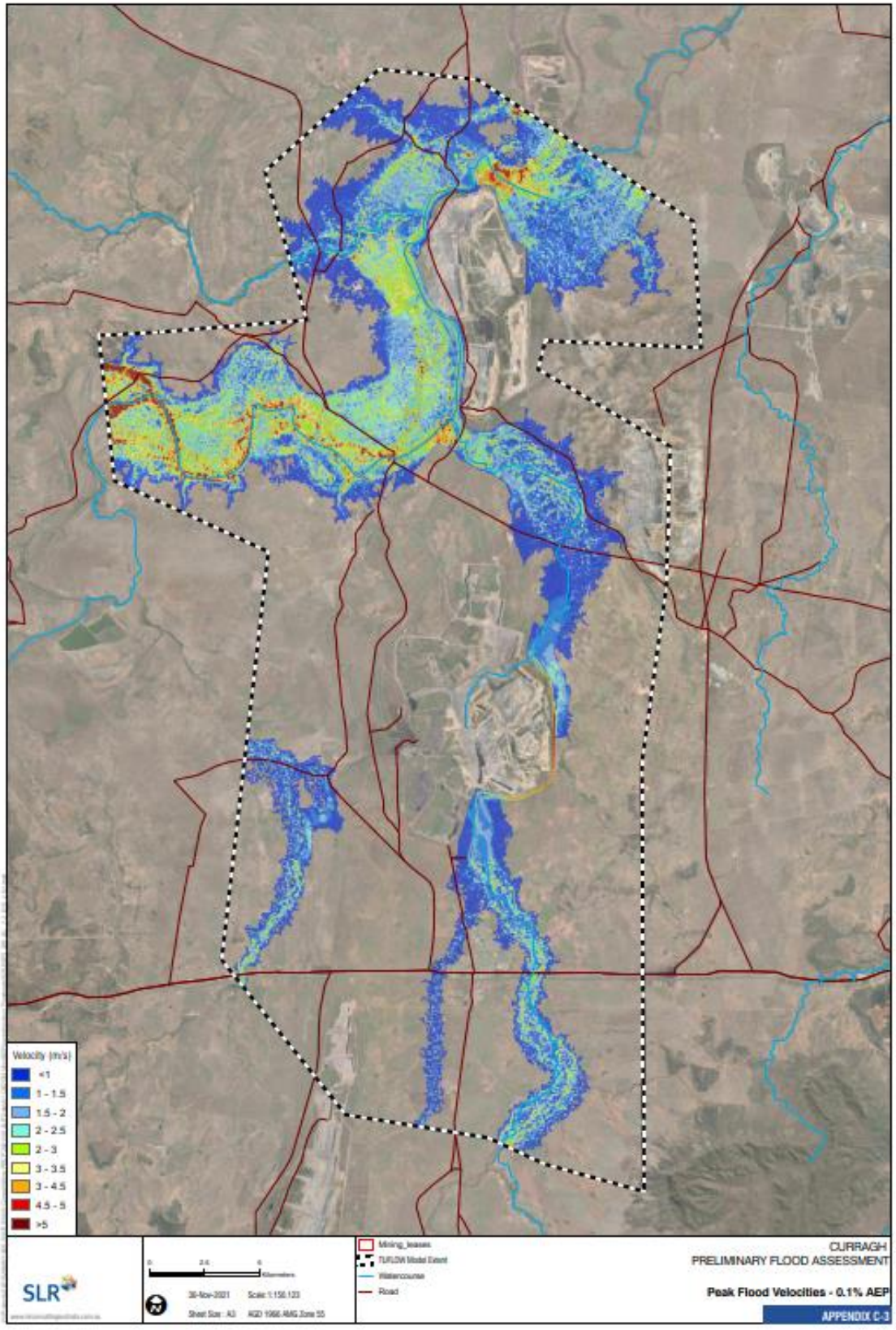


Figure 4-4 Peak flood velocities 0.1% AEP event

A summary of the modelled 0.1% AEP flood levels and velocities for the floodplain around the residual voids is provided in **Table 4-1** and shown in **Figure 4-5**.

Table 4-1 Maximum Surface Level Elevations and Velocities

Measurement Point	Indicative Water Level 0.1% AEP event (m AHD)	Average Velocity (m/s)
1	130.37	2.1 – 5.3
2	140.58	1.8 – 3.9
3	140.57	1.8 – 3.9
4	140.57	1.1 – 3.7
5	140.58	0.7 – 2.9
6	142.32	0.6 -2.6
7	145.19	1.5 - 5
8	148.9	2 - 4.5
9	152.12	0.8 - 5.4
10	156.94	1.5 - 4
11	162.67	0.5 – 2.5
12	160.05	0.5 – 1.7
13	165.89	0.5 – 1.7
14	170.39	0.5 – 3.9

Flood velocities can be substantial through areas where the floodplain is constrained. Velocities are significant in the Blackwater Creek diversion, due to the confinement of the creek flows. However, the diversion is an existing infrastructure and is considered stable in its current form.

Velocities are typically 3 - 4.5 m/s which will cause some erosion to the long-term stable embankment and appropriate treatment will be required. It should be noted that the hydraulic model utilised steady state inflows and this area is affected by backwater from the Mackenzie River. As such, velocities may be greater if Blackwater Creek is in flood with lower tailwater levels observed in the Mackenzie River. The Mackenzie River experiences velocities of greater than 6 m/s within the river banks adjacent to Curragh North, however velocities reduce to less than 2 m/s adjacent to the landform.

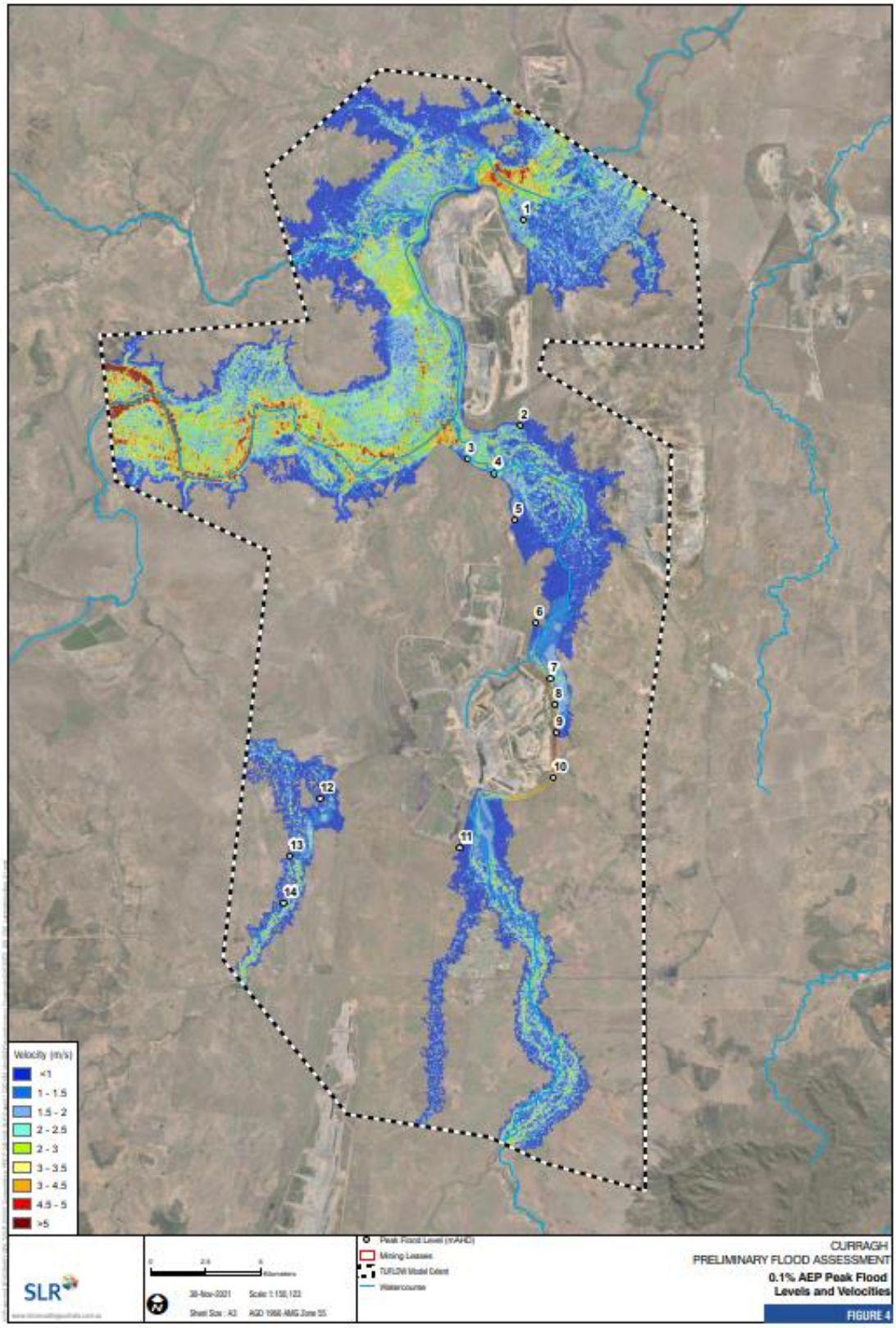


Figure 4-5 Measurement Points

4.5 Conclusions and Recommendations

The conservative flood modelling undertaken shows that the residual voids will not be inundated with flood water due to the Mackenzie River including Blackwater Creek and associated diversion with long-term stable embankments acting as a flood barrier. It is important to note that even if the residual void locations were to change the flood waters will still not inundate the voids as the proposed flood barriers provide protection to the whole mining area in a 0.1% AEP event.

It should be noted that the intention of the preliminary flood modelling is to help inform the development and finalisation of the post-mining landform design. A more detailed flood assessment for the final landform is recommended for the PRCP submission. The following recommendations for further work have been identified through the process of the flood modelling:

- Undertake ongoing monitoring of the Blackwater Creek diversion in accordance with legislative requirements will determine if any works are required to maintain the stability of the landform in this area;
- Investigate the erosion protection requirements for the long-term stable embankment and final landform design with consideration to the peak flood velocities;
- Obtain additional landform data, including LiDAR and bathymetric data, to develop a more refined assessment of the post-mining flood impacts; and
- Update the flood model to meet the detailed requirements of the PRCP Guideline.

5 Residual Void Hydrogeology

SLR have reviewed the existing groundwater, climate, geology, surface water and topography data available for Curragh Project and developed a Groundwater Technical Report (**Appendix B**) to support this CRVA. The objectives of the Groundwater Technical Report are to understand the post-closure groundwater regime around the mine and to:

- Present an understanding of the hydrogeological setting of the mine including potential groundwater receptors;
- Simulate the post mining groundwater level recovery using the final landform (mine void backfill levels) developed by CCPL to understand whether the final voids act as groundwater sinks or sources; and
- Understand the long-term effect of the proposed post mining landform on local groundwater levels i.e. the residual drawdown, and post-mining groundwater flux.

5.1 Conceptual Hydrogeological Model

Section 2 of the Groundwater Technical Report outlines the information for the Conceptional Hydrogeological Model (CHM) including:

- Topography and land use;
- Climate;
- Hydrology;
- Geology; and
- Groundwater monitoring data.

The surface geology across the study area (based on the 1:100,000 mapping), is presented in **Figure 5-1** and the regional (solid) geology is presented in **Figure 5-2.**

The study area is underlain by Permian to Quaternary sediments located within a gently folded and faulted sequence of the Bowen Basin. The Permo-Triassic sediments dip eastward and include the Triassic Rewan Formation and the underlying Permian Blackwater Group, which includes the Rangal Coal Measures, Burngrove Formation and Fair Hill Formation. The Triassic strata are overlain by unconsolidated Quaternary alluvium associated with creeks, rivers and floodplains and the poorly consolidated Tertiary sediments of the Duaringa and Emerald formations. The Back Creek Group underlies the Blackwater Group and forms the basement of the area.

The stratigraphic sequence underlying the study area is presented in **Table 5-1** and summarised below.

Table 5-1 Regional Stratigraphy

Age	Group	Stratigraphic Unit	Description
Quaternary		Alluvium	Soils, unconsolidated silts, sands, gravels and clays,
Cenozoic (Tertiary)		Duaringa Formation/ Emerald Formation	Claystone, siltstone, sandstone, conglomerate (often poorly consolidated), lignite, basalt
Triassic	Mimosa	Rewan Formation	Mudstone, interbeds of lithic sandstone.
Upper Permian	Blackwater Group	Rangal Coal Measures	Coal seams calcareous sandstone, calcareous shale, mudstone, calcareous tuff in places. Main coal seams include Aries, Castor, Pollux, Orion, Pisces.
		Burngrove Formation	Siltstone, carbonaceous shales and mudstone, fine lithic sandstone, calcareous lithic and feldspathic sandstone, tuffaceous shales and thin coal seams.
		Fair Hill Formation	Lithic and feldspathic labile sandstone, quartzose sublabile sandstone, siltstone, mudstone, calcareous and tuffaceous sandstone, volcanic conglomerate, carbonaceous mudstone, coal
Permian	Back Creek Group	Macmillan Formation	Interbedded mudstone and sandstone, prominent dark grey basal unit.

Extensive exploration drilling at Curragh and neighbouring mines was analysed by PB to develop a detailed understanding of the geology in the vicinity of the mine for the 2016 expansion project. This included the development of detailed conceptual cross sections which have been reproduced in Figures 7 to 10 (PB, 2016). The cross-sections show the geology of the study area and the progression of mining as of August 2015 and were developed using LiDAR, drill hole data and the mine geological model as well as exploration data for neighbouring mines obtained from Queensland Globe.

The locations of the cross-sections (which are shown on **Figure 5-2**), comprise a north-south long section (A-A' **Figure 5-3**), and three east-west long sections (B-B' **Figure 5-4**, C-C' **Figure 5-5**, and D-D' **Figure 5-6**)

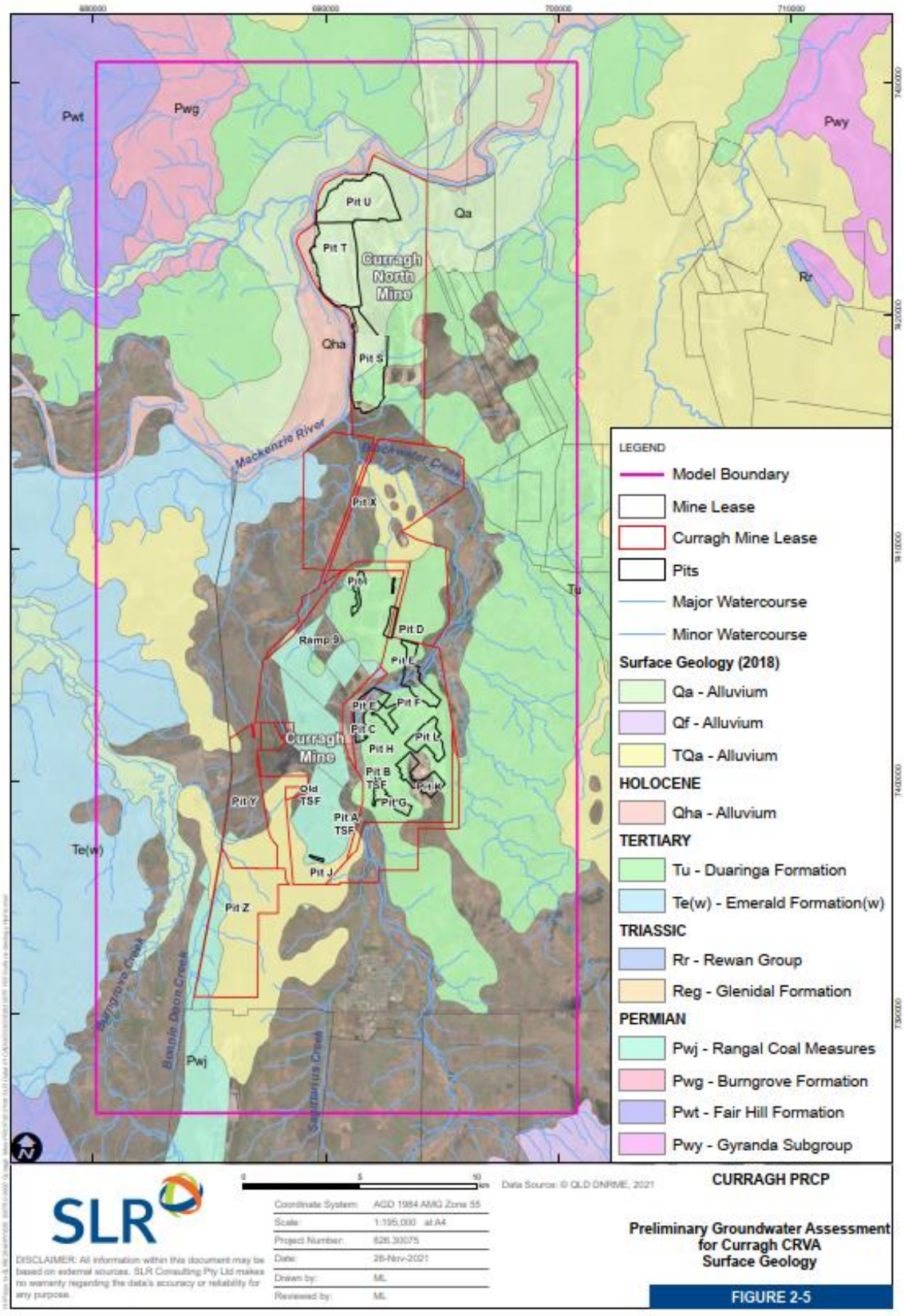


Figure 5-1 Surface Geology

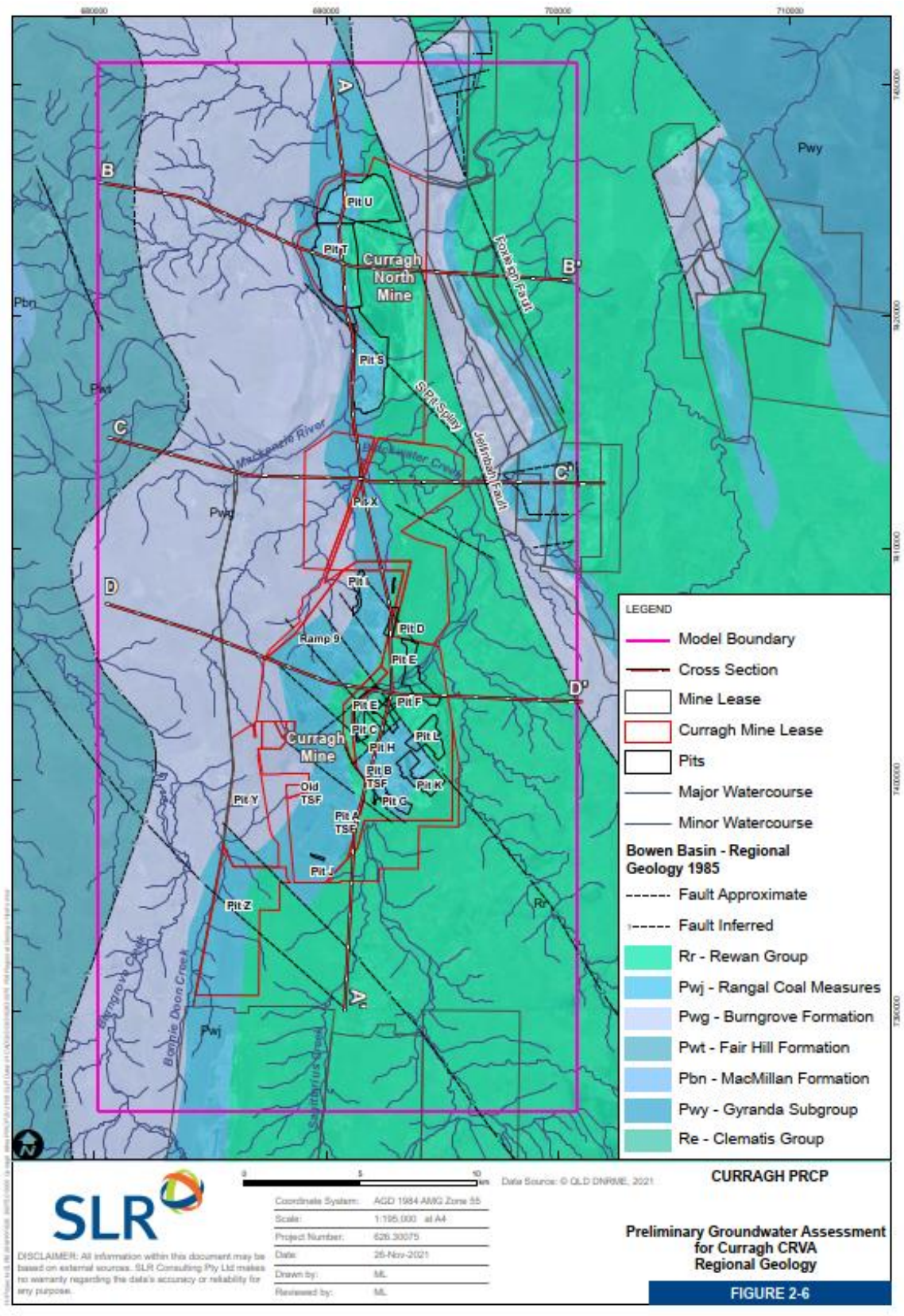


Figure 5-2 Regional Geology

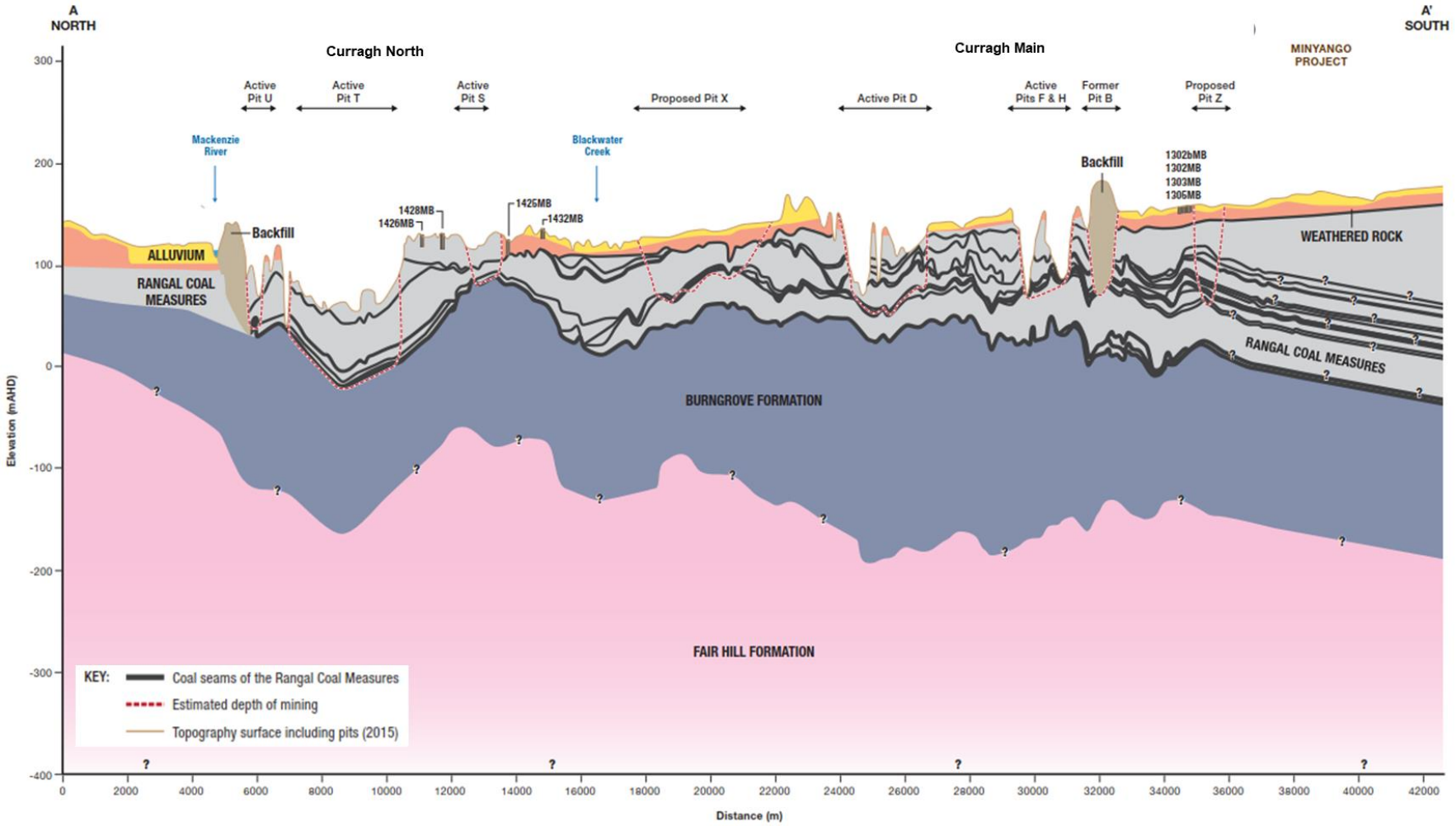


Figure 5-3 Conceptual geological cross-section A-A' (PB, 2016)

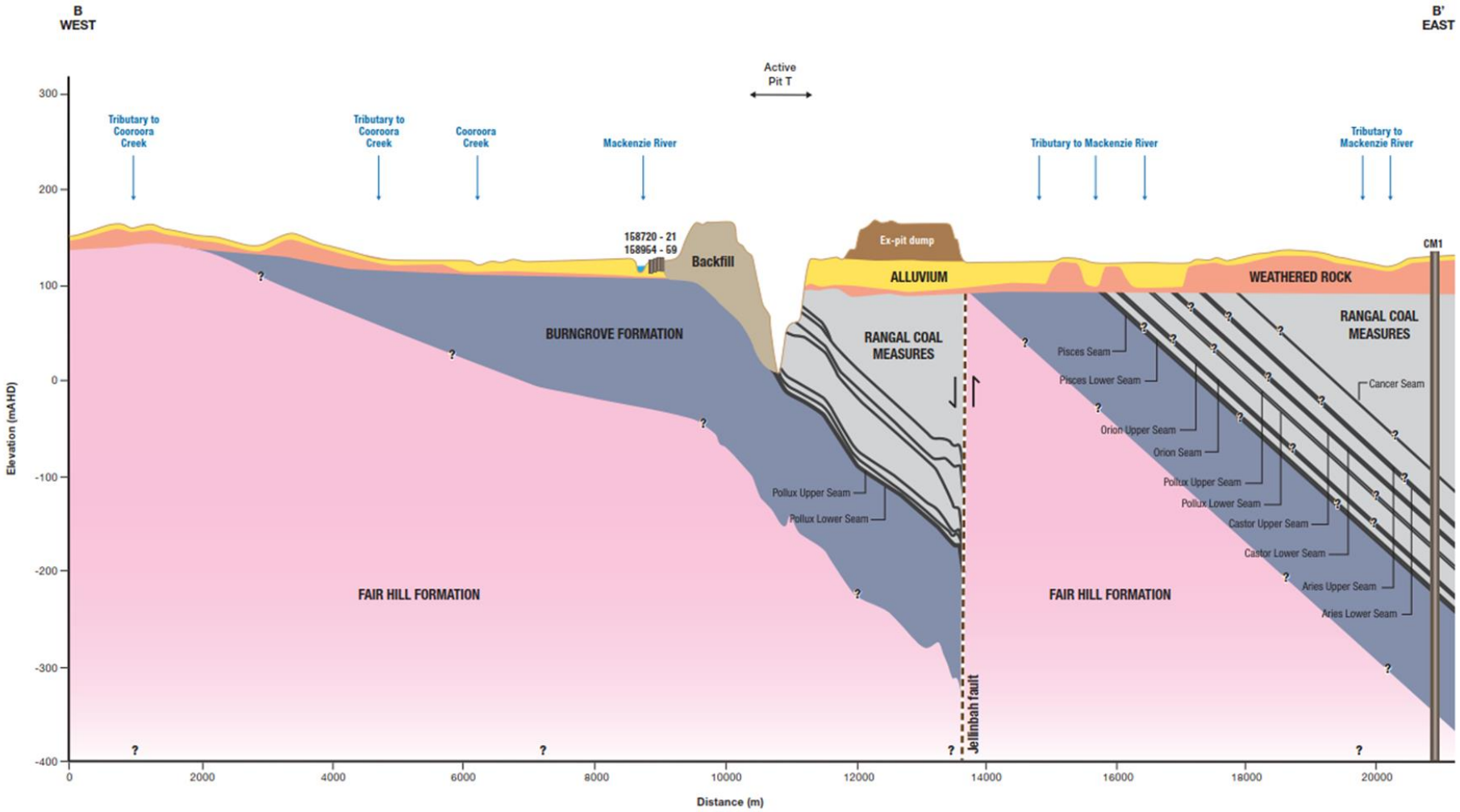


Figure 5-4 Conceptual geological cross-section B-B' (PB, 2016)

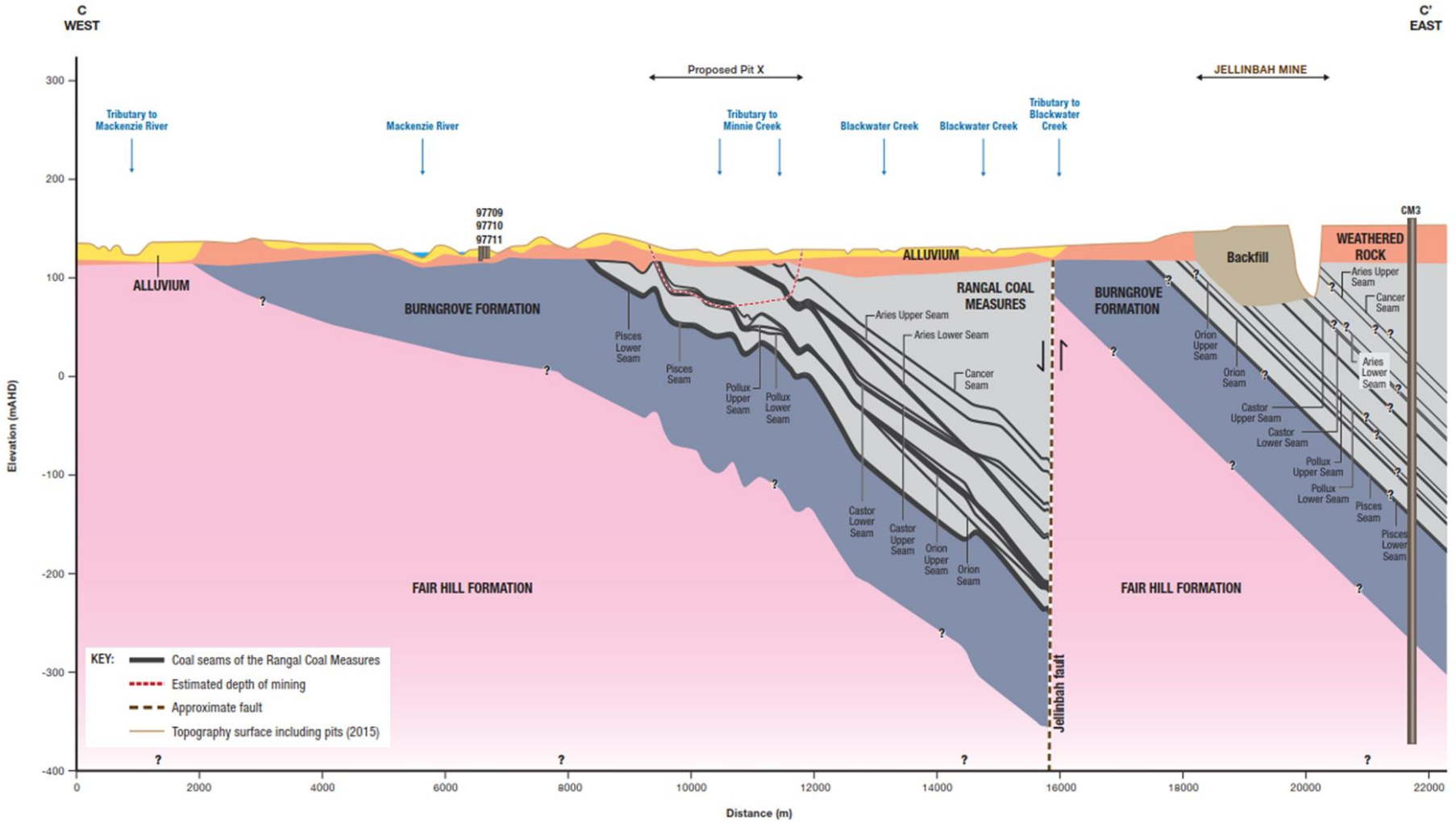


Figure 5-5 Conceptual geological cross-section C-C' (PB, 2016)

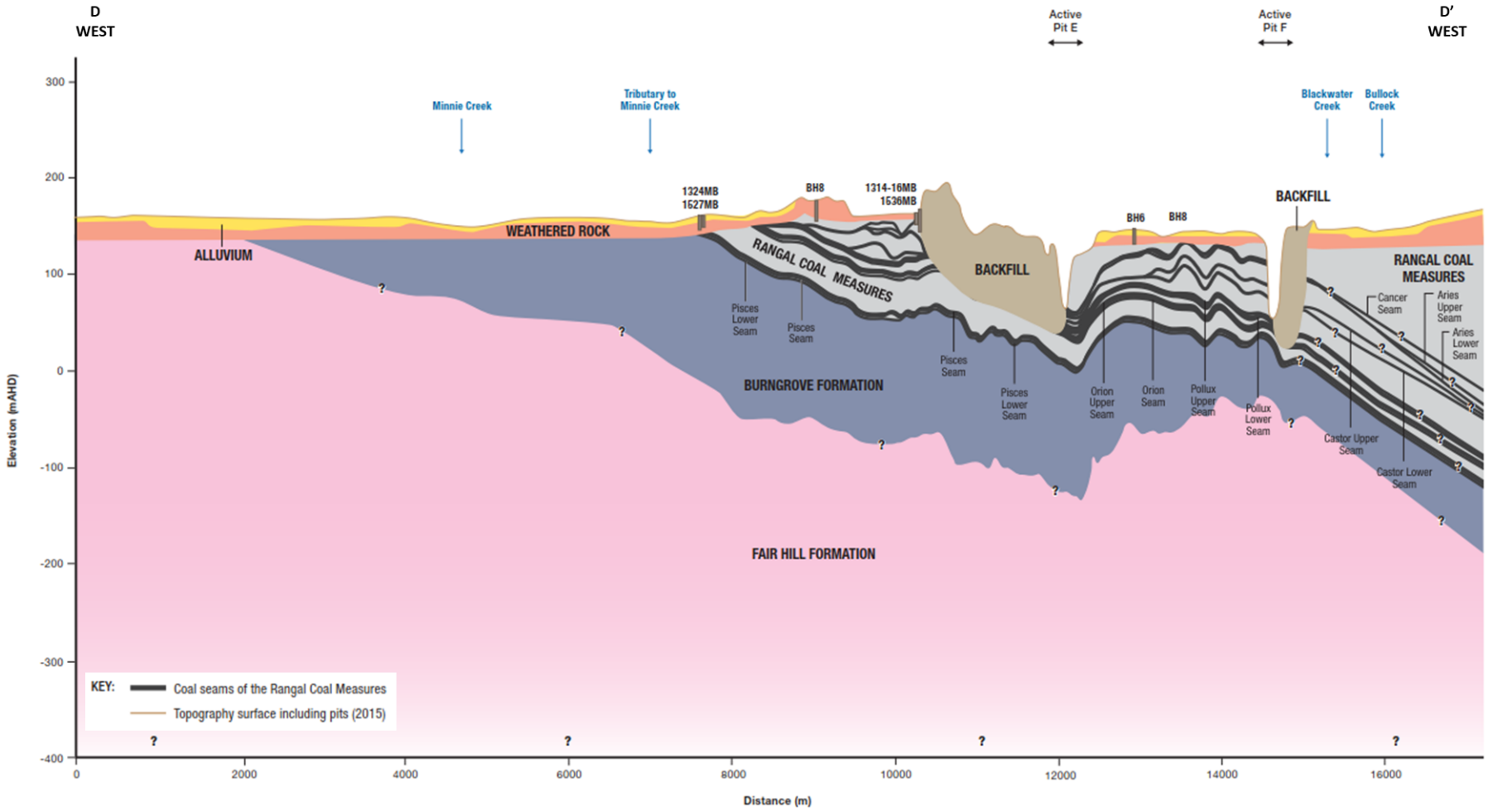


Figure 5-6 Conceptual geological cross-section D-D' (PB, 2016)

The main hydrostratigraphic units in the vicinity of the mine are described below, from the shallowest to the deepest/oldest:

- **Alluvium** – up to 30m thick in the north associated with the floodplain / channel deposits of the Mackenzie River. Thinner (up to 12 m), near extension Pit X and comprises clay, sand and gravel units. At Curragh Main and southern extension Pits up to 10 m thick but generally much thinner and predominantly clay and silt. The alluvium is dry in many areas. Unconfined water bearing sand and gravel may occur at the base of the alluvial sequence around Curragh North near proposed Pit X but it is considered unlikely to be significantly water bearing where it occurs in the south of the mine.
- **Regolith** - unconsolidated surface layer of weathered rock which may provide a preferential flow pathway for groundwater. Occurs across the Project area at thicknesses between 5 and 15 m. Includes weathered residual rocks of the Duaringa and Emerald formations, Rewan Formation, Rangal Coal Measures and Burngrove Formation in areas of outcrop and sub-cropping alluvium. Variable permeability.
- **Cenozoic** (Tertiary Duaringa and Emerald formations) - Occurs around Curragh Main extension Pits X and D. Comprises cemented sands and gravels and sandstones, siltstones and mudstones. Water bearing zones may occur in more permeable layers, unconfined to semi-confined.
- **Rewan Group** - is a regional aquitard comprising mudstones interbedded with siltstone and fine to medium grained labile sandstone.
- **Rangal Coal Measures** - Occurs along the strike of the mine and is overlain to the east by the Rewan. Groundwater flow is primarily within the coal seams (via interconnected cleats and fractures), which are confined by low permeability overburden and interburden. The coal measures are highly faulted resulting in "compartmentalisation" with coal seams juxtaposed against lower permeability interburden limiting the lateral continuity of flow. Faults themselves may form barriers to flow or provide conduits.
- **Burngrove Formation** – outcrops/subcrops to the west of the mine dipping east below the Rangal Coal Measures. Groundwater flow occurs primarily via the coal seams and fractured sandstone units with low permeability siltstone and claystone forming aquitards. As with the RCM sequence is considered to be highly faulted with coal seams juxtaposed against lower permeability interburden limiting the lateral continuity of groundwater flow. This Formation is considered the basement for the purposes of this assessment.

There are four registered bores within 3 km of Curragh Project. One of these bores is owned by the Central Highlands Regional Council, located at the campground near Bedford Weir, and they have indicated that the groundwater is relatively saline.

5.2 Numerical Hydrogeological Model

SLR has updated the original numerical groundwater model for Curragh Project which was developed in 2016 by Parsons Brinckerhoff for Wesfarmers Resources Pty Ltd. The original model was constructed and calibrated for the Curragh Extension Project assessment and was independently reviewed and audited by HydroSimulations in 2016. For this this study the 2016 model temporal datasets have been extended and a post-mining recovery simulation has been added with detailed final void modelling, to estimate effect of mine closure on the local groundwater regime.

The primary objective of this work is to identify groundwater related issues potentially resulting from the closure of the Curragh Project and secondarily, to lay the foundations for a more detailed assessment of potential groundwater issues at the complex as part of the closure planning process. The key objectives of this modelling exercise have been to:

- Update the model datasets and verify the model calibration;
- Update the mine progression in line with the current mine plan;
- Simulate the post mining groundwater level recovery using the final landform (mine void backfill levels) developed by Coronado to understand whether the final voids act as groundwater sinks or sources; and;
- Understand the long-term effect of the proposed post mining landform on local groundwater levels by comparing the long term post closure case to a null case (no mining activity).

The updates to the model included:

- Extending the rainfall in the model to include the latest climate measurements;
- Extending the calibration data set to include the latest groundwater level measurements and recalibrate the model;
- Recalibrating the model to include depth-dependent hydraulic conductivity in the Rangal Coal Measures;
- Updating the mine progression plan in the model, to include all foreseeable future mining at Curragh Project;
- Updating the temporal discretisation to include the recovery model; and
- Setting up the recovery model to include proposed residual voids at the end of foreseeable mining at Curragh Project.

Further information on the numerical model is provided in **Appendix B**.

5.3 Results

Post mining impacts were investigated with a recovery model, commencing at the end of active mining. A preliminary transient recovery model consisting of 16 time slices (each time slice set to 300-years) was developed to assess the relationship between the final voids' lake elevations and groundwater inflow. The net groundwater flux has been calculated as a cumulative void flux for each area at Curragh Project (Curragh North, X Pit, Curragh Main, Y Pit and Z Pit) (**Figure 5-7**) to account for interaction between the adjacent voids within each area. The simulated average groundwater flux at the end of the model run time (2133) for each residual void area, including throughflow from spoil and groundwater take from the Rangal Coal Measures, are presented in **Table 5-2**.

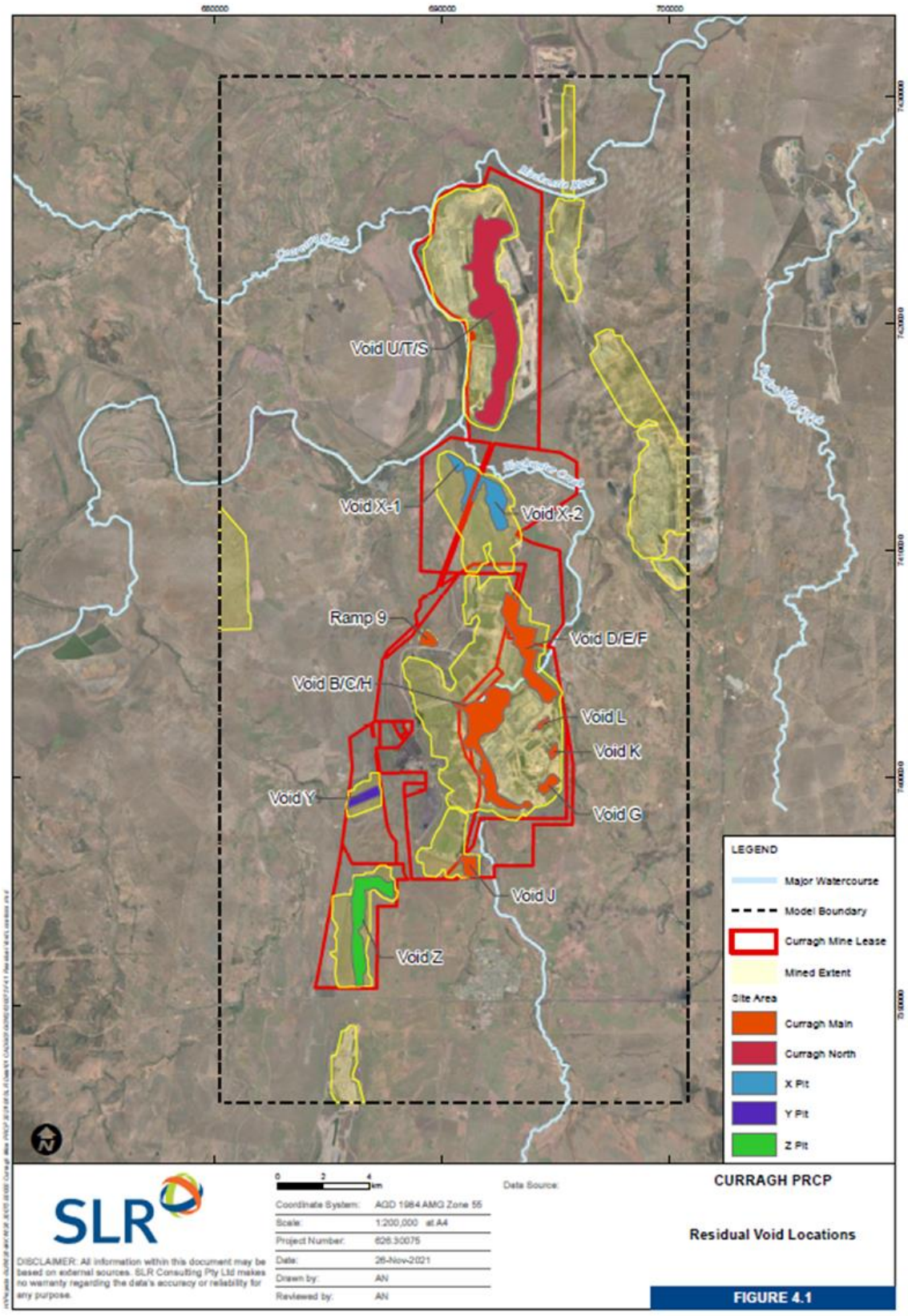


Figure 5-7 Hydrogeologic Residual Void Groups

Table 5-2 Post-Mining Equilibrium Residual Void Summary

Curragh Area:		Curragh N	X Pit		Curragh Main							Y Pit	Z Pit
Residual Void*:		U/T/S	Void 1	Void 2	D/E/F	B/C/H	L	K	G	J	Ramp 9	Y	Z
Final landform minimum elevation used in the numerical model (mAHD)		-48	78	34	26	41	92	65	64	93	77	116	78
Post-mining equilibrium void lake level (mAHD), the final lake levels were derived from the surface water model.		26	101	69	63	83	113	105	79	132	91	131	115
Void lake salinity (uS/cm), as predicted by the water balance model.**	~10 years	27,578	28,650	16,174	36,828	23,045	20,530	23,445	33,100	19,951	29,754	28,954	37,296
	~30 years	37,313	37,274	32,568	37,313	37,181	36,416	37,308	37,288	31,496	37,313	37,313	37,313
	~200 years	37,313	37,313	37,313	37,313	37,313	37,313	37,313	37,313	37,313	37,313	37,313	37,313
Net groundwater flux to void at equilibrium (total flux including inflow draining from the spoil and groundwater inflow from the RCM, ML/day)		4.82	0.49		1.75							0.11	1.00

* The residual voids have been grouped where a void may act as a source of water to an adjacent void, but where collectively they act as a groundwater sink.
** 37,313 µS/cm is the maximum salinity limit set in the surface water balance model (SLR 2021)

An equilibrium groundwater flux of 4.82 ML/day was predicted at Curragh North, where the minimum elevation of the final landform is 74 m lower than the other voids. The relative depth of the residual void at Curragh North is likely accountable for the higher predicted groundwater flux to the void in this area. Equilibrium total groundwater flux to the voids in Curragh North Pit, X Pit, Curragh Main, Y Pit and Z Pit are predicted to be 4.82, 0.49, 1.75, 0.11 and 1.00 ML/day respectively, indicating all simulated voids are predicted to be groundwater sinks with positive net groundwater flow into the voids. The simulated fluxes to the voids in the groundwater model are consistent with groundwater fluxes in the surface water model developed for simulating final landforms for Curragh Mine (SLR, 2021).

The predicted post-mining water table at equilibrium (end of recovery) is shown in **Figure 5-8**. Hydraulic gradients at equilibrium indicate an overall flow direction toward residual voids at Curragh Main and Curragh North. All residual voids show hydraulic heads decreasing with proximity to the void, indicating all voids are predicted to act as local groundwater sinks.

Predicted drawdown figures (**Figure 5-9** and **Figure 5-10**) show where residual drawdown impacts are predicted to exceed 1 m. **Figure 5-9** presents the residual drawdown just within the alluvium at post-mining equilibrium. Predicted recovered heads in the alluvium west of Curragh North show residual drawdowns of 1 to 2 m extending up to 3 km from mined pits at Curragh North although drawdowns at the very edge of the voids are higher (5-10 m). **Figure 5-10** presents the residual drawdown of the water table at post-mining equilibrium.

To investigate the potential movement of groundwater to or from the voids and spoil at post-mining equilibrium, the post-mining water table predicted for the end of recovery was used to infer potential flow pathways in and around the spoil at each area of mining. Particle tracking was used together with the post-mining water table to predict groundwater movement relative to the voids and areas of spoil. Particles are “dropped” on the post mining equilibrium water table and allowed to track down hydraulic gradient from their starting position. **Figure 5-11** shows the inferred flow pathways around the residual voids interpreted from the particle tracking simulation at post-mining equilibrium. The flow paths from the outer edges of the voids or spoil dumps informed by the recovered head levels indicate groundwater flow is toward each of the residual voids hence none of the voids are likely to act as sources to the groundwater system.

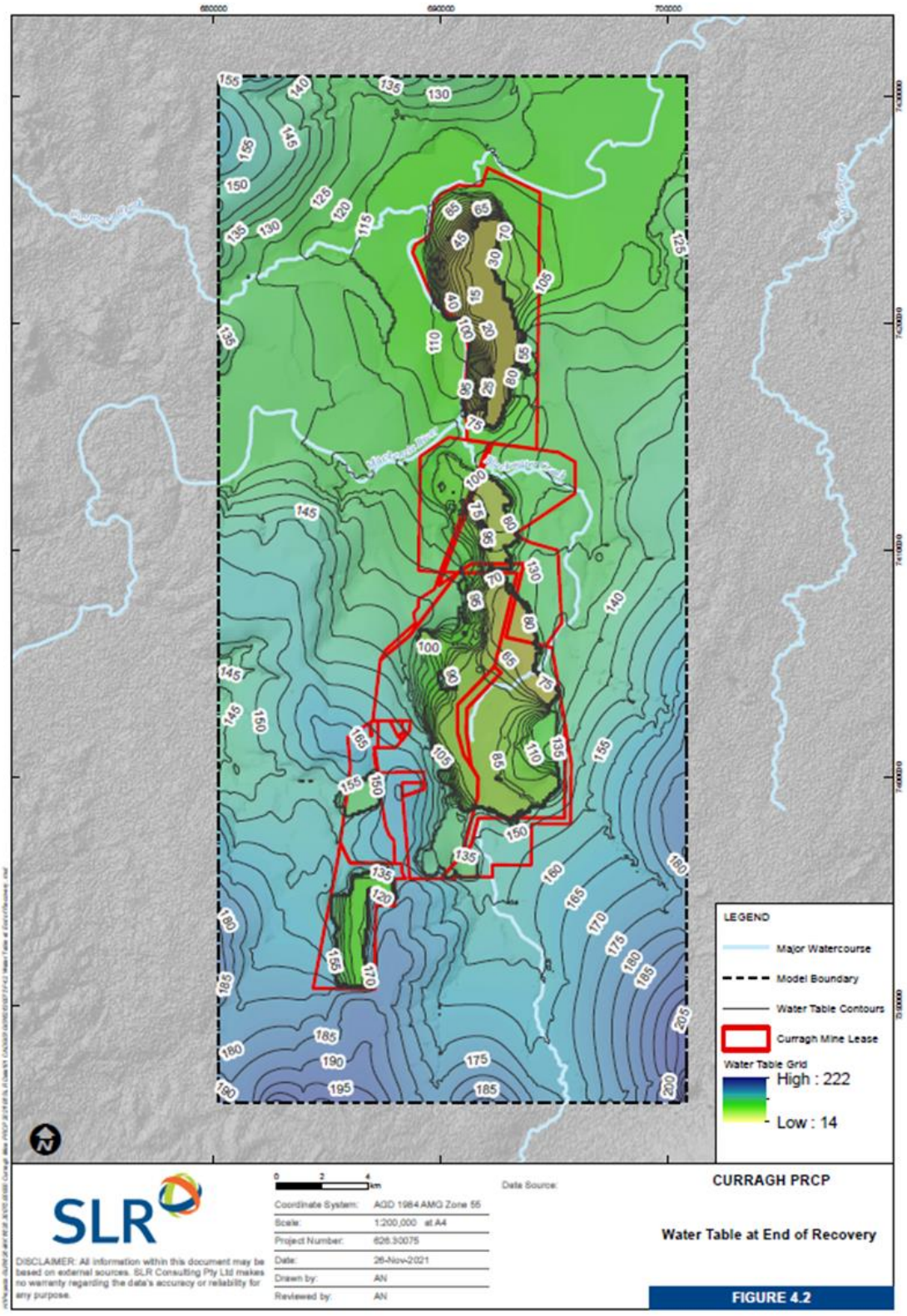


Figure 5-8 Predicted Water Table at End of Recovery

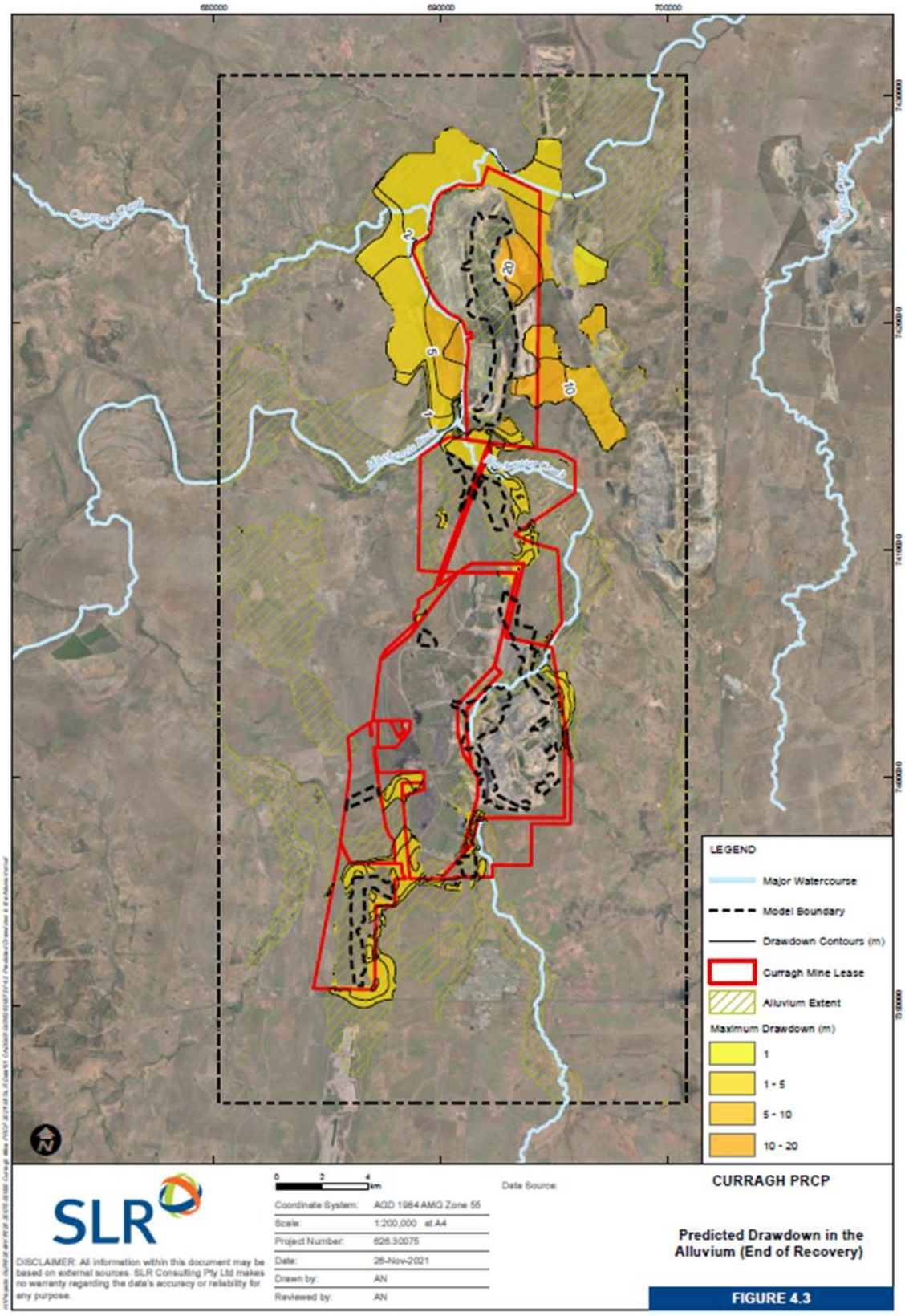


Figure 5-9 Predicted Residual Drawdown in Alluvium at End of Recovery

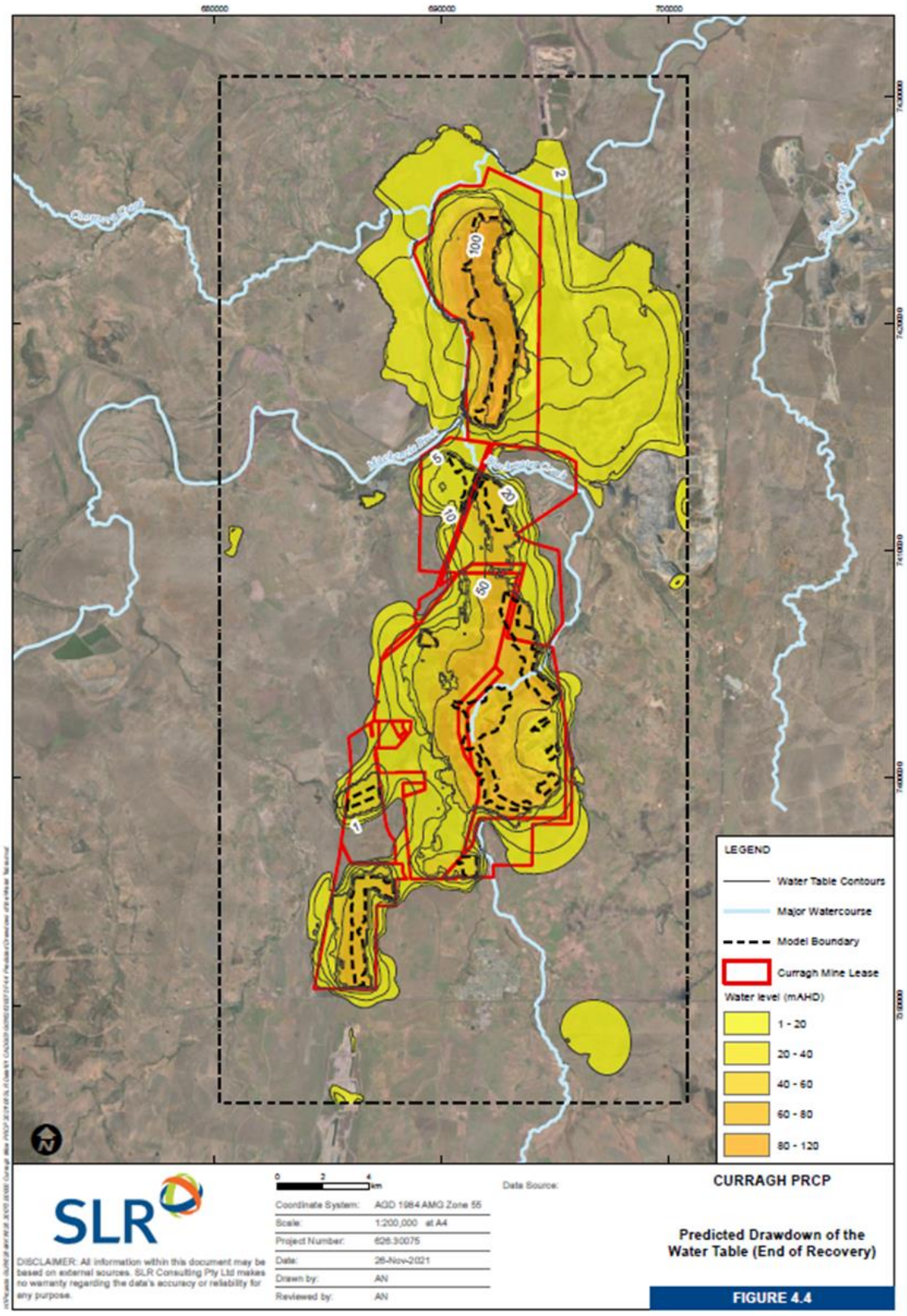


Figure 5-10 Predicted Residual Water Table Drawdown at End of Recovery

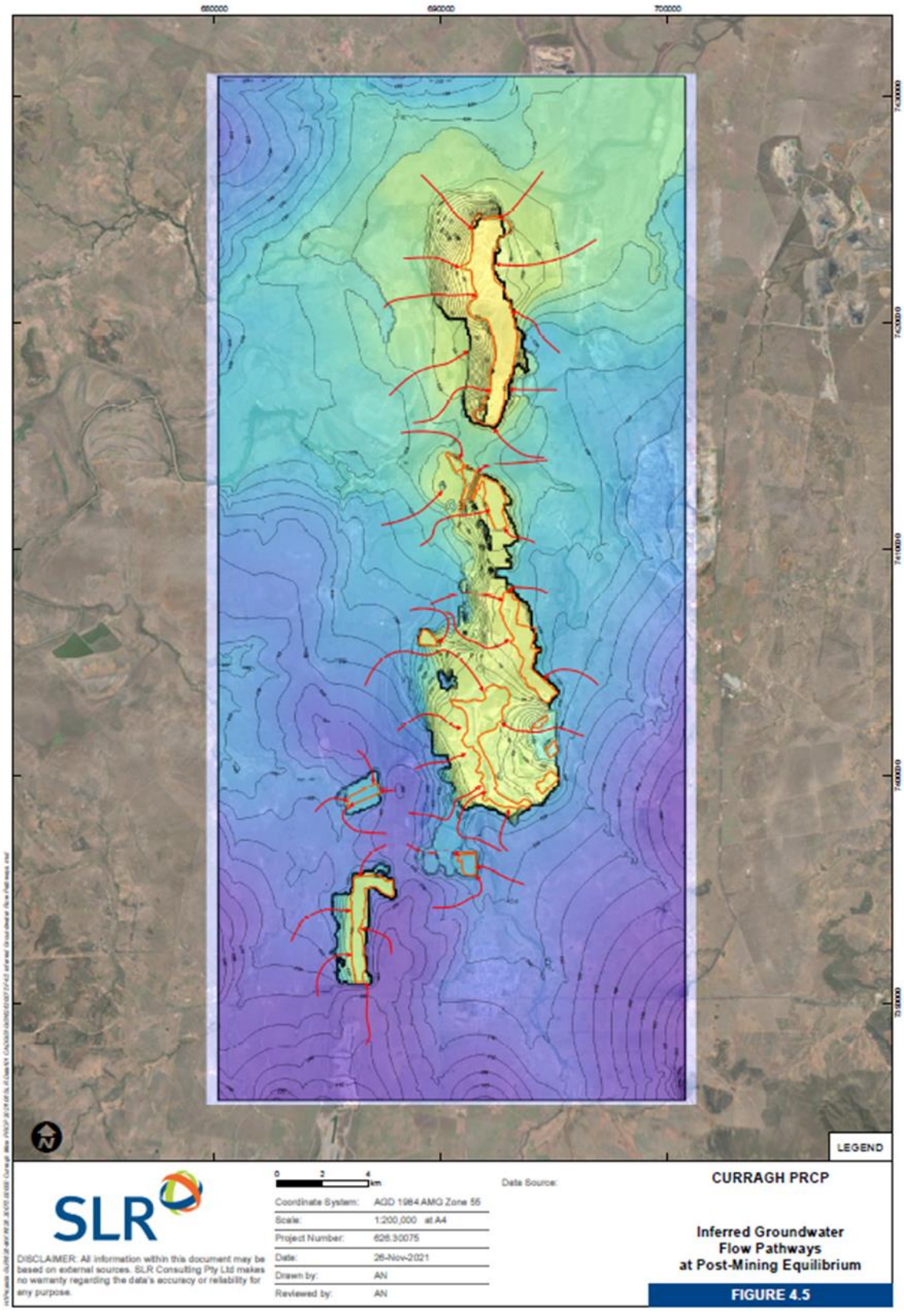


Figure 5-11 Inferred Groundwater Flow Pathways at Post-mining Equilibrium

5.4 Conclusions and Recommendations

The following key conclusions are drawn from the preliminary numerical modelling assessment of the post-mining groundwater environment at the Curragh Project:

- The numerical modelling indicates that lakes will form within the residual voids of the proposed final landform. These lakes will act as local groundwater 'sinks' with groundwater within mining disturbed areas (including the Pit A and B TSFs) migrating towards these sinks;

- Post-mining residual drawdown in the Mackenzie River Alluvium to the west of Curragh North will generally be in the order of 1-2m (but up to 10m near the mine voids), noting that the Mackenzie River is regarded as a "losing" watercourse with pre-mining groundwater levels in the alluvium 4-5 m below the river stage in the vicinity of the mine;

- Based on the geological data reviewed for this preliminary assessment (limited for the extension areas), it appears that equilibrium void lake levels are generally well below the level of alluvium and base of weathering (potential preferential pathways for outward seepage of water from the void lakes); and

- Post-mining, the total estimated "groundwater" inflow to all voids is approximately 8.2 ML/d although the majority of this is water derived from infiltration to the spoil and drainage into the void lake rather than inflow from the Rangal Coal Measures or Alluvium.

A more detailed assessment of the post-closure groundwater related issues with refined modelling is recommended for the PRCP submission. Section 5.3 of the Groundwater Report (**Appendix B**) details the key modelling update recommendations for the detailed groundwater assessment.

6 Residual Void Water Balance

SLR has developed a residual void water balance model (WBM) for the Curragh Project to determine the final void water level and quality of the residual voids. The details of the WBM are provided in **Appendix C**. The WBM has considered both surface water and groundwater inflows derived from the recovery groundwater model mentioned above.

6.1 Water Balance Modelling

As stated above there are 12 residual voids expected at the end of mine life, these voids have been listed below with multiple pits grouped where hydrologically linked for the purpose of the WBM:

- Curragh North: Void U/T/S;
- Curragh Main: Void D/E/F, Void B/C/H, Void L, Void K, Void G, Void J, Ramp 9; and
- Expansion Areas: Void X (1 and 2), Void Y, Void Z.

The WBM has been developed using GoldSim software package to assess the long-term void water level and water quality at Curragh Project. The model simulates daily changes in the volumes of stored water in response to inflows (rainfall, groundwater) and outflows (evaporation and controlled releases/overflows). The WBM was run for daily time step over 200-year simulation period, represented by 500 climate sequences, allowing the model to assess long term water levels, quality and risk of overflow for each void.

The input data includes catchment areas for each residual void (or group of voids), stage storage relationships, climate data including probabilistic rainfall and evaporation, runoff, groundwater inflow and water quality. The details of each input is outlined in **Appendix C**.

6.2 Results

6.2.1 Residual Void Water Levels

The WBM was predicted to stabilise after approximately 100 years to the approximate levels for the median condition shown in **Table 6-1**. It is noted that some individual voids within the WBM reached equilibrium level from approximately 20 years. Graphical representations of the results for each residual void are provided in **Appendix C.**

Table 6-1 Residual Void Water Level Summary

Void	Residual Void Level (50%ile) (mAHD)	Depth (m)	Spillway (mAHD)	Surface Area (ha)
Void U/T/S	26	74	120	286.5
Void D/E/F	63	36	135	63.5
Void B/C/H	83	42	154	109.3
Void L	116	24	135	17.2
Void K	107	42	135	8.5
Void G	79	14	135	9.2

Void	Residual Void Level (50%ile) (mAHD)	Depth (m)	Spillway (mAHD)	Surface Area (ha)
Void J	132	39	152	20.2
Ramp 9	91	14	147	17.1
Void X – 1	101	23	120	23.2
Void X – 2	69	35	120	49.4
Void Y	131	15	160	19.6
Void Z	115	37	164	72.3

The relative size of external catchment to the void footprint results in water levels that stabilise well below the indicative spill level with evaporative losses balancing inflows into the voids. A similar trend in water level is seen across all the residual voids. Water depths range from 14 m to 74 m within the voids for median conditions (50th percentile). During dry climatic conditions (5th percentile) water levels are approximately 2 m to 13 m lower. During very wet (99th percentile) climatic conditions the water level increases by 3 m to 20 m depending on the void and generally causes greater fluctuation in the equilibrium water level. Final water levels range from 9 m to 88 m below the indicative spill levels and are not expected to overtop.

6.2.2 Residual Void Water Quality

Water within the residual voids becomes highly saline throughout the simulation. This was not unexpected due to the high salinity of groundwater in the region and the assumption that no salt is lost from the system via evaporation. Within the WBM, salinity is capped at a maximum EC of 37,313 µS/cm which is equivalent to the point where the concentration of salt becomes high enough that the solution is saturated and any additional salt will precipitate out of solution. Salinity in all voids increases over time until reaching saturation after approximately 20 to 30 years.

The average salinity of the voids throughout the simulation period are provided in **Table 6-2**. Graphical representations of the results for each residual void are provided in **Appendix C.**

Table 6-2 Average Stage Salinity (EC µS/cm)

Void	Year 10	Year 30	Year 200
Void U/T/S	27,578	37,313	37,313
Void D/E/F	36,828	37,313	37,313
Void B/C/H	23,045	37,181	37,313
Void L	20,880	32,696	37,313
Void K	22,333	37,292	37,313
Void G	33,100	37,288	37,313
Void J	19,951	31,496	37,313
Ramp 9	29,754	37,313	37,313
Void X – 1	28,650	37,274	37,313
Void X – 2	16,174	32,568	37,313

Void	Year 10	Year 30	Year 200
Void Y	28,954	37,313	37,313
Void Z	37,296	37,313	37,313

6.3 Conclusions

At Curragh Project the residual void water levels are expected to range from 26 mAHD to 132 mAHD with water depths of 14 m to 74 m. The results indicate that the mine is not a net accumulator of water after approximately 100 years when the equilibrium water levels are reached. The final water levels remain below the spill level and the voids are unlikely to overtop in the 99th percentile climate scenario.

A significantly high concentration of salt is expected to accumulate within the residual voids. The elevated salinity of the groundwater inflows input a high level of salt into the voids which is not lost from the system via evaporation. The salinity of the voids is expected to exceed that of the groundwater and form highly concentrated solution. Although poor quality, water within the voids is not expected to interact with surrounding surface water given the final water levels.

7 Residual Void Geotechnical and Erosion Stability

7.1 Preliminary Landform Design

Geotechnical and geological information to support the possibility of adverse fault orientations and interactions relative to pitwall geometries and locations, and/or fault related rock mass shearing failures occurring is limited for most voids as the mining either hasn't commenced yet or not proceeded to the final void location. In order to provide a conservative approach on the residual void surface area and long-term void water level, the preliminary final landform has proposed a design which is appropriate for fault related rock mass shearing and/or adversely oriented structures – a standard overall slope of <22 degrees with a maximum slope of <45 degrees for the highwall side.

Landform cross sections (**Figure 7-1** and **Figure 7-2**) showing the different scenarios are shown in section 4 of **Appendix D**. The landform design options included in the geotechnical analysis are listed in **Table 7-1**. Some of the alternative options include a highwall angle of < 65 degrees.

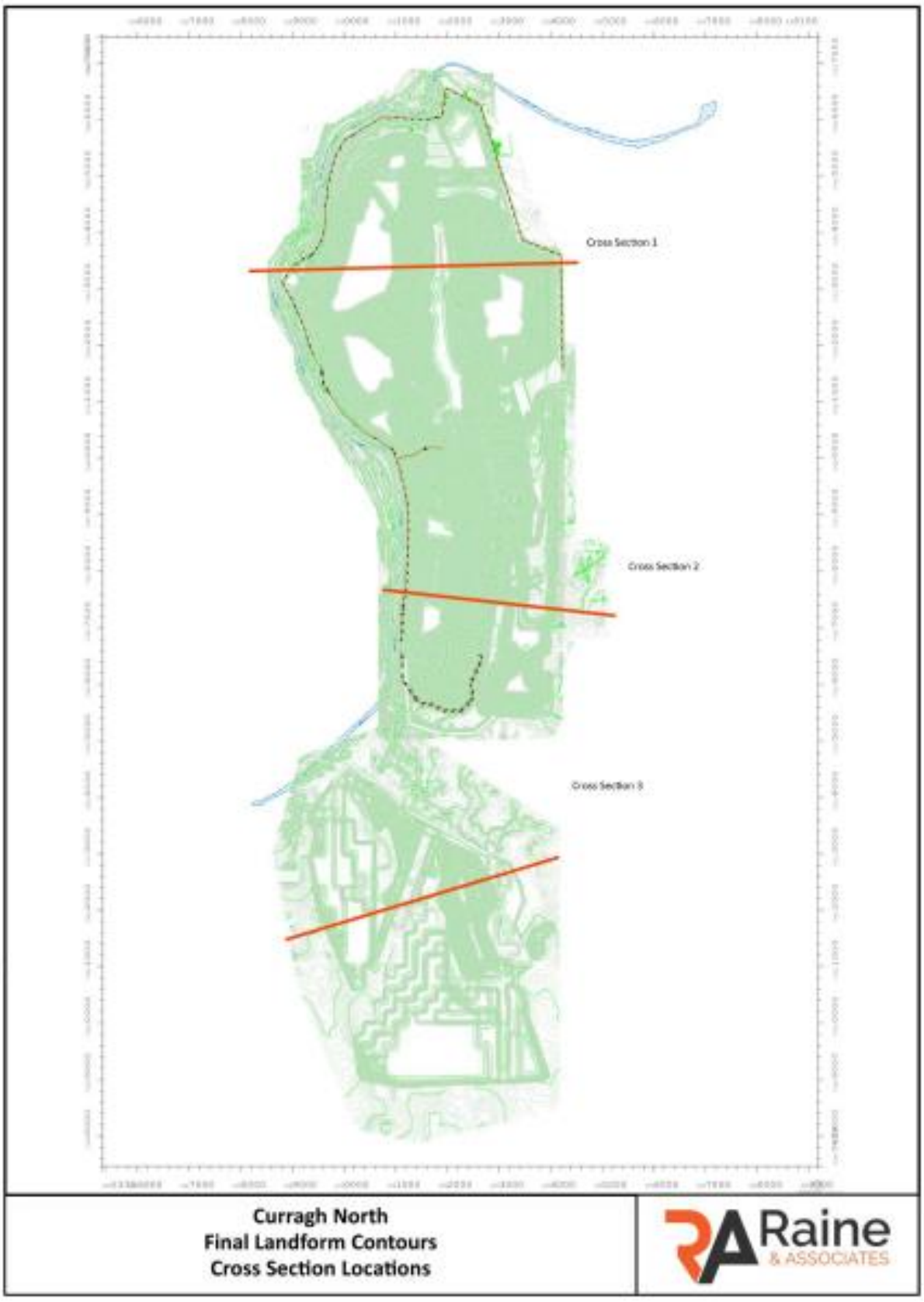


Figure 7-1 Curragh North Landform Cross Sections (Raine Associates, 2021)

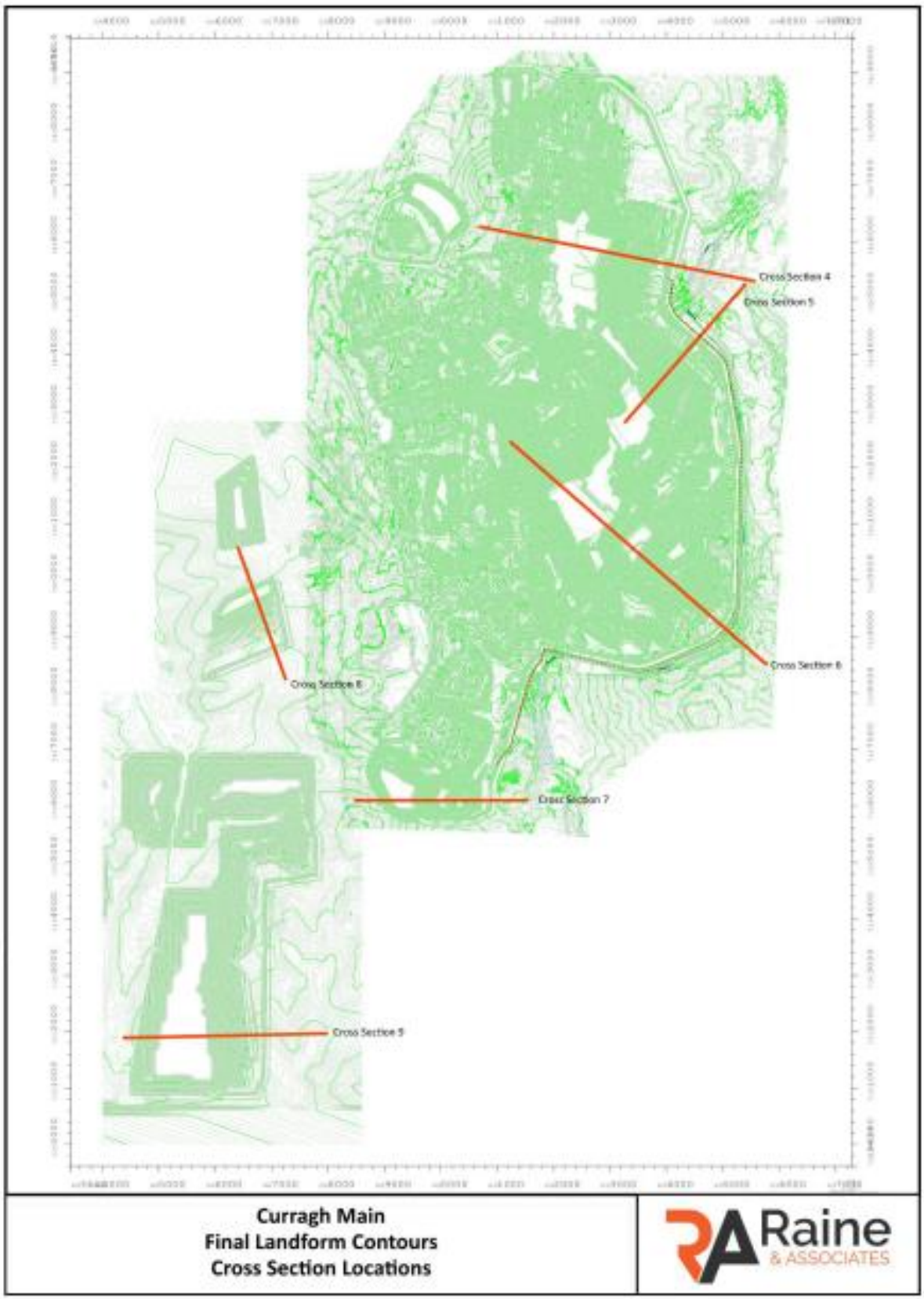


Figure 7-2 Curragh Main Landform Cross Sections (Raine Associates, 2021)

Table 7-1 Cross section landform option descriptions

Cross Section	Number	Scenario
U Pit	1	Planned Final Landform Option – Highwall Side
S Pit South	2	Planned Final Landform Option – Highwall Side
		Planned Final Landform Option – Lowwall Side
X Pit	3	Planned Final Landform Option – Highwall Side
D Pit	4	Planned Final Landform Option – Highwall Side
		Alternative Final Landform Option – Highwall Side
		Alternative Final Highwall Reshaped Final Slope Option – Highwall Side
F Pit	5	Planned Final Landform Option – Highwall Side
		Alternative Final Highwall Reshaped Final Slope Option – Highwall Side
		Planned Final Landform Out Board Slope
		Planned Final Landform Option – Lowwall Side
K Pit	6	Planned Final Landform Option – Highwall Side
		Alternative Final Landform Option – Highwall Side
		Alternative Final Highwall Reshaped Final Slope Option – Highwall Side
J Pit	7	Planned Final Landform Option – Highwall Side
		Planned Final Highwall Reshaped Final Slope - Highwall Side
Y Pit	8	Planned Final Landform Option – Highwall Side
		Planned Final Highwall Reshaped Final Slope - Highwall Side
Z Pit	9	Planned Final Landform Option – Highwall Side
		Planned Final Highwall Reshaped Final Slope - Highwall Side

The cross section of Pit D has been shown below (**Figure 7-3**) to demonstrate the different scenarios.

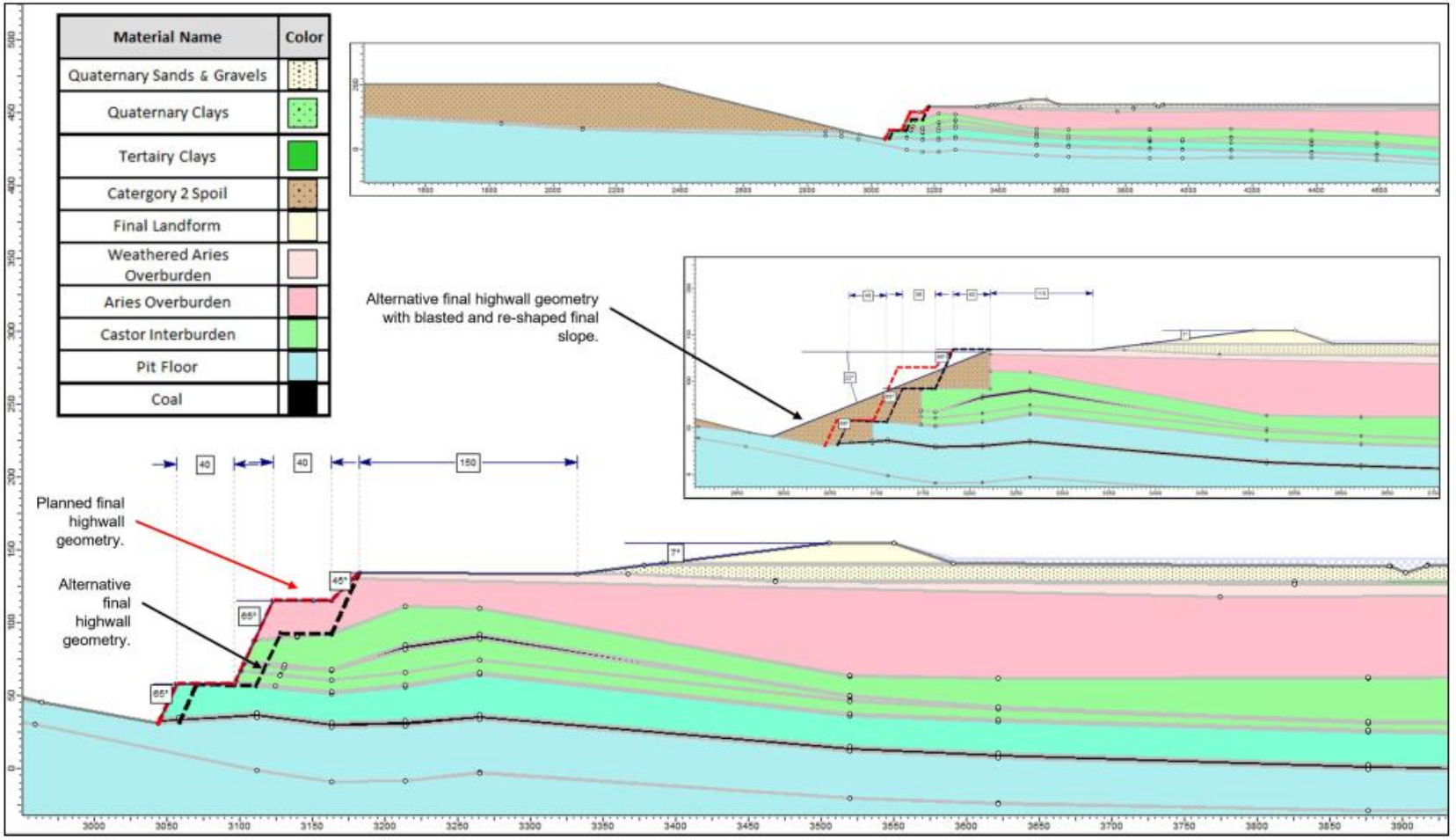


Figure 7-3 D Pit Cross Section (Raine Associates, 2021)

7.1.1 Long-term Stable Flood Barrier Embankment

As Curragh Project is located on a floodplain, an indicative cross section of the long-term stable embankment has been designed to prevent flood water ingress into the residual voids. The embankment design has been based on the B Pit embankment section developed from the B Pit Tailings Storage Facility Design Plan (Golders, 2017). A conceptual embankment design is shown in **Figure 7-4** with parameters outlined in **Table 7-2**. Stable embankments based on this concept and constructed to heights to provide freeboard to protect residual voids against the 0.1% AEP flood event are being incorporated into the final landform design for Curragh.

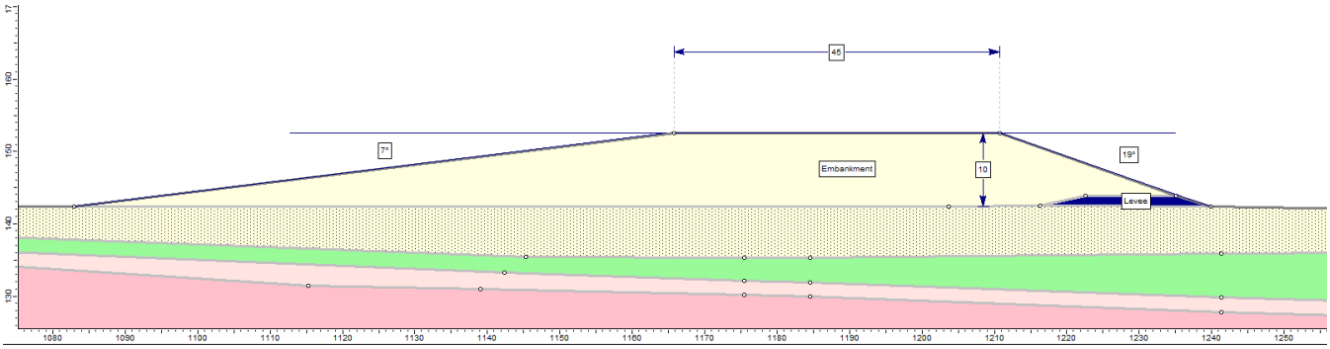


Figure 7-4 Stable Embankment Conceptual Design (Raine Associates, 2021)

Table 7-2 Indicative Stable Embankment Standard Parameters

Parameter	Value
Height	10 m (actual will be 0.1% AEP plus 1 m freeboard)
Top width	45 m (actual to be determined during design)
Water facing slope	<19° (actual to be long term stable to erosion and flood scour)
Residual void facing slope	7° (actual to be long term stable to erosion)

The outcomes of the flood model will be incorporated into the updated landform design for the PRCP to ensure flood water does not enter residual voids.

7.2 Geotechnical Stability

Raine Associates (2021) (Appendix D) have undertaken a slope stability analysis on the Curragh preliminary final landform highwall designs using two-dimensional limit equilibrium methods and Rocscience's proprietary software SLIDE 2.0. Nine cross-sections across the preliminary landform have been analysed with this method.

A minimum factor of safety (FoS) of 1.5 for static conditions and 1.1 for dynamic conditions (i.e. potential impacts of earthquakes) have been adopted as design acceptance criteria for this analysis. A summary of the slope stability analysis is presented in **Table 7-3**.

Table 7-3 Slope Stability Analysis Results

Cross Section	Scenario	Estimated Static FoS	Estimated Dynamic FoS
U Pit	Planned Final Landform Option – Highwall Side	1.8	1.7
S Pit South	Planned Final Landform Option – Highwall Side	1.8	1.7
	Planned Final Landform Option – Lowwall Side	1.7	1.6
X Pit	Planned Final Landform Option – Highwall Side	1.8	1.7
D Pit	Planned Final Landform Option – Highwall Side	2.4	2.3
	Alternative Final Landform Option – Highwall Side	3.2	2.7
	Alternative Final Highwall Reshaped Final Slope Option – Highwall Side	1.6	1.5
F Pit	Planned Final Landform Option – Highwall Side	1.9	1.8
	Alternative Final Highwall Reshaped Final Slope Option – Highwall Side	1.8	1.7
	Planned Final Landform Out Board Slope	1.7	1.6
	Planned Final Landform Option – Lowwall Side	2.9	2.6
K Pit	Planned Final Landform Option – Highwall Side	2.5	2.4
	Alternative Final Landform Option – Highwall Side	3.2	3.1
	Alternative Final Highwall Reshaped Final Slope Option – Highwall Side	1.7	1.6
J Pit	Planned Final Landform Option – Highwall Side	1.7	1.6
	Planned Final Highwall Reshaped Final Slope - Highwall Side	1.6	1.5
Y Pit	Planned Final Landform Option – Highwall Side	2.7	2.5
	Planned Final Highwall Reshaped Final Slope - Highwall Side	2.0	1.9
Z Pit	Planned Final Landform Option – Highwall Side	1.8	1.7
	Planned Final Highwall Reshaped Final Slope - Highwall Side	1.6	1.5

As shown in the above table, all scenarios at all pits were able to meet the minimum FoS for both the static and dynamic conditions.

7.3 Erosion Stability

7.3.1 Tertiary Highwall

Multiple waste characterisation reports and results have been reviewed for the highwall Tertiary spoil. The magnesium/calcium ratio and the exchangeable sodium percentage soil characterisation results indicate the Tertiary alluvium samples have a greater susceptibility to dispersion and erosion than Quaternary or Permian materials. To address this, standard slopes of 7 degrees have been included for sodic Tertiary materials in the preliminary final landform.

Curragh Project was involved in a rehabilitation trial relating to the impact of vegetative cover and slope on runoff, erosion and water quality for both topsoil and spoil cover material (Carroll *et al*., 2000) over mined spoil within overburden areas. The trial involved a number of topsoil and spoil plots at different slopes with different vegetation covers, the experimental design is shown in **Figure 7-5**.

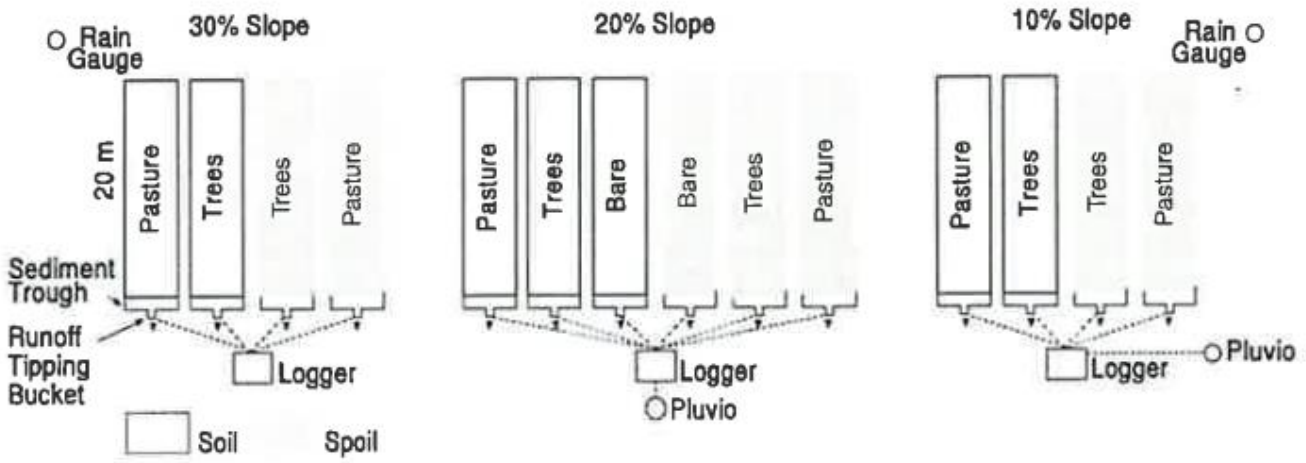


Figure 7-5 Experimental design (Carroll *et al*., 2000)

The exchangeable sodium percentage (ESP) for the Curragh soil had a mean of 7 % and the spoil had a mean of 28 %. The chemical characterisation data for the spoil material indicates the spoil is Tertiary spoil rather than Permian. Generally, material with an ESP of > 6 % is considered slightly sodic and dispersive whereas materials < 6 % are considered non-dispersive.

The results of an erosion study on topsoil on tertiary spoil and bare tertiary spoil at Curragh Project are shown in **Figure 7-6**. It is generally considered that 5 t/ha/yr of sediment loss is reasonable for stable vegetated natural landforms. None of the spoil trials were able to achieve a sediment loss of < 5 t/ha/yr across the different scenarios, due to the natural crusting characteristics and presumably low vegetation covers achieved in the Tertiary spoil plots. This suggests that even with vegetation cover dispersive Tertiary spoil without a material cover would be too erosive as a natural landform surface. The pasture on topsoil plots at Curragh showed that over a six year period sediment loss reduced significantly, with all slopes (30 %, 20 % and 10 %) presenting under 5 t/ha/yr in years 5 and 6 indicating that topsoiling Tertiary spoil was an effective method of rehabilitating Tertiary spoil even at steeper slopes.

The rehabilitation trials suggest that vegetating the Tertiary dispersive spoil alone will not be sufficient in reducing erosion and sediment runoff to an appropriate level. The application of topsoil and pasture seed as a cover for the dispersive spoil appears, from the trials, to reduce the sediment loss to an appropriate rate. Another option which is not included in the rehabilitation trial would be to apply a non-dispersive spoil as a rock mulch on the dispersive spoil and seed the area with native trees and shrubs.

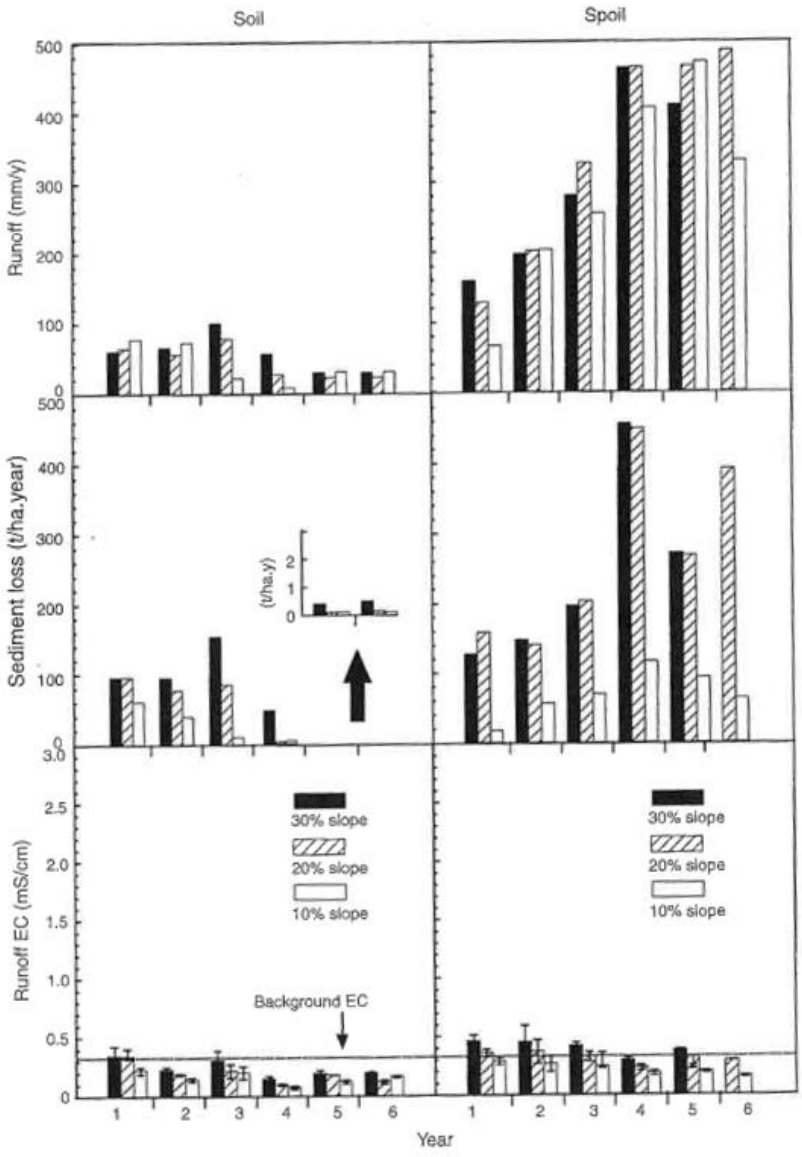


Figure 7-6 Curragh annual runoff, sediment loss, and average runoff EC (with standard error) for soil and spoil pasture plots on 10, 20 and 30% slope over six years

7.3.2 Stable Embankment

As stated above, the preliminary stable embankment design was based on the B Pit tailings embankment design by Golders (2017). The preliminary stable embankment design was formulated with the intent to test the structure height against the flood modelling extent and depth. Flood modelling of the conservative 0.1% AEP event has been completed including flood depths and velocities. These velocities will have to be tested against the material of the stable embankment and the proposed slope angle of 19 degrees.

It is likely that this slope will have to be reviewed due to some of the velocities modelled and that erosion protection for the embankment is further investigated. A potential option for enhancing the erosional stability of the embankment could be rock armouring.

7.4 Rehabilitation Method Options

7.4.1 Highwall Rehabilitation Strategies

The ACARP study undertaken by PW Baker & Assoc. Pty Ltd (2006) identifies 11 rehabilitation strategies for highwalls. SLR have identified Strategy 3, 5 and 6 as being relevant to the preliminary final landform and alternative highwall options at Curragh Project.

Strategy 5 represents the landform design where the geology is stable and a factor of safety >1.5 is achievable with the highwall left mostly as is. Strategy 3 represents the landform design for faulted ground where there is the potential for failures and therefore in order to meet a factor of safety >1.5 the slopes must be battered. Strategy 5 most closely aligns with the preliminary landform design option in un-faulted ground and leaves the Permian highwall generally as is with an average angle of 65 degrees and 7 degrees in the Tertiary. Strategy 5 includes leaving the Permian highwall as is and laying back the Tertiary to 30% (16.7 degrees) slope, cover with 2 m of Permian material, topsoil and seed (**Figure 7-7**). In all landform scenarios assessed for Curragh Project the Tertiary highwall is shaped to a slope of 7 degrees. It's uncertain at this stage what cover and vegetation will be applied to the Tertiary spoil, however the option presented in Strategy 5 could be a consideration pending cost and material availability.

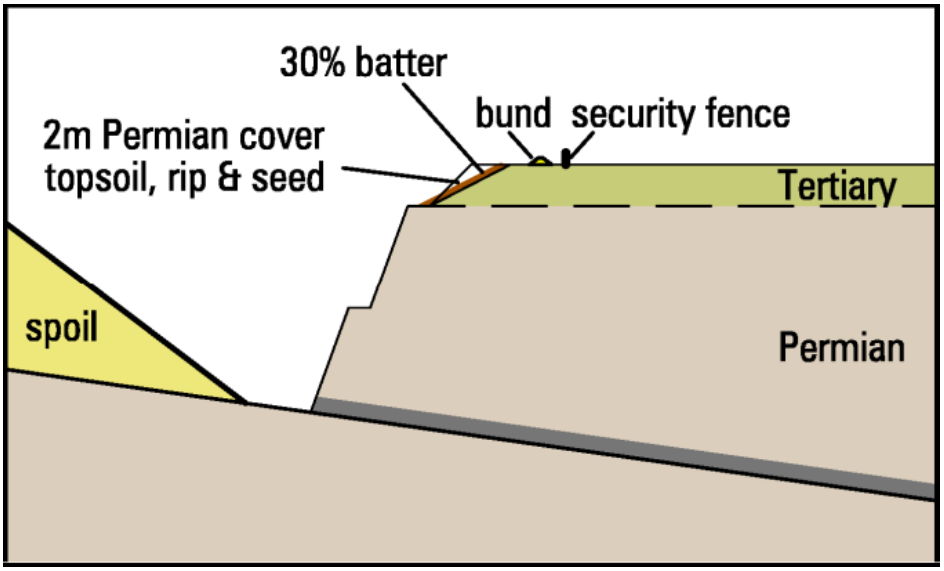


Figure 7-7 Strategy 5 (PW Baker & Assoc. Pty Ltd, 2006)

Strategy 3 has been used as a basis for the residual void landform design at Curragh Project in faulted ground with an overall angle of 22 degrees in the Permian and 7 degrees in the Tertiary (in some pits this is the planned landform and in others it's an alternative landform). Strategy 3 involves throw blasting the Permian and Tertiary highwall to the toe of the residual void, then aerial seeding and fertiliser (**Figure 7-8**). A bund and fencing are included in all three strategies identified. This methodology reduces the risk of highwall failure and there is the potential for vegetation growth on the blasted highwall but the surface area of the highwall is increased.

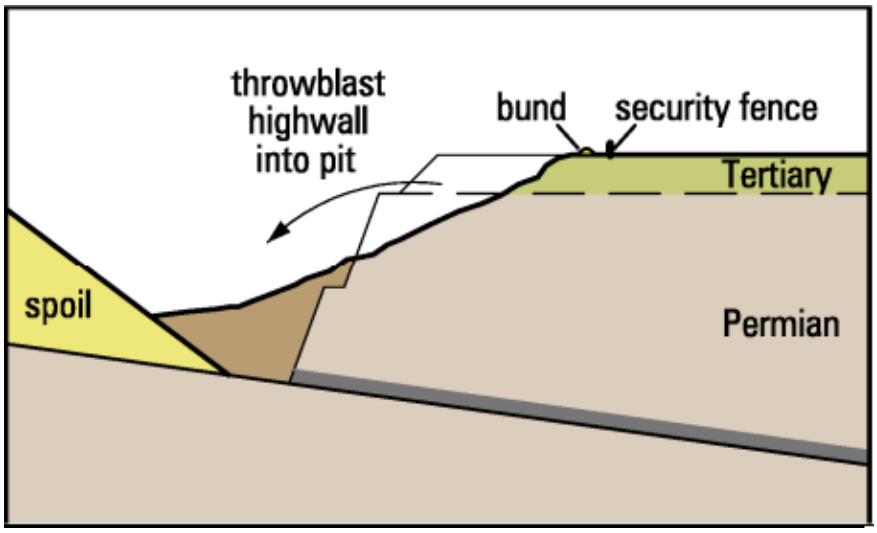


Figure 7-8 Strategy 3 (PW Baker & Assoc. Pty Ltd, 2006)

7.5 Conclusions and Recommendations

The Slope Stability Analysis has shown that in all scenarios tested the factor of safety was above the accepted design criteria and therefore considered structurally safe. While some rehabilitation trials and other site and regional studies have been undertaken on erosion, further work is required to confirm the proposed landform slopes for the Tertiary highwall and stable embankment.

The following recommendations are made in relation to finalising the post-mining landform:

- The construction of the final landform designs, including cut-fill volumes, are to be reviewed and developed;
- An erosional assessment is necessary to confirm the maximum slope angles for the various soil strength materials (including spoil materials). The final landform designs, and if deemed necessary the slope stability analysis, are to be updated based on the outcomes of the erosion assessment;
- Further assess the cover options of topsoil and non-dispersive spoil cover on the Tertiary material including material availability, effectiveness and potential land uses of the area;
- Geological, geotechnical and hydrogeological data collection programs for the final pitwalls are to be developed and implemented to inform the detailed design process;
- The hydrogeological and hydrological models should be developed, and an associated groundwater investigation program implemented;
- Investigations and studies should be undertaken to identify the potential location and extent of Paleochannels in the alluvial soil profile;
- As the final landform designs are progressed, and additional geological, geotechnical, hydrogeological and/or hydrological data is obtained, more detailed and extensive slope stability analysis may be required. This should include assessment of all slope geometries, remnant pitwalls and final voids. It is recommended that detailed design include probabilistic slope stability analysis;
- Review the embankment design, material and cover based on the results of the flood modelling; and
- Confirm the rehabilitation methodology for the final landform design.

8 Residual Void Outcomes and Criteria

8.1 Residual Void Constraints

When considering the final land outcomes for residual voids any regulatory, physical, chemical and economic constraints should be considered.

An objective of this CRVA update is to have this document accepted as a LOD and therefore have the residual void outcomes in this document transitioned into the PRCP without further assessment or restriction. The EP Act states that final voids on floodplains are prohibited and therefore must have a post-mining land use. This restriction does not apply to LODs and therefore SLR has proceeded with the assumption that the residual voids at Curragh Project may be left on a floodplain with best practices in place to prevent flood water ingress.

The residual void water balance modelling showed that all residual voids at Curragh Project have a highly saline water quality after only 30 years (>30,000 µS/cm). There are certain aquatic species that are able to habitat water of this salinity (such as Bony Bream, Rainbows, algal species) but other uses such as stock or irrigation are not suitable.

The slopes of the Permian highwalls in the preliminary final landform have a slope between 22 and 63 degrees depending on the geological stability. The landform will consist of interconnecting benches which is relatively safe to humans, stock and native fauna. As mentioned in **section 6.2.1** of this report, there is a significant space from the top of the highwall to the waterbody and SLR is recommending the installation of bunds, fencing and signage to prevent access to the steeper highwalls.

This report has focussed on the environmental and regulatory constraints of residual voids but it should also be mentioned that there is also an economic constraint for the final land outcomes of residual voids.

8.2 Residual Void Outcomes

The PRCP framework has two categories of final land outcomes: (1) post-mining land use (PMLU) or (2) non-use management area (NUMA). A NUMA is an area of land that cannot be rehabilitated to a stable condition after all activities have ended. The definition of stable condition is outlined in section 111A of the EP Act as:

> *Land is in a stable condition if-*
>
> *a) the land is safe and structurally stable; and*
>
> *b) there is no environmental harm being caused by anything on or in the land; and*
>
> *c) the land can sustain a post-mining land use.*

A post-mining land use is defined in the EP Act as the purpose for which land will be used after all activities have ended.

The residual void objectives in **section 3.1** of this report include safe and structurally stable and does not cause serious environmental harm except for the existence of the void itself. Therefore, the determining factor as to whether the residual voids can meet stable condition is whether the land can sustain a PMLU.

As mentioned above, the void water quality is not appropriate for stock watering or irrigation but may be appropriate for some aquatic species. The suitability of void water for aquatic habitat requires further investigation in order to confirm the feasibility of this use. Given the potential safety hazard of the highwall and water storage which will be restricted by the installation of fencing and signage, this rehabilitation strategy does not support a PMLU.

The void low wall, Tertiary highwall and stable embankment are all at appropriate slope angles to be considered safe and stable and therefore likely able to sustain a PMLU consistent with the surrounding area. While further erosion work is required to confirm that the stable embankment and Tertiary highwall will have an acceptable level of erosion, this will be reviewed as part of the PRCP.

Therefore, it is SLRs recommendation that the Permian Highwall and maximum void water level be considered as a NUMA and the void low wall have a PMLU of light grazing and open woodland, as shown in **Figure 8-1** and **Figure 8-2**. Given that the low wall, Tertiary highwall and stable embankment are considered able to achieve a PMLU, the criteria and further land outcomes and objectives for these areas is contained within the Rehabilitation Monitoring and Management Plan.

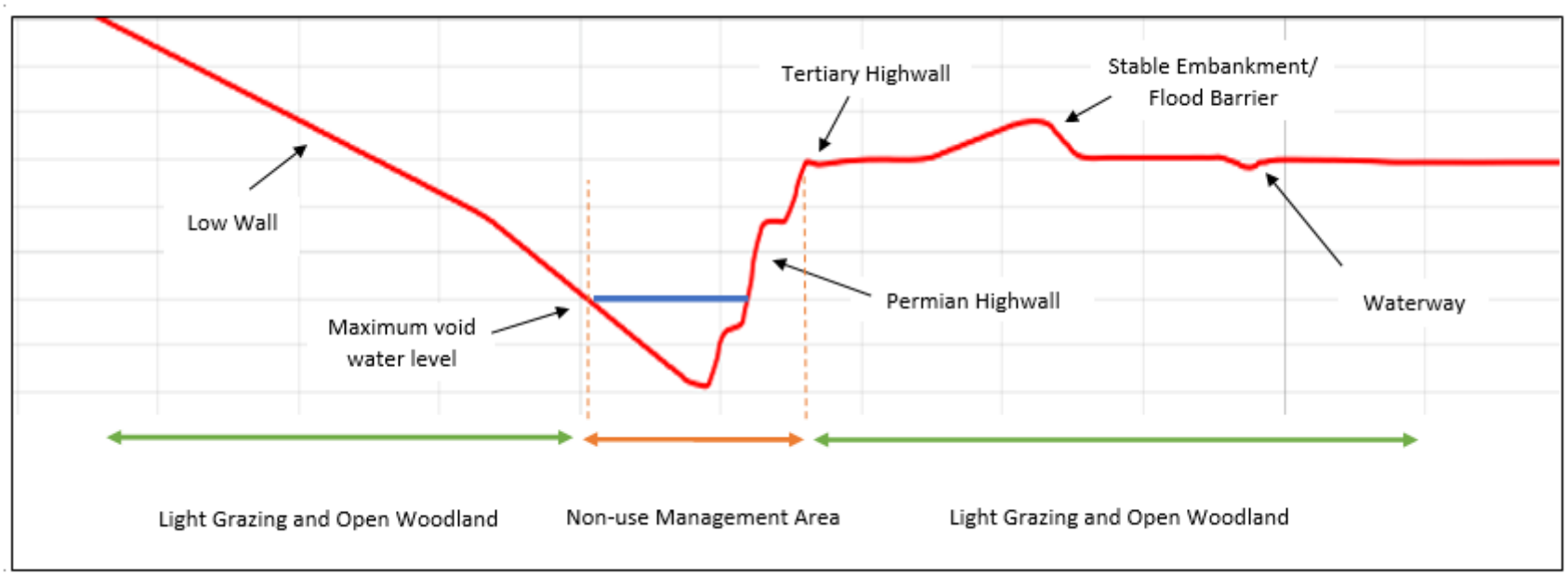


Figure 8-1 Conceptual Residual Void Cross Section with Land Outcomes

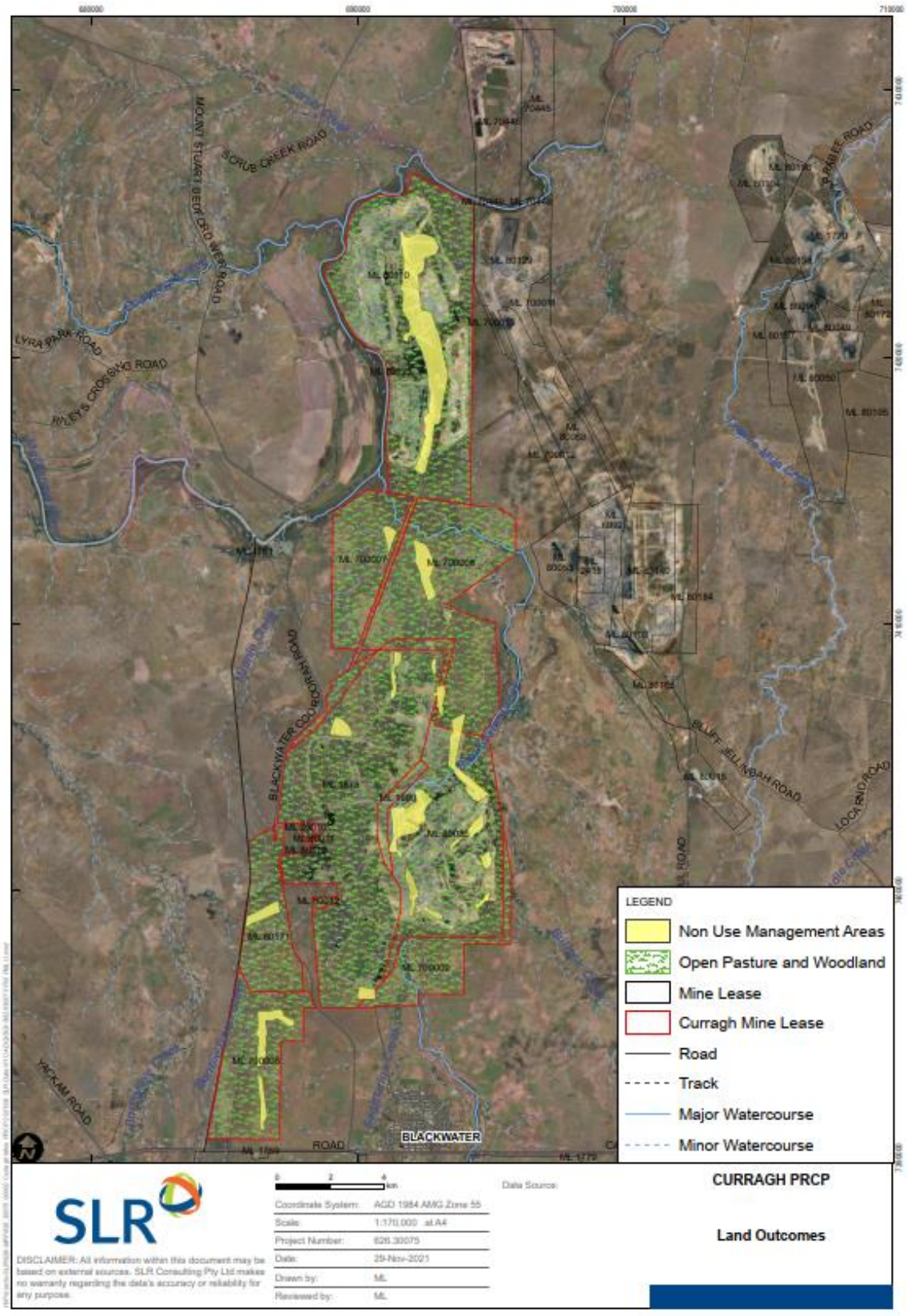


Figure 8-2 Curragh Project Proposed Land Outcomes

8.3 Non-use Management Areas

Based on the above technical information and assessment, the Curragh Project will have proposed NUMAs. SLR has attempted to reduce the extent of NUMA and maximise the area with a proposed PMLU by only including the maximum void water level and the highwall. It should be noted that the below areas and locations are based on the preliminary landform design which is subject to change before the PRCP is submitted.

The preliminary NUMAs for the whole Curragh Project are detailed in **Table 8-1**.

Table 8-1 Preliminary NUMA Areas

Pit	NUMA Area (ha)	NUMA Average Depth (m)
Pit S, T and U	637	26
Pit D and F	202	63 - 113
Pit G, H and I	259	83
Pit L	19	105
Pit K	13	79
Ramp 9	40	91
Pit J	28	132
Pit X	125	69
Pit Y	48	131
Pit Z	128	115

8.4 NUMA Criteria

SLR have developed completion criteria for the proposed NUMAs (**Table 8-2**) using the technical studies undertaken and detailed above. It should be noted that this criterion is only applicable to the Permian Highwall and maximum void water level. The void low wall, Tertiary highwall and embankment have criteria outlined in the RMMP.

Table 8-2 NUMA Criteria

Objective	Criteria	Justification
Safe for humans, livestock and native fauna	Static Factor of Safety >1.5 Dynamic Factor of Safety >1.1	Factor of safety design criteria is recommended in the Geotechnical Report (**Appendix D**).
	Certification from an appropriately qualified person that the residual void is safe to humans and livestock	Example from PRCP Guideline.
	Installation of fencing and signage where required.	The installation of fencing and signage would be confirmed in the PRCP once the final landform has been finalised.
Geotechnically and erosionally stable	The final landform does not form rill erosion of >30 cm.	This is a standard criteria for demonstrating erosional stability.

Objective	Criteria	Justification
	Permian highwalls battered to a geotechnically stable slope.	As recommended in Geotechnical Report. Where fault related rock mass shearing and/or adversely orientated structures are interpreted or inferred final walls may have to be constructed as softwalls at 22 degrees.
	Certification from an appropriately qualified person that the residual void is geotechnically and erosionally stable.	Example from PRCP Guideline.
Does not cause serious environmental harm to land, surface waters or any recognised groundwater aquifer, other than the environmental harm constituted by the existence of the residual void itself	Construction of a stable, long-term embankment which prevents the ingress of flood water into the residual voids.	The embankment will protect the voids from interacting with the floodplain. The Flood Model Report in **Appendix A** provides the minimum height for the embankment based on very conservative flood modelling. This height may be reviewed based on more detailed flood modelling recommended as part of the PRCP.
	Saline void water will not spill or seep into the surrounding environment at a concentration that will cause environmental harm.	The void water balance modelling shows that the voids are highly unlikely to spill. Groundwater modelling demonstrates that the voids are likely to act as sinks and not contaminate the surrounding environment.
	Certification from an appropriately qualified person that the residual void does not cause serious environmental harm to land, surface waters or any recognised groundwater aquifer, other than the environmental harm constituted by the existence of the residual void itself.	Similar example from PRCP Guideline.

8.4.1 Minimisation of Residual Void Area

Table 8-3 shows a comparison of the 2012 proposed residual voids and the 2021 preliminary NUMA areas. This shows that the area which could be interpreted as a NUMA in the PRCP has been reduced in this version of the CRVA. This was achieved by reviewing the parameters of what is considered a 'NUMA' and optimising the PMLU for the low wall and Tertiary highwall.

Table 8-3 Residual Voids / NUMA Areas 2012 vs 2021

Domain	2012 CRVA Residual Void Area (ha)	2021 CRVA NUMA Area (ha)
Curragh Main	1,096	561
Curragh North	646	637
Pit X	-	125
Pit Y	-	48
Pit Z	-	128
Total	**1,742**	**1,499**

9 Conclusions and Recommendations

This report has reviewed the proposed residual voids as presented in the preliminary final landform design provided by CCPL. The CRVA has been updated to include additional EA approved voids located in the Curragh extension leases (Pits X, Y and Z) and the updated residual void location for existing voids. The intent of this CRVA is to be approved as a Land Outcome Document with the purpose of transitioning the residual void land outcomes in this report to the PRCP.

This report includes a flood assessment, groundwater assessment, void water balance and geotechnical stability analysis of the proposed preliminary landform. The intent of these studies was to provide input into the preliminary landform design which can then be updated and improved upon for the PRCP submission.

The CRVA established four key objectives for residual voids which are outlined below.

1. *Safe for humans, livestock and native fauna.*

The final highwall landform for all voids, as well as optional alternative landforms, were assessed for slope stability. All landforms assessed had a factor of safety above the adopted design criteria, >1.5 for static conditions and >1.1 for dynamic conditions. This means that there is an acceptable factor of safety for the highwalls.

The residual void WBM found that there was a significant space between the top of the highwall and the long-term water level which may indicate that the water is not easily accessible and therefore may not be safe for human and/or animal interaction. To address this SLR has proposed that the installation of fencing and signage should be considered, and the extent required confirmed in the PRCP.

2. *Geotechnically and erosionally stable.*

The slope stability analysis using the factor of safety can also be used for assessing the geotechnical stability of the final landform. All landforms assessed had a factor of safety above the adopted design criteria, >1.5 for static conditions and >1.1 for dynamic conditions; hence, all landforms are considered geotechnically stable.

Erosion trials have been undertaken at Curragh Project previously for Tertiary spoil. These trials and literature have been reviewed and considered in the erosion assessment of the landform. Further work is required in order to confirm the proposed final landform now that results from the floodplain modelling have been provided.

3. *Does not cause serious environmental harm to land, surface waters or any recognised groundwater aquifer, other than the environmental harm constituted by the existence of the residual void itself.*

The residual void water balance model was used to determine residual void water levels and water quality. The 99th percentile water levels predicted for all voids were well under the spill level; and therefore, the high salinity water contained within the residual voids is unlikely to spill into the surrounding environment.

The groundwater assessment showed that the residual voids are likely to act as sinks and therefore not seep into the surrounding environment.

4. *The extent of residual voids is minimised as much as practicable.*

The extent of the residual voids from the 2012 version of this document has been significantly reduced, by approximately 300 ha, even though this assessment includes an additional five pits. The reduction in residual void classified as NUMA has been achieved by proposing a PMLU for the void low wall and Tertiary highwall.

SLR recommends that the Permian highwall and maximum void water level extent have a land outcome of NUMA. This is due to the safety hazards presented by these areas and hence the exclusion which constrains any potential use. It is acknowledged that further work is required for the PRCP submission; however, the preliminary information presented in this assessment is considered sufficient for the land outcome decision. It is recommended that the proposed residual void land outcomes and criteria presented in this report be transitioned into the PRCP where appropriate.

10 References

Carroll et al., 2000, Impact of vegetative cover and slope on runoff, erosion, and water quality for field plots on a range of soil and spoil materials on central Queensland coal mines, Aust. J. Soil Res., 38, 313-327

Golders, 2017, B Pit Tailings Storage Facility Design Plan

Parsons Brinkerhoff (PB), 2016, Curragh Extension Project – Groundwater Technical Report (2172652H-WAT-REP-002 RevB)

PW Baker & Assoc. Pty Ltd, 2006, Rehabilitation of Highwalls, ACARP Report C14048

APPENDIX A

FLOOD MODEL REPORT

CURRAGH MINE

Conceptual Residual Void Assessment
Preliminary Flood Impact

Prepared for:

Coronado Curragh Pty Ltd
Blackwater, QLD, 4717

SLR Ref: 626.30075-R01
Version No: -v1.0
November 2021

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BASIS OF REPORT

This report has been prepared by SLR Consulting Australia Pty Ltd (SLR) with all reasonable skill, care and diligence, and taking account of the timescale and resources allocated to it by agreement with Coronado Curragh Pty Ltd (the Client). Information reported herein is based on the interpretation of data collected, which has been accepted in good faith as being accurate and valid.

This report is for the exclusive use of the Client. No warranties or guarantees are expressed or should be inferred by any third parties. This report may not be relied upon by other parties without written consent from SLR.

SLR disclaims any responsibility to the Client and others in respect of any matters outside the agreed scope of the work.

DOCUMENT CONTROL

Reference	Date	Prepared	Checked	Authorised
626.30075-R01-v1.0	27 November 2021	Nicole Bichel	Michael Della	Emma Williams

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1 Introduction

1.1 Scope of Work

SLR was engaged by Coronado Curragh Pty Ltd (CCPL) to undertake floodplain modelling of the floodplain surrounding the Curragh Complex. The modelling was undertaken to assist in determining the stability and flood immunity requirements of the proposed residual voids.

Due to the preliminary nature of the assessment, a conservative approach to determining maximum flood levels for the 0.1% Annual Exceedance Probability (AEP) was taken. The key tasks carried out were:

- Estimate the maximum peak flows on the relevant tributaries in the site using flood frequency analysis (FFA);
- Develop a hydraulic model for the purpose of identifying flood risk posed to the proposed voids for 0.1% AEP flood event and developing final landform condition, based on available terrain data; and
- Produce a report detailing the methodology and findings of the above assessments, including all relevant mapping of flood extents, levels, and depths in relation to the proposed residual voids and long-term stable embankments.

1.2 Project Information

The mine is an open cut coal mine located in the Bowen Basin, approximately 6 km north of the town of Blackwater and approximately 200 km west of Rockhampton in Central Queensland. The Curragh Complex has been operating since 1983 and covers an area of approximately 19,650 ha. The project location is illustrated in **Figure 1**.

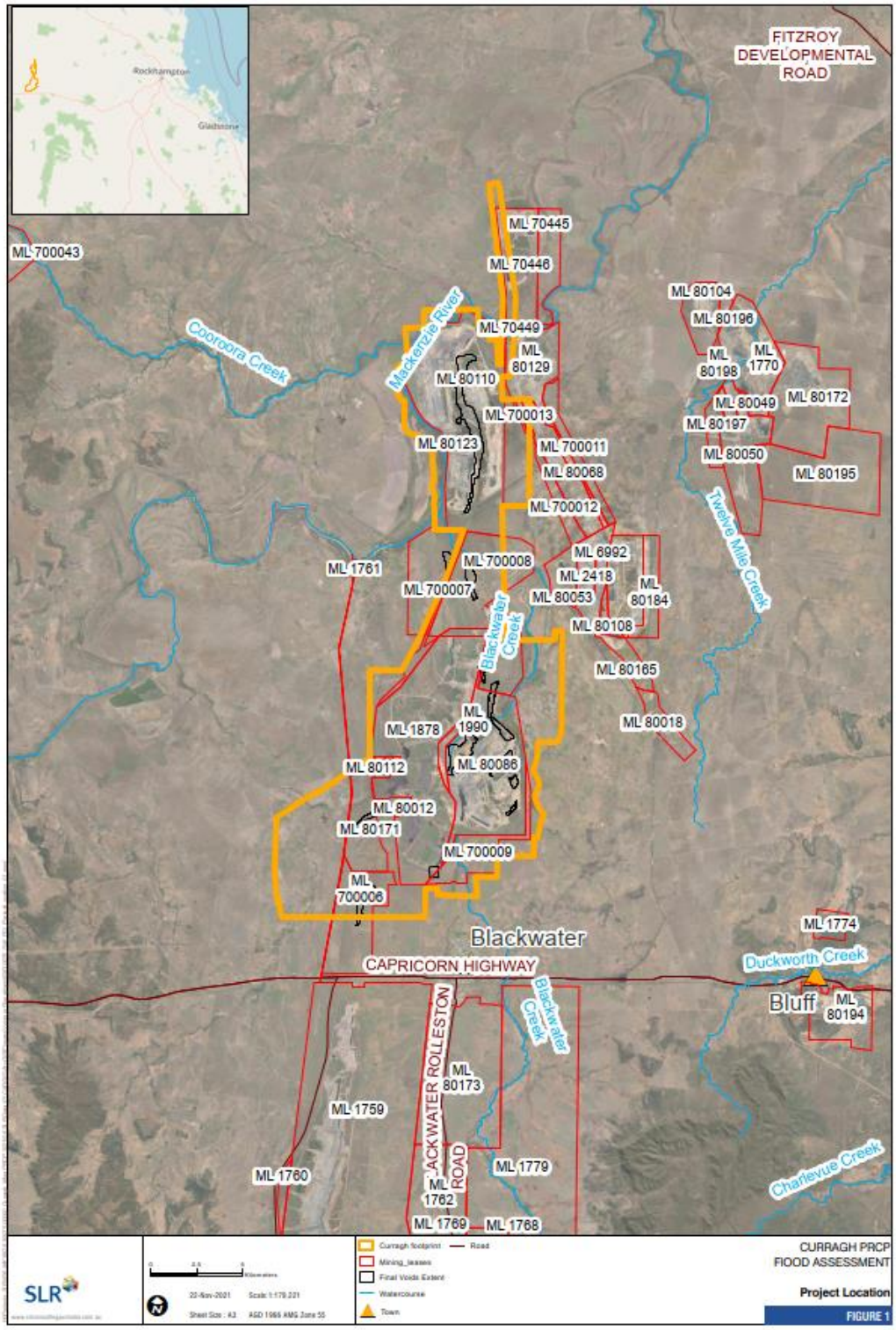


Figure 1. Project Location

1.3 Relevant Documentation

This assessment was undertaken cognisant of the following guidelines and documentation:

- *Environmental Protection Act 1994*;
- Environmental Protection Regulation 2019;
- 'Guideline – Progressive Rehabilitation and Closure Plans', Department of Environment and Science, March 2021 (PRCP Guideline);
- 'Information Sheet – Environmental Protection Act 1994 – Voids in Flood Plains', Department of Environment and Science, March 2020 (Voids in Flood Plains Information Sheet); and
- 'Australian Rainfall and Runoff (2019)' (ARR).

The assessment undertaken is preliminary in nature due to the immaturity of the residual void design surface. This assessment is focused on quantifying the flood risk to enable to appropriate assessments to be carried out for the Progressive Rehabilitation and Closure Plan (PRCP) in the future. As such, in accordance with the guidelines stated above, the flood assessment has been undertaken for the residual void landform only to understand the flood risk and stability of the landform. No assessment of the pre-mining landform has been carried out. Further details pertaining to the limitations of the assessment are provided in Section 1.4 of this report.

1.4 Assumptions and Limitations

This flood assessment has relied upon information which was received from the client and other sources. SLR has assumed that information provided is accurate and ,except where noted, SLR has not verified the accuracy of the information provided.

This report has been prepared for the purposes of gaining a preliminary understanding of the magnitude of a 0.1% AEP flood event for the relevant watercourse which impacts on the Curragh Complex. The intent of the assessment is to understand the extent that a long-term stable embankment would be required to protect the nominated residual voids from flood influx. As such, a level of conservatism has been built into the model, primarily through adoption of the most conservative flow estimate derived by the FFA and lack of creek and waterway definition. This results in a conservative volume of floodwater being conveyed on the floodplain rather than within the waterway banks, providing an overall conservative estimate of flood levels.

- The flood model has been developed based on inflows derived through a FFA approach. Numerous gauges were used along the Mackenzie River and its tributaries. The assessment shows a lack of convergence in the results. Specifically, the FFA showed estimates of the 0.1% AEP event at each gauge could vary by an order of magnitude. It is thought that this could be due to factors such as floodplain storage, artificial features such as dams and levees, short record lengths and gauge rating curve accuracy. Therefore, the most conservative flow estimate has been adopted. Detailed assessment into the estimate of a 0.1% AEP event for the catchment will be required prior to presentation of results in the PRCP.

- Flow estimates have been applied to the hydraulic model as a steady state inflow. This is a conservative approach as the effects of floodplain storage are removed. The flow estimates were applied as inflows into the model until inflows and outflows were equal.

- Flow estimates for tributaries of the Mackenzie River, such as Blackwater Creek, has been determined through a FFA on donor gauges scaled to the applicable catchment area. As above, the most conservative assessment was applied however this will need to be investigated further prior to understanding flood modelling for the PRCP.

- No assessment of coincident flooding between the Mackenzie River and other tributaries was carried out. Although in reality, flood peaks in Blackwater Creek could potentially occur at a different time to the peak in the Mackenzie River, it was assumed that the flood peak occurred at the same time, providing a conservative approach to estimate the peak water levels.

- The hydraulic model has been largely based on SRTM data due to the limited extent of available Lidar. SRTM data for the site has a vertical accuracy of +/-5-10m. Hydro-enforced SRTM was not used due to the inaccurate representation of waterway cross-sectional area when compared to available LiDAR data. A terrain surface was developed using the residual void landform, 1m Lidar and SRTM with some connectivity along the Mackenzie River provided through the use of artificial terrain manipulation.

- No artificial devices such as weirs were modelled in the hydraulic model.

- No bathymetric data for Mackenzie River was available and therefore not incorporated in the model.

- All roughness values were determined by review of aerial photography. No site visit or verification of the assessment was carried out.

- No infrastructure such as bridges or the like were included in the hydraulic model.

A more refined assessment of the flood impact will be required prior to submission of the PRCP to meet the data and modelling requirements outlined in the PRCP guideline.

This report should be read in full and no excerpts are to be taken as representative of the findings. This report has been prepared on behalf of CCPL and we accept no liability or responsibility whatsoever for, or in respect of, any use of, or reliance upon, this report by any third party.

1.5 Definitions and Terminology

The following definitions and abbreviations apply to the report.

Table 1 Report Definitions

Term	Definition
Annual Exceedance Probability (AEP)	The chance of a flood of a given size (or larger) occurring in any one year, usually expressed as a percentage. For example, if a flood level of 3.5 mAHD has an AEP of 1% or 1 in 100 (or 1:100), it means that there is a 1% chance (i.e., a 1 in 100 chance) of a flood level of 3.5 mAHD (or larger) occurring in any one year (see also average recurrence interval).
Australian Height Datum (AHD)	National survey datum corresponding approximately to mean sea level.

Term	Definition
Average Recurrence Interval (ARI)	The long-term average number of years between the occurrence of a flood as big as (or larger than) the selected event. ARI is another way of expressing the likelihood of occurrence of a flood event (see also annual exceedance probability).
Catchment	The catchment at a particular point is the area of land that drains to that point.
Design flood	A hypothetical flood representing a specific likelihood of occurrence (for example the 1% AEP probability flood).
Discharge	The rate of flow of water measured in terms of volume over time (i.e., the amount of water moving past a point). Discharge and flow are interchangeable.
DEM	Digital Elevation Model – a three-dimensional model of the ground surface.
Flood	Relatively high river or creek flows, which overtop the natural or artificial banks, and inundate floodplains and/or coastal inundation resulting from super elevated sea levels and/or waves overtopping coastline defences.
Flood Frequency Analysis	An analysis of historical flood records to determine estimates of design flood flows.
Floodplain	Land adjacent to a river or creek that is periodically inundated due to floods. The floodplain includes all land that is susceptible to inundation by the probable maximum flood (PMF) event.
Flood Storage	Floodplain areas that are important for the temporary storage of floodwaters during a flood
Floodway	A flow path (sometimes artificial) that carries significant volumes of floodwaters during a flood.
Historical Flood	A flood which has occurred in the past.
Hydrograph	A graph showing how a river or creek's discharge or water level changes with time.
Hydrology	The term given to the study of the rainfall-runoff process in catchments.
Levee	Operational mine protection device.
Long-term stable embankment	Landform feature which may protect residual voids from flood ingress, is not a regulated structure.
Peak flood level, flow or velocity	The maximum flood level, flow or velocity occurring during a flood event at a particular location.
Pit	Operational open cut mine pit/void
Probability	A statistical measure of the likely frequency or occurrence of flooding
Residual void	Post closure landform design term.
Runoff	The amount of rainfall from a catchment that actually ends up as flowing water in the river or creek.
Velocity	The speed at which floodwater are moving.
Water level	Same as flood level.

Table 2 Report Abbreviations

Abbreviation	Term
1D/2D	One dimensional / two dimensional
AEP	Annual Exceedance Probability
AHD	Australian Height Datum
ARI	Average Recurrence Interval
ARR2019	Australian Rainfall and Runoff 2019
BoM	Bureau of Meteorology
CCPL	Coronado Curragh Pty Ltd
CRVA	Concept Residual Void Assessment
Curragh Complex	Curragh Mine Complex "the mine"
DEM	Digital Elevation Model
km	Kilometres
m^3/s	Cubic Metres per second
mAHD	Elevation in metres relative to the Australian Height Datum

2 Available Data

The following data was supplied or accessed for development of the hydraulic model.

- Residual void landform (supplied as 0.5m contours);
- 1m LiDAR provided as x,y,z points;
- Shuttle Radar Topography Mission (SRTM) terrain data – sourced from Geoscience Australia for the hydraulic model extent where LiDAR wasn't available; and
- Aerial photography was sourced from Queensland Globe and was used to determine roughness of land uses within the floodplain extent.

3 Hydrologic Assessment

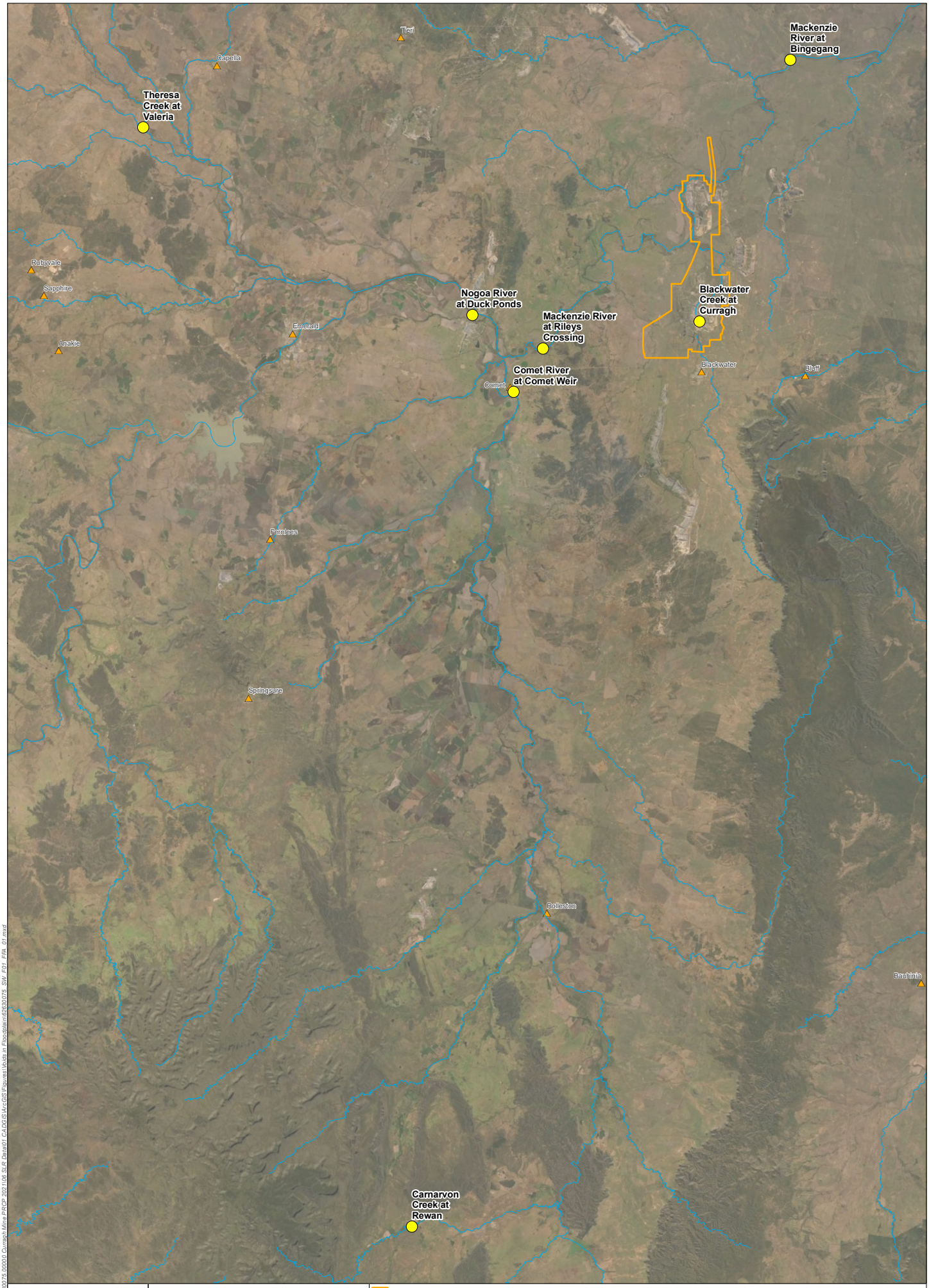
3.1 Stream Gauges

A hydrologic assessment was undertaken to provide flow estimates to the hydraulic model. The aim is to estimate the maximum peak flows for 0.1% AEP flood event of various watercourses in relation to the proposed voids. To achieve this, a flood frequency analysis was undertaken using recorded streamflow data sourced from the Department of Regional Development, Manufacturing and Water (DRDMW). Both the 1% and 0.1% AEP maximum peak flows are presented below, although this assessment utilised the 0.1% AEP event only.

There are no flow gauges in the immediate vicinity of the Curragh Complex. However, there are several current and historic gauges in the wider catchment. The gauges used in the assessment are provided below in Table 3 and have been used to estimate the maximum peak flows in the area of interest. Locations of the gauges are provided in Figure 2.

Table 3. Flood Frequency Analysis Locations within the Fitzroy Catchment

Site Name	Site No.	Years of Record	Catchment Area (km^2)
Mackenzie River at Bingegang	130106A	50	50,860
Mackenzie River at Riley's Crossing	130113A	17	45,040
Nogoa River at Duck Ponds	130219A	26	27,130
Comet River at Comet Weir	130501A & 130504A/B	99	16,460
Blackwater Creek at Curragh (Historic 1973-2009)	130108A & 130108B	37	777
Theresa Creek at Valeria	130210A	50	4,421
Carnarvon Creek at Rewan	130509A	36	351



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Kilometers

30-Nov-2021 Scale: 1:620,000

Sheet Size : A3 AGD 1966 AMG Zone 55

Curragh footprint
Watercourse
Town
Gauge Locations

CURRAGH
PRELIMINARY FIOOD ASSESSMENT
FFA Sites

FIGURE 2

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The two gauges on the Mackenzie River were selected for the analysis, being Mackenzie River at Rileys Crossing (130113A) and Mackenzie River at Bingegang (130106A).

The Bingegang site is located approximately 44 km north-west of Curragh Mine and has an upstream catchment area of 50,860 km^2 and has a continuous streamflow record of 50 years commencing in 1971. The Mackenzie River at Rileys Crossing is located approximately 75 km upstream of Bingegang and less than 30 km west of Currah Mine. The gauge has an upstream catchment area of 45,040 km^2 and has a continuous streamflow record of 17 years commencing in 2004.

Mackenzie River flows have also been continuously recorded at Nogoa River at Duck Ponds since 1993. This site has a catchment area of 27,130 km² and includes Lake Maraboon and Fairbairn Dam, which was completed in 1972. Fairbairn Dam has a significant impact on the flood response of the Mackenzie River (WRM, 2018) and therefore all observed flows from the gauge are representative of the impact Fairburn Dam has on reducing peak flood flows downstream.

The Comet River at Comet Weir gauge is 35 km south-west of Curragh Mine with a catchment area of 16,460 km^2. The current streamflow record commenced in 2002 providing 19 years of data. Two historic sites are also located in a proximal location. The historic Comet Weir site operated between 1919 and 1973, with the Comet Weir Inflow site between 1971 and 1994. Although this latter site has a catchment area of 40 km² less than the other two sites, the annual flood maxima for overlapping periods is similar. As such, these three records have been combined for this flood frequency assessment. It should be noted, however, that this site can be affected by backwater from the Mackenzie River (WRM, 2018)

Two gauges on Blackwater Creek were located toward the southern end of Curragh Mine, prior to the Creek's diversion around the eastern side of the mine. Combined, these two gauges provide a continuous streamflow record of 37 years with an upstream catchment area of 777 km².

The Theresa Creek gauge is approximately 100 km to the north-west of Curragh Mine. The continuous streamflow record for this site commenced in 1971 (50 years), with a gap in the record between February 2001 and February 2003. With these three years excluded, a total of 47 years of data was available for use from the Theresa Creek gauge.

The Carnarvon Creek gauge is located 170 km south-east of Curragh Mine. The streamflow record for this site has 36 years of data (commencing 1985). This is also the smallest catchment used in the assessment (351 km^2).

3.2 Flood Frequency Analysis

A frequency analysis was undertaken of the annual flood maxima series for each gauge. Three types of statistical distribution (Gumbel, Log Pearson III (LP3) and GEV) are assessed for how well they modelled the annual flood maxima series. As is standard practice, the frequency analyses are performed on a 12-month water year commencing 1 October, such that only the largest flood in each complete year was plotted, and the most appropriate statistical distribution was fitted to those annual values. The results of the FFA are shown in Appendix A.

For all gauges, a LP3 flood frequency distribution provided the best fit to the annual maximum data series. For each gauge, low flow outliers and incomplete years were excluded from the data series using the Grubbs Beck Test method prior to fitting the distribution.

It was assumed that any additional missing data have no significant effect on the results of the analysis. It should be noted that no additional quality control has been undertaken on these data specific to this project.

The 1% AEP and 0.1% AEP flows for each catchment are presented in **Table 4**. The Mackenzie River at Rileys Crossing gauge has a relatively short record (<20 years) which is generally not considered sufficient to derive 1% AEP and 0.1% AEP design events, as evident by the significantly over-estimated design flows at this site (**Table 4**). Consequently, the Rileys Crossing site is not used for any further analysis.

For comparison, 1% AEP Quantile Regression estimates have also been determined. These are significantly different to those derived from the flood frequency assessment, partly due to the Quantile Regression approach not explicitly accounting for the attenuating effects of large storage dams in the catchments.

Table 4. Flood Frequency Assessment and Quantile Regression (QR) Estimates

Site Name	Site No.	Quantile Regression (QR)	Regional Flood Frequency Method (RFFE)	Flood Frequency Analysis (FFA)	
		1 in 100 AEP (cumecs)	1 in 100 AEP (cumecs)	1 in 100 AEP (cumecs)	1 in 1000 AEP (cumecs)
Mackenzie River at Bingegang	130106A	27,665	27,800	12,777	54,393
Mackenzie River at Rileys Crossing	130113A	22,853	11,200	29,870	263,559
Nogoa River at Duck Ponds	130219A	16,805	8,310	9,040	36,412
Comet River at Comet Weir	130501A & 130504B	12,066	6,080	4,138	8,750
Blackwater Creek at Curragh (Historic 1973-2009)	130108A & 130108B	1,616	809	824	1,391
Theresa Creek at Valeria	130210A	5,408	1,340	4,508	12,690
Carnarvon Creek at Rewan	130509A	1,123	2,960	855	1,358

3.3 Area scaling of flood flows for ungauged catchments

To understand the flood flows that may be experienced in the immediate vicinity of the Curragh Complex, an assessment of flows for ungauged creeks was also required. Blackwater Creek flows through the Curragh Mine, its confluence with Minnie Creek just to the north before it discharges to the Mackenzie River. Adjacent to the Blackwater Creek catchment is Burngrove Creek to the west. Both are considered here for understanding the potential peak flows that may be experienced at Curragh Mine.

There are no flow records for Burngrove Creek or Minnie Creek, and the combined flow record for Blackwater Creek ended in 2009. This means that some significant flow events are not recorded; namely the event in 2011. Donor gauges were investigated based on similar catchment area and topography and proximity to the mine. Carnarvon Creek at Rewan and Theresa Creek at Valeria in addition to the Blackwater gauge were investigated for use. These two sites were chosen because they provide relatively long records (36 and 47 years respectively), and their catchment areas are comparable to the catchment areas of the tributaries around Curragh Mine.

For these three sites, design flows were estimated by scaling the Carnarvon Creek at Rewan and Theresa Creek at Valeria records as a function of area and the outputs compared. The results of the FFA scaling factors and resultant scaled flows are provided below in **Table 5, Table 6** and **Table 7.**

Table 5. Estimated design flows for Blackwater Creek and donor gauges.

Site Name	Site No.	Quantile Regression (QR)	Regional Flood Frequency Method (RFFE)	Flood Frequency Analysis (FFA)	
		1 in 100 AEP (cumecs)	1 in 100 AEP (cumecs)	1 in 100 AEP (cumecs)	1 in 1000 AEP (cumecs)
Blackwater Ck	130108A&B	1,616	809	824	1,391
Carnarvon Ck	130509A	1,123	1,340	855	1,358
Theresa Ck	130210A	5,408	2,960	4,508	12,690

Table 6. Scaling factors used to derive AEP event flows in the vicinity of Curragh Mine

Site name	Catchment Area (km^2)	Scaling Factor Theresa Creek (4,421km^2)	Scaling Factor Carnarvon Creek (351km^2)
Blackwater Creek at Mackenzie River (includes Minnie Creek)	1,109	0.251	3.16
Burngrove Creek at Mackenzie River	485	0.1097	1.38

Table 7. Scaled design flows for Blackwater Creek and Burngrove Creek Catchments.

Site Name	1 in 100 QR AEP	1 in 100 AEP (cumecs)	1 in 1000 AEP (cumecs)
Blackwater Creek at Mackenzie River	**2,053**		
Scaled using Theresa Creek		1,131	3,183
Scaled using Carnarvon Creek		2,702	4,290
Burngrove Creek at Mackenzie River	**1,214**		
Scaled using Theresa Creek		495	1,392
Scaled using Carnarvon Creek		1,182	1,876

The resulting flood flow estimates around Curragh Mine are presented in Table 7Error! Reference source not found.. Flows in Blackwater Creek derived by scaling the Carnarvon Creek AEP flows, are estimated to be 2,702 m^3/s for the 1% AEP event and 4,290 m^3/s for the 0.1% AEP event. These are significantly less when scaling the Theresa Creek flows, reducing the 1% AEP to 1,131 m^3/s and the 1 in 1000 AEP to 3,183 m^3/s.

Similarly, for Burngrove Creek the 1% AEP event is estimated as 1,181 m^3/s and 1,876 m^3/s for the 1% AEP and 0.1% AEP events by scaling the Carnarvon Creek flows. Scaling the Theresa Creek records results in lower AEP design flows.

The Carnarvon Creek scaled flows are, however, comparable to the 1% AEP flow estimated using the Quantile Regression approach, which resulted 2,053 m^3/s for the Blackwater Creek and 1,214 m^3/s in Burngrove Creek.

3.4 Discussion

For the purpose of understanding the potential flood flows in the vicinity of Curragh Mine, the above analyses have been used to estimate the 1% AEP and 0.1% AEP in the Mackenzie River, Blackwater Creek (including Minnie Creek) and Burngrove Creek. An earlier report by WRM (2018) estimates a 0.1% AEP flow of 17,200 m^3/s, near the confluence of Blackwater Creek and the Mackenzie River, which included a mixture of modelled and modified rating curve peak discharges from various sites.

In this study, the flow in the Mackenzie River has been estimated using the Bingegang site, which has 50 years of record. There is only a 10% increase in catchment area between the Curragh Mine and Bingegang, so provides some conservatism in the approach. The 1% AEP for this site is 12,777 m^3/s, increasing to 54,393 m^3/s for the 0.1% AEP event.

The closer site of Rileys Crossing only has 17 years of record and therefore provides a less reliable estimation of design flows. Despite a combined 99-year record for the Comet River, the site can be affected by backwater from the Mackenzie River making it less reliable to use in this instance.

For the Blackwater and Burngrove catchments, the design flows from Carnarvon Creek and Theresa Creek were scaled to provide estimates for these two catchments. These two sites were chosen because they are more comparable in size to the smaller tributary catchments around Curragh Mine. The Theresa Creek at Valeria site offers a longer record for flood frequency analysis, but area scaling of this record resulted in lower design flows overall. Although some distance from the Curragh Mine, the Carnarvon Creek site has 36 years of data including significant events since 2009 and are comparable with Quantile Regression estimates. As such, the scaled flows from this latter site are used to estimate the potential design flows around the Curragh Mine.

In summary, the following hydrologic inputs to the hydraulic model for the Curragh mine have been adopted.

- The Mackenzie River at Bingegang was used to estimate design flows in the Mackenzie River immediately upstream of Curragh Mine. With some adjustment for uncertainty the 1% AEP event was estimated as 12,777 m^3/s, and the 0.1% AEP was estimated as 54,393 m^3/s.
- As there were no gauges on the waterways in the immediate vicinity of the Curragh Mine, the scaled Carnarvon Creek flows were applied. These flows indicate a 1% AEP event of 2,702 m^3/s and a 0.1% AEP event of 4,290 m^3/s in Blackwater Creek (including Minnie Creek). For Burngrove Creek, the 1% AEP flow was 1,182 m^3/s and the 0.1% AEP flow was 1,876 m^3/s.

4 Hydraulic Modelling

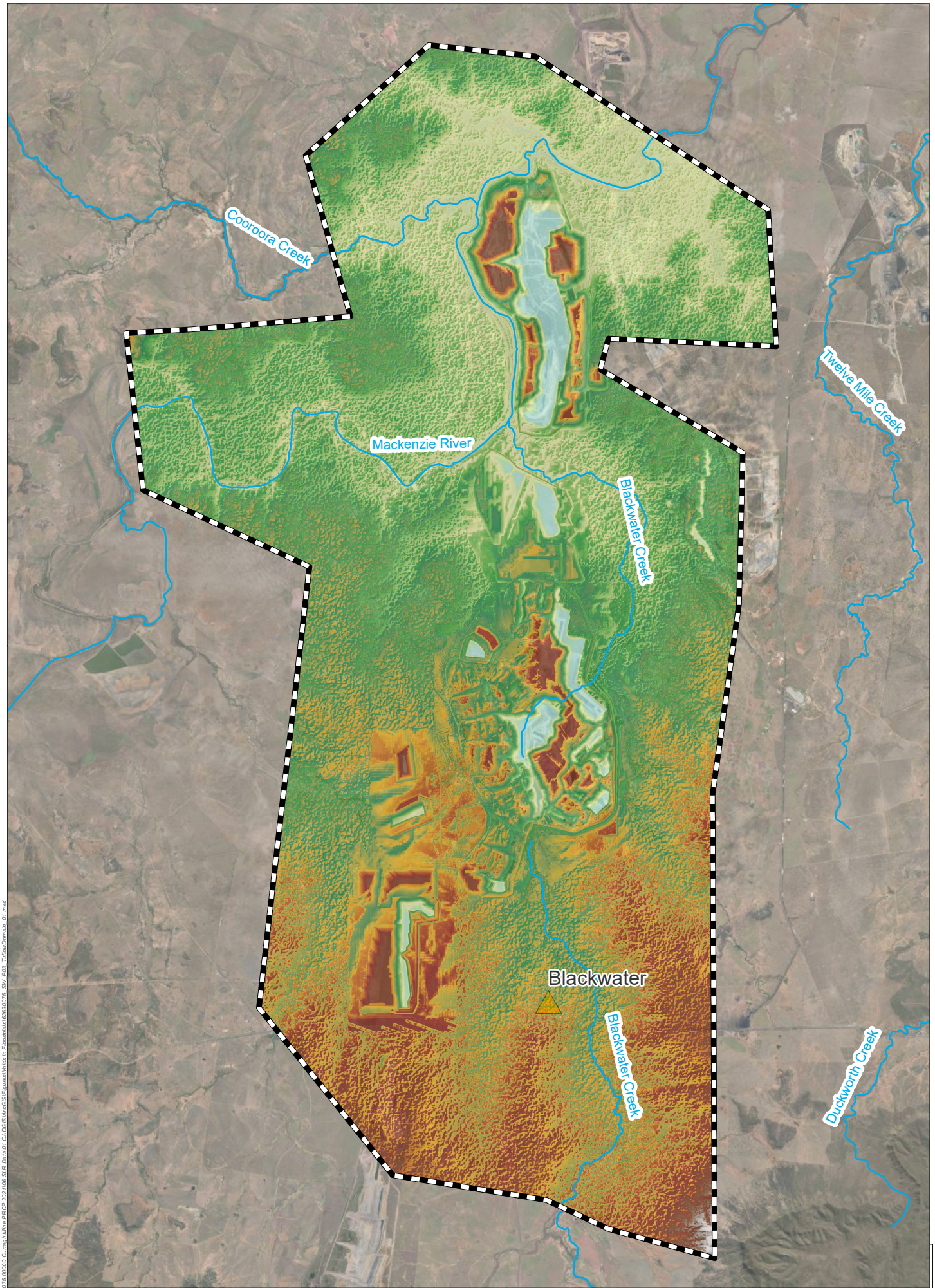
4.1 Software

A hydraulic model was developed for the purpose of assessing the post-mining flood extent. The industry standard hydrodynamic modelling software TUFLOW (Build 2020-10-AA) was utilised for the 2D hydraulic modelling. The TUFLOW Heavily Parallelised Compute (HPC) solution scheme was adopted in this project to minimise the model simulation time. Details of the model setup, methodology and results are provided in the following sections.

4.2 Topography

The residual void DEM as detailed below was utilised as the topography for the hydraulic modelling. A grid cell size of 20 metres was adopted for the model. The model domain and DEM data are shown in **Figure 3**.

Post-mining contour data was processed into a 5-metre spaced Digital Elevation Model (DEM). To create the residual void landform used in the floodplain modelling, the processed residual void DEM (which incorporated available 1m LiDAR) was overlaid on 1-second SRTM Derived DEM topographic data from Geoscience Australia. A long-term stable embankment has been incorporated into the residual void landform to provide flood immunity to the residual voids.



SLR
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0 2.5 5 Kilometers

30-Nov-2021 Scale: 1:145,000

Sheet Size : A3 AGD 1966 AMG Zone 55

TUFLOW Model Extent

Watercourse

Model DEM (mAHD)
High : 344.268
Low : 90

CURRAGH
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TUFLOW DEM and Model Extent

FIGURE 3

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4.3 Hydraulic Roughness

The hydraulic roughness for the model was adopted based on available Queensland Globe aerial imagery and the model landform. The adopted land use types are consistent with the current catchment characteristics. The Manning's roughness values adopted for the various land use types in the assessment are shown in **Table 8.**

Table 8. TUFLOW Manning's n Values

Land use	Manning's n
Creek	0.06
Waterways	0.025
Grassland	0.04
Light Scrub	0.05
Thick Scrub	0.08
Mining and rehabilitated area	0.05
Urban	0.2

4.4 Inflows

Inflows were applied to the hydraulic model as steady state discharges based on the Flood Frequency Analysis discussed in **Section 3.** The hydrographs were applied as total inflow boundaries via 2D boundary condition lines for the Mackenzie River, Blackwater Creek, Burngrove Creek, and Sagittarius Creek on the model domain as shown in **Figure 3**.

4.5 Downstream Boundaries

The downstream boundary for the TUFLOW model was positioned on Burngrove Creek on the western side and Mackenzie River on the northern boundary of the site. A stage-discharge relationship was applied as the tailwater condition for the 2D model domain, with the water surface gradient equivalent to the ground surface slope in the vicinity of the boundaries. Based on the post-mining landform data the slope of 0.004% to 0.2% was used for the boundary locations. Downstream boundaries are shown in **Figure 3Error! Reference source not found.**.

5 Results

The intent of the flood modelling was to determine whether the residual void landform was stable and sufficient to prevent ingress to any of the residual voids. The results of the TUFLOW model are illustrated for the 0.1% AEP flood event and are provided in **Appendix B**.

The results show that all residual voids within the Curragh Complex are not subject to flood inundation due to the current diversion of Blackwater Creek and the stable landforms defined as part of the residual void landform. The surface water elevations and velocities are presented in **Appendix B**Error! Reference source not found.**.**

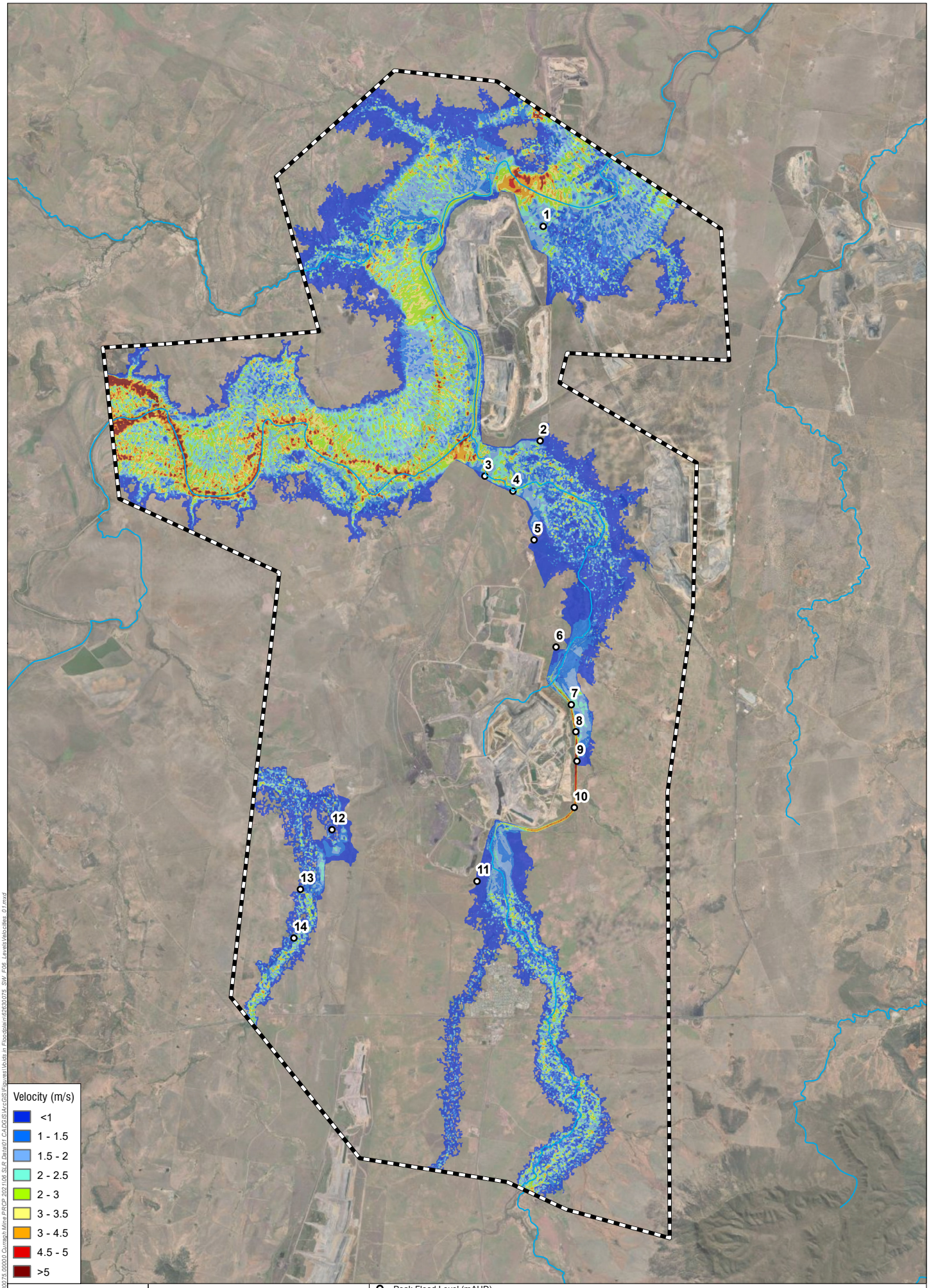
The modelled results show that a residual void landform can effectively use spoil dumps and long-term stable embankments to protect the residual voids from flood ingress. SLR adjusted the provided residual void landform along the existing Blackwater Creek diversion and between X Pit and Curragh North to provide additional protection. Modelled results for the 0.1% AEP flood event show:

- Landform heights of up to 141 mAHD plus freeboard are likely to be required North of Pit X.
- Blackwater Creek diversion should allow for flood levels up to 162.5 mAHD.

A summary of the modelled 0.1% AEP flood levels and velocities for each of the residual voids is provided in **Table 9** and
Figure 4.

Table 9. Maximum Surface Water Elevations

Void Name	Indicative Water Level 0.1% AEP event (m AHD)	Average Velocity (m/s)
1	130.37	2.1 – 5.3
2	140.58	1.8 – 3.9
3	140.57	1.8 – 3.9
4	140.57	1.1 – 3.7
5	140.58	0.7 – 2.9
6	142.32	0.6 -2.6
7	145.19	1.5 - 5
8	148.9	2 - 4.5
9	152.12	0.8 - 5.4
10	156.94	1.5 - 4
11	162.67	0.5 – 2.5
12	160.05	0.5 – 1.7
13	165.89	0.5 – 1.7
14	170.39	0.5 – 3.9



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30-Nov-2021 Scale: 1:150,123

Sheet Size : A3 AGD 1966 AMG Zone 55

Peak Flood Level (mAHD)
Mining Leases
TUFLOW Model Extent
Watercourse

CURRAGH
PRELIMINARY FLOOD ASSESSMENT

0.1% AEP Peak Flood Levels and Velocities

FIGURE 4

H:\Projects-SLR\626-MKY\626.30075.00000 Curragh Mine PRCP 2021\06 SLR Data\01 CAD\GIS\ArcGIS\Figures\Vols in Floodplain\626300075_SW_F06_Levels Velocities_01.mxd

Flood velocities can be substantial through areas where the floodplain is constrained. Velocities are significant in the Blackwater Creek diversion, due to the confinement of the creek flows. That being said, the diversion is an existing infrastructure and is considered stable in its current form. Ongoing monitoring of the diversion in accordance with legislative requirements will determine if any works are required to maintain the stability of the landform in this area.

Velocities are typically 3 - 4.5m/s which will cause some erosion to the long-term stable embankment and appropriate treatment will be required. It should be noted that the hydraulic model utilised steady state inflows and this area is affected by backwater from the Mackenzie River. As such, velocities may be greater if Blackwater Creek is in flood with lower tailwater levels observed in the Mackenzie River. Further investigation of this element to confirm the erosion protection requirements will be required as part of the PRCP submission.

The Mackenzie River experiences velocities of greater than 6 m/s within the river banks adjacent to Curragh North, however velocities reduce to less than 2 m/s adjacent to the landform. Again, further investigation of velocities upon refinement of the hydraulic model will be required for the PRCP to show the landform is stable when subjected to high velocity flood flows.

It should also be noted the current hydraulic model does not take into account any further modifications to the floodplain due to the progression of mining on adjacent mining leases outside the control of CCPL. Further assessment of how mine development on the floodplain adjacent to Curragh Complex should be undertaken to determine whether any of the impacts (flood level or velocity) are exacerbated.

6 Conclusion

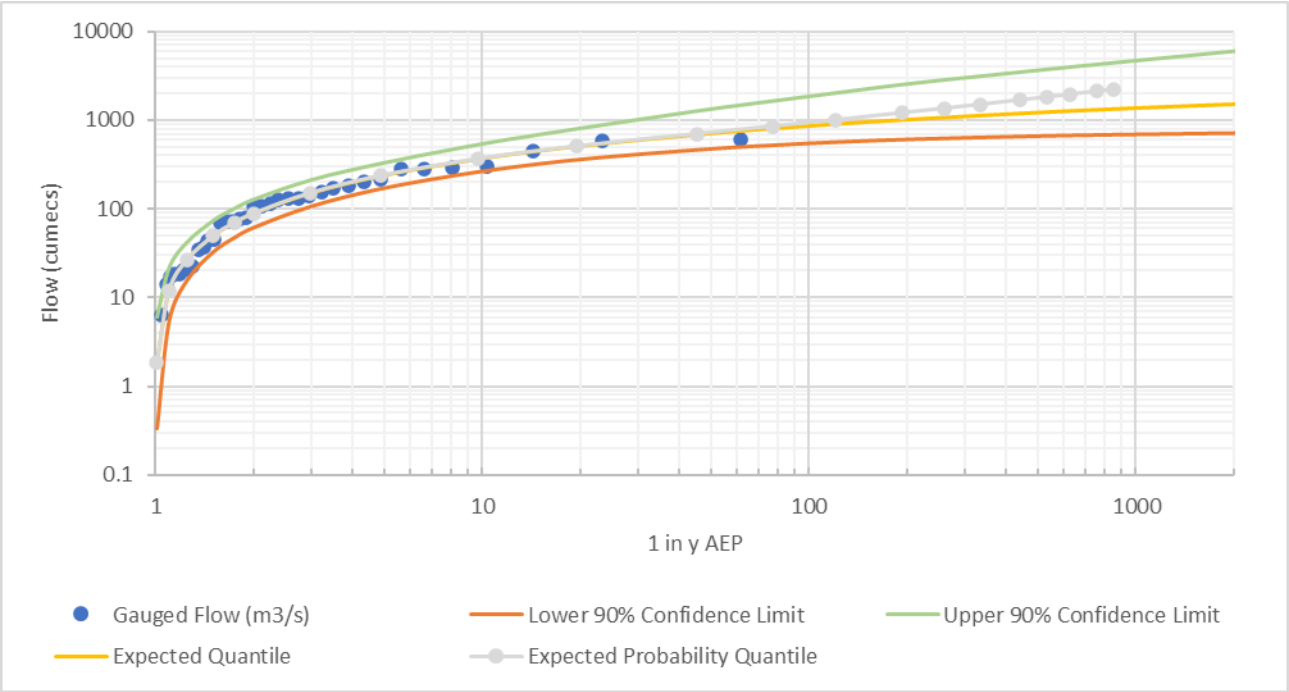
A flood assessment was carried out to determine the maximum flood level for a 0.1% AEP flood event for the floodplain which Curragh Complex spans.

Due to the limitations and assumptions detailed in Section 1.4, a conservative approach to determining flood levels was undertaken. The assessment found that with some adjustments to the long-term stable embankment proposed, the residual voids are not impacted by ingress of floodwater. The flood assessment has been based on a conservative estimate of estimated flood flows, however a full assessment of the flood risk to the site in accordance with the PRCP guidelines is required prior to submission of the PRCP.

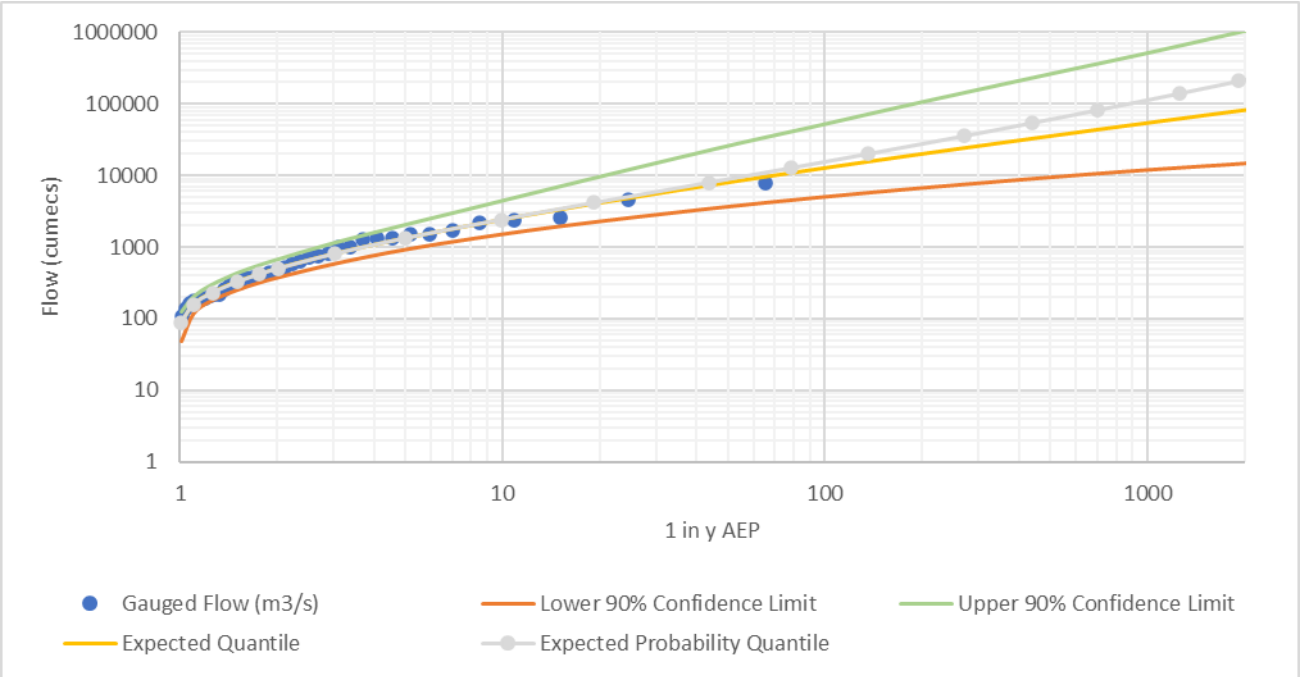
Furthermore, due to the narrowing of the floodplain, some areas specifically north of Pit X and to the west and north of Curragh North experience flood velocities which are excessive and will require treatment of the residual void landform to prevent scour. It is recommended that an erosion assessment be carried out once the flood modelling results have been refined and prior to the submission of the PRCP.

APPENDIX A

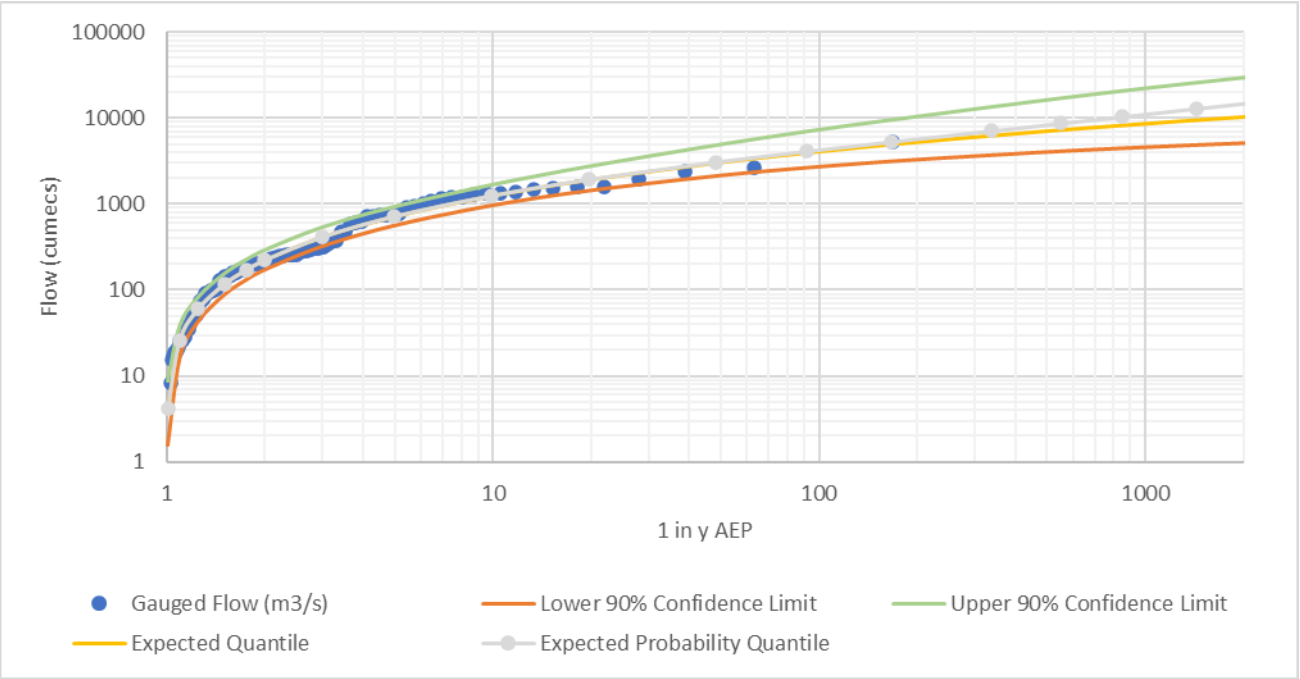
Flood Frequency Analysis (FFA) results



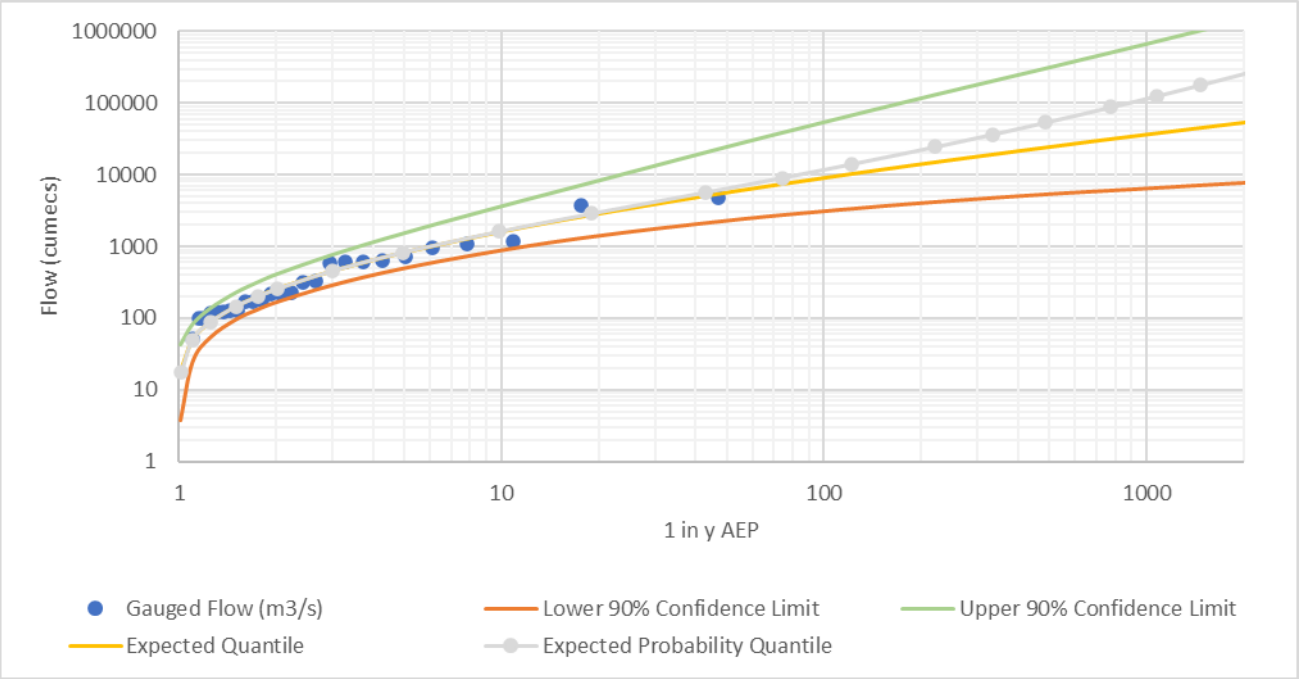
Carnarvon Creek at Rewan



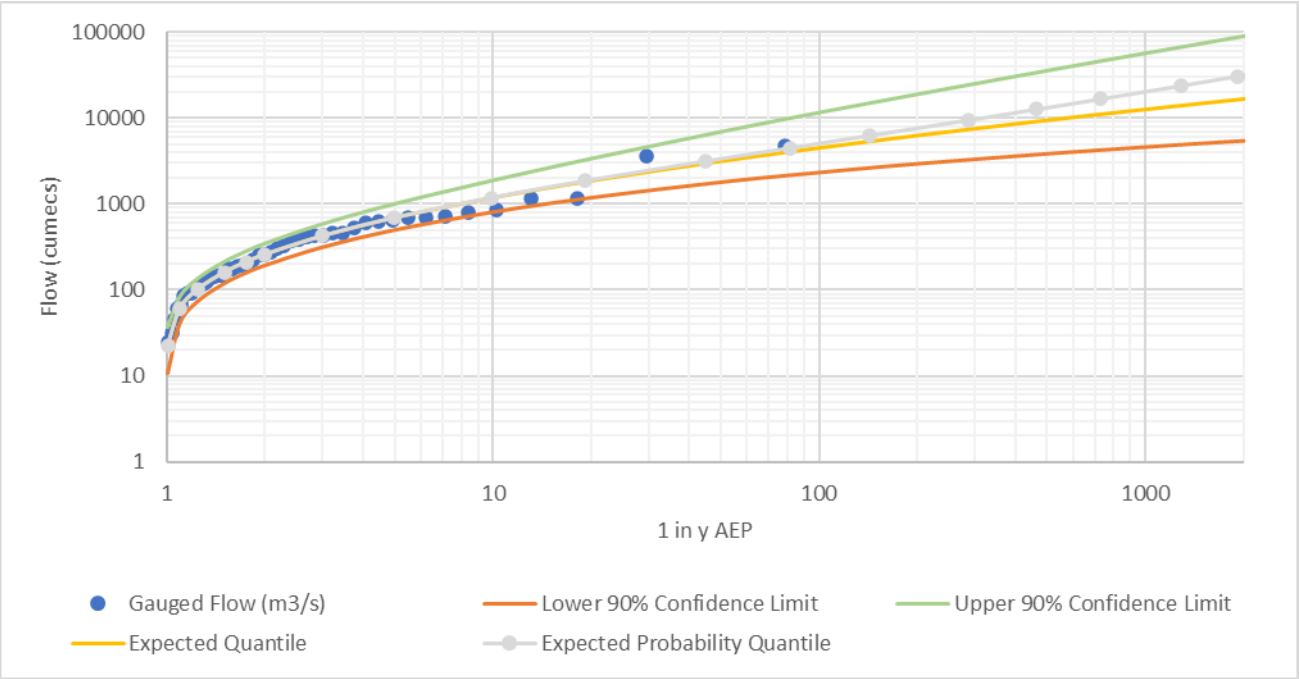
Mackenzie River at Bingegang



Comet River at Comet Weir



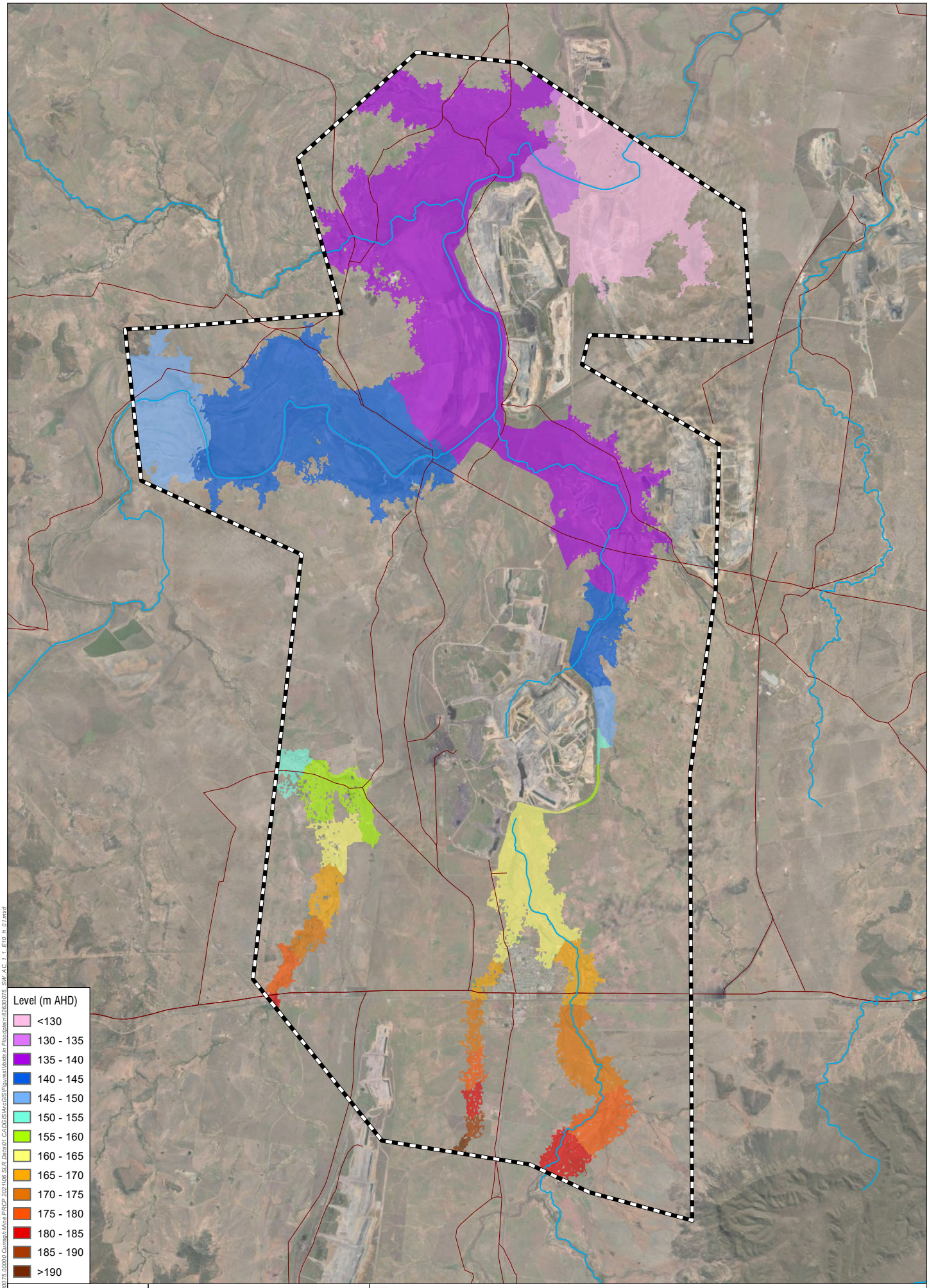
Nogoa River at Duck Ponds



Theresa Creek at Valeria

APPENDIX B

Hydraulic Model Results



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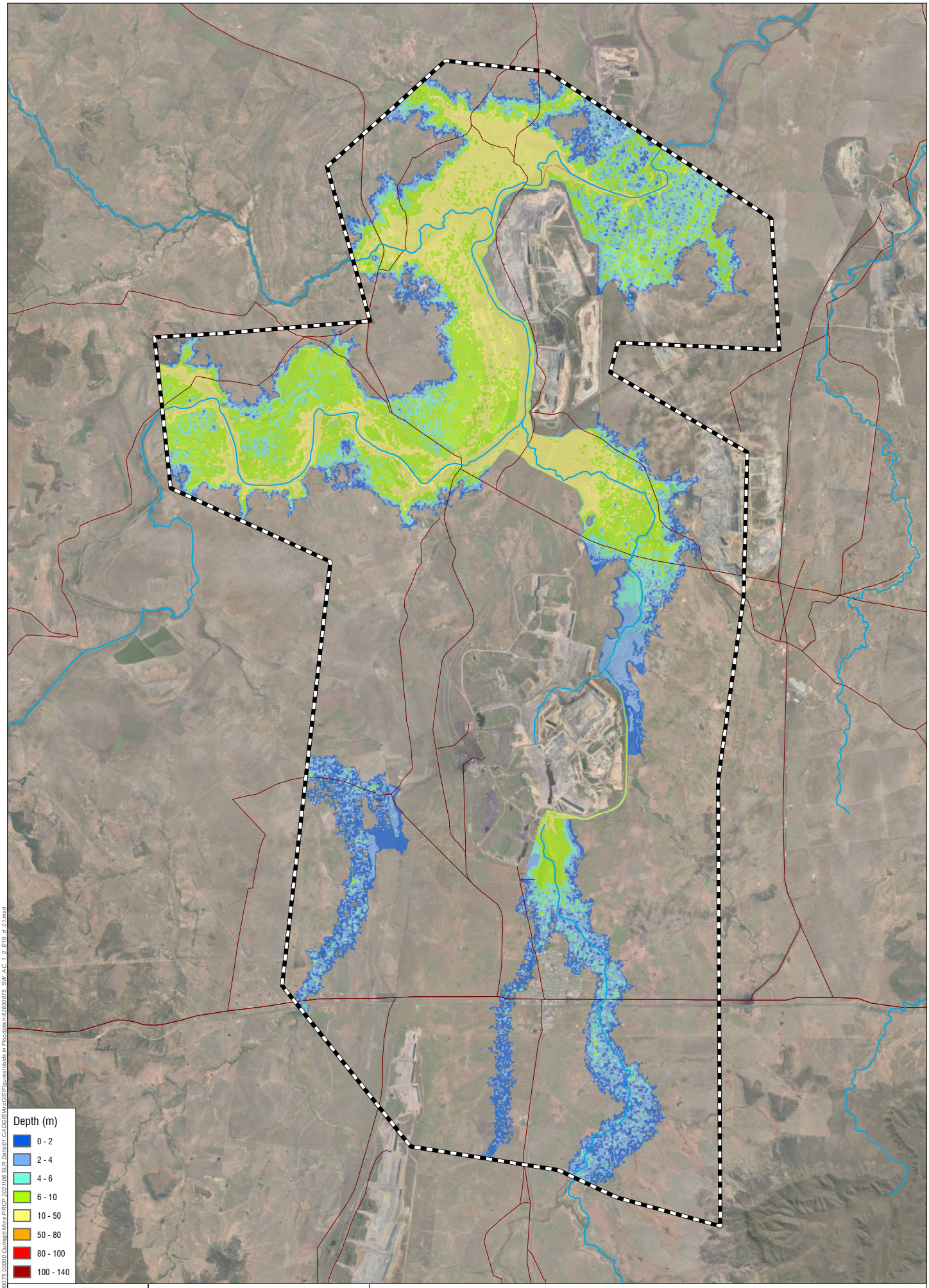
Mining_leases
TUFLOW Model Extent
Watercourse
Road

CURRAGH
PRELIMINARY FLOOD ASSESSMENT

Peak Flood Levels - 0.1% AEP

APPENDIX B1

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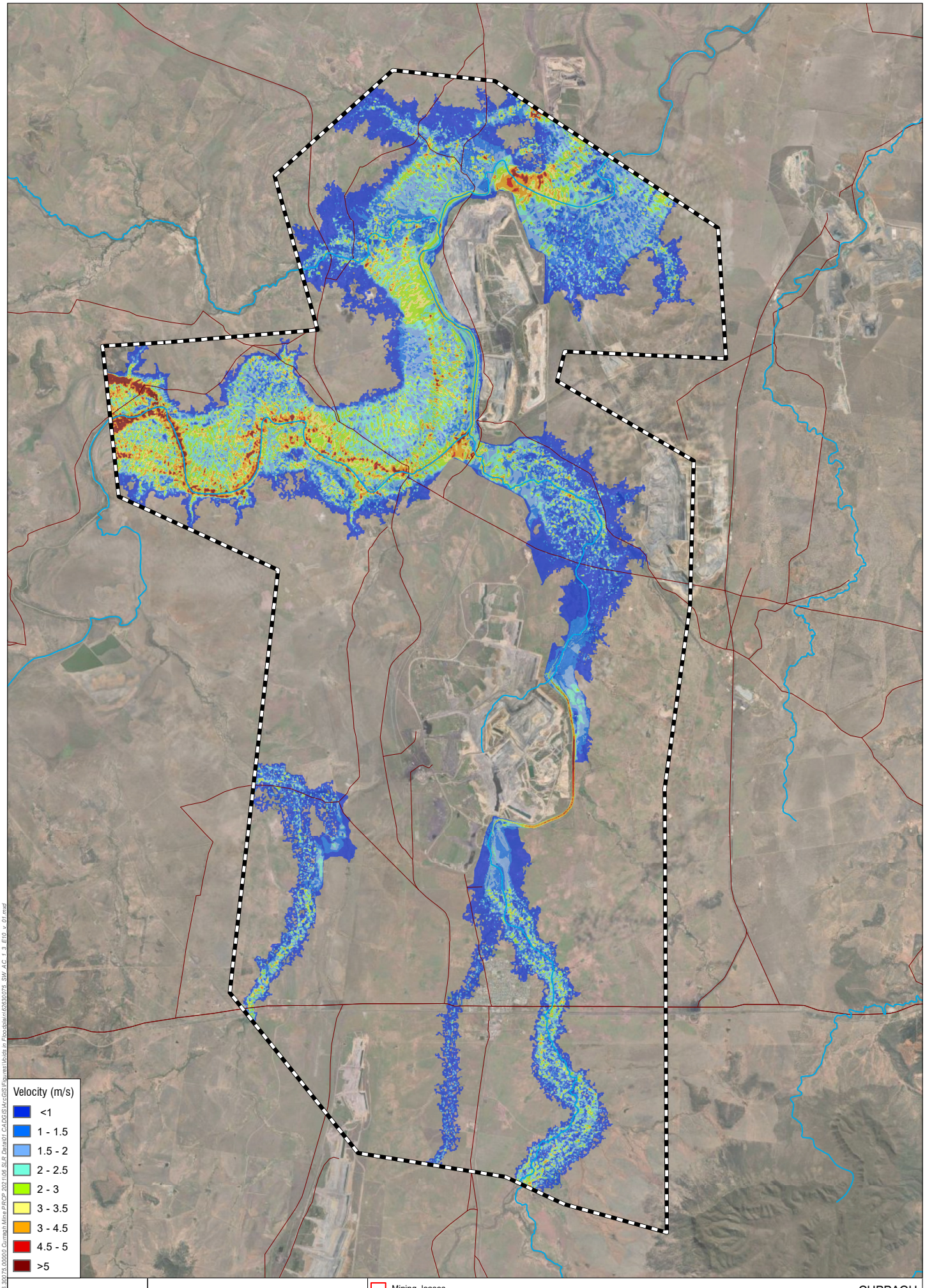
Mining_leases
TUFLOW Model Extent
Watercourse
Road

CURRAGH
PRELIMINARY FLOOD ASSESSMENT

Peak Flood Depths - 0.1% AEP

APPENDIX C2

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Sheet Size : A3 AGD 1966 AMG Zone 55

Mining_leases

TUFLOW Model Extent

Watercourse

Road

SLR

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CURRAGH
PRELIMINARY FLOOD ASSESSMENT

Peak Flood Velocities - 0.1% AEP

APPENDIX C-3

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APPENDIX B

GROUNDWATER REPORT

CURRAGH MINE COMPLEX

Concept Residual Void Assessment
Groundwater Technical Appendix

Prepared for:
Coronado Curragh Pty Ltd
Blackwater, QLD, 4717

SLR Ref: 626.30075.00000 -R01
Version No: -v0.1
November 2021

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BASIS OF REPORT

This report has been prepared by SLR Consulting Australia Pty Ltd (SLR) with all reasonable skill, care and diligence, and taking account of the timescale and resources allocated to it by agreement with Coronado Curragh Pty Ltd (the Client). Information reported herein is based on the interpretation of data collected, which has been accepted in good faith as being accurate and valid.

This report is for the exclusive use of the Client. No warranties or guarantees are expressed or should be inferred by any third parties. This report may not be relied upon by other parties without written consent from SLR.

SLR disclaims any responsibility to the Client and others in respect of any matters outside the agreed scope of the work.

DOCUMENT CONTROL

Reference	Date	Prepared	Checked	Authorised
626.30075.00000 -R01-v1.0	28 November 2021	Dariarne Edwards Arash Mohajeri John Barlow	Brian Rask John Barlow	Brian Rask Emma Williams

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1 Introduction

In September 2021 SLR was engaged by Coronado Curragh Pty Ltd (CCPL) to provide a Concept Residual Void Assessment (CRVA) for the Curragh Mine Complex (the mine). In support of the CRVA a groundwater assessment of the mine and final landforms has been undertaken including two key components, a conceptual hydrogeological model and numerical groundwater modelling. The objective of the groundwater assessment in support of the CRVA is to understand the post closure groundwater regime around the mine, and specifically to:

- present an understanding of the hydrogeological setting of the mine including potential groundwater receptors
- Simulate the post mining groundwater level recovery using the final landform (mine void backfill levels) developed by Coronado to understand whether the final voids act as groundwater sinks or sources; and;
- Understand the long-term effect of the proposed post mining landform on local groundwater levels i.e., the residual drawdown, and post-mining groundwater flux.

This groundwater assessment presents a preliminary assessment of the hydrogeological aspects of the mine closure primarily to support the CRVA submission in November 2021. A more detailed groundwater assessment will be prepared to support the Progressive Rehabilitation Closure Plan (PRCP) for the mine.

This preliminary assessment is based substantially on the Groundwater Technical Report prepared for Wesfarmers Resources Pty Ltd by WSP in support of the Curragh Extension Project (WSP 2016). The WSP assessment presents a comprehensive hydrogeological conceptualisation for the mine and the results of predictive numerical groundwater modelling. The WSP report, and specifically the numerical groundwater modelling, was peer reviewed by HydroSimulations (2016), and the 2016 model has been used as the basis for the numerical modelling completed for this assessment.

Section 2 of this report presents a summary of the hydrogeological setting of the mine and conceptual hydrogeological model drawing on the groundwater assessment prepared by WSP in 2016 for the mine expansion. Section 3 presents an overview of the numerical groundwater model setup and development, including model calibration and prediction. Section 4 describes the post closure modelling and groundwater recovery including the long term post-closure groundwater levels compared to pre mining conditions i.e., the residual drawdown. Conclusions, recommendations, and limitations are presented in Section 5.

2 Conceptual Hydrogeological Model

2.1 Physical Setting

The Curragh Mine is located in Central Queensland within the Fitzroy Basin in an area dominated by grazing, farming and coal mining. The mine extends across an area from approximately 3 km to 35 km north of the township of Blackwater, with an additional expansion pit (Pit Z) located 5km to the WNW of Blackwater. Neighbouring mines include Blackwater to the southwest of Blackwater Township, Mackenzie South located approximately 2.5 km east of Curragh and Jellinbah Central located approximately 5.5 km east of Curragh.

Figure 2-1shows the mine location in the context of the local area, drainage, surrounding mines, topography as well as the general mine layout and pit configuration.

The site is broadly divided into Curragh North (Pits S, T, U and associated spoil dumps); Curragh Main (Pits A & B (both TSFs), C, D, E, F, G, and H), and the expansion areas (Pits X, Y, Z, J and Ramp 9), where mining has not yet commenced. Mining at Curragh is projected to end in 2038.

2.1.1 Topography and land use

The land surrounding the mine is typically gently undulating and comprises the floodplain of Mackenzie River. The topography of the area is dominated by the major drainage features (Mackenzie River and tributaries), creek lines, and the open cut pits and spoil dumps of Curragh Mine and neighbouring mines. Topography and drainage near the Project area is shown on Figure 2-1.

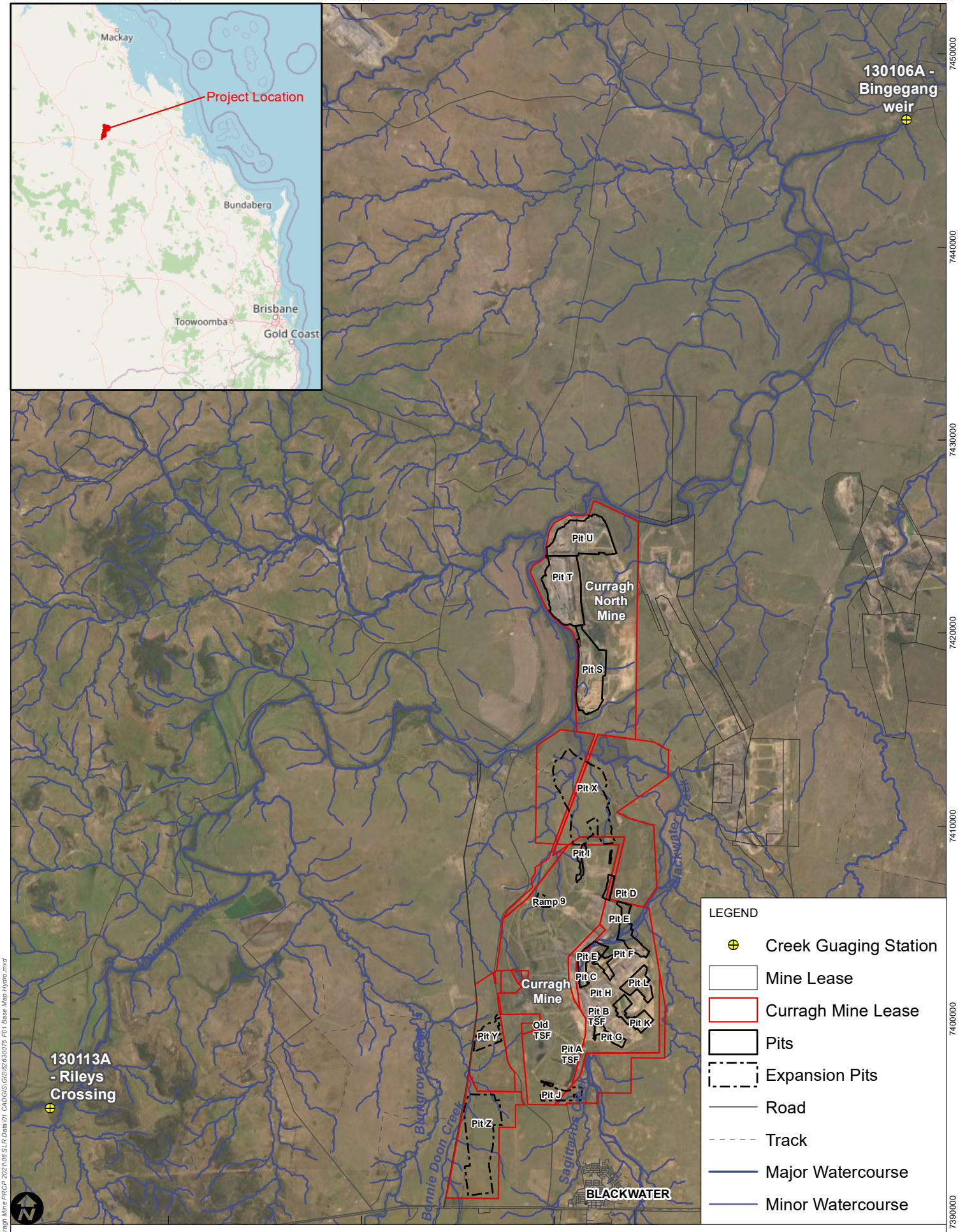
Aside from the Township of Blackwater and the surrounding mines land use is rural with large areas predominantly turned over to livestock grazing with some dryland cropping and minor irrigated cropping adjacent to Mackenzie River.

2.1.2 Climate

The climate of the region is subtropical with the highest rainfall and evaporation occurring from October through till March (BoM, 2021). Historical climate data was obtained for the period January 1900 to September 2021 from the Scientific Information for Landowners (SILO) database (Queensland Government, 2021) for the location of the Project area (latitude -23.5, longitude 148.9). Table 2-1 outlines the total monthly average rainfall and evaporation. The data shows that the total potential average annual evaporation (2,054 mm/yr) is almost four times annual rainfall (565 mm/yr). The high annual evaporation rates are strongly related to seasonal temperatures (Figure 2-2).

Table 2-1 Total Monthly Rainfall and Evaporation (January 1900 to August 2021)

Average Total Monthly (mm)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Rainfall	93	88	58	30	29	29	24	16	21	42	56	80	565
Evaporation	229	184	190	151	118	94	103	132	173	214	226	240	2,054



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0 5 10 km

Data Source:© OpenStreetMap, 2021, QLD DNREM, 2021

Coordinate System:	AGD 1984 AMG Zone 55
Scale:	1:250,000 at A4
Project Number:	626.30075
Date:	26-Nov-2021
Drawn by:	ML
Reviewed by:	ML

Preliminary Groundwater Assessment for Curragh CRVA
Curragh Mine location and layout

FIGURE 2-1

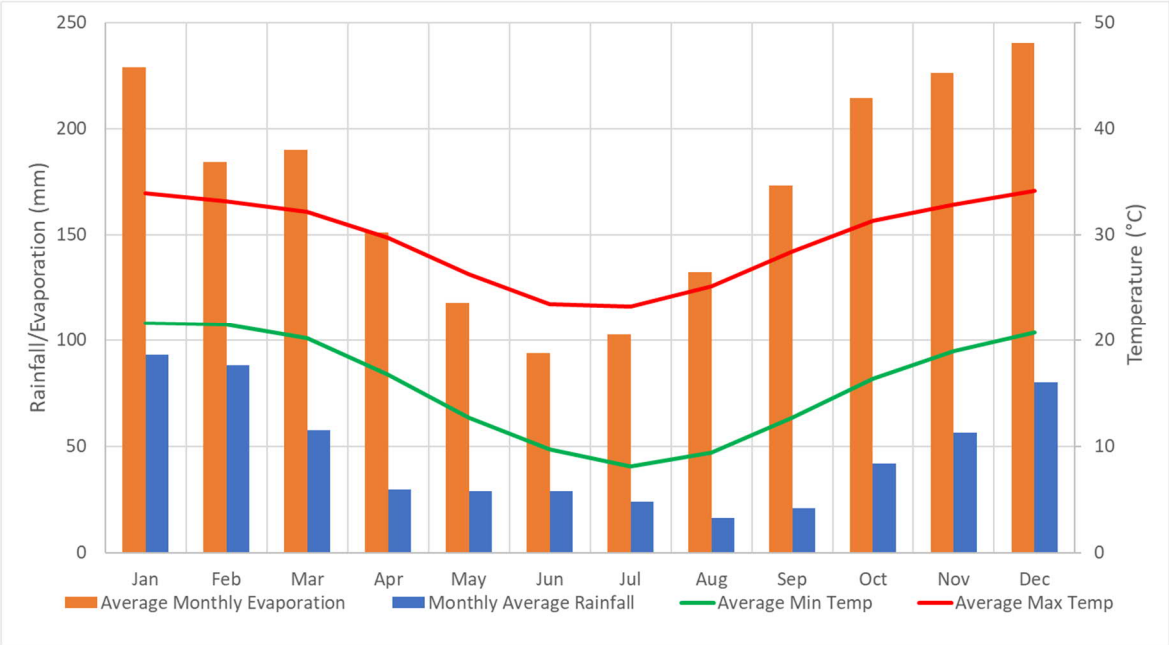


Figure 2-2 Average Monthly Evaporation, Rainfall and Temperature (January 1900 to August 2021)

In order to assess recent rainfall distribution into a historical context, the cumulative rainfall departure (CRD) was calculated for the data period 1900 to 2021 (Figure 2-3). The CRD is a summation of difference between the actual monthly rainfall compared to the average monthly for the same period. A rising slope in the CRD indicates periods of rainfall above the long term average (e.g., 2010 to 2012), and a falling slope indicates periods when rainfall is below the long term average (e.g., 1999 to 2007). Rainfall volumes over more recent years of the record (2017 to 2021) have been lower than average, as is indicated by the falling slope in the CRD.

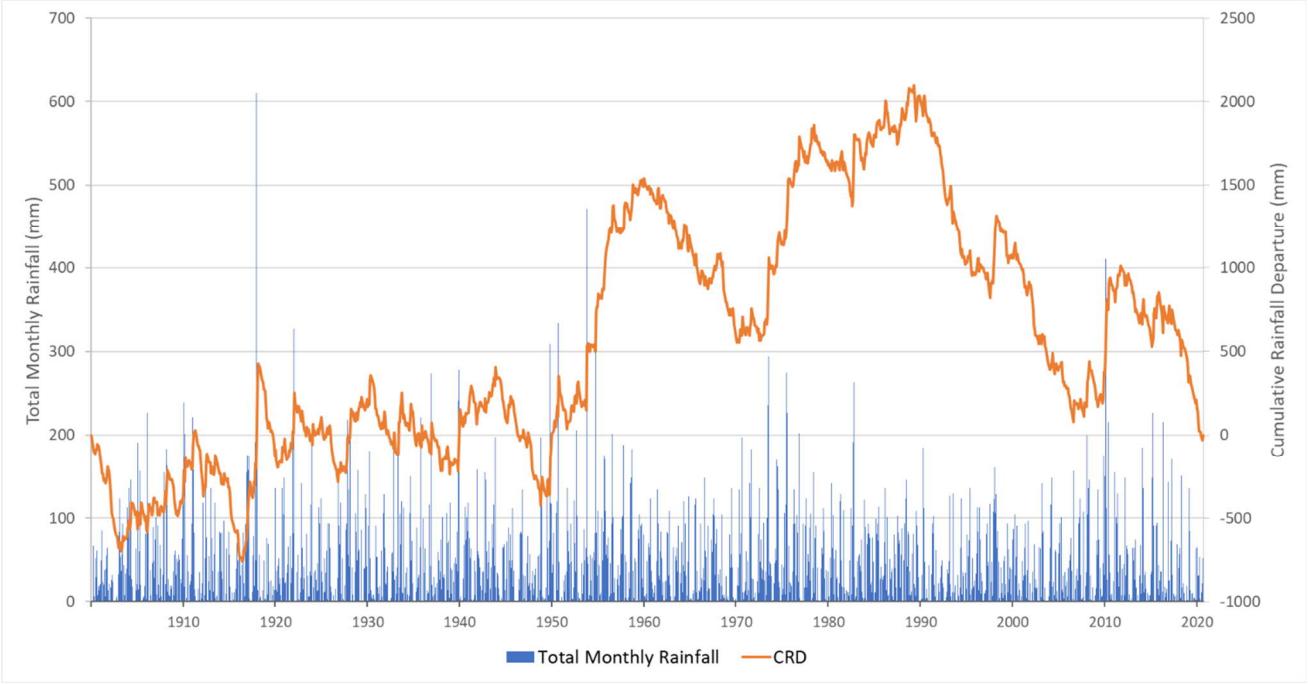


Figure 2-3 Cumulative Rainfall Departure and Total Monthly Rainfall (1900-2021)

Since the start of mining in 1983 the area has generally seen lower than average rainfall except for the remainder of the 1980s and significant wet seasons in late 1998 and 2010/11.

2.1.3 Hydrology

2.1.3.1 Mackenzie River

The mine extends across the floodplain of the Mackenzie River and its tributaries, the Mackenzie River being the main watercourse in the area and a major tributary of the Fitzroy River. The Mackenzie River forms at the confluence of the Nogoa and Comet rivers, 30km west of Blackwater. The total catchment area of Mackenzie River to Bingegang Weir, 25km downstream of the mine, is approximately 51,000 square km. To the northwest of the mine the Mackenzie River floodplain is a relatively flat, with the current course of the river meandering through an alluvial tract between approximately 3 to 8 km in width.

Fairbairn Dam located upstream on the Nogoa River approximately 80km WSW of Blackwater stores 1,300 gigalitres (GL) when full. Releases from the dam maintain levels downstream so that various towns, mines and irrigators can be supplied. This regulation of the Mackenzie River has altered the natural flow regime.

Figure 2-4 presents flow duration curves for the gauge at Riley's Crossing (130113A) 25km west of Blackwater, and for Bingegang weir (130106A) 25km north-west (downstream) of the northern extent of the mine. The data indicates that higher flows mostly driven by rainfall over the catchment naturally result in increasing flows downstream with Bingegang recording higher flows than Riley's Crossing upstream when flows at both gauges are above ~200 ML/d. Below ~200 ML/d the effects of river regulation by releases from Fairburn Dam and downstream extraction / losses appear to be apparent with perennial flow recorded at Riley's Crossing whilst downstream at Bingegang there appears to be no flow over the weir 70% of the time.

The main tributaries of Mackenzie River in the study area include Blackwater Creek, Burngrove Creek, Cooroora Creek and Scrub Creek.

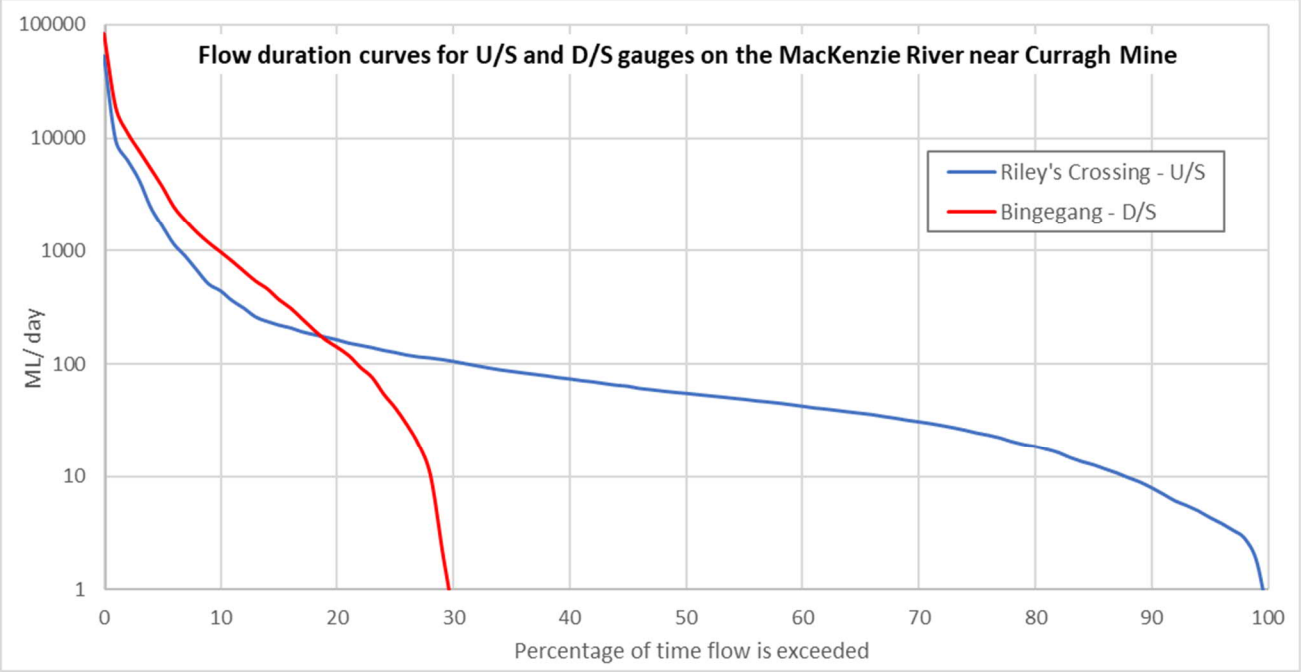


Figure 2-4 Flow Duration Curves for Gauging Stations on the Mackenzie River in the Vicinity of Curragh Mine (Nov 2013 – Oct 2021)

2.1.3.2 Blackwater Creek and tributaries

The main tributary of Mackenzie River in the study area is Blackwater Creek, which flows in a northerly direction to the east of Curragh Main via a major diversion around Pits J, K, L, F, and E. Blackwater Creek is naturally ephemeral although at its upstream end, it constantly flows due to discharge of treated effluent from Blackwater Wastewater Treatment Plant into Sagittarius Creek between Blackwater and the mine (PB 2016).

Blackwater Creek is highly modified having been diverted several times to accommodate mining at Curragh. The current Blackwater Creek diversion is a 9 km long engineered drainage structure made of compacted earth vegetated with grasses and shrubs. The discharge from Blackwater WTP is observed along the extent of the diversion although not north of the diversion (PB 2016).

Just downstream of the diversion around Curragh Main and to the east of the proposed Pit X Blackwater Creek becomes an ephemeral braided channel system.

Tributaries of Blackwater Creek include Taurus Creek, Sagittarius Creek, Minnie Creek and Bullock Creek, all of which are ephemeral. Minnie Creek flows through the proposed Pit X area and will be subject to a 5.3 km diversion near its confluence with Blackwater Creek plus a 2.9 km diversion of one of its unnamed tributaries around the western side of the pit prior to the commencement of mining in this area (PB 2016).

2.1.3.3 Burngrove Creek and tributaries

Other tributaries of Mackenzie River in the Project area include Burngrove Creek. A tributary of Burngrove Creek is Bonnie Doon Creek, which flows in a northerly direction to the west of proposed Pit Z and will be subject to a diversion. Both Burngrove Creek and Bonnie Doon Creek are ephemeral.

2.1.4 Geology

The surface geology across the study area (based on the 1:100,000 mapping), is presented in Figure 2-5 and the regional (solid) geology is presented in Figure 2-6

The study area is underlain by Permian to Quaternary sediments located within a gently folded and faulted sequence of the Bowen Basin. The Permo-Triassic sediments dip eastward and include the Triassic Rewan Formation and the underlying Permian Blackwater Group, which includes the Rangal Coal Measures, Burngrove Formation and Fair Hill Formation. The Triassic strata are overlain by unconsolidated Quaternary alluvium associated with creeks, rivers and floodplains and the poorly consolidated Tertiary sediments of the Duaringa and Emerald formations. The Back Creek Group underlies the Blackwater Group and forms the basement of the area.

The stratigraphic sequence underlying the study area is presented in Table 2-2 and summarised below.

2.1.4.1 Quaternary and Tertiary alluvium

Alluvium associated with the main watercourses of the Mackenzie River and Blackwater Creek (and their tributaries) is present across much of the extension areas as much of Curragh North.

In the proposed Pit X area, exploration drilling indicates the alluvium is typically less than 12m thick and predominantly comprised of clay with occasional channel sand and gravel lenses at depth. Alluvium in the vicinity of proposed Pit J and Pit Z is generally thin (typically 2m but up to 4m) and comprised of clay and silt. Alluvium occurs in the southeast corner of proposed Pit D extension and is typically less than 2m (and up to 10m) and comprised of clay and sand (WSP 2016).

Floodplain alluvium associated with the Mackenzie River occurs extensively at Curragh North and exhibits an overall fining upwards sequence and significant lateral variability with an average thickness of 18 - 20m. Drilling data indicates the alluvium may be up to 35 m thick and the base of the alluvium is deepest close to the Mackenzie River (WSP 2016).

Table 2-2 Regional Stratigraphy

Age	Group	Stratigraphic Unit	Description
Quaternary		Alluvium	Soils, unconsolidated silts, sands, gravels and clays,
Cenozoic (Tertiary)		Duaringa Formation/ Emerald Formation	Claystone, siltstone, sandstone, conglomerate (often poorly consolidated), lignite, basalt
Triassic	Mimosa	Rewan Formation	Mudstone, interbeds of lithic sandstone.
Upper Permian	Blackwater Group	Rangal Coal Measures	Coal seams calcareous sandstone, calcareous shale, mudstone, calcareous tuff in places. Main coal seams include Aries, Castor, Pollux, Orion, Pisces.
		Burngrove Formation	Siltstone, carbonaceous shales and mudstone, fine lithic sandstone, calcareous lithic and feldspathic sandstone, tuffaceous shales and thin coal seams.
		Fair Hill Formation	Lithic and feldspathic labile sandstone, quartzose sublabile sandstone, siltstone, mudstone, calcareous and tuffaceous sandstone, volcanic conglomerate, carbonaceous mudstone, coal
Permian	Back Creek Group	Macmillan Formation	Interbedded mudstone and sandstone, prominent dark grey basal unit.

2.1.4.2 Cenozoic sediments

The Duaringa Formation is present in the proposed Pit X and Pit D extension areas and outcrop extensively in the north, east and south of the study area. In the north of the study area the Cenozoic sediments have been eroded by the Mackenzie River. The Emerald Formation is present in the western section of the proposed Pit X area and outcrop in the west of the study area (WSP 2016).

The Cenozoic sediments consists of interbedded stiff to hard clayey sands, gravels and thick beds of ferruginous clays of medium to high plasticity. They are fluvial and colluvial in origin and partially consolidated. The sequence unconformably overlies Permian coal measures with an indistinct boundary due to the clay rich and ferruginous composition of both horizons caused by in-situ weathering (WSP 2016).

2.1.4.3 Triassic sediments

The Rewan Formation overlies the Rangal Coal Measures and outcrops / subcrops directly east of the mined areas. It typically comprises thinly interbedded mudstones, lithic sandstones and siltstones. Drilling in the Minyango mine area recorded Rewan Formation up to 350m thick with a depth of weathering between 30 and 70 m (WSP 2016).

2.1.4.4 Permian sediments

The Permian Rangal Coal Measures (RCM) is the uppermost sequence in the Blackwater Group and comprises predominantly fine grained to occasionally medium grained lithic sandstone, siltstone, mudstone, carbonaceous mudstone and coal.

The RCM contain seams of high quality PCI coal, high quality medium-to-low ash coals suitable for prime coking coal, anthracite and semi-anthracite, and high energy thermal coals. The Cancer, Aries, Castor, Pollux, Orion and Pisces seams within the RCM are mined at Curragh. The strata generally dip to the east at less than 3°, with dips increasing locally in fault zones. The Rangal Coal Measures outcrop / subcrop in Curragh North and Curragh Main areas. The Rangal Coal Measures also subcrop east (the upthrow side) of the Jellinbah Fault where they are extracted at Jellinbah Mine (WSP 2016).

The boundary between the Burngrove Formation and the overlying RCM is the Yarrabee Tuff Bed, a distinctive marker horizon. The tuff lies between the target Pisces seam in the RCM and the Pisces Lower seam. The upper part of the Burngrove Formation (below the Yarrabee Tuff Bed and Pisces Lower seam), comprise dark grey to grey mudstones grading to siltstones. The Burngrove Formation outcrops/subcrops in the proposed Pit X, Y and Z locations and to the west of Curragh Mine (WSP 2016).

The Fair Hill Formation underlies the Burngrove Formation and outcrops/subcrops to the west of the mine. The formation comprises lithic sandstone, conglomerate, mudstone, carbonaceous shale, coal, tuff and tuffaceous mudstone and includes the Fort Cooper Coal Measures.

The upper Permian sediments are weathered. The depth of weathering in the study area is approximately 14 metres below ground level (mbgl), except where Quaternary erosion and deposition has resulted in the replacement of Permian sediments by Quaternary alluvium. Where this occurs deeper weathering up to 35 mbgl is observed (WSP 2016).

2.1.5 Structural geology

The mine is located within an area of the Bowen Basin subject to faulting and gentle folding. The study area lies on the eastern limb of the Comet Ridge, adjacent to the Folded Zone within the Bowen Basin. This ridge was formed over an existing basement platform, creating a regional anticlinal structure with low amplitude and gentle folds (WSP 2016).

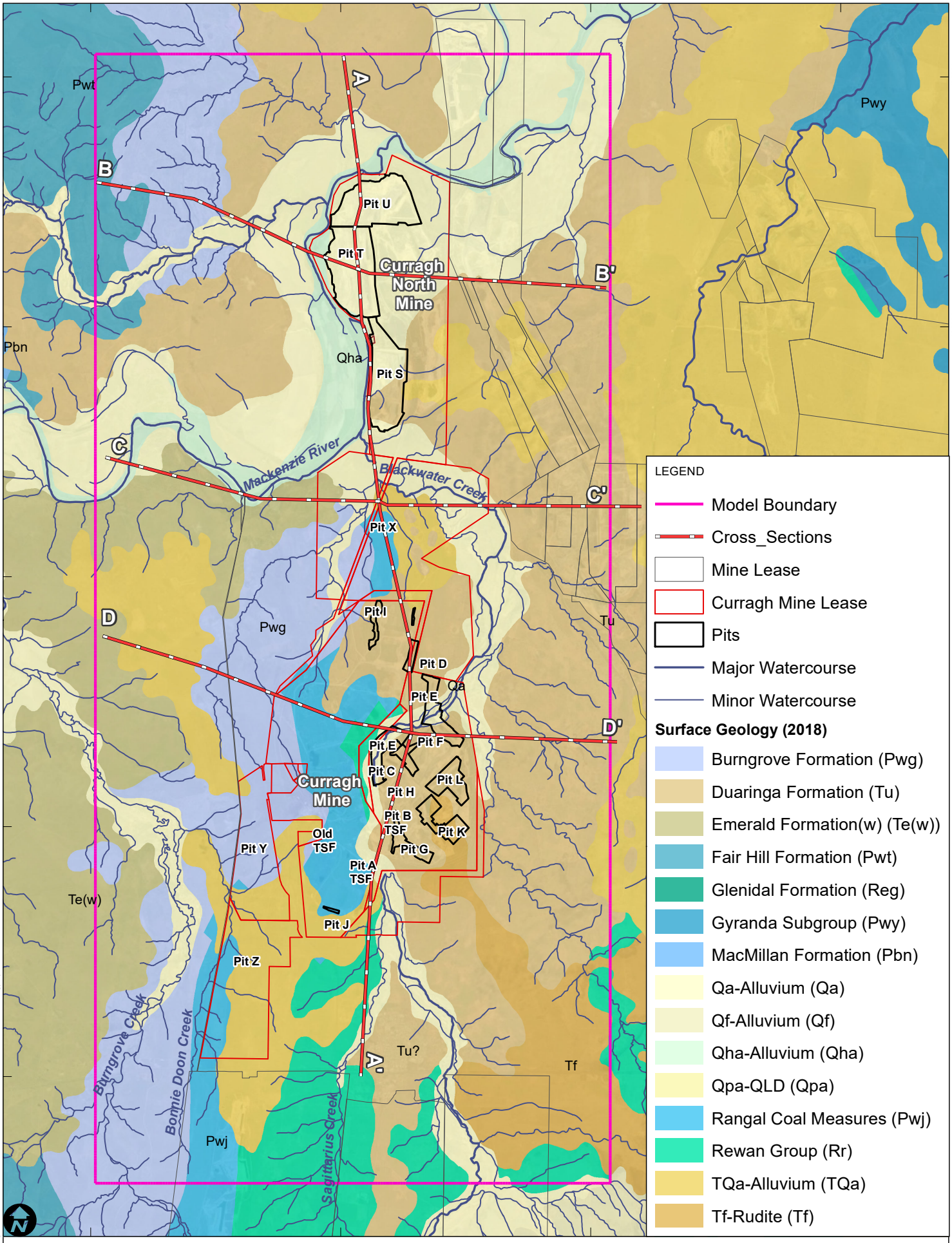
The NNW-SSE trending Jellinbah Fault is located directly east of Curragh North and approximately 5 km east of Curragh Main. It is the major fault structure in the Curragh Mine region. The fault has an approximate vertical displacement of 120 m brining the RCM back up to depths that allows the Jellinbah Mine to target the associated coal seams (WSP 2016).

The RCM in the vicinity of the mine have been affected by low angle thrust faulting from the north-east and results in seam displacements up to 20 m vertically. Fault deformation has resulted in seam thinning, seam repetitions and absenting occurring throughout the Curragh Mine (PB 2016).

2.1.5.1 Geological Cross-sections

Extensive exploration drilling at Curragh and neighbouring mines was analysed by PB to develop a detailed understanding of the geology in the vicinity of the mine for the 2016 expansion project. This included the development of detailed conceptual cross sections which have been reproduced in Figures 7 to 10 (PB 2016). The cross-sections show the geology of the study area and the progression of mining as of August 2015 and were developed using LiDAR, drill hole data and the mine geological model as well as exploration data for neighbouring mines obtained from Queensland Globe.

The locations of the cross-sections (which are shown on Figure 2-5), comprise a north-south long section (A-A' Figure 2-7), and three east-west long sections (B-B' Figure 2-8, C-C' Figure 2-9, and D-D' Figure 2-10)



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0 5 10 km

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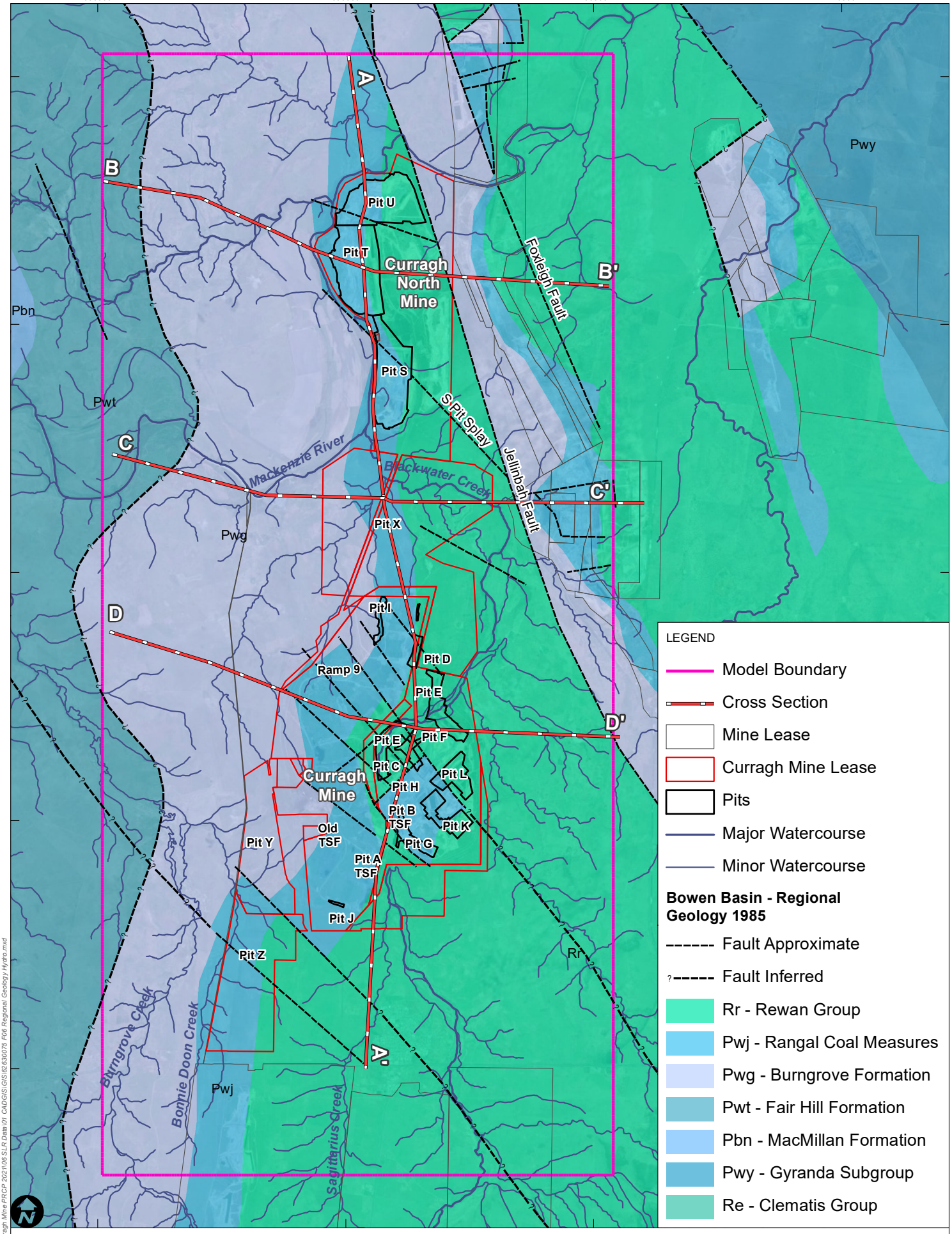
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Preliminary Groundwater Assessment for Curragh CRVA Surface Geology

FIGURE 2-5

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Preliminary Groundwater Assessment for Curragh CRVA Regional Geology

FIGURE 2-6

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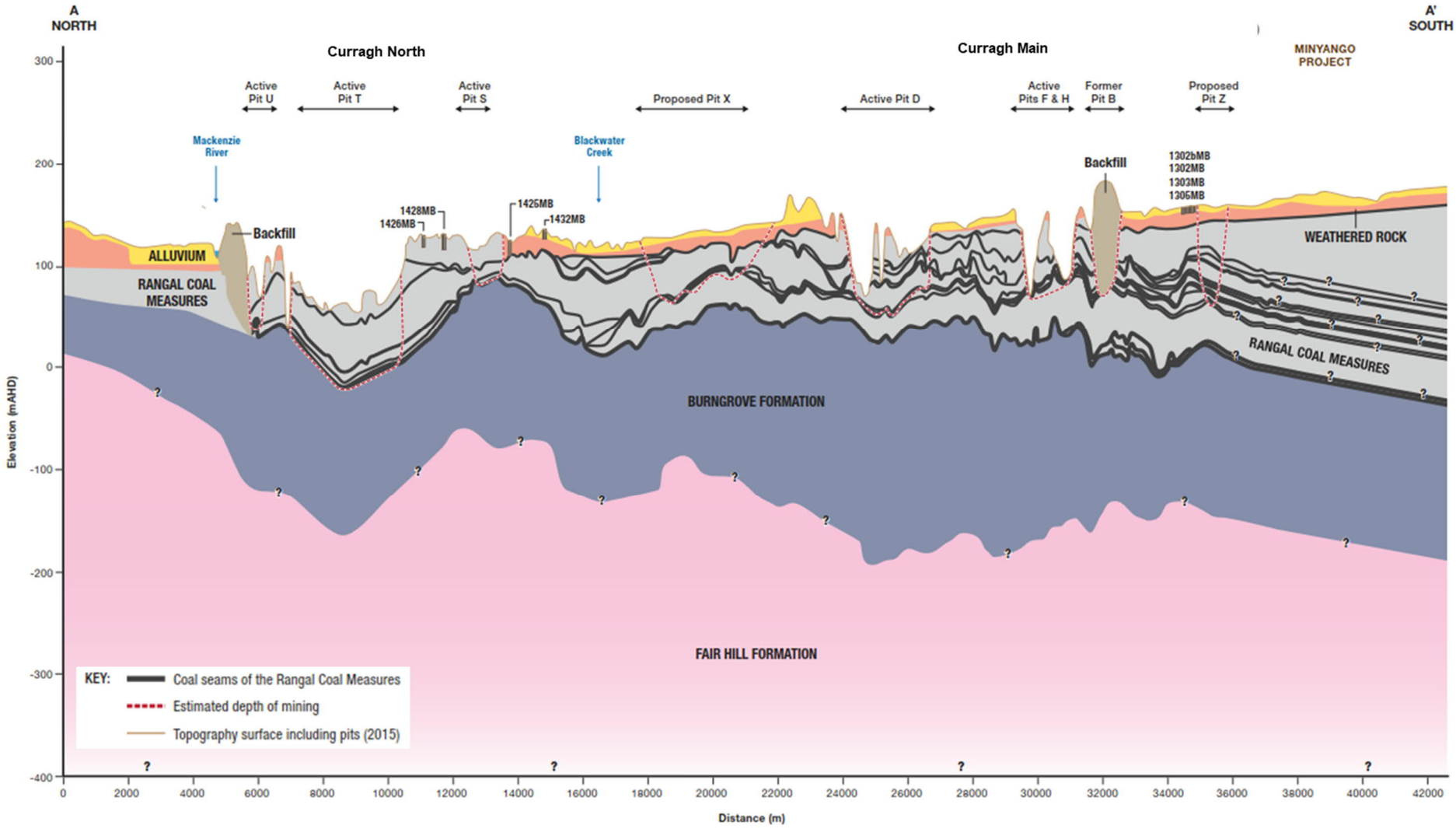


Figure 2-7 Conceptual geological cross-section A-A' (from PB, 2016)

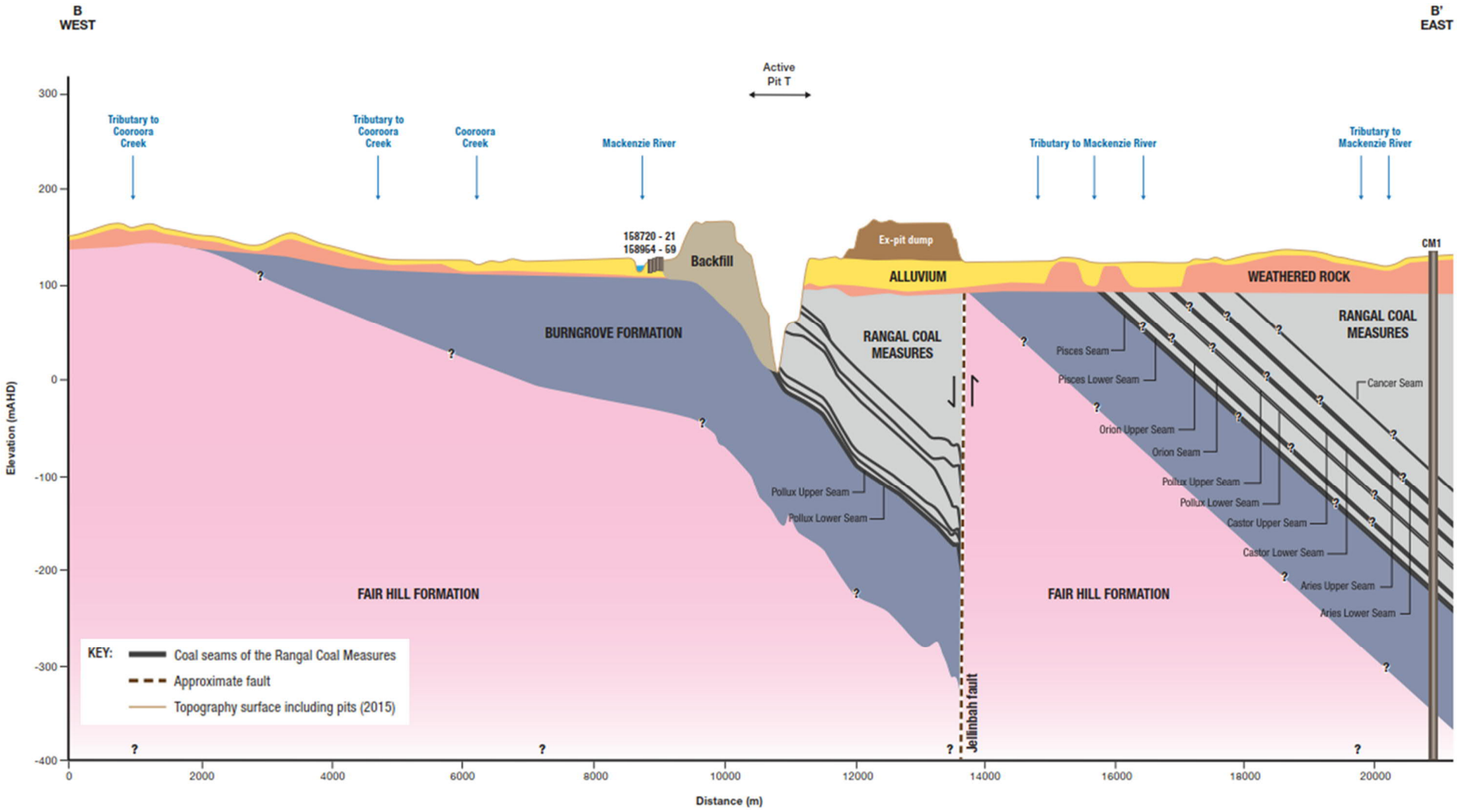


Figure 2-8 Conceptual geological cross-section B-B' (from PB, 2016)

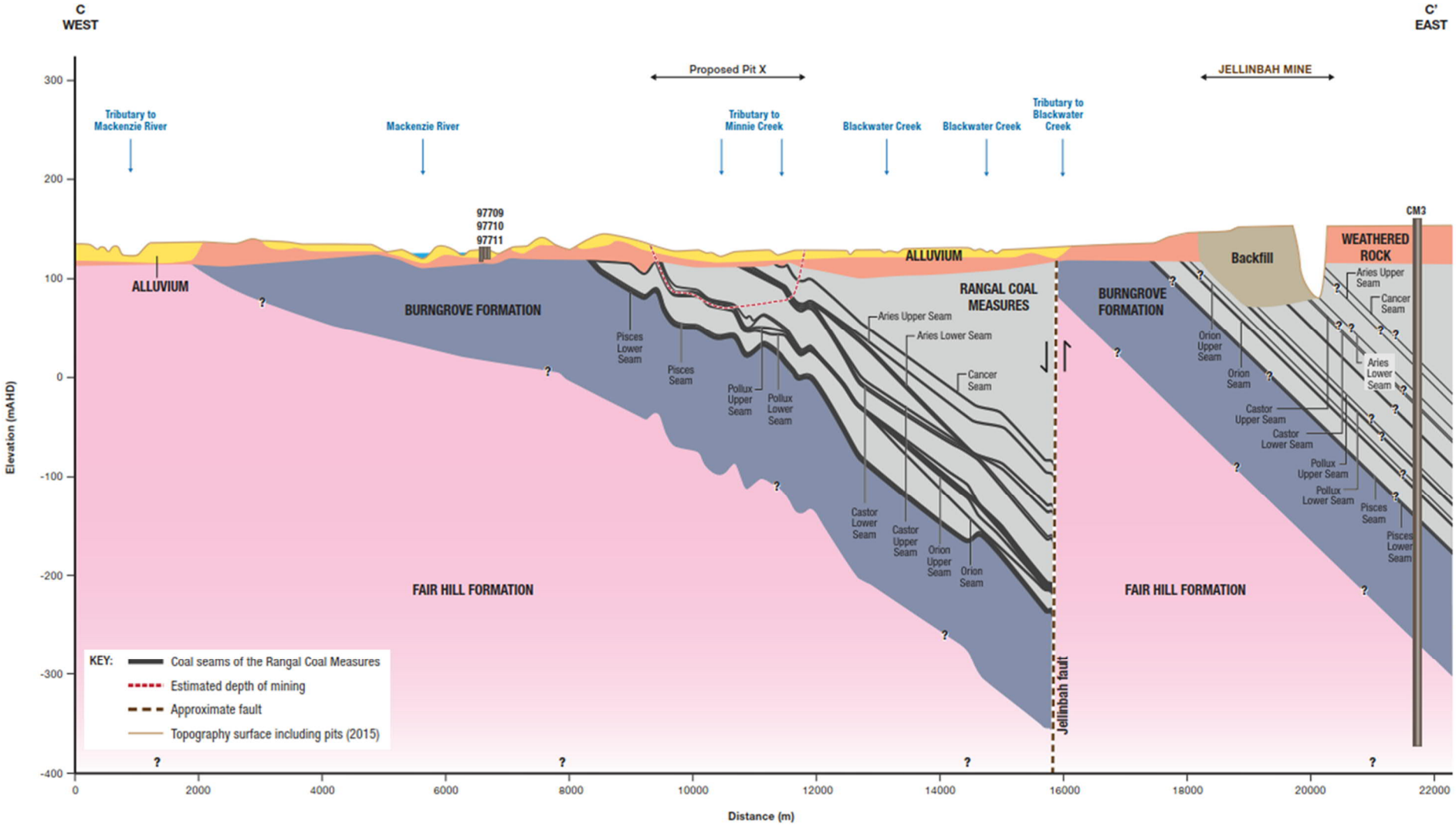


Figure 2-9 Conceptual geological cross-section C-C' (from PB, 2016)

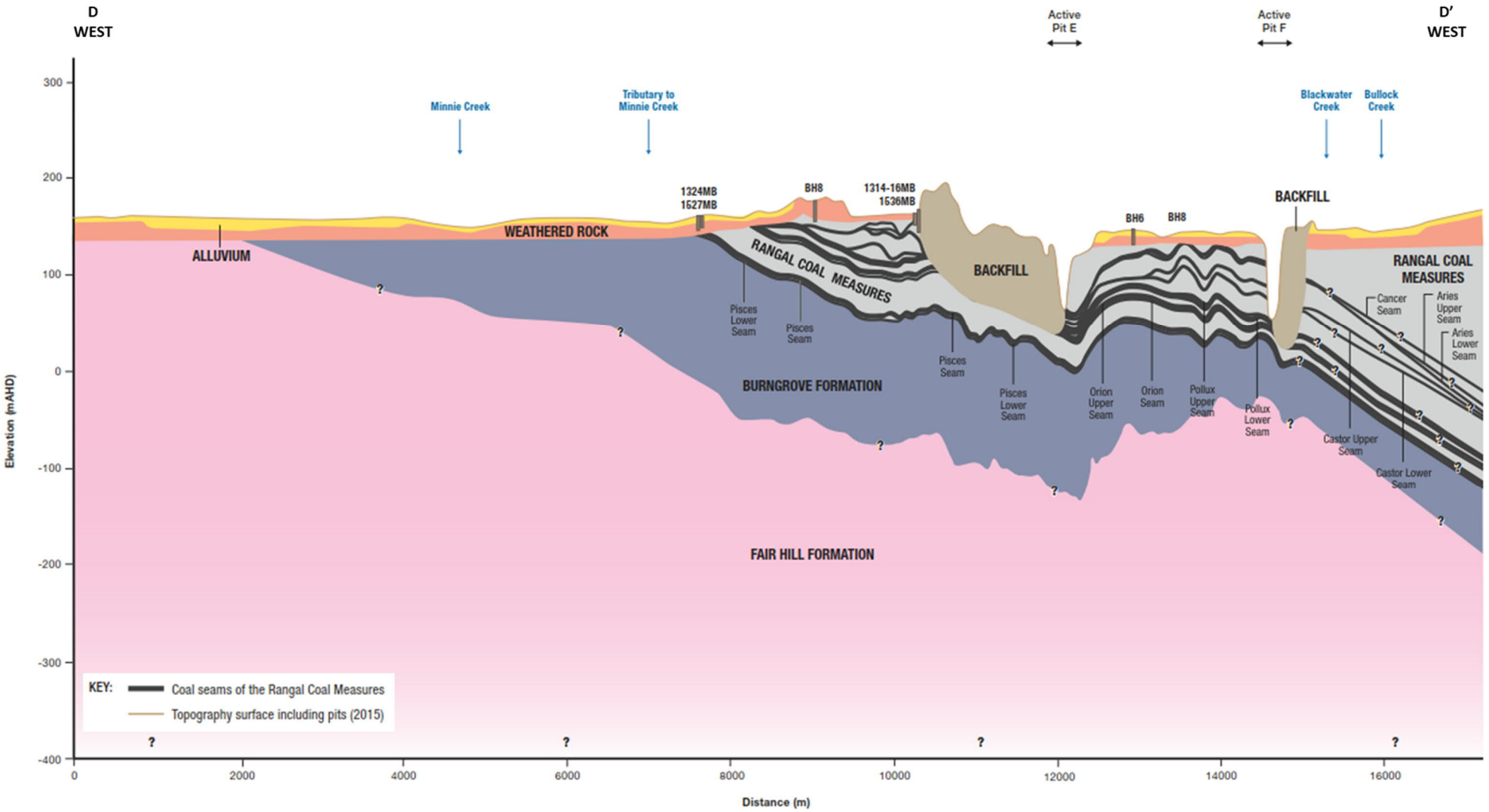


Figure 2-10 Conceptual geological cross-section D-D' (from PB, 2016)

2.2 Groundwater Monitoring Data

2.2.1 Groundwater Monitoring Network

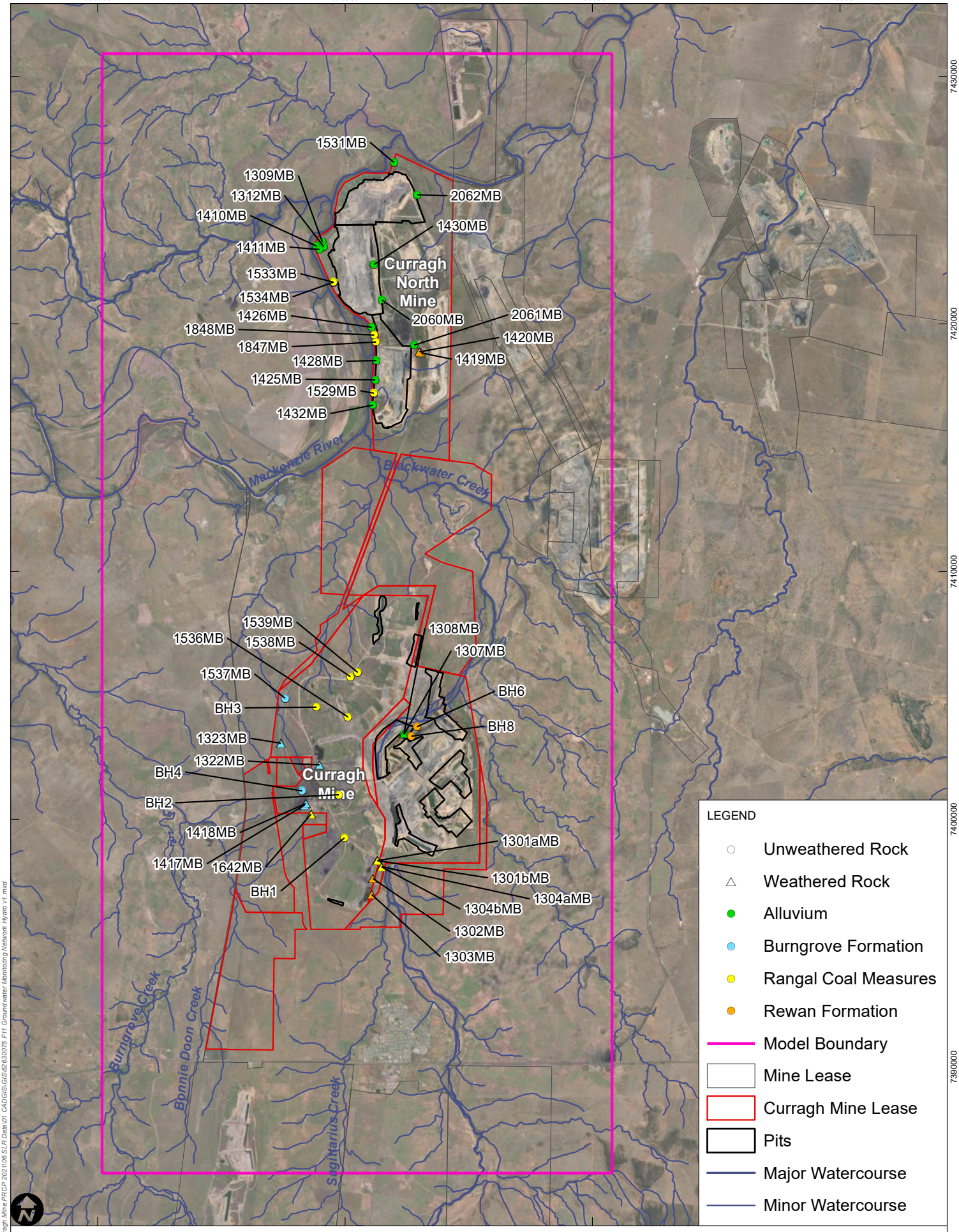
The groundwater monitoring network at Curragh Mine has progressively developed since the 1990s. The available monitoring data indicates that there are 36 bores from which data is currently collected with 22 used for groundwater quality monitoring and 23 used for groundwater level monitoring. The monitoring bore network for the mine is shown in Figure 2-11. Details of the monitoring bores, including bore construction, target formation and date of installation, are provided in Table 2-3.

Groundwater monitoring bores across the mine have been installed in the alluvium, Duaringa Formation, Rewan Formation, Rangal Coal Measures and the Burngrove Formation, with emphasis on water bearing units. The network has been designed to improve the understanding of the hydrogeological conditions in the area surrounding the mine and identify impacts associated within mining operations. Monitoring bore locations have been chosen to:

- provide spatial coverage across the area
- provide hydrogeological data on the range of formations and hydrogeological environments
- identify potential impacts to sensitive features such as groundwater dependent ecosystems (GDEs) and areas of potential surface water-groundwater interaction
- detect changes in groundwater conditions due to seepage from site infrastructure, including tailings storage facilities (TSFs), landfills, fuel farms and water storage dams
- establish a baseline of undisturbed groundwater conditions so that trigger levels can be developed to detect impacts associated with mining.

The Groundwater Monitoring Plan for the site identifies three categories of monitoring bore:

- compliance bores - monitored to assess potential impacts from mining activity on sensitive receptors
- reference bores - monitored to establish baseline groundwater conditions so that appropriate trigger levels for the detection of impacts associated with mining can be developed
- observation bores - monitored to improve the understanding of the hydrogeological conditions in the area surrounding the mine.



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H:\Projects-SLR\626-MKY\626.30075.00000 Curragh Mine PRCP 20211106 SLR Data \01 CAD\GIS\GIS\626.30075 F11 Groundwater Monitoring Network Hydro v1.mxd

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Reviewed by:	ML

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Preliminary Groundwater Assessment for Curragh CRVA Groundwater monitoring network

FIGURE 2-11

Table 2-3 Groundwater Monitoring Bores

Bore	Easting	Northing	Ground RL (mAHD)	Screen Depth (mbgl)	Formation description	Date installed	Location	Available data	
								Water Quality	Water Level
Alluvium									
1307MB*	692378	7403433	143.16	4 – 7	Alluvium	08-07-2013	Dam A	no	yes
1308MB*	692387	7403452	143.30	10 – 14	Alluvium / weathered Tertiary (Duaringa Fm.)	09-07-2013	Dam A	no	no
1309MB”	689082	7423302	124.43	12 – 18	Alluvium	10-07-2013	CN3 (between pit and Mackenzie R)	yes	yes
1312MB*	689148	7423118	125.93	11 – 17	Alluvium	11-07-2013	CN3 (between pit and Mackenzie R)	yes	yes
1426MB”	691085	7419864	128.79	12 – 26	Alluvium	25-11-2014	S Pit West - below levee north	yes	yes
1428MB*	691266	7418518	127.9	13 – 26	Alluvium	26-11-2014	S Pit West - below levee central	no	no
1531MB*	691987	7426518	125.53	21 – 27	Alluvium	16-07-2015	U Pit extension - north near levee	yes	yes
1533MB”	689529	7421689	132.36	21 – 27	Alluvium	15-07-2015	T Pit - West levee	no	no
1410MB”	688842	7423144	126.05	10 – 18	Alluvium	27-11-2014	CN3	yes	yes
1430MB*	691169	7422399	127.56	22 – 27	Alluvium	21-11-2014	T Pit - East (palaeochannel)	no	no
1432MB*	691123	7416724	134.75	2 – 5	Alluvium	25-11-2014	S Pit Tertiary Ridge	no	no
1411MB”	688974	7423011	128.23	9 – 20	Alluvium	21-11-2014	CN3	yes	yes
1425MB	691229	7417747	125.12	16 – 19	Alluvium	24-11-2014	S Pit West - below levee south	no	yes
2060MB	691488.4	7420977	123.88	18 – 24	Alluvium	-	Dam A	no	yes
2061MB	692800.1	7419144	129.75	26.5 – 32.5	Alluvium	-	Dam A	no	yes
2062MB	692921.8	7425213	123.77	13 – 19	Alluvium	-	Dam A	no	yes
Tertiary									
1301aMB*	691313	7398339	151.83	4 – 11	Tertiary (weathered)	06-07-2013	New TSF (formerly Pit A R2)	yes	no
1302MB*	691118	7397611	153.64	3 – 6	Tertiary (weathered)	05-07-2013	New TSF (formerly Pit A R2)	yes	no
1303MB*	691086	7396966	156.9	3 – 6	Tertiary (weathered)	05-07-2013	New TSF (formerly Pit A R2)	yes	no
1304aMB*	691481	7398090	153.35	6 – 9	Tertiary (weathered)	04-07-2013	New TSF (formerly Pit A R2)	yes	no
1419MB^	693083	7418830	137.96	1.2 – 15	Tertiary (weathered Duaringa Fm.)	19-11-2014	Curragh North Fuel Farm	yes	no
1420MB”	693004	7418881	138.43	1.2 - 15	Tertiary (weathered Duaringa Fm.)	20-11-2014	Curragh North Fuel Farm	yes	no

Bore	Easting	Northing	Ground RL (mAHD)	Screen Depth (mbgl)	Formation description	Date installed	Location	Available data	
								Water Quality	Water Level
Rewan Formation									
BH6*	692902	7403743	141.98	n/a	Rewan Fm	n/a	Dam A and B	no	no
BH8*	692678	7403357	142.90	n/a	Rewan Fm	n/a	Dam A	no	no
Rangal Coal Measures									
BH1"	689978	7399250	157.70	n/a	RCM	n/a	Crib hut 3	yes	no
BH2"	689746	7400993	169.8	n/a	RCM	n/a	R5 landfill	yes	no
BH3"	688846	7404539	176.52	n/a	RCM	n/a	R8 landfill	yes	no
1301bMB*	691308	7398335	151.69	14 – 18	RCM (weathered)	06-07-2013	New TSF (formerly Pit A R2)	yes	no
1304bMB*	691481	7398084	153.33	14 – 17	RCM (weathered)	02-07-2013	New TSF (formerly Pit A R2)	yes	yes
1529MB"	691161	7417212	123.81	33 – 39	RCM	17-07-2015	S Pit West - below levee south	yes	yes
1534MB^	689540	7421687	132.52	27 – 33	RCM	13-07-2015	T Pit - West levee	yes	yes
1536MB"	690116	7404141	148.504	35.5 – 41.5	RCM	02-07-2015	Landfill - east	yes	yes
1538MB^	690217	7405768	153.18	73 – 79	RCM	29-06-2015	Ramp 10/11	yes	yes
1539MB*	690523	7405931	152.2	53 – 59	RCM	03-07-2015	Ramp 10/11 - second site	yes	yes
1642MB	688631	7400213	174.587	1.4 – 18.5	RCM (weathered)	n/a		no	yes
1847MB	691245.7	7419276	129.169	76.5 – 85.5	RCM (Pisces)	n/a		no	yes
1848MB	691184.3	7419553	128.902	85 – 94.5	RCM (Pisces)	n/a		no	yes
Burngrove Formation									
BH4"	688260	7401147	170.19	n/a	Burngrove Fm.	n/a	CHPP landfill	yes	no
1322MB*	688976	7402204	162.69	2 – 25	Burngrove Fm. (weathered)	26-07-2013	Down gradient of industrial process area	no	yes
1323MB^	687417	7403078	164.44	11 – 25	Burngrove Fm. (weathered)	25-07-2013	Up gradient of mining ops	yes	yes
1417MB^	688376	7400592	175.56	1.2 – 15	Burngrove Fm. (weathered)	18-11-2014	Curragh Fuel Farm	yes	no
1418MB"	688428	7400647	175.56	1.2 – 16	Burngrove Fm. (weathered)	18-11-2014	Curragh Fuel Farm	yes	no
1537MB^	687589	7404885	157.71	30.5 – 36.5	Burngrove Fm. (coal seam)	27-06-2015	SAR	yes	yes

*Observation bore, ^Reference bore, "Compliance bore

2.3 Hydrogeology

2.3.1 Hydrostratigraphy

The main hydrostratigraphic units in the vicinity of the mine are described below, from the shallowest to the deepest/oldest:

- Alluvium – up to 30m thick in the north associated with the floodplain / channel deposits of the Mackenzie River. Thinner (up to 12 m), near extension Pit X and comprises clay, sand and gravel units. At Curragh Main and southern extension Pits up to 10 m thick but generally much thinner and predominantly clay and silt. The alluvium is dry in many areas. Unconfined water bearing sand and gravel may occur at the base of the alluvial sequence around Curragh North near proposed Pit X, but it is considered unlikely to be significantly water bearing where it occurs in the south of the mine.
- Regolith - unconsolidated surface layer of weathered rock which may provide a preferential flow pathway for groundwater. Occurs across the Project area at thicknesses between 5 and 15 m. Includes weathered residual rocks of the Duaringa and Emerald formations, Rewan Formation, Rangal Coal Measures and Burngrove Formation in areas of outcrop and sub-cropping alluvium. Variable permeability.
- Cenozoic (Tertiary Duaringa and Emerald formations) - Occurs around Curragh Main extension Pits X and D. Comprises cemented sands and gravels and sandstones, siltstones and mudstones. Water bearing zones may occur in more permeable layers, unconfined to semi-confined.
- Rewan Group - is a regional aquitard comprising mudstones interbedded with siltstone and fine to medium grained labile sandstone.
- Rangal Coal Measures - Occurs along the strike of the mine and is overlain to the east by the Rewan. Groundwater flow is primarily within the coal seams (via interconnected cleats and fractures), which are confined by low permeability overburden and interburden. The coal measures are highly faulted resulting in “compartmentalisation” with coal seams juxtaposed against lower permeability interburden limiting the lateral continuity of flow. Faults themselves may form barriers to flow or provide conduits.
- Burngrove Formation – outcrops/subcrops to the west of the mine dipping east below the Rangal Coal Measures. Groundwater flow occurs primarily via the coal seams and fractured sandstone units with low permeability siltstone and claystone forming aquitards. As with the RCM sequence it is considered to be highly faulted with coal seams juxtaposed against lower permeability interburden limiting the lateral continuity of groundwater flow. This Formation is considered the basement for the purposes of this assessment.

2.3.1.1 Alluvium

The alluvium is comprised of coarse sands, gravels, silt, and clay. Groundwater present within the sand and gravel units is generally regarded as unconfined. Floodplain alluvium associated with the Mackenzie River and Blackwater Creek occurs extensively across Curragh North and the northern part of the extension Pit X.

For the 2016 expansion project hydrogeological assessment PB undertook a review of bore logs from the exploration drilling program which identified that Curragh North is underlain by a paleochannel system of significant thickness (12 - 30 m), predominantly comprising sand and gravel. The Pit X extension area is underlain by a thinner alluvial sequence (typically less than 12 m) predominantly comprising clay with sand and gravel lenses, generally occurring at depth. The alluvium in the southern areas of the mine is generally thin (<10m but typically much thinner) and comprised predominantly of clay and silt (PB 2016).

The Mackenzie River channel has migrated across the floodplain over time resulting in coarse sediments (sands and gravels) being deposited as point bar/channel lenses with overlying finer floodplain sediments. There is significant lateral variability and discontinuity in the coarser alluvial deposits which is likely to control/limit connectivity to the Mackenzie River (PB 2016). The permeability of the sands and gravels horizons within the alluvium will be variable and depend on the fines (silt/clay) content.

Groundwater studies undertaken at Curragh North prior to the commencement of mining found the majority of monitoring bores installed in alluvium were dry. Where intersected, groundwater occurred within coarse basal sands and gravels (PB 2016).

Potential impacts from mining activities will depend on intersection of the alluvium by mining and connectivity between pits and watercourses via the alluvium with the main receptors being landholder bores and GDEs.

2.3.1.2 Rangal Coal Measures

Coal seams are typically the most permeable horizons within the Rangal Coal Measures and are considered fractured rock aquifers with groundwater flow occurring via joints and cleats. The coal measures have also been extensively faulted which is likely to restrict flow through the coal seams due to the lateral discontinuity. The faults themselves may present barriers to flow or provide pathways for groundwater flow.

To the east of the mining activity the coal seam aquifers are confined by the interburden layers of low permeability shale, siltstone and mudstone.

2.3.1.3 Burngrove Formation

The Burngrove Formation comprises an interbedded fractured rock aquifer system with water bearing units comprising fractured or weathered sandstone and coal seams. These fractured rock aquifer units are confined by low permeability sequences of siltstone, mudstone and tuff. The fractured rock aquifers are heterogeneous in properties and distribution over their spatial extent.

2.3.2 Groundwater Levels and Flow Direction

Groundwater level data was provided by the mine for late 2015 onward and is presented in hydrographs below for the alluvium, RCM and Burngrove Formation. Earlier groundwater level data presented in the 2016 PB groundwater assessment for the mine expansion is also described below.

2.3.2.1 Alluvium

The alluvium associated with Mackenzie River is dry in many areas and where water is present, it generally occurs in coarse paleochannel deposits at the base of the alluvium. Perched groundwater in sand and gravel lenses within low permeability fines (silt and clay) has also been recorded in previous investigations (PB, 2016).

Pre-mining groundwater levels in the alluvium at Curragh North were generally 18 to 22 mbgl with groundwater levels recorded since commencement of mining ranging from approximately 16 to 26 mbgl (PB, 2016).

The alluvium associated with Blackwater Creek in the southern area of the mine is dry in many areas.

More recent groundwater level data for the alluvium is presented in Figure 2-12. The data appears to show clear responses to rainfall variations through 2016 and 2017 and a slight declining trend (in line with low rainfall since early 2018), apparent in some bores.

Most of the current alluvial monitoring is focused on the Mackenzie River alluvial deposits directly west of Curragh North. The only current alluvial monitoring south of this is at 1307MB within Curragh Main with the alluvial groundwater level reflecting the higher elevation of this area.

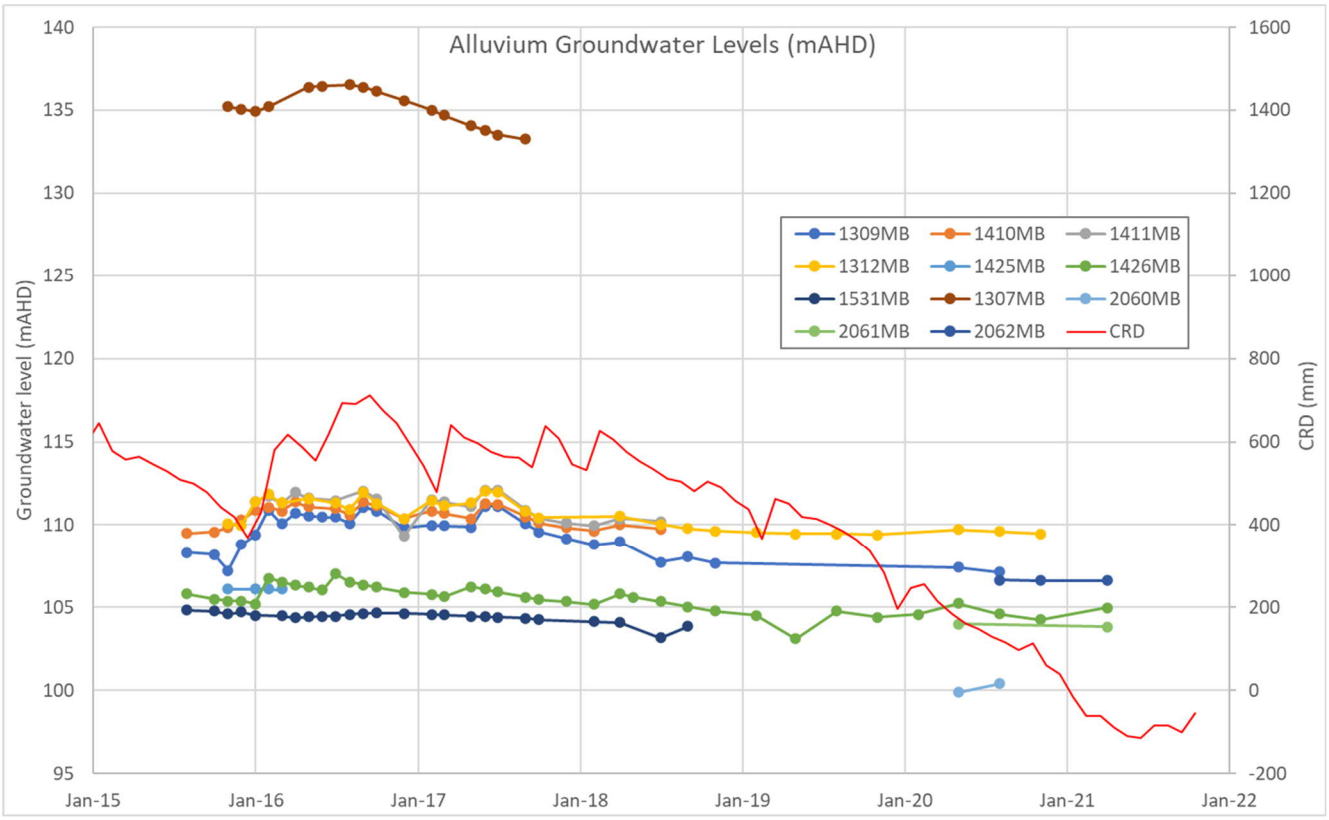


Figure 2-12 Alluvium Groundwater Levels and Cumulative Rainfall Departure

Overall, the alluvial groundwater levels clearly reflect a northerly flow direction along the Mackenzie River west of Curragh North. The 2016 PB assessment numerical modelling indicated that groundwater flow in the alluvium followed topography and drainage lines to the north and northeast. Data for 1309MB and 1312MB for July 2013 to the end of 2015 is consistent with subsequent data obtained from these bores.

2.3.2.2 Rangal Coal Measures

Monitoring of the Pisces seam at Curragh North prior to the commencement of mining indicated pressure heads of 0 to 78 m above the seam. Groundwater levels in RCM outcrop areas were observed to respond to rainfall variations seen in the CRD and groundwater level recovery was also observed at some locations where mining progression had moved away from certain bores (PB, 2016).

Prior to mining, groundwater flow direction in the Permian strata was to the north-east at a very gentle gradient of 1 in 400 (Douglas Partners 2014). Since commencement of mining, groundwater flow direction in the Permian strata has been influenced locally by dewatering in the active pit areas of Curragh and Jellinbah mines.



Figure 2-13 RCM Groundwater Levels and Cumulative Rainfall Departure

Recent groundwater level monitoring data for RCM bores is presented in Figure 2-13 and generally shows very steady levels with little or no response to the CRD although several bores show slight declining trends from 2017 onward in line with lower than average rainfall although this may also be due to the influence of mining. Bore 1743MB shows a rising trend from 2017 onward, contrary to the CRD. This bore is located to the east of the Pit A TSF and south of Pit B TSF and screened at shallow depth (14-17 m bgl). It is possible that the rising groundwater level trend in this bore relates to the filling of the adjacent TSFs.

2.3.2.3 Burngrove Formation

Groundwater levels recorded in the Burngrove Formation since commencement of mining have ranged from approximately 6 to 29 mbgl with shallow bores in unconfined outcrop areas showing levels that correspond to long term rainfall trends. (PB, 2016).

Recent groundwater level monitoring data for the four bores installed in the Burngrove Formation are presented in Figure 2-14 All four bores are installed on the west side of Curragh Main to depths of less than 35m bgl. 1417MB shows a slight declining trend over time and possibly some response to the CRD over this period. 1537MB and to a lesser extent 1322MB show a slight rising trend over the monitoring period, possibly due to the progression of mining activity away from these locations. Recovery responses may also be somewhat masked by lower than average rainfall over the monitoring period.

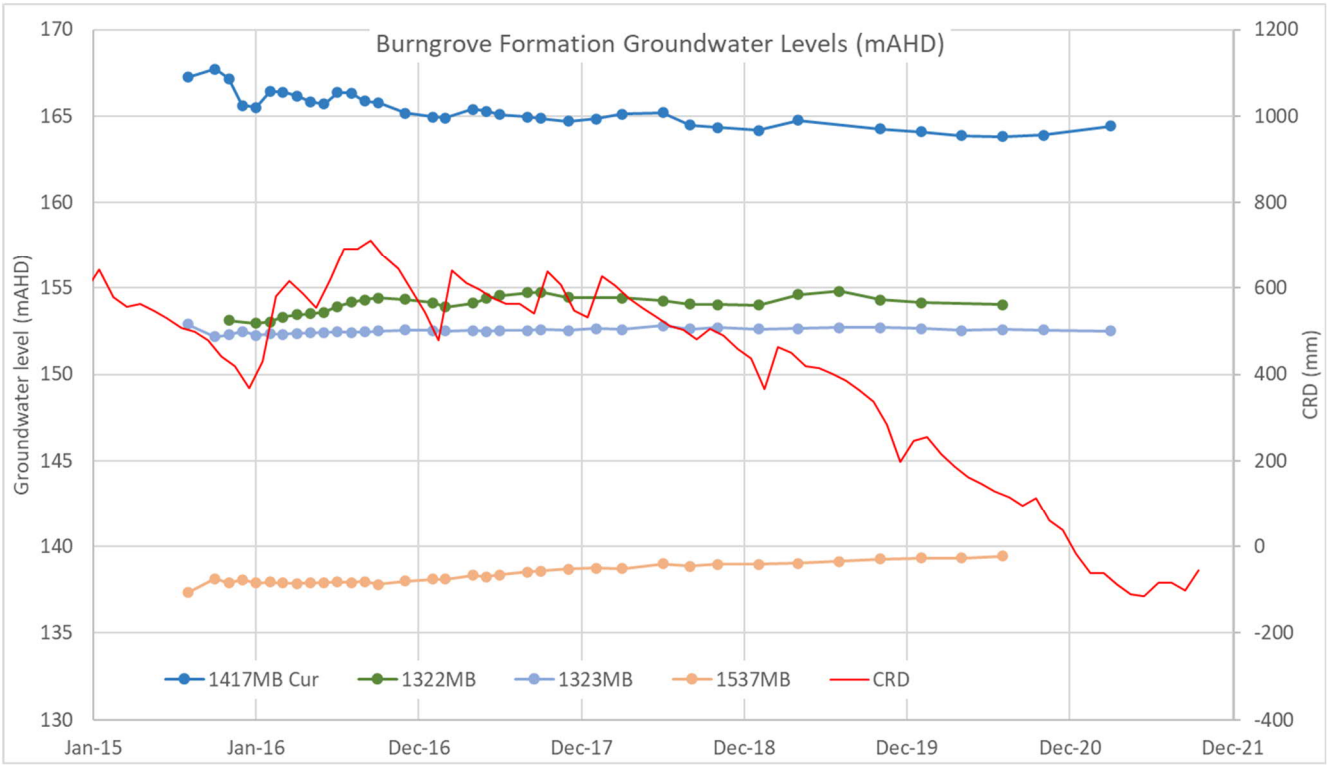


Figure 2-14 Burngrove Formation Groundwater Levels and Cumulative Rainfall Departure

2.3.3 Pre-mining groundwater flow

Modelled pre-mining heads are presented in

Figure 3-4 and show a generally northerly flow of groundwater across the southern area of the model domain, turning more towards the north-east in the northern part of the domain, essentially aligned with the Mackenzie River which flows in the same direction.

2.3.4 Effects of faulting on groundwater flow

As well as the larger mapped faults referred to in Section 2.1.5, the many minor faults will be present throughout the Permian strata.

A seismic survey across an area approximately 4x4km directly south of Blackwater was completed for the Minyango Project in 2011 (Velseis, 2012). The aim was to map the roof of the Aries and Pollux seams, mapping structures / faulting including characterisation of displacement, orientation and fault type. A total of 709 structural features were interpreted within the 16 sq km survey area for all seams.

Most structures (faults) interpreted from the survey were high angle with two main faulting trends identified striking either NNW-SSE or approximately E-W. No dominant fault type was identified with a similar number of faults characterised as reverse, normal and undefined. Many of the structures classified as undefined appear as if they may have been reactivated as they display both normal and reverse characteristics. The largest vertical displacements interpreted across the Aries and Pollux seams were 53.5m and 38m respectively. However, most faults interpreted across both horizons had displacements of less than 15m.

The high degree of faulting within the Rangal Coal Measures identified locally by the Velseis survey will have will have resulted in “compartmentalisation” with the faulting juxtaposing the more permeable coal seams against interburden. This will limit the coal seams exposed in the pit highwalls from acting as continuous pathways for potential seepage migration with abrupt discontinuation of seams where they are displaced by faulting against lower permeability interburden.

faulting around Curragh is likely to have resulted in strong compartmentalisation within the coal measures although it is likely that while some faults act as barriers to flow others may act as conduits.

2.3.5 Hydraulic Properties

Hydraulic property data obtained from the Curragh site and surrounding mines and other relevant sources for the key formations of interest was collated by PB for the 2016 Curragh expansion project and has been reproduced in Table 2-4.

The parameter ranges presented in Table 2-4 indicates the highly variable hydraulic conductivity in the alluvium depending on the silt / clay content. The coal seams within the Rangal Coal Measures exhibit variably moderate permeability, and typically significantly higher than the interburden strata.

Table 2-4 Hydraulic Parameter Estimates (reproduced from PB, 2016)

Age / Formation	Lithology	Kh (m/d)	Kv (m/d)	Ss (m^{-1})	Sy	Source	Project	Source
Quaternary Alluvium	Mackenzie River alluvium - silty clay	0.0009 – 0.001				Falling head test	Curragh North	1
	Mackenzie River alluvium - sand	0.09 – 9				Falling head test	Curragh North	1
	Mackenzie River alluvium - sand/gravel	0.9 – 9				Falling head test	Curragh North	1
	Mackenzie River alluvium - gravel	10				Constand rate test	Mackenzie South	2
	Blackwater Creek alluvium	0.4				Rising head test	Minyango	3
	Blackwater Creek alluvium	0.6	0.018			Calibrated model parameters	Minyango	3
	Floodplain/ river alluvium	1 – 40	0.1 – 2	0.0005	0.05 – 0.18	Calibrated model parameters	Arrow Energy	7
	Not specified0.00	100	10	0.001	0.25	Unknown	Ensham Central	6
	Not specified	0.7 – 1.5		0.0001		Unknown	Barabala North	13
	Not specified	10	1		0.2		Millenium expansion	8
	Not specified	0.088 – 0.38		0.00001		Unknown	Caval Ridge	9
	Not specified	10	1	0.00005	0.1	Unknown	Springsure Creek	11
Tertiary	Duaringa Fm. - unspecified	0.05	0.005	0.00005	0.12	Calibrated model parameters	Arrow Energy	7
		0.6	0.018				Minyango	3
	Weathered – sandy gravels	0.9				Unknown	Curragh North	1
	Weathered – claystone / cemented strata	0.43				Unknown	Curragh North	1
Triassic Rewan Fm.	Sedimentary strata	0.00075	0.0000001	0.00005	0.05	Calibrated model parameters	Arrow Energy	7
		0.00015 – 0.055				Falling head tests	Minyango	3
		0.0009	0.000054			Calibrated model parameters	Minyango	3
		0.00001 – 0.0001	0.000001 – 0.00001	0.000001	0.005	Unknown	Ensham Central	6
		0.1	0.00001	0.000005	0.05	Unknown	Daunia	10

Age / Formation	Lithology	Kh (m/d)	Kv (m/d)	Ss (m^{-1})	Sy	Source	Project	Source
		0.0001	0.0000007	0.00001	0.01	Unknown	Springsure Creek	11
		0.000007				Calibrated model parameters	Carmichael	12
Permian Rangal Coal Measures	Overlying units	0.04	0.001			Packer tests	Curragh North	1
	Fractured coal	0.009 – 0.09				Packer tests	Curragh North	1
	Intact coal	0.017				Packer tests	Curragh North	1
	Aries coal seam	0.003				Falling head test	Minyango	3
		0.14				Drill stem test	Minyango	4
	Aries / Castor coal seam	0.00014				Packer leak-off test	Cook Colliery	5
	Castor coal seam	0.06				Drill stem test	Minyango	4
	Pollux coal seam	0.017				Drill stem test	Minyango	4
		0.9				Constant rate test	Mackenzie South	2
	Pisces coal seam	0.003				Drill stem test	Minyango	4
	Interburden	0.0001	1×10^{-8}	8.5×10^{-6}	0.05	Calibrated model parameters	Arrow Energy	7
		0.00009	1.8×10^{-6}			Calibrated model parameters	Minyango	3
		0.1		5×10^{-6}	0.05	Unknown	Daunia	10
		0.001	0.00001	0.00001	0.01	Unknown	Springsure Creek	11
Permian Burngrove	Coal and interburden	0.00044	8.8×10^{-6}	0.00005	0.12	Calibrated model parameters	Minyango	3
		0.000009	9.9×10^{-7}			Calibrated model parameters		
Permian Fair Hill Fm.	Fort Cooper coal seams (Virgo/ Leo/ Aquarius)	0.000017				Packer leak-off test	Cook Colliery	5

1 Minserve (1998), cited in Parsons Brinckerhoff (2003), 2 ERM (2002), cited in AGE (2006), 3 AGE (2013a), 4 Polymetra (2009), cited in AGE (2013a), 5 North Queensland Energy (1993), cited in AGE (2013a), 6 AGE (2006), cited in HydroSimulations (2014), 7 Ausenco-Norwest (2012), 8 Matrix Plus (2010), 9 URS (2009), cited in HydroSimulations (2014), 10 BHP Billiton Mitsubishi Alliance, cited in HydroSimulations (2014), 11 CDM Smith (2013), cited in HydroSimulations (2014), 12 GHD (2013), 13 JBT (2012), cited in HydroSimulations (2014)

2.3.6 Groundwater Quality

Groundwater quality data has been provided for the bores listed in Table 2-5 and which are shown on Figure 2-11. Data is generally available from late 2015 onward with limited data provided from before this time. Historically, groundwater quality monitoring was undertaken infrequently from 1997 to 2012 with the frequency increasing thereafter. Samples were analysed for electrical conductivity (EC), pH, major ions, nutrients, dissolved metals and hydrocarbons and water quality statistics for selected analytes are shown in Table 2-6.

Table 2-5 Currently available groundwater quality data

Screened Formation	Bore ID	Data availability	
		From	To
Alluvium	1309MB	28-10-2015	01-04-2020
Alluvium	1312MB	03-10-2019	03-10-2019
Alluvium	1426MB	30-10-2015	10-11-2020
Alluvium	1531MB	28-10-2015	13-05-2020
Alluvium	1410MB	03-03-2016	29-06-2018
Alluvium	1411MB	28-04-2016	11-06-2019
Tertiary (weathered)	1301aMB	30-01-2020	06-01-2021
Tertiary (weathered)	1302MB	03-10-2019	07-01-2021
Tertiary (weathered)	1303MB	03-10-2019	07-01-2021
Tertiary (weathered)	1304aMB	18-09-2013	13-06-2016
Tertiary (weathered Duaringa Fm.)	1419MB	06-08-2015	28-06-2018
Tertiary (weathered Duaringa Fm.)	1420MB	30-12-2016	20-06-2017
RCM	BH1	26-06-2000	09-11-2020
RCM	BH2	09-02-2000	16-11-2020
RCM	BH3	09-02-2000	11-11-2020
RCM (weathered)	1301bMB	03-10-2019	06-01-2021
RCM (weathered)	1304bMB	04-09-2013	06-01-2021
RCM	1529MB	06-08-2015	10-11-2020
RCM	1534MB	06-08-2015	09-12-2020
RCM	1536MB	16-04-2018	14-05-2020
RCM	1538MB	19-08-2015	11-11-2020
RCM	1539MB	29-10-2015	20-08-2018
Burngrove Fm.	BH4	09-02-2000	09-12-2020
Burngrove Fm. (weathered)	1323MB	07-01-2014	09-11-2020
Burngrove Fm. (weathered)	1417MB	05-08-2015	09-11-2020
Burngrove Fm. (weathered)	1418MB	22-06-2015	11-11-2020
Burngrove Fm. (coal seam)	1537MB	30-10-2015	10-11-2020

Table 2-6 Groundwater quality (recent data) for the Mackenzie River Alluvium, Rangal Coal Measures and Burngrove Formation at Curragh

Analyte	95% Species protection for freshwater [1]	Livestock (ANZECC)	ADWG [A]	Groundwater Quality Objectives for the Fitzroy River Basin						Mackenzie River Alluvium				Tertiary				Rangal Coal Measures				Burngrove Fm.			
				Deep (Zone 34)			Shallow (Zone 13)																		
				20th	50th	80th	20th	50th	80th	No.	20th	50th	80th	No.	20th	50th	80th	No.	20th	50th	80th	No.	20th	50th	80th
pH	-	-	6.5 – 8.5 [C]	7.4	7.8	8.03	7.5	8.0	8.3	45	6.92	7.19	7.65	17	7.33	7.51	7.71	122	7.1	7.4	7.7	82	7.31	7.59	7.91
TDS	-	See Table 2-7	600 [C]							34	334	378	640	25	1,132	2,350	9,596	134	1,090	8,434	9,674	114	2242	4710	8366
EC (µS/cm)	-	-		3,419	6,100	16,000	630	1,150	2,509	45	484.6	573	3468	17	1,702	3,290	13,420	118	1,620	14,250	16,000	80	5718	10900	14560
Aluminium (mg/L)	0.055	5	0.2 [C]							34	0.01	0.01	0.01	25	0.01	0.01	0.024	139	0.01	0.01	0.019	116	0.01	0.01	0.01
Arsenic (mg/L)	0.013	0.5	0.01							34	0.001	0.003	0.0104	25	0.001	0.001	0.0016	138	0.001	0.001	0.005	118	0.001	0.001	0.001
Antimony (mg/L)	0.009	-	0.003							32	0.001	0.001	0.001	14	0.001	0.001	0.001	64	0.001	0.001	0.001	78	0.001	0.001	0.001
Boron (mg/L)	0.37	5	4							0				1		0.87		23	0.938	1.10	1.36	11	0.63	0.78	0.85
Cadmium (mg/L)	0.0002	0.01	0.002							0				1		0.0001		23	0.0001	0.0001	0.0001	11	0.0001	0.0001	0.0001
Calcium (mg/L)	-	1,000	-	46	145	442	21	40	73	15	34.8	41	51	8	142	150	182	128	70	130	170	59	74	110	212
Chloride (mg/L)	-	-	250 [C]	753	1,900	5,505	30	110	400	21	49	67	771	14	1,895	2,800	4,356	139	1,292	4,300	5,140	86	580	2000	4060
Chromium (mg/L)	0.0033 (CrIII)	1	0.05 (as CrVI)							0				1		0.001		23	0.001	0.016	0.0268	11	0.001	0.006	0.013
Cobalt (mg/L)	0.0014	1	-							0				1		0.001		23	0.001	0.001	0.0068	11	0.001	0.001	0.001
Copper (mg/L)	0.0014	0.4 (sheep) 1 (cattle) 5 (pigs & poultry)	2	0.017	0.030	0.030	0.000	0.010	0.030	0				1		0.001		23	0.0014	0.004	0.006	11	0.001	0.004	0.005
Iron (mg/L)	-	not sufficiently toxic	0.3 [C]	0.000	0.050	0.246	0.00	0.01	0.04	34	0.376	2.12	5.82	25	0.05	0.05	0.554	138	0.05	0.17	1.2	119	0.05	0.05	0.29
Lead (mg/L)	0.0034	0.1	0.01							0				1		0.001		25	0.001	0.001	0.001	13	0.001	0.001	0.001
Magnesium (mg/L)	-	2,000	-	35	115	491	21	54	119	9	14	18	21.4	10	198	296	335	67	51	148	400	42	47	100	483
Mercury (mg/L)	0.0006	0.002	0.001							28	0.0001	0.0001	0.0001	18	0.0001	0.0001	0.0005	131	0.0001	0.0001	0.0005	104	0.0001	0.0001	0.0001
Manganese (mg/L)	1.9	not sufficiently toxic	0.5	0.000	0.050	0.291	0.00	0.01	0.02	0				1		1.2		23	0.022	0.19	0.634	11	0.23	0.27	0.3
Nickel (mg/L)	0.011	1	0.02							0				1		0.003		38	0.0044	0.008	0.013	17	0.0012	0.003	0.005
Potassium (mg/L)		-								21	3	4	6	13	7.5	11	12	82	6	8	13	60	2	5	11
Selenium (mg/L)	0.005	0.02	0.01							33	0.01	0.01	0.01	19	0.01	0.01	0.01	112	0.01	0.01	0.01	103	0.01	0.01	0.01
Silver (mg/L)	0.00005	-	0.1							0				1		0.001		23	0.001	0.001	0.0016	11	0.001	0.001	0.001
Sodium (mg/L)	-	-	180 [2]	480	1100	2565	56	135	326	21	36	42	648	13	1,800	2,100	2,700	135	1,400	2,600	3,336	85	580	1150	1890
SO_4 (mg/L)	-	1,000	250 [C]	25	138	398	5	24	125	21	5	48	150	14	599	1,100	1,690	140	3	529	801	87	28	194	398
Uranium (mg/L)	ID	0.2	0.017							0				1		0.005		23	0.001	0.007	0.008	11	0.001	0.001	0.001
Zinc (mg/L)	0.008	20	3	0.010	0.025	0.317	0.000	0.015	0.050	0				1		0.024		23	0.0038	0.012	0.0246	11	0.005	0.014	0.02
Total Hardness as CaCO3 (mg/L)	-	-	200 [C]	359	919	3,208	145	350	650	18	140	192	576	9	352	403	444	65	232	830	980	52	396	651	797

Metals concentrations presented for groundwater are dissolved, greyed out values for groundwater quality represent method detection limits

1 Australian and New Zealand Guidelines for Fresh and Marine Water Quality (2018) - for dissolved metals and metalloids, guideline value relates to slightly-moderately disturbed systems, 95% species protection.

2 Natural component of water - guideline value is taste threshold.

A ADWG are recommended guidelines for human consumption of water (i.e. post-treatment), NHMRC (2011)

ID - insufficient data

C Aesthetic guideline / Insufficient data to set a guideline value based on health considerations.

Table 2-7 Total dissolved solids (mg/L) - livestock water quality guidelines and groundwater quality

Livestock	Low range	Medium range	High range
Beef Cattle	0 – 4,000	4,000 – 5,000	5,000 – 10,000
Dairy Cattle	0 – 2,400	2,400 – 4,000	4,000 – 7,000
Sheep	0 – 4,000	4,000 – 10,000	10,000 – 13,000
Horses	0 – 4,000	4,000 – 6,000	6,000 – 7,000
Pigs	0 – 4,000	4,000 – 6,000	6,000 – 8,000
Poultry	0 – 2,000	2000 – 3,000	3,000 – 4,000
Formation	20th %ile	50th %ile	80th %ile
Mackenzie Alluvium	334	378	640
Tertiary	1,132	2,350	9,596
Rangal Coal Measures	1,090	8,434	9,674
Burngrove Fm.	2242	4710	8366

Low range - No adverse effects expected
Medium Range - Animals may have initial reluctance to drink, but stock should adapt without loss of production.
High range - Loss of production and a decline in animal condition and health would be expected. Stock may tolerate these levels for short periods if introduced gradually.

To provide a broad picture of groundwater quality in the vicinity of the mine Table 2-6 and Table 2-7 presents water quality statistics (20th, 50th and 80th percentiles) for each of the main formations monitored together with the following relevant water quality guidelines:

- Livestock drinking water guidelines (ANZECC, 2000) – given the rural agricultural setting of the mine the stock watering guidelines are considered relevant to assessing local groundwater values.
- Australian Drinking Water Guidelines (ANZECC, NRMMC 2011) – given the rural setting of the mine and the potential presence of local stock and domestic bores the drinking water guidelines are considered relevant to assessing local groundwater values.
- Australian and New Zealand Guidelines for Fresh and Marine Water Quality (2018) – these guidelines, originating from the ANZECC & ARMCANZ (2000) water quality guidelines, provide guideline values for the protection of fresh and marine water habitats. The values selected from this guidance relates to slightly-moderately disturbed freshwater systems for 95% species protection. These guidelines are considered relevant for protection of the Mackenzie River and its tributaries.
- Groundwater Quality Objectives for the Fitzroy River Basin (Zone 13 & 34) (DEHP 2011) - These guidelines are intended to be protective of surface waters where there is the potential for groundwater surface water interaction i.e., groundwater quality should not compromise identified EVs and WQOs for those waters. This guidance groundwater quality objectives i.e., background groundwater quality statistics that should be maintained for groundwaters, for 44 zones and depths (shallow and deep) across the Fitzroy Basin. The mine lies within Zone 13 which is categorised as Low-Moderate salinity alluvial groundwater – reflective of the Mackenzie River Alluvium. In addition, guideline values for Zone 34 (deep) have been included which is regarded as saline groundwater and considered more representative of deeper groundwater within the RCM and Burngrove Formation.

A summary of general groundwater quality compared these to guideline values is presented below.

- Livestock drinking water guidelines (ANZECC, 2000) – except for sulphate in Tertiary strata at the 50th and 80th percentile none of the guideline values for stock watering in Table 2-6 are exceeded in any lithology even at the 20th percentile. TDS is considered separately in Table 2-7:
    - Mackenzie River Alluvium – Salinity is suitably low for stock watering.
    - Tertiary – salinity is generally low and suitable for most stock although higher salinities are observed around the 80th percentile rendering it suitable for beef cattle and sheep only.
    - RCM – salinity is elevated with concentrations around the 50th percentile becoming unsuitable for more salt sensitive livestock. Maximum TDS significantly exceeds the high range guidelines for livestock
    - Burngrove Formation - salinities around the 50th percentile concentration are generally still suitable for all but the most sensitive livestock (poultry and dairy cattle) but increase to similar concentrations seen in the Tertiary and RCM at the 80th percentile. Maximum TDS significantly exceeds the high range guidelines for livestock
- Australian Drinking Water Guidelines (ANZECC, NRMMC 2011) – groundwater quality in the Mackenzie River Alluvium to the west of Curragh North is considered generally suitable for drinking water based on chemical quality noting the exceedances below. The composition of groundwater in the Tertiary, RCM, and Burngrove Fm. Is considered unsuitable for drinking water, primarily due to its generally high salinity. The following exceedances of guideline values are noted:
    - Mackenzie River Alluvium - The (aesthetic) guidelines for TDS, Na and total hardness are exceeded at the 80th percentile and the (aesthetic) guideline for Fe is exceeded at all percentiles. In addition, the guideline for As is fractionally exceeded at the 80th percentile.
    - Tertiary - The (aesthetic) guidelines for TDS, Cl, Na, SO4 and hardness are exceeded at the 20th percentile. In addition, the guidelines for Al, As and Fe are exceeded at the 80th percentile and one analysis for Mn also exceeds the guideline.
    - RCM - The (aesthetic) guidelines for TDS, Cl, Na and hardness are exceeded at the 20th percentile, and SO4 at the 50th percentile. In addition, the guidelines for As, Fe and Mn are exceeded at the 80th percentile.
    - Burngrove Formation - The (aesthetic) guidelines for TDS, Cl, Na and hardness are exceeded at the 20th percentile, and SO4 at the 80th percentile.
- Australian and New Zealand Guidelines for Fresh and Marine Water Quality (2018) – 95% species protection. With regard to the potential impacts on surface water ecosystems local groundwater the following exceedances identified:
    - Mackenzie River Alluvium – none of the guideline values are exceeded at the 20th percentile.
    - Tertiary – The guideline for B and Zn is exceeded although the sample count for these analytes is just 1.
    - RCM - The guideline for B is exceeded at the 20th percentile; Cr, Cu and Zn at the 50th percentile and, Co, K and Ag at the 80th percentile.
    - Burngrove Formation - The guideline for B is exceeded at the 20th percentile; Cu and Zn at the 50th percentile and, Cr at the 80th percentile.

- Groundwater Quality Objectives for the Fitzroy River Basin (Zone 13 & 34) (DEHP 2011) - These guidelines are intended to be protective of surface waters where there is the potential for groundwater - surface water interaction. The Mackenzie River Alluvium has been compared to Zone 13 (shallow) guidelines which are intended for low salinity alluvial groundwater. The Tertiary, RCM and Burngrove Formation groundwater has been compared to guidelines for Zone 34 (deep) which are considered more appropriate for the deeper geology across the mine:
    - Mackenzie River Alluvium – pH (groundwater slightly lower than the 20th %ile guideline); and exceedances for EC (80th %ile), Ca (20th and 50th %iles), Fe (20th, 50th and 80th %iles), Na (80th %ile), and SO4 (50th and 80th %iles).
    - Tertiary – pH (groundwater slightly lower than the 20th %ile guideline); and exceedances for Ca (20th and 50th %iles), Mg (20th and 50th %iles), Mn (20th, 50th and 80th %iles), Na and SO4 (20th, 50th and 80th %iles).
    - RCM - pH (groundwater slightly lower than the 20th and 50th %ile guideline); and exceedances for Fe (50th and 80th %iles), Mg (20th %ile), Mn, Na and SO4 (20th, 50th and 80th %iles).
    - Burngrove Formation - pH (groundwater slightly lower than the 20th %ile guideline); and exceedances for EC (20th and 50th %iles), Fe (80th %ile), Mg (20th %iles), Mn (20th, 50th and 80th %iles), Na and SO4 (50th and 80th %iles).

For bores with sufficient data on major ion chemistry, the mean major ion concentrations have been plotted on a Piper Diagram (Figure 2-15), to determine key differences in the hydrochemical facies of groundwater sampled from different strata. The Piper Plot displays individual bores colour coded for the different formations: Mackenzie River Alluvium (yellow), Tertiary (red), RCM (grey) and Burngrove Formation (green).

The fresher groundwater of the Mackenzie River Alluvium (yellow), fall within the Mg-HCO3 field while the RCM bores plot mostly within the Na-Cl field as does groundwater sampled from the Burngrove Formation. The two bores screened in the Tertiary plot separately in the Na-Cl field and the adjacent mixed Ca-Mg-Cl field.

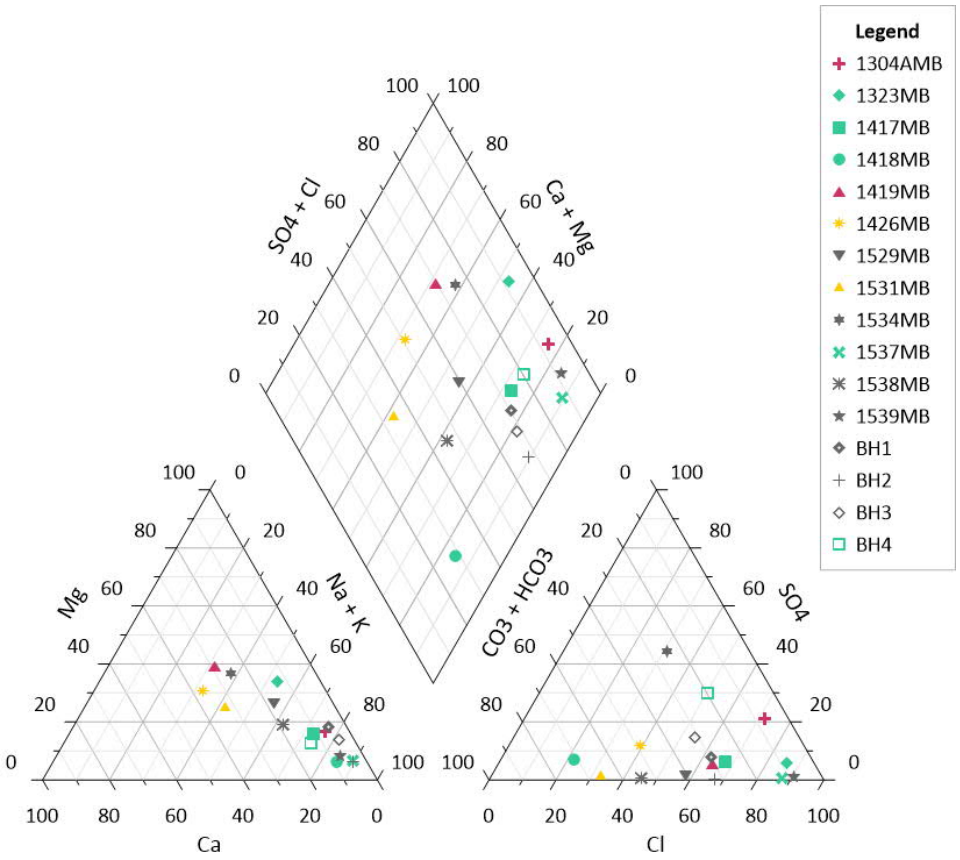


Figure 2-15 Piper plot of groundwater major ion chemistry

2.3.7 Groundwater Recharge and Discharge

2.3.7.1 Recharge

Recharge of the alluvial aquifers occurs via stream flow, particularly during periods of high flow and flooding, as well as via rainfall infiltration. Most creeks in the region are ephemeral, although flow in the Mackenzie River is controlled by releases from Fairbairn Dam and the upper reach of Blackwater Creek flows due to discharge from the Blackwater Wastewater Treatment Plant. These streams may provide a constant source of recharge to the underlying alluvial and weathered rock groundwater systems. Groundwater studies undertaken at Curragh North prior to the commencement of mining found the alluvium was dry in many areas which may be related to clays and silts in the upper part of the alluvial profile restricting direct recharge and streamflow infiltration (PB 2003).

In the initial phases of mining at Pit S at Curragh North in late 2014, conceptual understanding was that Mackenzie River may provide recharge to the alluvium with a hydraulic gradient in the alluvium towards Pit S (Douglas and Partners, 2014). However, the 2016 PB assessment indicates that very minor inflow from the alluvium in the wall buttress on the Mackenzie River side of the pit has been observed and no change in water levels in Mackenzie River during mining (PB 2016). This may be due to the disconnected nature of the permeable channel deposits and the presence of clay and silt layers limiting the connectivity between the alluvium and mining operations directly east of the Mackenzie River at Curragh North (PB 2016).

From a review of available monitoring data Parsons Brinckerhoff (2003) identified a limited response in alluvial groundwater levels to rainfall events and subsequent river level rises and suggest this was due to the monitored alluvial groundwater being perched, and the high fines content of the alluvial sand and gravel lenses.

Following a review of alluvial bore logs between the Mackenzie River and proposed Pit X, and Blackwater Creek and proposed extension Pits D and J which identified a relatively high proportion of clay, PB (2016) again suggest that recharge to alluvium in these areas may be limited.

Recharge to the aquifer units within the RCM and Burngrove Formation is likely to occur predominantly through rainfall infiltration in outcrop areas, and via vertical leakage, particularly where coal seams subcrop permeable alluvium. Some recharge may also occur via stream flow where formations outcrop / subcrop along creek lines, for example where the RCM outcrops Bonnie Doon Creek.

2.3.7.2 Discharge

The major discharge from the RCM in the vicinity of the mine is direct inflow to the mine pits. Regional groundwater flow is also a discharge mechanism with the general direction of groundwater flow being toward the north-east.

Evapotranspiration from the water table is also a significant discharge mechanism in areas where the water table is shallow and within the rooting depth of vegetation.

The BOM GDE Atlas indicates that Mackenzie River, Blackwater Creek and Cooroora Creek have a moderate potential for groundwater interaction. There is potential that groundwater in alluvium may discharge to Mackenzie River at times, particularly during the wet season when groundwater levels may rise. This is discussed further below.

Local extraction of groundwater by landholders is also a discharge mechanism although this appears to be limited in the vicinity of the mine (Section 2.4.2).

Other streams in the study area, including Blackwater Creek, Minnie Creek, Sagittarius Creek and Bonnie Doon Creek, are considered unlikely to receive baseflow from groundwater. This is consistent with site observations which indicate these streams are dry during the dry season and only flow following rainfall runoff during the wet season (PB 2016).

2.3.8 Surface Water Groundwater Interaction

2.3.8.1 Mackenzie River (including Cooroora Creek)

The Mackenzie River is the main watercourse in the vicinity of the mine with regulation and releases from Fairburn Dam having altered the natural flow regime. Cooroora Creek is a tributary of Mackenzie River to the west of Curragh North.

2.3.8.1.1 Occurrence of groundwater

Groundwater studies undertaken by Parsons Brinckerhoff (2003) at Curragh North prior to the commencement of mining found that most monitoring bores installed in alluvium were dry. Where water was present in monitoring bores, it occurred within the basal palaeochannel deposits of gravel and coarse sands.

2.3.8.1.2 Pre-mining groundwater levels

Groundwater studies undertaken by Parsons Brinckerhoff (2003) at Curragh North prior to the commencement of mining included installation of a groundwater monitoring network in the Mackenzie River alluvium and monitoring levels in the Mackenzie River.

Monitoring was undertaken from November 2001 to May 2003 at three alluvial bores located immediately adjacent to Mackenzie River (near current Pit U and Pit T). Hydrographs for these bores and levels in the Mackenzie River are presented in Figure 2-16 and show that groundwater levels in the alluvium were 3-5 m below the Mackenzie River stage. The monitoring also shows that high flow events captured in the monitoring data with river stage increases of over 1m had little or no impact on groundwater levels in the neighbouring alluvial groundwater bores. The data was interpreted as an indication that prior to mining at Curragh North, there was limited leakage from the river to the alluvium, and no discharge of groundwater from the alluvium to the river.

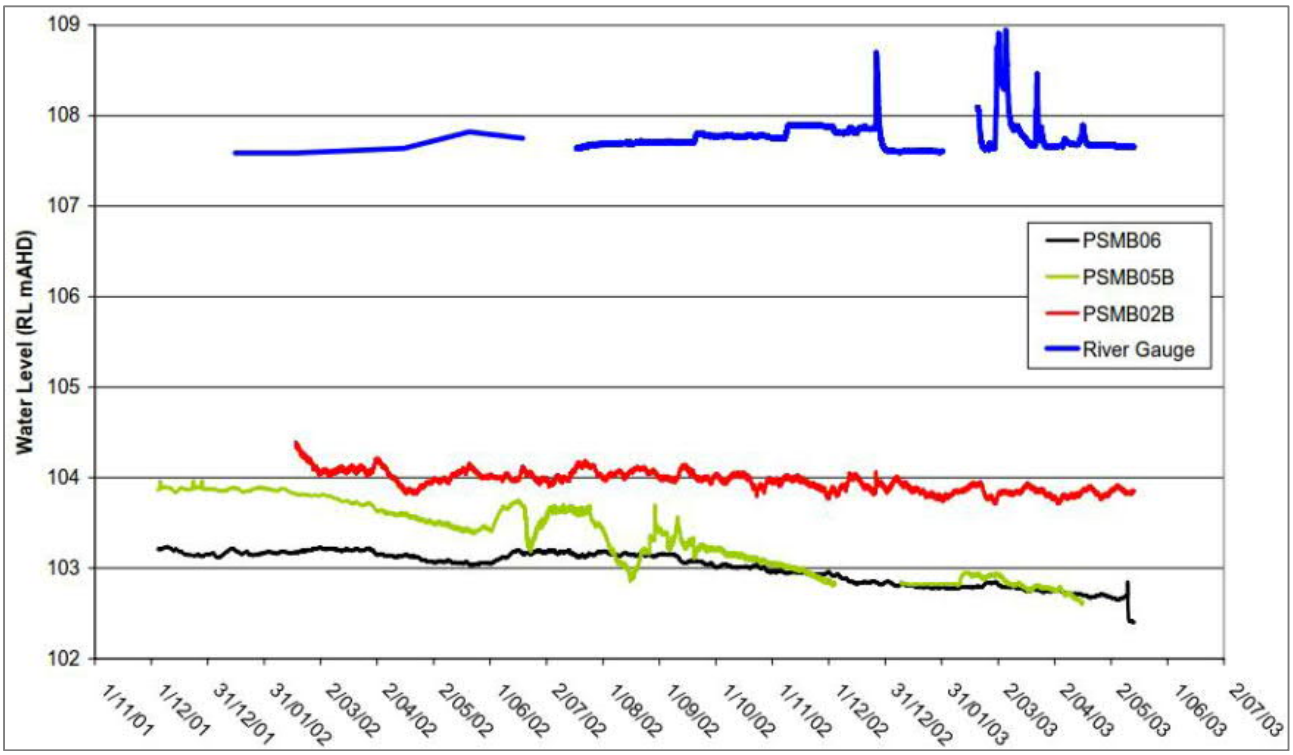


Figure 2-16 Mackenzie River stage and Mackenzie alluvium groundwater levels (reproduced from AGE, 2006)

Groundwater monitoring undertaken for the Mackenzie South Project observed a similar relationship with groundwater levels in an alluvial bore (MSP0203), immediately adjacent to the Mackenzie River 4.2 m below the river stage prior to the commencement of mining (AGE, 2006). It is noted that the monitoring undertaken for the Curragh North and Mackenzie South projects was undertaken during a period of low rainfall.

2.3.8.1.3 Observations of mining adjacent to the river

Curragh North pits (S, T and U) experience inflows from the alluvium, which, in this area is relatively thick and comprised of sand and gravel. Average daily inflow from the alluvium to these pits is estimated to be 3.5 Ml/d (40 l/s), with the bulk of this inflow occurring at Pit U (3 Ml/d) (PB 2016).

A review of inflows to Pit S by Douglas Partners (2014) indicated that at the start of mining in late 2014, inflows were observed from sand and gravel at the base of the alluvium. Curragh Mine also reported that saturated alluvium was encountered in Pit S at approximately 5 to 10 mbgl with initial inflow/dewatering rates of approximately 6.5 Ml/day (PB 2016).

Two months after mining started in Pit S, the alluvium on the western pit face adjacent to Mackenzie River was dewatered and the majority of inflow was observed from the east pit face and monitoring bores screened to the base of the alluvium between the Mackenzie River and Pit S were dry or recorded water levels near the base (PB 2016).

Site observations of limited seepage from west buttress wall of Pit S suggest there is limited hydraulic connection between the Mackenzie River and the alluvium intersected in Pit S. This may be due to low permeability alluvial silt and clay between the river and pit, combined with low permeability riverbed material. Curragh Mine personnel have observed that pit inflows have not changed in relation to changing water levels in the Mackenzie River or wet season rainfall conditions (PB 2016).

2.3.8.1.4 Riverbed materials

Inspection of the Mackenzie River by AGE (2006) immediately downstream of Curragh North, found the material exposed in the banks to be clay bound gravels suggesting the Mackenzie River stream bed is of relatively low permeability, limiting seepage of water from the river to the alluvium. Similar stream bed materials were observed in the Nogoa River upstream, where a detailed study of connectivity between the river and underlying alluvium was undertaken for Ensham Mine (AGE, 2006). The study involved installation of 23 monitoring bores in alluvium along both sides of the Nogoa River and excavation of pits in the stream bed and showed that there was no connection between the alluvium and river (AGE, 2006). The findings of this study were supported by investigations undertaken by the Queensland government on the Nogoa River floodplain which concluded 'it is unlikely that there is any connection between the river system and groundwater. Groundwater is restricted to the deeper section of the alluvium and there are large tracts of dry alluvium' (cited in AGE 2006).

2.3.8.2 Blackwater Creek

Blackwater Creek is a tributary of Mackenzie River. It is a highly modified system having undergone three previous channel alterations due to Curragh Mine workings including a 9.4 km diversion in 2010.

The field investigation program for the Minyango project found the Blackwater Creek alluvium was only saturated in areas where there is a significant thickness of deeper alluvial sediment (AGE 2013). Within the study area, the Blackwater Creek alluvium forms a relatively thin heterogeneous system, with lenses of poorly connected clean sand separated by lower permeability clayey facies and bedrock highs (PB 2016). The constant flow in the upstream section of Blackwater Creek is understood to be from the Blackwater Wastewater Treatment Plant (WTP) which discharges effluent via Sagittarius Creek.

Depth to groundwater (based the PB 2016 calibrated numerical groundwater model) indicates that Blackwater Creek is unlikely to receive baseflow from groundwater, with groundwater levels more than three metres below the stream bed. This is supported by observation of the downstream end of Blackwater Creek being dry except following rainfall.

Blackwater Creek was conceptualised by PB in 2016 to be a losing stream that is disconnected from the water table.

2.4 Groundwater Related Values

2.4.1 Groundwater dependent ecosystems (GDEs)

A Groundwater Dependent Ecosystem (GDE) is one in which the plant and/ or animal community is dependent on the availability of groundwater to maintain its structure and function. The BoM Groundwater Atlas (BoM, 2021) indicates areas of primarily low potential terrestrial GDEs / IDEs (inflow dependent ecosystems associated with the riparian corridor of the Mackenzie River and, to a lesser extent, Blackwater Creek (Figure 2-17). These terrestrial GDEs are vegetation ecosystems that rely on the subsurface presence of groundwater.

The 2016 PB assessment (due to its objective of assessing impacts associated with expansion), considered the potential for impacts on GDEs in considerable detail. The area of potential subsurface GDEs was assumed to be restricted to areas of saturated alluvium based on the results from the numerical groundwater modelling. It was also assumed that within the areas of saturated alluvium that groundwater dependence was related to the depth to the water table and vegetation rooting depth. The following criteria were used to refine the areas of likely and potential subsurface GDEs in the vicinity of the site:

- Where field verified and Queensland Herbarium mapped regional ecosystems associated with likely and potential GDEs intersected with modelled areas of saturated alluvium
- depth to groundwater within the area of saturated alluvium:
    - High – depth to groundwater within saturated alluvium <10 m
    - Possible – depth to groundwater within saturated alluvium between 10 and 20 m
    - Unlikely – depth to groundwater within saturated alluvium >20 m.

The assessment (PB, 2016) identified that much of the reach of the Mackenzie River and Cooroora Creek (tributary of the Mackenzie), within the model domain, and the northern reaches of Blackwater Creek, had a high potential to host terrestrial GDEs along the riparian corridor with a likely depth to groundwater of <10 m.

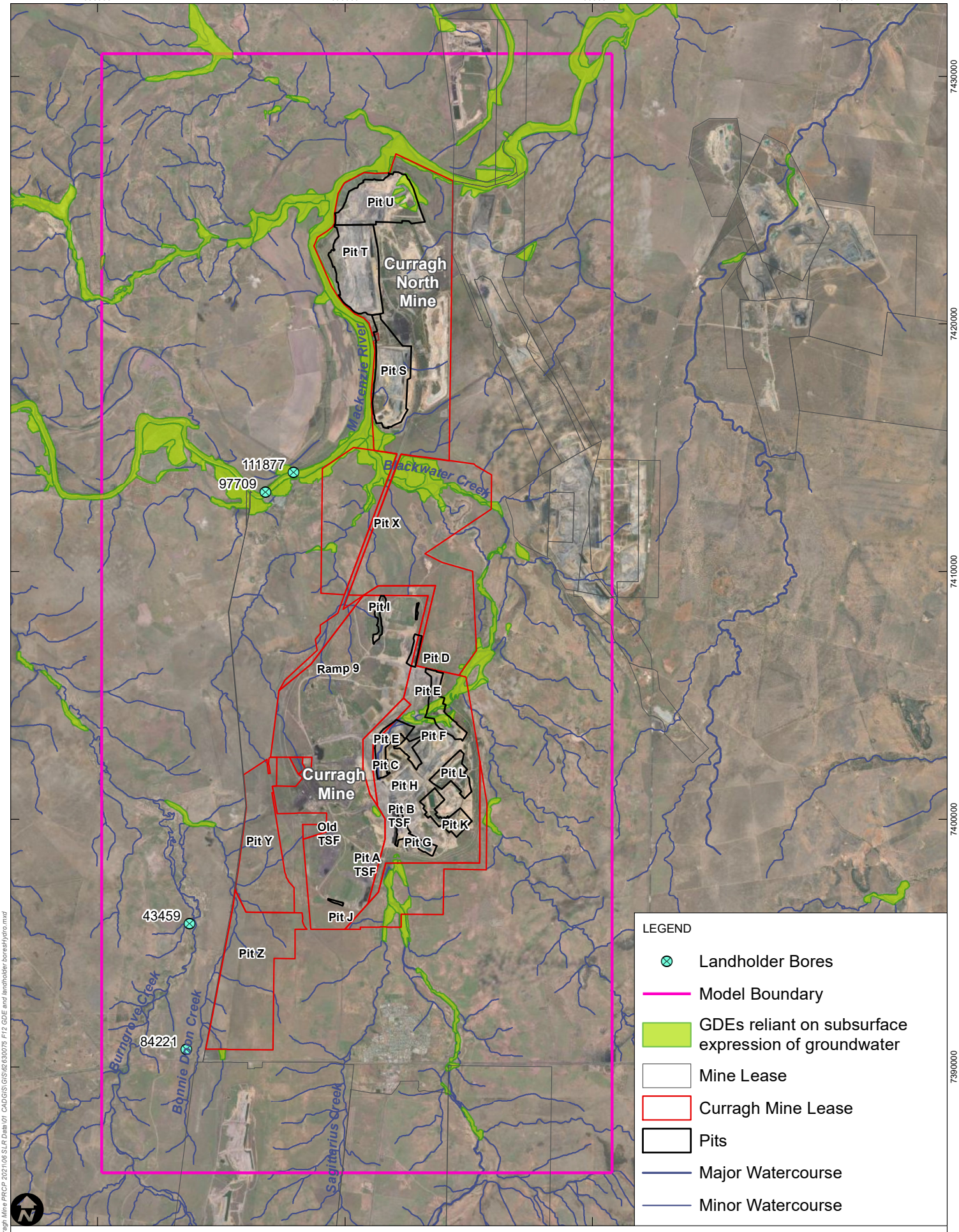
2.4.2 Local groundwater use

There are four registered bores within 3km of Curragh mining operations (existing or proposed); details are presented in Table 2-8 and their locations are shown on Figure 2-17.

Table 2-8 Registered bores within 3km of Curragh mining operations

RN		Depth (m)	SWL (mbgl)	Water quality	Yield (L/s)	Installed
43459	-	-	-	-	-	-
84221	Burngrove Formation	31	30	salty	0.12	1988
97709	-	57	13	Fresh	3.2	1998
111877	Mackenzie River Alluvium	23	15			2002

RN111877 is owned by Central Highlands Regional Council and located at the campground approximately 150 m south of Bedford Weir on the Mackenzie River. The Council have indicated the bore is used to irrigate grass near and in the toilet block at the campground and that the groundwater is relatively saline. The bore is used to fill a 45,000 L tank 2 to 3 times each week (PB, 2016).



H:\Projects-SLR\626-MKY\626.30075.00000 Curragh Mine PRCP 2021\06 SLR Data \01 CADGIS\GIS\626.630075 F12 GDE and landholder boresHydro.mxd

SLR

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Coordinate System:	AGD 1984 AMG Zone 55
Scale:	1:195,000 at A4
Project Number:	626.30075
Date:	26-Nov-2021
Drawn by:	ML
Reviewed by:	ML

CURRAGH PRCP

Preliminary Groundwater Assessment for Curragh CRVA Landholder bores and GDEs

FIGURE 2-17

3 Numerical Groundwater Modelling

3.1 Model History and Current Objectives

A numerical groundwater model for Curragh Mine was developed in 2016 by Parsons Brinckerhoff for Wesfarmers Resources Pty Ltd. The model was constructed and calibrated with the primary objective of quantifying the potential impacts of the Curragh Extension Project on groundwater resources and associated environmental values. The model was independently peer reviewed and audited by HydroSimulations in 2016. The peer review found the modelling design, model calibration and predictions to be fit for the purpose of quantifying impacts from proposed mining for the Curragh Extension Project.

The 2016 model has been provided to SLR Consulting by CCPL and has been updated for use in this preliminary assessment of post-closure groundwater related issues at the mine. For this study the 2016 model temporal datasets have been extended and a post-mining recovery simulation has been added with detailed final void modelling, to estimate the effect of mine closure on the local groundwater regime.

The primary objective of this work is to identify groundwater related issues potentially resulting from the closure of the Curragh Complex and secondarily, to lay the foundations for a more detailed assessment of potential groundwater issues at the complex as part of the closure planning process. The key objectives of this modelling exercise have been to:

- Update the model datasets and verify the model calibration;
- Update the mine progression in line with the current mine plan;
- Simulate the post mining groundwater level recovery using the final landform (mine void backfill levels) developed by Coronado to understand whether the final voids act as groundwater sinks or sources; and;
- Understand the long-term effect of the proposed post mining landform on local groundwater levels by comparing the long term post closure case to a null case (no mining activity).

The 2016 study classified the model as a Class 2 confidence level (HydroSimulations, 2016). The objective of the updates was to enable the groundwater model to continue to reliably simulate the existing and future groundwater conditions at Curragh Complex at a regional scale. The updates to the model included:

- Extending the rainfall in the model to include the latest climate measurements;
- Extending the calibration data set to include the latest groundwater level measurements and recalibrate the model;
- Recalibrating the model to include depth-dependent hydraulic conductivity in the Rangal Coal Measures;
- Updating the mine progression plan in the model, to include all foreseeable future mining at Curragh Complex;
- Updating the temporal discretisation to include the recovery model; and
- Setting up the recovery model to include proposed residual voids at the end of foreseeable mining at Curragh Complex.

Based on the model confidence level classification from the 2016 study and relevant updates to the model, the updated model remains a Class 2 confidence level.

3.2 Model Design Summary

3.2.1 Model Code

MODFLOW-USG (Panday *et al.* 2013) was used as the model code. MODFLOW-USG is the latest version of industry standard MODFLOW code and was determined to be appropriate and the most suitable modelling code for accomplishing the model objectives., therefore the model software remains unchanged from the Curragh Model (Parsons Brinckerhoff, 2016).

SLR used MODFLOW-USG to update and re-run the model.

3.2.2 Model Extent and Mesh Design

The model geometry including the grid and layering have been left unchanged from the 2016 groundwater model update by Parsons Brinckerhoff.

Model extent and mesh design have been carried over from the existing Curragh Model (Parsons Brinckerhoff, 2016) developed on behalf of Wesfarmers Resources Pty Ltd for the Curragh Extension Project. No changes to model extent or mesh design were necessary to adopt the Curragh Model for use at the Project. The model domain is presented in Figure 3-1.

The model domain encompasses the Project and is elongated in a north to south direction, covering all historical and future mining operations at Curragh Mine. The model domain is 20.6 km x 45.2 km, with a structured grid of cell size 100 m x 100 m. Where layers are discontinuous, cells were defined as no-flow cells using the BAS package. There are 93,112 cells in each of the 10 model layers, resulting in a total of 931,120 cells.

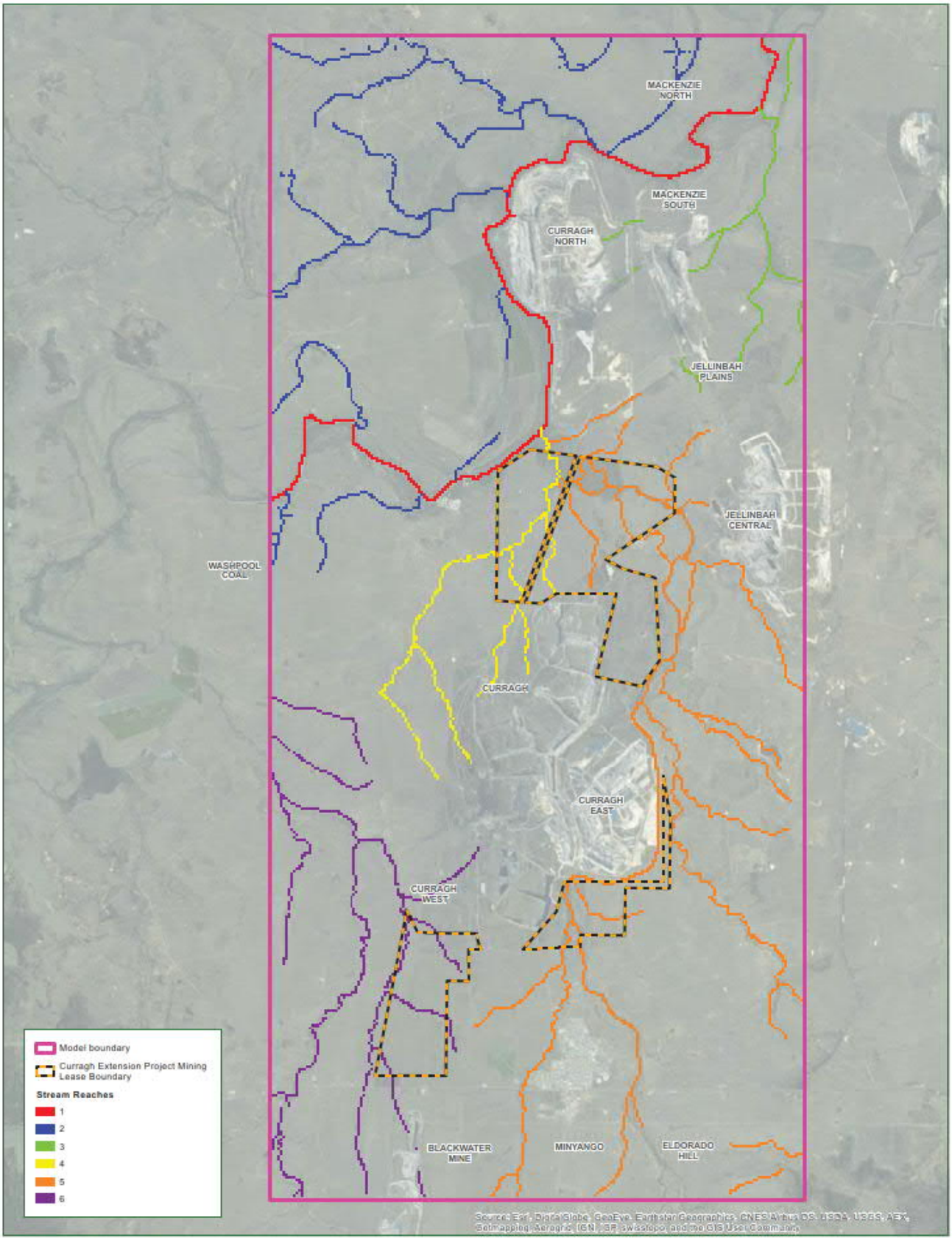


Figure 3-1 Model Domain (Parson Brinckerhoff, 2016)

As discussed in Parsons Brinckerhoff (2016), topography within the Project area of the model domain has been defined using Curragh Mine LiDAR data, beyond the extents of which high quality DEM data was used.

The model domain is discretised into 10 layers, as listed in Table 3-1. Model layer extents (lateral and vertical) have been defined using the Curragh Mine VULCAN database, with the support of exploration data from Queensland Globe for geological extent beyond the Curragh Mine area.

As discussed in Parsons Brinckerhoff (2016), the hydrogeological units represented in the model have been simplified based on hydraulic properties in order to minimise model run time while maintaining sufficient conceptual detail. The Rangal Coal Measures (RCM) are represented over three model layers, with coal seams aggregated into upper, middle and lower RCM seams. The RCM layers are not present to the western and eastern extents of the model domain where dipping of geological strata and thrusting have resulted in outcropping of the Burngrove Formation.

The modelling of faults in the model has not been updated from the Curragh Model. Included in the model are major regional faults and smaller scale local faults identified in the Curragh Extension Project hydrogeological conceptual model. The Jellinbah Fault, a regional thrust fault running in a north-westerly direction to the east of the Project resulting in up to 400 m of displacement, has been incorporated into the model through the offset of model layer elevations. Conceptual cross-sections developed using site LiDAR and drill hole data are included in the Groundwater Technical Report for the Curragh Extension Project (Parsons Brinckerhoff, 2016) and detail the structural geology of the model domain.

Table 3-1 Model Layers and Thicknesses

Model Layer	Formation	Unit	Average Thickness (m)	Maximum Thickness (m)
1	Alluvium	Surface cover	9.2	54.7
2	Weathered rock	Tertiary and minor Triassic Clematis, weathered Permian	15.3	67.8
3	Rewan Formation and RCM overburden	Triassic sandstone, siltstone, mudstone	72.6	520.1
4	Upper RCM seams	Cancer, Aries, Castor seams	2.3	12.1
5	RCM interburden	Sandstone, siltstone	18.2	84.5
6	Middle RCM seams	Pollux (upper and lower), Orion (upper and lower)	2.3	12.1
7	RCM interburden	Sandstone, siltstone	11.0	69.4
8	Lower RCM seams	Pisces seam	1.9	17.0
9	Burngrove Formation	Sandstone, siltstone, mudstone, coal seams	120.2	357.1
10	Fair Hill Formation	Sandstone, mudstone, coal seams	500.0	750.5

3.2.3 Temporal discretisation

The simulated time period in the original model (PB, 2016) starts at 1983, with a steady-state stress period to represent the pre-mining conditions, followed by 11 transient stress periods of 3 years representing historical mining at Curragh Complex. The predictive period comprised 26 transient annual stress periods and a final 100-year stress period, ending in 2142. The temporal discretisation of the model has been updated from that originally used in the Curragh Model, to allow for an extension of the mining period to 2048.

The transient calibration model was based on temporal data at bi-annual intervals from the end of the steady state calibration (January 1983) until December 2020. Together, the initial steady-state and transient calibration comprise 17 stress periods. Table 3-2 summarises the calibration model stress periods and simulated timing of active mining. The predictive part of the model comprises annual stress periods, starting from January 2021 until January 2048. The predictive model stress period setup is detailed in Table 3-3, alongside simulated mine-timings.

Table 3-2 Calibration Model Stress Period Setup

Calibration Period	Interval	Stress Period	Date (from)	Date (to)	Mackenzie (North & South) (OC)	Curragh North (OC)	Jellinbah (Plains & Central) (OC)	Washpool Coal (OC)	Curragh (OC)	Curragh East (OC)	Blackwater (OC)	Eldorado Hill (UG)
Steady-state		1	Steady-state									
Transient	Bi-annual	2	01/01/1983	31/12/1985					x			x
	Bi-annual	3	01/01/1986	31/12/1988					x			x
	Bi-annual	4	01/01/1989	31/12/1991	x		x		x			x
	Bi-annual	5	01/01/1992	31/12/1994	x		x		x			x
	Bi-annual	6	01/01/1995	31/12/1997	x		x		x			x
	Bi-annual	7	01/01/1998	31/12/2000	x		x		x		x	x
	Bi-annual	8	01/01/2001	31/12/2003	x	x	x		x	x	x	x
	Bi-annual	9	01/01/2004	31/12/2006	x	x	x		x	x	x	x
	Bi-annual	10	01/01/2007	31/12/2009	x	x	x		x	x		x
	Bi-annual	11	01/01/2010	31/12/2012	x	x	x		x	x		x
	Bi-annual	12	01/01/2013	31/12/2015	x	x	x		x	x		x
	Annual	13	01/01/2016	31/12/2016	x	x	x		x	x		x
	Annual	14	01/01/2017	31/12/2017	x	x	x	x	x	x		x
	Annual	15	01/01/2018	31/12/2018	x	x	x	x	x	x		x
	Annual	16	01/01/2019	31/12/2019	x	x	x	x	x	x		
	Annual	17	01/01/2020	31/12/2020	x	x	x	x	x	x		

Table 3-3 Predictive Model Stress Period Setup

Predictive Interval	Stress Period	Date (from)	Date (to)	Mackenzie (North & South) (OC)	Curragh North (OC)	Jellinbah (Plains & Central) (OC)	Curragh (OC)	Curragh East (OC)	Curragh West (OC)
Annual	18	01/01/2021	31/12/2021	x	x	x	x	x	
Annual	19	01/01/2022	31/12/2022	x	x	x	x	x	x
Annual	20	01/01/2023	31/12/2023	x	x	x	x	x	x
Annual	21	01/01/2024	31/12/2024	x	x	x	x	x	x
Annual	22	01/01/2025	31/12/2025	x	x	x	x	x	x
Annual	23	01/01/2026	31/12/2026	x	x	x	x	x	x
Annual	24	01/01/2027	31/12/2027	x	x	x	x	x	x
Annual	25	01/01/2028	31/12/2028	x		x	x	x	x
Annual	26	01/01/2029	31/12/2029	x		x	x	x	x
Annual	27	01/01/2030	31/12/2030	x		x		x	x
Annual	28	01/01/2031	31/12/2031	x		x		x	x
Annual	29	01/01/2032	31/12/2032	x		x		x	x
Annual	30	01/01/2033	31/12/2033	x		x		x	x
Annual	31	01/01/2034	31/12/2034	x		x		x	x
Annual	32	01/01/2035	31/12/2035	x		x		x	x
Annual	33	01/01/2036	31/12/2036	x		x			x
Annual	34	01/01/2037	31/12/2037	x		x			x
Annual	35	01/01/2038	31/12/2038	x		x			
Annual	36	01/01/2039	31/12/2039	x		x			
Annual	37	01/01/2040	31/12/2040	x					
Annual	38	01/01/2041	31/12/2041	x					
Annual	39	01/01/2042	31/12/2042						
Annual	40	01/01/2043	31/12/2043						
Annual	41	01/01/2044	30/12/2044						
Annual	42	01/01/2045	31/12/2045						
Annual	43	01/01/2046	31/12/2046						
Annual	44	01/01/2047	31/12/2047						

3.2.4 Model Stresses and Boundary Conditions

Stresses and boundary conditions used in the model have been adopted from the Curragh Model (Parsons Brinckerhoff, 2016) and included:

- Rainfall Recharge: MODFLOW recharge package (RCH) was used to simulate groundwater recharge in the model. The model applied recharge in six zones across the model domain according to surface geology. The model assigned a proportion of annual rainfall to each of the zones, estimated through chloride mass balance and the calibration process. Recharge rates applied in the Curragh Model are presented in Parsons Brinckerhoff (2016).
- Evapotranspiration: MODFLOW evapotranspiration package (EVT) was used to simulate evapotranspiration in the model. The long-term average, annual, actual evapotranspiration for the Curragh Mine area is approximately 650 mm (Parsons Brinckerhoff, 2016). Evapotranspiration for the model domain was set to 50% of this annual actual rate with an extinction depth of 3 m.
- Fixed head boundaries: MODFLOW general head boundary package (GHB) was used to apply fixed heads. A general head boundary condition was applied to cells along the north, south, east and west boundaries of the model, setting groundwater levels to 4.5 m below the top of Layer 1 to represent approximate effects of neighbouring mines on the groundwater regime.
- Rivers: MODFLOW river package (RIV) and MODLFOW drain package (DRN) were used to simulate surface drainage in the model. The model included the Mackenzie River and some tributaries of Mackenzie River, including Blackwater Creek. The Mackenzie River was represented at a constant level using the RIV package, with stage elevations defined as the lowermost elevation (from Curragh Mine LiDAR) within each 100 m cell. The smaller tributaries to the Mackenzie River were represented using the DRN package, with drain stage elevations also defined using minimum elevations from the Curragh Mine LiDAR data.
- Mining: MODFLOW drain package (DRN) was used to simulate historical and future open pit mining and underground mining with the model domain.

For the purpose of this study, SLR updated the RCH package with the latest rainfall data until January 2021. No changes were made to historical mining at surrounding sites. The simulated future mine progression in the model was primarily based on the 2016 study. Some changes were made to the simulated mine progression at Curragh Mine to reflect historical mining that occurred after 2016, and updates to future mine progression plans.

3.3 Model Recalibration

Transient calibration was previously undertaken on the existing Curragh Model (Parsons Brinckerhoff, 2016), and has been used as a starting point for re-calibration of the updated model. Automated calibration utility PEST ++ (Doherty 2019) and manual calibration were used to match the available transient water level data.

The 2016 calibration included 328 data points from 39 sites. The recalibration update consisted of an additional 687 data points from new and existing sites. The updated calibration data set includes all available groundwater measurements recorded from August 1997 until June 2021. In all, 1015 target heads were established for 69 bores from the following sites:

- Jellinbah Coal Mine: 19 groundwater level observations sites;
- Minyango Project: 3 groundwater level observations sites;

- Curragh Mine: 46 groundwater monitoring bores located across the Curragh, Curragh East and Curragh North mining areas; and
- Other bores: 1 water resource investigation bore.

Groundwater bores used for the calibration were weighted as 1 each in the calibration where data was considered reliable. Curragh monitoring bores BH1, BH3 and BH4 were weighted as 0.5, and BH2 and BH5 were weighted as 0.1, consistent with the weighting applied in the calibration of the existing Curragh Model (PB, 2016), reflective of data reliability. Bore 1314MB was removed from the calibration as the observed data indicated significant measurements errors. The observation points and their average residuals are presented in Appendix B.

The hydraulic properties (horizontal and vertical conductivity, specific yield and specific storage), and recharge rates were adjusted during the transient recalibration to provide best match between the measurements and model simulated heads. Manual parameter adjustment was undertaken to ensure the calibrated parameters were consistent with the conceptual understanding of the hydrogeological system. Vertical hydraulic conductivity was calibrated as a factor of horizontal conductivity (K_V/K_H). Reduced vertical hydraulic conductivity is typically observed due to sedimentary layering throughout the sequence, and by aggregation of strata in a numerical model.

3.3.1 Calibration Statistics

One of the industry standard methods to evaluate the calibration of the model is to examine the statistical parameters associated with the calibration. This is done by assessing the error between the modelled and observed (measured) water levels in terms of the root mean square (RMS). A root mean square (RMS) is expressed as:

$$RMS = \left[1/n \sum (h_o - h_m)_i^2\right]^{0.5}$$

Where:

- n = number of measurements
- h_o = observed water level
- h_m = simulated water level

RMS is considered to be the best measure of error, if errors are normally distributed. The weighted RMS error for the calibrated model is 5.3 m.

The acceptable value for the calibration criterion depends on the magnitude of the change in heads over the model domain. If the ratio of the RMS error to the total head change in the system is small, the errors are only a small part of the overall model response. Scaled RMS (SRMS) error is the RMS divided by the range of measured heads. The weighted SRMS is 5.5% which indicates a good calibration well within the Australian guideline indicator of 10% SRMS error (MDBC, 2001; Barnett *et al*., 2012).

Figure 3-2 shows the observed and simulated groundwater levels graphically for all bores used in the calibration. The current model shows a consistent match to the observations when compared to the Parsons Brinckerhoff (2016) model calibration, which showed a weighted RMS of 3.8 m and weighted SRMS of 5.8%.

Figure 3-3 shows the distribution of calibration residuals. As shown in the figure, all calibration residuals for calibration data points are within ± 20 m. A negative residual represents an over estimation of water levels, while a positive residual represents an underestimate. Figure 3-3 indicates that in general, the model tends to over-predict groundwater levels.

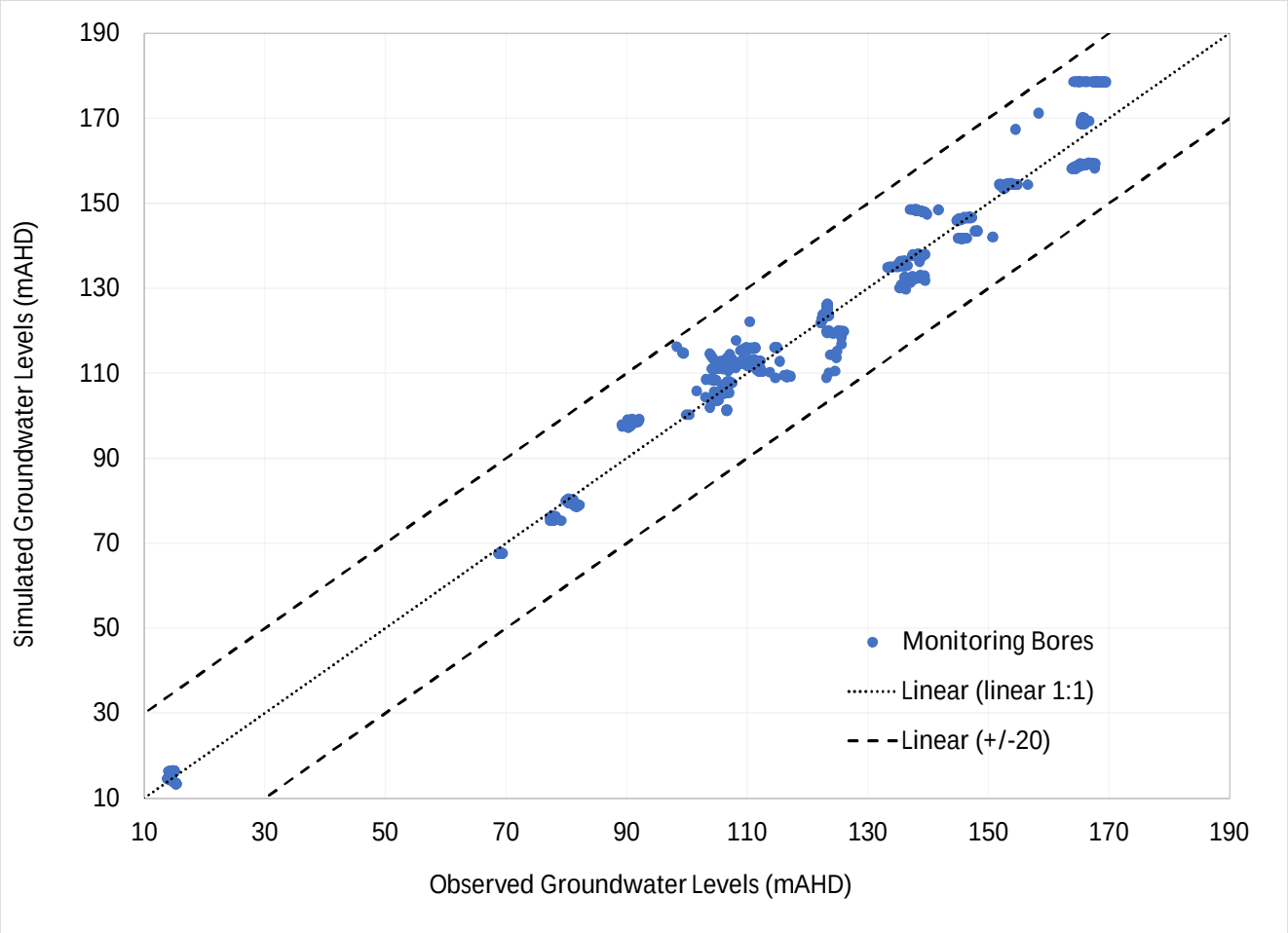


Figure 3-2 Calibration Scattergram – Modelled vs Observed Groundwater Levels (All Bores)

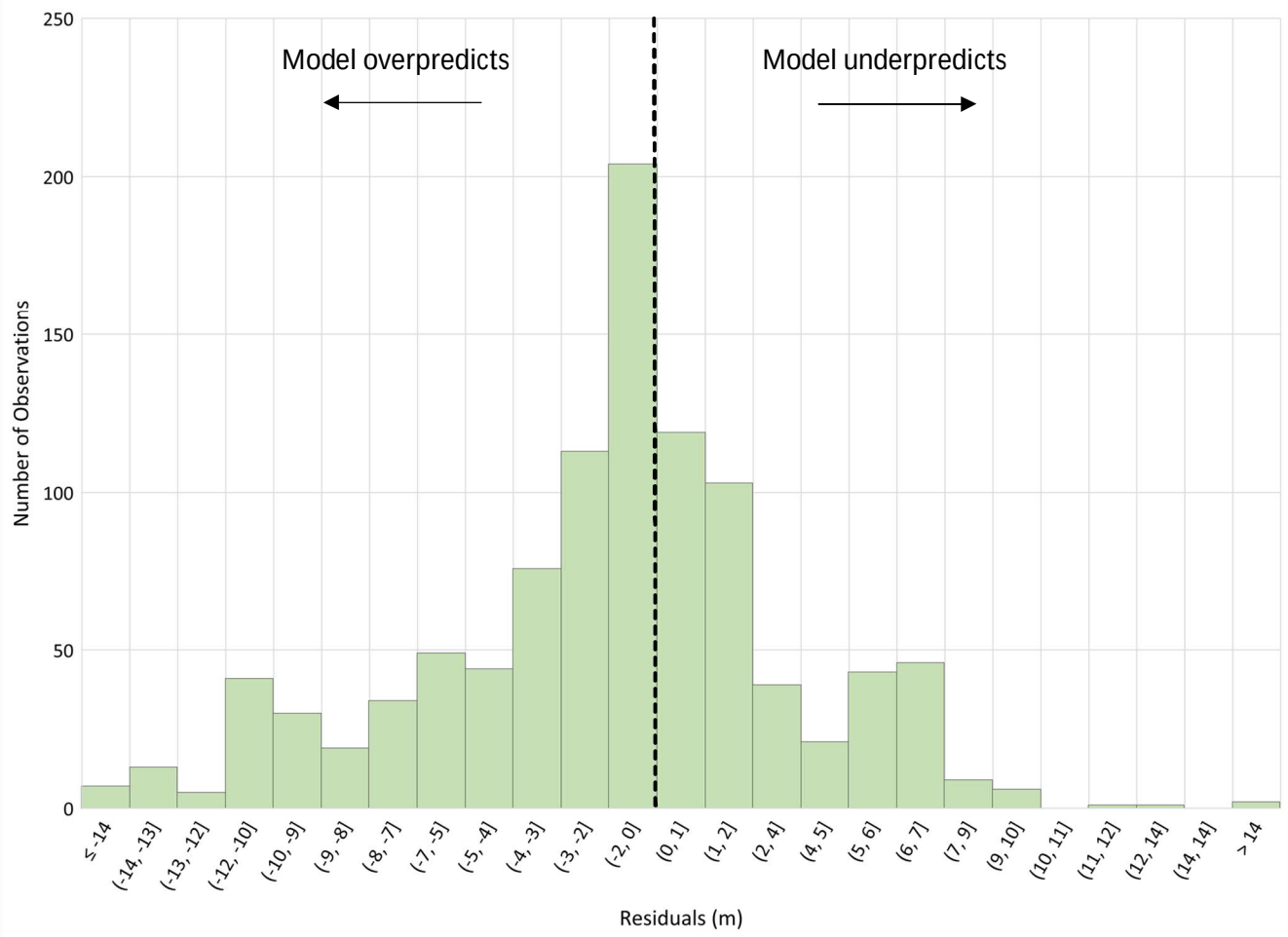


Figure 3-3 Calibration Residual Histogram Scattergram

The overall transient calibration statistics are presented in Table 3-4. As shown in the table, all calibration targets are calibrated within ±20 m of the observed measurements. This provides an indication of sufficient fit for the regional dataset; however, further discussion on the fit between modelled and observed trends is included in Section 3.3.2.

Table 3-5 shows the average calibration residual and absolute average residual per model layer. The residual is the difference between the measured and the modelled water level at each bore. Table 3-5 shows an overall overestimation of water levels in the model layers across the model domain. The table shows Layer 5 has the largest average residual, and Layer 3 has the largest absolute average residual.

Table 3-4 Calibration Statistics

Statistic	Value
Sum of Squares (m2)	25242.96
Mean of Squares (m)	28.10
Square Root of Mean of Squares (RMS) (m)	5.30
Scaled Root Mean Square (SRMS) (%)	5.50
Root Mean Fraction Square (RMFS) (%)*	3.87
Scaled Root Mean Fraction Square (SRMFS) (%) **	5.31
Sum of Residuals (m)	3742.29
Mean Residual (m)	3.65
Scaled Mean Residual (%)	3.79
Coefficient of Determination (tend to unity)	1.02
Targets within ±2m	457
Targets within ±5m	706
Targets within ±20m	1015

*RMFS represents the sample standard deviation of the differences between predicted values and observed values as a fraction of the observed value expressed as a percentage.

** SRMFS scales the RMFS error by the ratio of the mean observed value to the range of the observed values expressed as a percentage.

Table 3-5 Average Residual by Model Layer

Model Layer	Formation	Unit	Average Residual (m)	Average Absolute Residual (m)	Number of Observation Targets	Number of bores
1	Alluvium	Surface cover	-1.70	2.45	294	27
2	Weathered rock	Tertiary and minor Triassic Clematis, weathered Permian	1.81	2.78	136	9
3	Rewan/RCM overburden	Triassic sandstone, siltstone, mudstone	3.19	6.51	34	7
4	Upper RCM seams	Cancer, Aries, Castor seams	-	-	-	-
5	RCM interburden	Sandstone, siltstone	-3.62	5.10	104	9
6	Middle RCM seams	Pollux (upper and lower), Orion (upper and lower)	-	-	-	-
7	RCM interburden	Sandstone, siltstone	-2.90	4.11	68	3
8	Lower RCM seams	Pisces seam	-	-	-	-
9	Burngrove Formation	Sandstone, siltstone, mudstone, coal seams	-2.17	4.26	379	14
10	Fair Hill Formation	Sandstone, mudstone, coal seams	-	-	-	-

3.3.2 Calibration Fit

3.3.2.1 Groundwater levels

This section provides discussion on the modelled to observed groundwater level trends (calibration hydrographs) for key bores across the Curragh Complex. Calibration hydrographs, showing the fit between modelled and observed groundwater levels are presented in Appendix C. As shown by the hydrographs, in general, the model has replicated the groundwater transient trends in the bores.

Reproducing historical changes in groundwater levels at Curragh Complex required accurate data for mining intervals (spatial extent and depth), backfilling and voids water level as well as the screening depth interval (or targeted geological unit) for each bore. In many cases, this information was incomplete or not available. Considering these limitations, the response to the historical mining at Curragh Complex were reasonably simulated in most bores around the historical mining areas. This includes bores such as 1301MB, 1302MB, 1303MB, 1304MB, 1307MB and 1308MB.

Within the mine area, the model overpredicts or underpredicts groundwater levels by approximately 5 to 7 m when comparing to the observed groundwater levels in the Rangal Coal Measures. This can be seen in the calibration hydrographs for bores 1534MB, 1536MB, 1847MB and 1848MB.

Water levels in the alluvium and regolith in the vicinity of the mine are generally well represented and are within 5m of the measured water level. This can be seen in a number of monitoring bores, including 1312MB, 1322MB, 1410MB, 1411MB and BH8A.

Groundwater levels in regional bores to the far north and south of the model domain are overestimated by 10 to 15 m. Only one measurement is available for each bore located to the north. These bores target the alluvium (158166 and 158209), the RCM (158171, 158207, 158208, 158210, MIN_MB2 and MIN_MB4) and the Burngrove Formation (13010010). The difference in groundwater level between observed and simulated likely relate to the simplification of the geological units into discrete model layers away from the project area, where limited data is available.

3.3.2.2 Mine Pit Inflows

Parsons Brinckerhoff (2016) calibration data set included measured inflows. The model calculated the volume of water removed by mining based on hydraulic properties and gradients, not by direct user input. The calibration was undertaken to match the magnitude of water being removed based on observations.

Simulated model inflows were compared against observed inflows in the calibration data set. There were no additional inflow measurements available after 2016. Table 3-6 summarises the average observed and simulated inflows to the mine workings over the 2016 model update calibration period.

Overall, the model provides a reasonable fit to measured pit inflows for 2016. The modelled pit inflows are underpredicted at Curragh North pit U, and overpredicted at the Curragh East pits and Curragh North pit T and S.

Table 3-6 Mine Pit Inflows

	Curragh East (C, D, E, F, H pits)	Curragh North (U pit)	Curragh North (T pit)	Curragh North (S pit)
Total Measured Inflow (ML/d)	0.46	5.60	1.00	0.60
Modelled Inflow (ML/d)	1.20	3.57*	2.34*	0.93

*Average pit inflow rate taken from 2002 to 2016.

3.3.3 Water Balance

The water balance for the steady-state and transient calibration simulations are presented in Table 3-7 and Table 3-8, respectively. The water balance for the steady-state model indicates that recharge was the largest net inflow contributor to the model (10.72 ML/d). In the transient simulation, the largest net contribution to the model was also recharge (10.28 ML/d). Regional net groundwater inflows were 3.03 and 5.81 ML/day for the steady state and transient runs respectively, indicating that groundwater leaves the model domain through this boundary.

Net outflows of 6.86 ML/d (steady state) and 4.59 ML/d (transient) from the model occur due to baseflow seepage to the Mackenzie River (i.e. surface water and groundwater interaction in the Mackenzie River). This is the largest component of outflow from the model during steady state calibration. Also contributing to outflow from the groundwater system is evapotranspiration (6.90 and 5.40 ML/d outflow for the steady state and transient simulations, respectively). The mass balance error for the steady state and transient calibrations are 0.00 %, within the error threshold recommended by the Australian Groundwater Modelling Guidelines (Barnett et al., 2012), and indicating the model is stable and achieves an accurate numerical solution.

Table 3-7 Steady State Model Mass Balance

Component	Inflow (ML/day)	Percent of Total Inflow (%)	Outflow (ML/day)	Percent of Total Inflow (%)
Recharge (RCH)	10.72	62.46	-	-
ET (from GW) (EVT)	-	-	6.90	40.17
SW-GW Interaction (RIV) *	2.65	15.44	9.51	55.38
Regional GW Flow (GHB)	3.79	22.10	0.76	4.45
Mines (DRN)	-	-	-	-
Storage	-	-	-	-
Total	17.17	100.00	17.17	100.00

Table 3-8 Transient Model Water Balance

Component	Inflow (ML/day)	Percent of Total Inflow (%)	Outflow (ML/day)	Percent of Total Inflow (%)
Recharge (RCH)	10.28	29.23	-	-
ET (from GW) (EVT)	-	-	5.40	15.34
SW-GW Interaction (RIV) *	3.51	9.99	8.10	23.03
Regional GW Flow (GHB)	6.44	18.30	0.63	1.79
Mines (DRN)	-	-	15.11	42.96
Storage	14.95	42.49	5.94	16.89
Total	35.18	100.00	35.18	100.00

3.3.4 Calibrated Hydraulic Parameters

Table 3-9 summarises the calibrated values for horizontal and vertical hydraulic conductivity used in the model.

Table 3-9 Calibrated Hydraulic Parameters

Model Layer	Formation	Unit	Horizontal Hydraulic Conductivity (m/day)*	Anisotropy Kz/Kx
1	Alluvium	Gravel	1.50E+01	2.46E-01
	Alluvium	Sand/clay	8.22E-01	1.67E-02
	Alluvium	Clay	1.30E+00	1.00E-02
	Regolith	Rewan Formation (weathered)	5.20E-03	3.15E-02
	Regolith	Rangal Coal Measures (weathered)	2.26E-02	3.48E-01
	Regolith	Bungrove and Fair Hill Formation (weathered)	1.64E+00	7.05E-02
2	Regolith	Weathered rock	1.24E-01	4.74E-02
3	Rewan Formation	Triassic sandstone, siltstone, mudstone	3.13E-03	1.47E-02
4	RCM Upper Seams	Cancer, Aries, Castor seams	4.89E-04	2.19E-01
5	RCM Interburden	Sandstone, siltstone	1.21E-04	5.11E-02
6	RCM Middle Seams	Pollux (upper and lower), Orion (upper and lower)	2.31E-03	1.56E-02
7	RCM Interburden	Sandstone, siltstone	3.62E-01	1.00E-02
8	RCM Lower Seam	Pisces seam	1.00E+00	3.48E-02
9	Burngrove Formation	Sandstone, siltstone, mudstone, coal seams	7.78E-05	9.22E-02
10	Fair Hill Formation	Sandstone, mudstone, coal seams	4.81E-04	4.06E-01

Note: * upper hydraulic conductivity derived from depth of 20 m below surface and using depth formula

The hydraulic conductivity of the Permian interburden material and coal seams in the model reduces with depth in order to reflect field observations. The hydraulic conductivity of the interburden/overburden and coal seam layers decreases with depth according to Equation 1 (exponential):

Coal/Interburden: $HC = HC_0 \times e(-0.012 \times depth)$ (Eq. 1)

Where:

- HC is horizontal hydraulic conductivity at specific depth;
- HC_0 is horizontal hydraulic conductivity at depth of 0 m (intercept of the curve);
- depth is depth of the floor of the layer (thickness of the cover material);
- slope is a term representing slope of the formula (steepness of the curve).

HC_0 was estimated in the calibration. It varies for the coal seams and for the interburden and overburden units in the model. The final calibrated parameters used in the existing Curragh Model are consistent with the range of field and literature derived hydraulic parameters compiled for the conceptual model in the Groundwater Technical Report for the Curragh Extension Project (Parsons Brinckerhoff, 2016).

3.3.5 Calibrated Storage Properties

Table 3-10 summarises the calibrated values for specific storage and specific yield.

Table 3-10 Calibrated Storage Parameters

Model Layer	Formation	Unit	Specific Yield	Specific Storage SS (m^{-1})
1	Alluvium	Gravel	5.00E-02	1.32E-06
	Alluvium	Sand/clay	9.70E-02	3.30E-06
	Alluvium	Clay	2.35E-03	1.00E-05
	Regolith	Rewan Formation (weathered)	5.90E-03	2.99E-06
	Regolith	Rangal Coal Measures (weathered)	2.11E-02	1.00E-05
	Regolith	Bungrove and Fair Hill Formation (weathered)	1.00E-03	7.97E-06
2	Regolith	Weathered rock	5.00E-02	1.00E-05
3	Rewan Formation	Triassic sandstone, siltstone, mudstone	8.27E-03	4.57E-06
4	RCM Upper Seams	Cancer, Aries, Castor seams	1.00E-02	4.43E-07
5	RCM Interburden	Sandstone, siltstone	6.55E-03	4.47E-06
6	RCM Middle Seams	Pollux (upper and lower), Orion (upper and lower)	3.91E-03	1.00E-07
7	RCM Interburden	Sandstone, siltstone	1.12E-03	1.14E-07
8	RCM Lower Seam	Pisces seam	6.67E-03	3.97E-06
9	Burngrove Formation	Sandstone, siltstone, mudstone, coal seams	2.68E-03	4.24E-07
10	Fair Hill Formation	Sandstone, mudstone, coal seams	1.58E-03	1.00E-07

3.3.6 Calibrated Recharge

Recharge is predominantly through direct rainfall infiltration through the soil profile, and along the ephemeral drainage lines. The rate of recharge infiltration depends on the location, topography and geology at each model cell. Initial estimates of recharge were adopted from the previous Curragh Model (Parsons Brinckerhoff, 2016). As discussed in Section 3.2.4, the MODFLOW-USG recharge package simulated diffuse rainfall recharge across the model domain. For the steady state simulation, the model calculated the recharge rate as a percentage of long-term annual rainfall (1.55 mm/year) for each geological unit outcropping at the surface and for the transient simulation, the model calculated the recharge rate as a percentage of actual annual rainfall. The model then adjusted these initial percentages through the calibration process. Table 3-11 presents the calibrated recharge rate to each geological unit in the model.

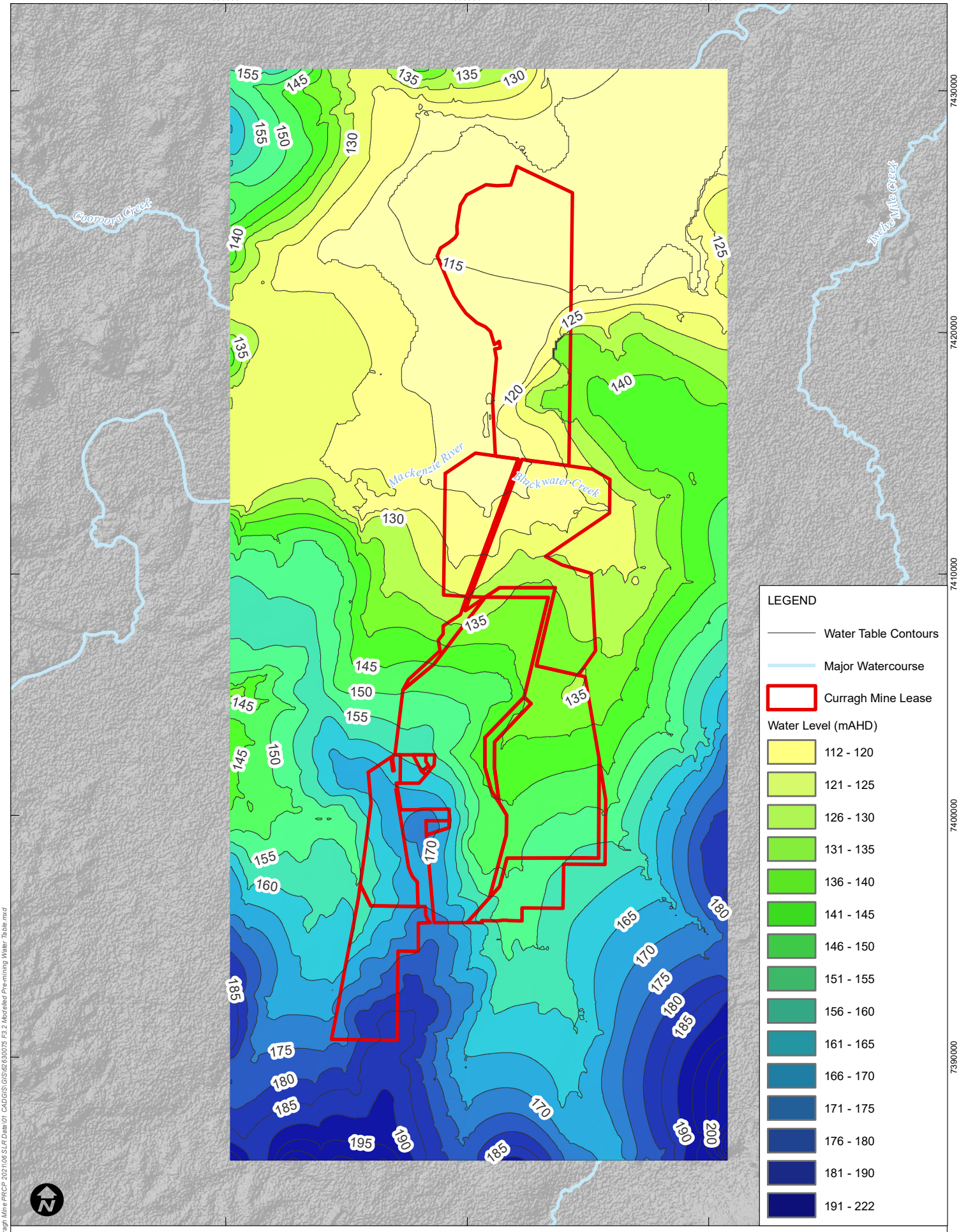
Table 3-11 Calibrated Rainfall Recharge

Model Geology Zone	(mm/year)	% Annual Rainfall	CMB Estimated (mm/year)
Alluvium	0.0028	0.18	5.5
Alluvium (Sand and Clay)	0.0543	3.51	-
Alluvium (Clay)	0.0774	5.00	-
Weathered Rock (Rewan)	0.0002	0.01	0.38
Weathered Rock	0.0077	0.50	0.50
Weathered Rock (Fairhill and Burngrove)	0.0003	0.02	0.38
Fresh Spoil Emplacement	0.0155	1.00	-
Mine Void	0.0000	0.00	-

3.3.7 Calibrated Pre-Mining Groundwater Levels

Figure 3-4 show the calibrated pre-development water table. Water table is the shallowest groundwater below surface regardless of geological unit. As shown in Figure 3-4, the simulated water levels reflect the flow regime prior to commencement of any mining within the model domain and indicate a general flow of groundwater towards the north-west discharging through the RIV boundary condition at the northern boundary of the model. The simulated water table reflect the surface topography.

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0 2 4 km

Coordinate System:	AGD 1984 AMG Zone 55
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Project Number:	626.30075
Date:	26-Nov-2021
Drawn by:	AN
Reviewed by:	AN

Data Source:

CURRAGH PRCP

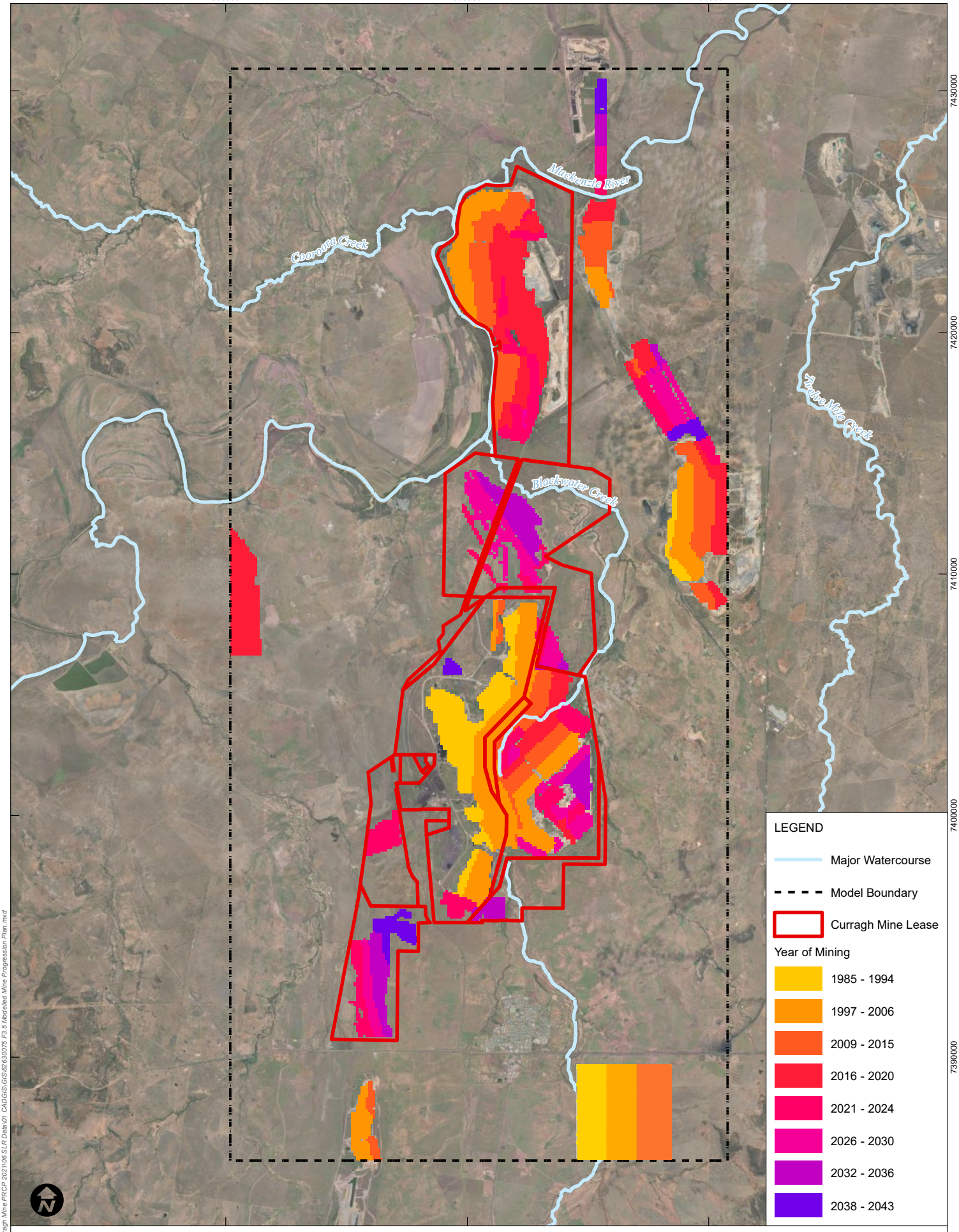
Preliminary Groundwater Assessment for Curragh CRVA
Modelled Pre-mining Water Table
(End of Steady State Simulation)

FIGURE 3-4

H:\Projects-SLR\626-MKY\626.30075.00000 Curragh Mine PRCP 20211106 SLR Data\01 CADGIS\GIS\626.30075 F3.2 Modelled Pre-mining Water Table.mxd

3.4 Predictive Model

Transient predictive modelling was used to simulate the proposed mining at Curragh (the expansion Pits X, Y, Z, J D and Ramp 9), as well as mining at other approved and foreseeable mines within the model domain. The predictive model stress period setup is detailed in Section 3.2.3, and the simulated predictive mine progression for the Project is presented spatially in Figure 3-5.



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Preliminary Groundwater Assessment for Curragh CRVA Modelled Mine Progression

FIGURE 3-5

All mining areas included in the model were simulated using the MODFLOW Drain (DRN) package. A nominally high drain conductance of 100 square metres per day (m^2/day) was applied to drain cells to simulate rapid removal of water from the system. Drain cells simulating mining were projected down to the base of the target coal seams. A one-year operational window was assumed for mine cells at the Project, after which time the drains were removed and the MODFLOW Time Varying Materials (TVM) package was used to assign spoil properties to the cells.

The model cell properties were updated to spoil properties guided by operational mine plans. Horizontal hydraulic conductivity of 0.3 m/day and vertical hydraulic conductivity of 0.1 m/day is applied to the spoil. The storage parameters used for the spoil were a specific yield of 0.05 and a storage coefficient of 1.0×10^{-5} m^{-}.

3.4.1 Predictive Water Balance

The water balance for the predictive simulation is presented in Table 3-12. The water balance for the predictive model indicates that recharge was the largest net inflow contributor to the model (11.01 ML/d). Regional groundwater inflow and outflow are 13.37 and 0.33 ML/day respectively, indicating that groundwater enters the model domain through this boundary.

The largest net contributor to outflow from the model during the predictive simulation were the drain cells, used to simulate mining activity and groundwater flux from minor tributaries (12.55 ML/d). A net outflow of 1.24 ML/d from the model occurs due to baseflow seepage to the Mackenzie River. Also contributing to outflow from the groundwater system was evapotranspiration (3.24 ML/d outflow). The mass balance error for the predictive calibration is 0.00 %.

Table 3-12 Predictive Model Water Balance

Component	Inflow (ML/day)	Percent of Total Inflow (%)	Outflow (ML/day)	Percent of Total Inflow (%)
Recharge (RCH)	11.01	24.85	-	-
ET (from GW) (EVT)	-	-	3.24	7.32
SW-GW Interaction *	4.62	10.43	5.86	13.22
Regional GW Flow (GHB)	13.37	30.15	0.33	0.74
Mines (DRN)	-	-	12.55	28.32
Storage	15.32	34.57	22.34	50.40
Total	44.32	100.00	44.32	100.00

* The other tributaries or drainage lines in the model are set as drains to the groundwater system and do not result in any recharge.

3.4.2 Predicted Mine Inflows

Average modelled pit inflows were calculated as time weighted averages for Project drain cells, for the predictive simulation period (2021-2039). The total inflow rates predicted for Curragh Mine range from 0.33 to 4.28 ML/day, with an average predicted inflow rate of 1.36 ML/day The average total pit inflow rate predicted by the model is reasonably consistent with the average total inflow of 0.97 ML/day predicted by the existing Curragh Model (Parsons Brinckerhoff, 2016). The additional pit inflow predicted by the updated model is likely attributable to changes in the Curragh Mine progression plan since 2016.

4 Recovery Model

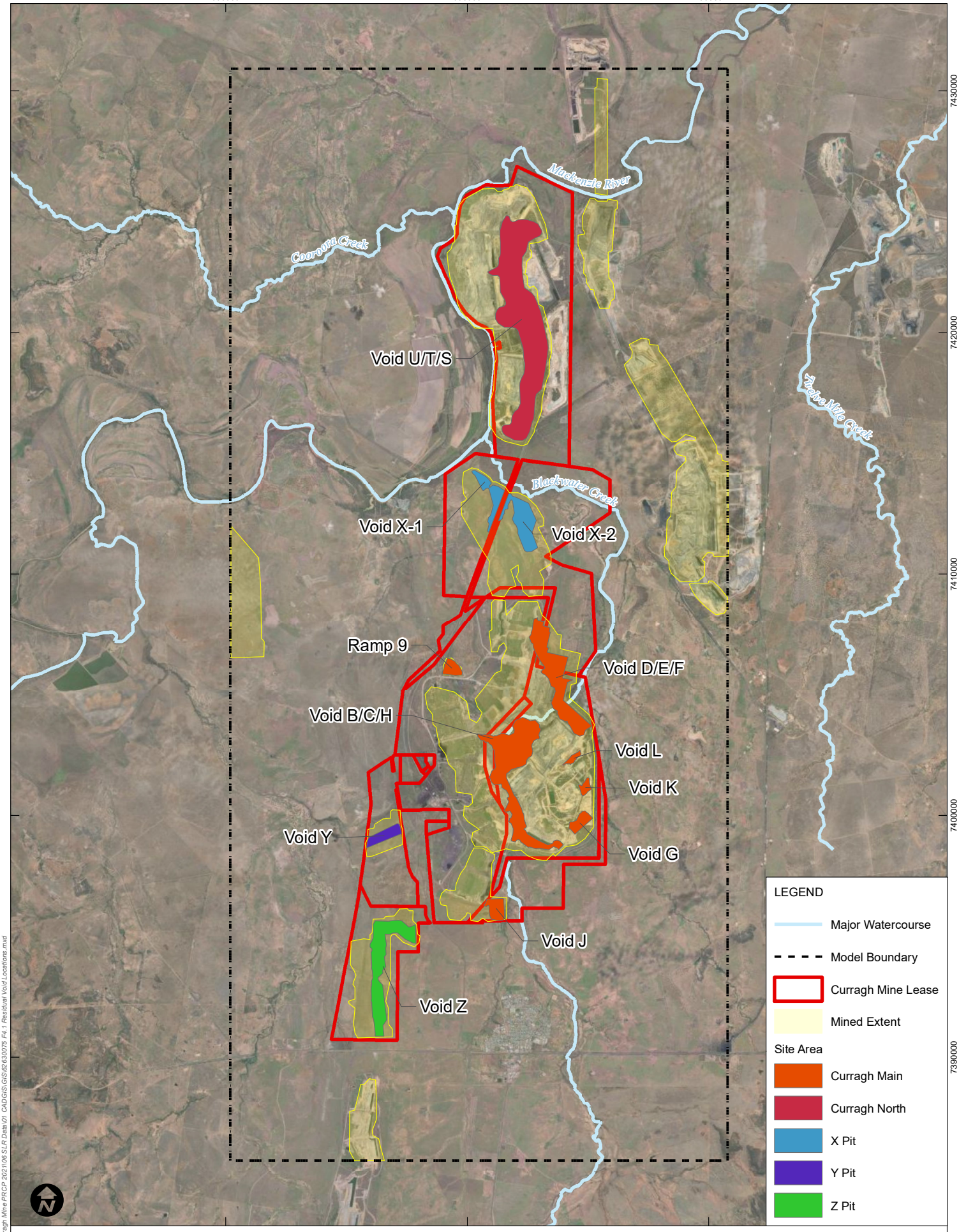
4.1 Recovery Model Setup

The location of the final voids at Curragh Complex are provided in Figure 4-1.

Post mining impacts were investigated with a recovery model, commencing at the end of active mining. A preliminary transient recovery model consisting of 16 time slices (each time slice set to 300-years) was developed to assess the relationship between the final voids' lake elevations and groundwater inflow. At the start of the recovery model, all model drain cells were removed and the properties of the final void cells were converted to values representative of a void. The void cells were assigned high horizontal and vertical hydraulic conductivities (1000 m/day) and storage parameters based on the compressibility of water (specific yield of 1.0, storage coefficient of 5.0×10^{-6} m^{-1}), to simulate free water movement within the void. This approach is often referred to as a 'high-K' lake. A constant head boundary condition was used to simulate increasing lake elevations in each of the final voids over the recovery period and the resultant groundwater inflows – lake level curve for each of the final voids during recovery were incorporated in the site water balance model for the Project's surface water modelling (SLR, 2021).

The pit lake recovery level and timings were predicted by the surface water balance modelling. These elevation and recovery timing derived from the surface water modelling was replicated within the numerical groundwater model using the time variant constant head boundary condition. The model predicted water levels in the final voids to reach equilibrium conditions after approximately 20 to 50 years, dependent on void structure and interaction with the regional groundwater system. Void recovery graphs in each of the voids over the recovery period are presented in Appendix D.

A summary of predictions from the recovery model, including final void water levels (at equilibrium) are presented in Section 4.2.



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Preliminary Groundwater Assessment for Curragh CRVA

Residual Void Locations

FIGURE 4.1

H:\Projects-SLR\626-MKY\626.30075.00000 Curragh Mine PRCP 2021\06 SLR Data \01 CAD\GIS\GIS\626.30075 F4.1 Residual Void Locations.mxd

4.2 Post-mining Equilibrium

Simulated post-mining groundwater fluxes to the final voids at equilibrium conditions were extracted for both scenarios using MODFLOW-USG ZONBUD utility. The net groundwater flux has been calculated as a cumulative void flux for each area at Curragh Complex (Curragh North, X Pit, Curragh Main, Y Pit and Z Pit) to account for interaction between the adjacent voids within each area. The simulated average groundwater takes at the end of recovery (2133) at each of the site areas are presented in Table 4-1.

The groundwater takes presented in Table 4-1 are total groundwater takes, including throughflow from spoil and groundwater take from the Rangal Coal Measures (RCM). An equilibrium groundwater flux of 4.82 ML/day was predicted at Curragh North, where the minimum elevation of the final landform is 74 m lower than the other voids. The relative depth of the residual void at Curragh North is likely accountable for the higher predicted groundwater flux to the void in this area. Equilibrium total groundwater flux to the voids in Curragh North Pit, X Pit, Curragh Main, Y Pit and Z Pit are predicted to be 4.82, 0.49, 1.75, 0.11 and 1.00 ML/day respectively, indicating all simulated voids are predicted to be groundwater sinks with positive net groundwater flow into the voids. The simulated fluxes to the voids in the groundwater model are consistent with groundwater fluxes in the surface water model developed for simulating final landforms for Curragh Mine (SLR, 2021).

Based on the geological data reviewed for this preliminary assessment (which is limited for the extension areas), it appears that equilibrium void lake levels are generally well below the level of alluvium and base of weathering (Table 4-1). If these levels were exceeded, the alluvium and weathered rock profile could potentially present preferential pathways for outward seepage of water from the void lakes.

The predicted water salinity results presented in Table 4-1 have been derived from the preliminary surface water modelling of residual voids (SLR,2021). The predicted salinities indicate that the void lakes should stabilise at approximately 37,000 µS/cm after 200 years.

Table 4-1 Post-Mining Equilibrium Residual Void Summary

Curragh Area:		Curragh N	X Pit		Curragh Main							Y Pit	Z Pit
Residual Void[1]:		U/T/S	Void 1	Void 2	D/E/F	B/C/H	L	K	G	J	Ramp 9	Y	Z
Final landform minimum elevation used in the numerical model (mAHD)		-48	78	34	26	41	92	65	64	93	77	116	78
Post-mining equilibrium void lake level (mAHD), the final lake levels were derived from the surface water model.		26	101	69	63	83	113	105	79	132	91	131	115
Approximate base of weathering / alluvium elevation (mAHD)		100	110	115	120	130	130*	130*	135*	140*	120	135*	150
Void lake salinity (uS/cm), as predicted by the water balance model.[2]	~10 years	27,578	28,650	16,174	36,828	23,045	20,530	23,445	33,100	19,951	29,754	28,954	37,296
	~30 years	37,313	37,274	32,568	37,313	37,181	36,416	37,308	37,288	31,496	37,313	37,313	37,313
	~200 years	37,313	37,313	37,313	37,313	37,313	37,313	37,313	37,313	37,313	37,313	37,313	37,313
Net groundwater flux to void at equilibrium (total flux including inflow draining from the spoil and groundwater inflow from the RCM, ML/day)		4.82	0.49		1.75							0.11	1.00

Notes:
1 The residual voids have been grouped where a void may act as a source of water to an adjacent void, but where collectively they act as a groundwater sink.
2 37,313 µS/cm is the maximum salinity limit set in the surface water balance model (SLR 2021)
* Approximate elevation of base of weathering estimated from available data.

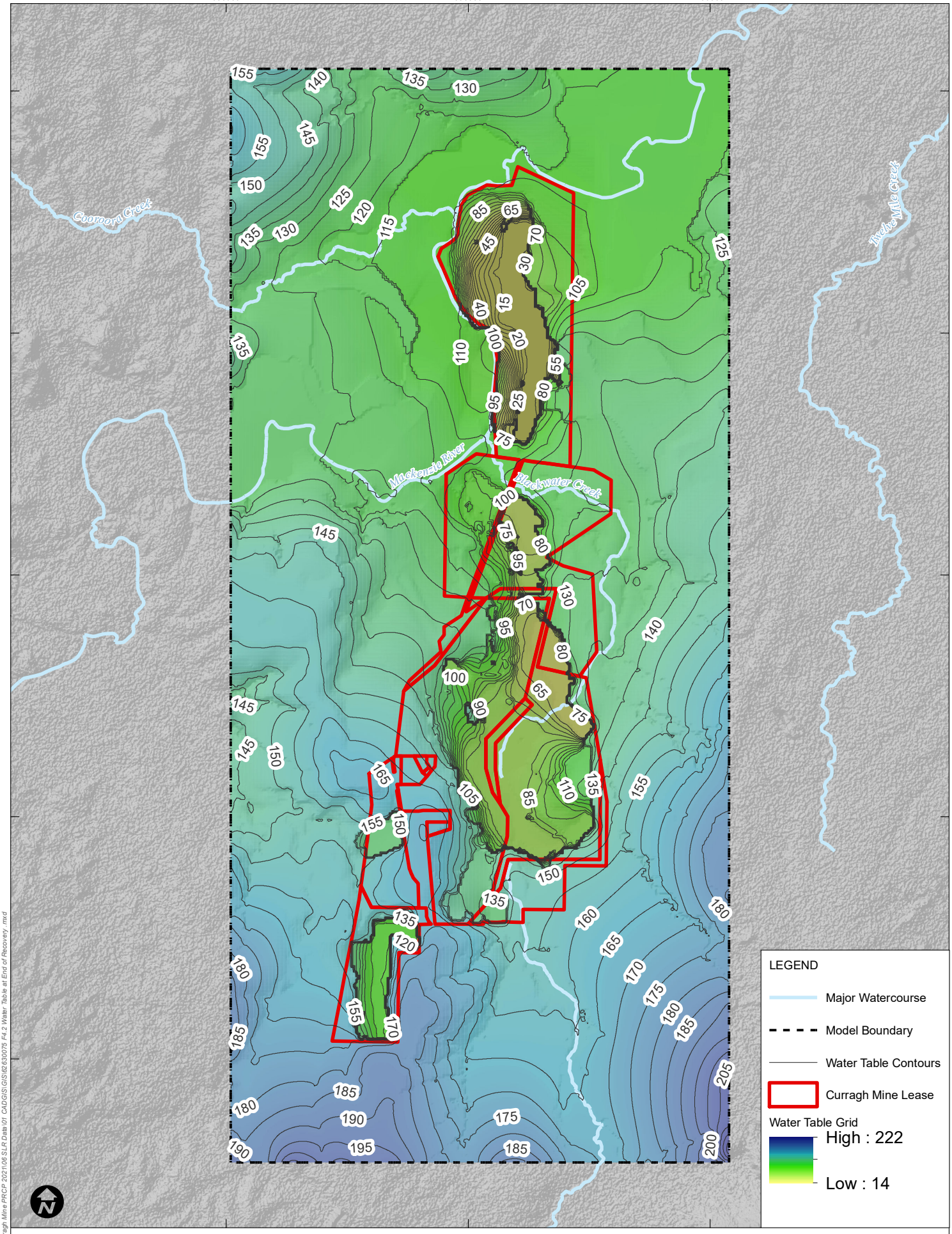
4.3 Post-mining Gradients and Residual Drawdown

The predicted post-mining water table at equilibrium (end of recovery) is shown in Figure 4-2. Hydraulic gradients at equilibrium indicate an overall flow direction toward residual voids at Curragh Main and Curragh North. All residual voids show hydraulic heads decreasing with proximity to the void, indicating all voids are predicted to act as local groundwater sinks.

Residual drawdown refers to the remaining drawdown impact associated with mining at Curragh Complex and is obtained by comparing the difference predicted equilibrium post-closure groundwater levels at Curragh Complex against a 'null-mining' model scenario. The 'null-mining' model run does not include any historical or future mining at Curragh Complex but all other stresses and boundary conditions remain unchanged from the model simulating mining at Curragh Complex. The residual drawdown is essentially a comparison of groundwater levels between a mining and closure scenario, and a no mining scenario.

Predicted drawdown figures (Figure 4-3 and Figure 4-4) show where residual drawdown impacts are predicted to exceed 1 m. Figure 4-3 presents the residual drawdown just within the alluvium at post-mining equilibrium. Predicted recovered heads in the alluvium west of Curragh North show residual drawdowns of 1 to 2 m extending up to 3 km from mined pits at Curragh North although drawdowns at the very edge of the voids are higher (5-10 m). Figure 4-4 presents the residual drawdown of the water table at post-mining equilibrium.

To investigate the potential movement of groundwater to or from the voids and spoil at post-mining equilibrium, the post-mining water table predicted for the end of recovery was used to infer potential flow pathways in and around the spoil at each area of mining. Particle tracking was used together with the post-mining water table to predict groundwater movement relative to the voids and areas of spoil. Particles are "dropped" on the post mining equilibrium water table and allowed to track down hydraulic gradient from their starting position. Figure 4-5 shows the inferred flow pathways around the residual voids interpreted from the particle tracking simulation at post-mining equilibrium. The flow paths from the outer edges of the voids or spoil dumps informed by the recovered head levels indicate groundwater flow is toward each of the residual voids hence none of the voids are likely to act as sources to the groundwater system. Although the tailings storage facilities (Pit A and Pir B TSFs), have not been modelled explicitly for this preliminary assessment, the particle tracking indicates that groundwater flow around the TSFs would move into towards the residual voids at Curragh Main.



SLR

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Coordinate System:	AGD 1984 AMG Zone 55
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Project Number:	626.30075
Date:	26-Nov-2021
Drawn by:	AN
Reviewed by:	AN

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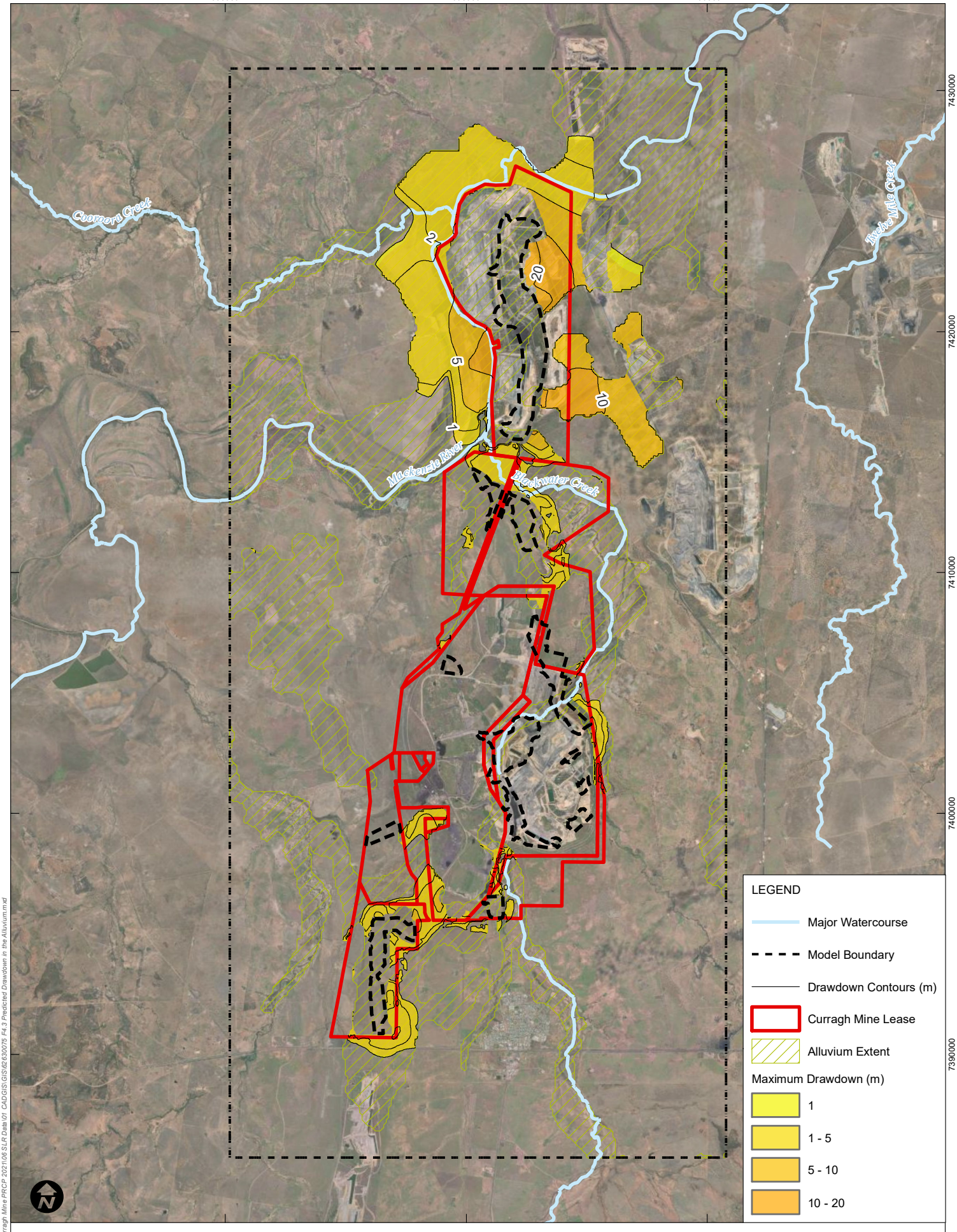
CURRAGH PRCP

Preliminary Groundwater Assessment for Curragh CRVA

Water Table at End of Recovery

FIGURE 4-2

H:\Projects-SLR\626-MKY\626.30075.00000 Curragh Mine PRCP 20210106 SLR Data\01 CAD\GIS\GIS\626.30075 F4.2 Water Table at End of Recovery .mxd



H:\Projects-SLR\626-MKY\626.30075.00000 Curragh Mine PRCP 2021\06 SLR Data \01 CAD\GIS\GIS\626.30075 F4.3 Predicted Drawdown in the Alluvium.mxd

SLR

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0 2 4 km

Coordinate System:	AGD 1984 AMG Zone 55
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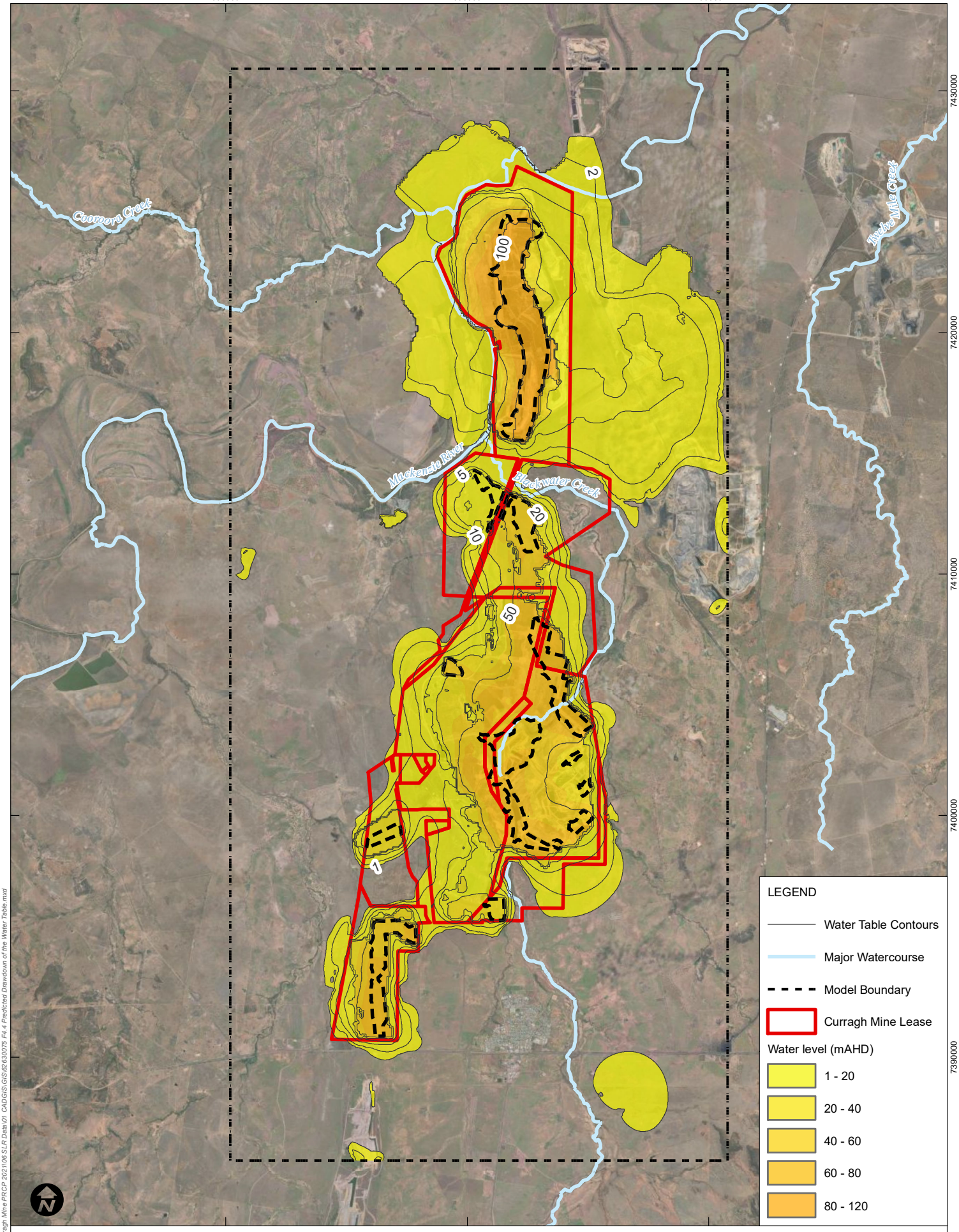
Data Source:

CURRAGH PRCP

Preliminary Groundwater Assessment for Curragh CRVA

Predicted Drawdown in the Alluvium (End of Recovery)

FIGURE 4.3



H:\Projects-SLR\626-MKY\626.30075.00000 Curragh Mine PRCP 2021\06 SLR Data \01 CADGIS\ GIS\626.30075 F4.4 Predicted Drawdown of the Water Table.mxd

SLR

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0 2 4 km

Coordinate System:	AGD 1984 AMG Zone 55
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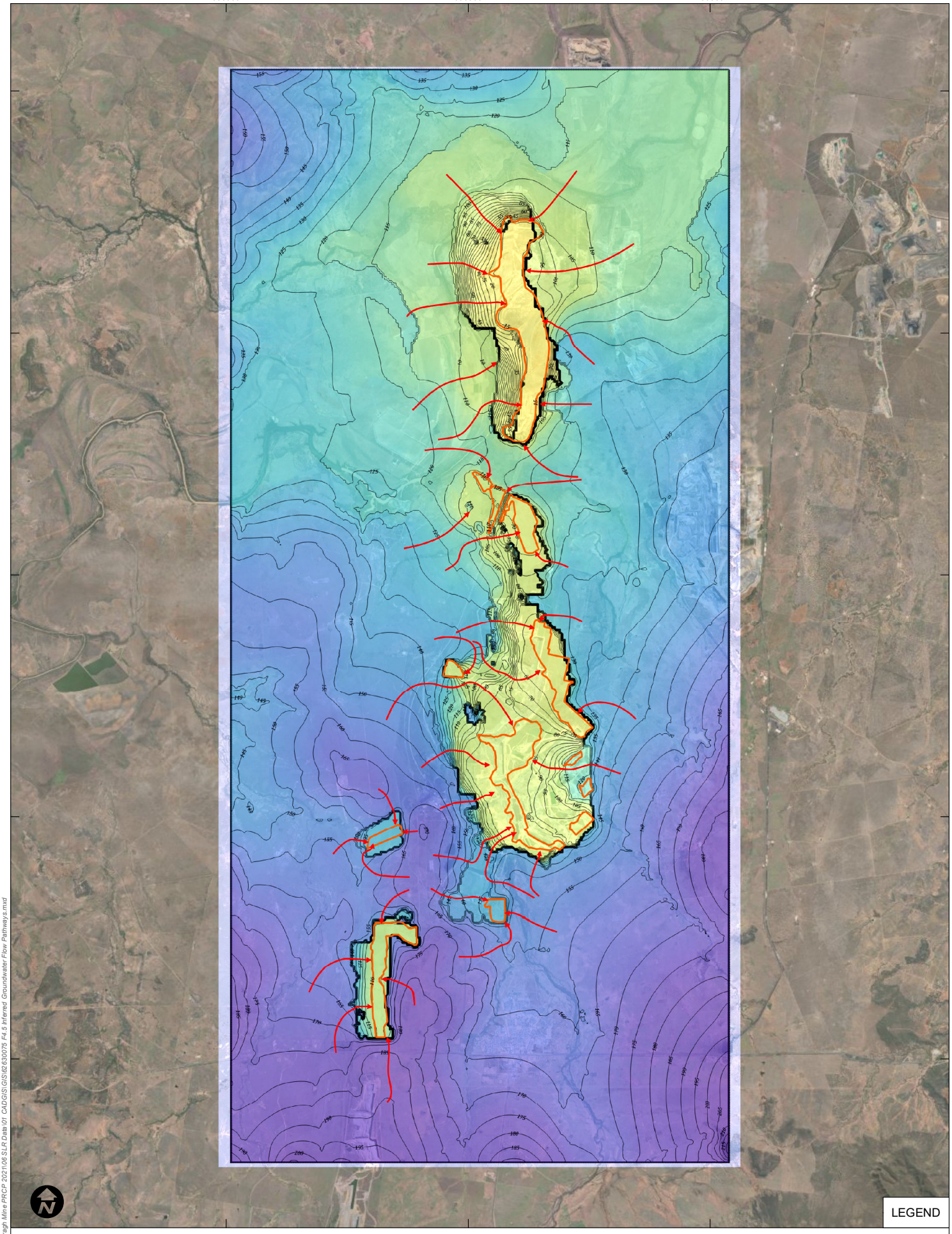
Data Source:

CURRAGH PRCP

Preliminary Groundwater Assessment for Curragh CRVA

Predicted Drawdown of the Water Table (End of Recovery)

FIGURE 4-4



SLR

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0 2 4 km

Coordinate System:	AGD 1984 AMG Zone 55
Scale:	1:200,000 at A4
Project Number:	626.30075
Date:	26-Nov-2021
Drawn by:	AN
Reviewed by:	AN

Data Source:

CURRAGH PRCP

Preliminary Groundwater Assessment for Curragh CRVA

Inferred Groundwater Flow Pathways at Post-Mining Equilibrium

FIGURE 4-5

H:\Projects-SLR\626-MKY\626.30075.00000 Curragh Mine PRCP 2021\06 SLR Data \01 CADGIS\GIS\626.30075 F4.5 Inferred Groundwater Flow Pathways.mxd

5 Conclusions and Recommendations

5.1 Conclusions

The numerical groundwater model updated for Curragh Complex achieved the modelling objectives, as outlined in Section 3.1. Model calibration statistics are within suggested guidelines (MDBC, 2001) and mass balance errors remain at 0%, through the model calibration and predictive modelling. The groundwater model was updated to considers all available data to date, including an updated mine plan for some of the pits. The model, therefore, serves as a useful tool to represent the transient groundwater conditions within the Curragh Complex area, over the life of the mine. The following key conclusions are drawn from the preliminary numerical modelling assessment of the post-mining groundwater environment at the Curragh Complex:

- The numerical modelling indicates that lakes will form within the residual voids of the proposed final landform. These lakes will act as local groundwater 'sinks' with groundwater within mining disturbed areas (including the Pit A and B TSFs) migrating towards these sinks.
- Post-mining residual drawdown in the Mackenzie River Alluvium to the west of Curragh North will generally be in the order of 1-2m (but up to 10m near the mine voids), noting that the Mackenzie River is regarded as a "losing" watercourse with pre-mining groundwater levels in the alluvium 4-5m below the river stage in the vicinity of the mine (Section 2.3.8.1).
- Based on the geological data reviewed for this preliminary assessment (limited for the extension areas), it appears that equilibrium void lake levels are generally well below the level of alluvium and base of weathering (potential preferential pathways for outward seepage of water from the void lakes).
- Post-mining, the total estimated "groundwater" inflow to all voids is approximately 8.2 Ml/d although the majority of this is water derived from infiltration to the spoil and drainage into the void lake rather than inflow from the Rangal Coal Measures or Alluvium.

5.2 Model Limitations

It is important to note that groundwater models have inherent uncertainties which should be quantified and reduced where required and possible. The limitations and uncertainty associated with the model are discussed below. The IESC *Uncertainty analysis – Guidance for groundwater modelling within a risk management framework* (2018) identifies four key sources of scientific uncertainty affecting groundwater model simulations:

- Structural/conceptual.
- Parameterisation.
- Measurement error.
- Scenario uncertainties.

These four sources of scientific uncertainty have been qualitatively assessed with regards key aspects of the Curragh Mine groundwater model, as presented in Table 5-1.

Overall, the model is considered fit for purpose to achieve the objectives of the preliminary groundwater assessment outlined in Section 1 based on the data provided and the project timeframe. In case of future versions of the model including the PRCP assessment, updates should be conducted to further refine the model. The table includes actions to verify if aspects of the model are currently fit for purpose, as well as recommendations to improve the model for the PRCP.

Table 5-1 Groundwater Model and Data Limitations and Recommended updates for more Detailed Assessment of Closure

Type	Part	Status	Comment
Structural/ Conceptual	Grid and Model Extent	Fit for purpose. Improvements required.	• The model has a structured 100 m x 100 m cell grid that includes the site, neighbouring mines and drainage features. • Further modelling of closure should consider developing an unstructured grid that can allow efficiency and flexibility with detailed cell refinement around the final voids, the tailings and along drainage features such as Mackenzie River. • The model extent should be reviewed and revised if necessary for the PRCP assessment.
	Layers	Fit for purpose of preliminary assessment. Improvement required.	• The top of layer 1 should be updated using the latest site LiDAR. • Representation of alluvium and regolith should be refined based on CSIRO and available geology. • Verify extent of modelled alluvium matches observed extent of alluvium near pits, along Mackenzie River. • The model structure should be refined based on the site latest geology model and the model vertical resolution should be revisited and refined if necessary. Comparison between the model layers and drill hole information indicates some discrepancy in the model layers. Changes required could be verified by comparing the current site geological model surfaces to the groundwater model layers. • The MODFLOW-USG pinch out option should be used to allow discontinuous geology units to be better represented in the model (e.g. outcrop, or cross geological faults).
	Conceptualisation – Geological Structure	Fit for purpose of preliminary assessment. Improvement may be required.	• The structure of the geology is based on site and regional geological mapping. No geological structures (i.e. faults) have been included in the model other than through layer displacements from site geological models. • Faults are known in the region, and review of latest site-specific data (if available) is recommended.
	Conceptualisation – GDEs	Fit for purpose of preliminary assessment. Improvement may be required.	• Most recent information on where GDE's may be located (i.e. ecological sites) is required to ensure the local groundwater regime relevant to the GDE is adequately understood and captured in the model.

Type	Part	Status	Comment
	Conceptualisation – Surface Water Groundwater Interactions	Fit for purpose of preliminary assessment. Verification required.	• The RCM outcrop / subcrop in Curragh North and Curragh Main areas. The RCM also subcrop east (the upthrow side) of the Jellinbah Fault where they are extracted at Jellinbah Mine. The vertical connectivity between where the coal seam occurs at subcrop near alluvium and surface water features such as Mackenzie River tributaries should be verified in the future version of the model and refined if necessary.
	Conceptualisation – Saturated Extent of Alluvium and Regolith	Fit for purpose of preliminary assessment. Future improvements maybe be required.	• The model slightly under or over-predicts groundwater levels in alluvium, but generally within 5 m of observed levels. • Additional monitoring points may be required to verify the presence/absence of groundwater in the Alluvium at key locations i.e. west of Curragh North. • Any additional data or study on alluvium extent and thickness at Curragh Complex should be reviewed and captured (where relevant) in future updates of the model. Such improvements are not critical for the preliminary assessment for the CRVA.
Parameterisation	Hydraulic Conductivity – Depth Dependence	Fit for purpose of preliminary assessment. Future improvements may be required.	• Limited site specific hydraulic conductivity data (horizontal and to a lesser extent vertical) obtained in 1998. The data shows a general decline in hydraulic conductivity with depth that is replicated in the model. • Additional data (if available) should be utilised to verify and update the modelled change with depth, and to refine model calibration and predictions.
	Spoil and Tailings Properties	Fit for purpose of preliminary assessment. Future improvements may be required.	• No site-specific data is available for the spoil and tailings. Spoil properties were adopted from existing studies. • Measurements of spoil and tailings hydraulic properties should be carried out and utilised to verify and refine the model calibration and predictions in the future version of the model.

Type	Part	Status	Comment
	Rivers	Fit for purpose of preliminary assessment. Future improvements required.	• Mackenzie River stage height is assigned a long term annual average level assumed in the previous version of the model. • Future versions of the model should refine model time slices to allow river stage heights that are changed temporally in the historical calibration model based on observed levels from gauges with the average quarterly levels assumed in the predictive model. • No site-specific information on surface water discharge, flow monitoring or water storage has been included in the model but should be considered for inclusion in further modelling work. • Blackwater Creek and other minor tributaries within the vicinity of Curragh Complex are ephemeral and only flow briefly after rainfall. Therefore, river stage height of zero was assigned to these watercourses in the model.
	Recharge	Fit for purpose	• Recharge zonation is based on mapped surface geology and calibrated recharge rates. Soil mapping and site water quality data could be further utilised to base recharge rates.
Measurement Error	Observation Data Quality	Fit for purpose of preliminary. Future improvements required.	• Require further review of bore construction details, target geology and monitoring methodology to reliably apply to the groundwater model.
	Landholder Bore Data Quality	Fit for purpose	• Further detailed review of impacts at the locations of landholder bores should be undertaken with the updated model for PRCP
	Temporal spread	Fit for purpose of preliminary. Future improvements may be required.	• Timeseries water level data from the site as well as the neighbouring mines (Minyango, Jellinbah) for the alluvium and Permian coal measures. • Future versions of the model could be designed with refined model time slices to allow climate seasonality and temporal behaviour of the groundwater system to be simulated in the model.
Scenario Uncertainties Future stresses/ conditions	Calibration	Fit for purpose of preliminary. Future improvements may be required.	• A transient calibration model set up in existing model. The model was calibrated to observed groundwater levels (1983-2021) and observed mine inflows (2015). • Using shorter time slices in the model would allow climate seasonality to be better represented in the model. • The model calibration could be further refined with more recent data on mine inflows.

Type	Part	Status	Comment
	Predictive	Fit for purpose of preliminary. Future improvements may be required.	• Model captures open cut mining progression and timing at Curragh Complex, based on the 2016 model with a few areas updated based on the most recent data. • The model also includes future mining at surrounding mines based on publicly available data and the information from the previous version of the model. • The simulated mining progression and the timing for the pits I will require an update to match with the actual mine progression. This may require extension or changes to the predictive model timing.
	Sensitivity and uncertainty	Fit for purpose of preliminary. Future improvements may be required.	• Predictive uncertainty analysis was conducted on the previous version of the model and is not considered necessary for the purpose of this preliminary assessment for the CRVA. • Additional work to test the uncertainty of the model parameters may be required. This includes differences in the properties spoil properties and hydraulic properties of the in-situ strata. As well the influence of streamflow and recharge on model predictions and recovery.

5.3 Recommendations

A more detailed assessment of post-closure groundwater related issues with refined modelling will be completed for the Curragh Mine PRCP. Based on the work completed for this preliminary assessment, and Table 5-1, the following key recommendations are made for the detailed groundwater assessment and refinement of the numerical model:

- More detailed evaluation of the interaction between the voids and alluvial groundwater, particularly in relation to the Mackenzie River Alluvium, should be undertaken;
- A more detailed estimation of net groundwater flux from the Rangal Coal Measures to each of the residual voids should be completed (excluding drainage of infiltration through the spoil to the voids).
- Assessment of the final landform for the tailings storage facilities, using site specific information on the tailings (permeability and water quality), and the potential for contaminant migration from the TSFs;
- Assessment of other potential sources of contamination such as landfills and fuel storage sites;
- More detailed assessment of final pit lake levels against the base of weathering / alluvium, particularly for the voids with the highest predicted equilibrium lake levels; and,
- Assessment of the effect of the Mackenzie River flooding on groundwater ingress to the voids via the alluvium / weathered rock.

In relation to updates to the numerical groundwater model required to investigate the effects of closure of the Curragh Mine on the local groundwater environment we recommend that:

- The existing conceptual model should be reviewed and refined using the latest data and observations and relevant updates made to the representation within the numerical model;
- The model geological layering should be revised based on the latest site geological model including any new information on the depth, nature and extent of the Mackenzie River Alluvium;
- The Mackenzie River should be represented using the latest data including a channel depth should be applied to replicate the incised nature of the river;
- The simulated mining in the model should be refined to represent the actual historical mining and the latest proposed future mine progression. The timing of events such as in-pit spoil emplacement within the open-cut pits and tailing emplacement should be captured in the model as accurately as possible. Any conductivity test on spoil and tailings and, the tailings fill elevation should be included in the model;
- The model design should be updated to an unstructured grid and the layering should also use the “pinch out” option of MODFLOW-USG where required to model the geology more accurately;
- Any new field data available on the horizontal and vertical hydraulic conductivity for the main stratigraphic units should be used to update the model. There is currently limited data on storage parameters, which influences predicted groundwater fluxes and the extent of residual drawdown. The revision of model parameterisation would be calibrated using PEST (parameter estimation function), and constrained by site data and documented ranges for Bowen Basin stratigraphy; and,
- Climate data should be updated from SILO, and stress period timing aligned with site climate seasonality. Recharge rates should be calibrated, and the bounds set based on available site water quality data and historical modelling.

6 References

Ausenco-Norwest, 2012. Groundwater Model, Northern Bowen Basin Regional Model Impact Predictions, Queensland, Australia. Prepared for Arrow Energy Pty Ltd. Available at: http://www.arrowenergy.com.au/__data/assets/pdf_file/0018/3870/Appendix- Model-Technical-Report.pdf.

Barnett, B., Townley, L.R., Post, V., Evans, R.E., Hunt, R.J., Peeters, L., Richardson, S., Werner, A.D., Knapton, A. and Boronkay, A., 2012. Australian Groundwater Modelling Guidelines. Waterlines Report Series No. 82, June 2012.

AGE 2006. Ensham Central Project EIA - Groundwater Impact Assessment. Prepared for Hansen Consulting, cited in HydroSimulations, Baralaba North Continued Operations (BNCOP) for Cockatoo Coal Ltd, April 2014.

AGE, 2013. Minyango Project Groundwater. Proj G1562. Report for Hansen Bailey. April 2013.

Bureau of Meteorology (BOM). (2021). Map of Climate Zones Australia. Retrieved August 20, 2021, from http://www.bom.gov.au/climate/how/newproducts/images/zones.shtml

Doherty, J., 2010. PEST - Model Independent Parameter Estimation. User Manual 5th Edition. Watermark Numerical Computing.

Douglas Partners 2014. Report on S Pit Groundwater Study Review, Curragh Coal Mine via Blackwater, Central Queensland, Project 80724.00, November 2014.

HydroSimulations, 2016. Curragh Extension Project Groundwater Model: Final Review (Ref: HC2016/26).

MDBC (Middlemis, H., Merrick, N., and Ross, J.), 2001. Murray-Darling Basin Commission – Groundwater Flow Modelling Guideline. Report for MDBC. January 2001.

Parsons Brinckerhoff 2003. Curragh North Coal Mine – Hydrology, flooding and groundwater report, Project No. 2132105A-PR001Ebt (Appendix G of Curragh North Mine Environmental Impact Statement). August 2003.

Parsons Brinkerhoff (PB), 2016. Curragh Extension Project – Groundwater Technical Report (2172652H-WAT-REP-002 RevB)

Queensland Government. (2021). *Scientific Land Owners (SILO) database – Australian climate data from 1889 to yesterday*. Retrieved August, 23, 2021, from https://www.longpaddock.qld.gov.au/silo/point-data/

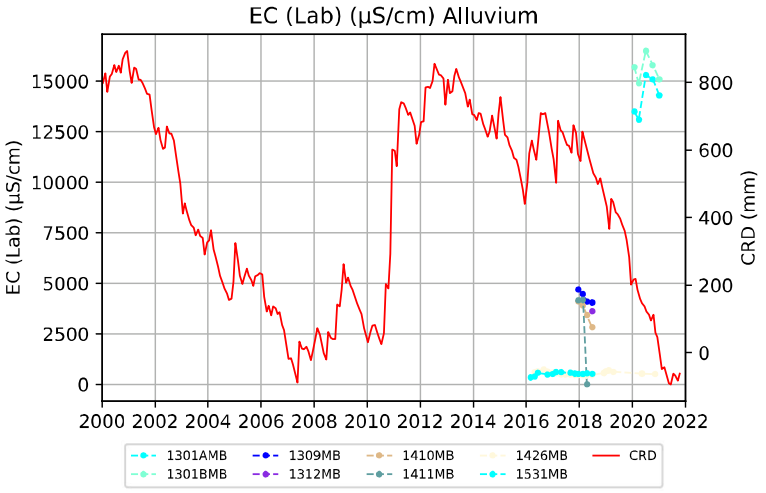
Panday, S., Langevin, C.D., Niswonger, R.G., Ibaraki, M., and Hughes, J.D., 2013., MODFLOW–USG version 1: An unstructured grid version of MODFLOW for simulating groundwater flow and tightly coupled processes using a control volume finite-difference formulation: USGS Techniques and Methods 6-A45.

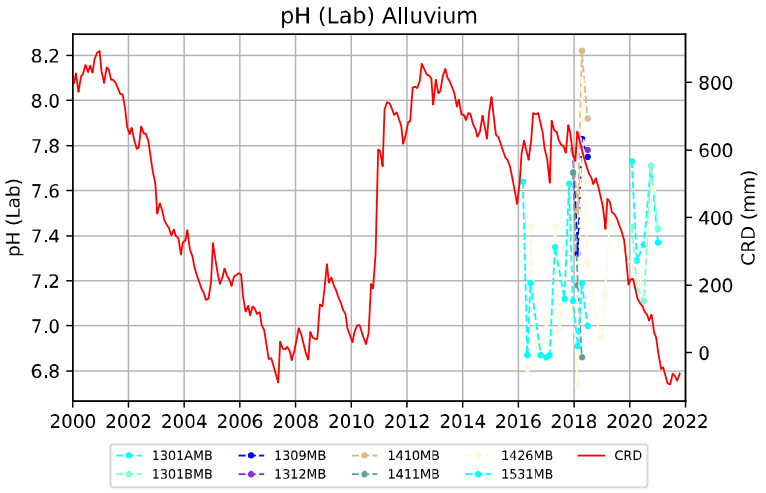
SLR, 2021. Curragh Mine Complex, Residual Void Modelling, November 2021.

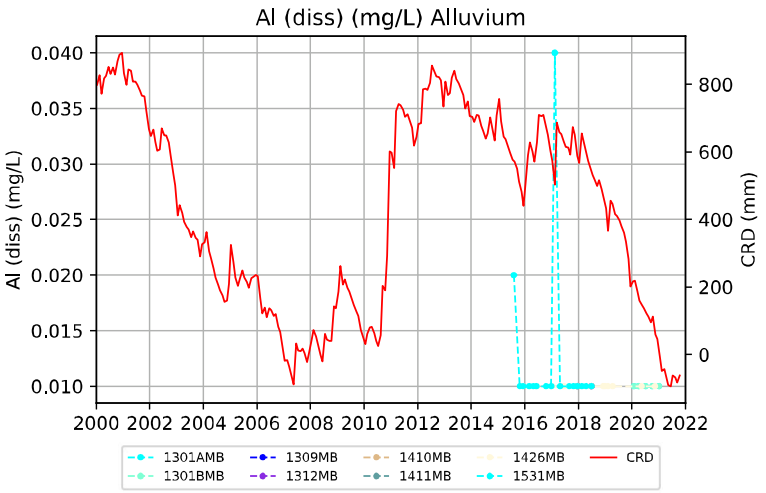
Velseis Processing Pty Ltd (2012). 2011 Minyango 3D Seismic Survey, Minyango Project Area, Qld. Final Report, Interpretation and Data Processing.

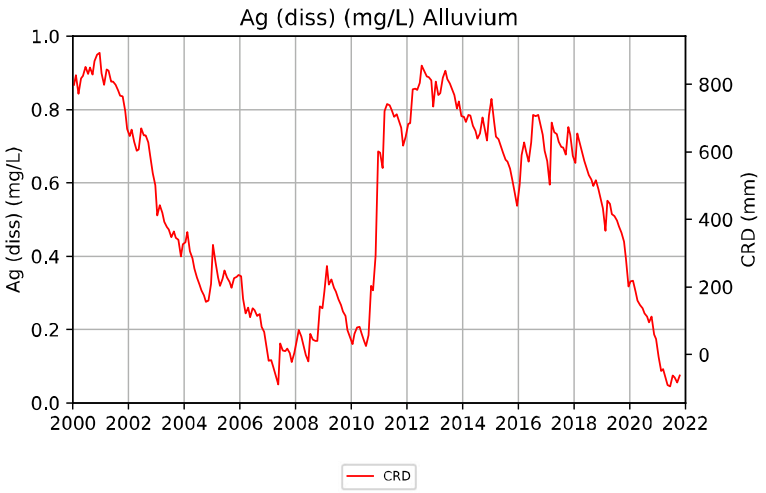
APPENDIX A

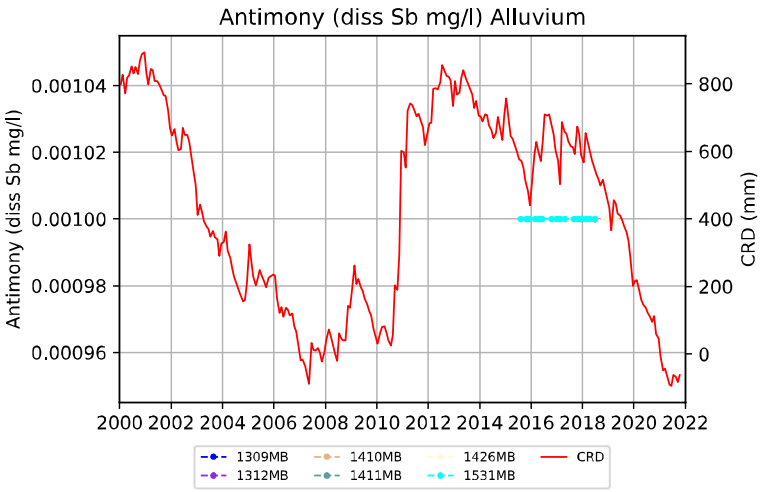
Groundwater quality charts

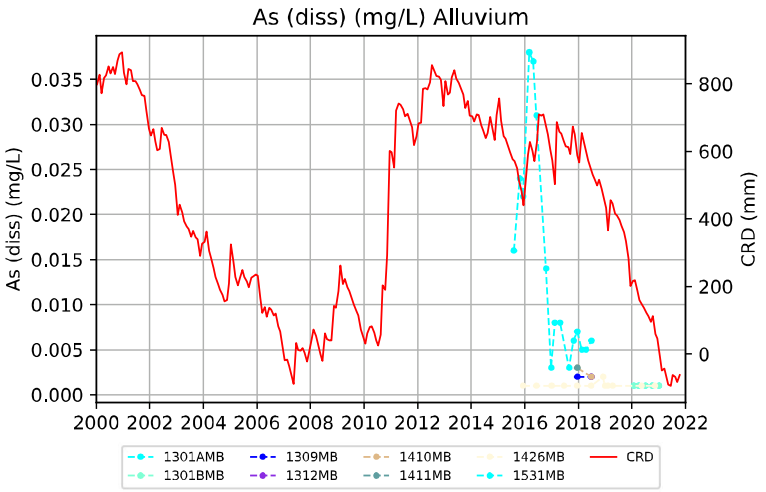

EC (Lab) (µS/cm) Alluvium
EC (Lab) (µS/cm)
CRD (mm)
1301AMB
1301BMB
1309MB
1312MB
1410MB
1411MB
1426MB
1531MB
CRD

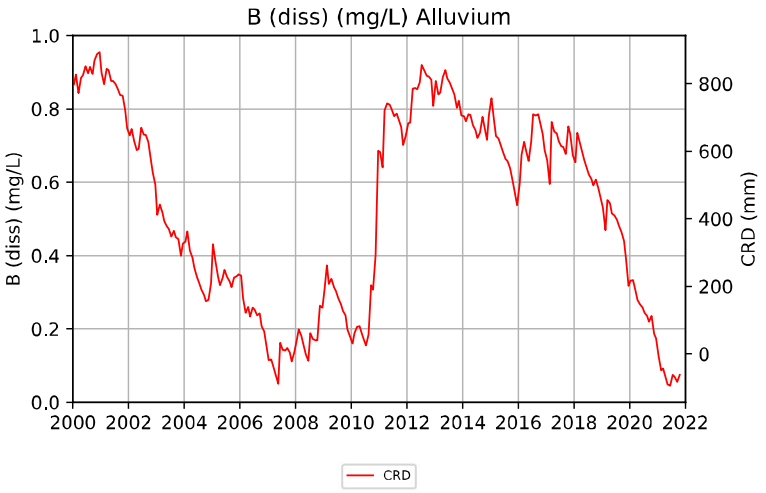

pH (Lab) Alluvium
pH (Lab)
CRD (mm)
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1301BMB
1309MB
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1531MB
CRD

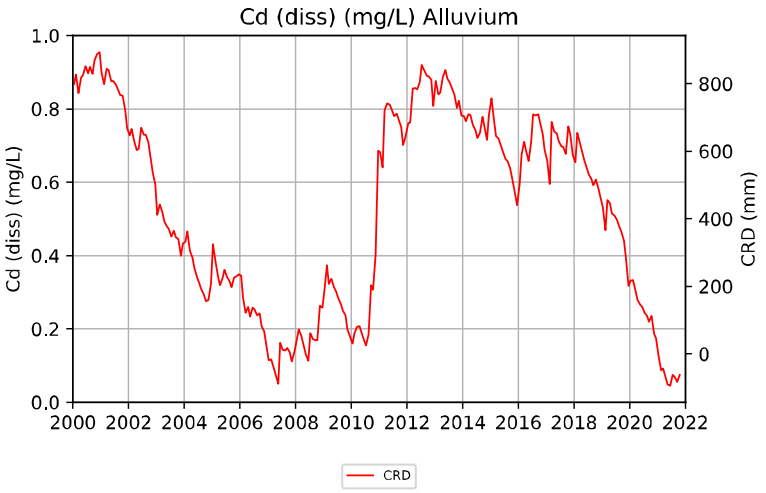

Al (diss) (mg/L) Alluvium
Al (diss) (mg/L)
CRD (mm)
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1301BMB
1309MB
1312MB
1410MB
1411MB
1426MB
1531MB
CRD

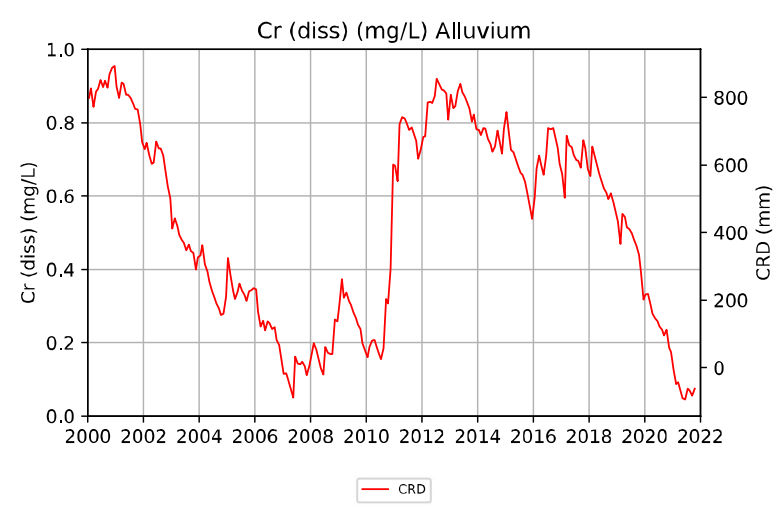

Ag (diss) (mg/L) Alluvium
Ag (diss) (mg/L)
CRD (mm)
CRD

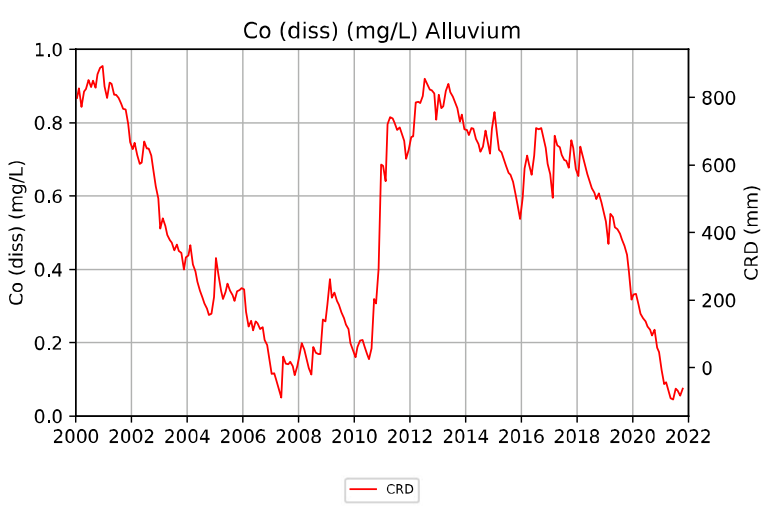

Antimony (diss Sb mg/l) Alluvium
Antimony (diss Sb mg/l)
CRD (mm)
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1312MB
1410MB
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1531MB
CRD

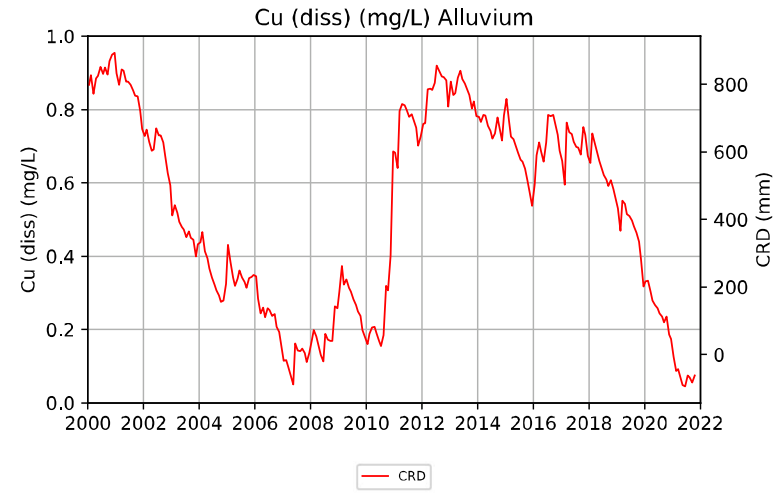

As (diss) (mg/L) Alluvium
As (diss) (mg/L)
CRD (mm)
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1301BMB
1309MB
1312MB
1410MB
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1426MB
1531MB
CRD

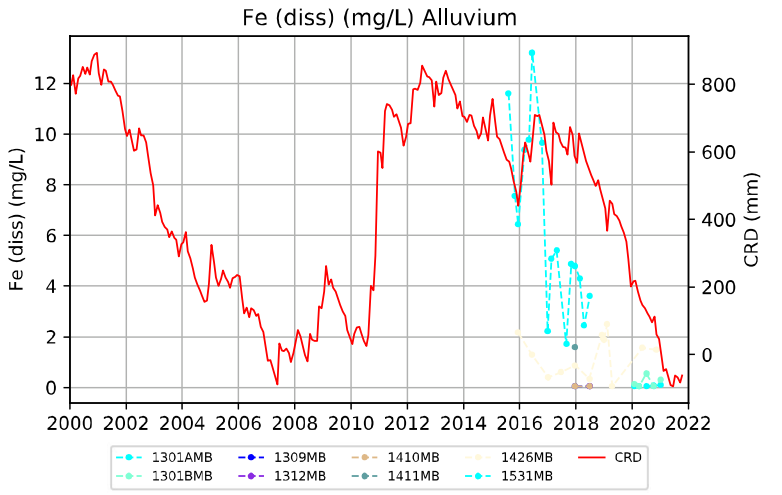

B (diss) (mg/L) Alluvium
B (diss) (mg/L)
CRD (mm)
CRD

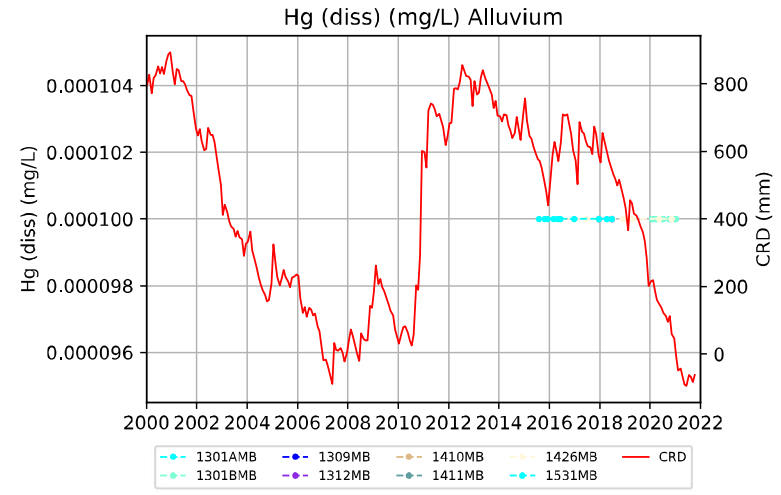

Cd (diss) (mg/L) Alluvium
Cd (diss) (mg/L)
CRD (mm)
CRD

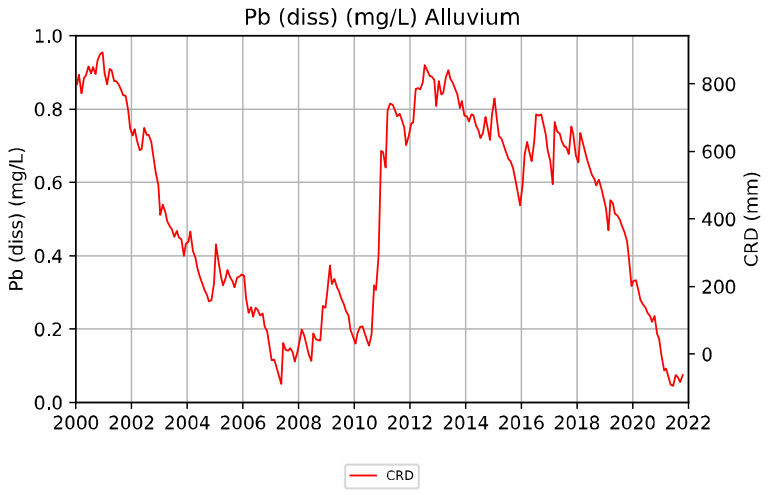

Cr (diss) (mg/L) Alluvium
Cr (diss) (mg/L)
CRD (mm)
CRD

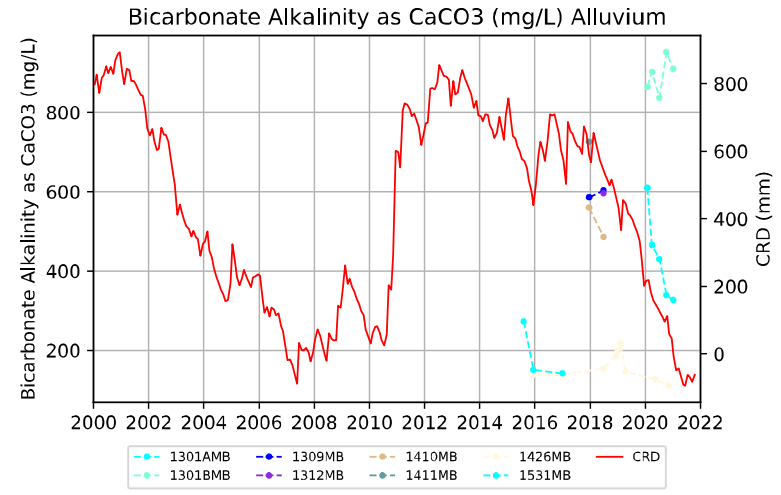

Co (diss) (mg/L) Alluvium
Co (diss) (mg/L)
CRD (mm)
CRD

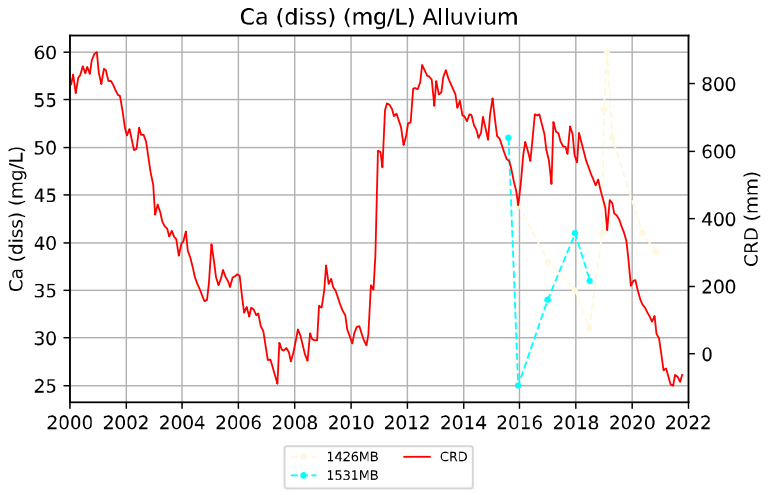

Cu (diss) (mg/L) Alluvium
Cu (diss) (mg/L)
CRD (mm)
CRD

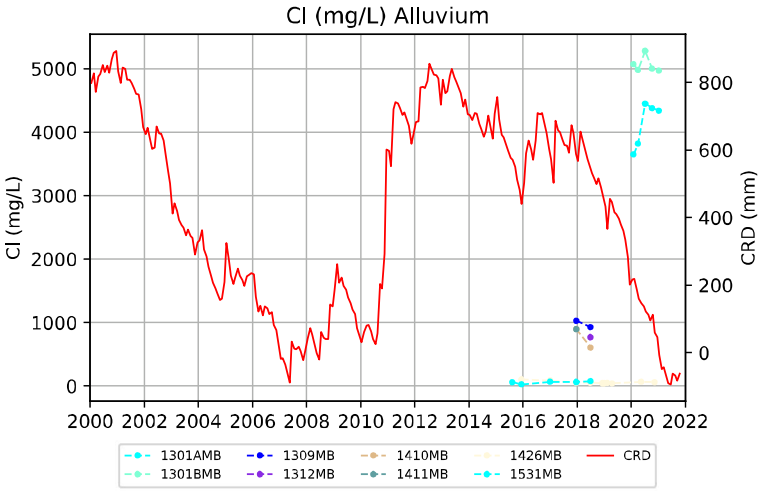

Fe (diss) (mg/L) Alluvium
Fe (diss) (mg/L)
CRD (mm)
1301AMB
1301BMB
1309MB
1312MB
1410MB
1411MB
1426MB
1531MB
CRD

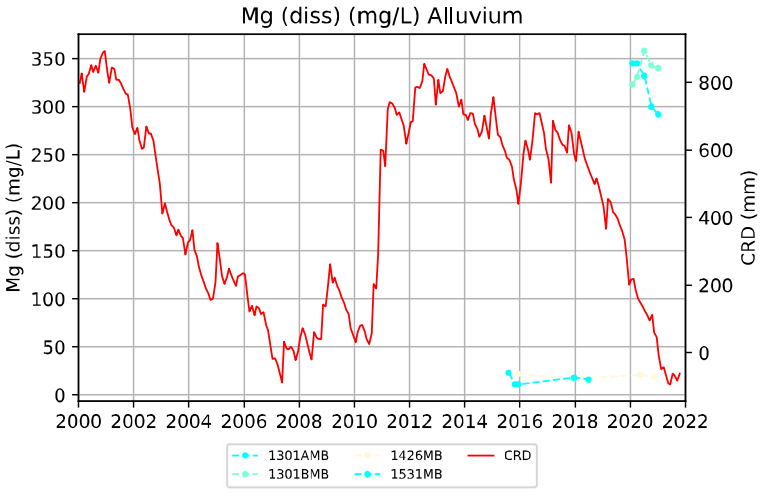

Hg (diss) (mg/L) Alluvium
Hg (diss) (mg/L)
CRD (mm)
1301AMB
1301BMB
1309MB
1312MB
1410MB
1411MB
1426MB
1531MB
CRD

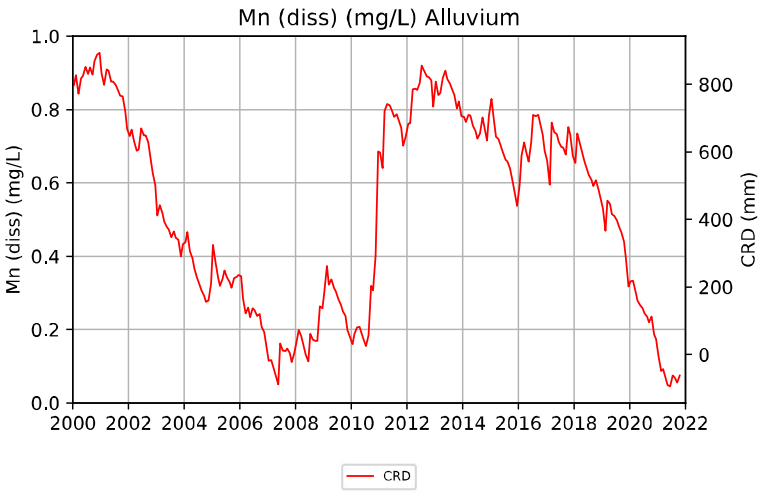

Pb (diss) (mg/L) Alluvium
Pb (diss) (mg/L)
CRD (mm)
CRD

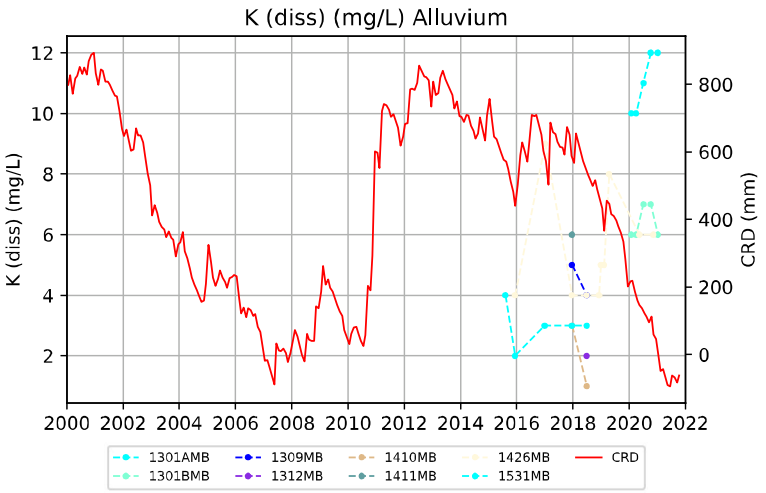

Bicarbonate Alkalinity as CaCO3 (mg/L) Alluvium
Bicarbonate Alkalinity as CaCO3 (mg/L)
CRD (mm)
1301AMB
1301BMB
1309MB
1312MB
1410MB
1411MB
1426MB
1531MB
CRD

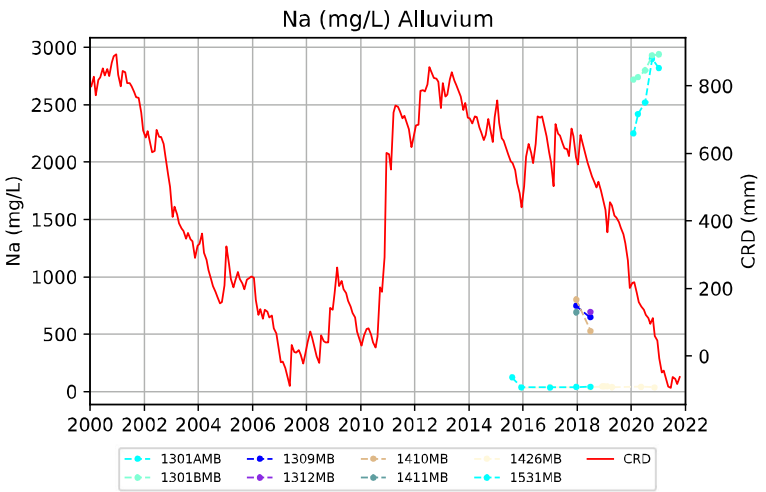

Ca (diss) (mg/L) Alluvium
Ca (diss) (mg/L)
CRD (mm)
1426MB
1531MB
CRD

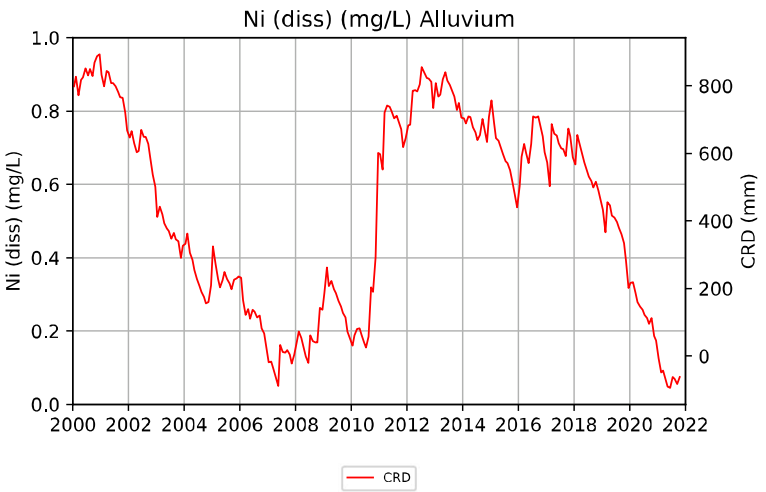

Cl (mg/L) Alluvium
Cl (mg/L)
CRD (mm)
1301AMB
1301BMB
1309MB
1312MB
1410MB
1411MB
1426MB
1531MB
CRD

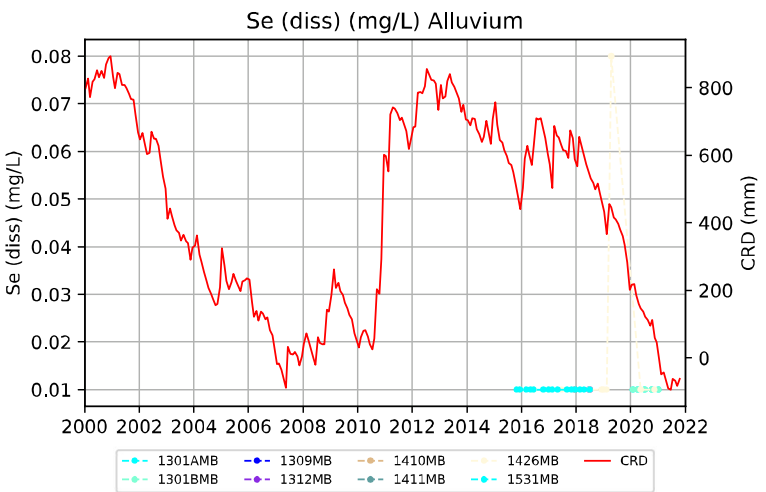

Mg (diss) (mg/L) Alluvium
Mg (diss) (mg/L)
CRD (mm)
1301AMB
1301BMB
1426MB
1531MB
CRD

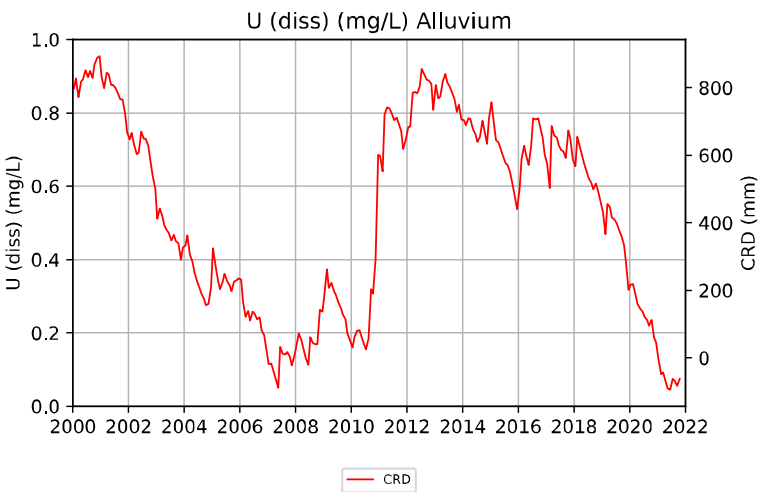

Mn (diss) (mg/L) Alluvium
Mn (diss) (mg/L)
CRD (mm)
CRD

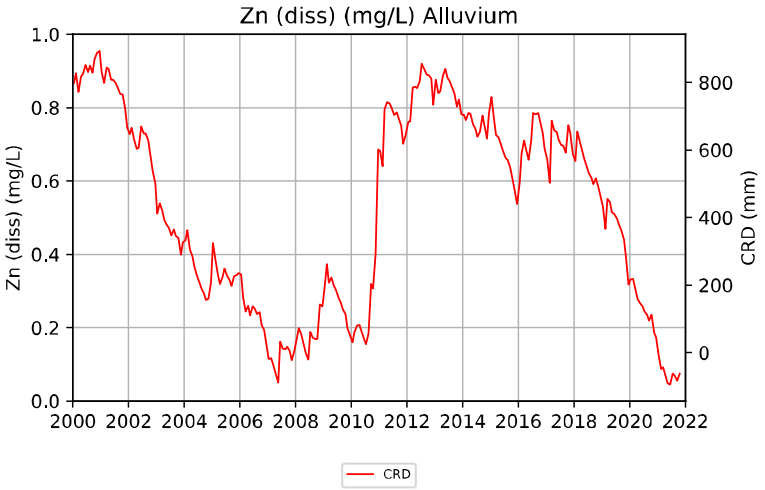

K (diss) (mg/L) Alluvium
K (diss) (mg/L)
CRD (mm)
1301AMB
1301BMB
1309MB
1312MB
1410MB
1411MB
1426MB
1531MB
CRD

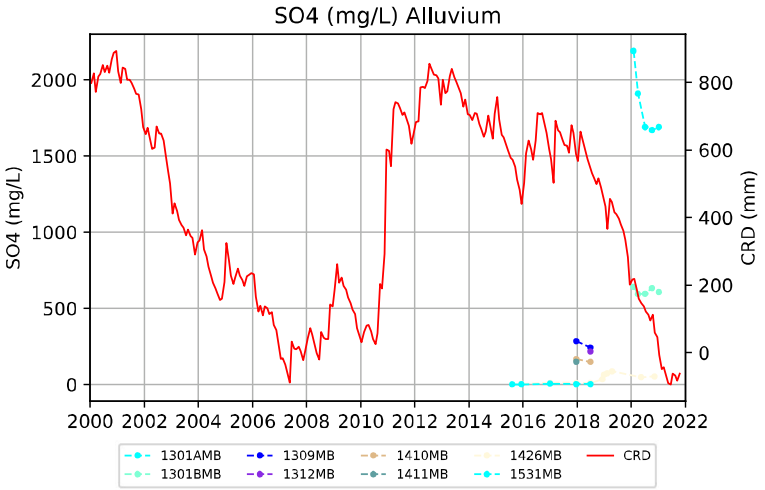

Na (mg/L) Alluvium
Na (mg/L)
CRD (mm)
1301AMB
1301BMB
1309MB
1312MB
1410MB
1411MB
1426MB
1531MB
CRD

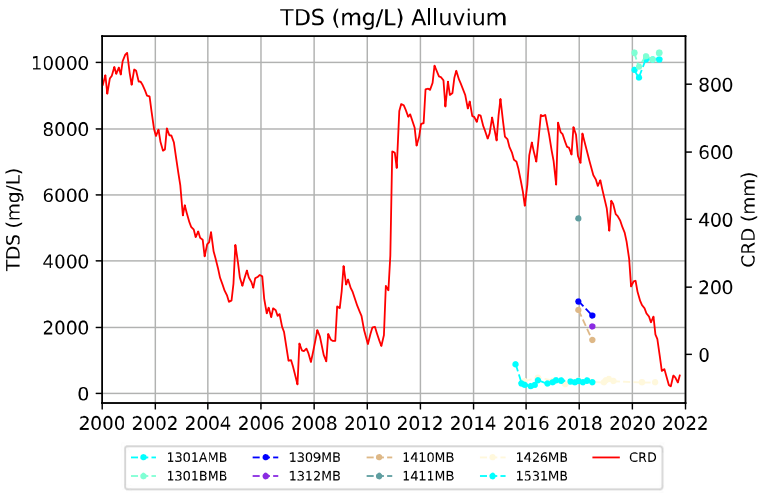

Ni (diss) (mg/L) Alluvium
Ni (diss) (mg/L)
CRD (mm)
CRD

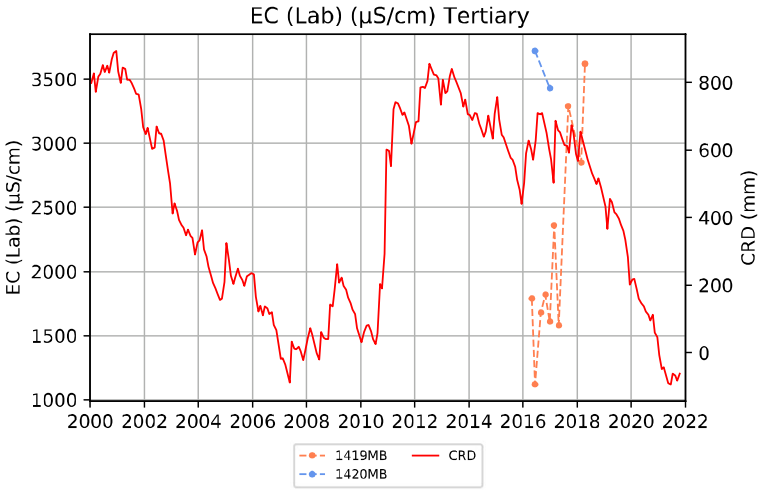

Se (diss) (mg/L) Alluvium
Se (diss) (mg/L)
CRD (mm)
1301AMB
1301BMB
1309MB
1312MB
1410MB
1411MB
1426MB
1531MB
CRD

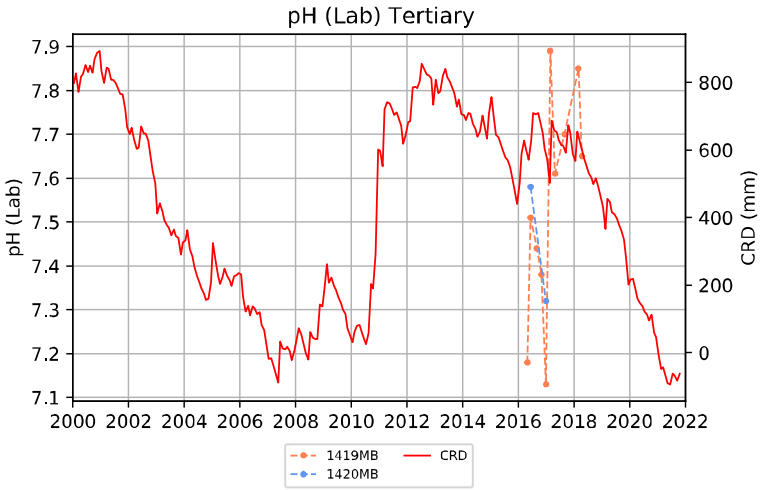

U (diss) (mg/L) Alluvium
U (diss) (mg/L)
CRD (mm)
CRD

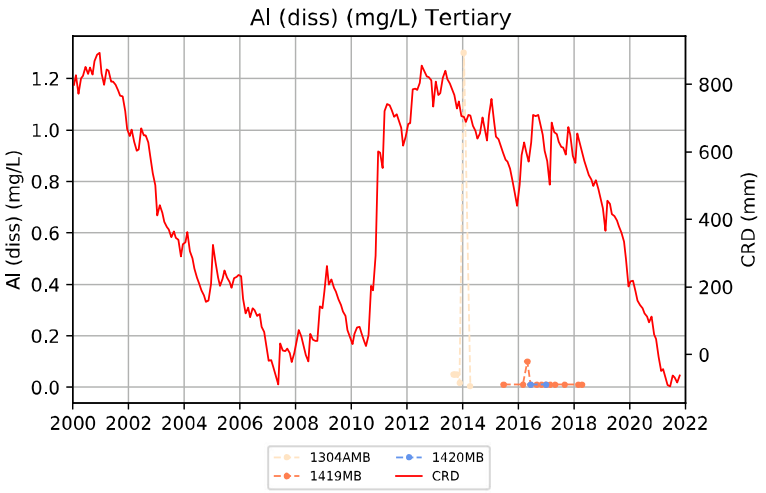

Zn (diss) (mg/L) Alluvium
Zn (diss) (mg/L)
CRD (mm)
CRD

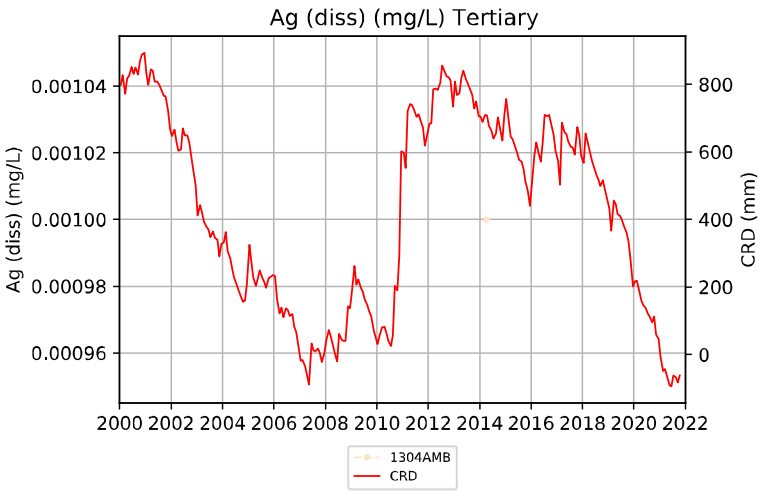

SO4 (mg/L) Alluvium
SO4 (mg/L)
CRD (mm)
1301AMB
1301BMB
1309MB
1312MB
1410MB
1411MB
1426MB
1531MB
CRD

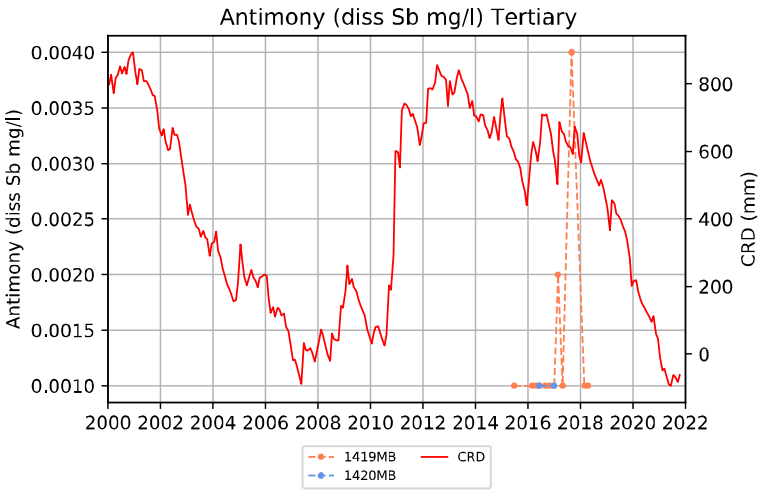

TDS (mg/L) Alluvium
TDS (mg/L)
CRD (mm)
1301AMB
1301BMB
1309MB
1312MB
1410MB
1411MB
1426MB
1531MB
CRD

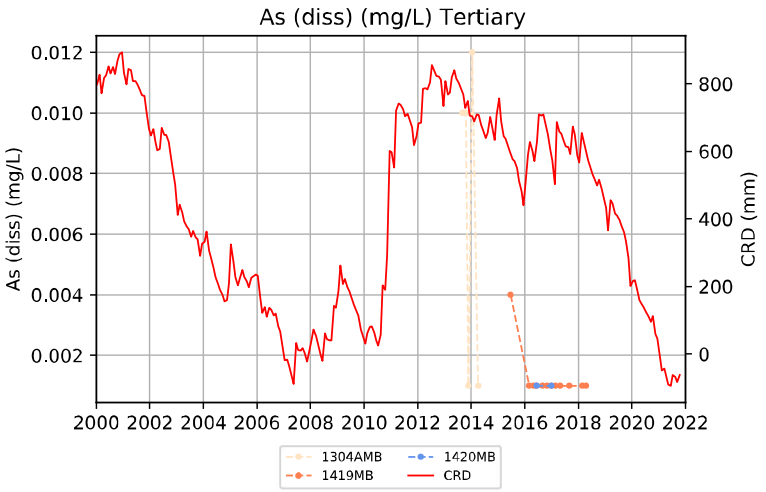

EC (Lab) (µS/cm) Tertiary
EC (Lab) (µS/cm)
CRD (mm)
1419MB
1420MB
CRD

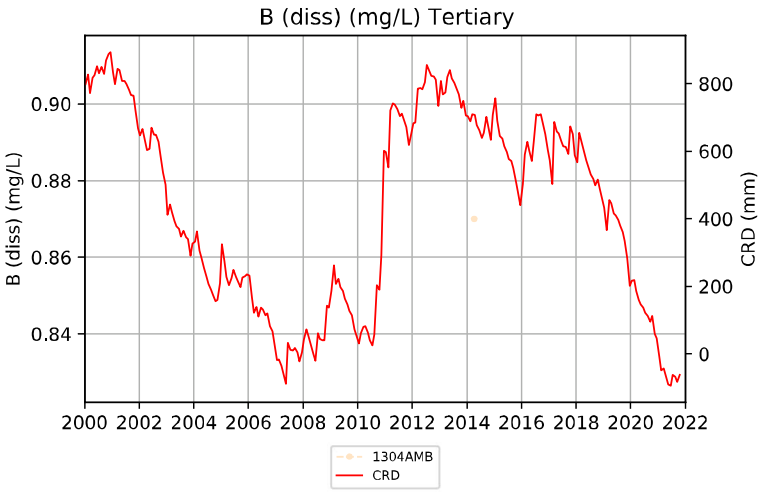

pH (Lab) Tertiary
pH (Lab)
CRD (mm)
1419MB
1420MB
CRD

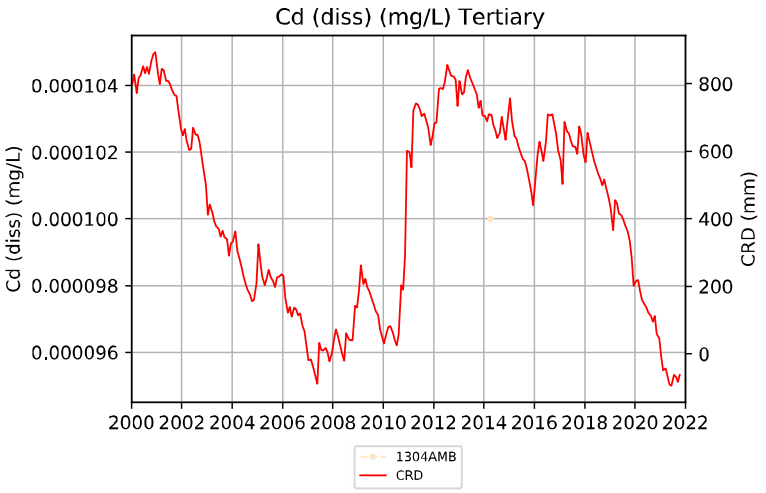

Al (diss) (mg/L) Tertiary
Al (diss) (mg/L)
CRD (mm)
1304AMB
1420MB
1419MB
CRD

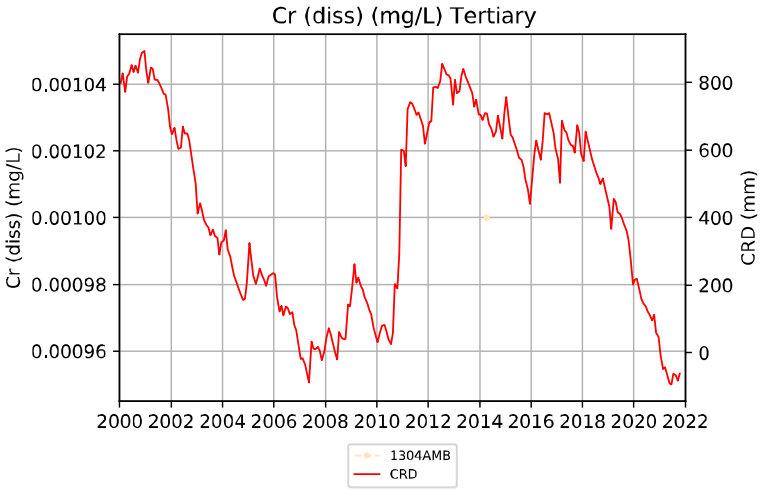

Ag (diss) (mg/L) Tertiary
Ag (diss) (mg/L)
CRD (mm)
1304AMB
CRD

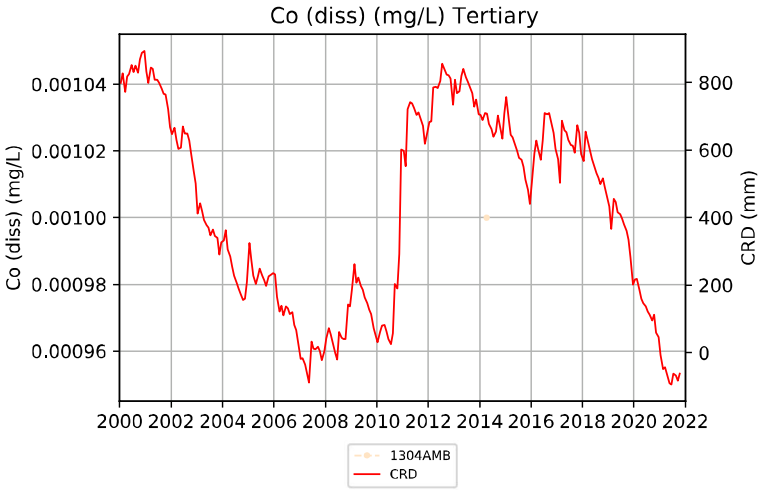

Antimony (diss Sb mg/l) Tertiary
Antimony (diss Sb mg/l)
CRD (mm)
1419MB
1420MB
CRD

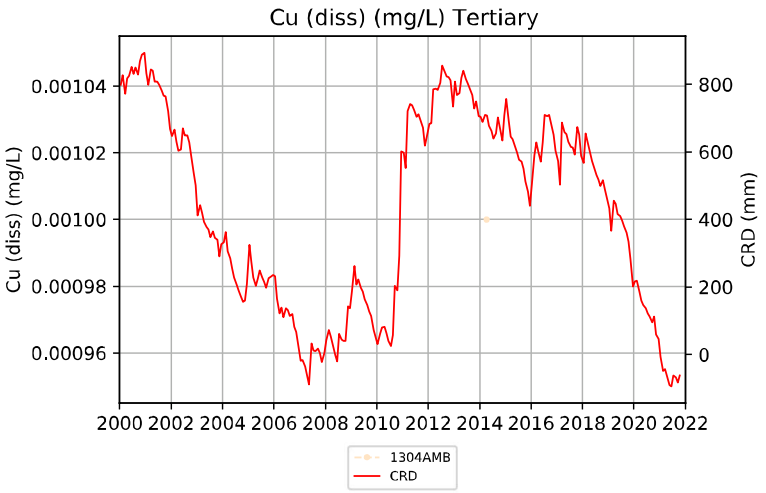

As (diss) (mg/L) Tertiary
As (diss) (mg/L)
CRD (mm)
1304AMB
1420MB
1419MB
CRD

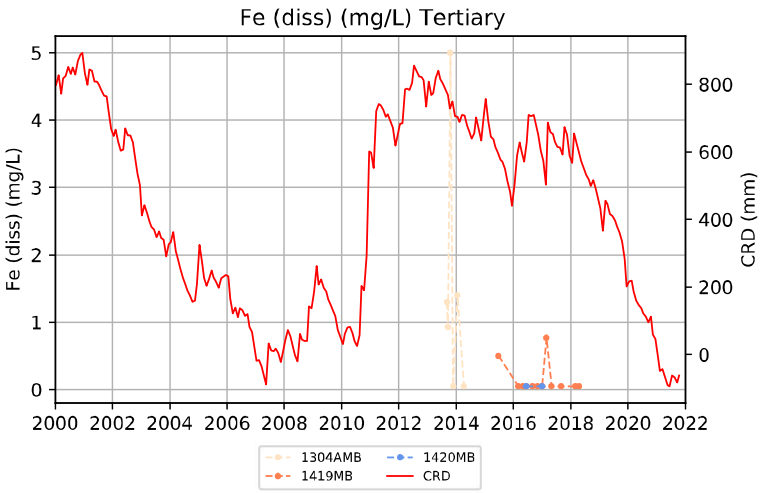

B (diss) (mg/L) Tertiary
B (diss) (mg/L)
CRD (mm)
1304AMB
CRD

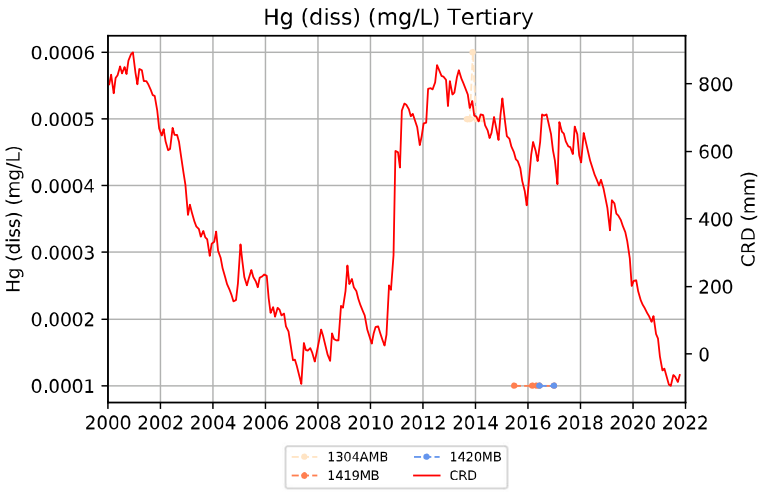

Cd (diss) (mg/L) Tertiary
Cd (diss) (mg/L)
CRD (mm)
1304AMB
CRD

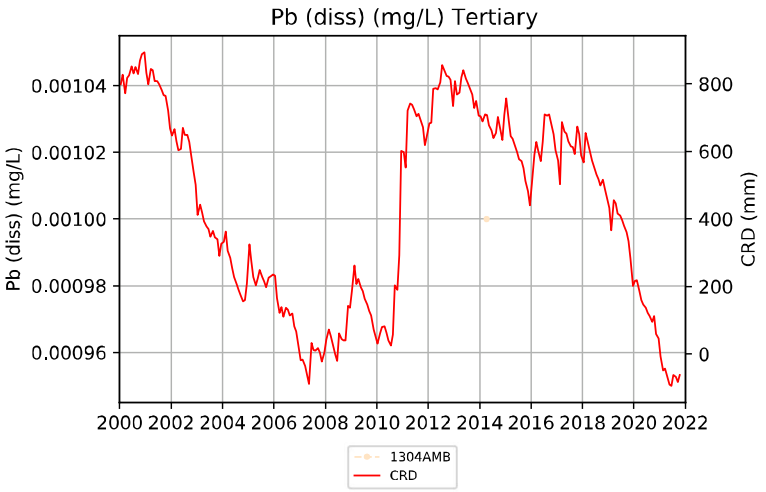

Cr (diss) (mg/L) Tertiary
Cr (diss) (mg/L)
CRD (mm)
1304AMB
CRD

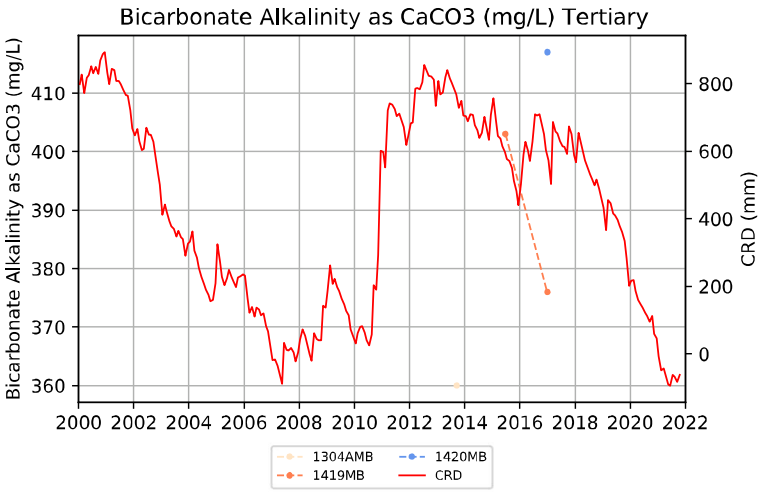

Co (diss) (mg/L) Tertiary
Co (diss) (mg/L)
CRD (mm)
1304AMB
CRD

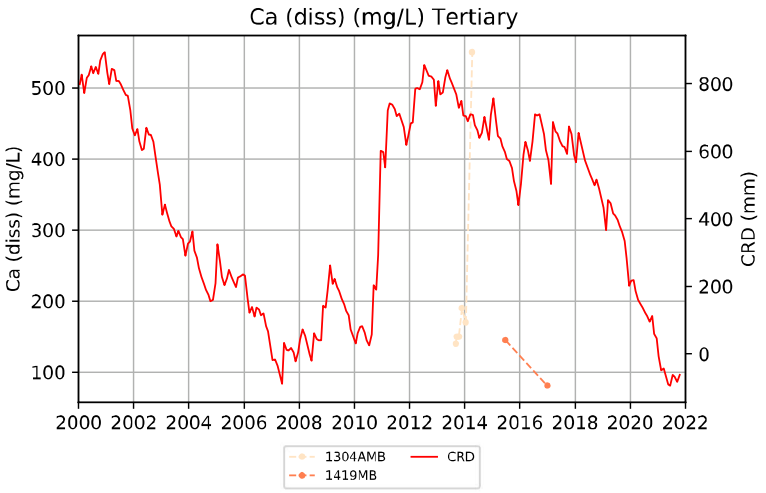

Cu (diss) (mg/L) Tertiary
Cu (diss) (mg/L)
CRD (mm)
1304AMB
CRD

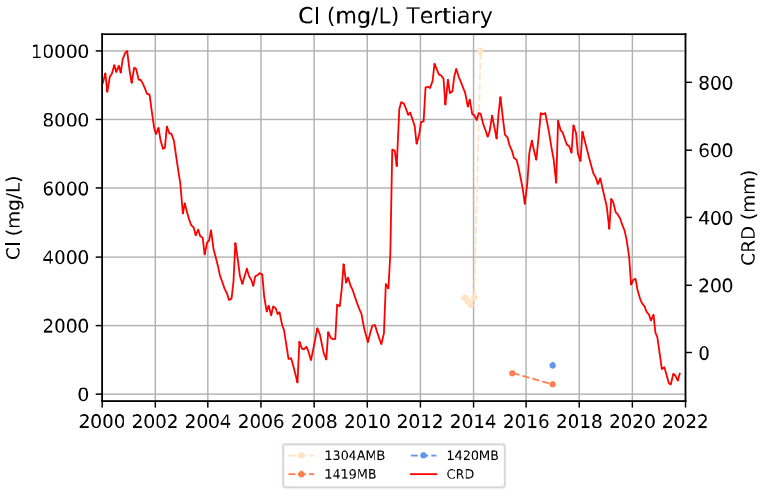

Fe (diss) (mg/L) Tertiary
Fe (diss) (mg/L)
CRD (mm)
1304AMB
1420MB
1419MB
CRD

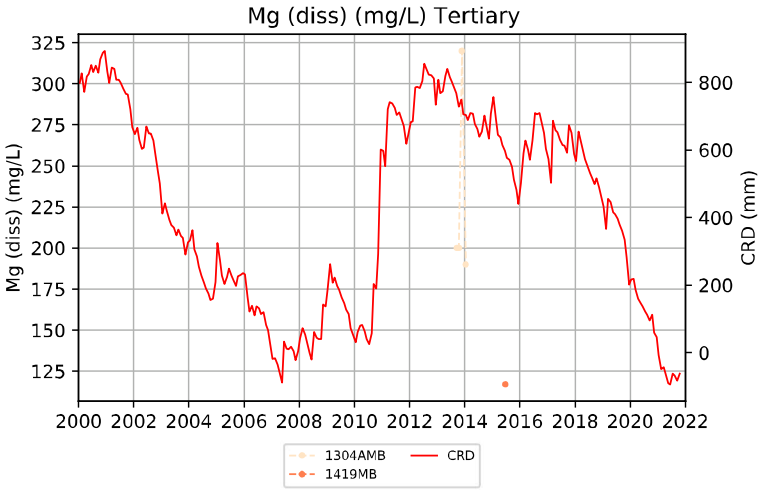

Hg (diss) (mg/L) Tertiary
Hg (diss) (mg/L)
CRD (mm)
1304AMB
1420MB
1419MB
CRD

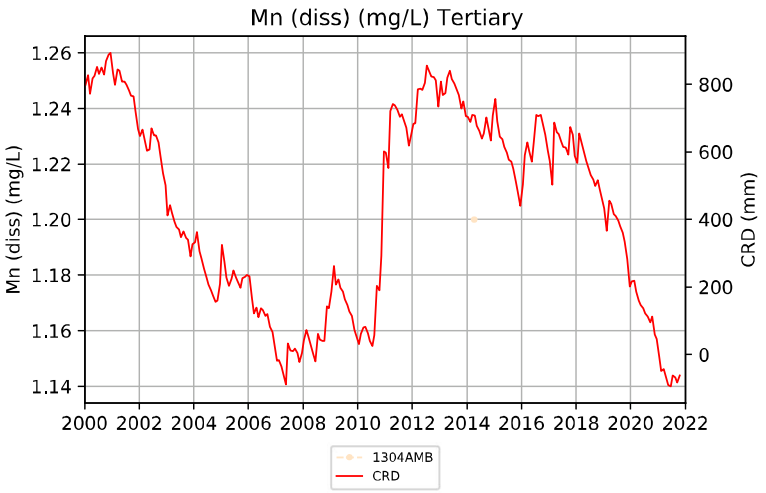

Pb (diss) (mg/L) Tertiary
Pb (diss) (mg/L)
CRD (mm)
1304AMB
CRD

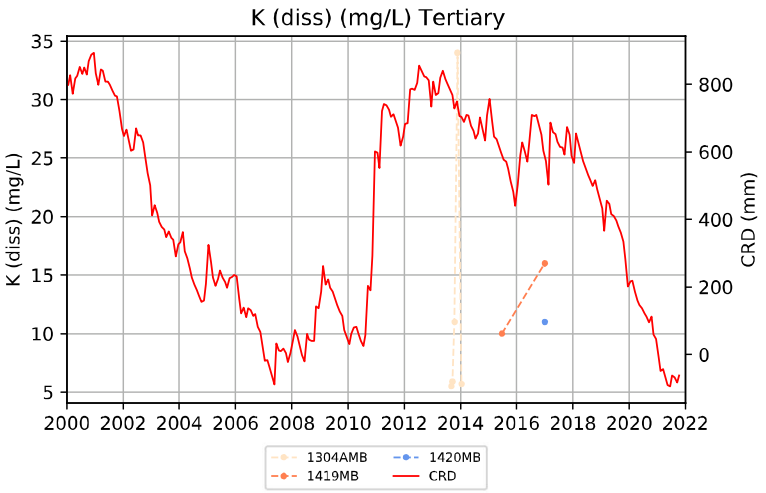

Bicarbonate Alkalinity as CaCO3 (mg/L) Tertiary
Bicarbonate Alkalinity as CaCO3 (mg/L)
CRD (mm)
1304AMB
1420MB
1419MB
CRD

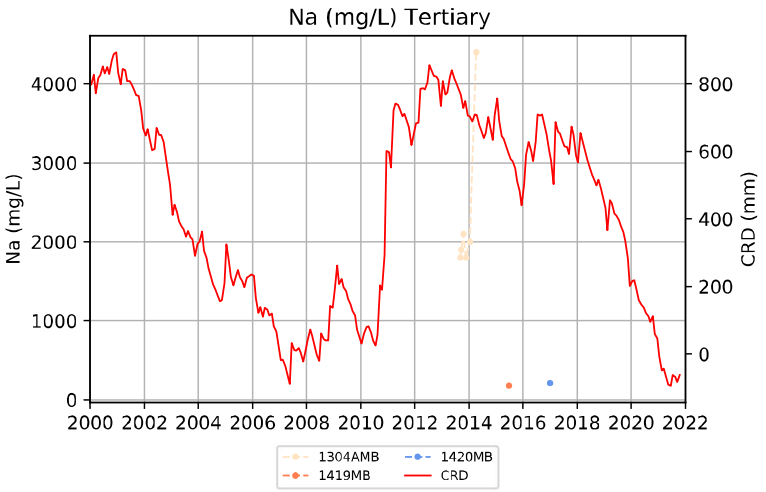

Ca (diss) (mg/L) Tertiary
Ca (diss) (mg/L)
CRD (mm)
1304AMB
CRD
1419MB

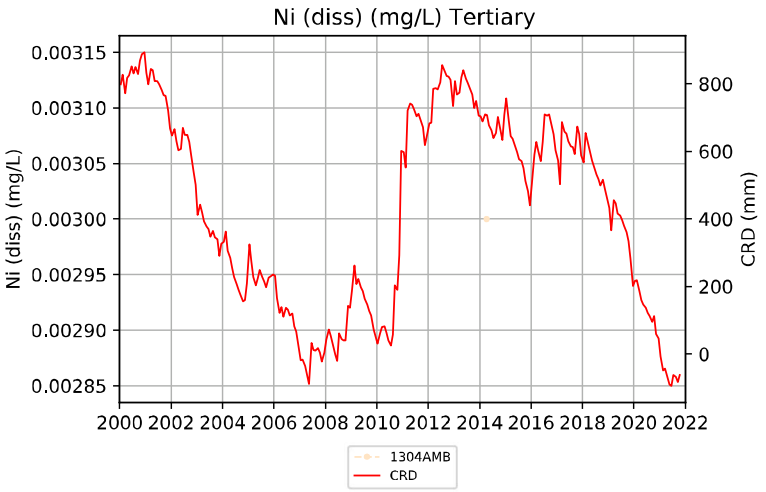

Cl (mg/L) Tertiary
Cl (mg/L)
CRD (mm)
1304AMB
1420MB
1419MB
CRD

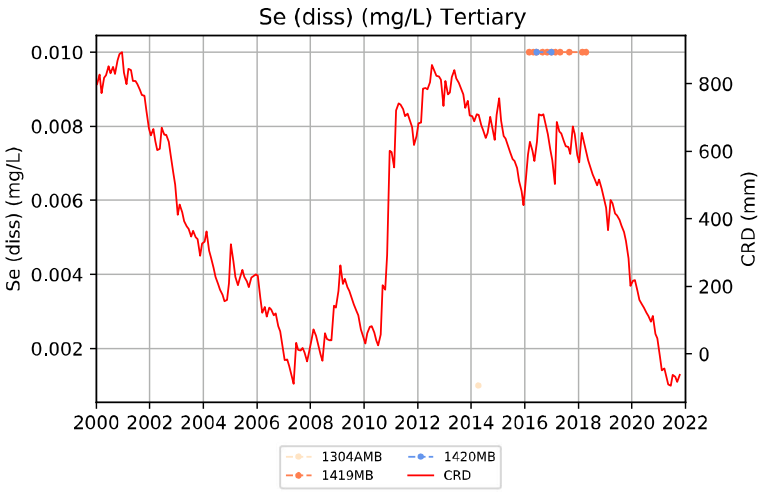

Mg (diss) (mg/L) Tertiary
Mg (diss) (mg/L)
CRD (mm)
1304AMB
CRD
1419MB

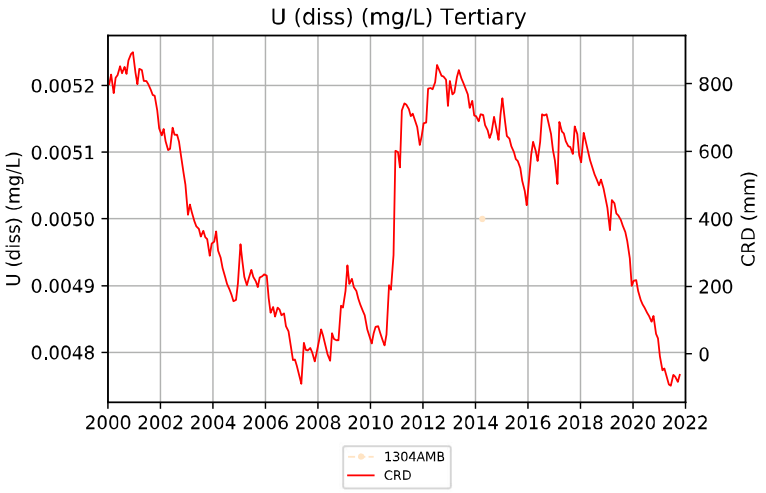

Mn (diss) (mg/L) Tertiary
Mn (diss) (mg/L)
CRD (mm)
1304AMB
CRD

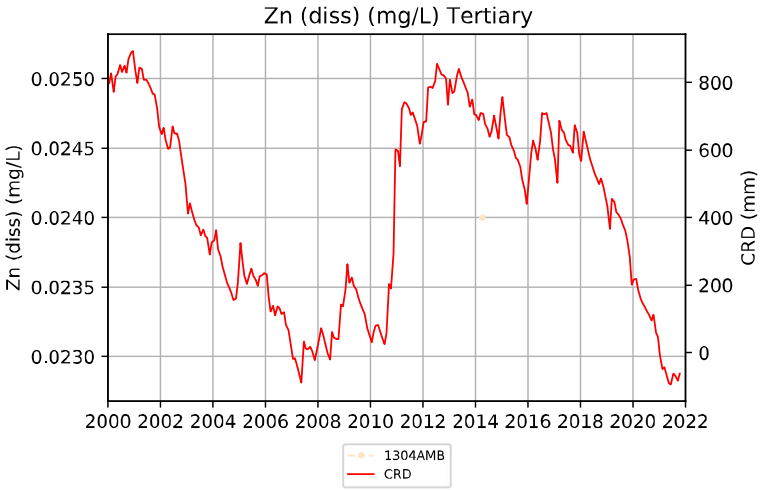

K (diss) (mg/L) Tertiary
K (diss) (mg/L)
CRD (mm)
1304AMB
1420MB
1419MB
CRD

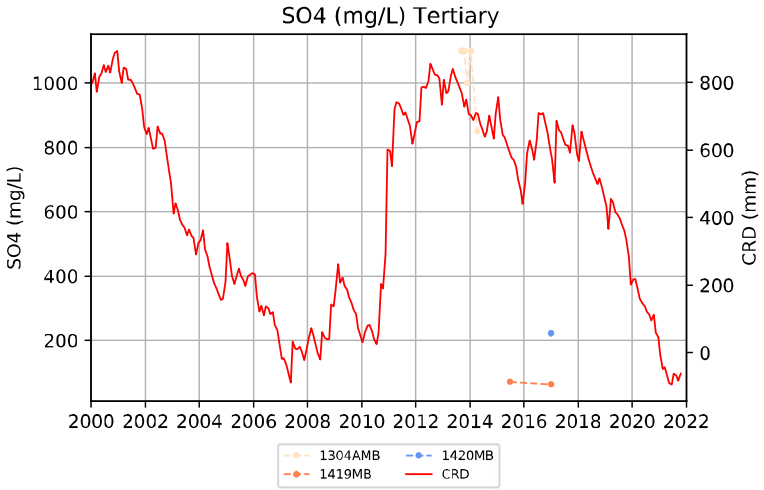

Na (mg/L) Tertiary
Na (mg/L)
CRD (mm)
1304AMB
1420MB
1419MB
CRD

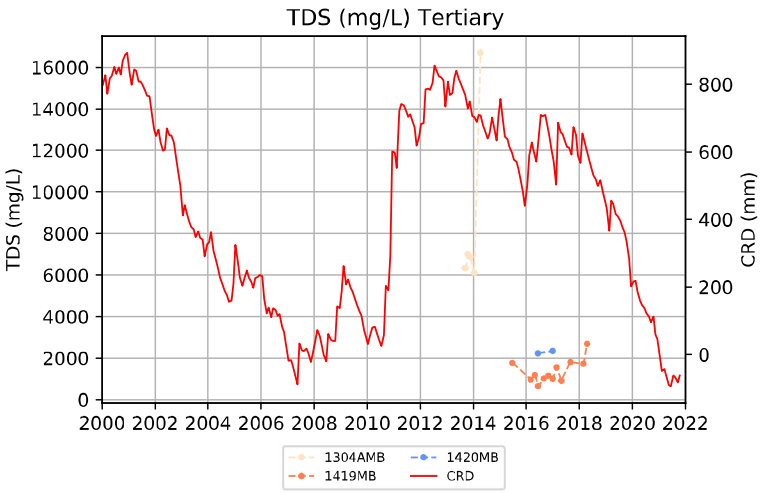

Ni (diss) (mg/L) Tertiary
Ni (diss) (mg/L)
CRD (mm)
1304AMB
CRD

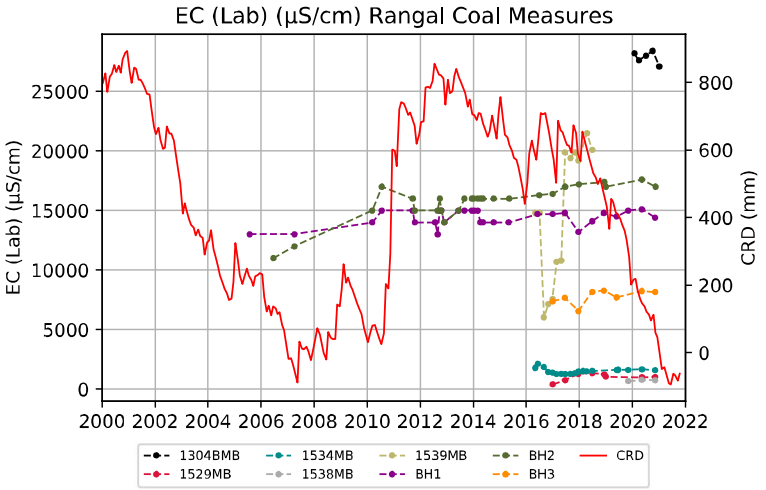

Se (diss) (mg/L) Tertiary
Se (diss) (mg/L)
CRD (mm)
1304AMB
1420MB
1419MB
CRD

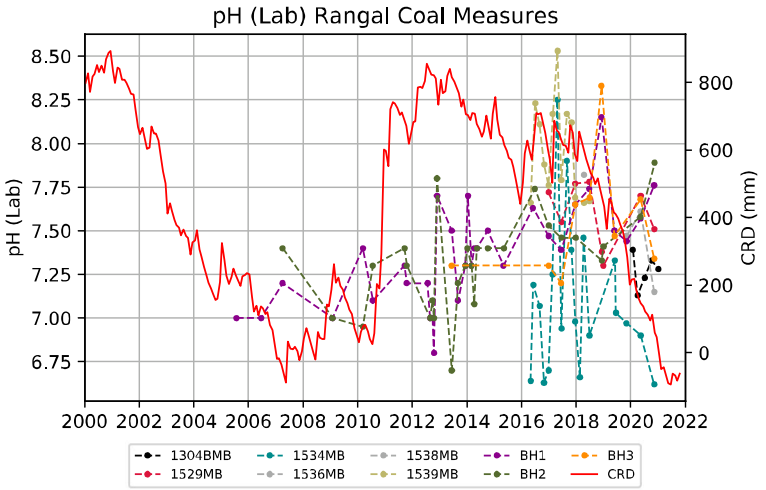

U (diss) (mg/L) Tertiary
U (diss) (mg/L)
CRD (mm)
1304AMB
CRD

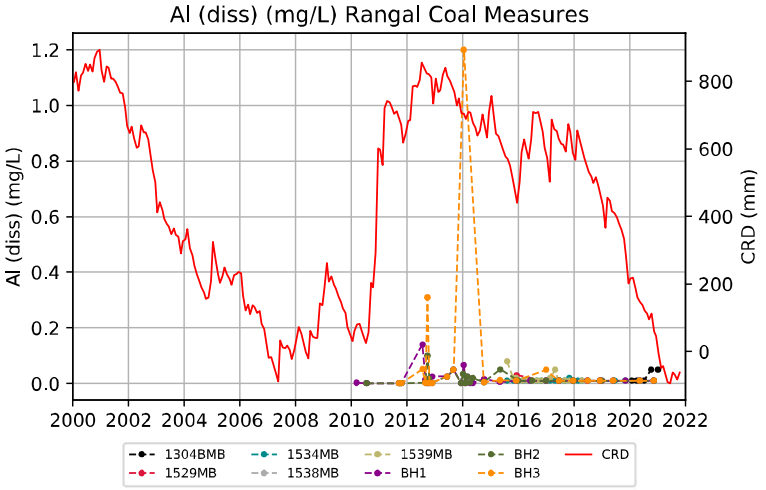

Zn (diss) (mg/L) Tertiary
Zn (diss) (mg/L)
CRD (mm)
0.0250
0.0245
0.0240
0.0235
0.0230
800
600
400
200
0
2000 2002 2004 2006 2008 2010 2012 2014 2016 2018 2020 2022
1304AMB
CRD

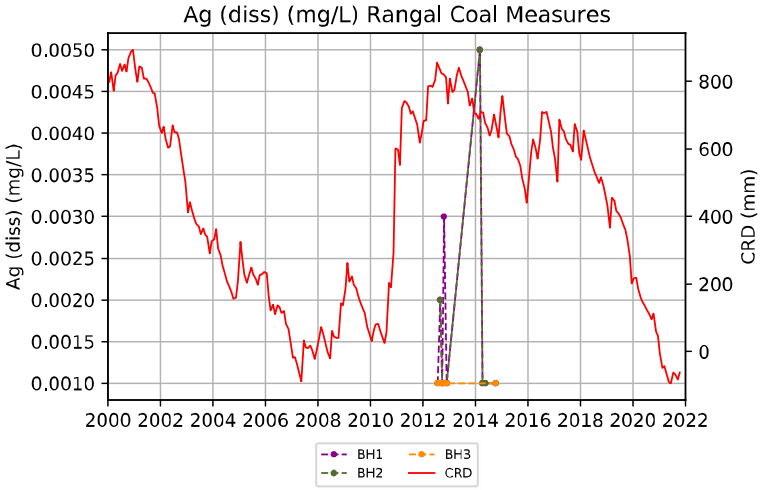

SO4 (mg/L) Tertiary
SO4 (mg/L)
CRD (mm)
1000
800
600
400
200
800
600
400
200
0
2000 2002 2004 2006 2008 2010 2012 2014 2016 2018 2020 2022
1304AMB
1420MB
1419MB
CRD

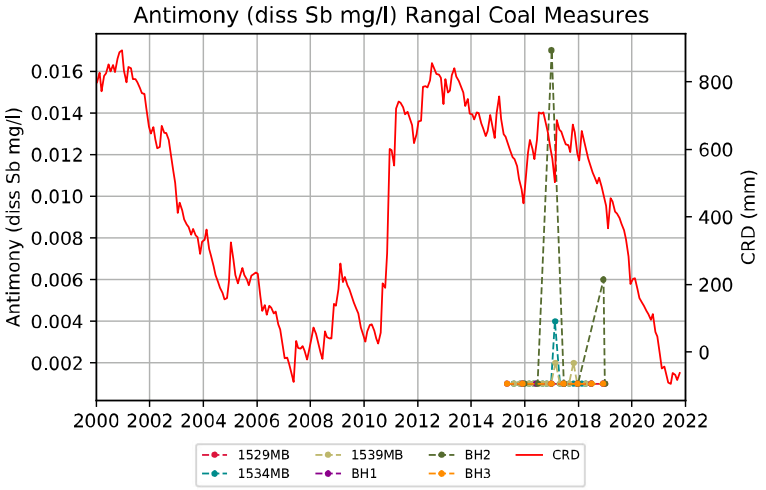

TDS (mg/L) Tertiary
TDS (mg/L)
CRD (mm)
16000
14000
12000
10000
8000
6000
4000
2000
0
800
600
400
200
0
2000 2002 2004 2006 2008 2010 2012 2014 2016 2018 2020 2022
1304AMB
1420MB
1419MB
CRD

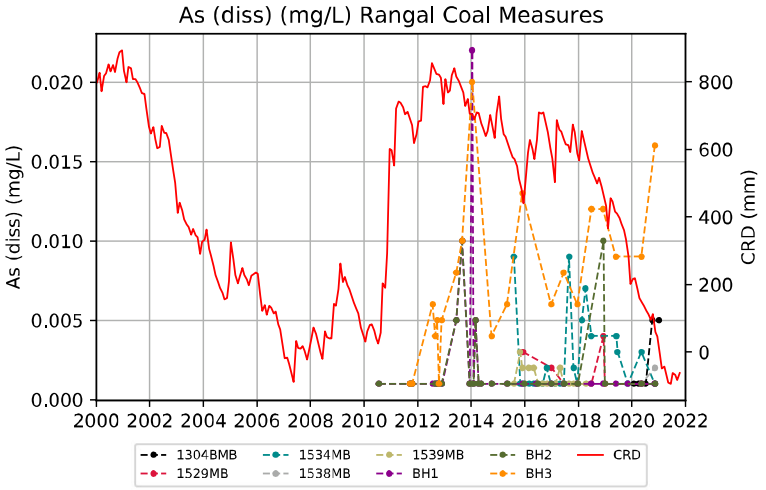

EC (Lab) (µS/cm) Rangal Coal Measures
EC (Lab) (µS/cm)
CRD (mm)
1304BMB
1529MB
1534MB
1538MB
1539MB
BH1
BH2
BH3
CRD

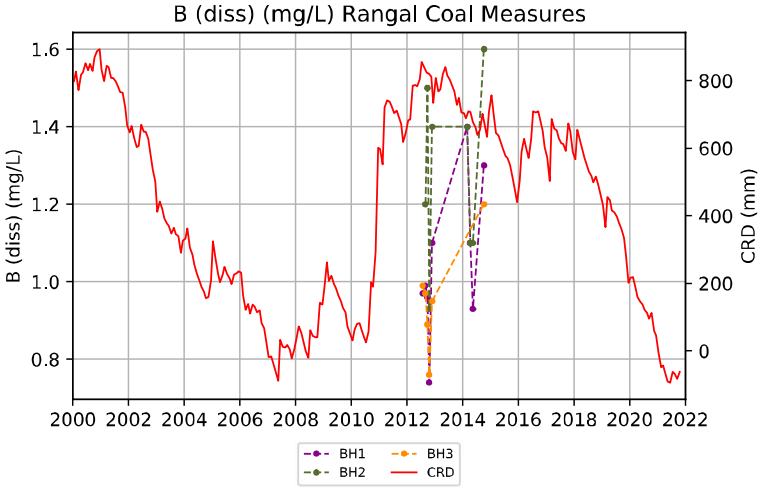

pH (Lab) Rangal Coal Measures
pH (Lab)
CRD (mm)
1304BMB
1529MB
1534MB
1536MB
1538MB
1539MB
BH1
BH2
BH3
CRD

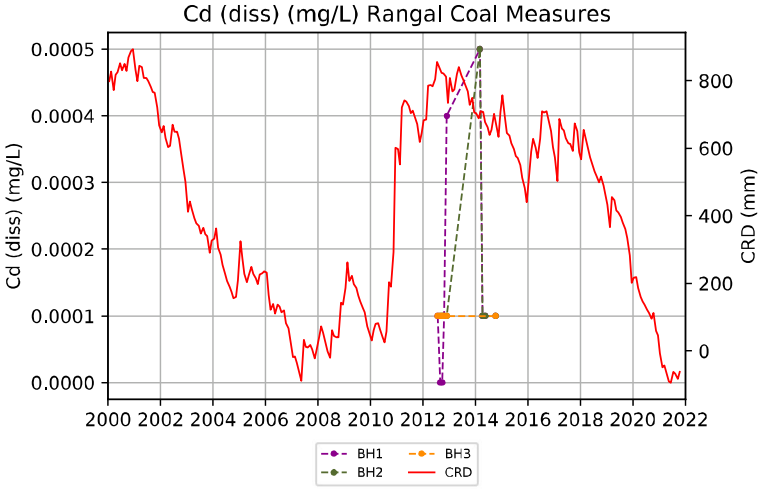

Al (diss) (mg/L) Rangal Coal Measures
Al (diss) (mg/L)
CRD (mm)
1304BMB
1529MB
1534MB
1538MB
1539MB
BH1
BH2
BH3
CRD

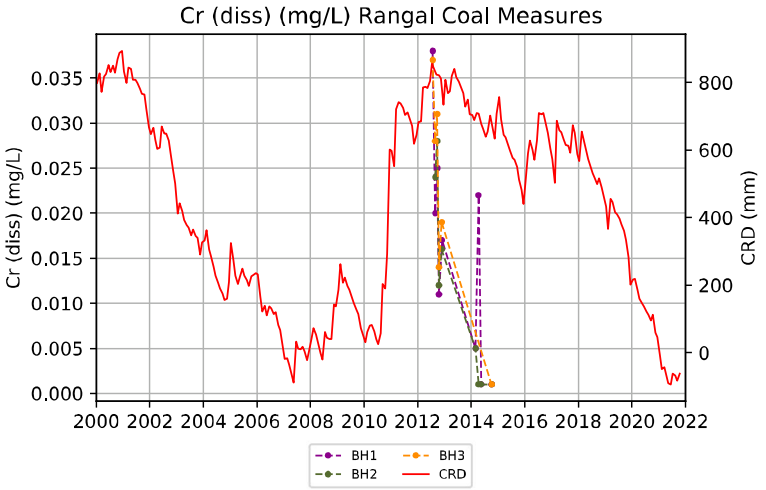

Ag (diss) (mg/L) Rangal Coal Measures
Ag (diss) (mg/L)
CRD (mm)
BH1
BH2
BH3
CRD

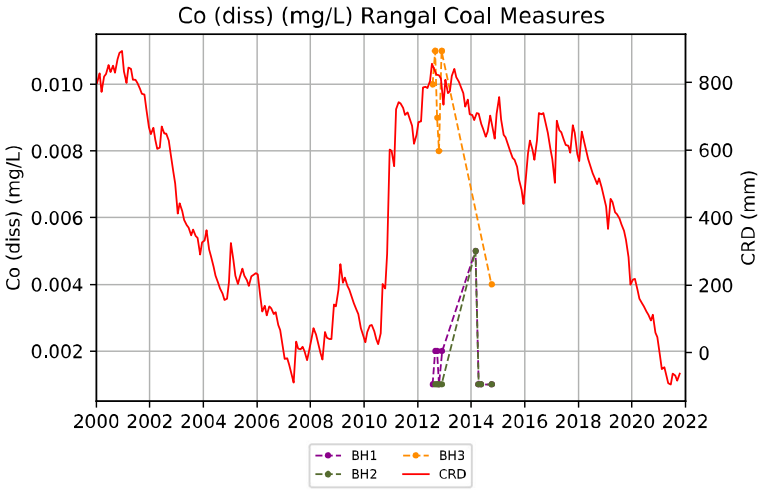

Antimony (diss Sb mg/l) Rangal Coal Measures
Antimony (diss Sb mg/l)
CRD (mm)
1529MB
1534MB
1539MB
BH1
BH2
BH3
CRD

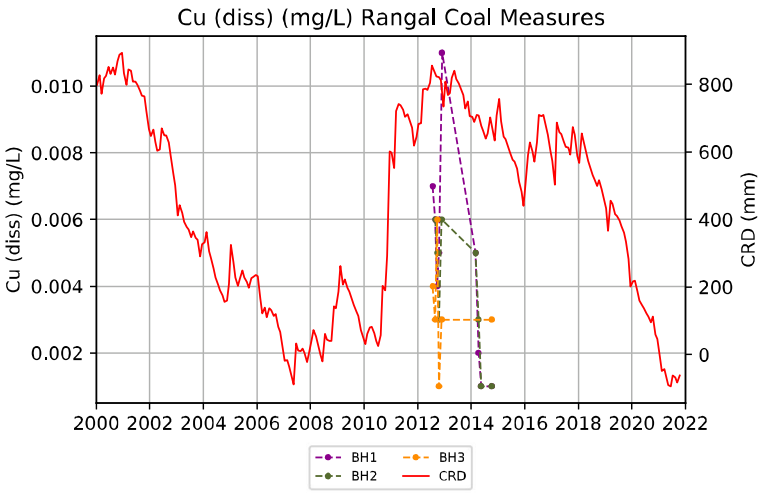

As (diss) (mg/L) Rangal Coal Measures
As (diss) (mg/L)
CRD (mm)
1304BMB
1529MB
1534MB
1538MB
1539MB
BH1
BH2
BH3
CRD

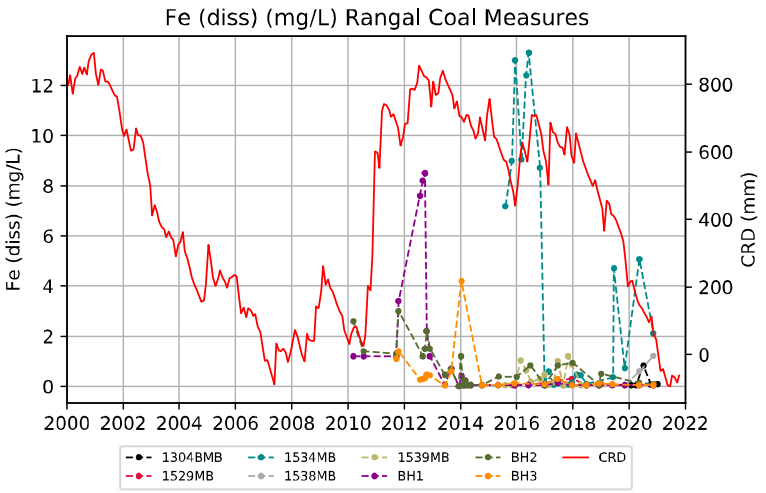

B (diss) (mg/L) Rangal Coal Measures
B (diss) (mg/L)
CRD (mm)
BH1
BH2
BH3
CRD

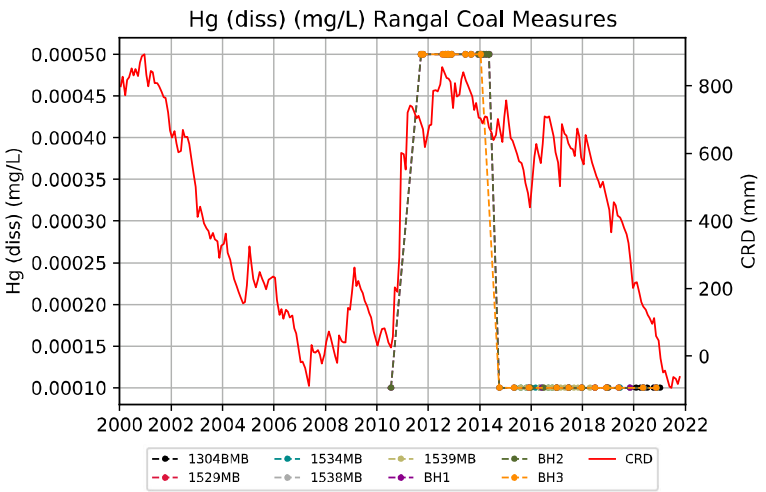

Cd (diss) (mg/L) Rangal Coal Measures
Cd (diss) (mg/L)
CRD (mm)
BH1
BH2
BH3
CRD

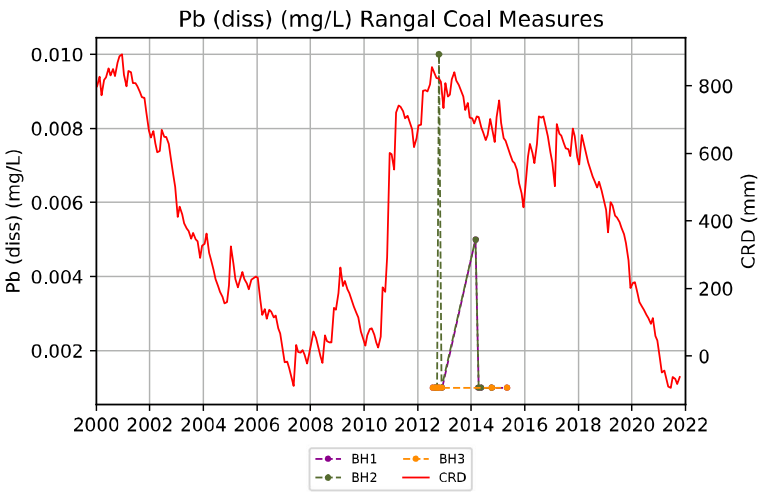

Cr (diss) (mg/L) Rangal Coal Measures
Cr (diss) (mg/L)
CRD (mm)
BH1
BH2
BH3
CRD

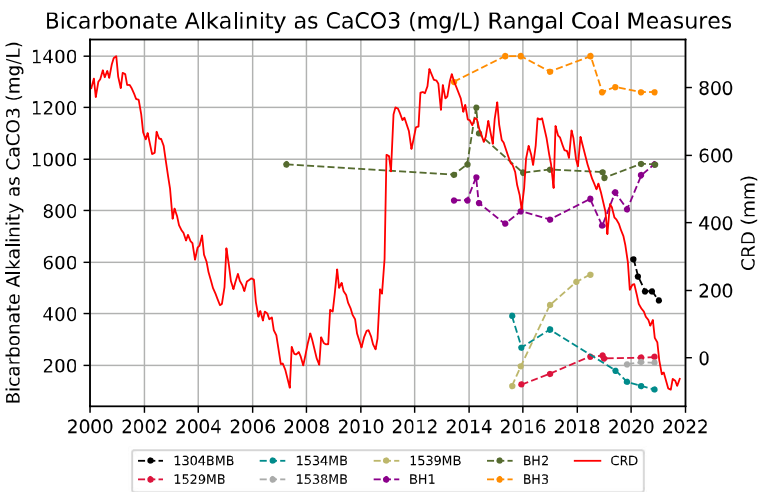

Co (diss) (mg/L) Rangal Coal Measures
Co (diss) (mg/L)
CRD (mm)
BH1
BH2
BH3
CRD

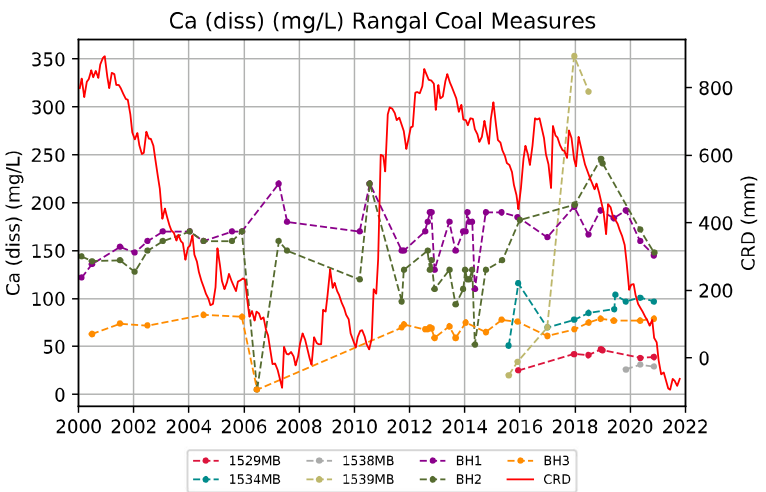

Cu (diss) (mg/L) Rangal Coal Measures
Cu (diss) (mg/L)
CRD (mm)
BH1
BH2
BH3
CRD

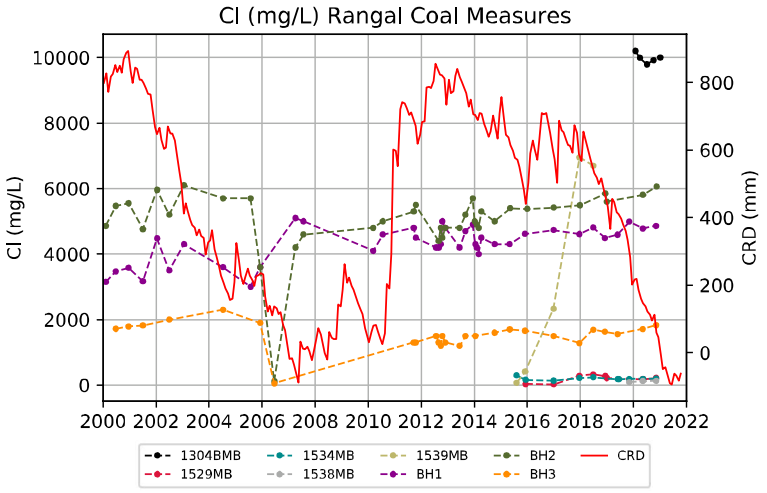

Fe (diss) (mg/L) Rangal Coal Measures
Fe (diss) (mg/L)
CRD (mm)
1304BMB
1529MB
1534MB
1538MB
1539MB
BH1
BH2
BH3
CRD

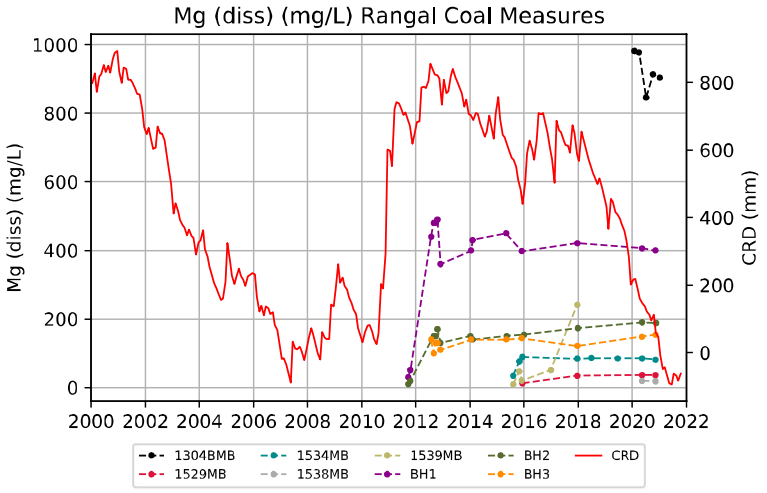

Hg (diss) (mg/L) Rangal Coal Measures
Hg (diss) (mg/L)
CRD (mm)
1304BMB
1529MB
1534MB
1538MB
1539MB
BH1
BH2
BH3
CRD

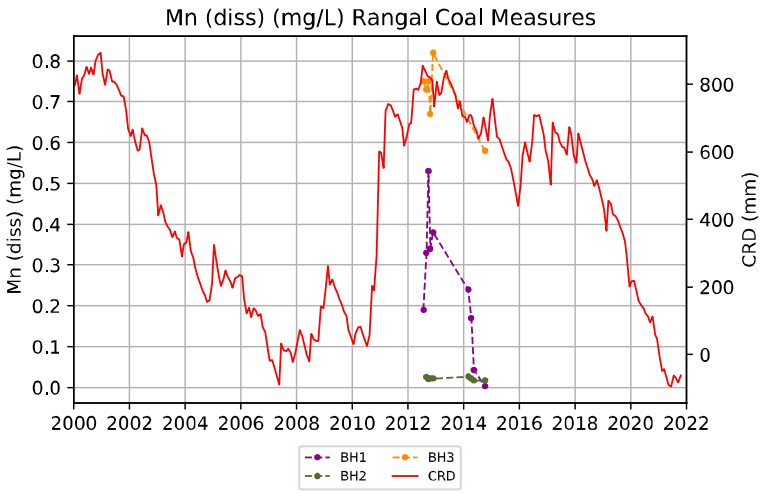

Pb (diss) (mg/L) Rangal Coal Measures
Pb (diss) (mg/L)
CRD (mm)
BH1
BH2
BH3
CRD

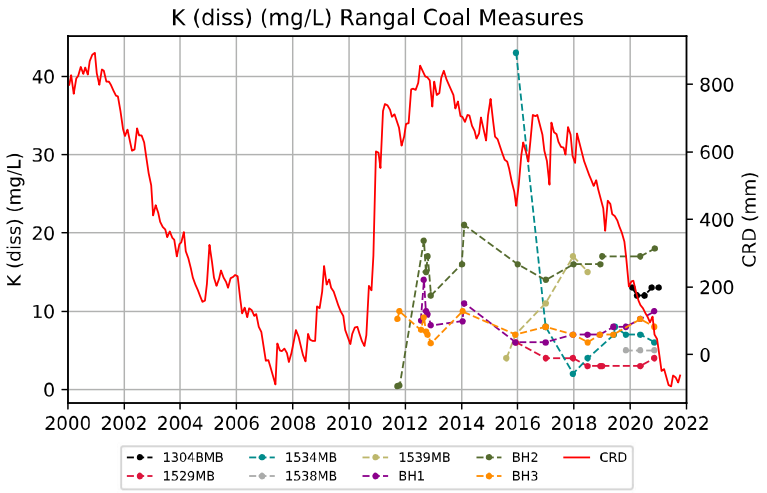

Bicarbonate Alkalinity as CaCO3 (mg/L) Rangal Coal Measures
Bicarbonate Alkalinity as CaCO3 (mg/L)
CRD (mm)
1304BMB
1529MB
1534MB
1538MB
1539MB
BH1
BH2
BH3
CRD

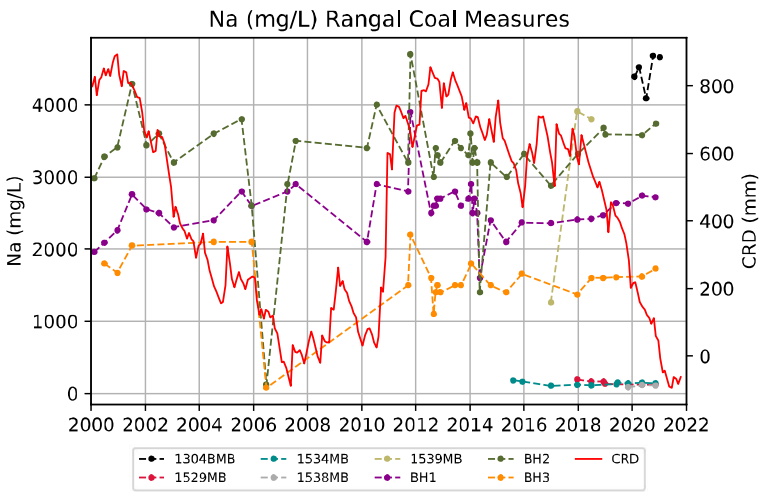

Ca (diss) (mg/L) Rangal Coal Measures
Ca (diss) (mg/L)
CRD (mm)
1529MB
1534MB
1538MB
1539MB
BH1
BH2
BH3
CRD

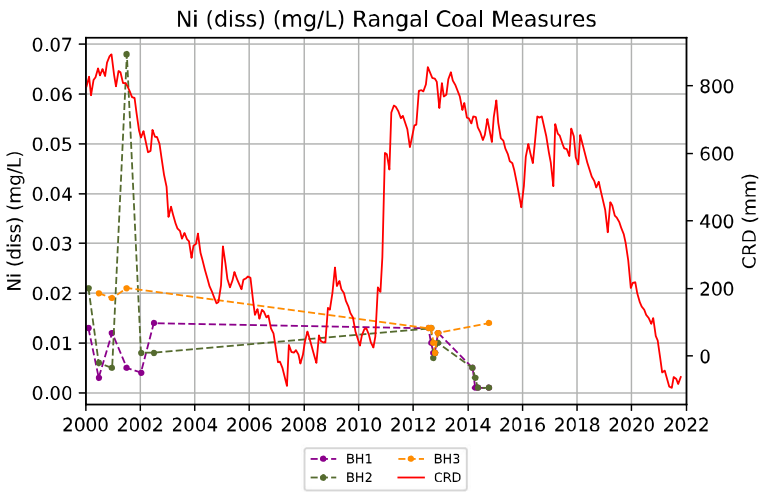

Cl (mg/L) Rangal Coal Measures
Cl (mg/L)
CRD (mm)
1304BMB
1534MB
1539MB
BH2
CRD
1529MB
1538MB
BH1
BH3

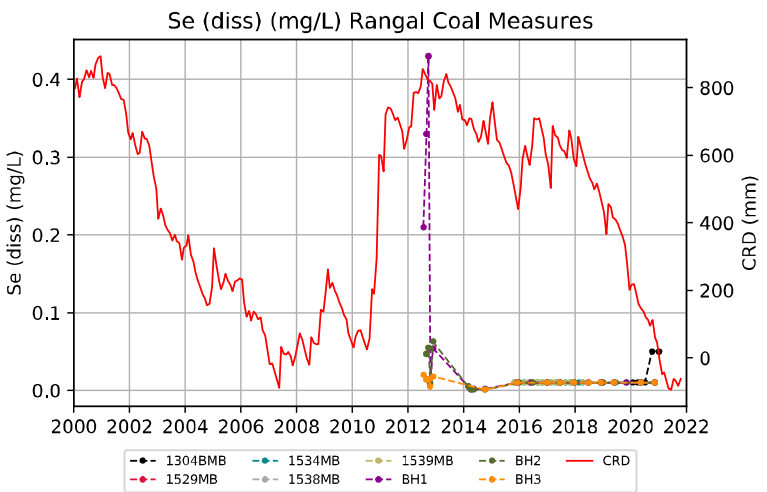

Mg (diss) (mg/L) Rangal Coal Measures
Mg (diss) (mg/L)
CRD (mm)
1304BMB
1534MB
1539MB
BH2
CRD
1529MB
1538MB
BH1
BH3

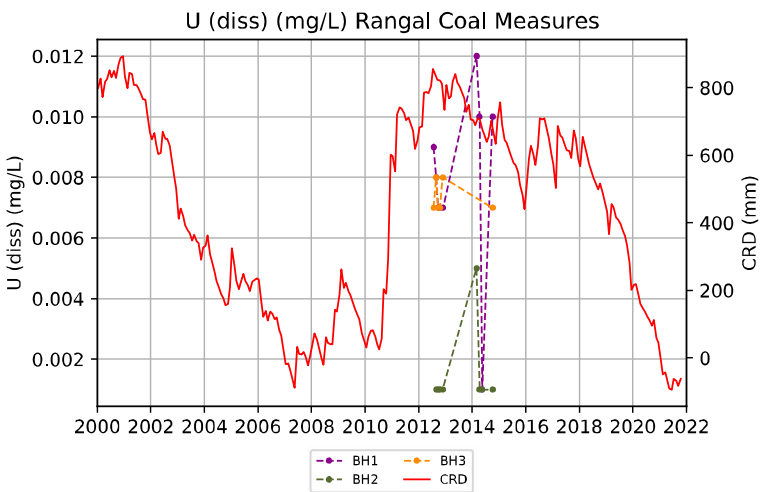

Mn (diss) (mg/L) Rangal Coal Measures
Mn (diss) (mg/L)
CRD (mm)
BH1
BH3
BH2
CRD

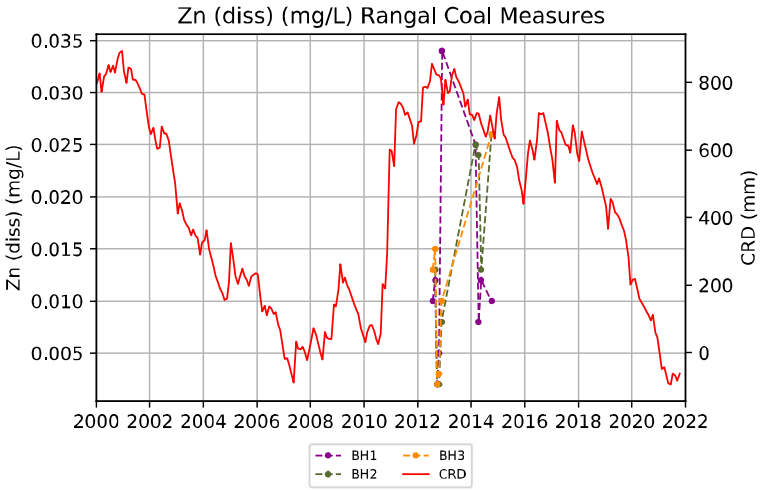

K (diss) (mg/L) Rangal Coal Measures
K (diss) (mg/L)
CRD (mm)
1304BMB
1534MB
1539MB
BH2
CRD
1529MB
1538MB
BH1
BH3

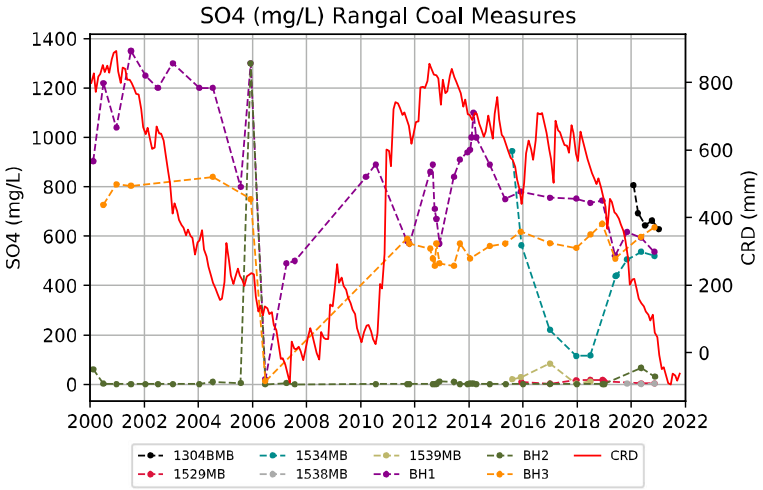

Na (mg/L) Rangal Coal Measures
Na (mg/L)
CRD (mm)
1304BMB
1534MB
1539MB
BH2
CRD
1529MB
1538MB
BH1
BH3

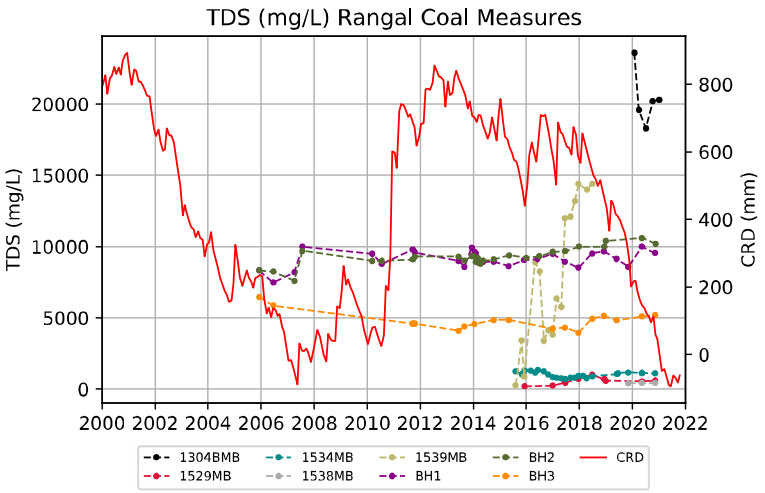

Ni (diss) (mg/L) Rangal Coal Measures
Ni (diss) (mg/L)
CRD (mm)
BH1
BH3
BH2
CRD

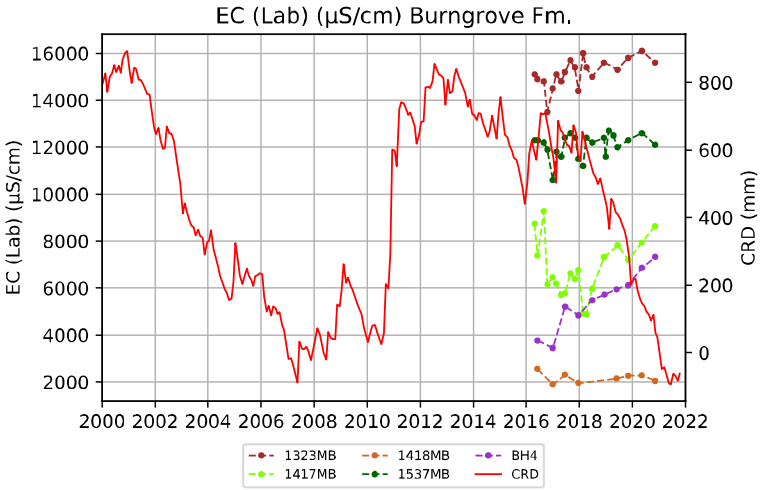

Se (diss) (mg/L) Rangal Coal Measures
Se (diss) (mg/L)
CRD (mm)
1304BMB
1534MB
1539MB
BH2
CRD
1529MB
1538MB
BH1
BH3

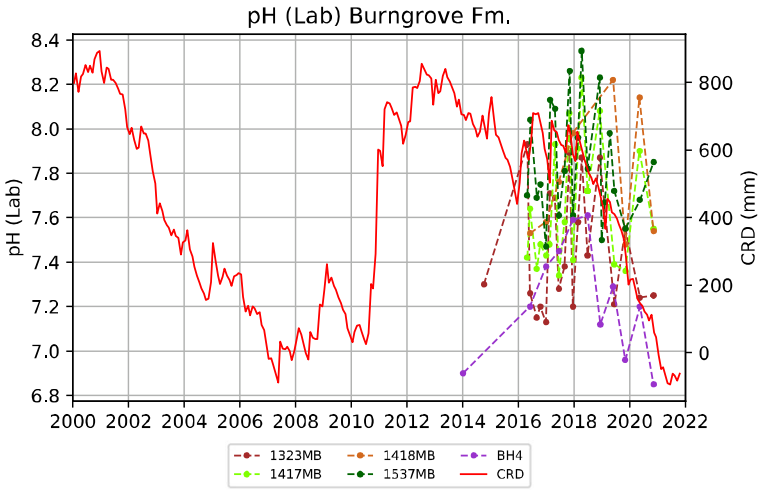

U (diss) (mg/L) Rangal Coal Measures
U (diss) (mg/L)
CRD (mm)
BH1
BH3
BH2
CRD

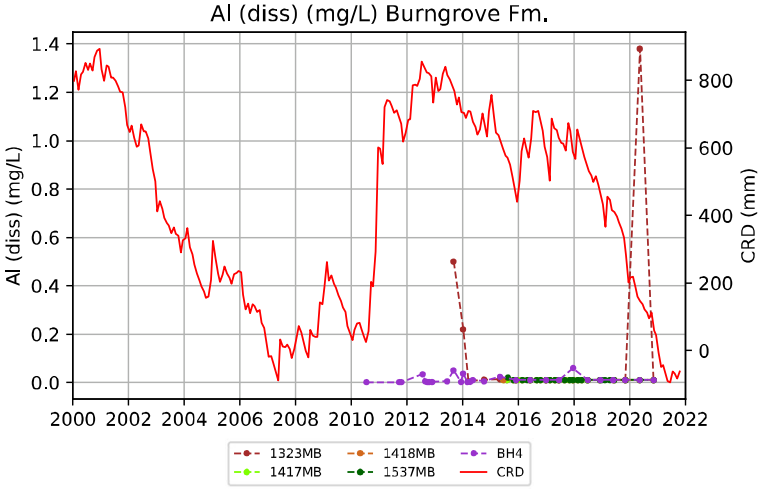

Zn (diss) (mg/L) Rangal Coal Measures
Zn (diss) (mg/L)
CRD (mm)
BH1
BH2
BH3
CRD

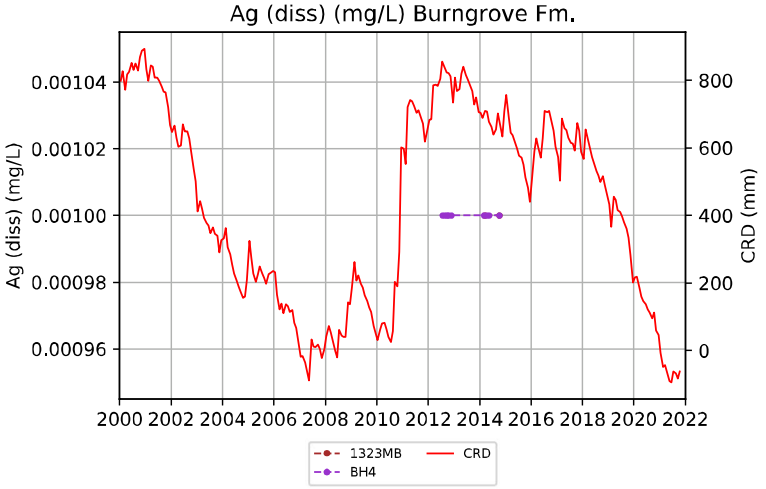

SO4 (mg/L) Rangal Coal Measures
SO4 (mg/L)
CRD (mm)
1304BMB
1529MB
1534MB
1538MB
1539MB
BH1
BH2
BH3
CRD

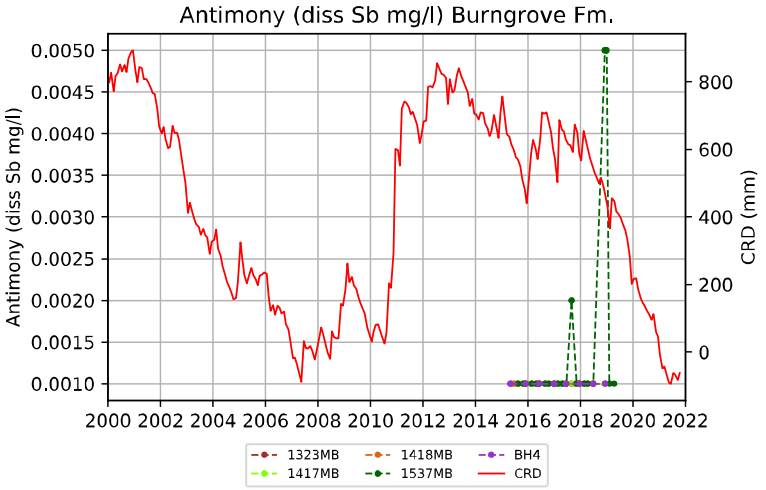

TDS (mg/L) Rangal Coal Measures
TDS (mg/L)
CRD (mm)
1304BMB
1529MB
1534MB
1538MB
1539MB
BH1
BH2
BH3
CRD

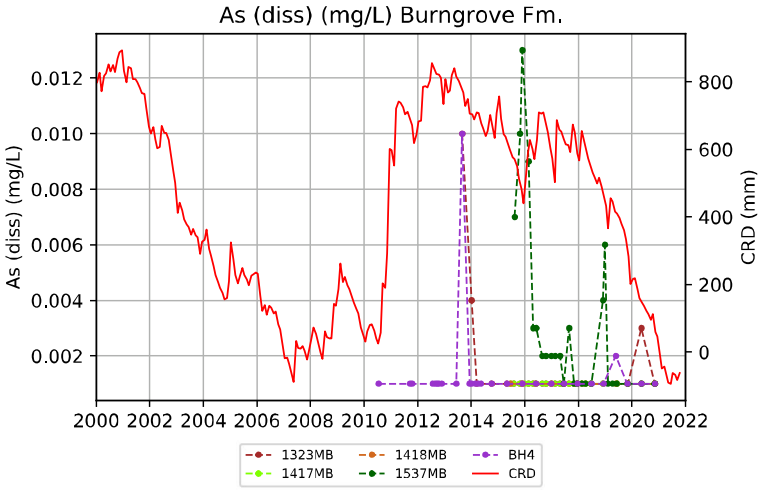

EC (Lab) (µS/cm) Burngrove Fm.
EC (Lab) (µS/cm)
CRD (mm)
1323MB
1418MB
BH4
1417MB
1537MB
CRD

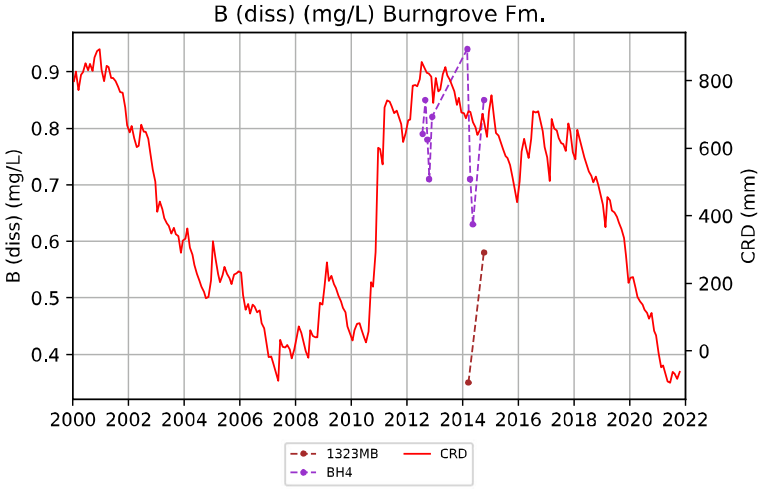

pH (Lab) Burngrove Fm.
pH (Lab)
CRD (mm)
1323MB
1418MB
BH4
1417MB
1537MB
CRD

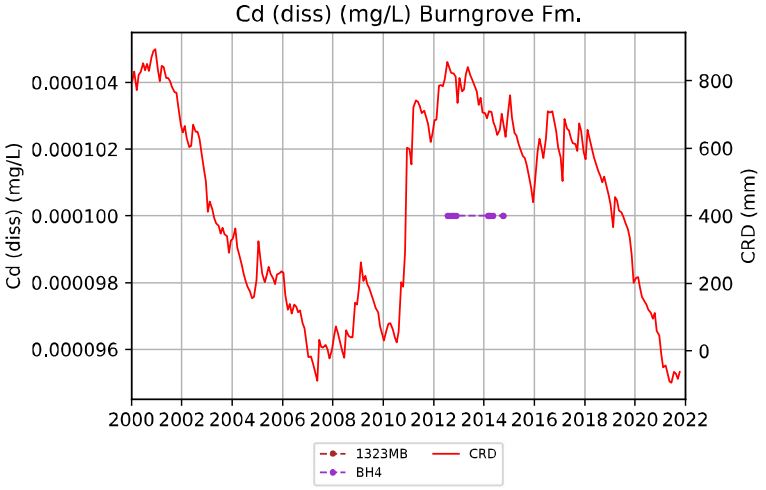

Al (diss) (mg/L) Burngrove Fm.
Al (diss) (mg/L)
CRD (mm)
1323MB
1418MB
BH4
1417MB
1537MB
CRD

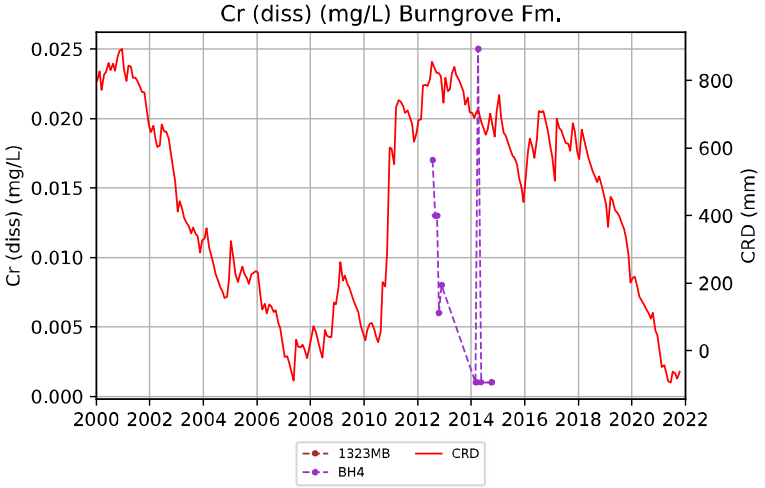

Ag (diss) (mg/L) Burngrove Fm.
Ag (diss) (mg/L)
CRD (mm)
1323MB
CRD
BH4

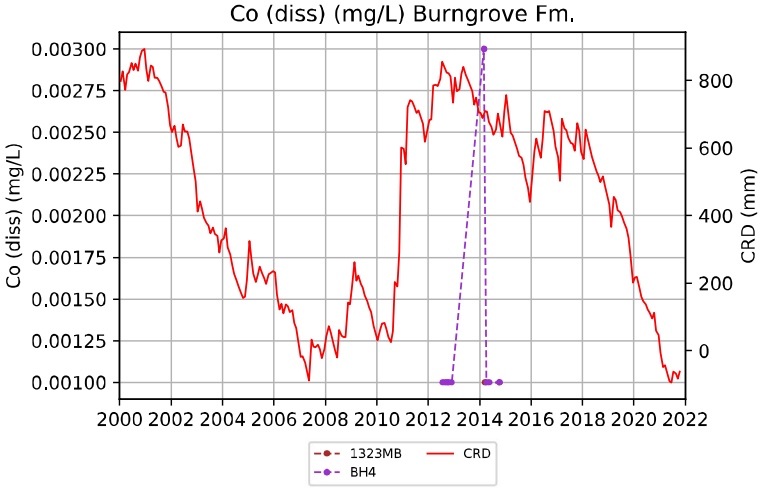

Antimony (diss Sb mg/l) Burngrove Fm.
Antimony (diss Sb mg/l)
CRD (mm)
1323MB
1418MB
BH4
1417MB
1537MB
CRD

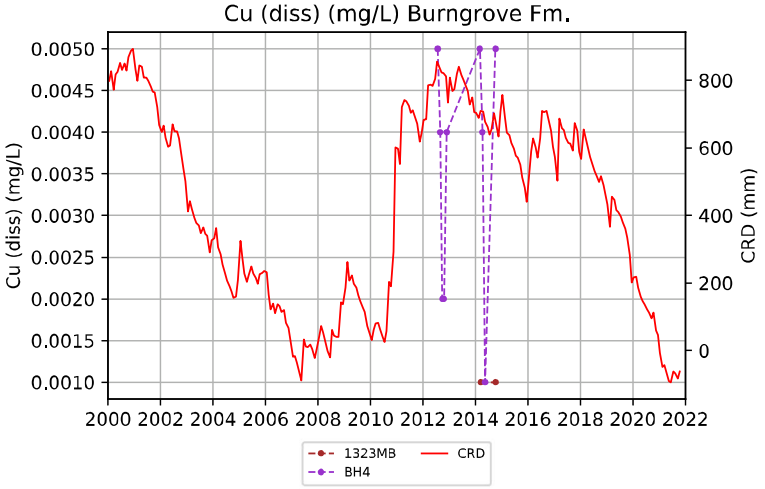

As (diss) (mg/L) Burngrove Fm.
As (diss) (mg/L)
CRD (mm)
1323MB
1418MB
BH4
1417MB
1537MB
CRD

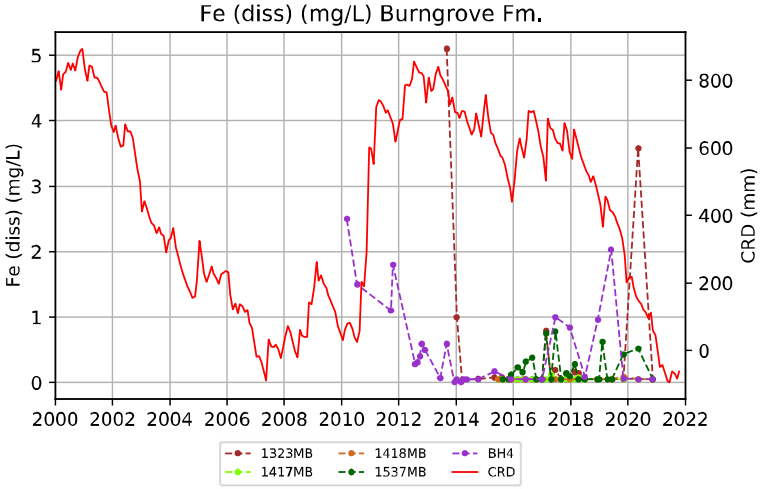

B (diss) (mg/L) Burngrove Fm.
B (diss) (mg/L)
CRD (mm)
1323MB
CRD
BH4

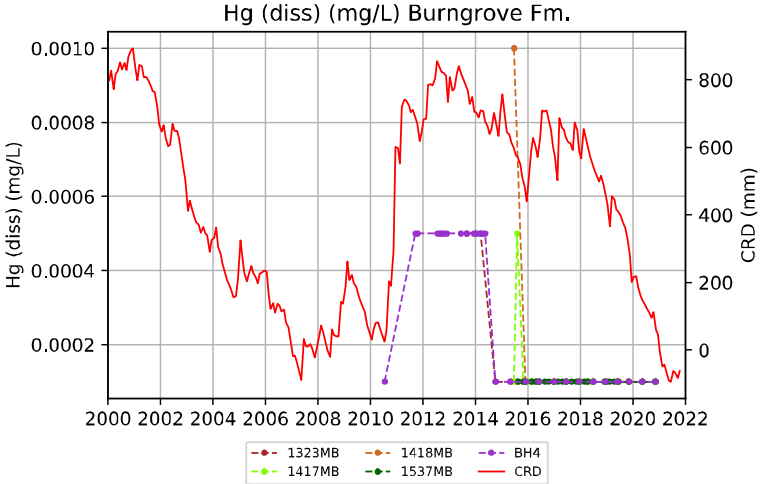

Cd (diss) (mg/L) Burngrove Fm.
Cd (diss) (mg/L)
CRD (mm)
1323MB
CRD
BH4

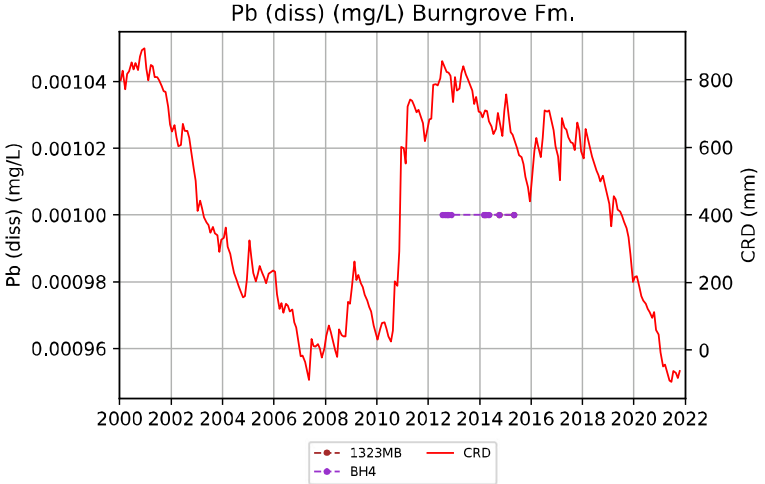

Cr (diss) (mg/L) Burngrove Fm.
Cr (diss) (mg/L)
CRD (mm)
1323MB
BH4
CRD

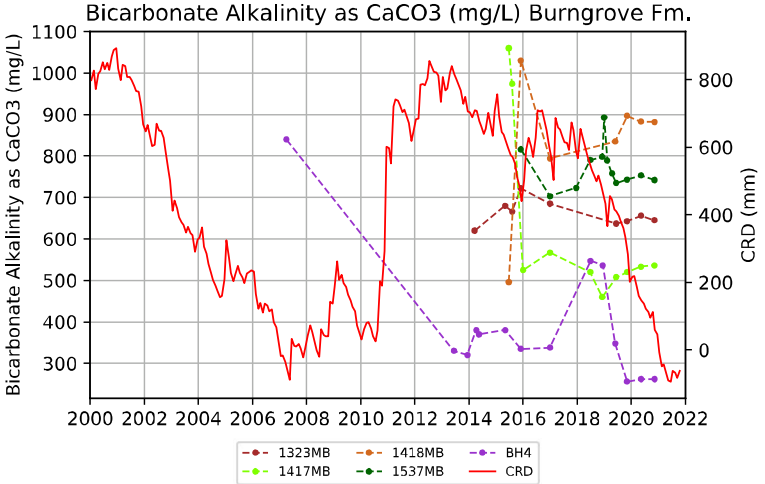

Co (diss) (mg/L) Burngrove Fm.
Co (diss) (mg/L)
CRD (mm)
1323MB
BH4
CRD

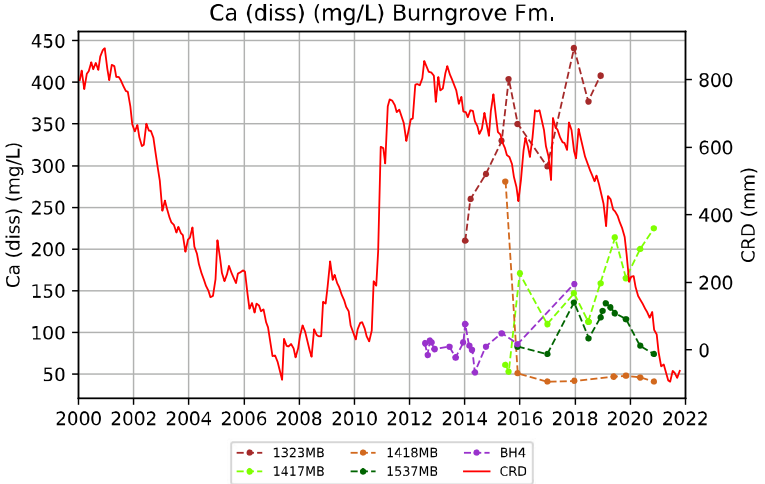

Cu (diss) (mg/L) Burngrove Fm.
Cu (diss) (mg/L)
CRD (mm)
1323MB
BH4
CRD

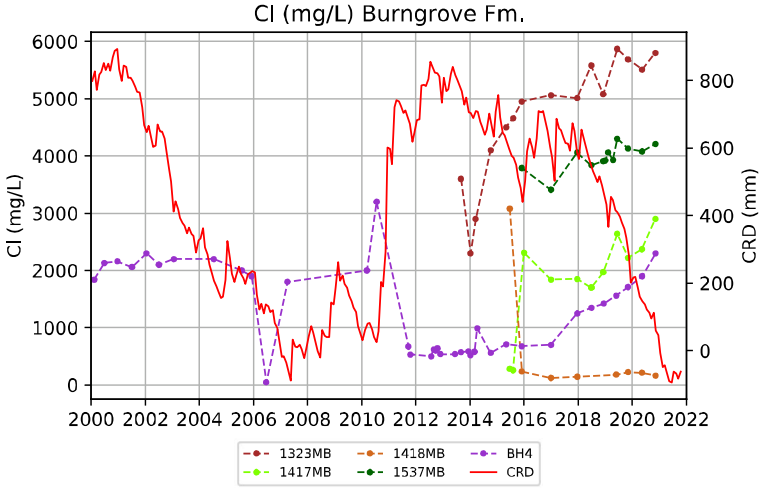

Fe (diss) (mg/L) Burngrove Fm.
Fe (diss) (mg/L)
CRD (mm)
1323MB
1418MB
BH4
1417MB
1537MB
CRD

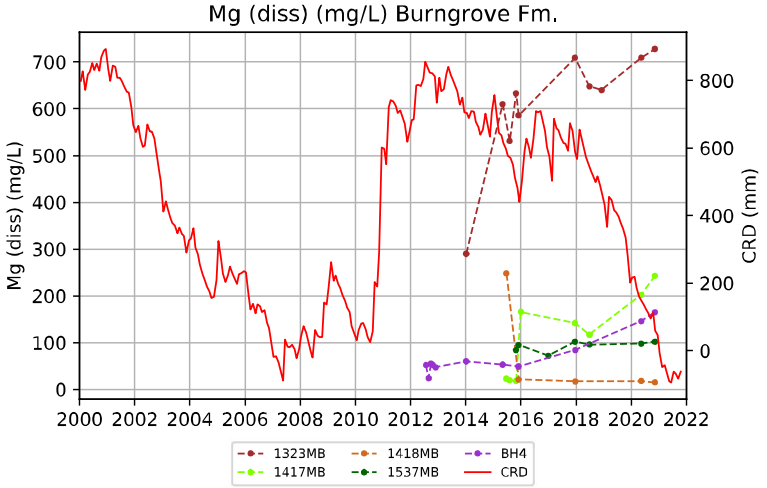

Hg (diss) (mg/L) Burngrove Fm.
Hg (diss) (mg/L)
CRD (mm)
1323MB
1418MB
BH4
1417MB
1537MB
CRD

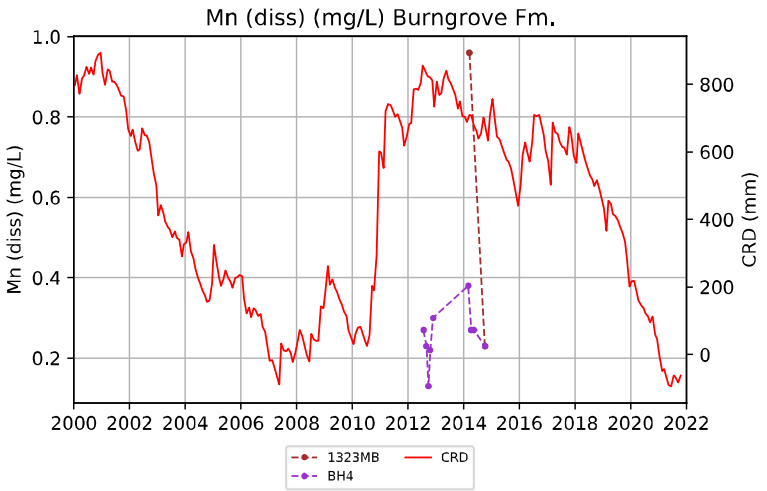

Pb (diss) (mg/L) Burngrove Fm.
Pb (diss) (mg/L)
CRD (mm)
1323MB
BH4
CRD

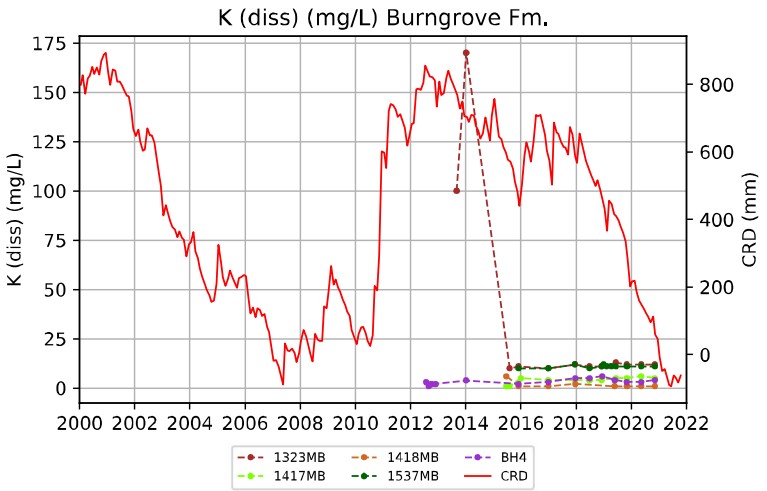

Bicarbonate Alkalinity as CaCO3 (mg/L) Burngrove Fm.
Bicarbonate Alkalinity as CaCO3 (mg/L)
CRD (mm)
1323MB
1418MB
BH4
1417MB
1537MB
CRD

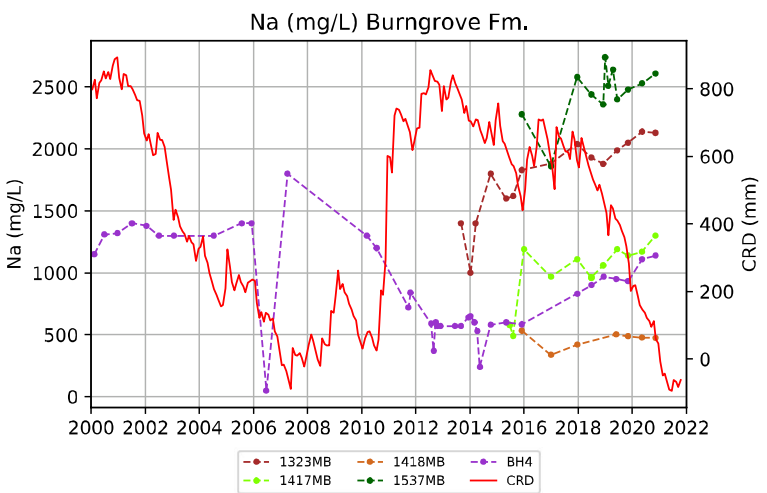

Ca (diss) (mg/L) Burngrove Fm.
Ca (diss) (mg/L)
CRD (mm)
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1418MB
BH4
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1537MB
CRD

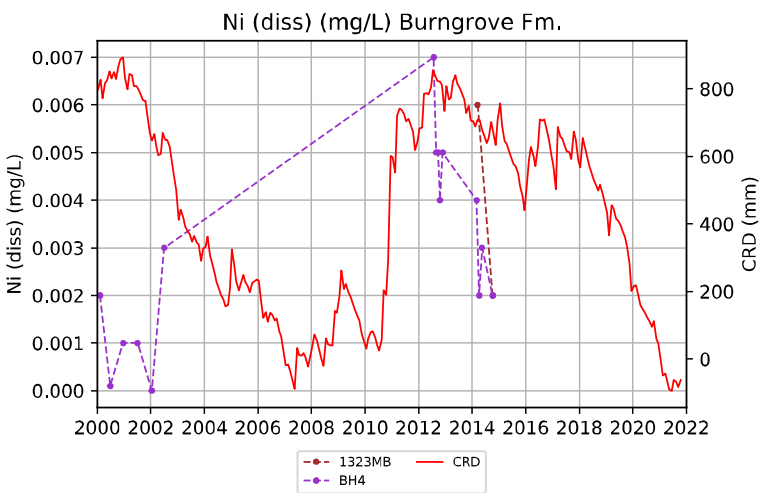

Cl (mg/L) Burngrove Fm.
Cl (mg/L)
CRD (mm)
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1418MB
BH4
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CRD

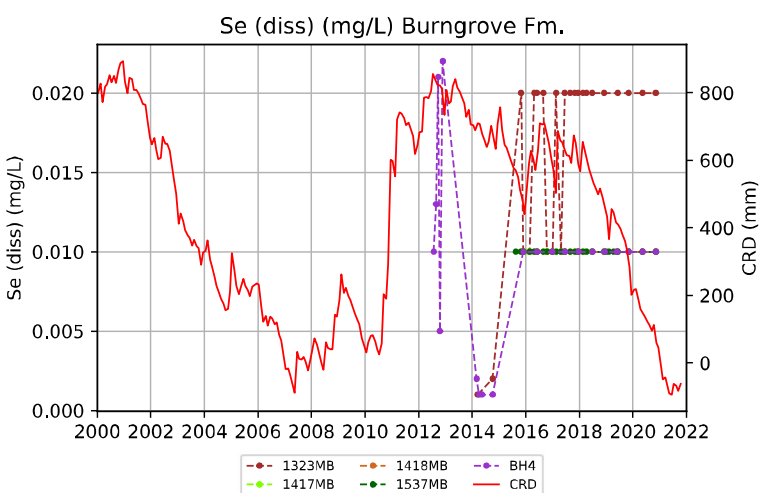

Mg (diss) (mg/L) Burngrove Fm.
Mg (diss) (mg/L)
CRD (mm)
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1418MB
BH4
1417MB
1537MB
CRD

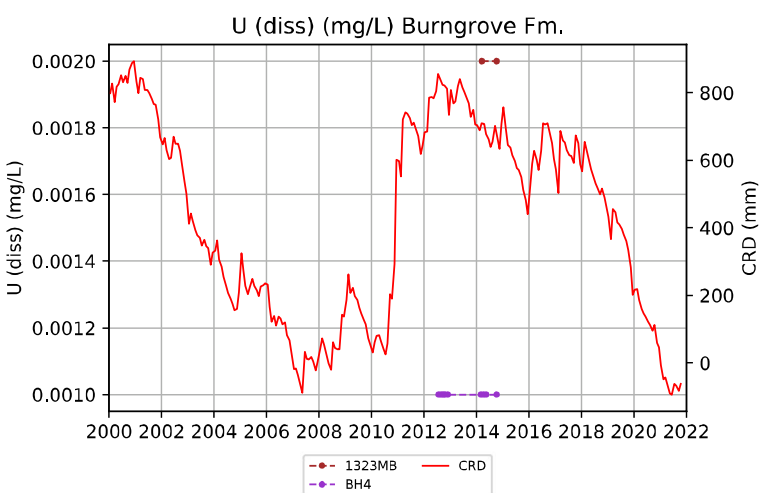

Mn (diss) (mg/L) Burngrove Fm.
Mn (diss) (mg/L)
CRD (mm)
1323MB
CRD
BH4

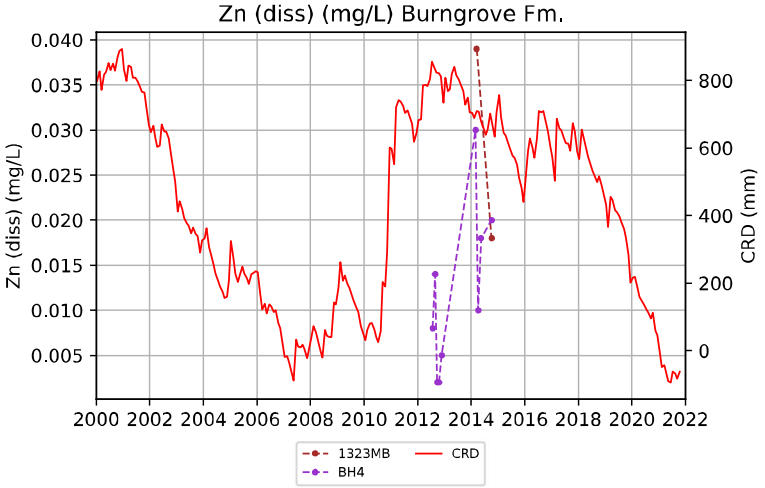

K (diss) (mg/L) Burngrove Fm.
K (diss) (mg/L)
CRD (mm)
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1418MB
BH4
1417MB
1537MB
CRD

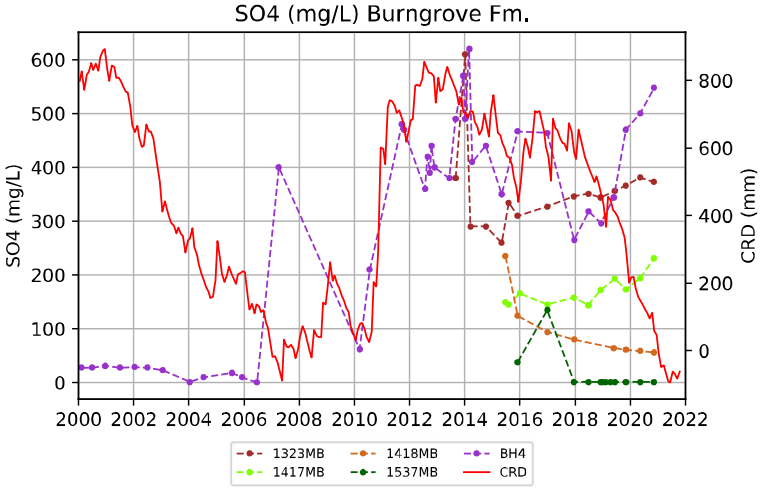

Na (mg/L) Burngrove Fm.
Na (mg/L)
CRD (mm)
1323MB
1418MB
BH4
1417MB
1537MB
CRD

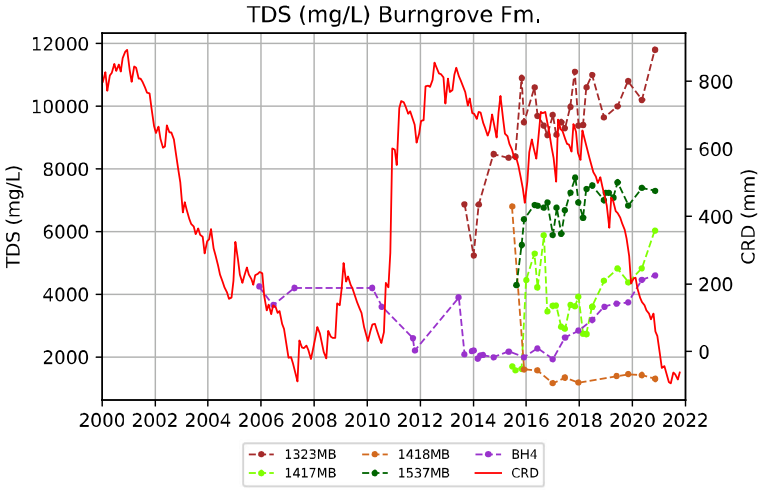

Ni (diss) (mg/L) Burngrove Fm.
Ni (diss) (mg/L)
CRD (mm)
1323MB
CRD
BH4


Se (diss) (mg/L) Burngrove Fm.
Se (diss) (mg/L)
CRD (mm)
1323MB
1418MB
BH4
1417MB
1537MB
CRD


U (diss) (mg/L) Burngrove Fm.
U (diss) (mg/L)
CRD (mm)
1323MB
CRD
BH4

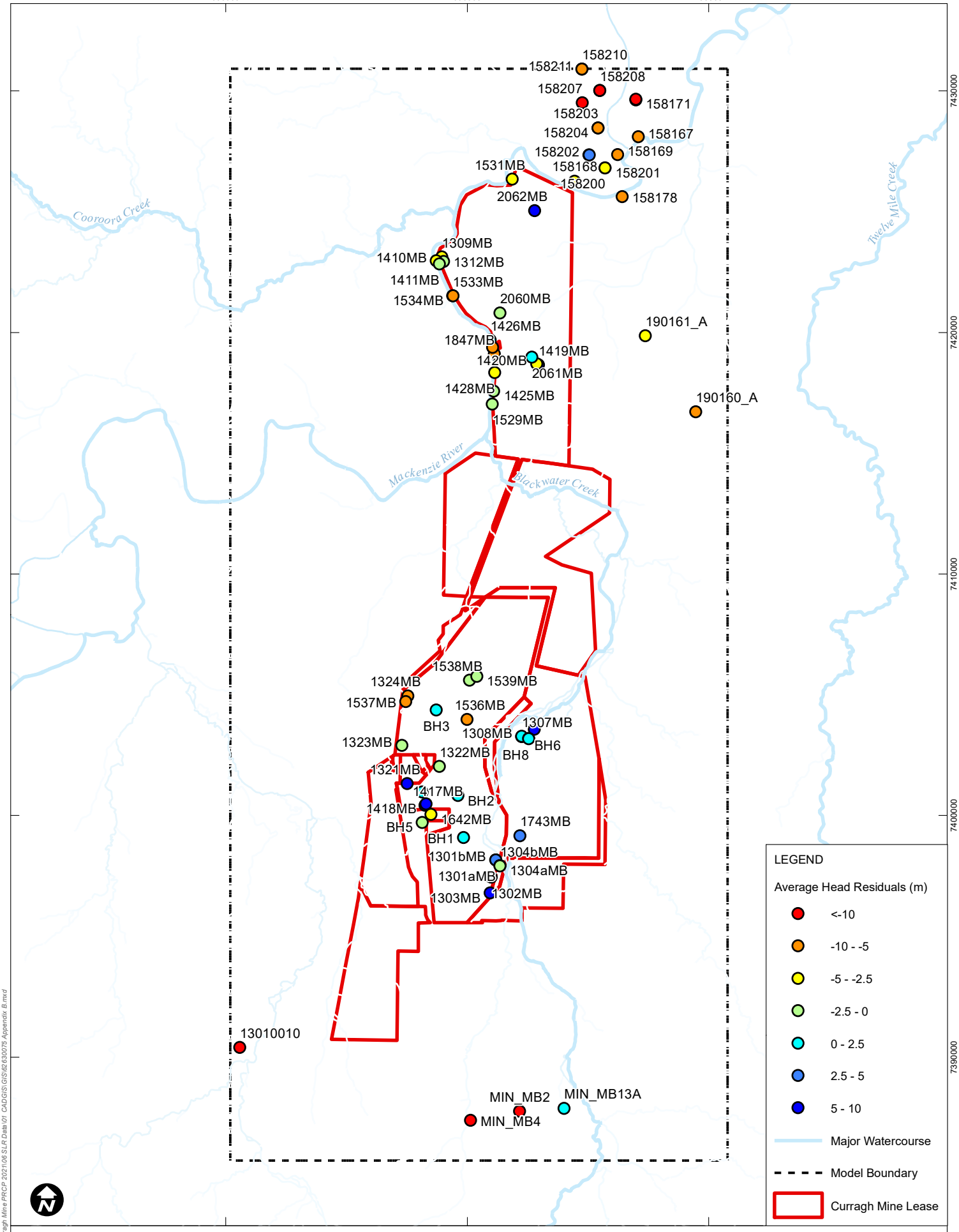

Zn (diss) (mg/L) Burngrove Fm.
Zn (diss) (mg/L)
CRD (mm)
1323MB
CRD
BH4


SO4 (mg/L) Burngrove Fm.
SO4 (mg/L)
CRD (mm)
1323MB
1418MB
BH4
1417MB
1537MB
CRD


TDS (mg/L) Burngrove Fm.
TDS (mg/L)
CRD (mm)
1323MB
1418MB
BH4
1417MB
1537MB
CRD

APPENDIX B

Calibration Average Residuals



SLR

DISCLAIMER: All information within this document may be based on external sources. SLR Consulting Pty Ltd makes no warranty regarding the data's accuracy or reliability for any purpose.

0 2 4 km

Coordinate System:	AGD 1984 AMG Zone 55
Scale:	1:200,000 at A4
Project Number:	626.30075
Date:	26-Nov-2021
Drawn by:	AN
Reviewed by:	AN

Data Source:

CURRAGH PRCP

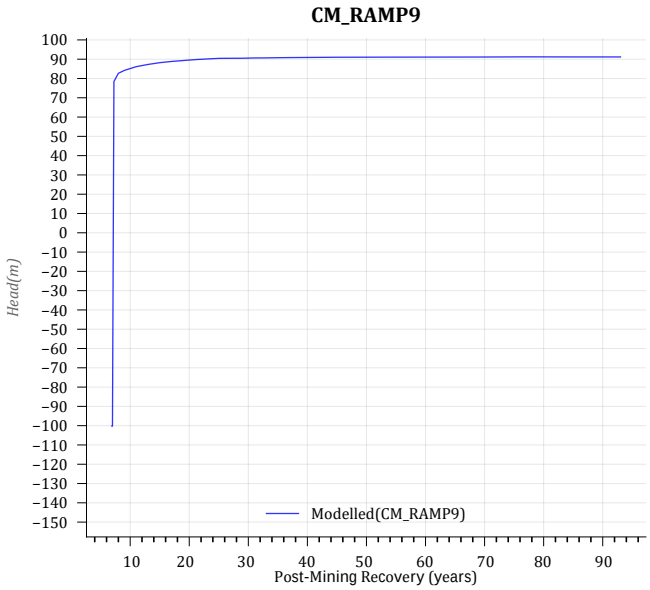
Calibration Residuals

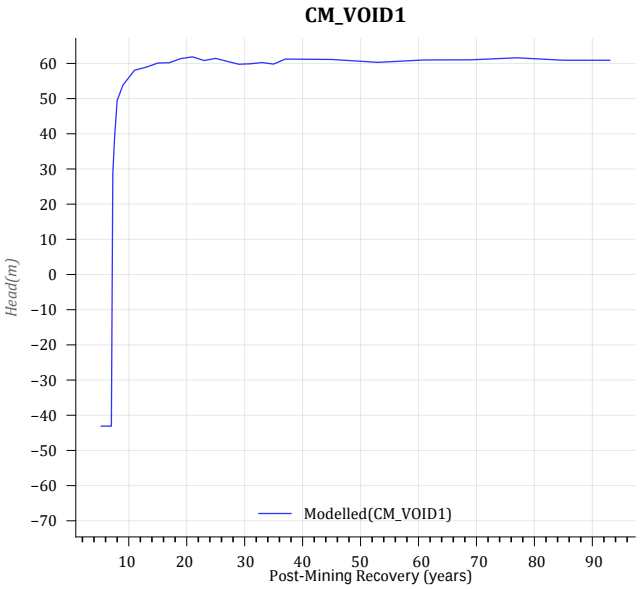
APPENDIX B

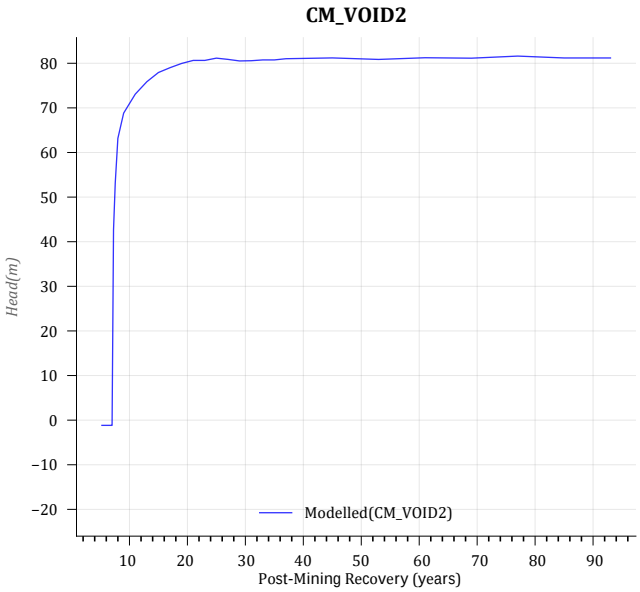
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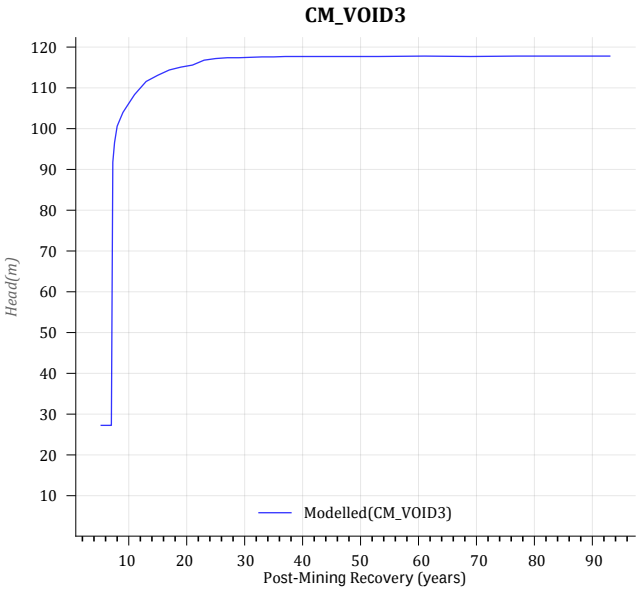
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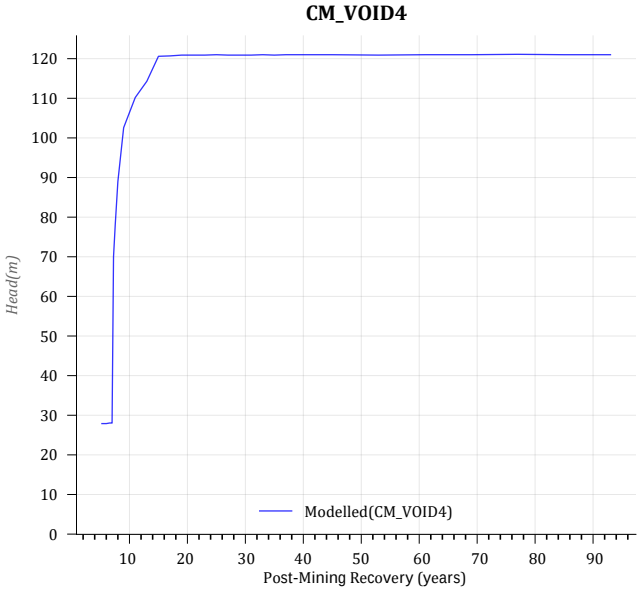
Calibration Hydrographs

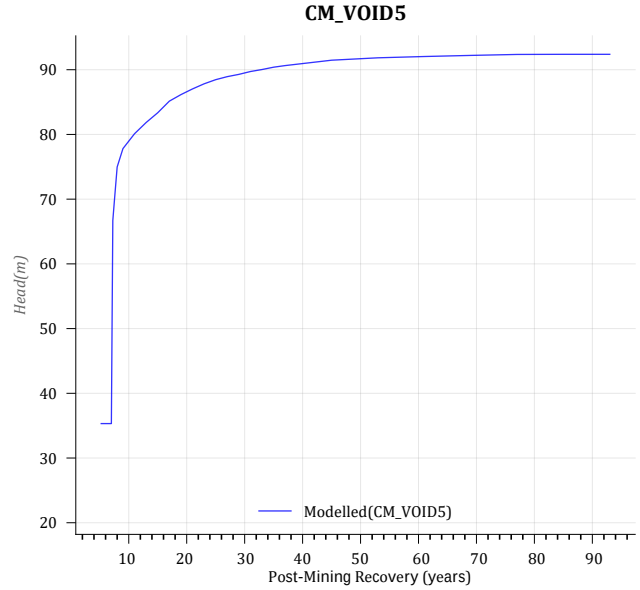

CM_RAMP9
Head(m)
Post-Mining Recovery (years)
Modelled(CM_RAMP9)

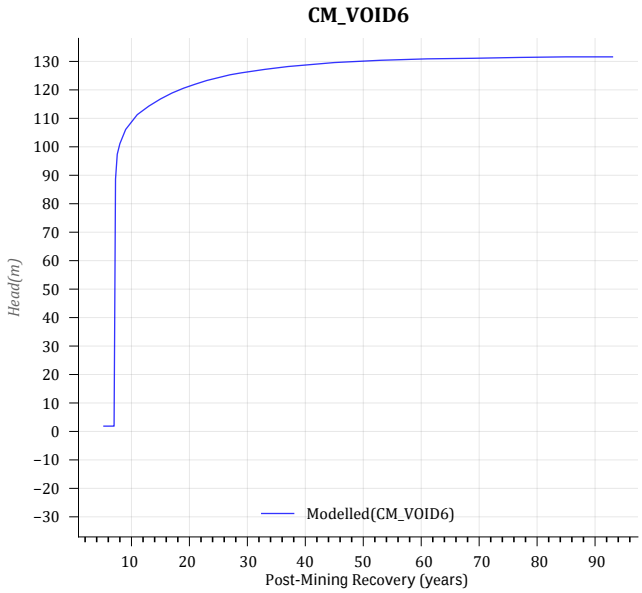

CM_VOID1
Head(m)
Post-Mining Recovery (years)
Modelled(CM_VOID1)

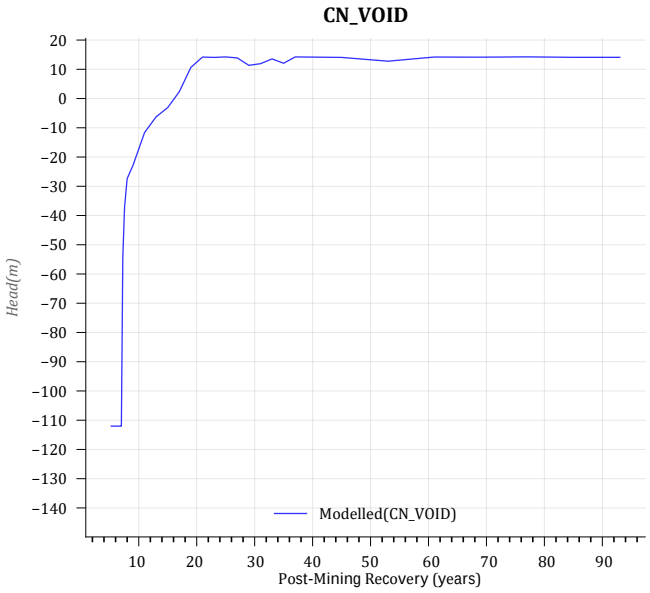

CM_VOID2
Head(m)
Post-Mining Recovery (years)
Modelled(CM_VOID2)

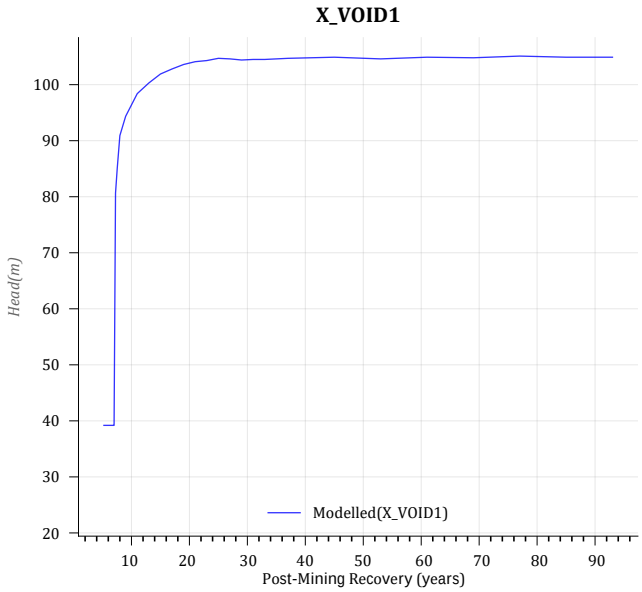

CM_VOID3
Head(m)
Post-Mining Recovery (years)
Modelled(CM_VOID3)

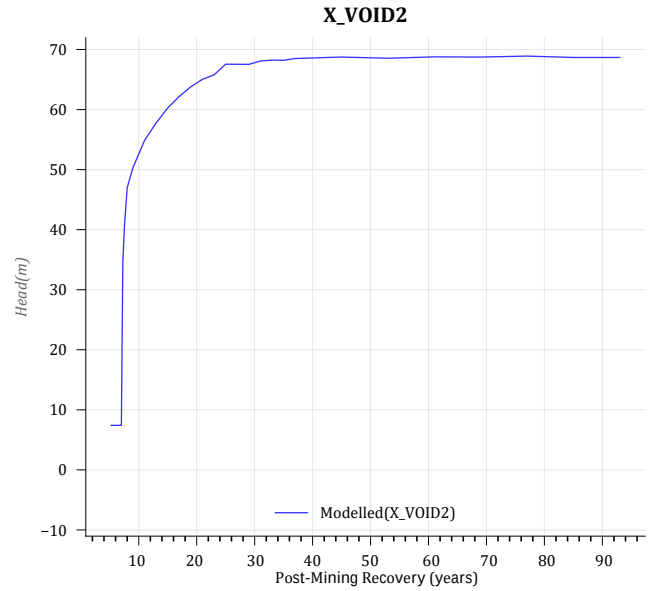

CM_VOID4
Head(m)
Post-Mining Recovery (years)
Modelled(CM_VOID4)

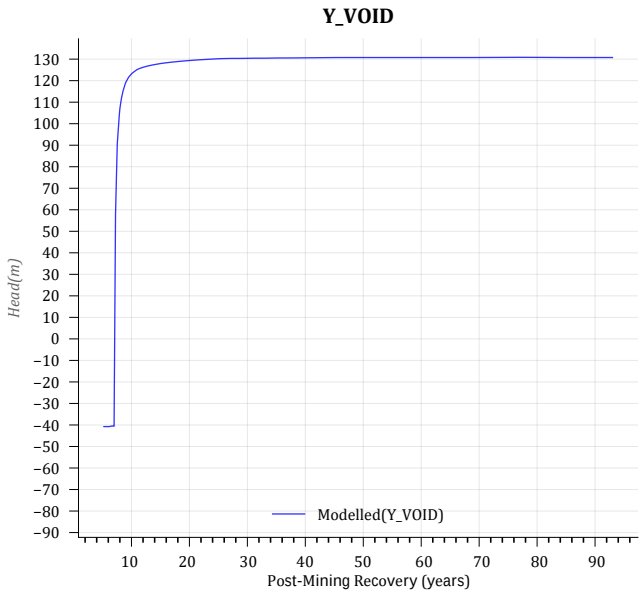

CM_VOID5
Head(m)
Post-Mining Recovery (years)
Modelled(CM_VOID5)

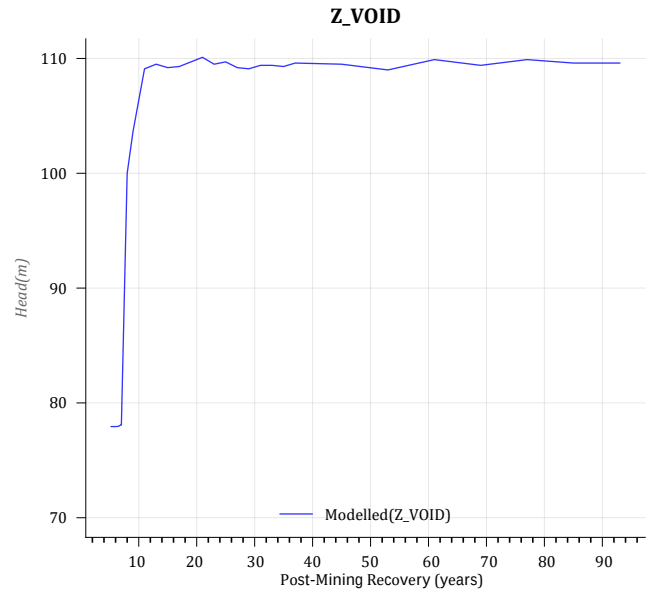

CM_VOID6
Head(m)
Post-Mining Recovery (years)
Modelled(CM_VOID6)


CN_VOID
Head(m)
Post-Mining Recovery (years)
Modelled(CN_VOID)


X_VOID1
Head(m)
Post-Mining Recovery (years)
Modelled(X_VOID1)

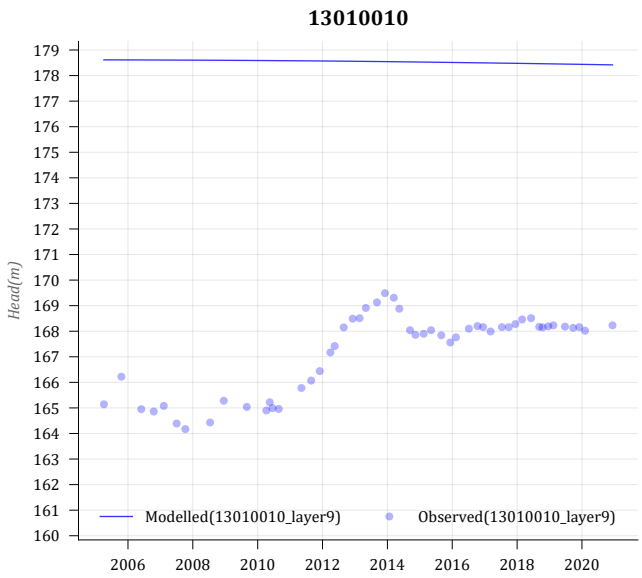

X_VOID2
Head(m)
Post-Mining Recovery (years)
Modelled(X_VOID2)

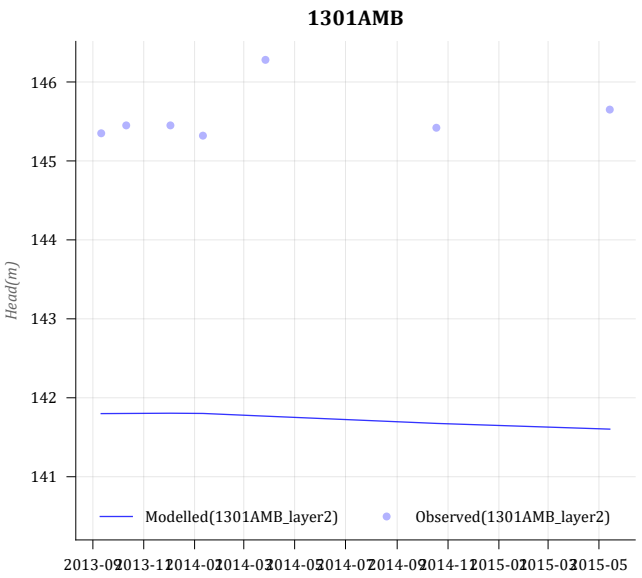

Y_VOID
Head(m)
Post-Mining Recovery (years)
Modelled(Y_VOID)

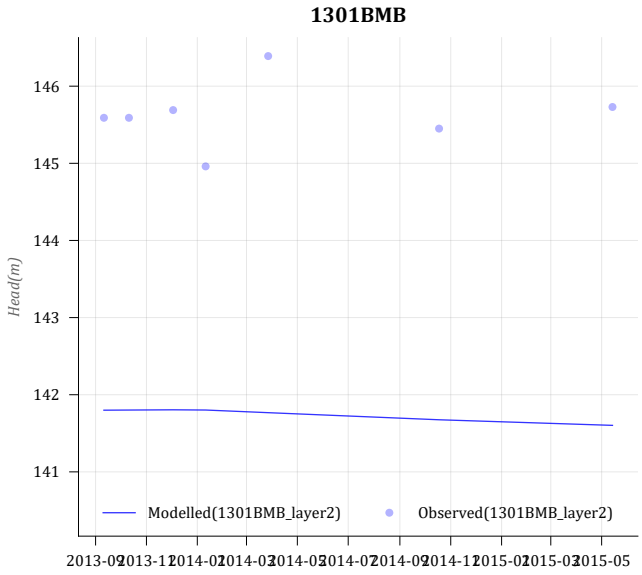

Z_VOID
Head(m)
Post-Mining Recovery (years)
Modelled(Z_VOID)

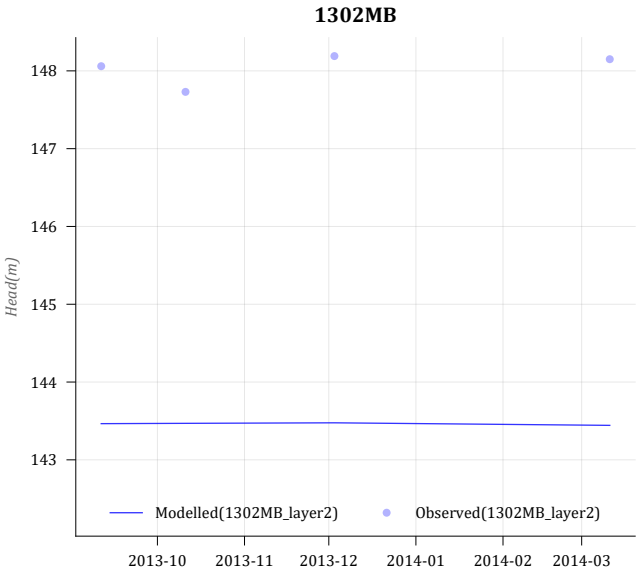
APPENDIX D

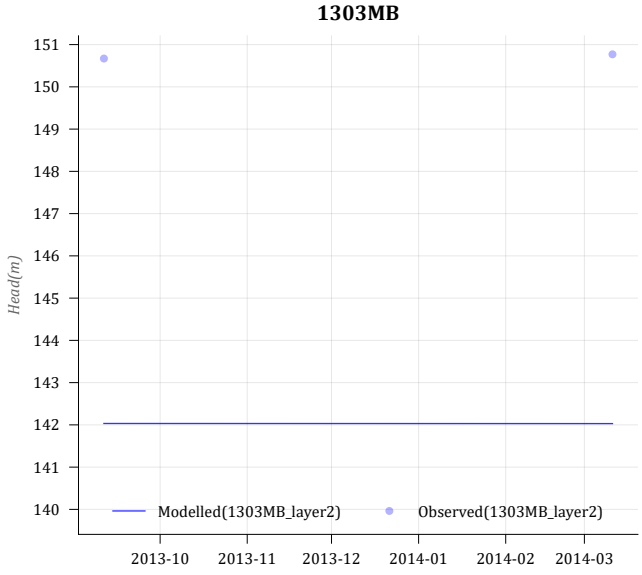
Post Mining Recovery Hydrographs

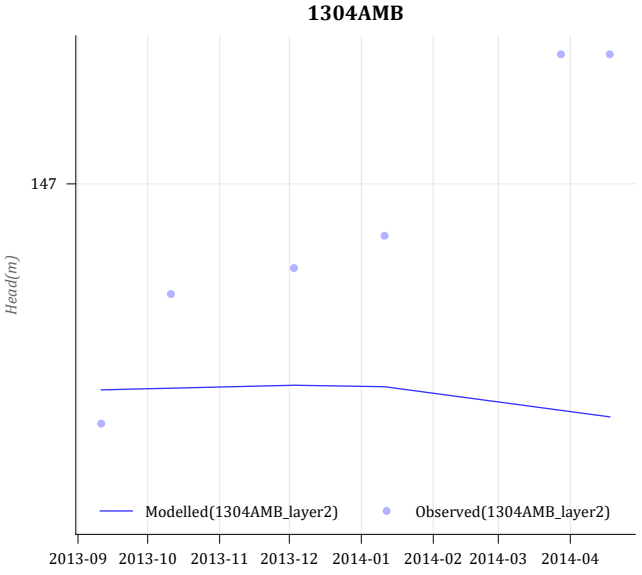

13010010
Head(m)
Modelled(13010010_layer9)
Observed(13010010_layer9)

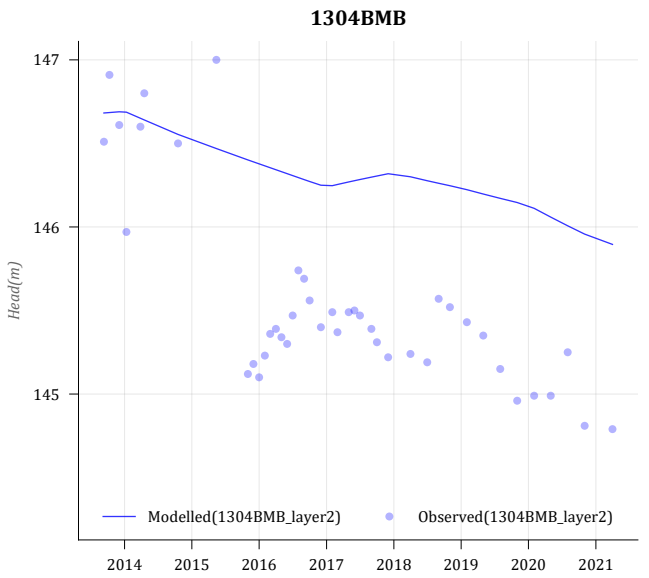

1301AMB
Head(m)
Modelled(1301AMB_layer2)
Observed(1301AMB_layer2)

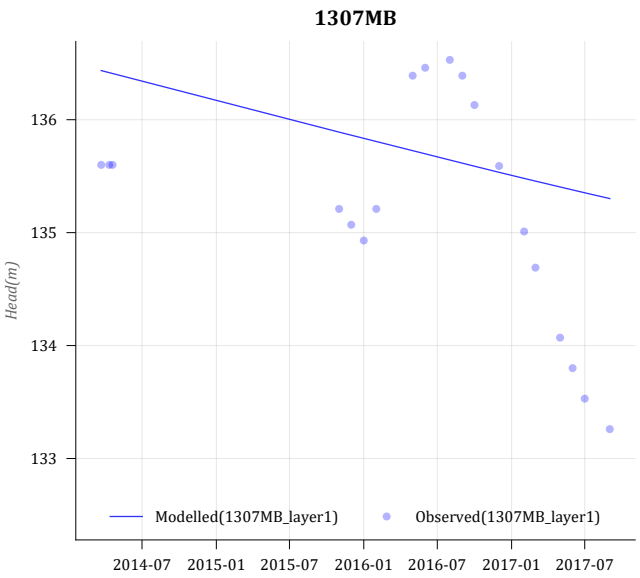

1301BMB
Head(m)
Modelled(1301BMB_layer2)
Observed(1301BMB_layer2)

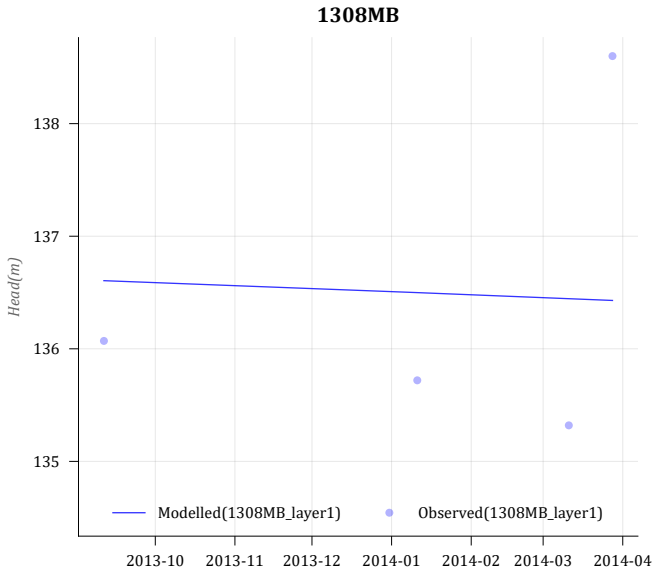

1302MB
Head(m)
Modelled(1302MB_layer2)
Observed(1302MB_layer2)

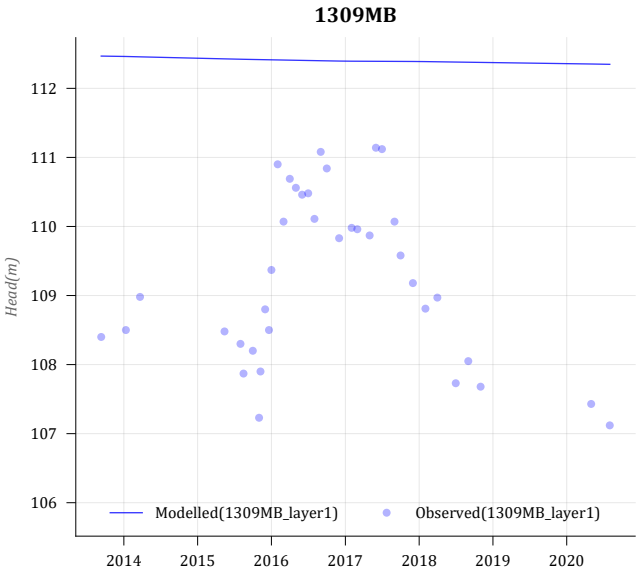

1303MB
Head(m)
Modelled(1303MB_layer2)
Observed(1303MB_layer2)

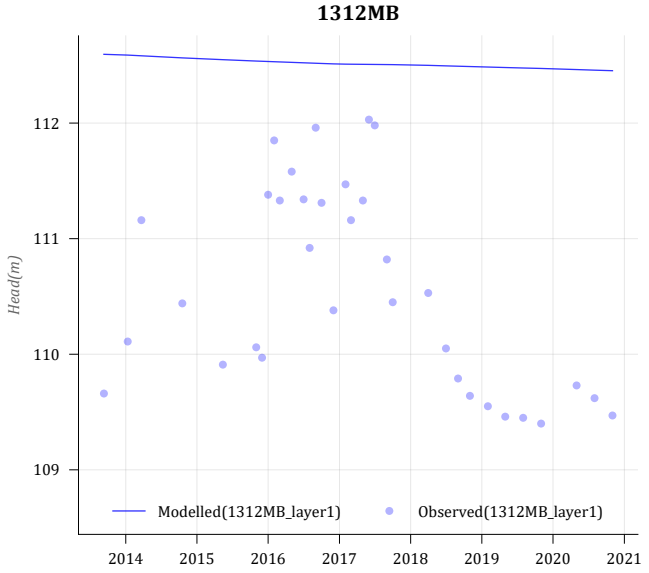

1304AMB
Head(m)
Modelled(1304AMB_layer2)
Observed(1304AMB_layer2)

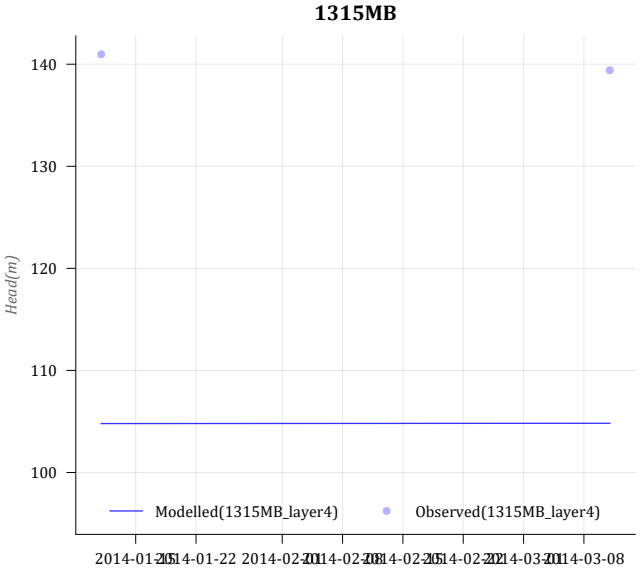

1304BMB
Head(m)
147
146
145
Modelled(1304BMB_layer2)
Observed(1304BMB_layer2)
2014
2015
2016
2017
2018
2019
2020
2021

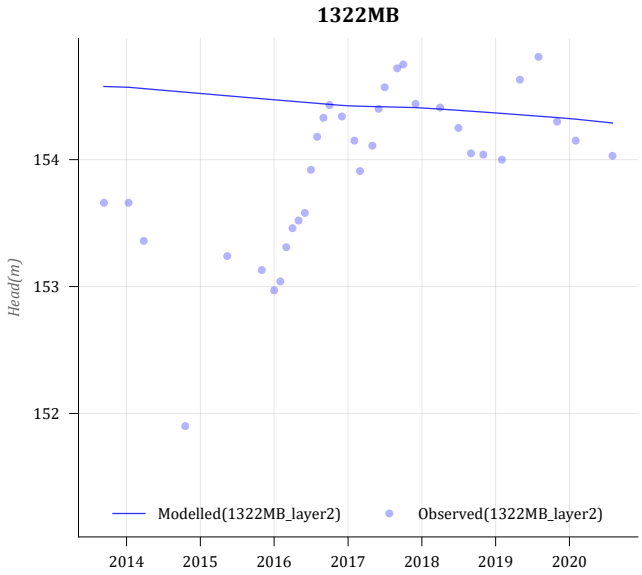

1307MB
Head(m)
136
135
134
133
Modelled(1307MB_layer1)
Observed(1307MB_layer1)
2014-07
2015-01
2015-07
2016-01
2016-07
2017-01
2017-07

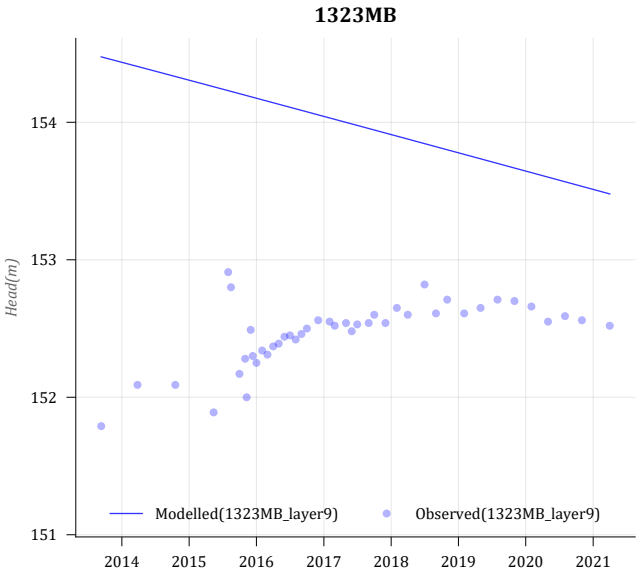

1308MB
Head(m)
138
137
136
135
Modelled(1308MB_layer1)
Observed(1308MB_layer1)
2013-10
2013-11
2013-12
2014-01
2014-02
2014-03
2014-04

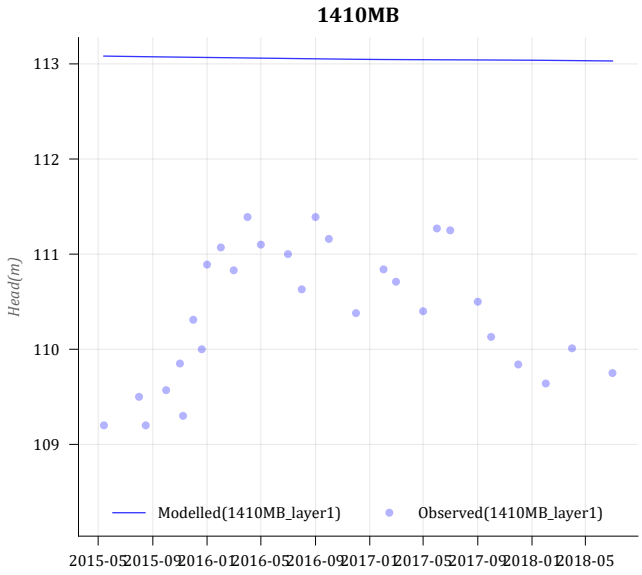

1309MB
Head(m)
112
111
110
109
108
107
106
Modelled(1309MB_layer1)
Observed(1309MB_layer1)
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2015
2016
2017
2018
2019
2020

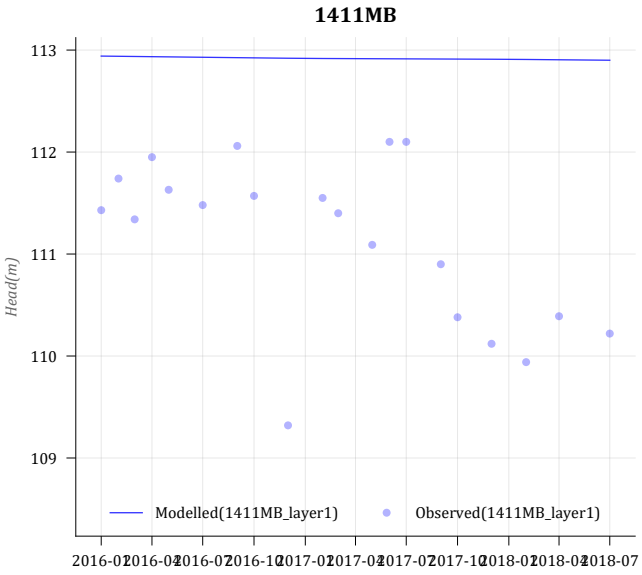

1312MB
Head(m)
112
111
110
109
Modelled(1312MB_layer1)
Observed(1312MB_layer1)
2014
2015
2016
2017
2018
2019
2020
2021

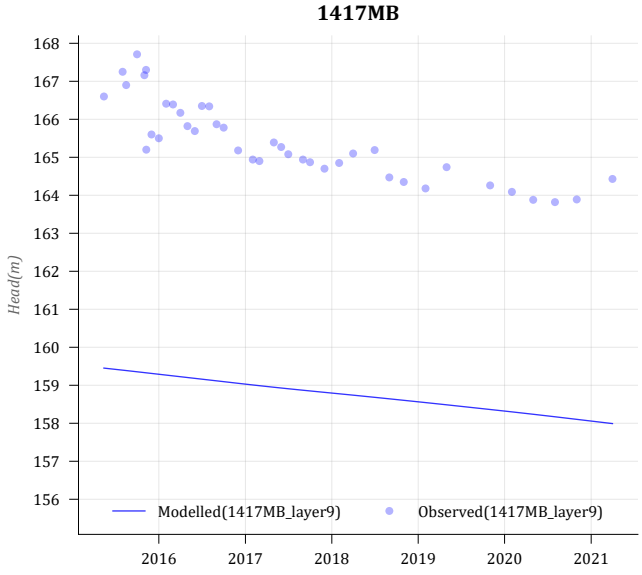

1315MB
Head(m)
140
130
120
110
100
Modelled(1315MB_layer4)
Observed(1315MB_layer4)
2014-01-15
2014-01-22
2014-02-01
2014-02-08
2014-02-15
2014-02-22
2014-03-01
2014-03-08

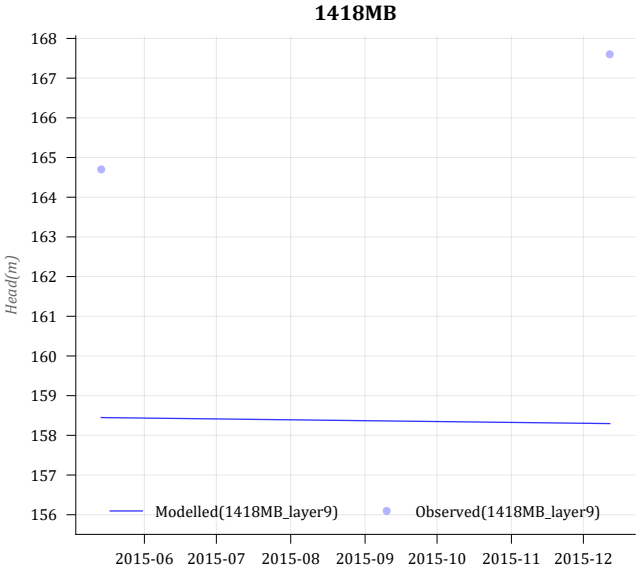

1322MB
Head(m)
154
153
152
Modelled(1322MB_layer2)
Observed(1322MB_layer2)
2014
2015
2016
2017
2018
2019
2020

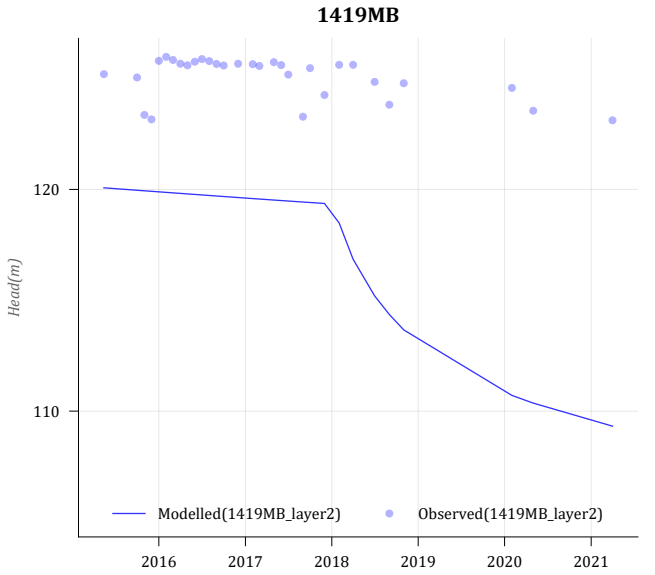

1323MB
Head(m)
154
153
152
151
Modelled(1323MB_layer9)
Observed(1323MB_layer9)
2014
2015
2016
2017
2018
2019
2020
2021

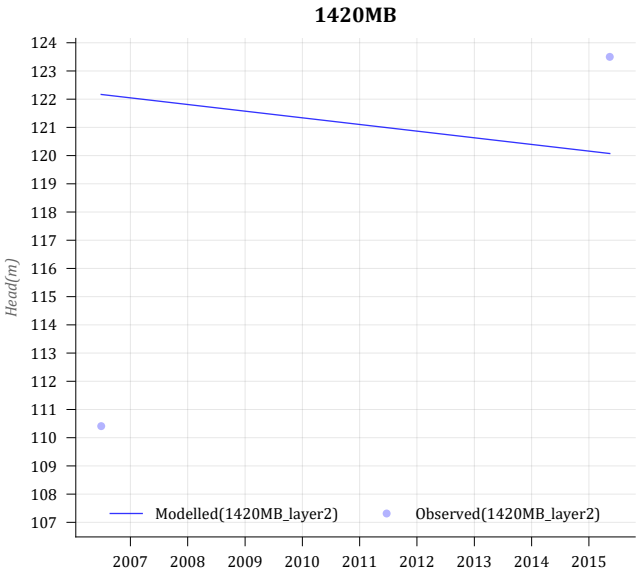

1410MB
Head(m)
113
112
111
110
109
Modelled(1410MB_layer1)
Observed(1410MB_layer1)
2015-05
2015-09
2016-01
2016-05
2016-09
2017-01
2017-05
2017-09
2018-01
2018-05

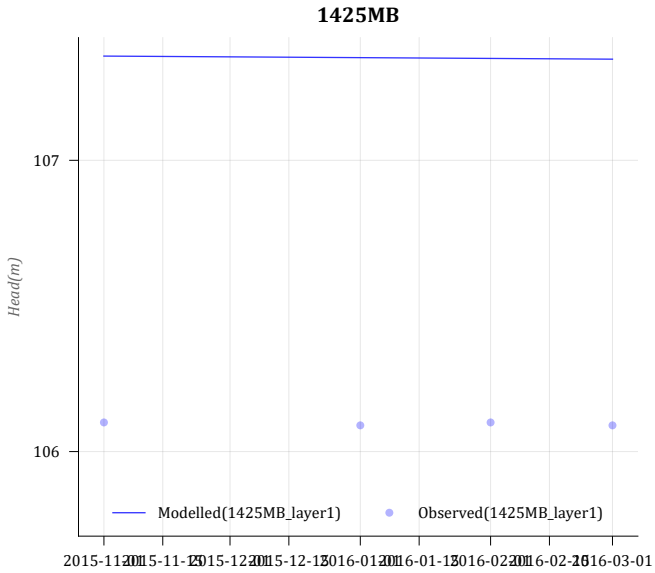

1411MB
Head(m)
113
112
111
110
109
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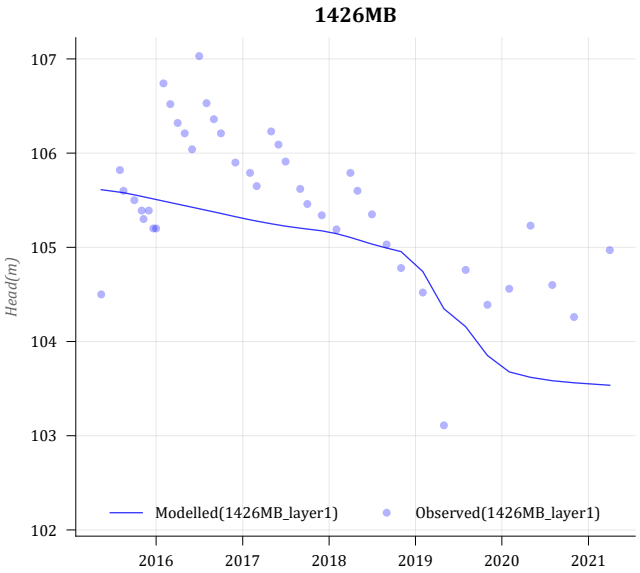

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Head(m)
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2020
2021

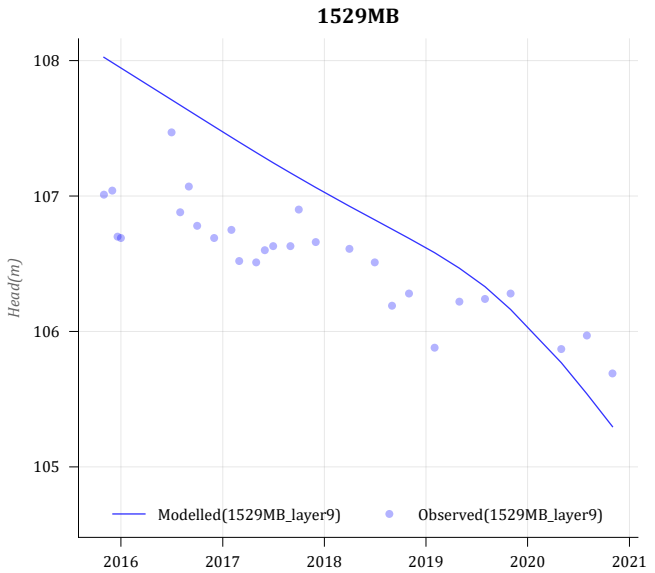

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Head(m)
168
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2015-11
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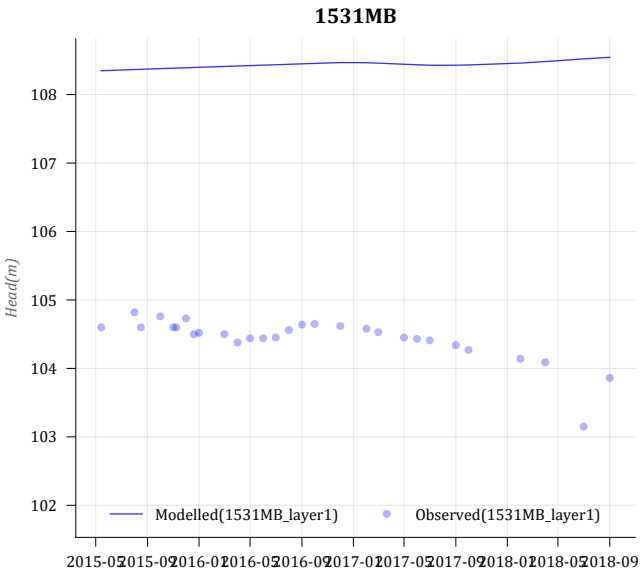

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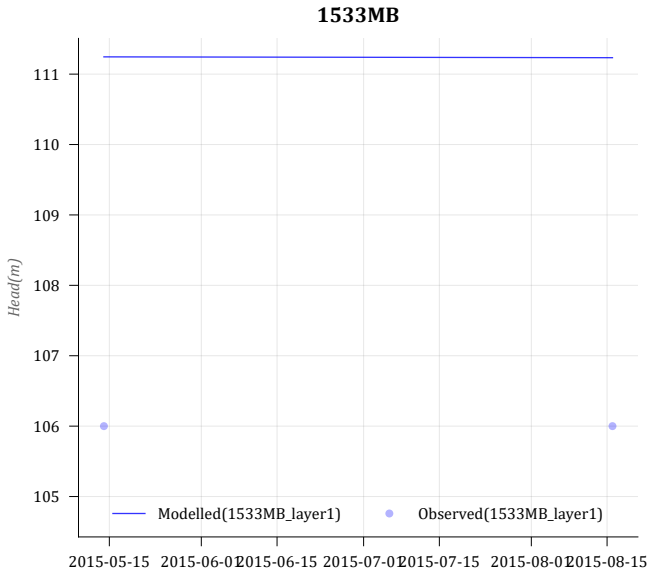

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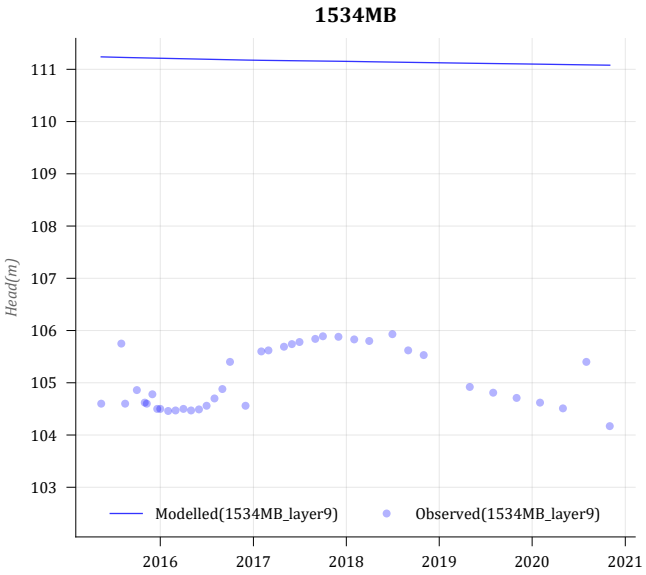

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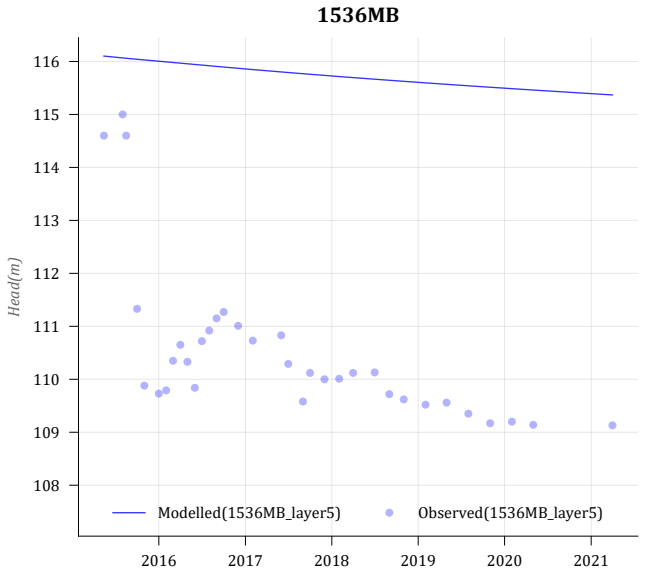

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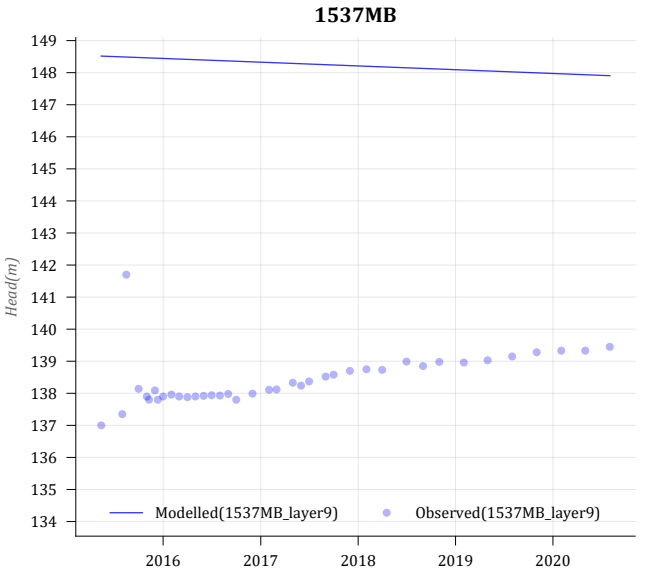

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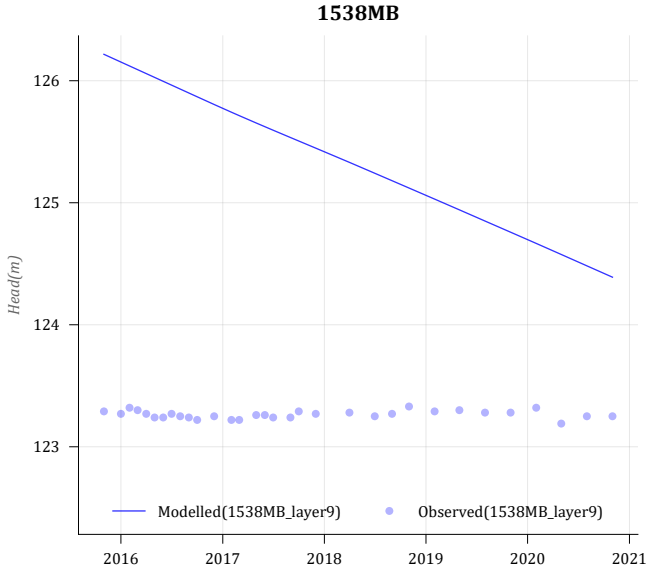

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Observed(1531MB_layer1)
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2018-09

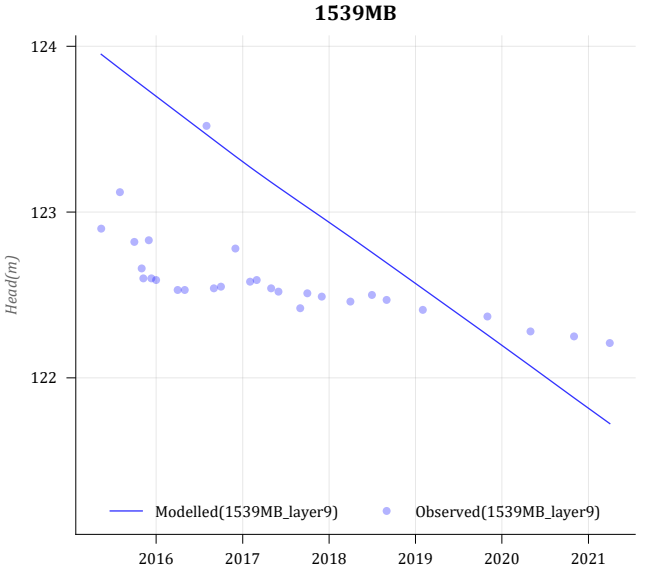

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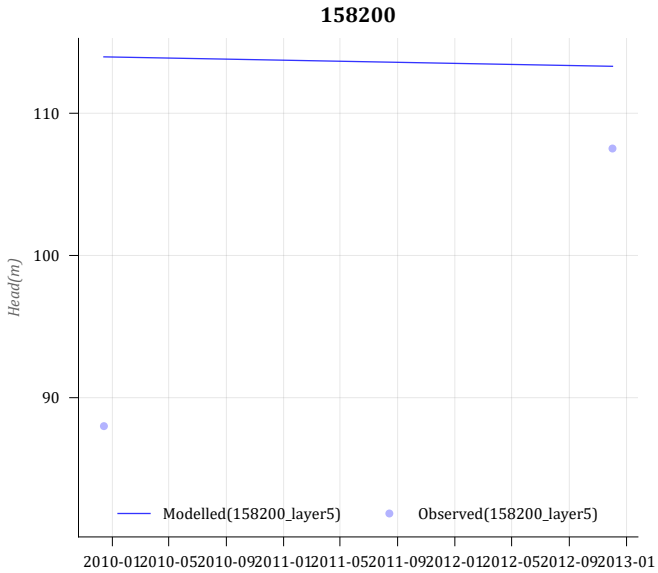

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2020
2021
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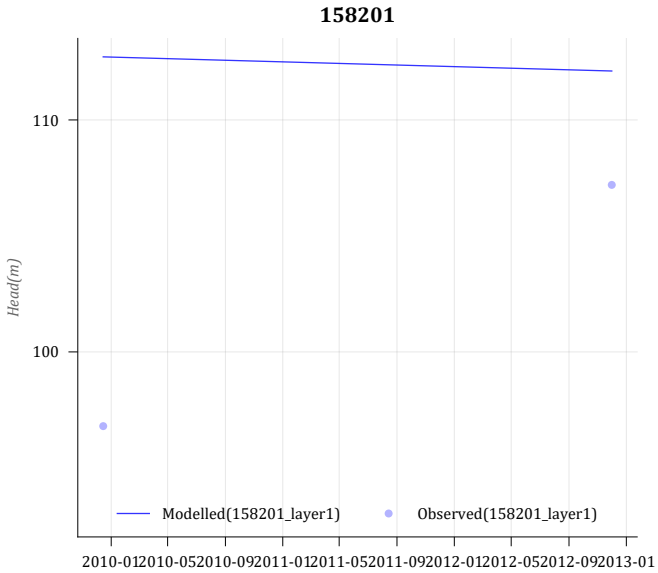

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Head(m)
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115
114
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2018
2019
2020
2021
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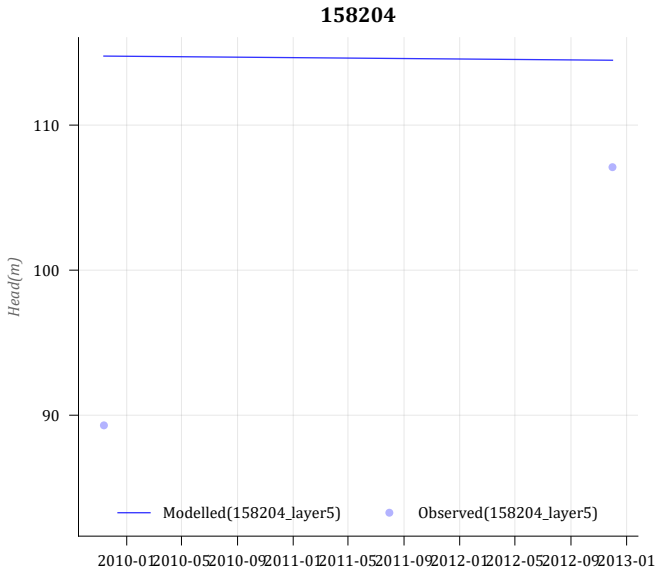

1537MB
Head(m)
149
148
147
146
145
144
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142
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135
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2018
2019
2020
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Observed(1537MB_layer9)

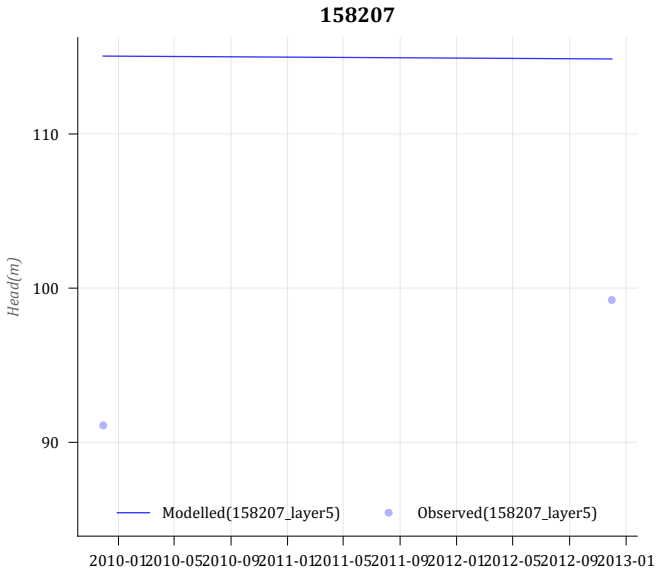

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Head(m)
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2019
2020
2021
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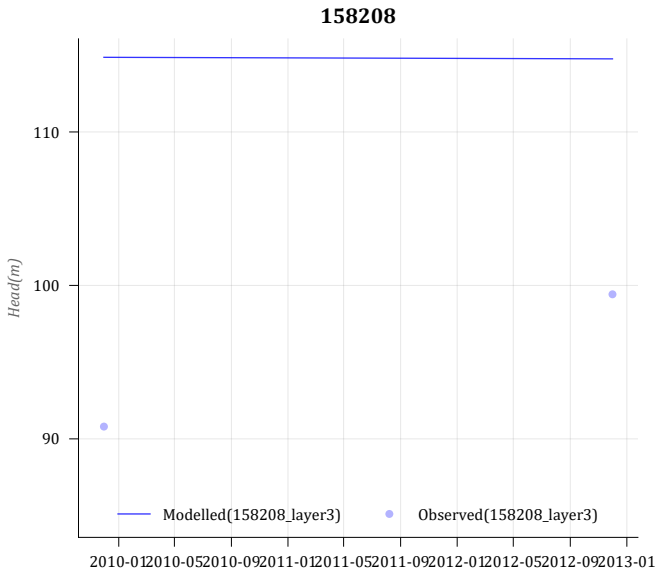

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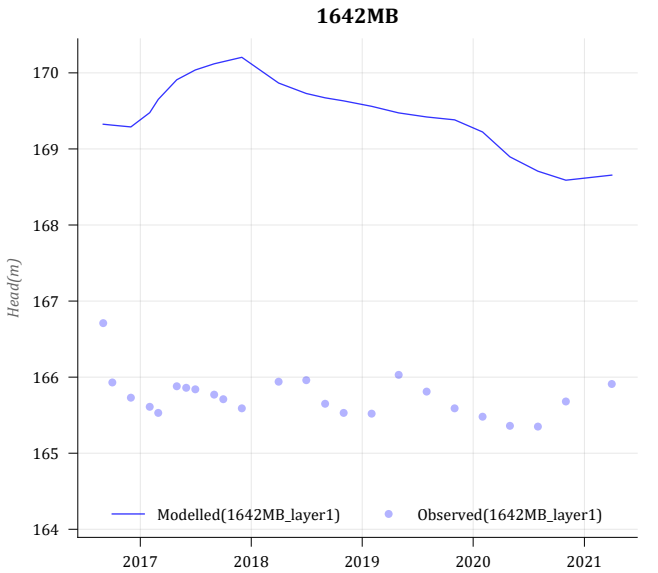

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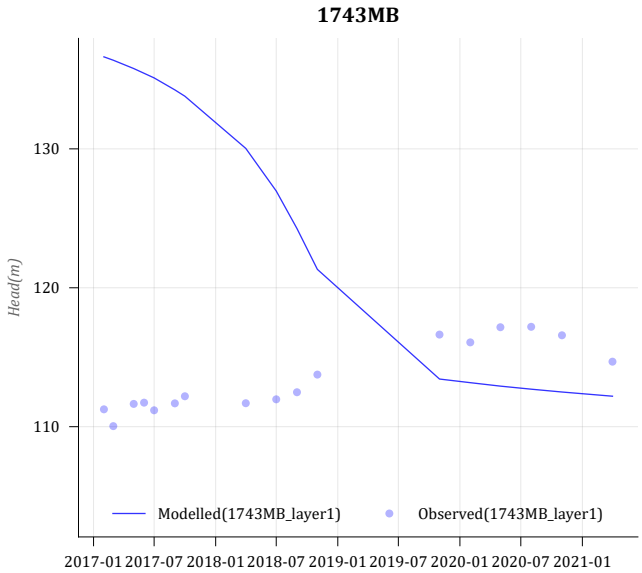

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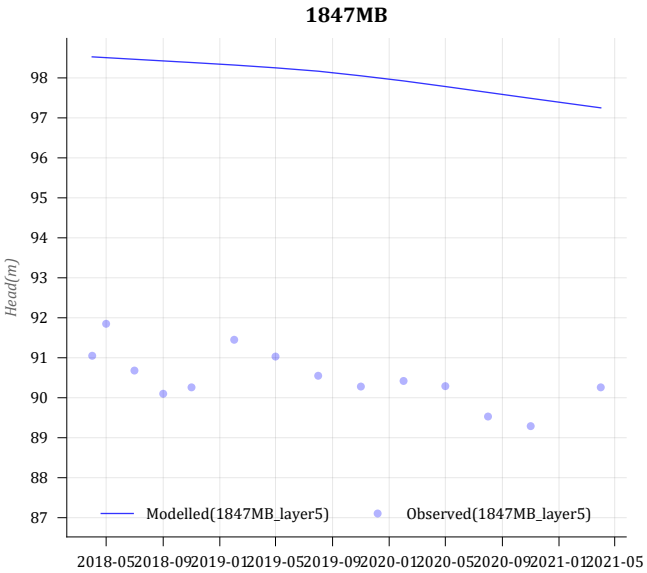

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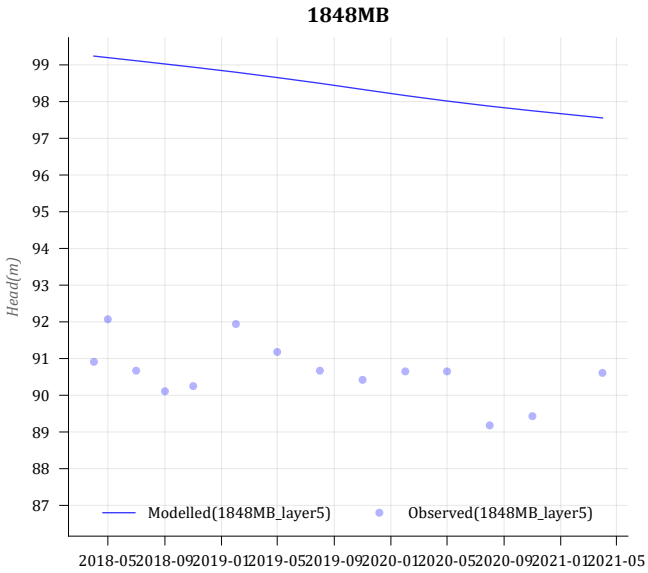

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2012-05
2012-09
2013-01


158208
Head(m)
110
100
90
Modelled(158208_layer3)
Observed(158208_layer3)
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2010-09
2011-01
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2011-09
2012-01
2012-05
2012-09
2013-01


1642MB
Head(m)
170
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167
166
165
164
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Observed(1642MB_layer1)
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2020
2021

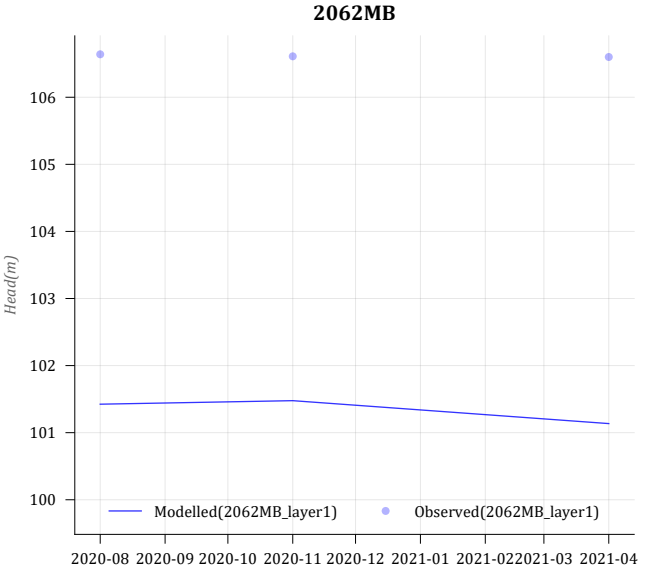

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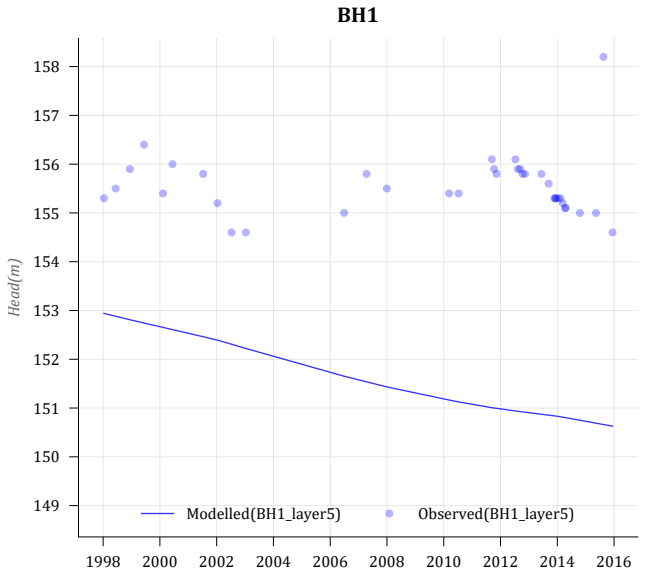

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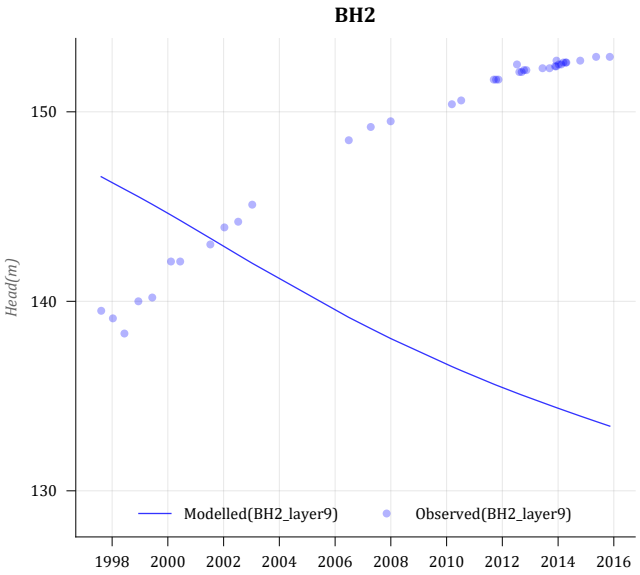

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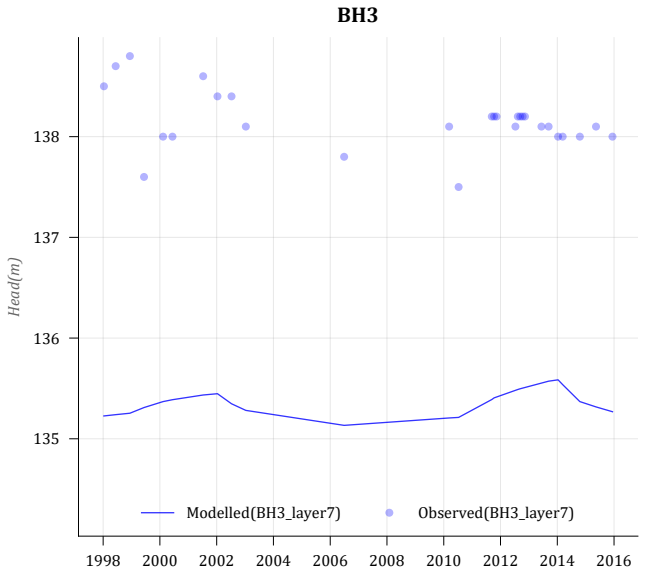

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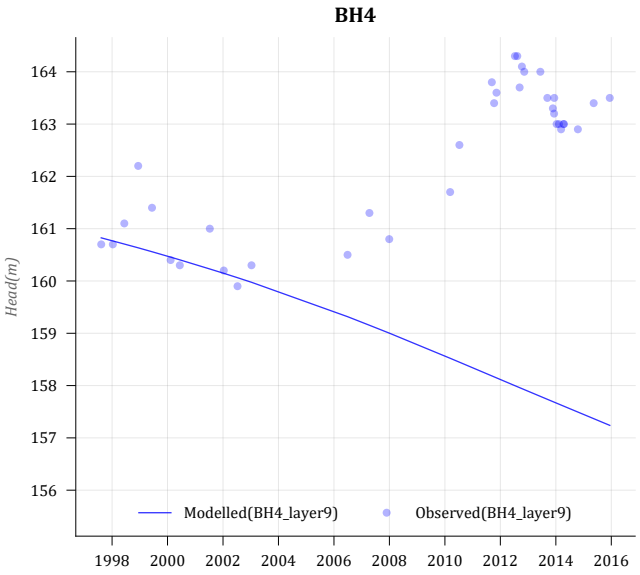

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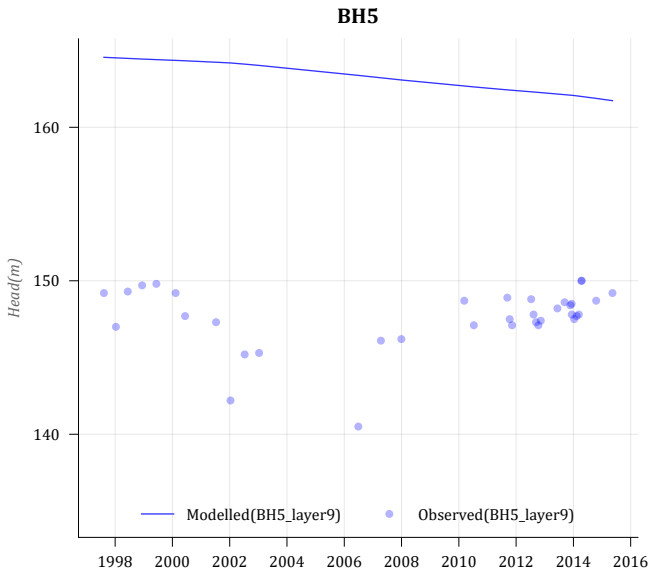

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103
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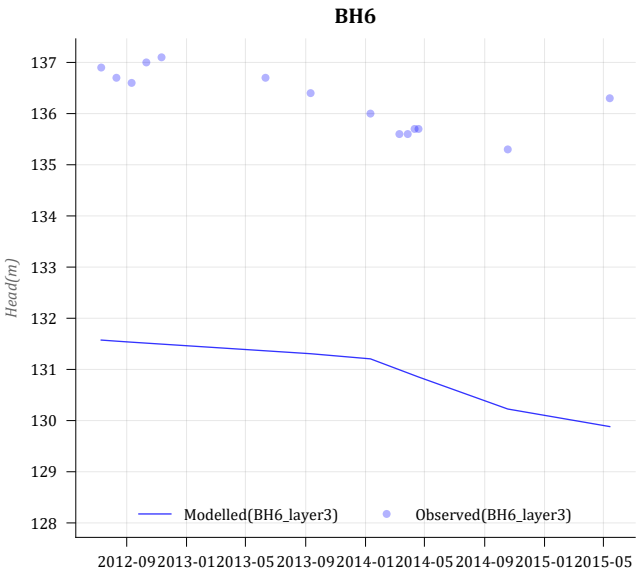

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Head(m)
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157
156
155
154
153
152
151
150
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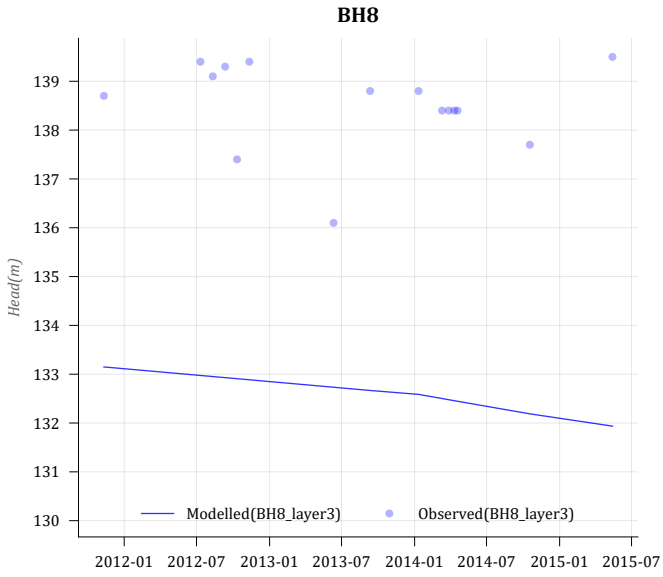

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Head(m)
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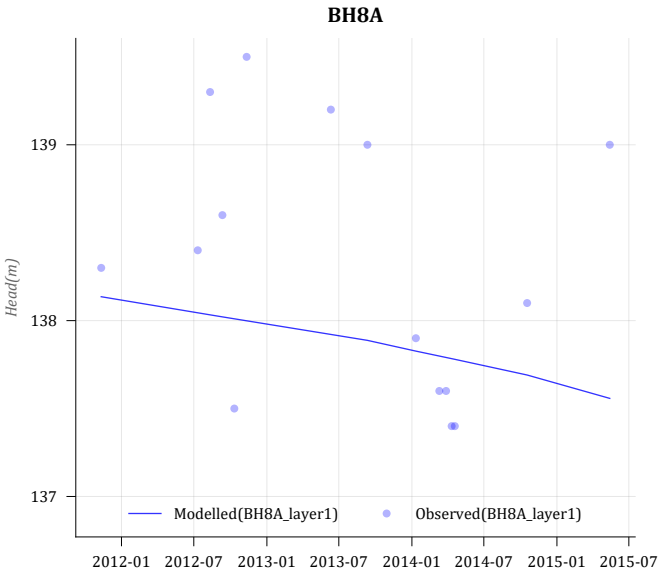

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135
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2012
2014
2016


BH4
Head(m)
164
163
162
161
160
159
158
157
156
Modelled(BH4_layer9)
Observed(BH4_layer9)
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2004
2006
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2010
2012
2014
2016


BH5
Head(m)
160
150
140
Modelled(BH5_layer9)
Observed(BH5_layer9)
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2000
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2006
2008
2010
2012
2014
2016


BH6
Head(m)
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136
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134
133
132
131
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129
128
Modelled(BH6_layer3)
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Head(m)
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131
130
Modelled(BH8_layer3)
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2013-07
2014-01
2014-07
2015-01
2015-07


BH8A
Head(m)
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137
Modelled(BH8A_layer1)
Observed(BH8A_layer1)
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2012-07
2013-01
2013-07
2014-01
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2015-01
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APPENDIX C

VOID WATER BALANCE REPORT

CURRAGH MINE COMPLEX

Residual Void Modelling

Prepared for:

Coronado Curragh Pty Ltd
Blackwater,
QLD, 4717



SLR Ref: 626.30075-R01
Version No: -v2.0
November 2021

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BASIS OF REPORT

This report has been prepared by SLR Consulting Australia Pty Ltd (SLR) with all reasonable skill, care and diligence, and taking account of the timescale and resources allocated to it by agreement with Coronado Curragh Pty Ltd (the Client). Information reported herein is based on the interpretation of data collected, which has been accepted in good faith as being accurate and valid.

This report is for the exclusive use of the Client. No warranties or guarantees are expressed or should be inferred by any third parties. This report may not be relied upon by other parties without written consent from SLR.

SLR disclaims any responsibility to the Client and others in respect of any matters outside the agreed scope of the work.

DOCUMENT CONTROL

Reference	Date	Prepared	Checked	Authorised
626.30075-R01-v2.0	29 November 2021	Emily Curtis	Nicole Bichel	Nicole Bichel
626.30075-R01-v1.0	26 November 2021	Emily Curtis	Nicole Bichel	Nicole Bichel

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Appendix C Residual Void Water Quality

1 Introduction

SLR was engaged by Coronado Curragh Pty Ltd (CCPL) to provide a Concept Residual Void Assessment (CRVA) for the Curragh Mine Complex (the mine). In support of the CRVA a Residual Void Water Balance Model (WBM) for the mine and has been developed to determine the final water level and quality of the residual voids.

1.1 Scope of works

The scope of work includes the development of a surface water final void model which accounts for the modelled groundwater inflows derived from the recovery groundwater model.

An iterative modelling process is required between the groundwater numerical model and the WBM to develop a groundwater inflow relationship for the final void. The final void model then provides long-term estimate of water level and salt concentration for the void stored water while the groundwater recovery model allows estimating post-closure (equilibrium) groundwater levels, potential areas of seepage and discharge to creeks.

This report covers the WBM development. For further information regarding the groundwater numerical model can be found in the Concept Residual Void Groundwater Technical Appendix (SLR, 2021).

1.2 Residual Voids

Following closure of the mine, 12 residual void areas are expected to remain. The arrangement of these voids for the purpose of the WBM are listed below with multiple pits grouped where hydrologically linked.

- Curragh North: Void U/T/S
- Curragh Main: Void D/E/F, Void B/C/H, Void L, Void K, Void G, Void J, Ramp 9; and
- Expansion Areas: Void X (1 and 2), Void Y, Void Z.

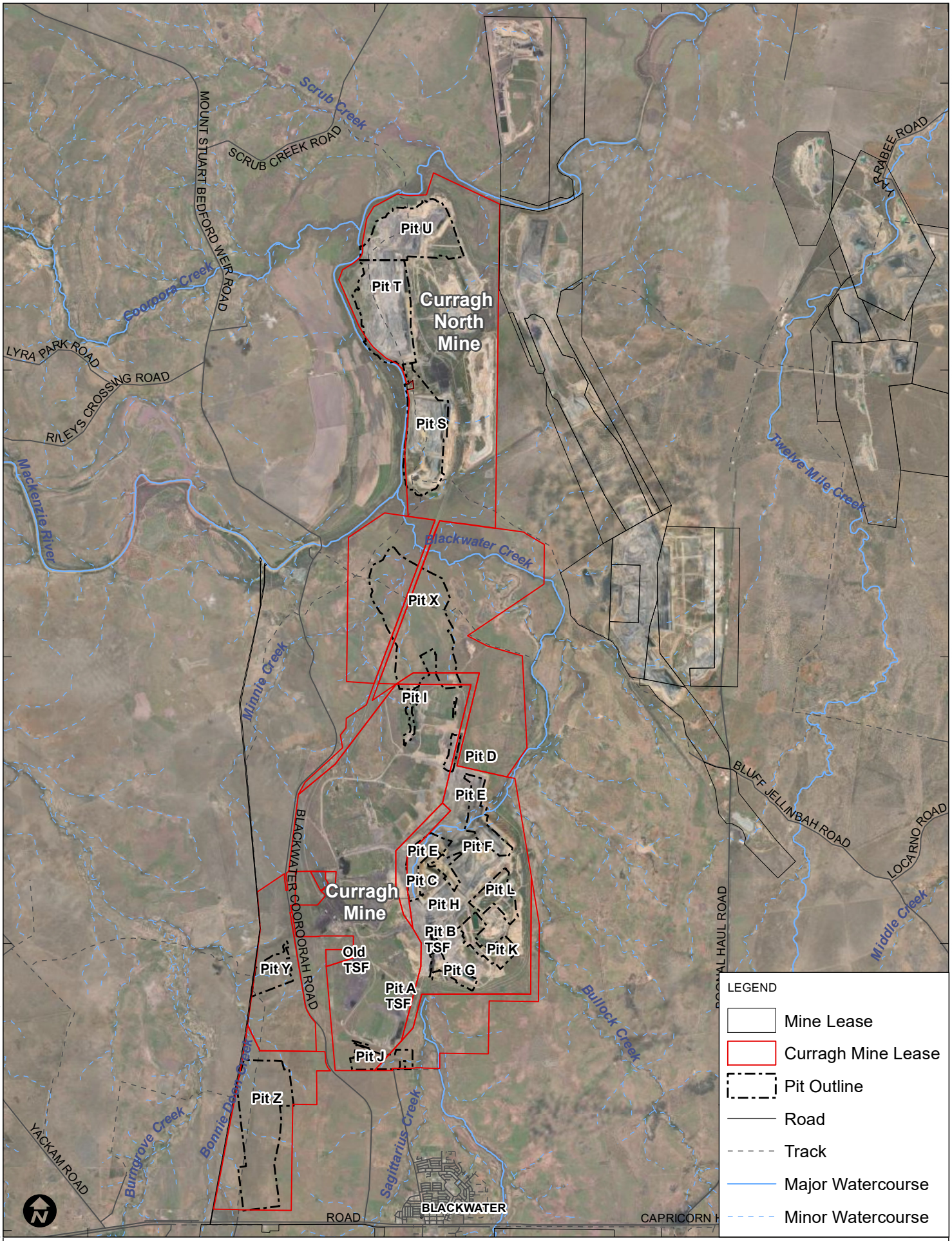
The assessed voids are shown in **Figure 1-1**.

1.3 Supplied Data

The following data was provided by CCPL to SLR to complete the assessment

- A final landform as separate designs for Curragh main, Curragh North and Void X, Y and Z. The final void designs were provided in dxf format as 0.5m contours.
- 1m Lidar data for the existing site (dated 2021).

Anticipated groundwater inflow volumes and associated water quality was derived from the numerical groundwater report.



SLR

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0 2 4 km

Coordinate System:	AGD 1984 AMG Zone 55
Scale:	1:170,000 at A4
Project Number:	626.30075
Date:	24-Nov-2021
Drawn by:	ML
Reviewed by:	ML

Data Source:

CURRAGH PRCP

Current Mine Layout

FIGURE 1.1

H:\Projects-SLR\626-MKY\626.30075.00000 Curragh Mine PRCP 2021\06 SLR Data\01 CAD\GIS\GIS\626.630075 F01 Base Map.mxd

2 Water Balance Modelling

A Water Balance Model (WBM) was developed using Goldsim software package to assess the long-term water level and water quality was of the residual voids following closure of CCPL.

The model simulates daily changes in the volumes of stored water in response to inflows (rainfall, groundwater) and outflows (evaporation and controlled releases/overflows). The WBM was run for daily time step over 200-year simulation period, represented by 500 climate sequences, allowing the model to assess long term water levels, quality and risk of overflow for each void.

2.1 Catchment Areas

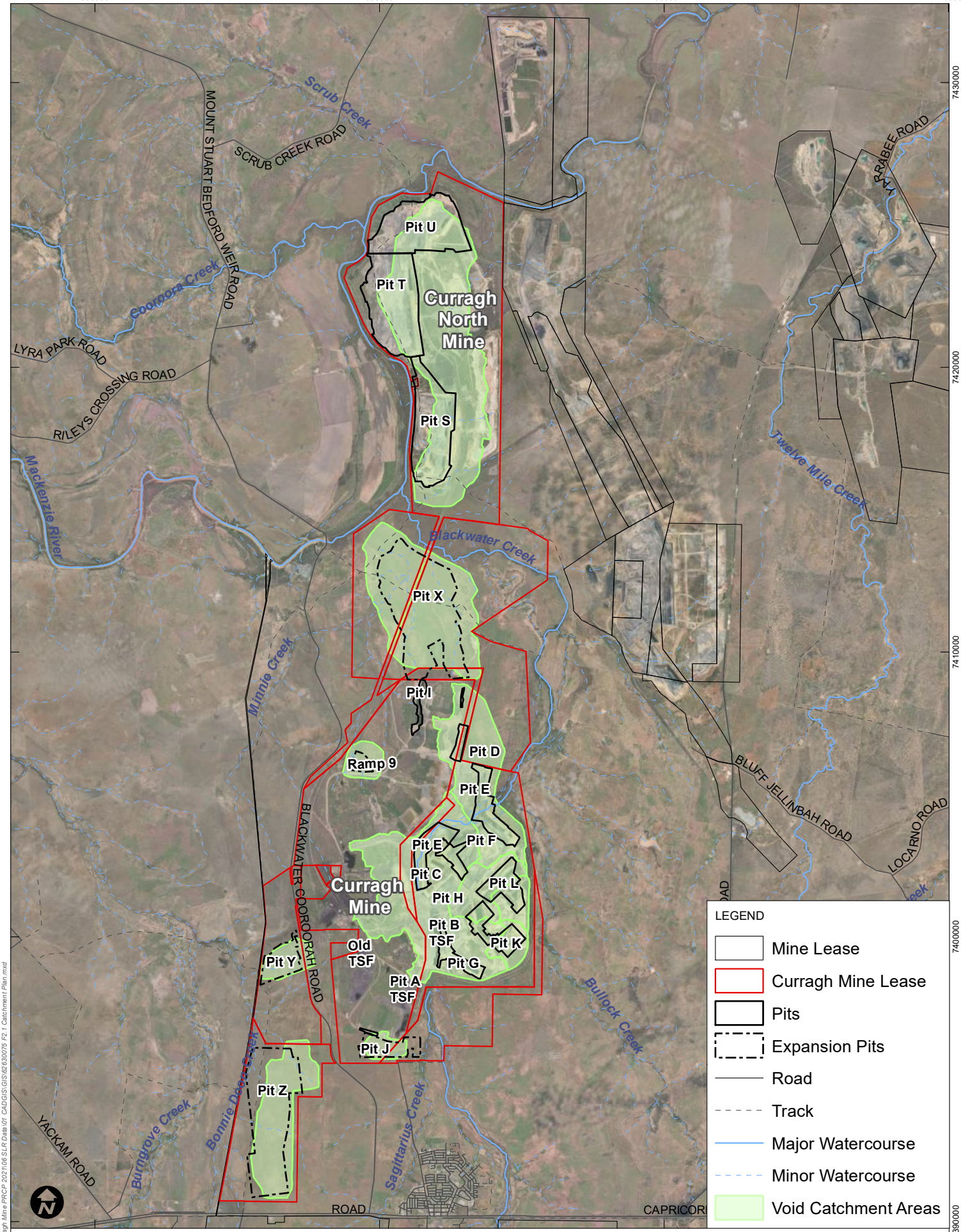
The catchment configurations for the residual voids at the mine were determined based on the final landform contours provided by CCPL. The residual void catchments consist primarily of rehabilitated spoil dumps, with an elevated stable landform constructed around the perimeter prevent external catchment and flood ingress into the voids. A summary of the catchment breakdown is provided in **Table 1.** The catchments are shown in **Figure 2-1 Catchment Plan** .

Table 1 Catchment Summary

Curragh Area	Residual Void	Residual Void Footprint (ha)	Catchment Area (ha)
Curragh North	Void U/T/S	1105.6	1334.4
Curragh Main	Void D/E/F	347.5	648.6
	Void B/C/H	673.7	1227.1
	Void L	63.1	287.2
	Void K	35.6	129.0
	Void G	45.2	107.4
	Void J	40.9	69.3
	Ramp 9	45.4	104.4
X Pit	Void X – 1	90.9	458.2
	Void X – 2	169.0	764.6
Y Pit	Void Y	64.0	117.9
Z Pit	Void Z	295.6	426.0

2.2 Stage Storage Relationship

The stage storage surface area curves were derived from the final landform contours, provided by CCPL. Void depths range from 42m to 168m with inverts from -48m AHD to 116 m AHD. Residual void stage storage surface area relationship for each residual void is provided in **Appendix A**.



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SLR

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0 2 4 km

Coordinate System:	AGD 1984 AMG Zone 55
Scale:	1:170,000 at A4
Project Number:	626.30075
Date:	26-Nov-2021
Drawn by:	AN
Reviewed by:	AN

Data Source:

CURRAGH PRCP

Catchment Plan

FIGURE 2.1

2.3 Climate

Long term historical climate data has been collected by the Bureau of Meteorology (BoM) for the New Caledonia station (035132) at -23.429, 148.927 for 1900 to 2020 and was sourced from the Scientific Information for Land Owners (SILO) data drill as a Patch Point Data set. The Patch Point Data provides infilling of any missing data from nearby gauges based on relationships developed between the overlapping records of each gauge.

A summary of the annual average climate data is given in **Figure 2-2**.

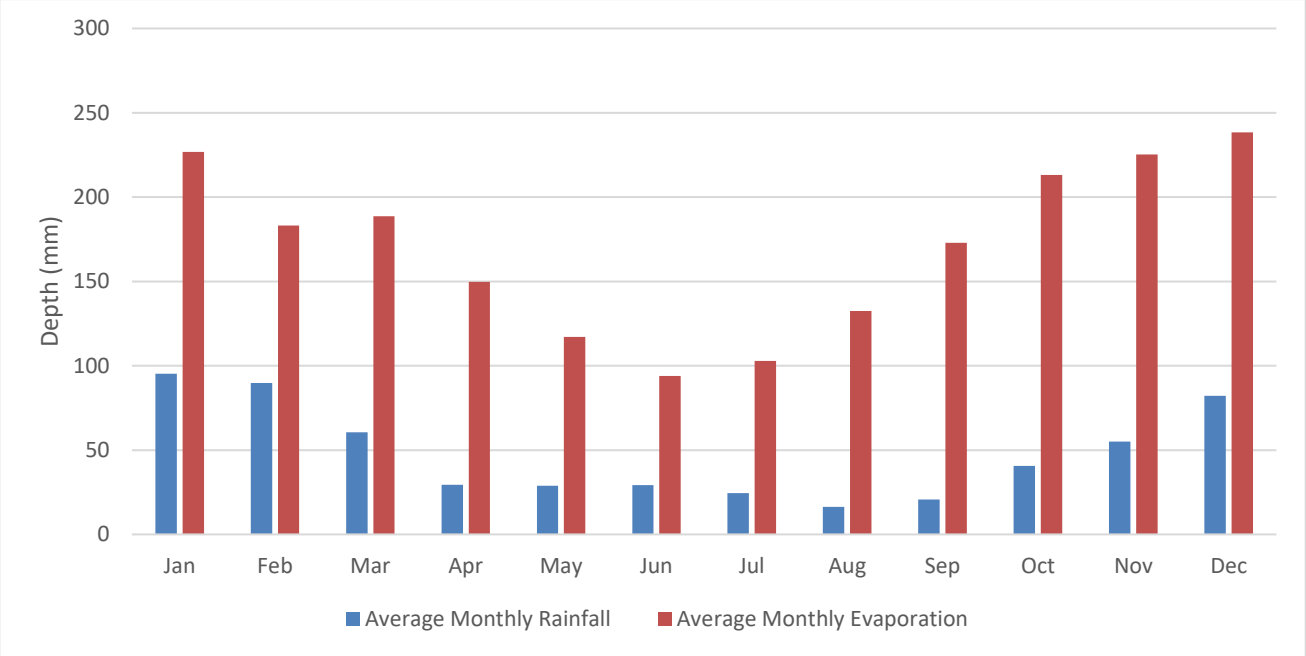


Figure 2-2 Long Term Average Rainfall and Evaporation

The average annual rainfall in the region (BoM Station 035132) is approximately 572mm, with the distribution of monthly rainfall shown in **Figure 2-2**. Rainfall is greatest during the summer months December to February, with 47% of annual rainfall occurring over these months. The highest monthly average rainfall total is 95mm in January, and the driest month is August with an average rainfall of 16mm.

The site experiences large water loss year-round, with an average annual evaporation for the site of 2,044mm. On a monthly basis, maximum evaporation occurs later in the year (October to December). During the dryer months evaporation is significantly lower, with the lowest total typically occurring in June. **Figure 2-2** summaries the average evaporation for all moths of the year for the site.

2.3.1 Probabilistic Rainfall

Probabilistic rainfall was generated for the WBM. The purpose of the probabilistic rainfall generation is to develop a wide range of climate sequences based on the recorded rainfall data of the area. These sequences have the same statistical characteristics of the historical data set for a range of parameters including mean, variance, skew, and the number of wet days or dry days. The 500 sequences of probabilistic data are summarised as exceedance probabilities. Some sequences may be wetter or dryer than others in order to account for the variability of the climate which may occur following establishment of the residual voids. The probabilistic rainfall data replicated the seasonality of the rainfall data.

The probabilistic rainfall data was generated from the historical data using the eWater CRC Stochastic Climate Library (SCL). Data was generated from 500 replicates of 120 years (from 1900 to 2020 as consistent with the available historical data record) of daily rainfall data for in accordance with the SCL Manual. Probabilistic rainfall at 200 years length were generated. The generated data was found to be representative of the historical record within acceptable tolerances for key statistics.

Comparison of the probabilistic data and the historical rainfall record for the annual rainfall totals is shown in **Figure 2-3**. Review of **Figure 2-3** shows the model simulates a range greater than that of the recorded historical rainfall data but the median (50th percentile) of the results are aligned.

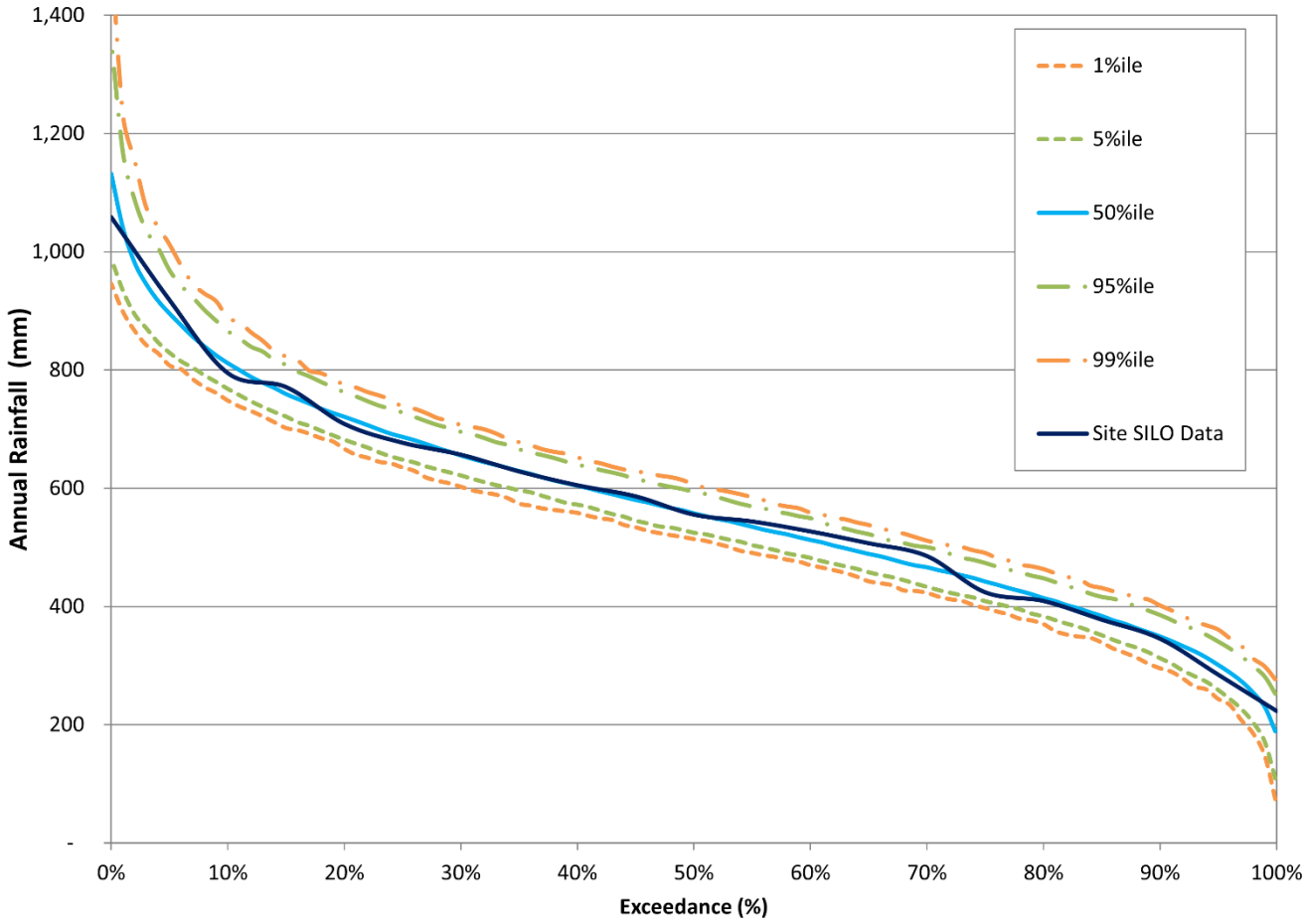


Figure 2-3 Comparison of Historical and Probabilistic Data

2.3.2 Evaporation

The evaporation rates in the model were sourced from the SILO. For the WBM, monthly averages were used as the evaporation data for the area is limited. The extended evaporation records available in SILO consisted of infilled data from monthly averages (rather than daily records from other gauges) for the period prior to gauge readings. This is most likely due to the limited available data for infilling. **Table 2** outlines the adopted lake evaporation rates and pan factor. Pan factors have been determined using the Morton Lake Evaporation.

Table 2 Adopted Monthly Evaporation Rates

Month	Evaporation (mm/d)	Pan Factor
January	7.3	0.90
February	6.5	0.93
March	6.1	0.90
April	5.0	0.89
May	3.8	0.86
June	3.1	0.84
July	3.3	0.87
August	4.3	0.88
September	5.8	0.87
October	6.9	0.88
November	7.5	0.89
December	7.7	0.89

2.4 Runoff Modelling

The WBM utilises the Australian Water Balance Model (AWBM) rainfall runoff module to calculate the rainfall and runoff inflows in each catchment. There are two AWBM modules in the WBM representing the runoff response for the following land use types:

- Void; and
- Rehabilitation.

The rainfall is converted to runoff using the Australian Water Balance Model (AWBM), illustrated in **Figure 2-4**. This runoff can be split into two forms:

1. Surface runoff which travels overland to the destination; or
2. Sub-surface which travels through the ground to reach the destination.

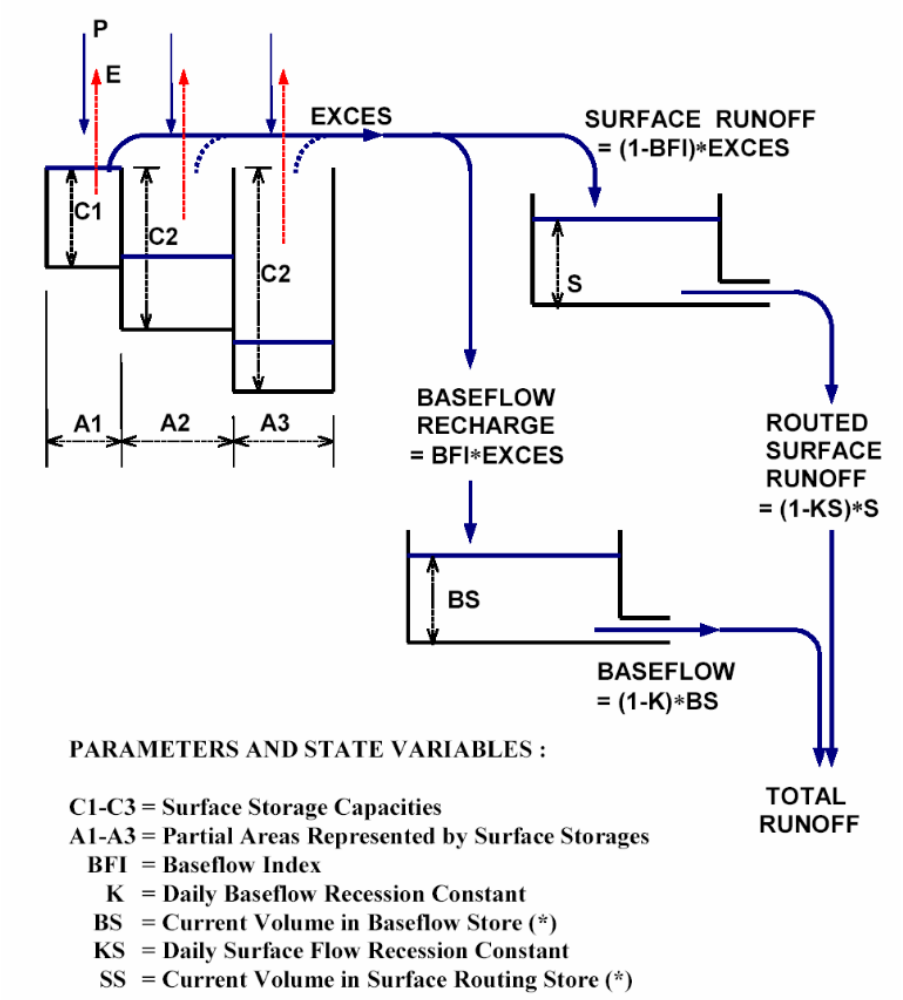


Figure 2-4 AWBM Rainfall Runoff Model

AWBM parameters were adopted based on values derived in the area for similar projects and are considered suitable for use in this assessment. A summary of the AWBM parameters used for different catchment types are presented in **Table 3**.

Table 3 Adopted AWBM Parameters

Parameter	Abb	Landuse	
		Void	Rehabilitation
Small storage capacity (mm)	C1	10	11
Medium storage capacity (mm)	C2	25	60
Large storage capacity (mm)	C3	50	130
Small partial area portion	A1	0.134	0.134
Medium partial area portion	A2	0.433	0.433
Large partial area portion	A3	0.433	0.433
Baseflow Index	BFI	0.1	0.35

Parameter	Abb	Landuse	
		Void	Rehabilitation
Baseflow recession	K	0.6	0.6
Daily streamflow recession	KS	0.1	0.1

2.5 Groundwater Inflow

Groundwater inflows into the WBM were derived from the groundwater model developed for the CRVA in the and provided as a relationship between water level and inflow (SLR, 2021). This was modelled as an inflow in the WBM and were calculated daily based on the current water level in the void as predicted by the WBM.

Further information relating to derived groundwater inflows can be found in Section 4.2 of the Concept Residual Void Groundwater Technical Appendix (SLR, 2021).

2.6 Water Quality

The water balance model was developed to include a high-level salt balance to track both the quantity and quality of water on-site. The salt balance tracks the water quality in all of the inflows into the voids and subsequent effects from evaporation and releases on the storage water quality. The water quality values are presented in **Table 4**Error! Reference source not found.. These adopted values are consistent with those adopted for other Queensland mine sites.

Based on groundwater monitoring data at the mine, an EC of 12,500 µS/cm was adopted as the average salinity concentration of groundwater inflows. Salinity parameters for surface runoff were determined based on prior experience in the area.

Adopted water quality parameters are summarised in **Table 4**.

Table 4 Adopted Salinity Generation Parameters

Inflow	Salinity (EC) (µS/cm)
Void	3000
Rehabilitation	250
Groundwater Inflow	12,500

The above salinity values are converted to a concentration in milligrams per litre using an average multiplication factor of 0.67 (Measuring Salinity DERM, June 2007) to quantify the mass of salt transferred in the model.

3 Results

The WBM was run for a range of rainfall conditions to allow for the calculation of percentiles of the final void levels. These percentiles represent the results range due to variability in climate. The results of the WBM focus on the 5th, 50th and 99th percentile. This represents the dry, median and very wet climatic condition. The 99th percentile result is used to assess the risk of overflow of the voids.

3.1 Residual Void Water Levels

The WBM was predicted to stabilise after approximately 100 years to the approximate levels for the median condition shown in **Table 5**. It is noted that some individual voids within the WBM reached equilibrium level from approximately 20 years. Graphical representations of the results for each residual void are provided in **Appendix B.**

Table 5 Residual Void Water Level Summary

Void	Residual Void Level (50%ile) (mAHD)	Depth (m)	Surface Area (ha)
Void U/T/S	26	74	286.5
Void D/E/F	63	36	63.5
Void B/C/H	83	42	109.3
Void L	113	21	13.9
Void K	107	42	8.5
Void G	79	14	9.2
Void J	132	39	20.2
Ramp 9	91	14	17.1
Void X – 1	101	23	23.2
Void X – 2	69	35	49.4
Void Y	131	15	19.6
Void Z	115	37	72.3

The relative size of external catchment to the void footprint results in water levels that stabilise well below the indicative spill level with evaporative losses balancing inflows into the voids. A similar trend in water level is seen across all the residual voids. Water depths range from 14m to 74m within the voids for median conditions (50th percentile). During dry climatic conditions (5th percentile) water levels are approximately 2m to 13m lower. During very wet (99th percentile) climatic conditions the water level increases by 3m to 20m depending on the void and generally causes greater fluctuation in the equilibrium water level. Final water levels range from 9m to 88m below the indicative spill levels and are not expected to overtop.

3.2 Water Quality

Water within the residual voids becomes highly saline throughout the simulation. This was not unexpected due to the high salinity of groundwater in the region and the assumption that no salt is lost from the system via evaporation. Within the WBM salinity is capped at a maximum EC of 37,313 µS/cm which is equivalent to the point where the concentration of salt becomes high enough that the solution is saturated and any additional salt will precipitate out of solution. Salinity in all voids increases over time until reaching saturation after approximately 20 to 30 years.

The average salinity of the voids throughout the simulation period are provided in **Table 6**. Graphical representations of the results for each residual void are provided in **Appendix C.**

Table 6 Average Stage Salinity (EC µS/cm)

	Year 10	Year 30	Year 200
Void U/T/S	27,578	37,313	37,313
Void D/E/F	36,828	37,313	37,313
Void B/C/H	23,045	37,181	37,313
Void L	17,843	34,498	37,313
Void K	22,333	37,292	37,313
Void G	33,100	37,288	37,313
Void J	19,951	31,496	37,313
Ramp 9	29,754	37,313	37,313
Void X – 1	28,650	37,274	37,313
Void X – 2	16,174	32,568	37,313
Void Y	28,954	37,313	37,313
Void Z	37,296	37,313	37,313

4 Conclusions

At Curragh Complex the residual void water levels are expected to range from 26mAHD to 132mAHD with water depths of 14m to 74m. The results indicate that the mine is not a net accumulator of water after approximately 100 years when the equilibrium water levels are reached. The final water levels remain below the spill level and the voids are unlikely to overtop in the 99 percentile climate scenario.

A significantly high concentration of salt is expected to accumulate within the residual voids. The elevated salinity of the groundwater inflows input a high level of salt into the voids which is not lost from the system via evaporation. The salinity of the voids is expected to exceed that of the groundwater and form highly concentrated solution. Although poor quality, water within the voids is not expected to interact with surrounding surface water given the final water levels.

APPENDIX A

Stage Storage Curves

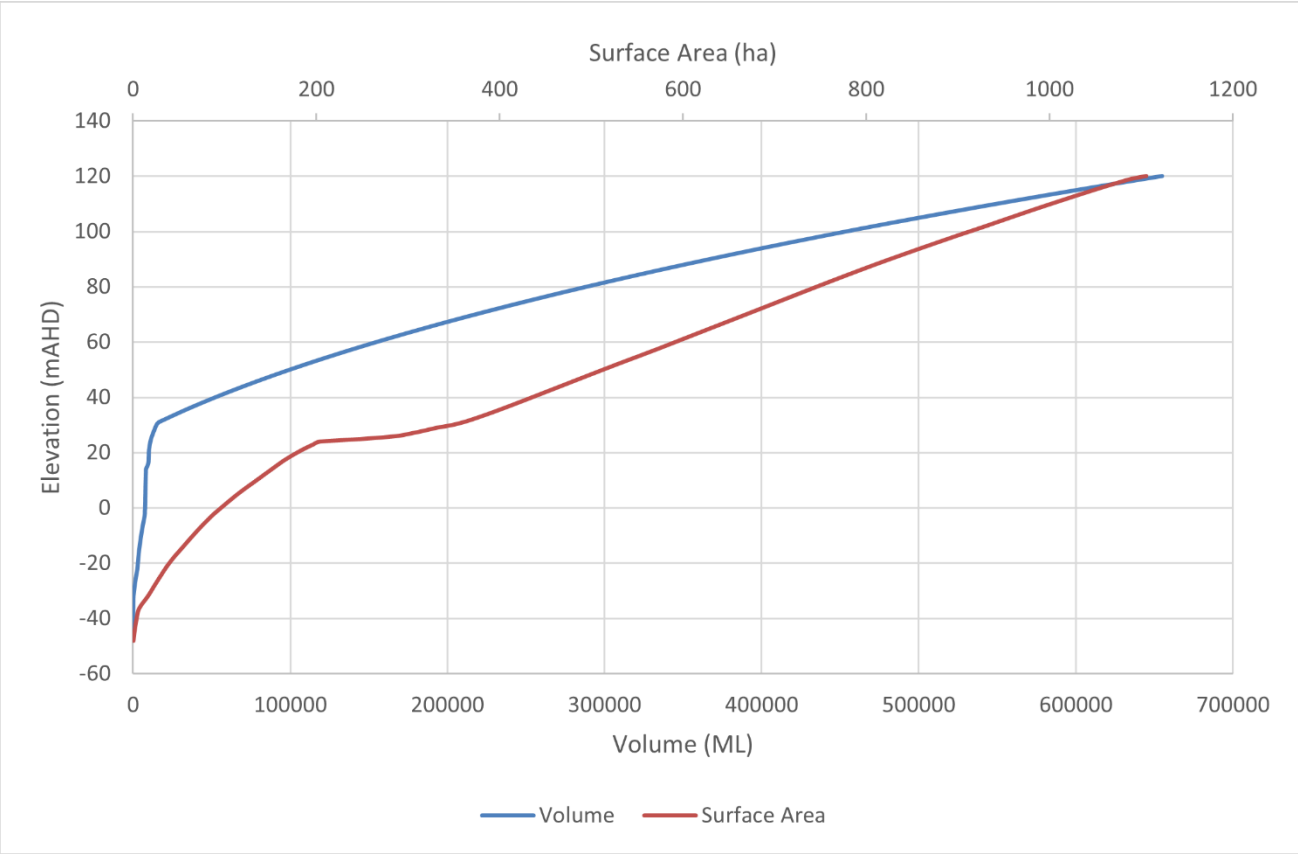


Figure 1A - Curragh North: Void U/T/S

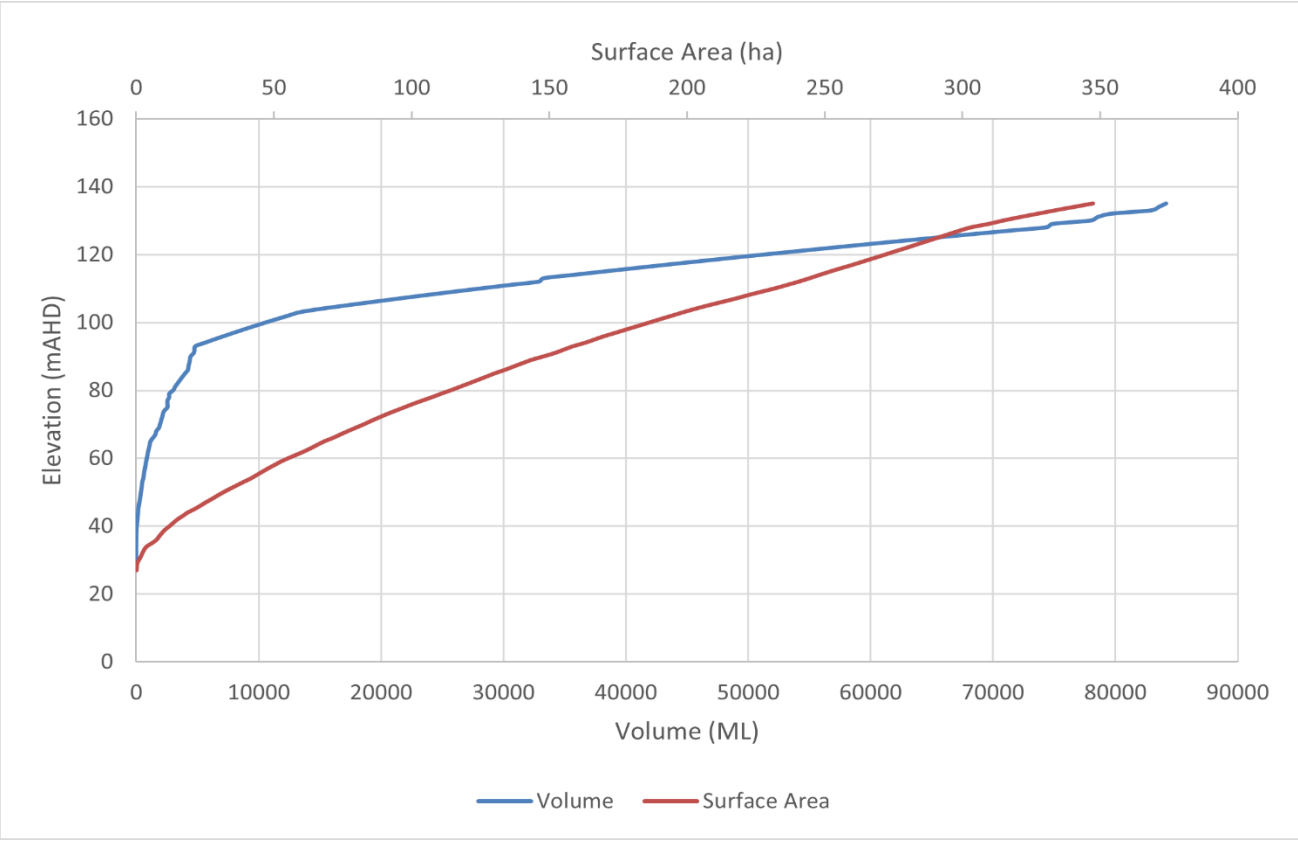


Figure 2A - Curragh Main: Void D/E/F

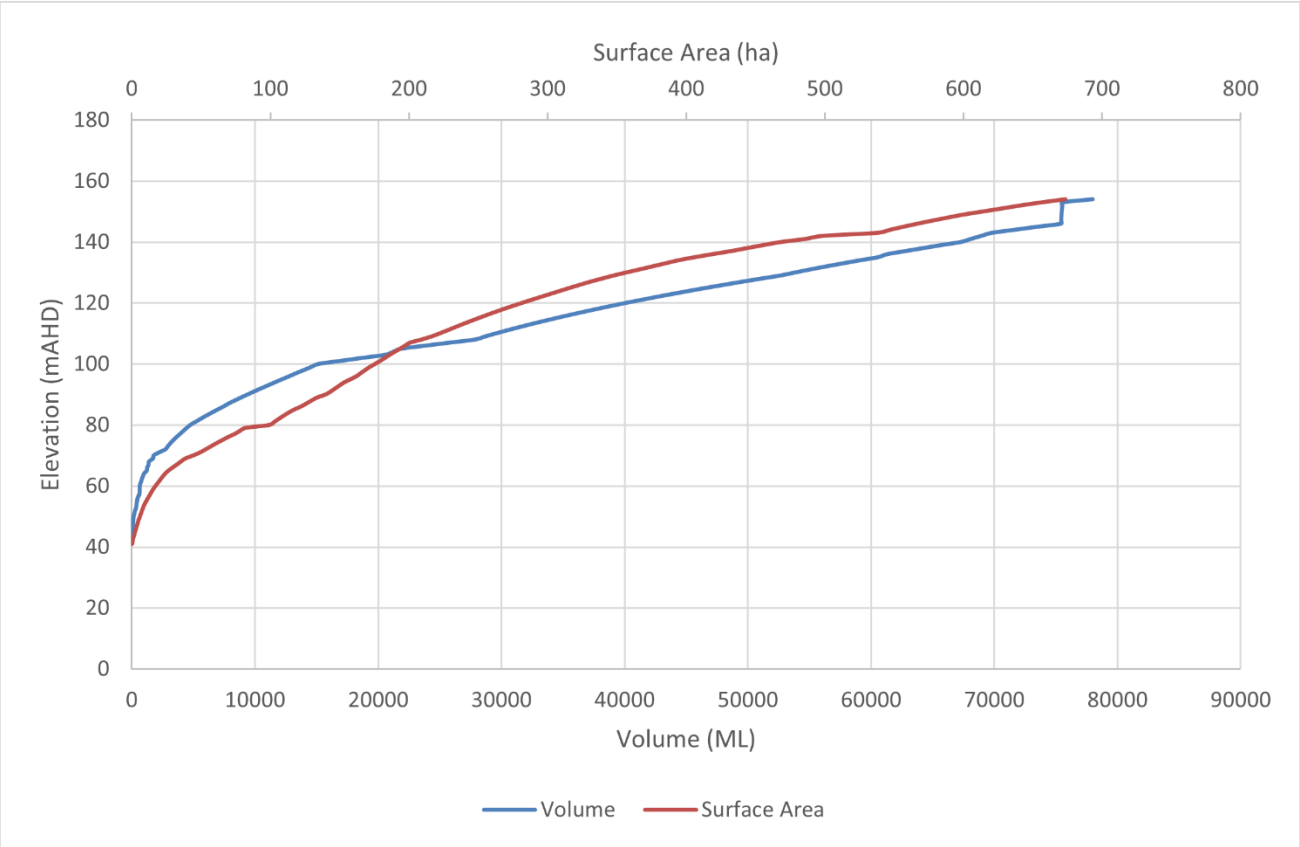


Figure 3A - Curragh Main: Void B/C/H

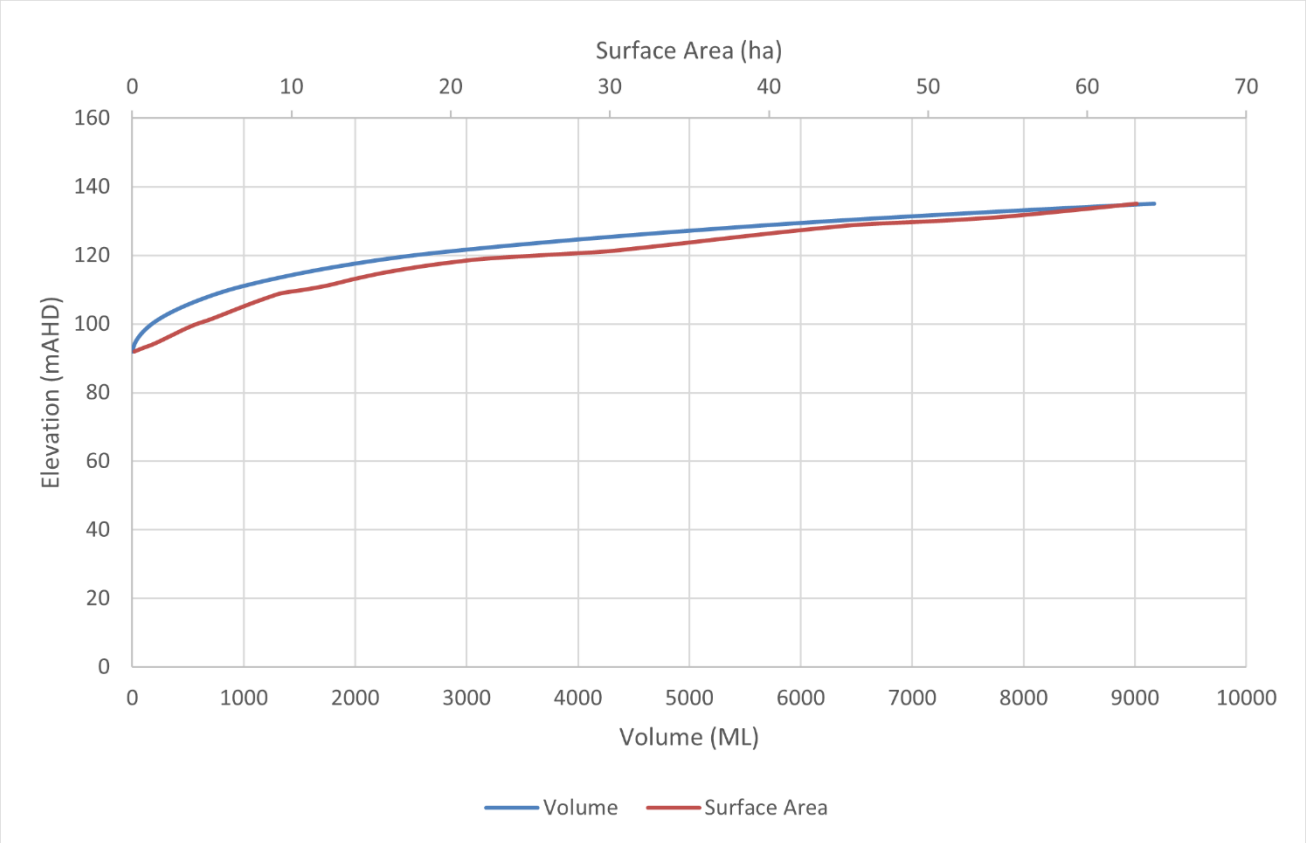


Figure 4A - Curragh Main: Void L

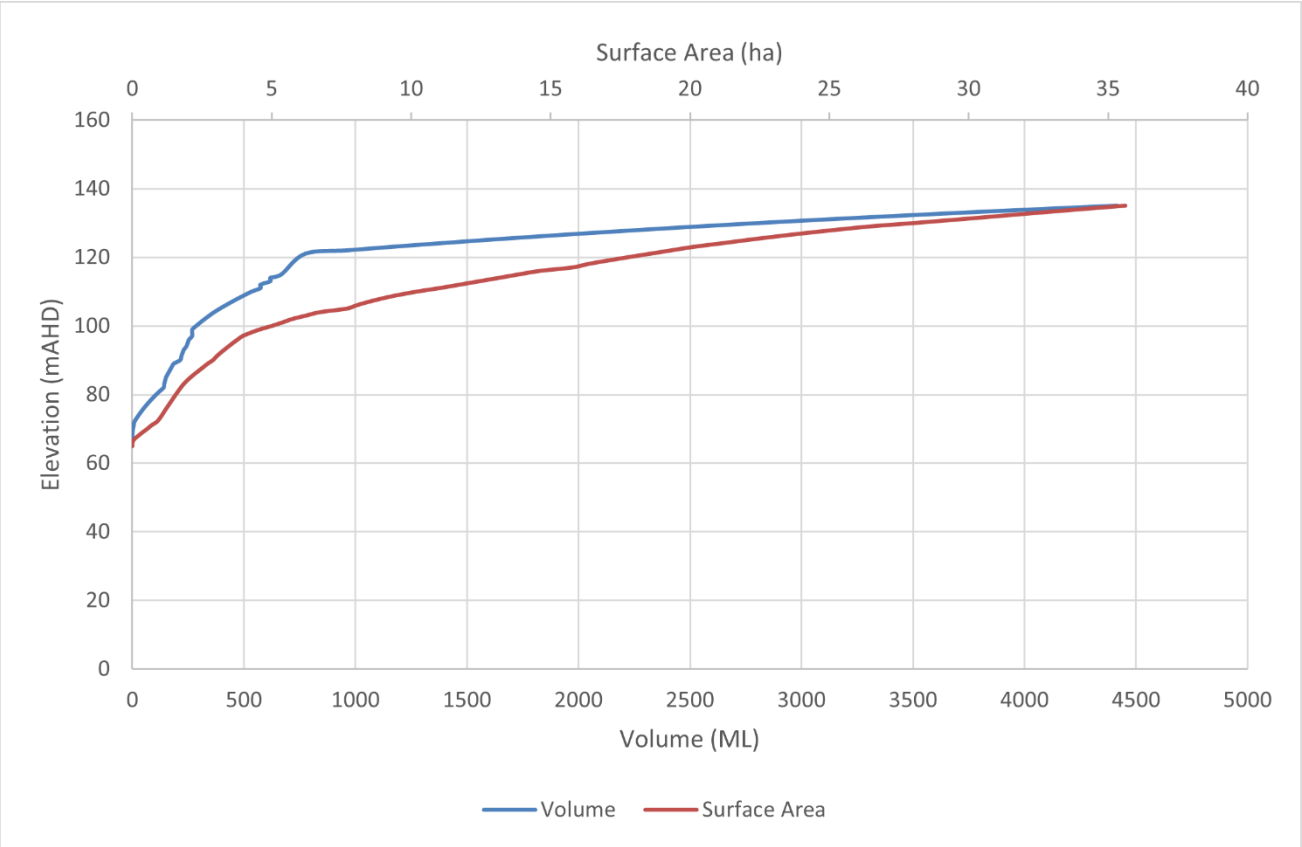


Figure 5A - Curragh Main: Void K

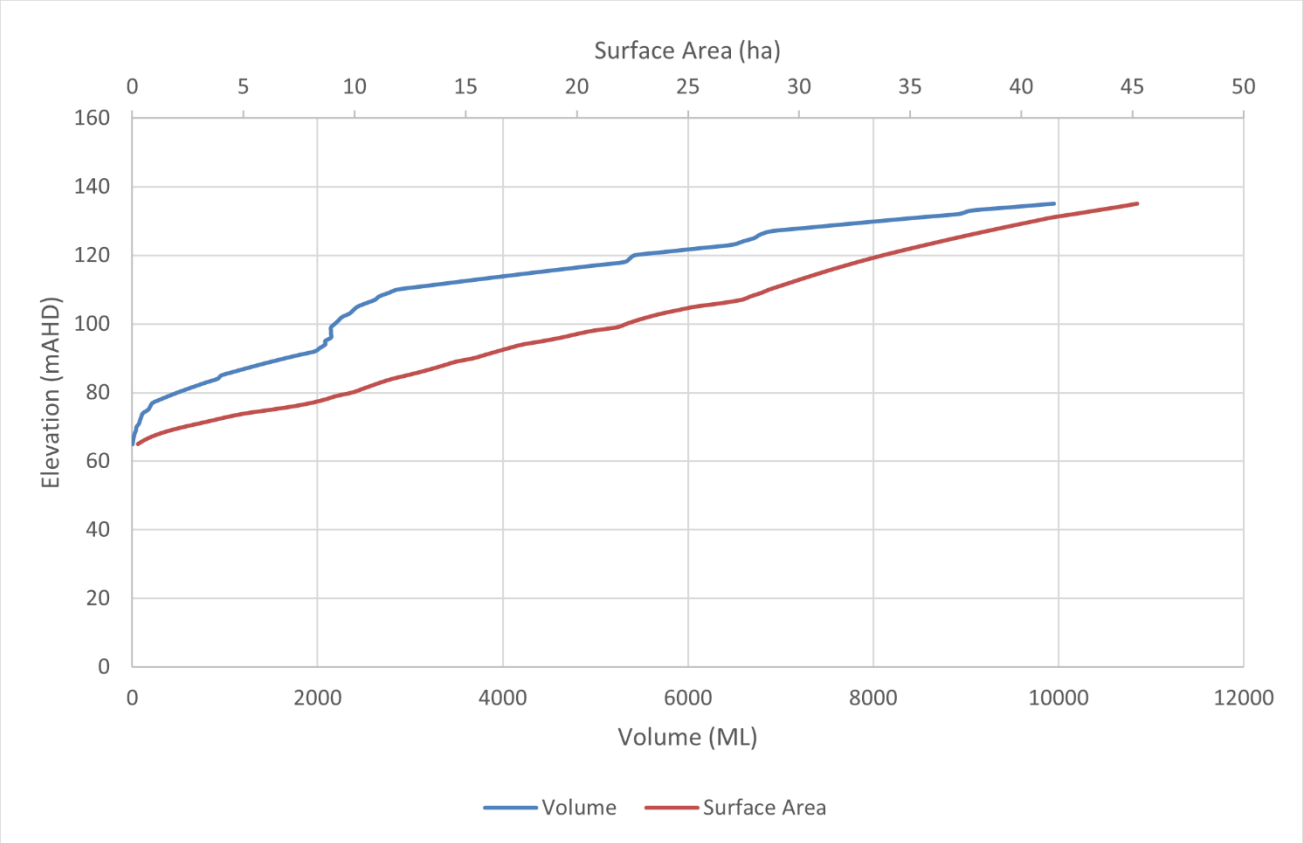


Figure 6A - Curragh Main: Void G

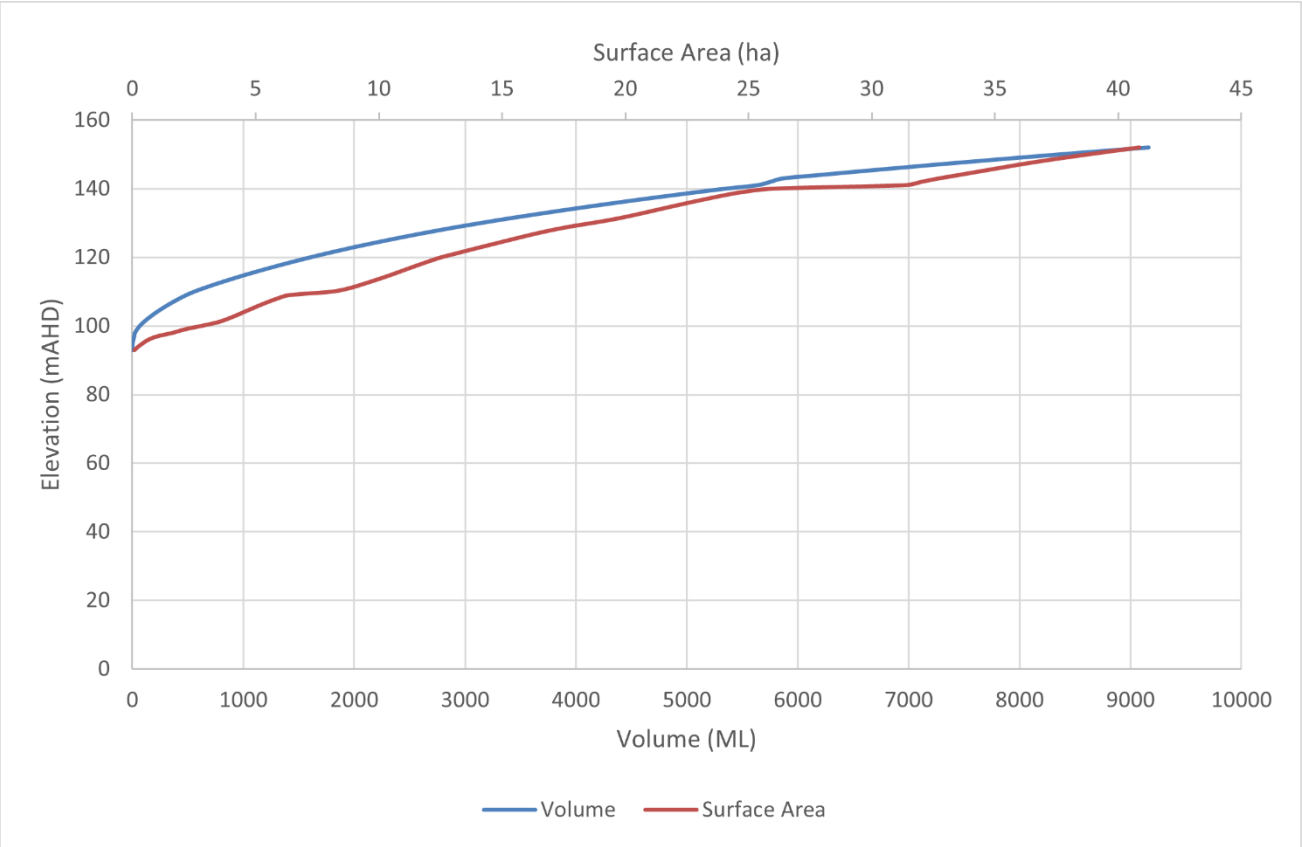


Figure 7A - Curragh Main: Void J

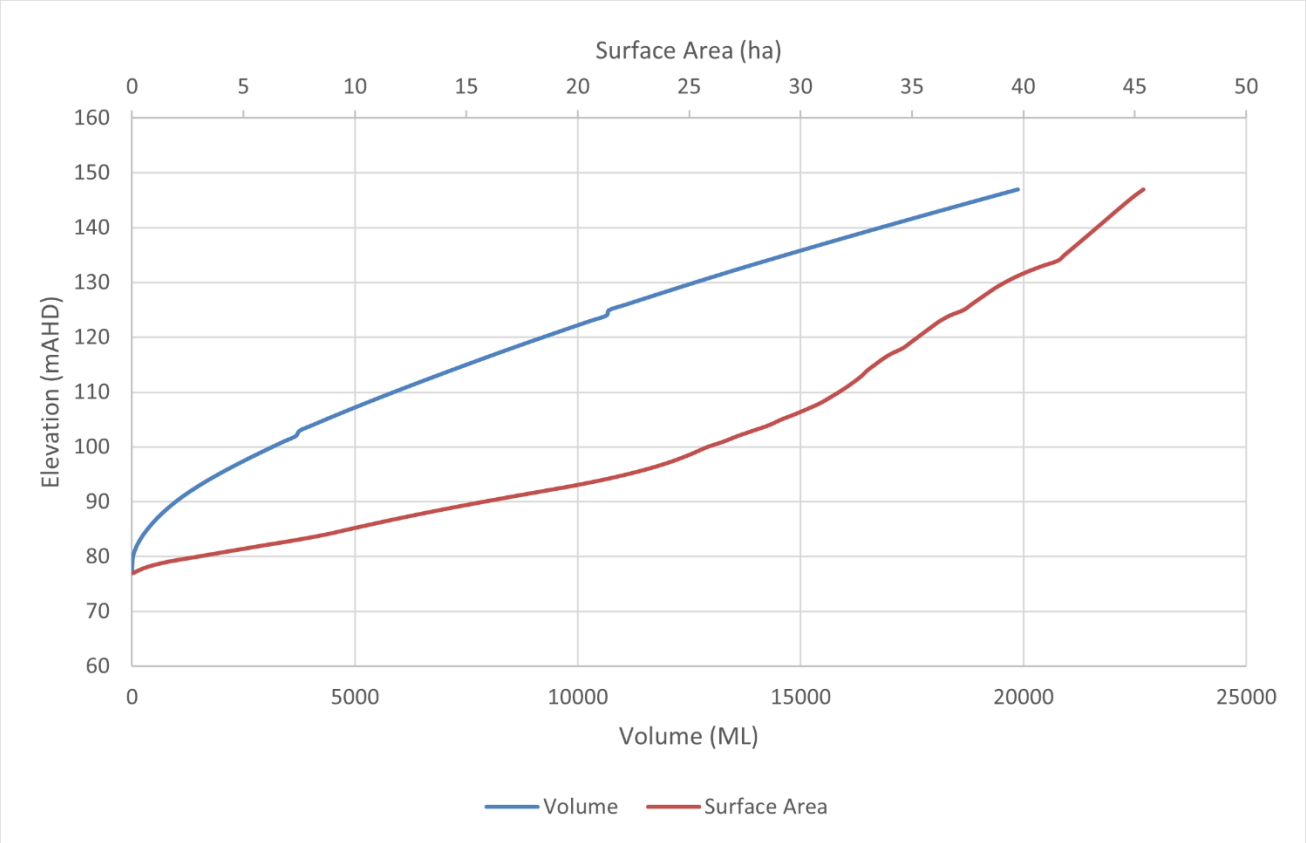


Figure 8A - Curragh Main: Void Ramp 9

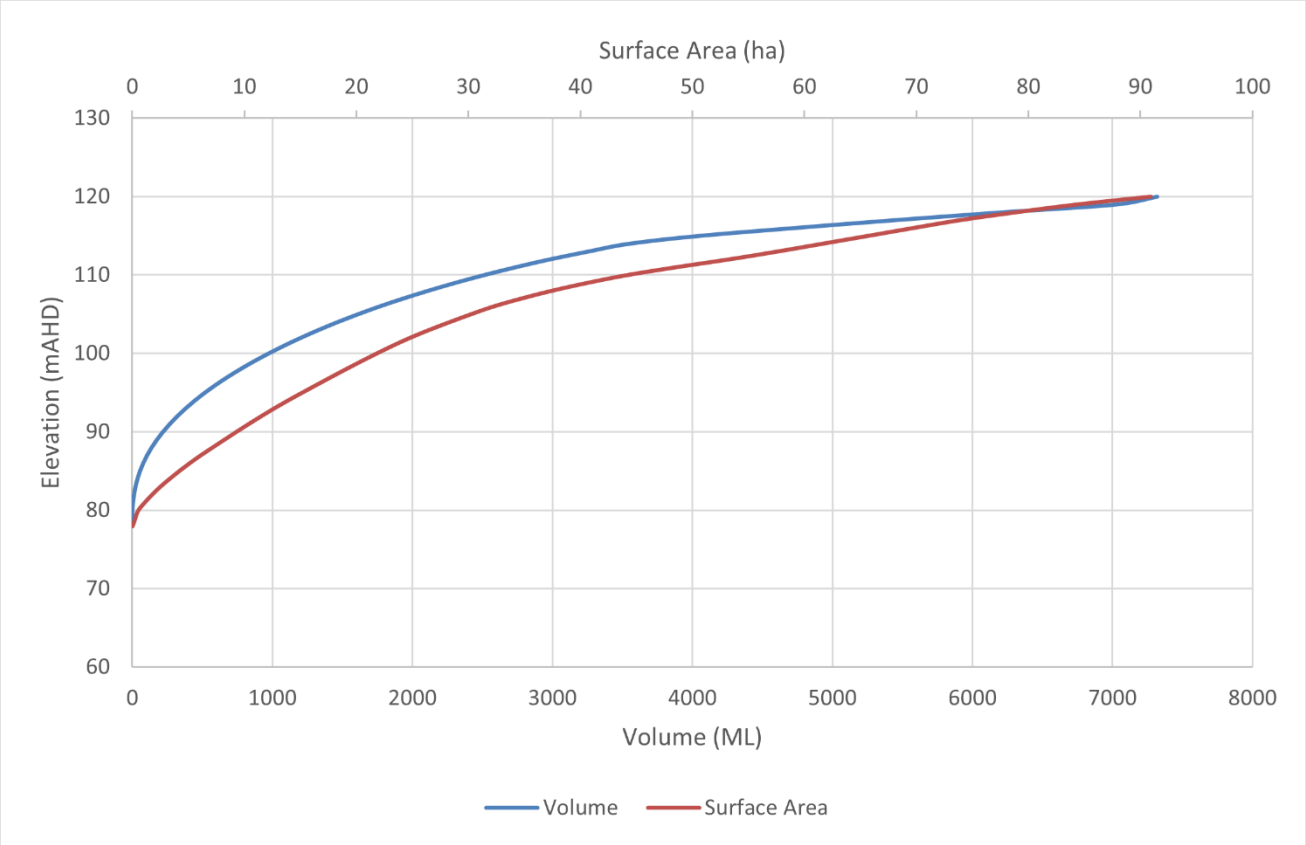


Figure 9A - Void X – 1

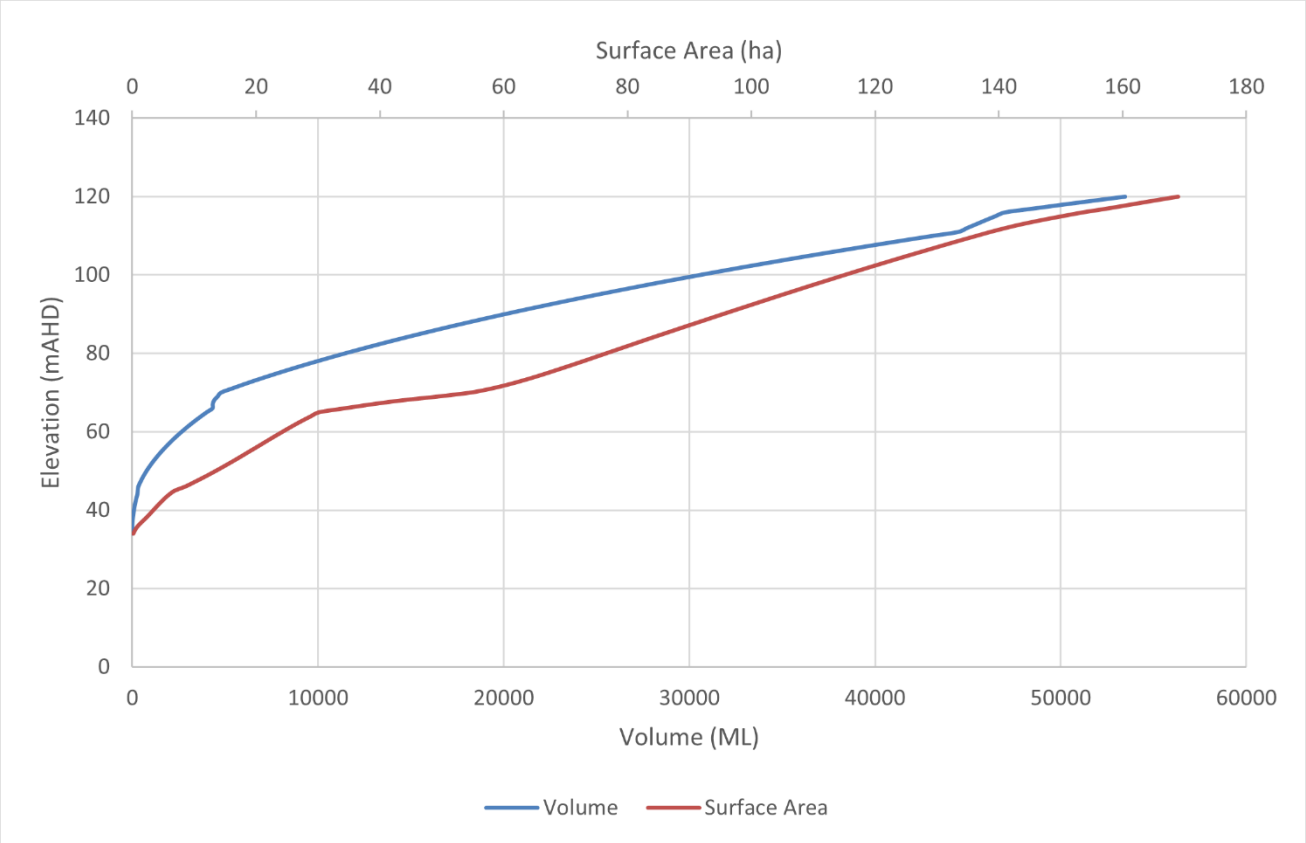


Figure 10A – Void X – 2

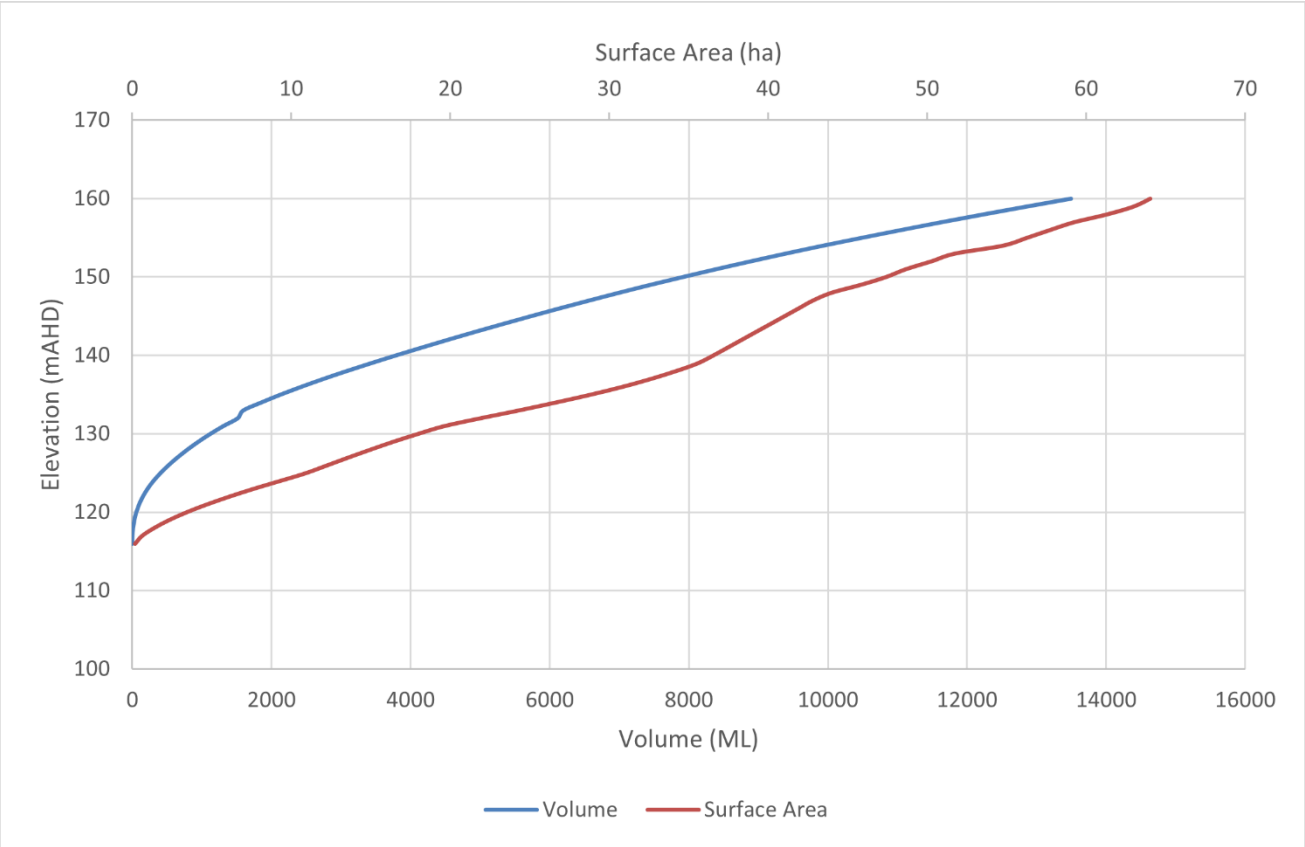


Figure 11A – Void Y

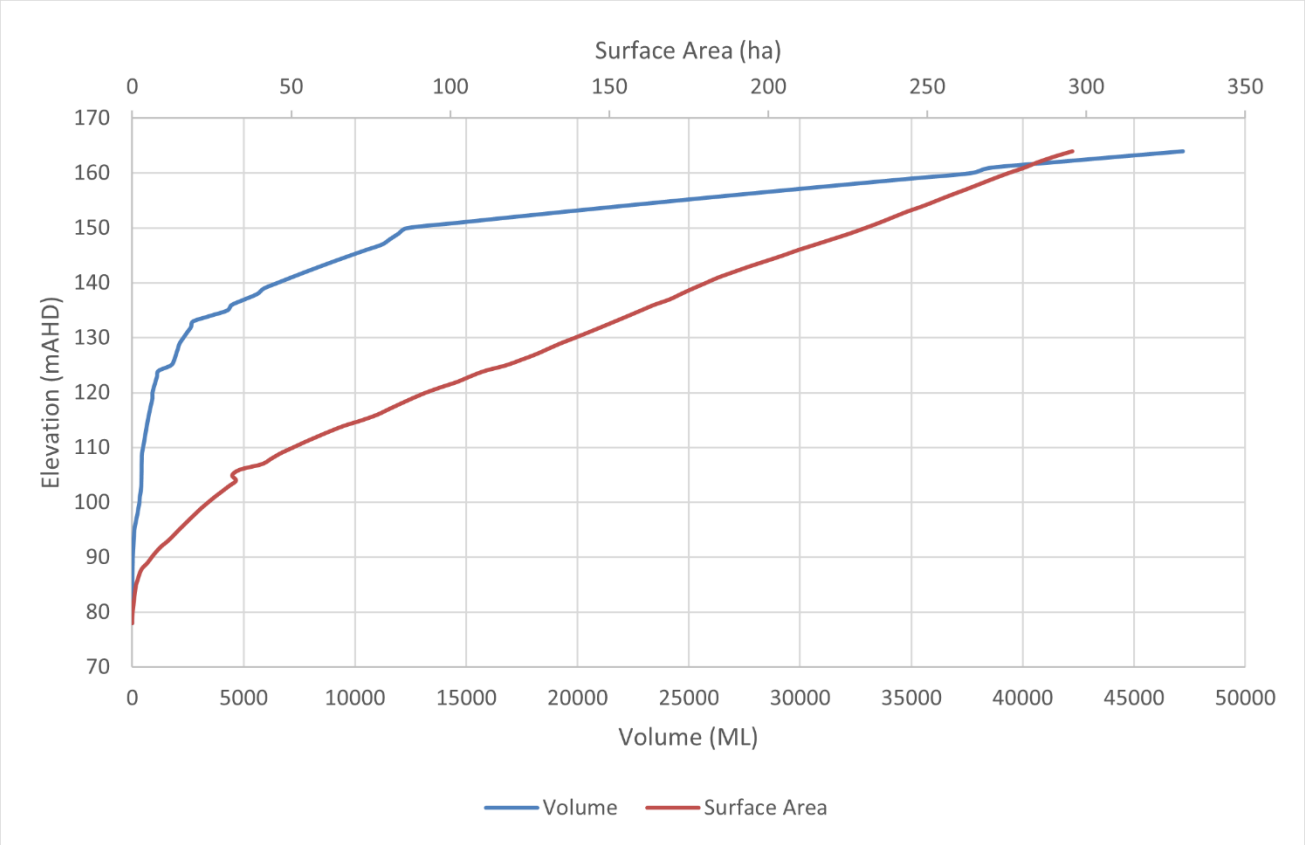


Figure 12A – Void Z

APPENDIX B

Residual Void Water Levels

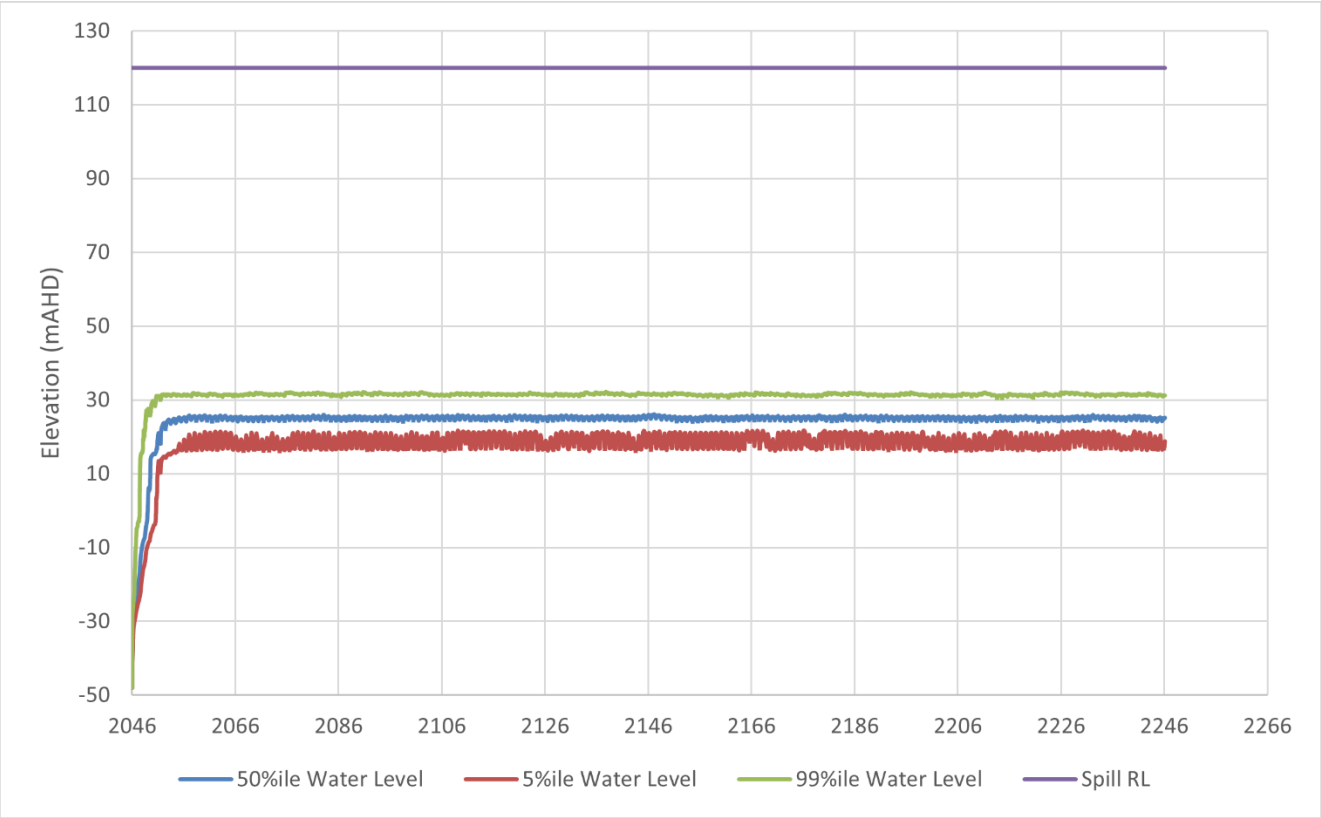


Figure 1B – Curragh North: Void U/T/S Final Water Level

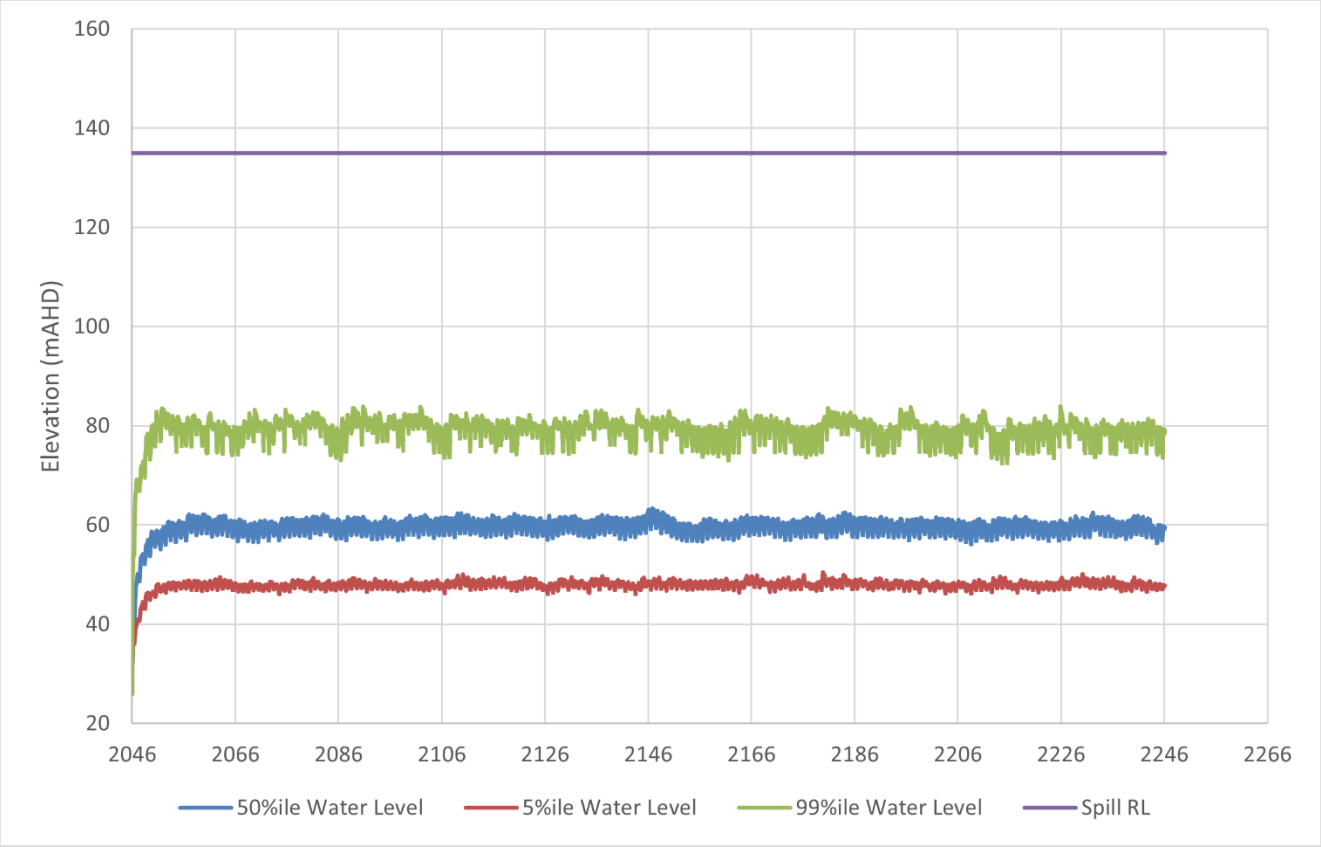


Figure 2B – Curragh Main: Void D/E/F Final Water Level

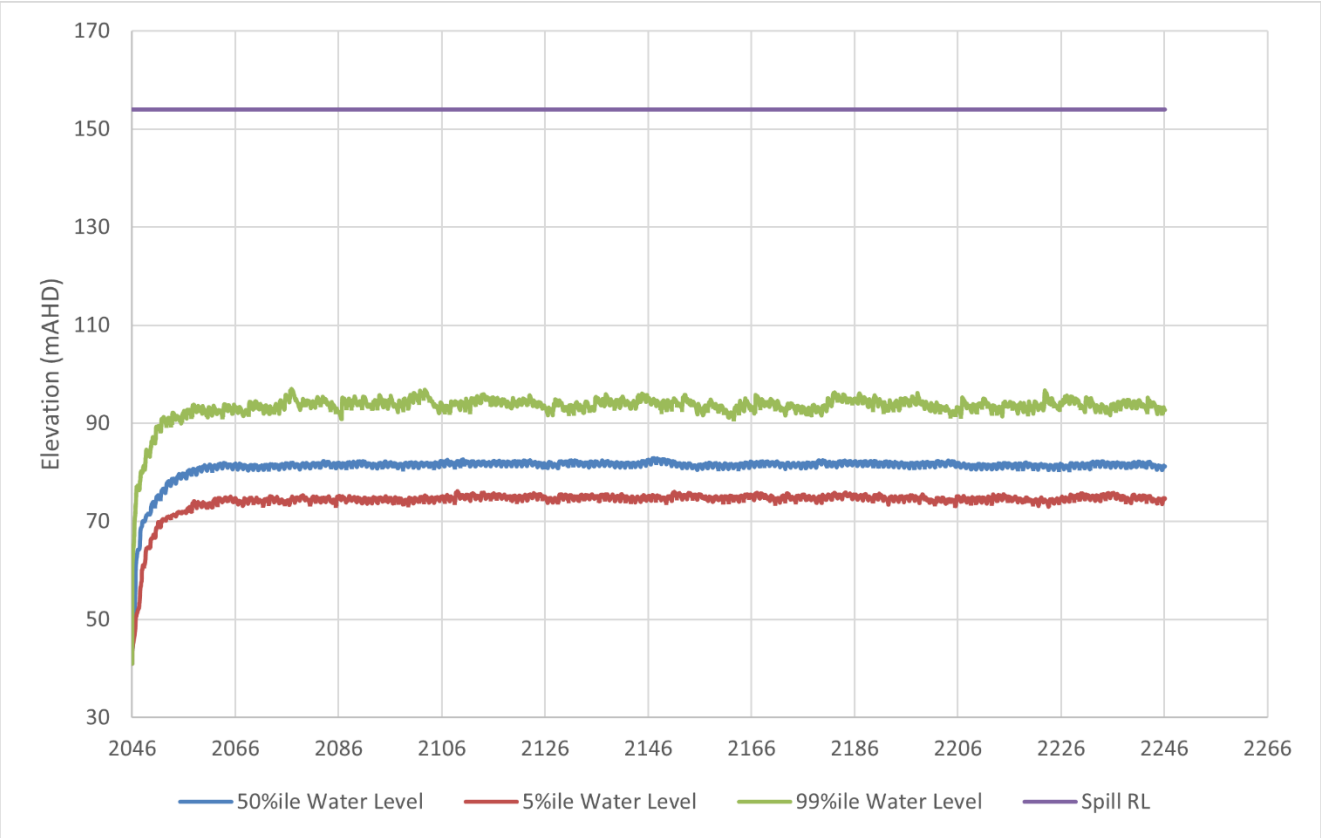


Figure 3B - Curragh Main: Void B/C/H Final Water Level

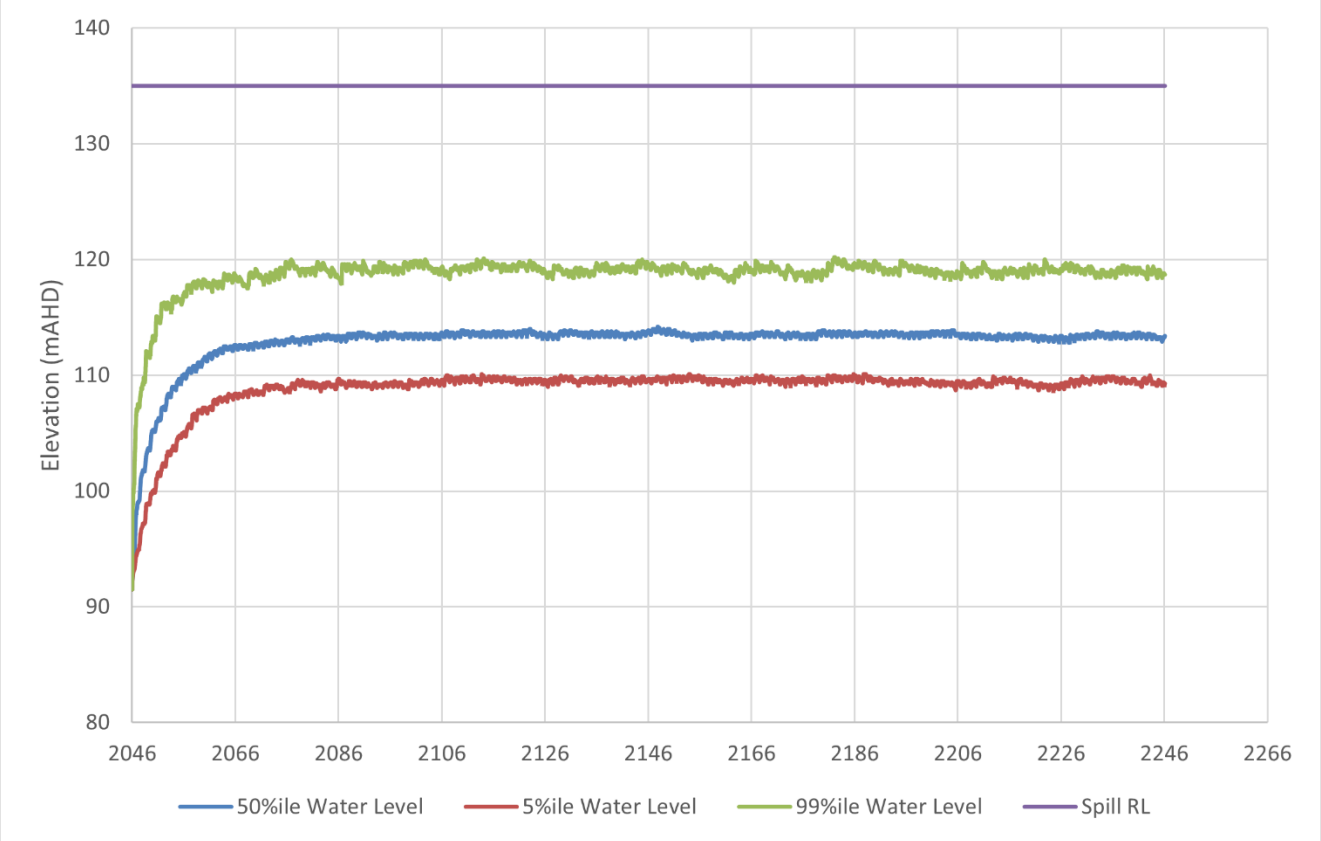


Figure 4B - Curragh Main: Void L Final Water Level

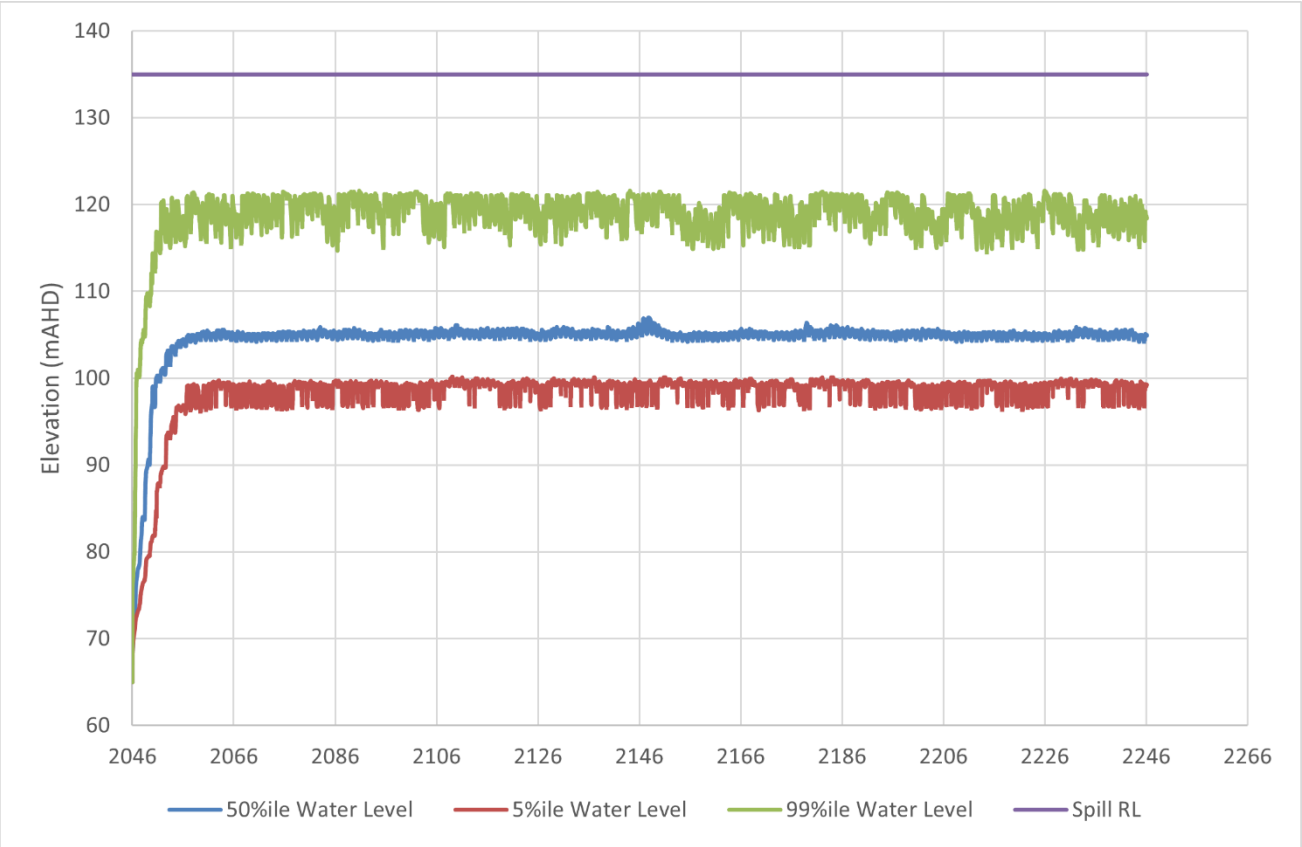


Figure 5B - Curragh Main: Void K Final Water Level

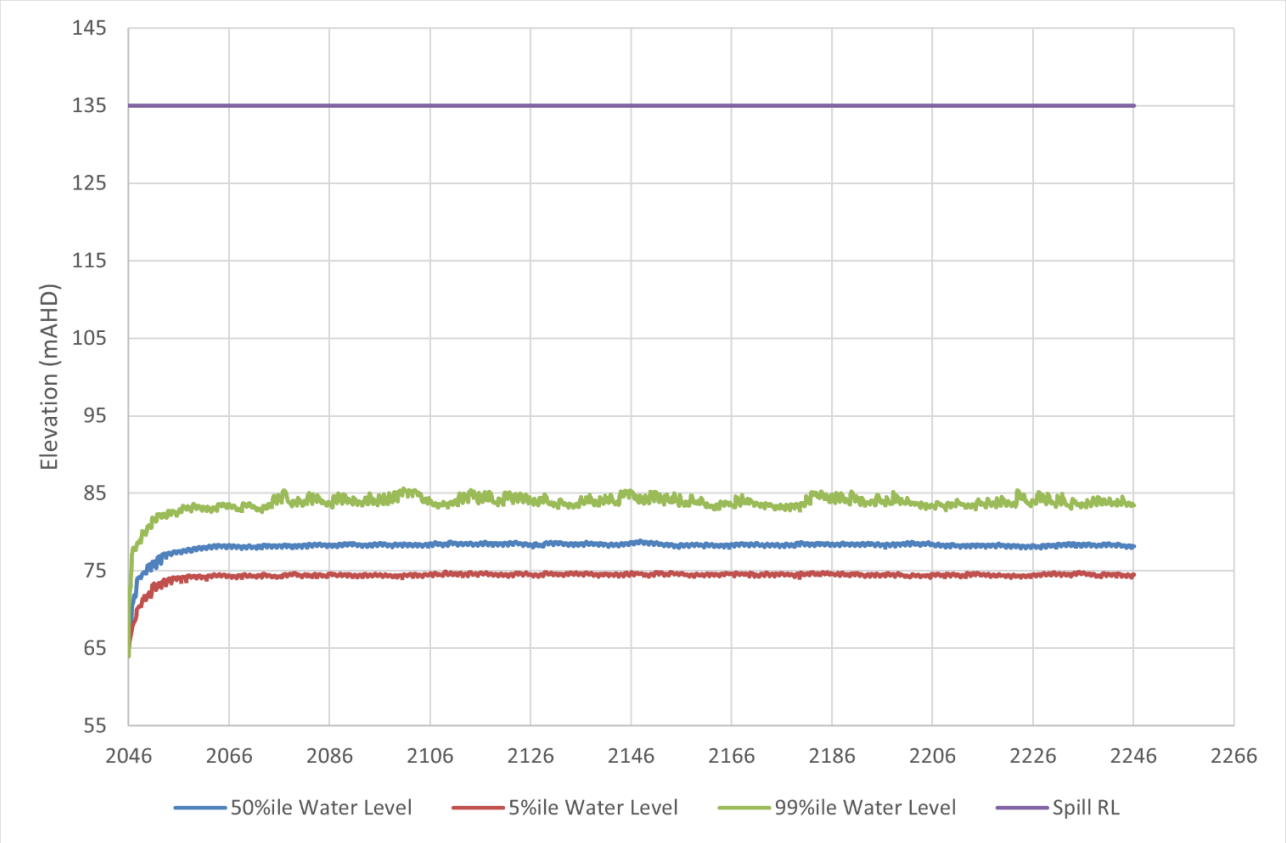


Figure 6B - Curragh Main: Void G Final Water Level

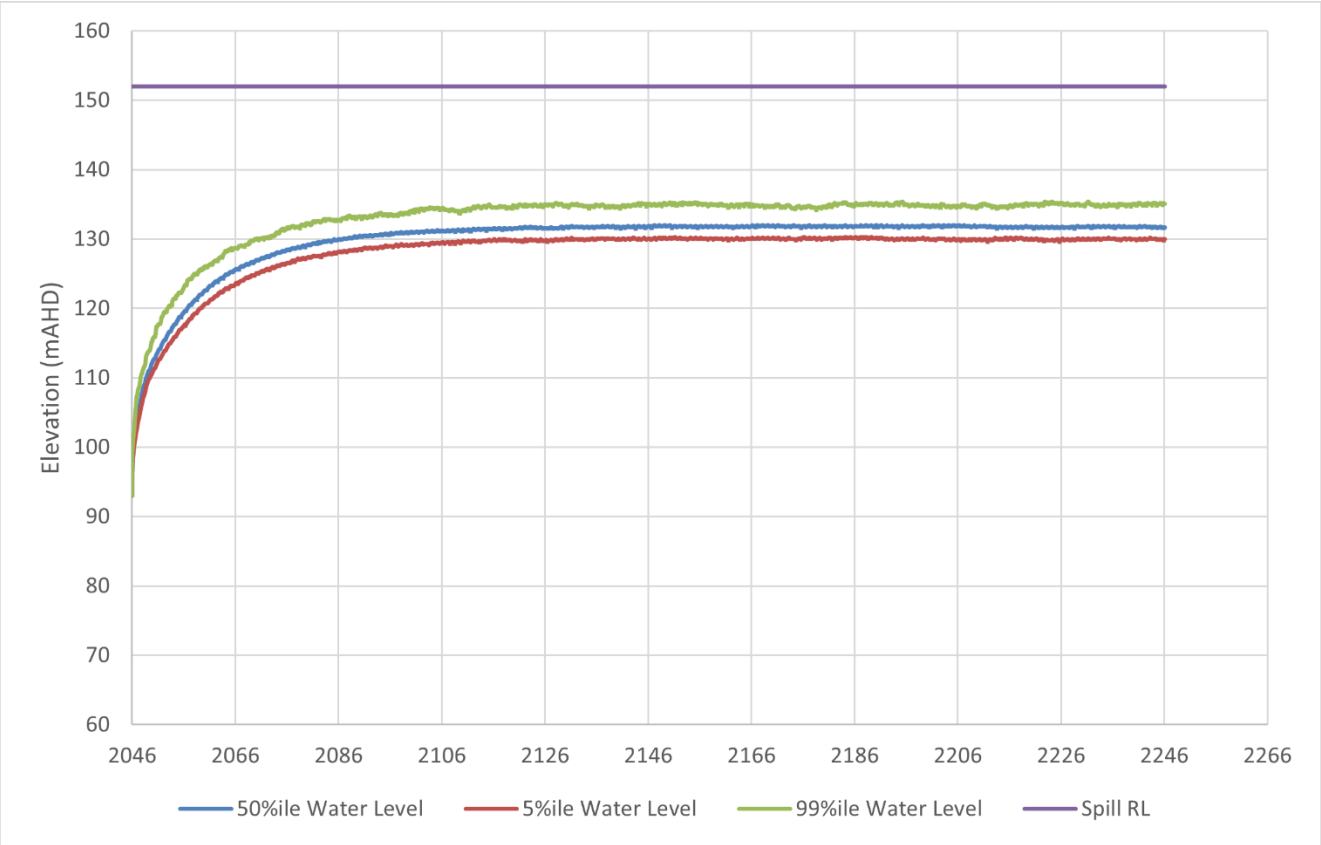


Figure 7B - Curragh Main: Void J Final Water Level

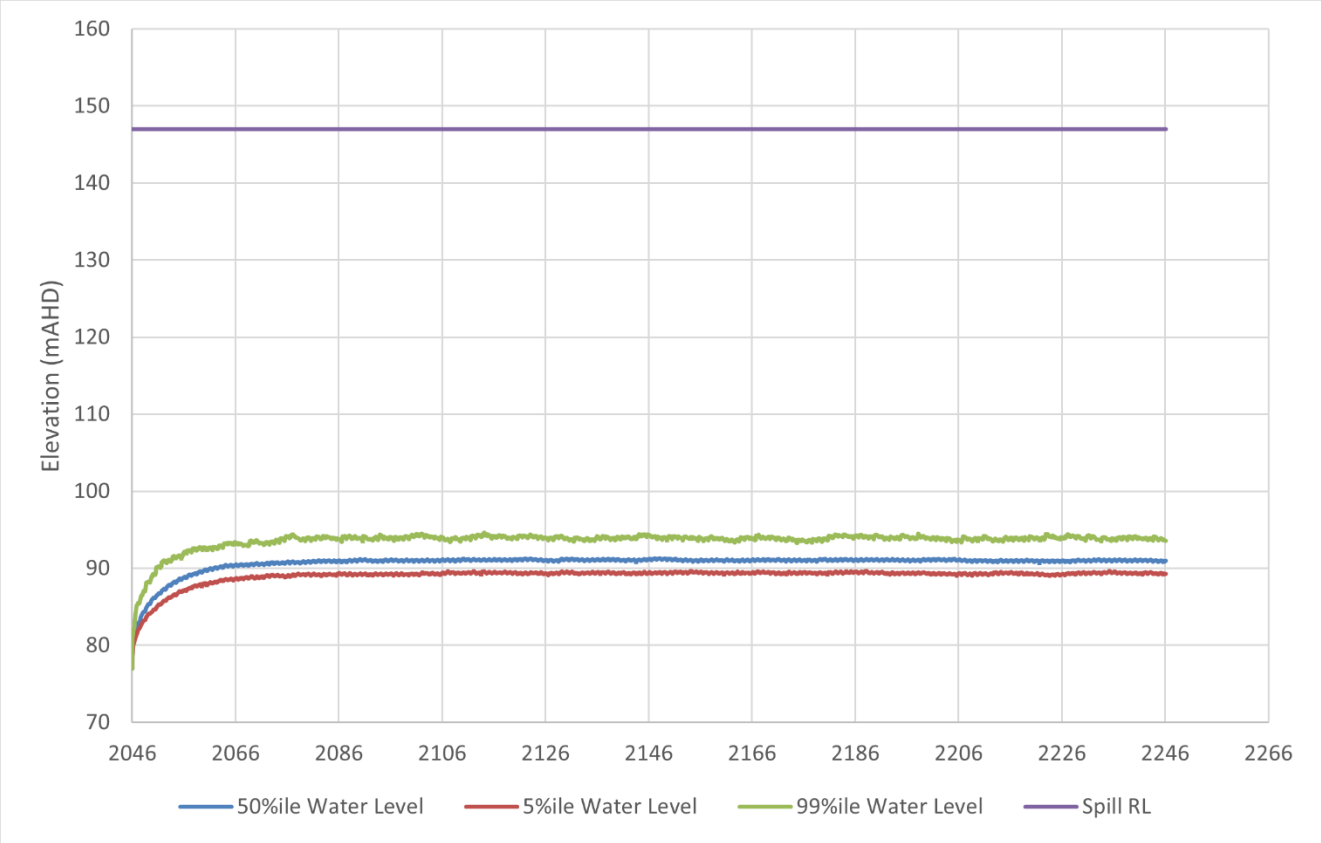


Figure 8B - Curragh Main: Void Ramp 9 Final Water Level

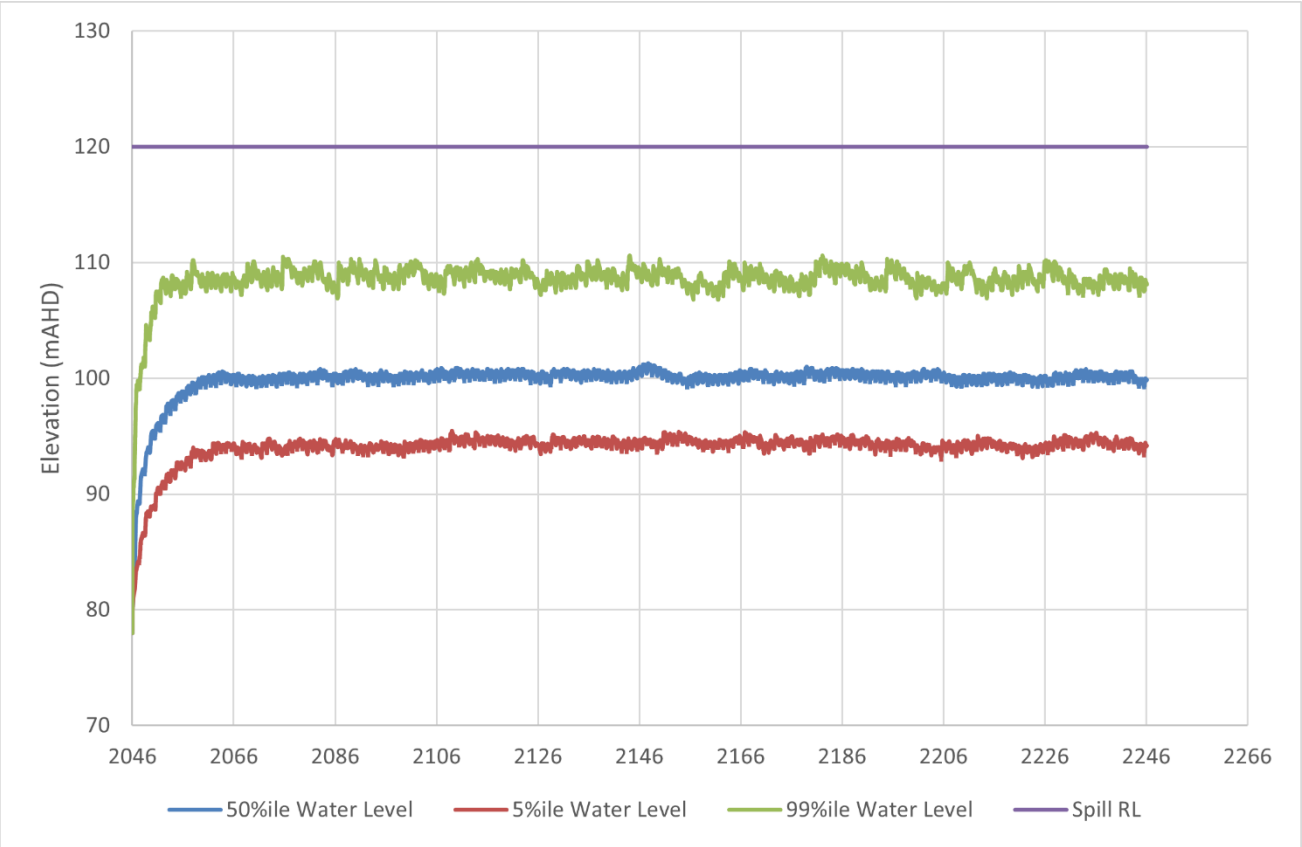


Figure 9B - Void X – 1 Final Water Level

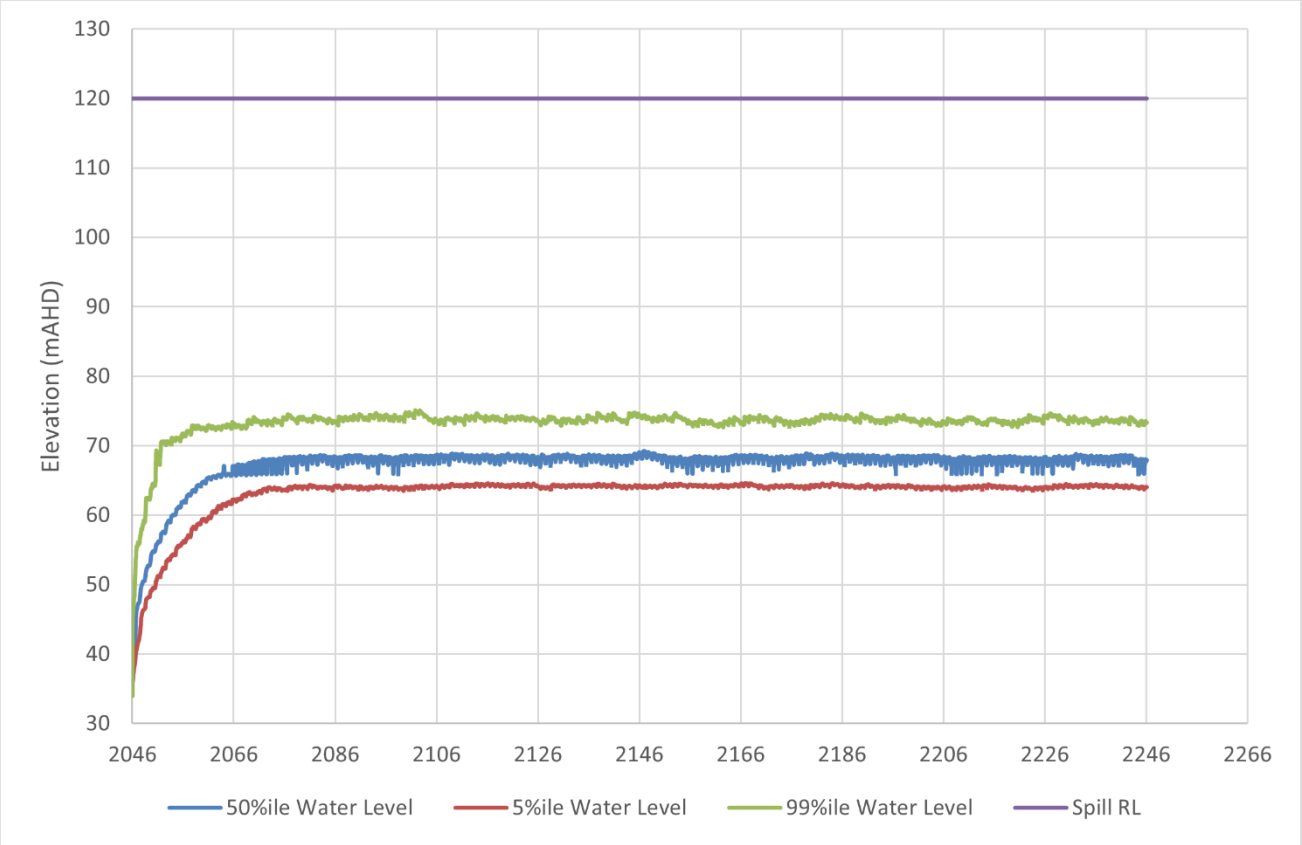


Figure 10B - Void X – 2 Final Water Level

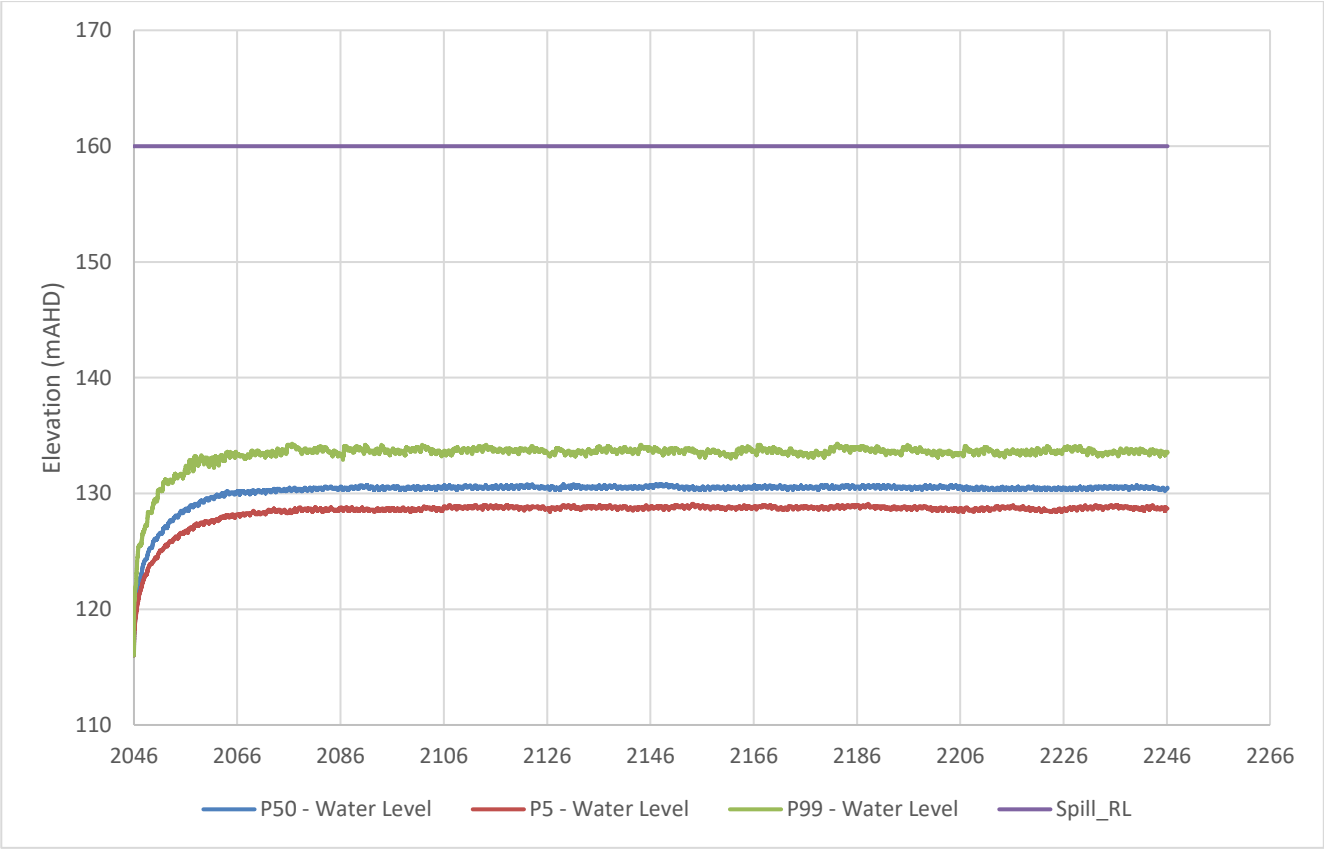


Figure 11B - Void Y Final Water Level

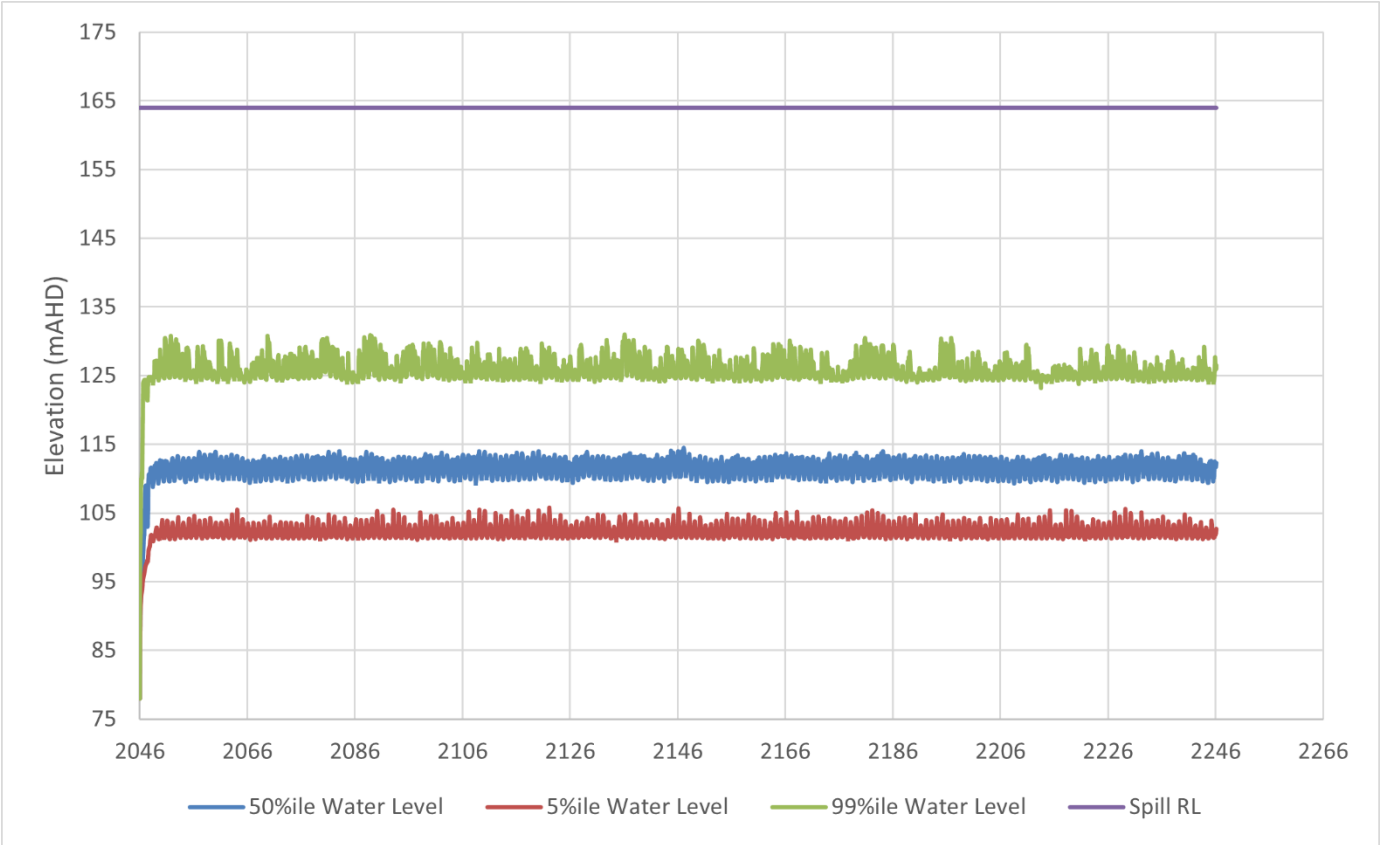


Figure 12B - Void Z Final Water Level

APPENDIX C

Residual Void Water Quality

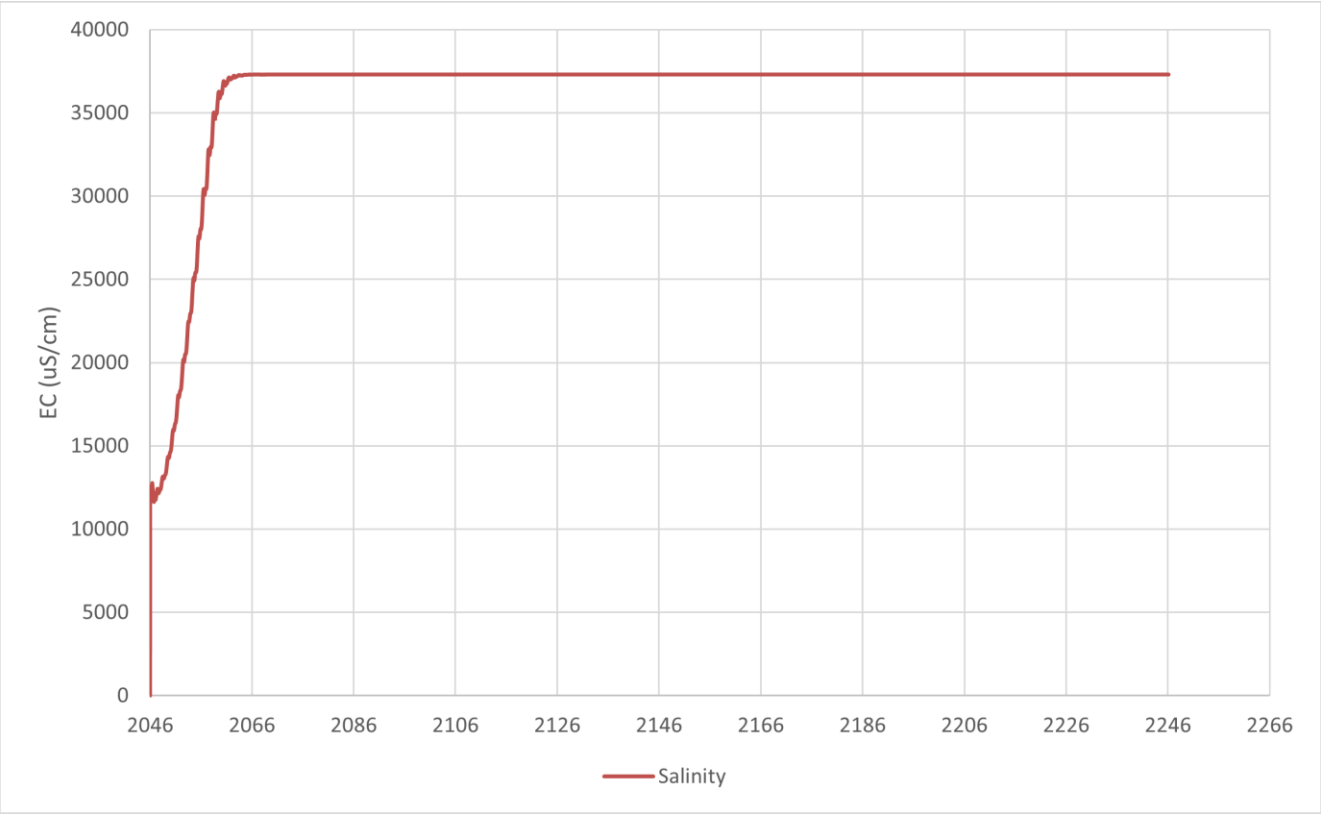


Figure 1C – Curragh North: Void U/T/S Water Quality

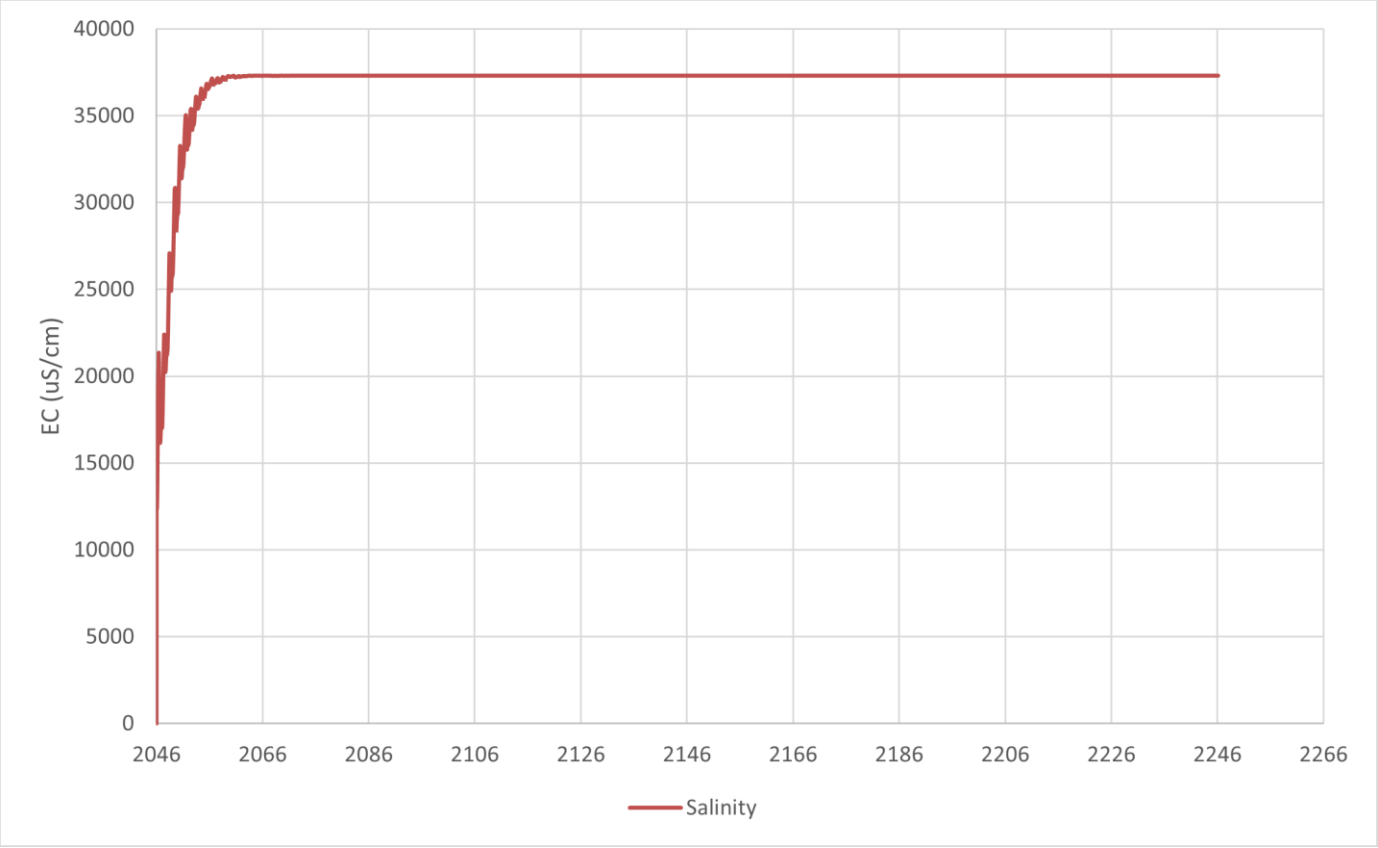


Figure 2C – Curragh Main: Void D/E/F Water Quality

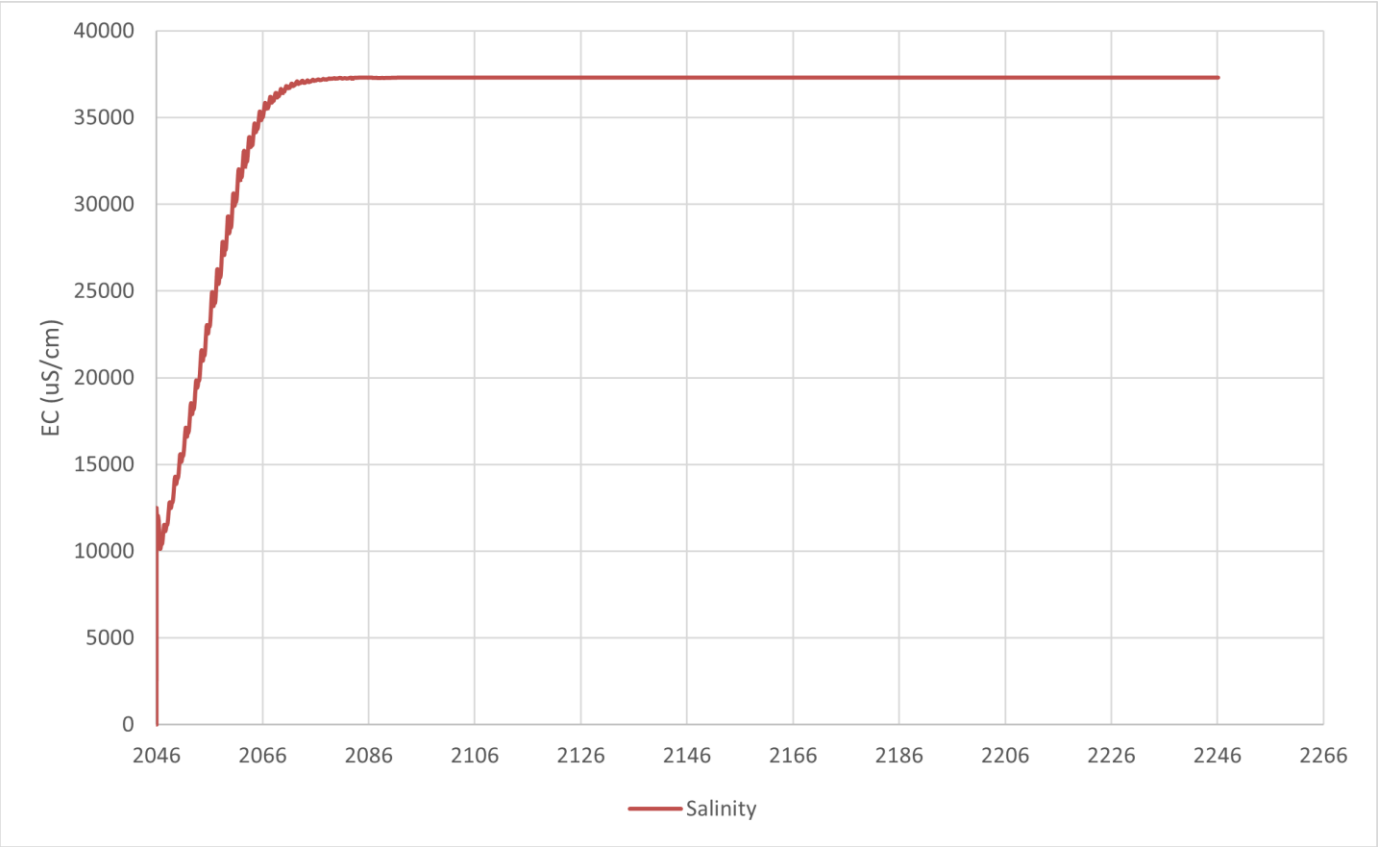


Figure 3C – Curragh Main: Void B/C/H Water Quality

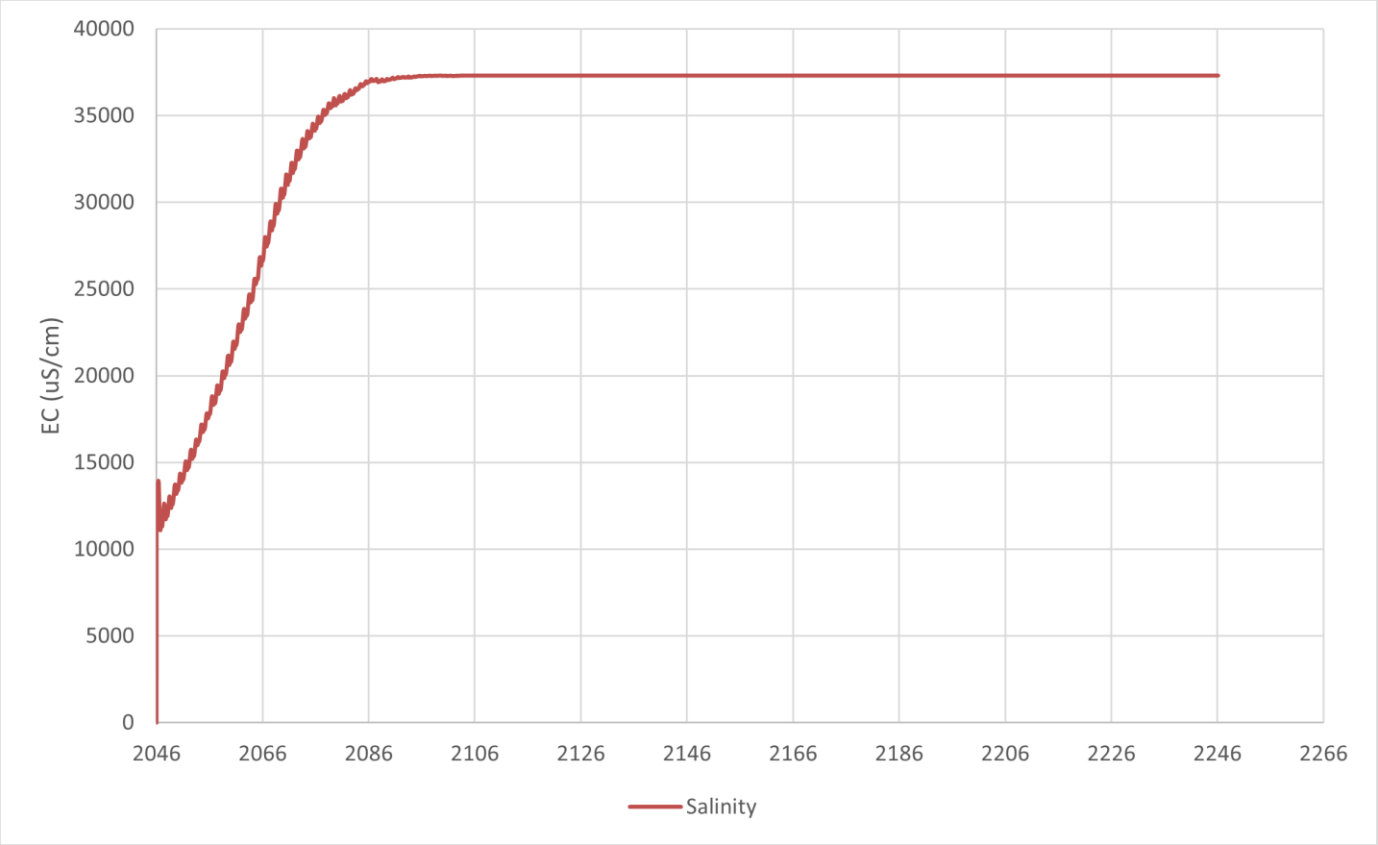


Figure 4C – Curragh Main: Void L Water Quality

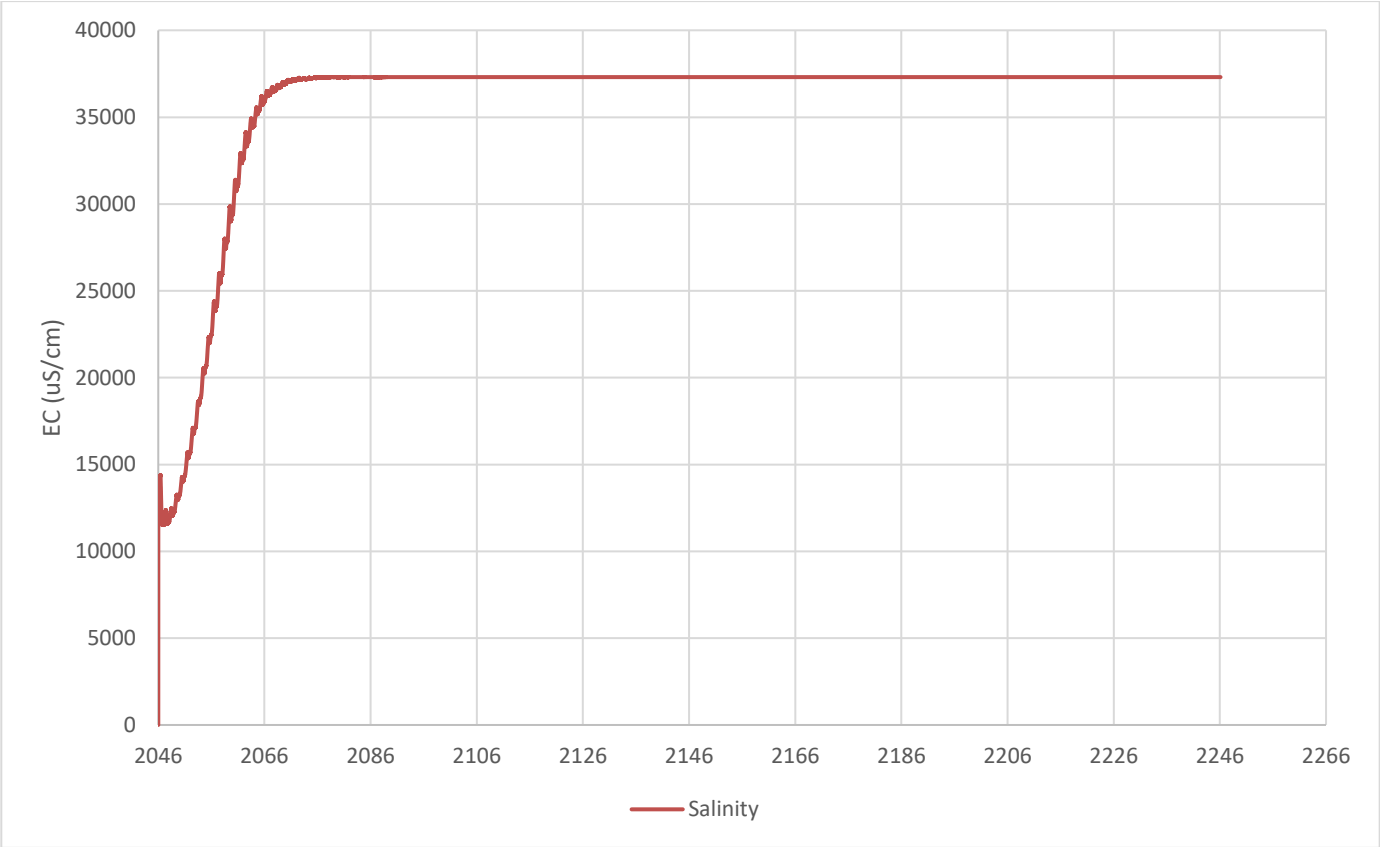


Figure 5C – Curragh Main: Void K Water Quality

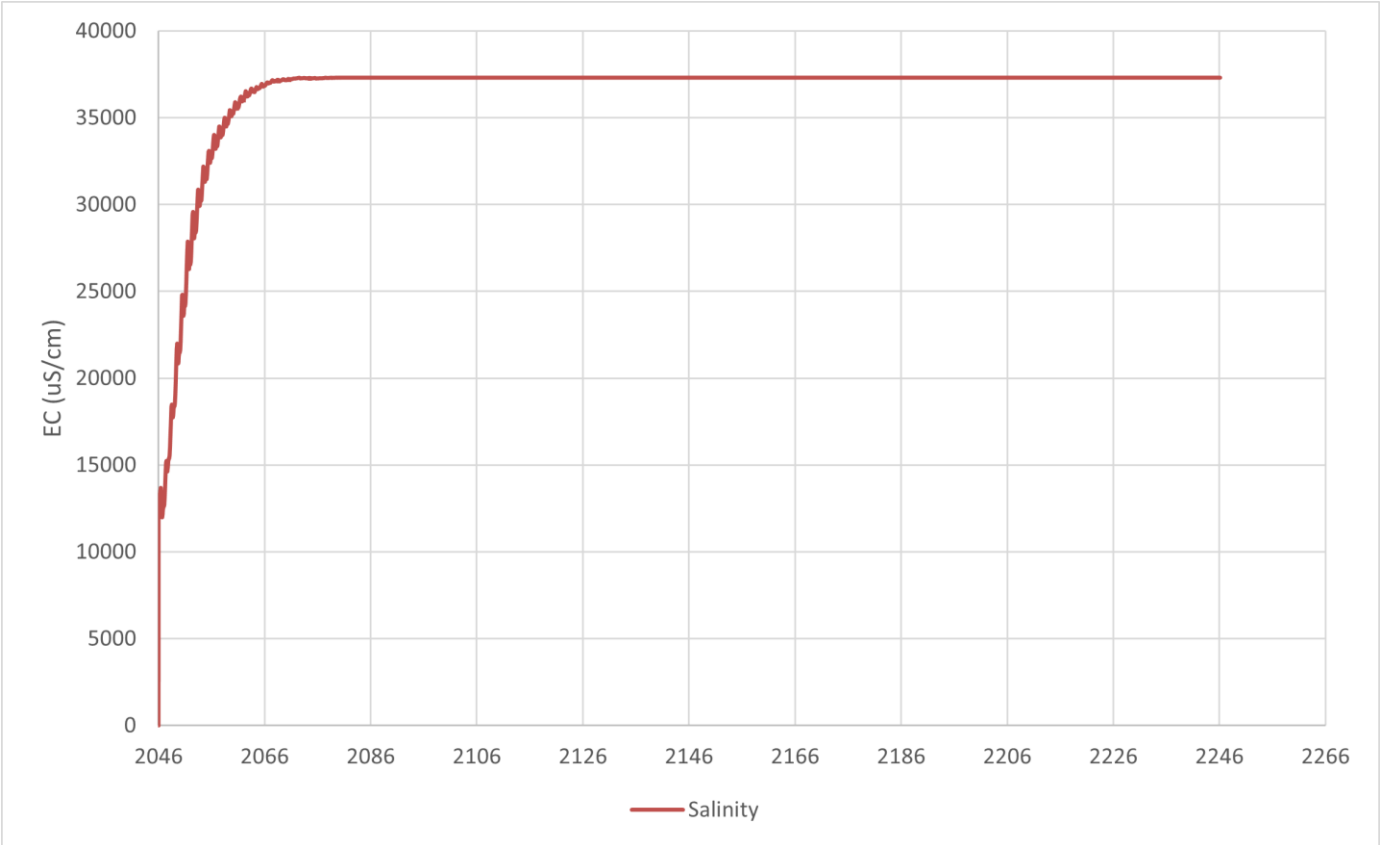


Figure 6C – Curragh Main: Void G Water Quality

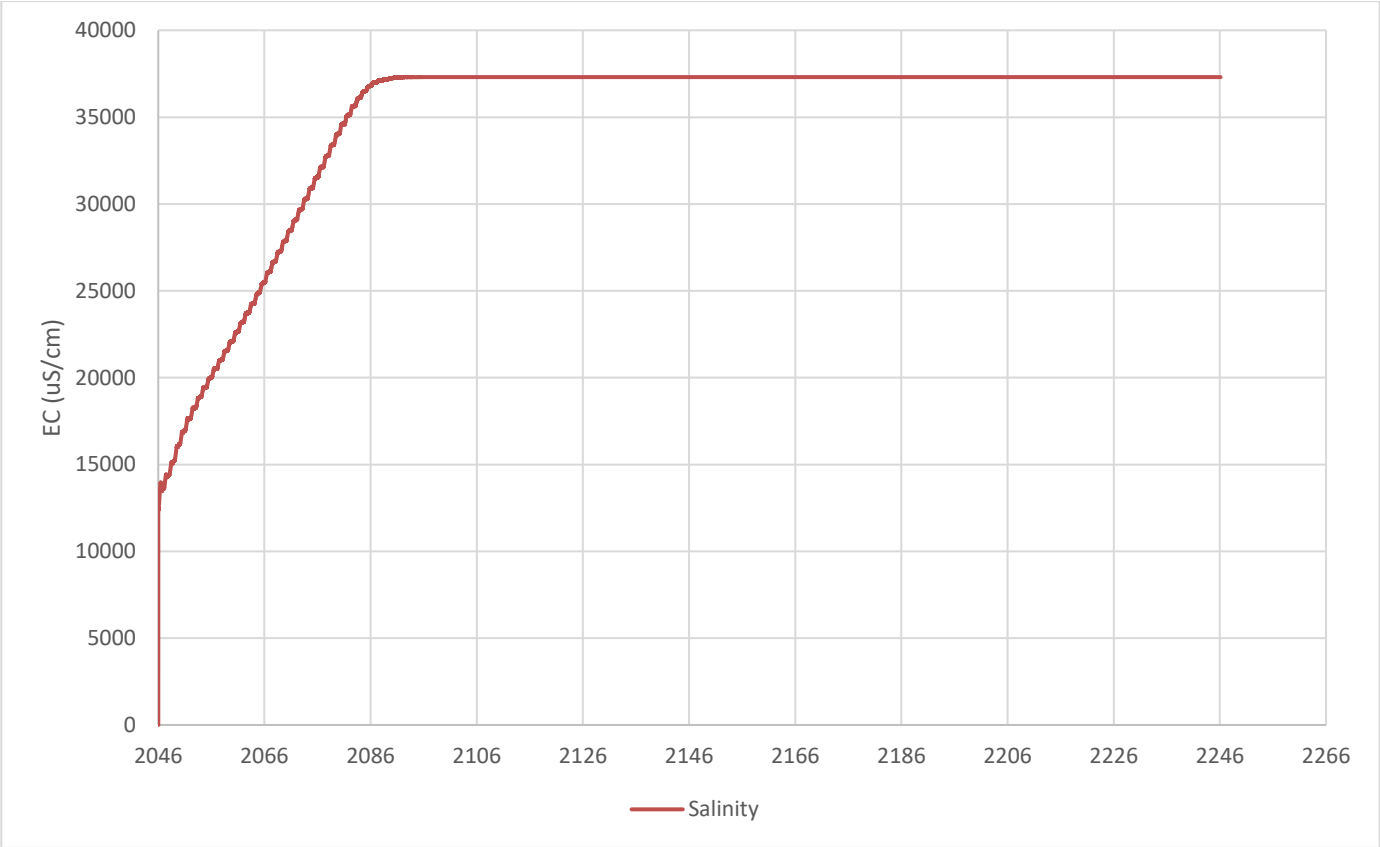


Figure 7C – Curragh Main: Void J Water Quality

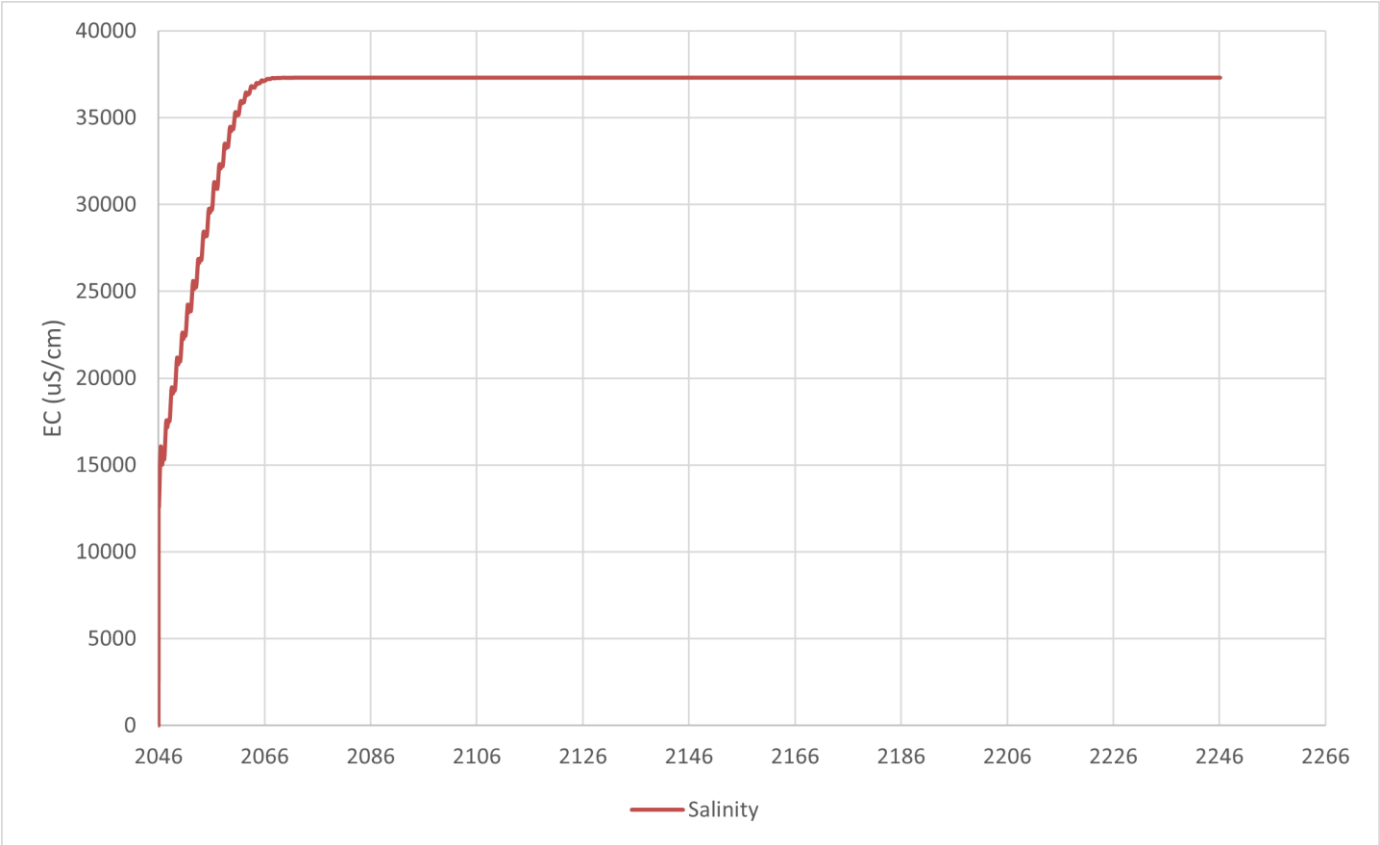


Figure 8C – Curragh Main: Void Ramp 9 Water Quality

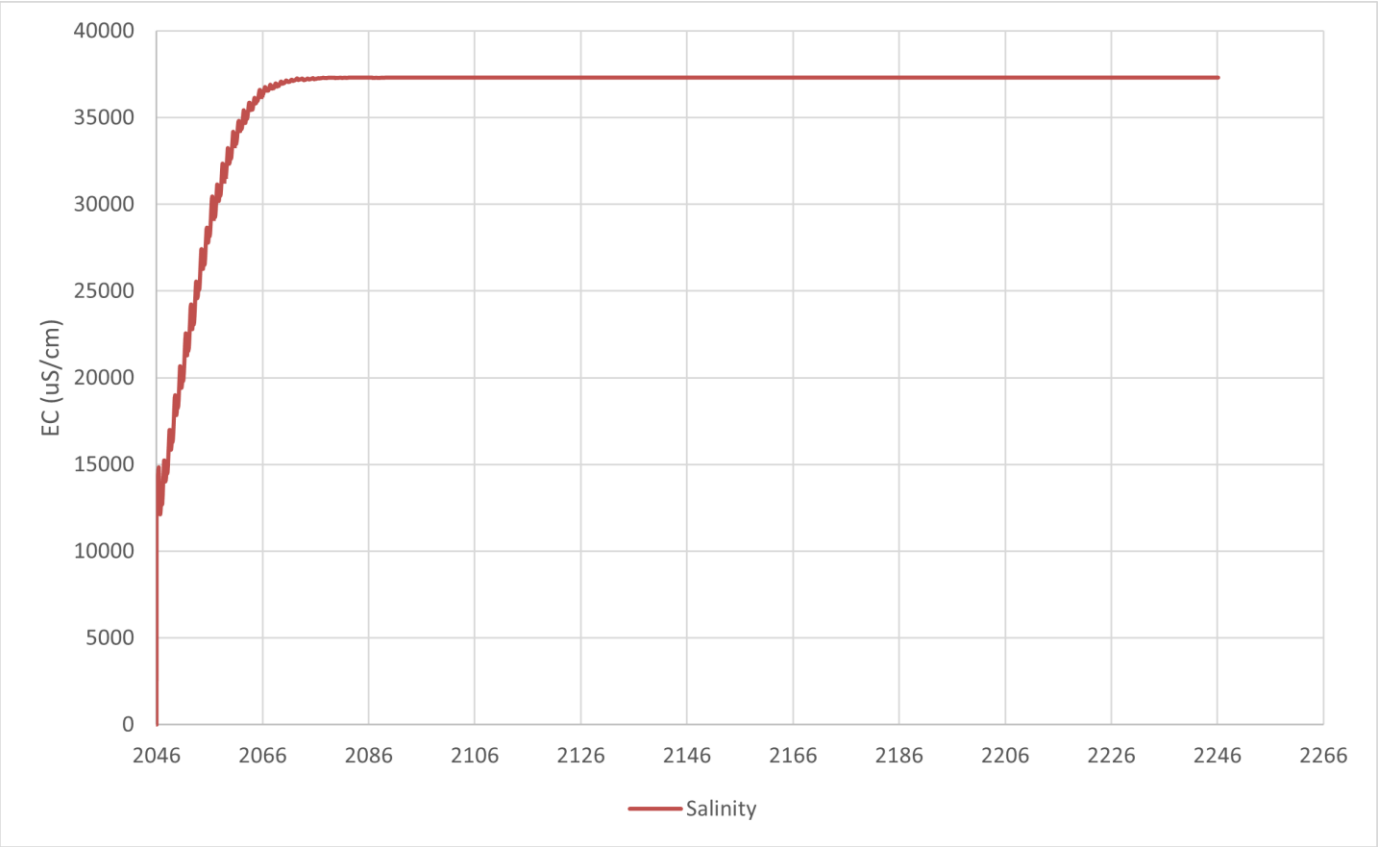


Figure 9C – Void X – 1 Water Quality

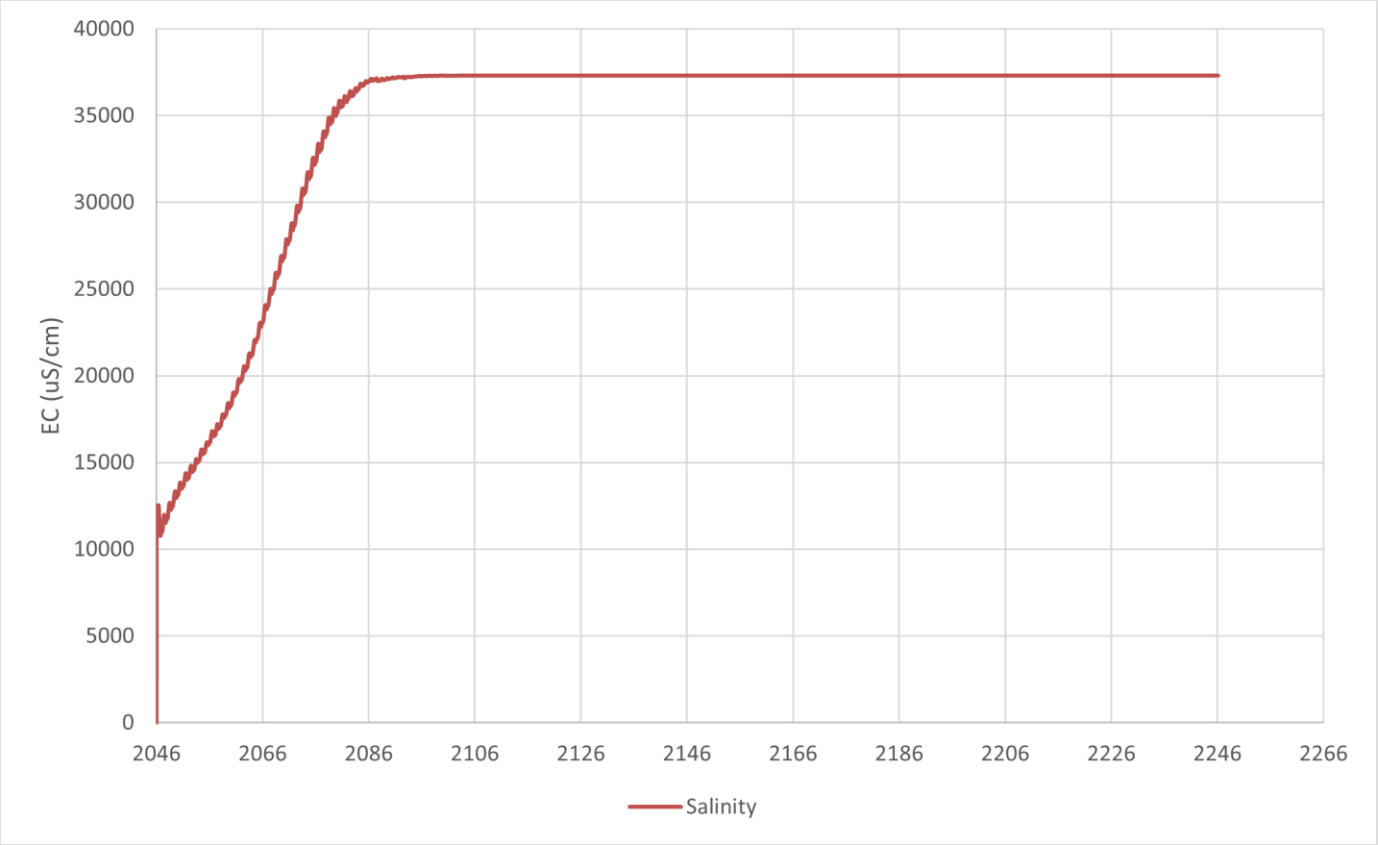


Figure 10C – Void X – 2 Water Quality

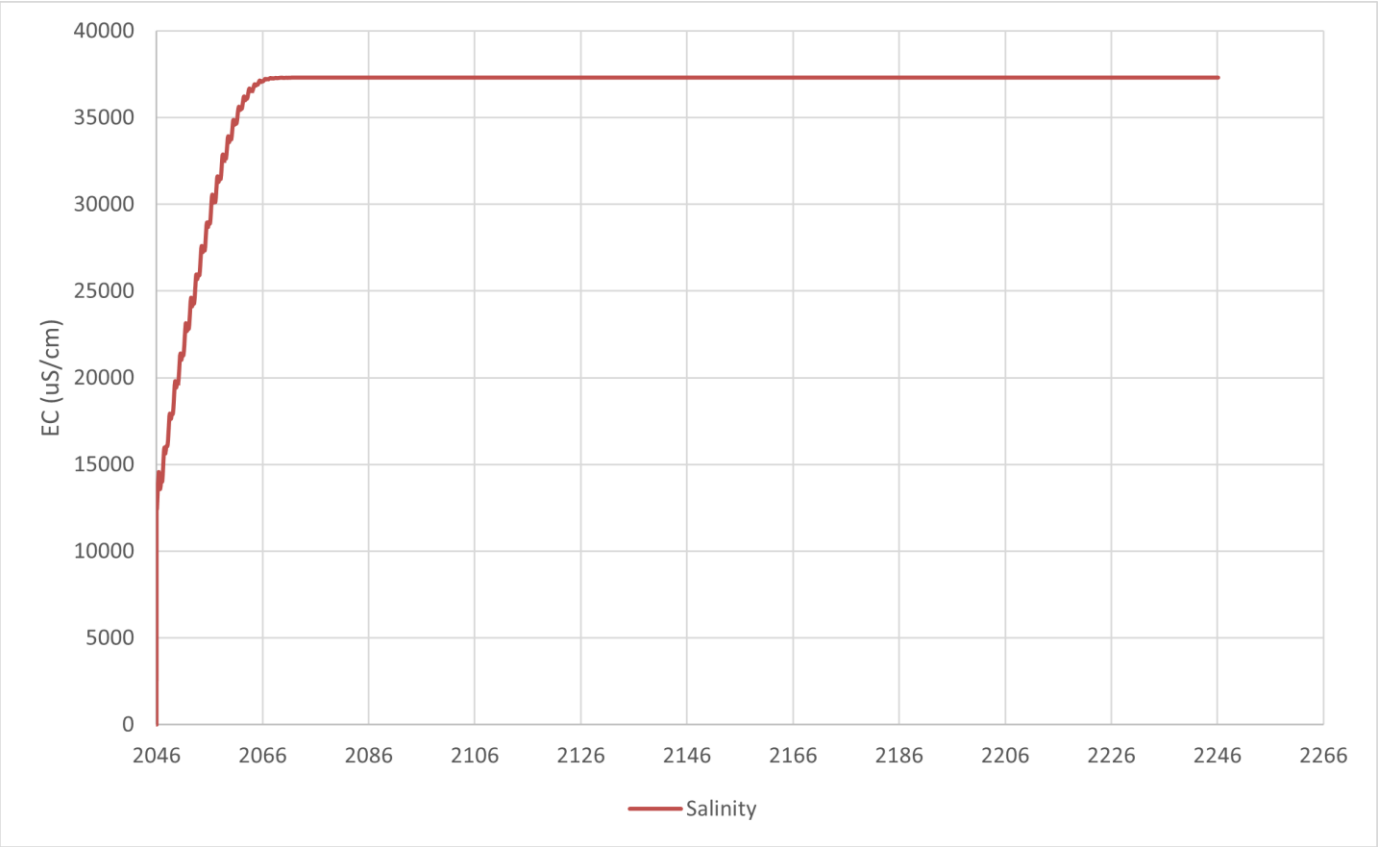


Figure 11C – Void Y Water Quality

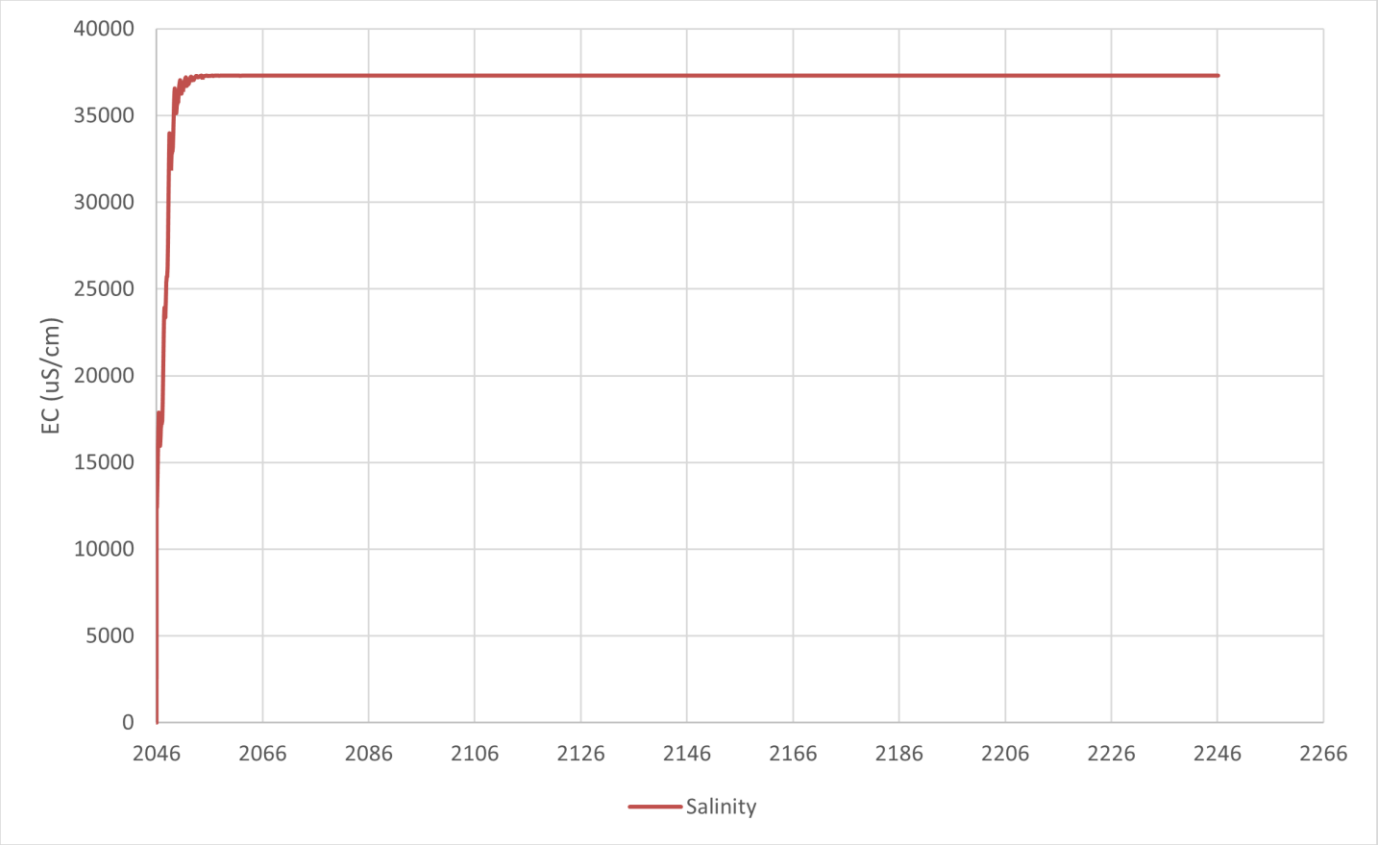


Figure 12C – Void Z Water Quality

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APPENDIX D

INITIAL GEOTECHNICAL SLOPE STABILITY ANALYSIS

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Curragh Mine
Final Landform Design

Initial Geotechnical Slope Stability Analysis

Prepared for:

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QLD 4717
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Appendices

Appendix A – Limit Equilibrium Slope Stability Analysis Outputs
Appendix B – Design Risk & Opportunities Register

1. Introduction

This report has been prepared by Raine & Associates (R&A) for Coronado Curragh Pty Ltd (CCPL) in relation to their Curragh Coal Mine (Curragh). This report presents the results of initial two-dimensional limit equilibrium slope stability analyses undertaken by R&A in relation to the final landform designs developed for Curragh.

1.1 Purpose

The purpose of this report is to assist CCPL, as part of the Curragh Planning System (CPS), identify, assess, manage, and document pre-emptively, potential geotechnical hazards associated with the longer-term slope stability of the Curragh final landform designs.

Qualifications and Limitations associated with the work presented in this report are provided in Section 8.

1.2 Available Data

The following data was made available by CCPL (Table 1-1).

Table 1-1 Supplied Data

Data Name and Format	Supplier	Comment
20200922.dhd	CCPL	Vulcan dataset of Geobank Output
CN Pit 20211101.dxf	CCPL	DXF contour model of the Curragh North final landforms
X Pit 20211030.dxf	CCPL	DXF contour model of the X Pit final landform
Y Pit 20211101.dxf	CCPL	DXF contour model of the Y Pit final landform
Z Pit 20211030.dxf	CPPL	DXF contour model of the Z Pit final landform
CM Pit 20211103b 2m.dxf	CCPL	DXF contour model of the Curragh Main final landforms, using 2m contours
CM Pit 20211103b half m.dxf	CCPL	DXF contour model of the Curragh Main final landforms, using 0.5m contours
CN Mining Surface 20211102.dxf	CCPL	DXF model of the Curragh North final mining surface, prior to remediation
2020Aug_LT_WOA_PublishedMOdel	CCPL	Life of Mine grids, inclusive of all coal seams and unconformable
Ramp 9	CCPL	A directory of Vulcan layers for Ramp 9, inclusive of powerlines, infrastructure, permanent roads, waterways and pit shell
210621.dhd.isix & .isis	CCPL	Borehole database for all of Curragh
0684-08-C1_FloorStudyDesignReport.pdf	WRM	Flood study for northern levee design – Jellinbah Mackenzie North Pit
211014 – pit shell plus dumps 0.5m contours.dxf	CCPL	DXF contour model of Y Pit final pit shell, including dumps, using 0.5m contours
211014 – void and footprint outlines.dxf	CCPL	DXF model of void and footprint outlines for Y Pit
1532295-052-R-Rev3-PitB-Design-Plan FINAL 20171124.pdf	CCPL	B Pit tailings storage facility design plan

Data Name and Format	Supplier	Comment
2172961A-GEO-REP-002 RevB.pdf	CCPL	Geotechnical investigation and assessment for capping, Curragh Coal Mine – Old Tailings Dam Rehabilitation
AGD84_AMG_Z55_Curragh_2107_Submission	CCPL	Registered images and topographic models from Curragh's survey department – Current as at July 2021
AGD84_AMG_Z55_Curragh_2108_Submission	CCPL	Registered images and topographic models from Curragh's survey department – Current as at August 2021
1911.stat.blackwater.creek.arch_d	CCPL	Vulcan layer outlining Blackwater Creek
1911.stat.levee.arch_d	CCPL	Vulcan layer outlining the current position of levees
1911.stat.mackenzie.river.arch_d	CCPL	Vulcan layer outlining the Mackenzie River
FW_ Hydraulic conductivities (email)	SLR	Hydraulic Permeabilities
1in1000_E009_Waterlevel_Curragh.pdf	SLR	Flood levels

1.3 References

The slope stability analyses presented in this report reference the following documents:

- R&A Report: *RA002_201706_02_Rev0 Slope Stability Analysis for Out of Pit Dumps_Rev0*, dated November 2017;
- Hawley, M. and Cunning, J. (2017), *Guidelines for Mine Waste Dump and Stockpile Design*, CSIRO;
- Martin, D. and Stacey, P., (2018) *Guidelines for Open Pit Slope Design* in Weak Rocks, CSIRO;
- Read, J. and Stacey, P., (2009) *Guidelines for Open Pit Slope Design*, CSIRO; and,
- Simmons, J. and McManus, D. (2004), *Shear Strength Framework for Design of Dumped Spoil Slopes for Open Pit Coal Mines*.

1.4 Safe Design

As noted in Section 1.1, the purpose of this report is to help CCPL, as part of the CPS, identify, assess, manage and document pre-emptively, potential geotechnical hazards associated with the longer-term slope stability of the Curragh final landform designs.

As a result, it is necessary that this report conforms with the legislated reporting requirements under the Qld Work Health & Safety Act 2011, the Work Health & Safety Regulation 2011 and the Coal Mining Safety and Health Act 1999. As part of this obligation R&A recommend and encourage that discussions, design reviews and risk workshops be undertaken in relation to the final landform designs considered in this report (Appendix B).

2. Geological Conditions, Structural Analysis and Interpretation

The Curragh Coal Mine is located approximately 30 km north of the town of Blackwater in Central Queensland's Bowen Basin and is comprised of two active mining areas, which are referred to as Curragh Main and Curragh North.

Curragh is located on the western flank of the Bowen Basin and resides in the Upper Blackwater Group, which comprises of the Rangal Coal Measures, the Burngrove Formation and the Fair Hill Formation. In general, the Rangal Coal Measures are mined at Curragh. These deposits are comprised of grey mudstone and siltstone, light grey fine-grained sandstone and the productive coal seams of Cancer, Aries, Castor, Pollux, Orion and Pisces. Mining of the Burngrove Formation coal seams is also being considered. The local basin coal seam stratigraphy is presented in Figure 2-2.

Locally, the Aries and Castor Coal Seams, and the Pollux, Orion, and Pisces Coal Seams are observed to coalesce. Where the Aries and Castor Coal Seams coalesce, they are named the Mammoth Seam (Figure 2-1). The Mammoth Coal Seam is observed in the footprint of the current S-Pit Main and S-Pit South mining areas. Where the Pollux, Orion, and Pisces Coal Seams coalesce, they are named the Mackenzie Seam (Figure 2-1). The Mackenzie Seam (sometimes also referred to as the Pisces Seam) is mined at Curragh North and is directly underlain by the Yarrabee Tuff and Pisces Lower Coal Seam.

Curragh is located adjacent to the northwest trending Jellinbah Thrust Belt, which is believed to exhibit vertical stratigraphic throws in the order of 100's of metres. The dominant geological structures at Curragh are observed to be north-northwest to south-southeast trending thrusts faults crosscut by younger transcurrent and normal faults.

Zones of significant rock mass and coal seam shearing are likely in the vicinity of larger-scale faults. These zones are characterised by extensive shearing, repeating and/or stripping of stratigraphic units and represent areas of structural and geological complexity. Pitwall design revisions are often implemented at Curragh to mitigate the risks associated with geological faults and pitwall stability.

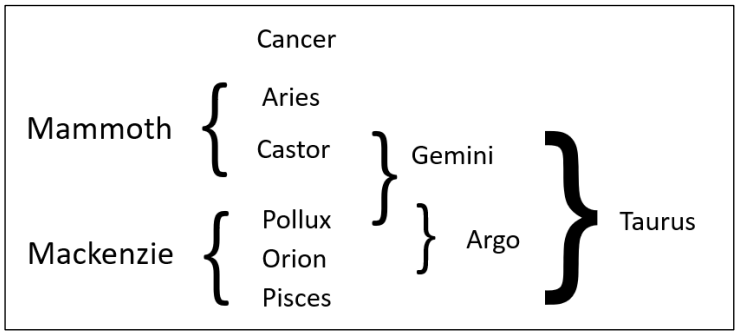


Figure 2-1 Rangal Coal Measure coalesces naming convention (Curragh Geology Training Manual, CCPL)

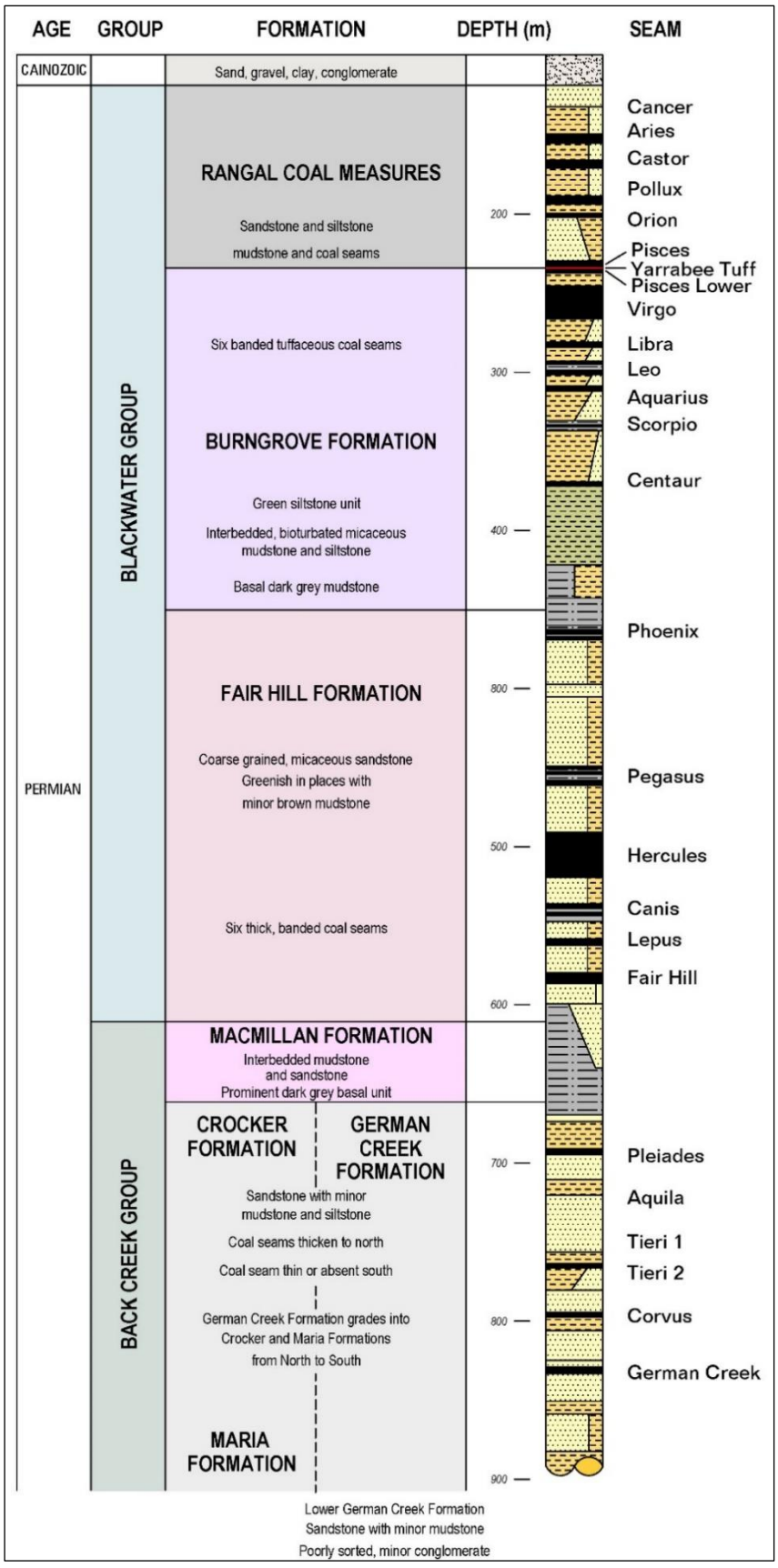


Figure 2-2 Coal Seam Stratigraphy (Curragh Geology Training Manual, CCPL)

2.1 Quaternary and Tertiary Lithology

The alluvial soil materials observed at Curragh are comprised of Quaternary Sands, Gravels and Clays, and Tertiary Clays and Sandy Clays.

2.2 Permian Interburden Lithology

The Permian stratigraphy observed at Curragh Main is comprised predominately of the Rangal Coal Measures, generally consisting of coal, sandstone, siltstone, claystones, and carbonaceous units (refer to Table 2-1).

Table 2-1 General Permian Material Classifications – Curragh Main

Material Name	Material Description
Siltstones, Sandstones, Claystones and Carbonaceous Units	Interlaminated and bedded siltstone and sandstones with occasional mudstone and / or carbonaceous units occurring in the Aries Overburden, Castor Interburden, Pollux Interburden and Orion Interburdens.
Coal	Black coal.

The Permian stratigraphy observed in Curragh North generally consists of coal, sandstone, and siltstone, with occasional mudstone and carbonaceous units, and stratigraphically continuous tuffaceous layers (i.e. Yarrabee Tuff and Tuff Lower; refer to Table 2-2).

Table 2-2 General Permian Material Classifications – Curragh North

Material Name	Material Description
Siltstones & Sandstones	Interlaminated and bedded siltstone and sandstone with occasional mudstone and/or carbonaceous units occurring in the Aries Overburden, Castor Interburden and Mackenzie Interburden.
Massive Sandstones	Massive to thickly bedded sandstone, typically medium to coarse grained occurring predominately in the Mackenzie Interburden.
Coal	Black coal.
Yarrabee Tuff	Stratigraphically continuous tuffaceous layer.
Tuff Lower	Stratigraphically continuous tuffaceous layer located approximately 1m to 2m below the Yarrabee Tuff.
Burngrove Formation	Sandstone and siltstone residing in the pit floor.

2.3 Seismic Risk

The Geoscience Australia Earthquake Hazard Maps (Earthquake Hazard Maps) present peak ground acceleration (response spectral period of 0.01 seconds) on rock expected for a 50 year return period, in units of *g*, evaluated for the geometric mean of the horizontal components.

For Curragh, the following have been obtained from the Earthquake Hazard Maps (Figure 2-3 and Figure 2-4):

- Exceedance probability of 10% in 50 years = 0.0-0.005g; and
- Exceedance probability of 2% in 50 years = 0.0-0.02g.

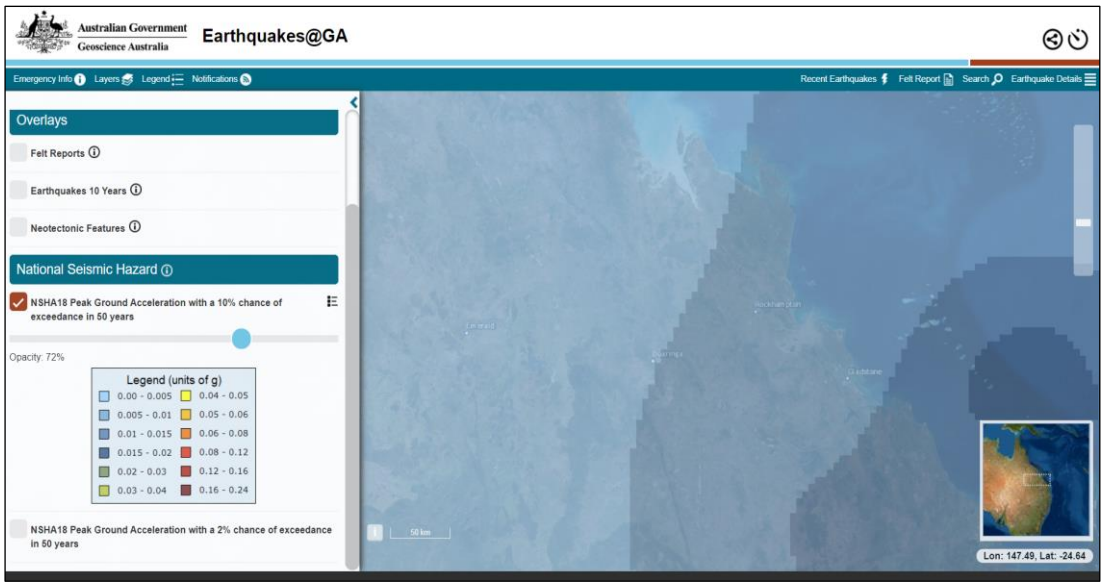


Figure 2-3 Geoscience Australia Earthquake Hazard Map - 10% chance of exceedance in 50 years

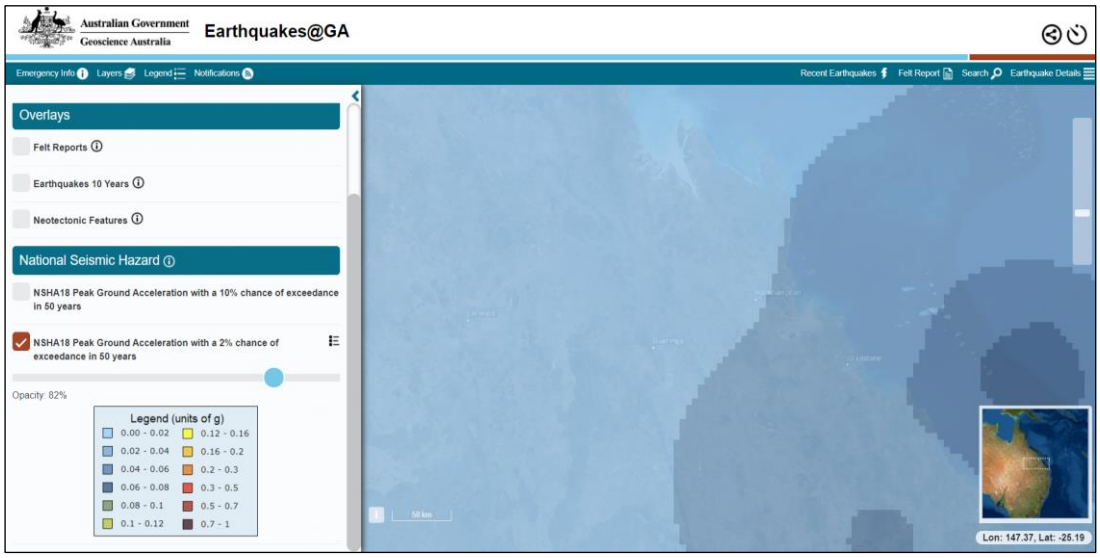


Figure 2-4 Geoscience Australia Earthquake Hazard Map - 2% chance of exceedance in 50 years

2.4 Predicted Flood Levels

Predicted flood levels for a 1:1000 AEP flood have been provided by SLR Consulting Australia Pty Ltd (SLR) and are outlined in Table 2-3. Refer to Section 4 of this report for Section locations and orientations.

Table 2-3 Supplied Flood Levels for selected section locations

Section	Flood Level (AGD66)	Section	Flood Level (AGD66)
Section 1	137.62 mAHD	Section 6	156.6 mAHD
Section 2	140.0 mAHD	Section 7	162.7 mAHD
Section 3	140.5 mAHD	Section 8	Dry
Section 4	142.7 mAHD	Section 9	Dry
Section 5	143.4 mAHD	-	-

3. Geotechnical Laboratory Data

3.1 Soil Test Results

Laboratory test results for soil and alluvial materials utilised in these works were obtained from the following sources:

- The Minserve Group Pty Ltd (1998), Jellinbah Station Project (CN) Report. The following data were obtained from this report:
    - 4 Emerson Class Tests;
    - 21 Atterberg Limits Test Results; and,
    - 25 Particle Size Distribution Test Results.
- Golder Associates Pty Ltd (2012), Design Report Curragh U, S & T Pit Levee Raising Report. The following data were obtained from this report:
    - 44 CPT Profiles (located in the vicinity of the S-Pit and T-Pit South levee);
    - 26 Emerson Class Tests;
    - 38 Atterberg Limits Test Results; and,
    - 40 Particle Size Distribution Test Results.
- Drilling through alluvial soils and weathered rock in S-Pit South (2016):
    - 11 Atterberg Limits Test Results; and,
    - 6 Particle Size Distribution Test Results.
- Grab samples obtained from exposed alluvial materials in S-Pit and S-Pit South (2018 and 2019):
    - 10 Emerson Class Tests;
    - 17 Atterberg Limits Test Results; and,
    - 17 Particle Size Distribution Test Results.

Atterberg Limits, and Particle Size Distribution test data are presented in Figure 3-1, Figure 3-2 and Figure 3-3. Laboratory certificates and associated reports are provided on the CCPL systems.

3.2 Rock Core Laboratory Test Results

Uniaxial Compressive Strength data obtained from cored boreholes drilled at Curragh are provided in Table 3-1 and Table 3-2. Direct shear test results for the Yarrabee Tuff are provided in Figure 3-4. Laboratory certificates are provided on the CCPL system.

Table 3-1 Summary of Uniaxial Compressive Strength Data Available for Curragh Main

Material Unit	Lithology	Mean Strength (UCS)	No of Samples
Aries Overburden	Siltstones, Sandstones, Mudstones & Carbonaceous Materials	15.73	55
Castor Interburden	Siltstones, Sandstones, Mudstones & Carbonaceous Materials	17.96	38
Pollux Interburden	Siltstones, Sandstones, Mudstones & Carbonaceous Materials	23.59	59
Virgo Interburden	Sandstones & Siltstones	17.75	10
Coal	Black Coals	7.13	12
Yarrabee Tuff	Tuff	25.30	5
Pit Floor	Sandstone, Siltstone & Carbonaceous Materials	28.69	49

Table 3-2 Summary of Uniaxial Compressive Strength Data Available for Curragh North

Material Unit	Lithology	Mean Strength (UCS)	No of Samples
Aries Overburden	Siltstones, Sandstones, Mudstones, Claystones & Carbonaceous Materials	24.24	109
Castor Interburden	Siltstones, Sandstones & Carbonaceous Materials	27.61	21
Mackenzie Interburden	Siltstones, Sandstone, Carbonaceous Materials & Massive Sandstone	26.87	162
Aries, Castor & Mackenzie Seams	Black Coals	6.92	15
Yarrabee Tuff	Tuff	15.61	3
Pit Floor	Sandstone, Siltstone & Carbonaceous Materials	28.69	43

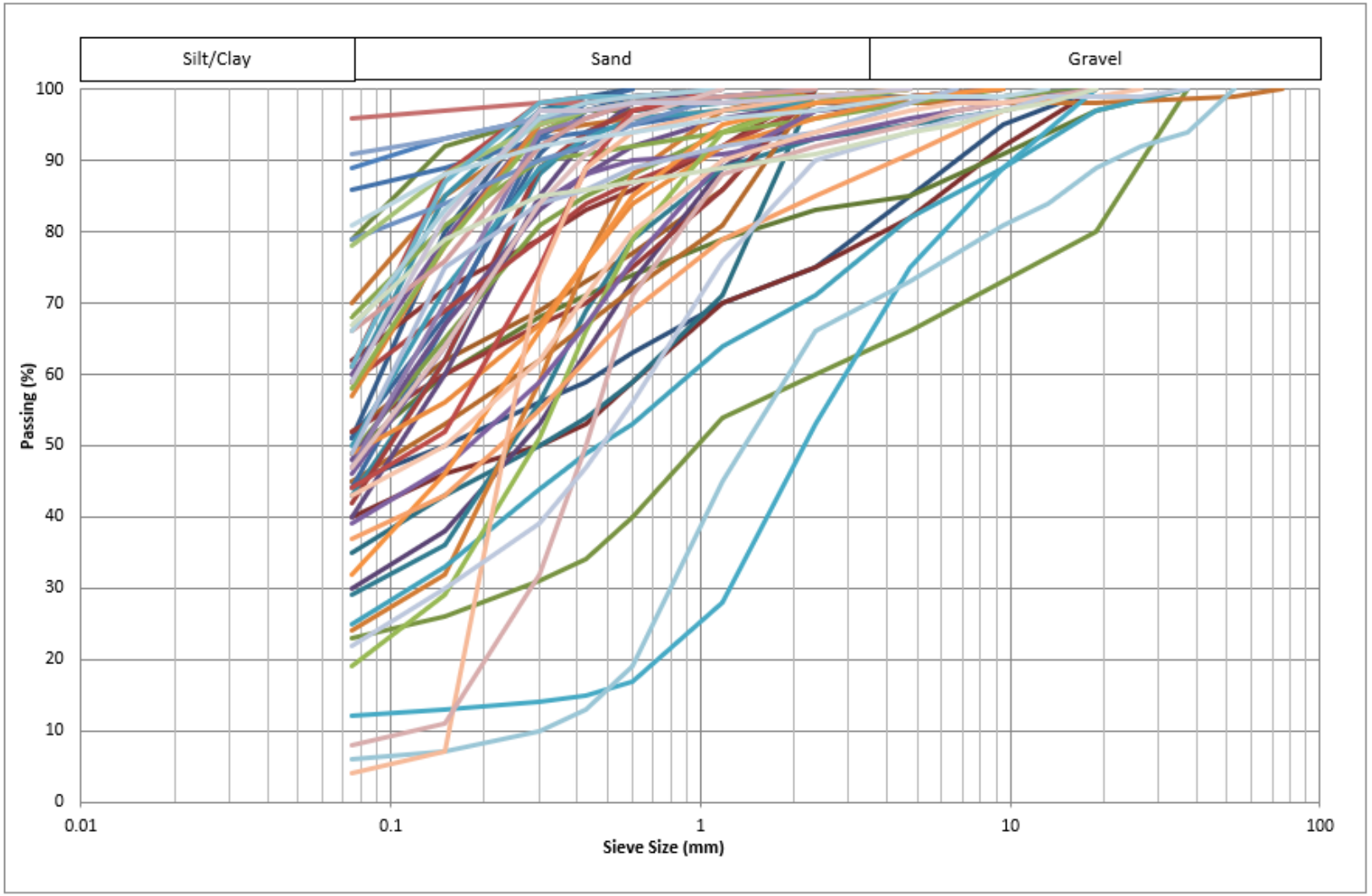


Figure 3-1 Particle Size Distribution Chart – Quaternary Soil Materials

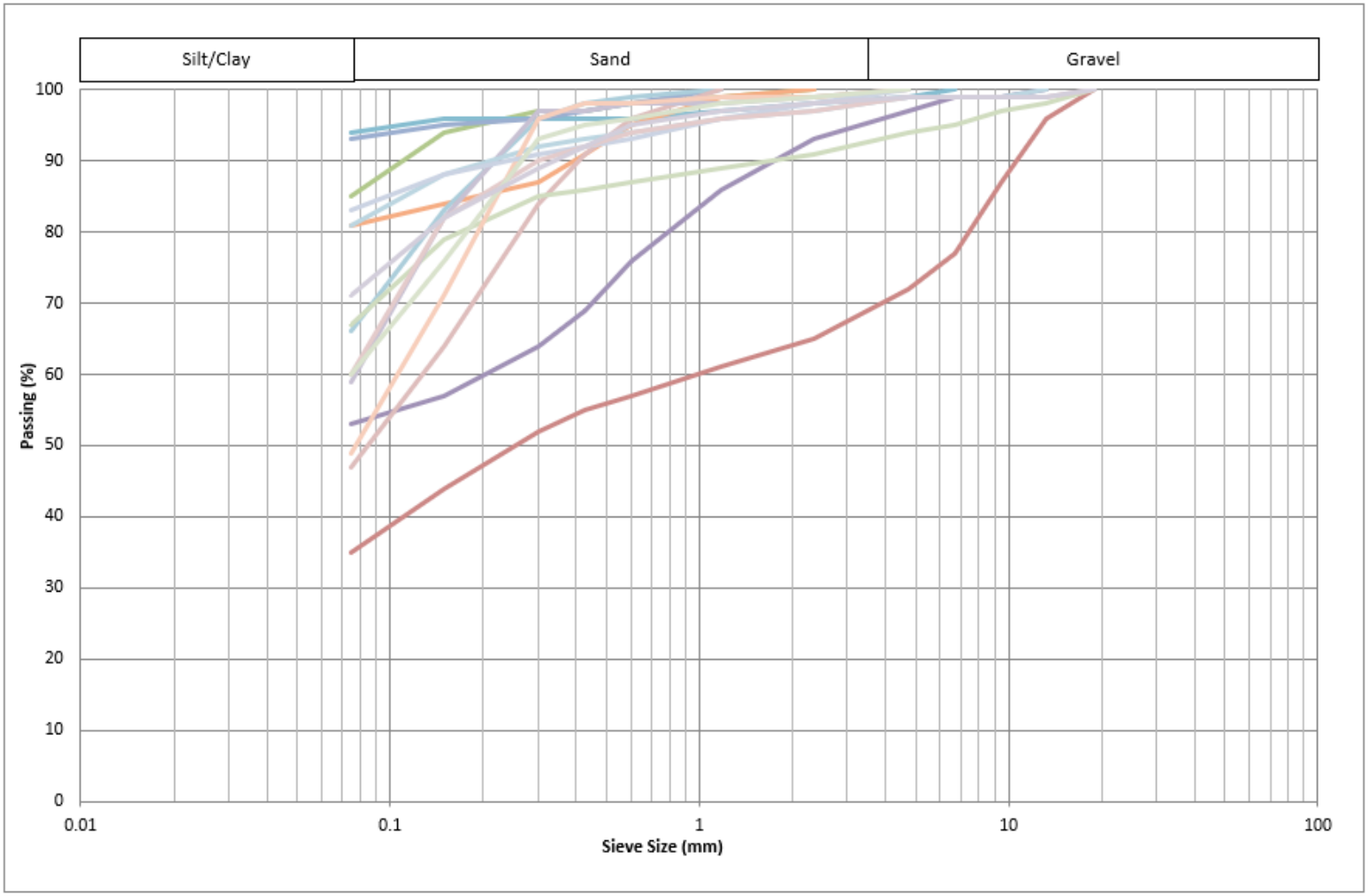


Figure 3-2 Particle Size Distribution Chart – Tertiary Soil Materials

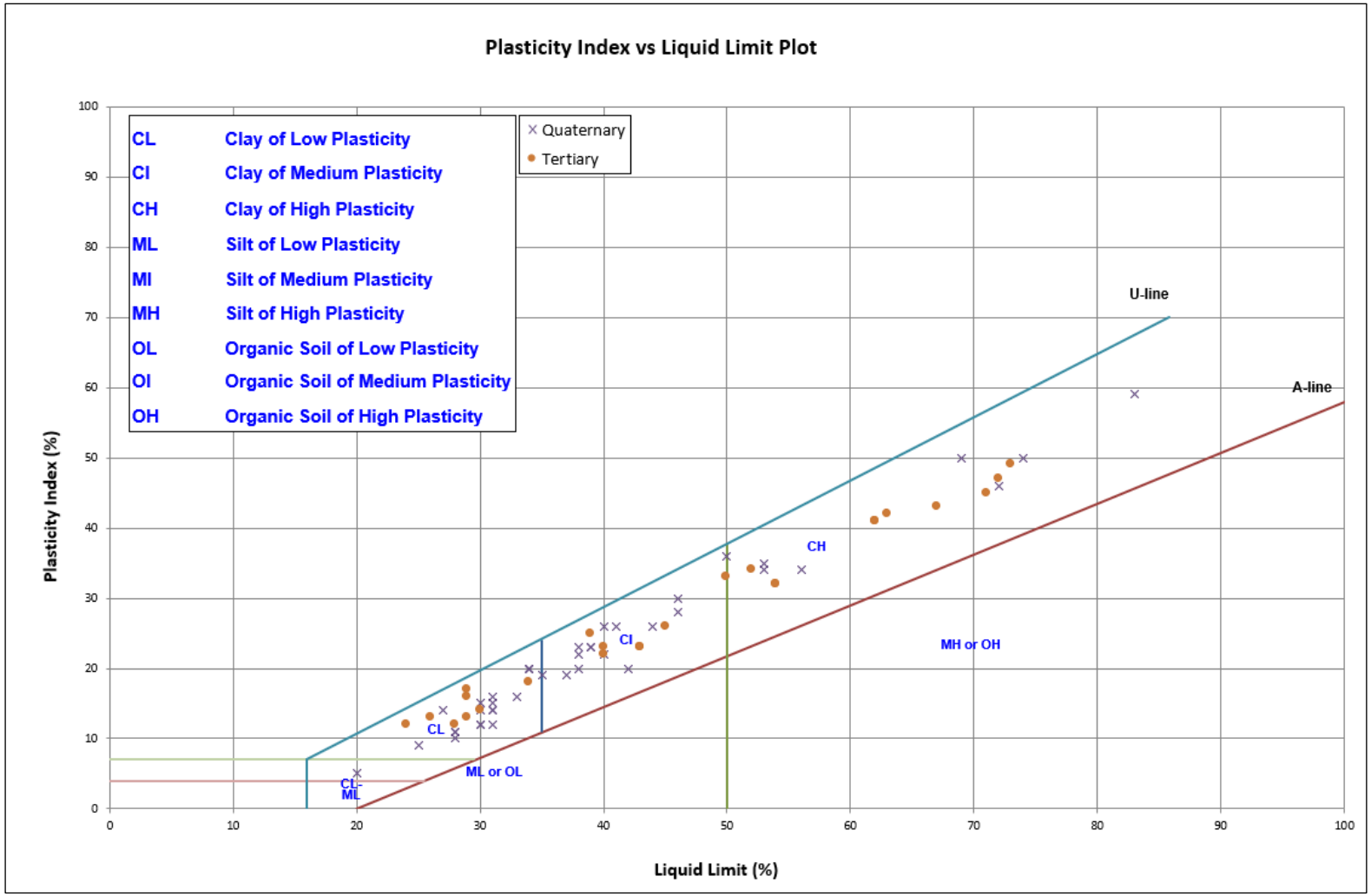


Figure 3-3 Casagrande Chart – Quaternary & Tertiary Clays

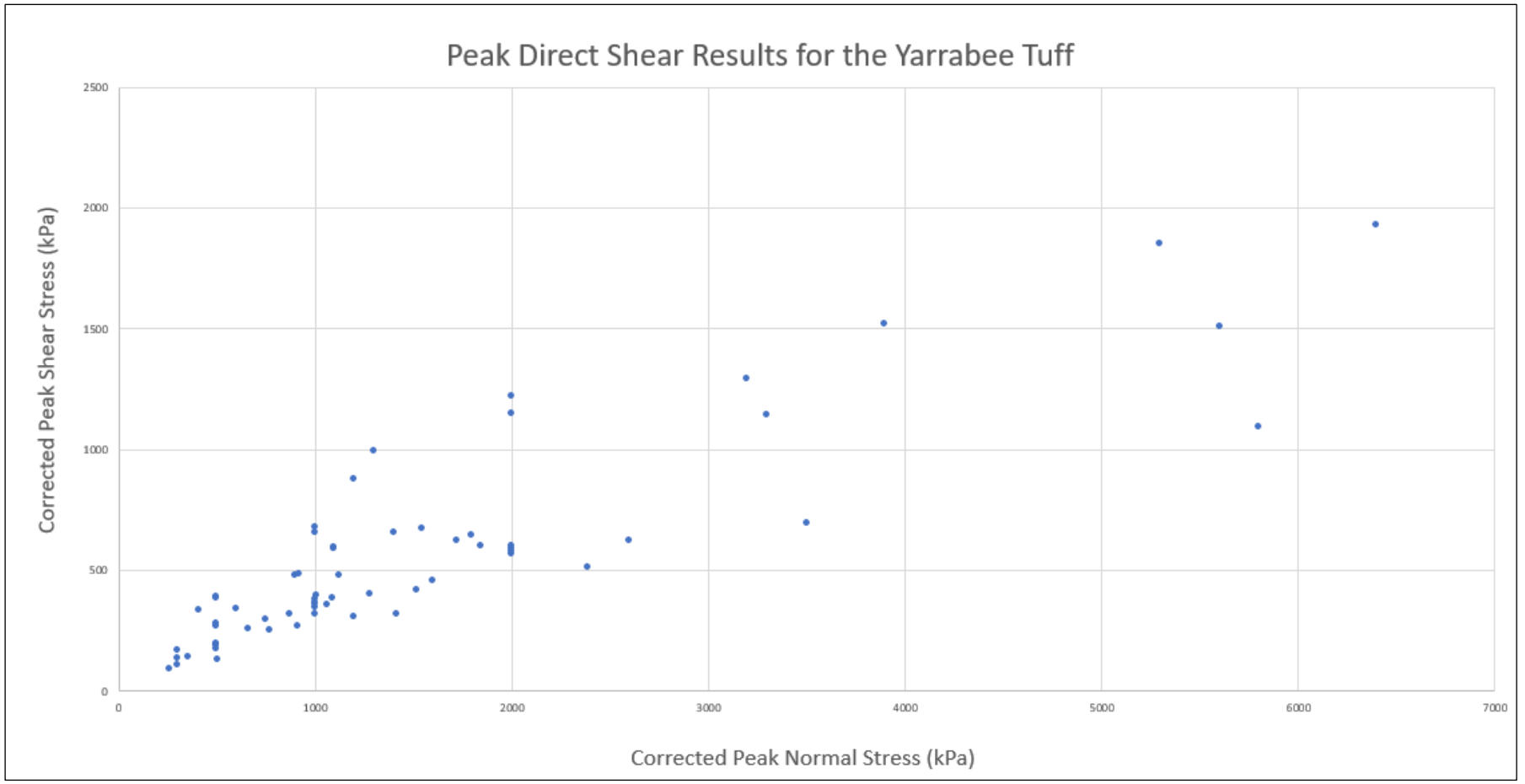


Figure 3-4 Peak Direct Shear Data for the Yarrabee Tuff at Curragh

4. Final Landform Designs

The final landform designs, which form the basis for this works, have been provided by CCPL (refer to Section 1.2).

As noted in Section 2, pitwall design revisions are often developed and implemented to mitigate the risks associated with geological faults and pitwall stability. As a result, where the current final landform design comprises remnant pitwalls alternative pitwall design options are presented for consideration. These alternative options provide some contingency for the possibility that adverse ground conditions, including geological faults, could be encountered at the planned final pitwall locations.

To account for the flood levels supplied for X-Pit the supplied final landform surface has been raised by approximately 10m for the purpose of the analyses presented in this report.

The following cross-sections and scenarios have been considered (refer to Figure 4-1 to Figure 4-11):

- Section 1 U-Pit Cross Section;
- Section 2 S-Pit South Cross Section;
- Section 3 X-Pit Cross Section;
- Section 4 D-Pit Cross Section;
- Section 5 F-Pit South Cross Section;
- Section 6 K-Pit Cross Section;
- Section 7 J-Pit Cross Section;
- Section 8 Y-Pit Cross Section; and,
- Section 9 Z-Pit Cross Section.

The adopted geotechnical ground model scenarios are provided in Table 4-1.

Table 4-1 Adopted Ground Model Scenarios

Cross Section	Scenario
Section 1: U-Pit	Planned Final Landform Option - Highwall Side
Section 2: S-Pit South	Planned Final Landform Option - Highwall Side
	Planned Final Landform Option - Lowwall Side
Section 3: X-Pit	Planned Final Landform Option - Highwall Side
Section 4: D-Pit	Planned Final Landform Option - Highwall Side
	Alternative Final Landform Option - Highwall Side
	Alternative Final Highwall Re-Shaped Final Slope Option - Highwall Side

Cross Section	Scenario
Section 5: F-Pit South	Planned Final Landform Option - Highwall Side
	Alternative Final Highwall Re-Shaped Final Slope Option - Highwall Side
	Planned Final Landform Out Board Slope
	Planned Final Landform Option - Lowwall Side
Section 6: K-Pit	Planned Final Landform Option - Highwall Side
	Alternative Final Landform Option - Highwall Side
	Alternative Final Highwall Re-Shaped Final Slope Option - Highwall Side
Section 7: J-Pit	Planned Final Landform Option - Highwall Side
	Planned Final Highwall Re-Shaped Final Slope - Highwall Side
Section 8: Y-Pit	Planned Final Landform Option - Highwall Side
	Planned Final Highwall Re-Shaped Final Slope - Highwall Side
Section 9: Z-Pit	Planned Final Landform Option - Highwall Side
	Planned Final Highwall Re-Shaped Final Slope - Highwall Side

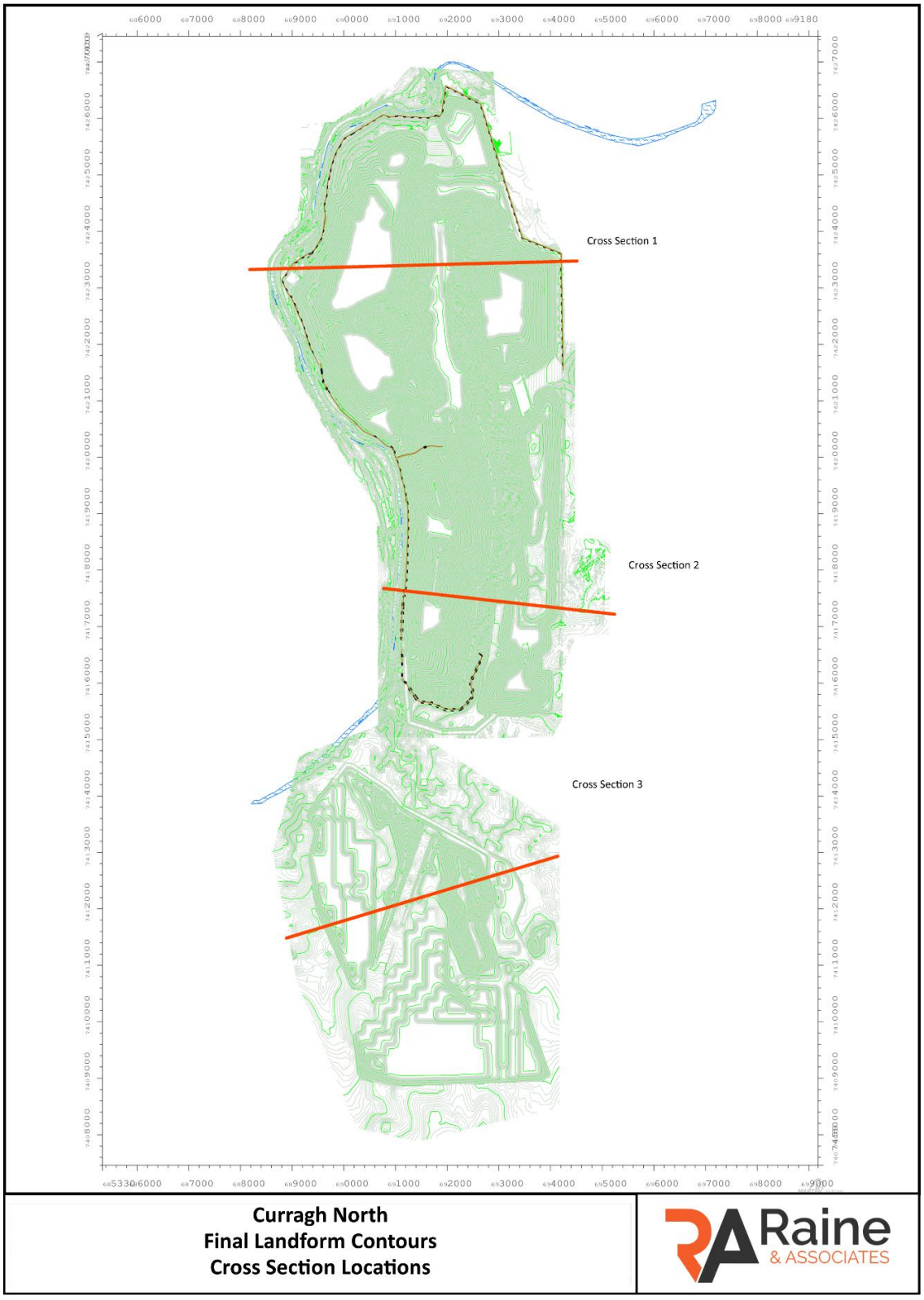


Figure 4-1 Curragh North Final Landform & Cross Section Locations

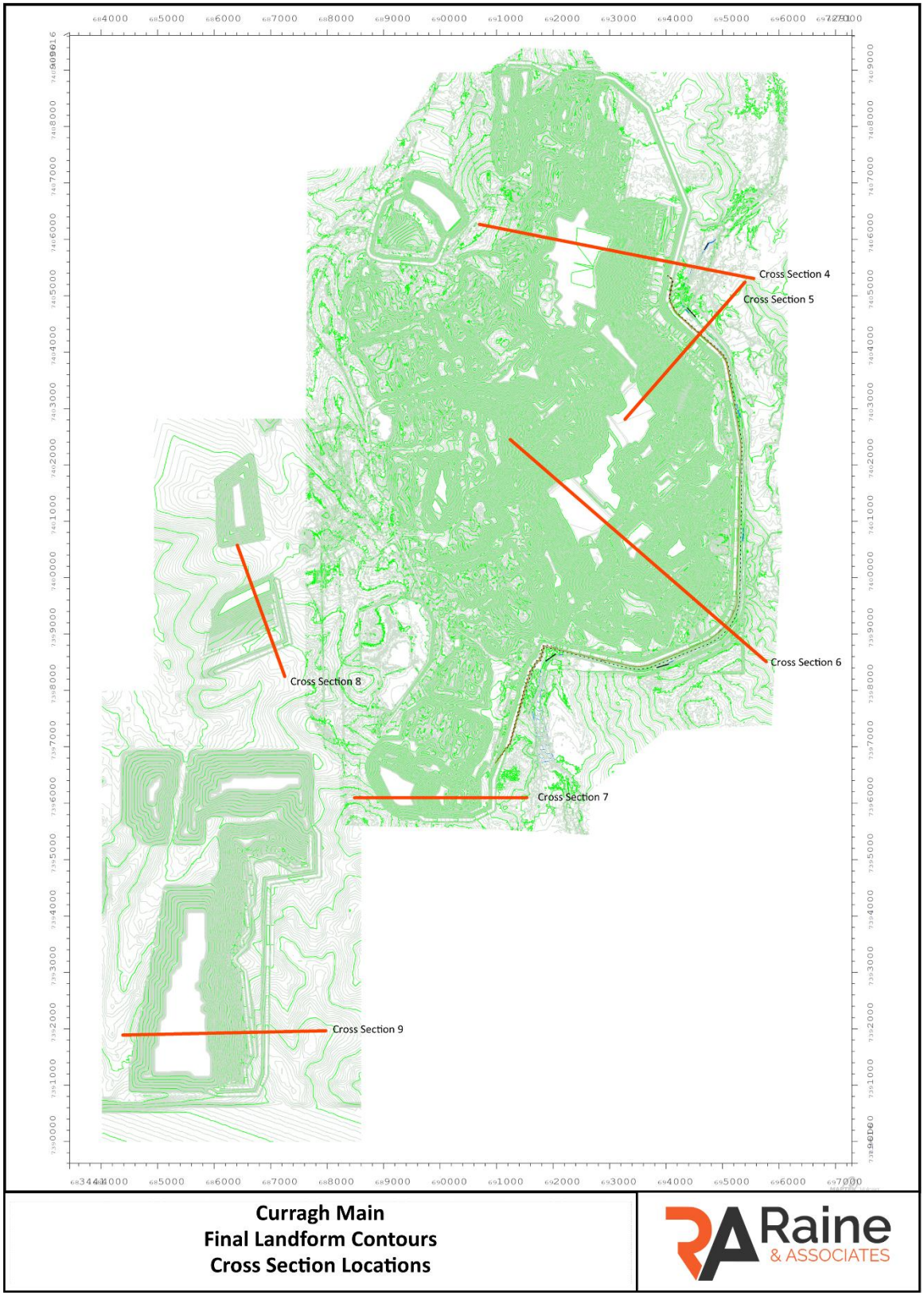


Figure 4-2 Curragh Main Final Landform& Cross Section Locations

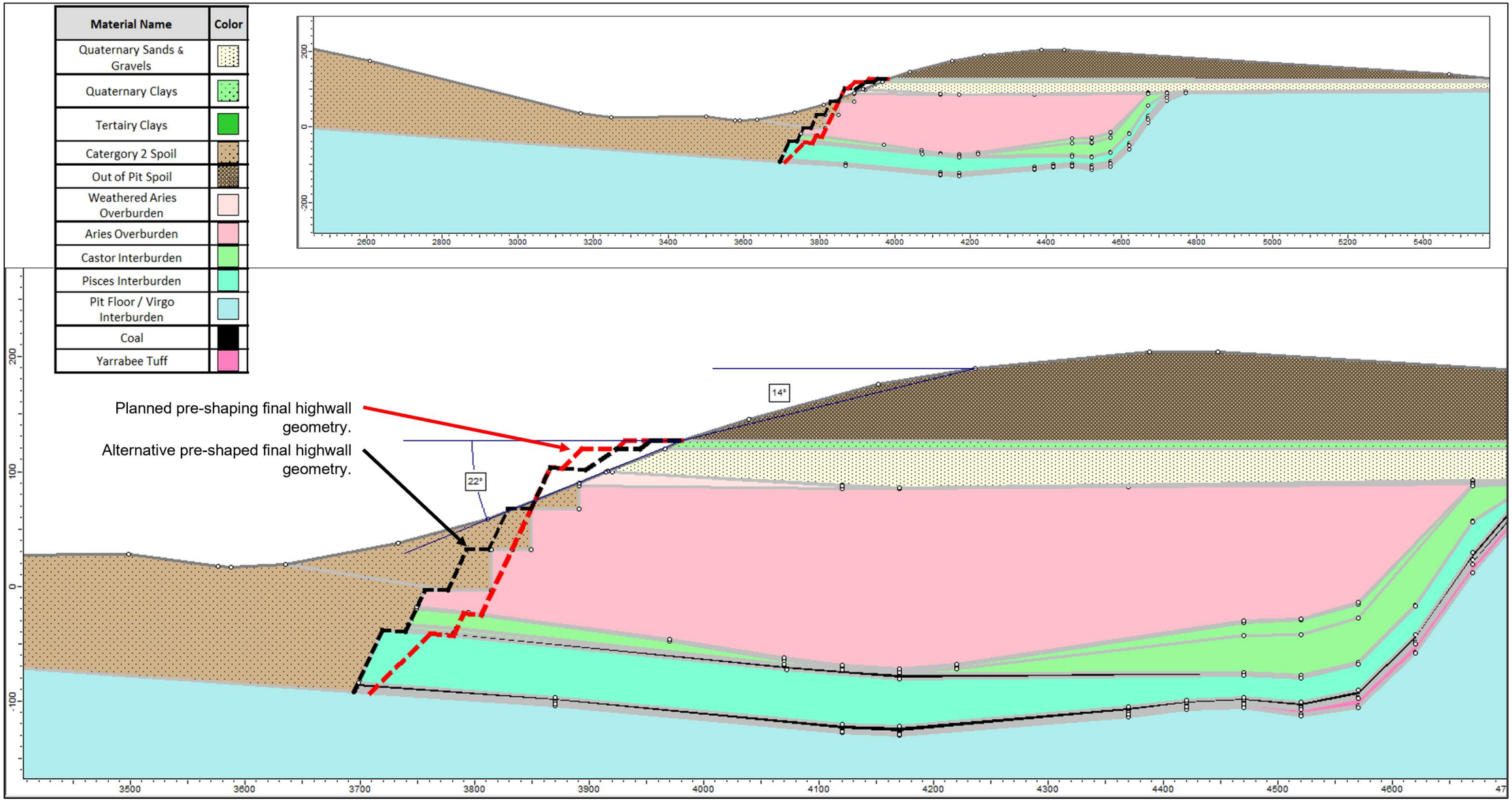


Figure 4-3 Cross Section 1 – Curragh North U-Pit

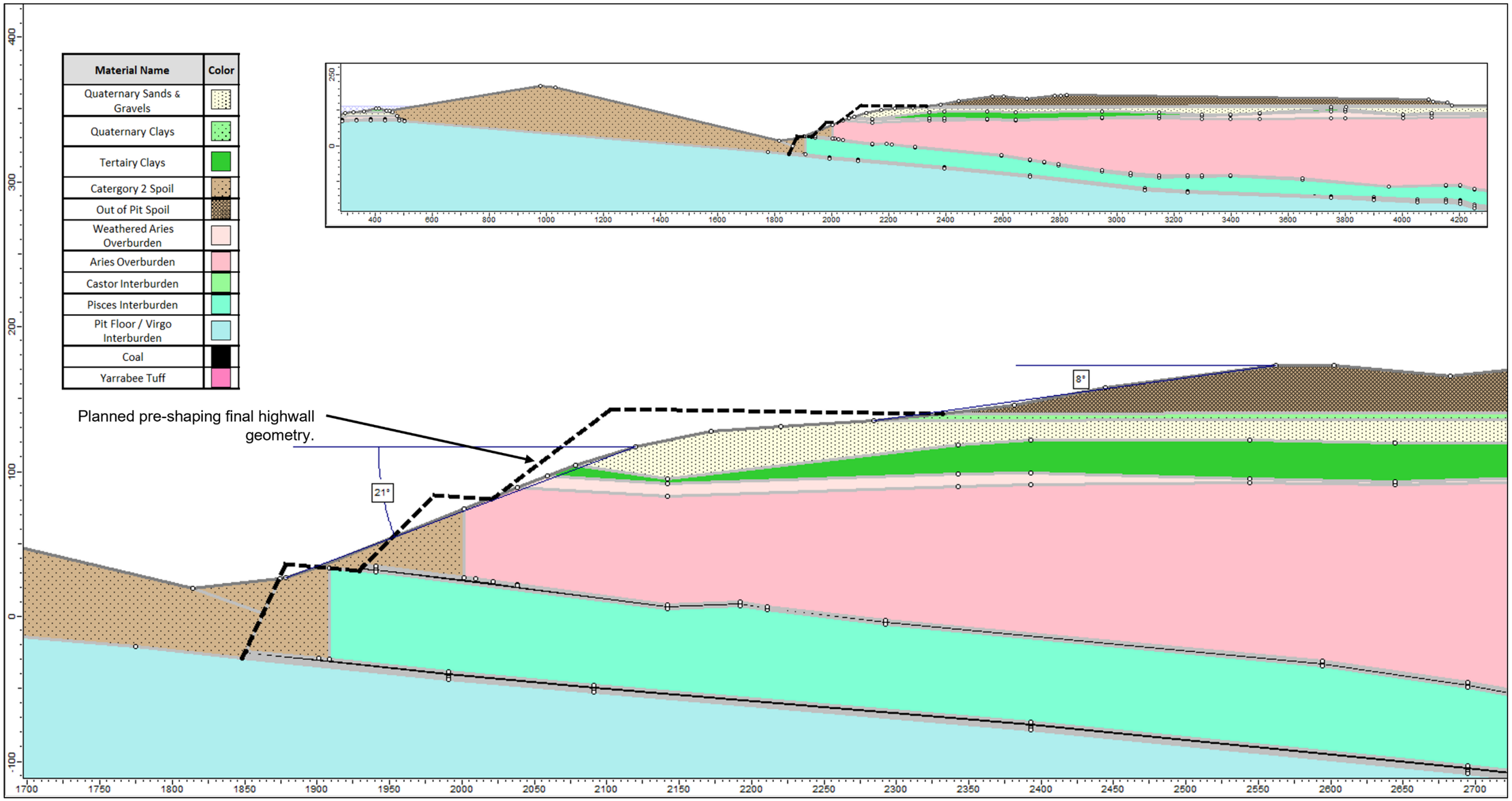


Figure 4-4 Cross Section 2 – Curragh North S-Pit South

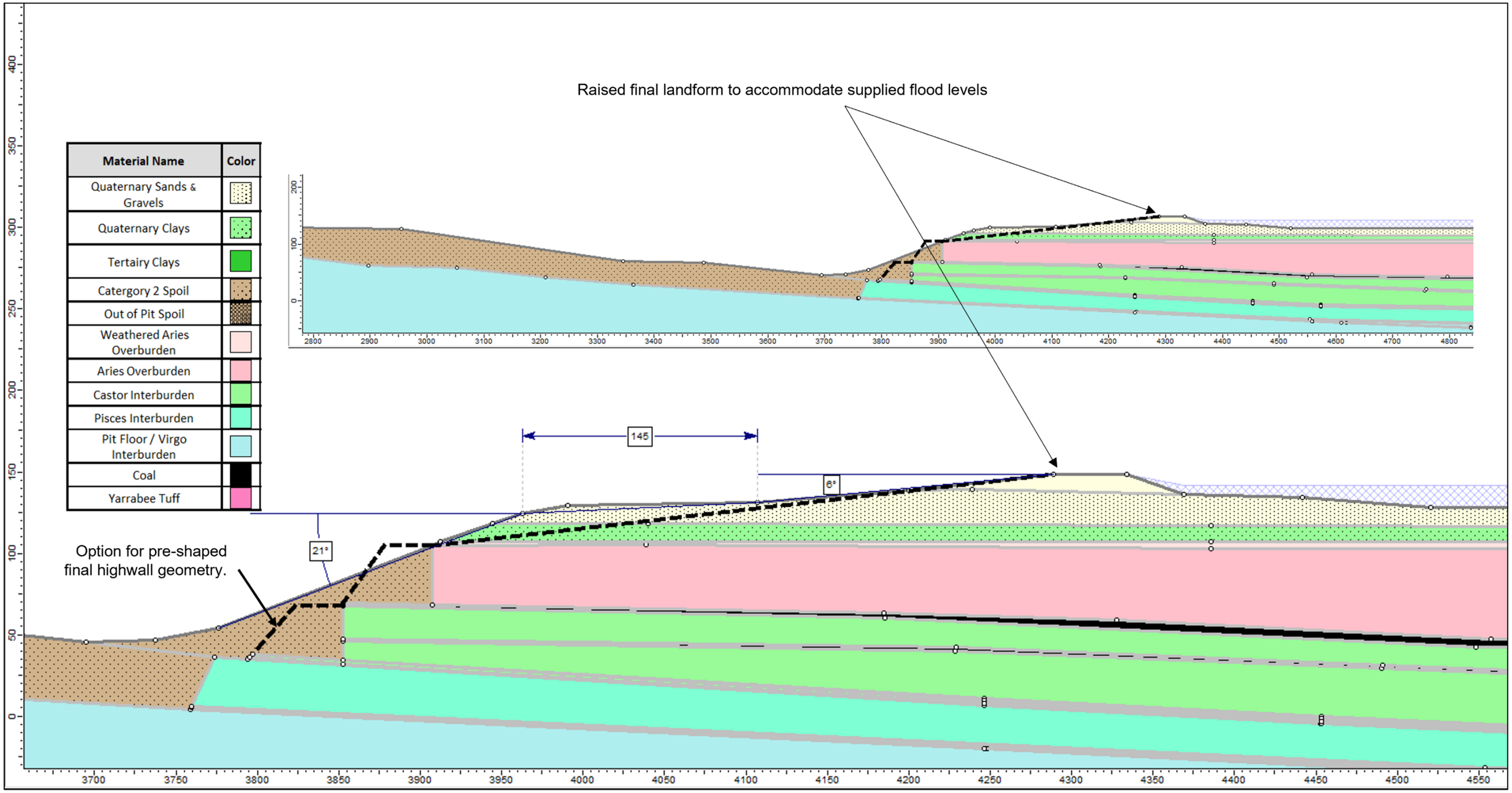


Figure 4-5 Cross Section 3 – X-Pit

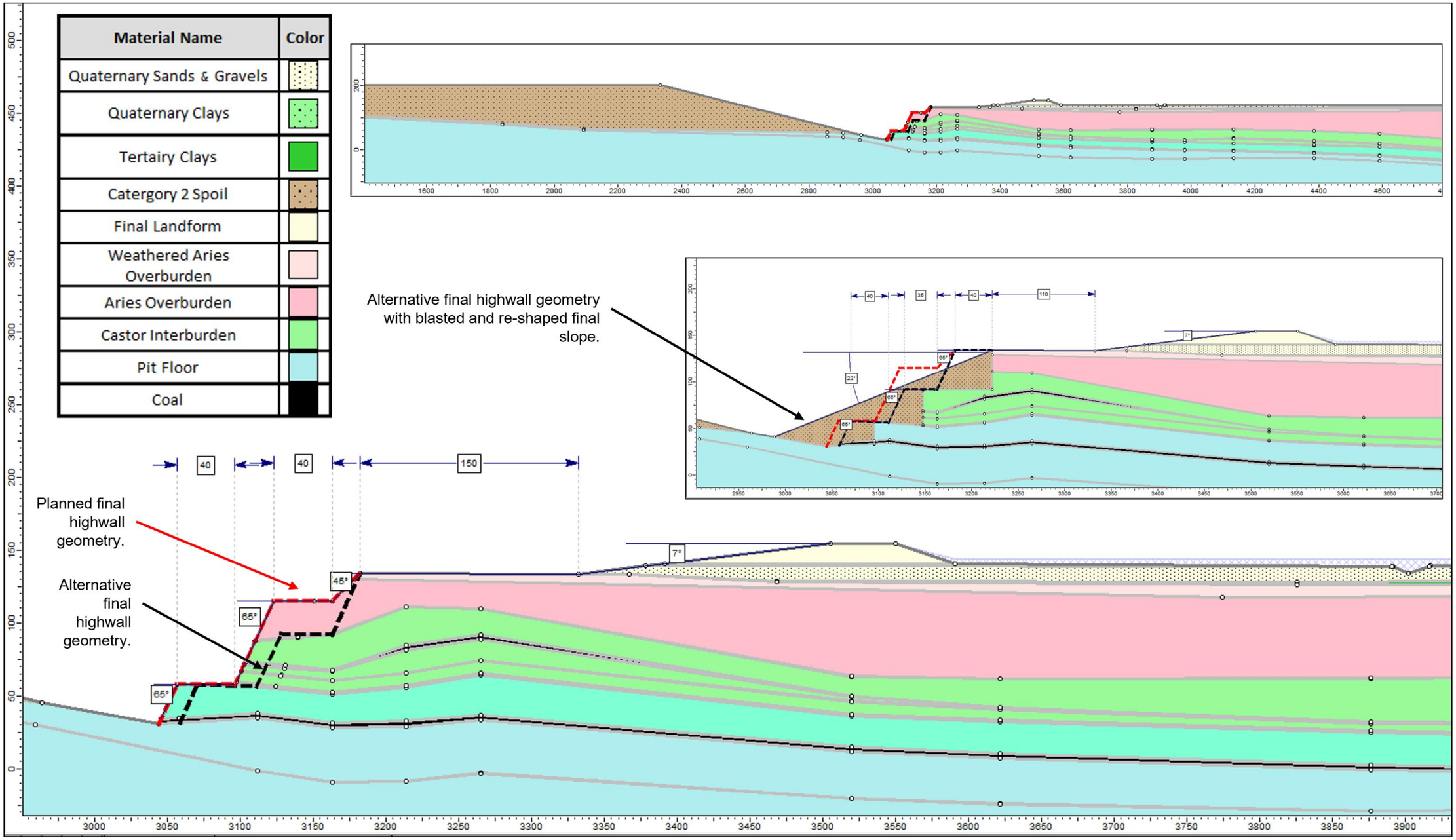


Figure 4-6 Cross Section 4 – Curragh Main D-Pit

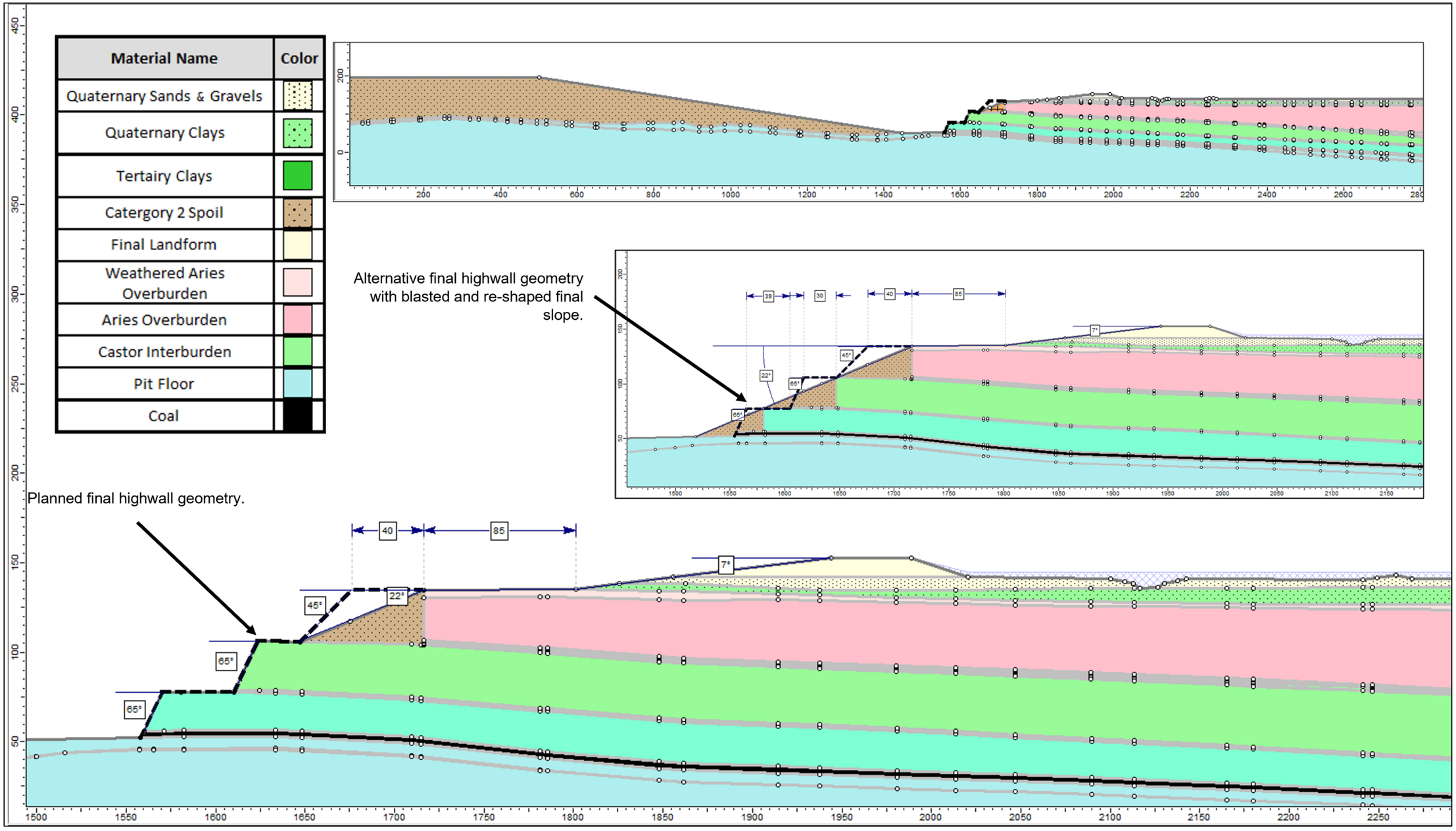


Figure 4-7 Cross Section 5 – Curragh Main F-Pit

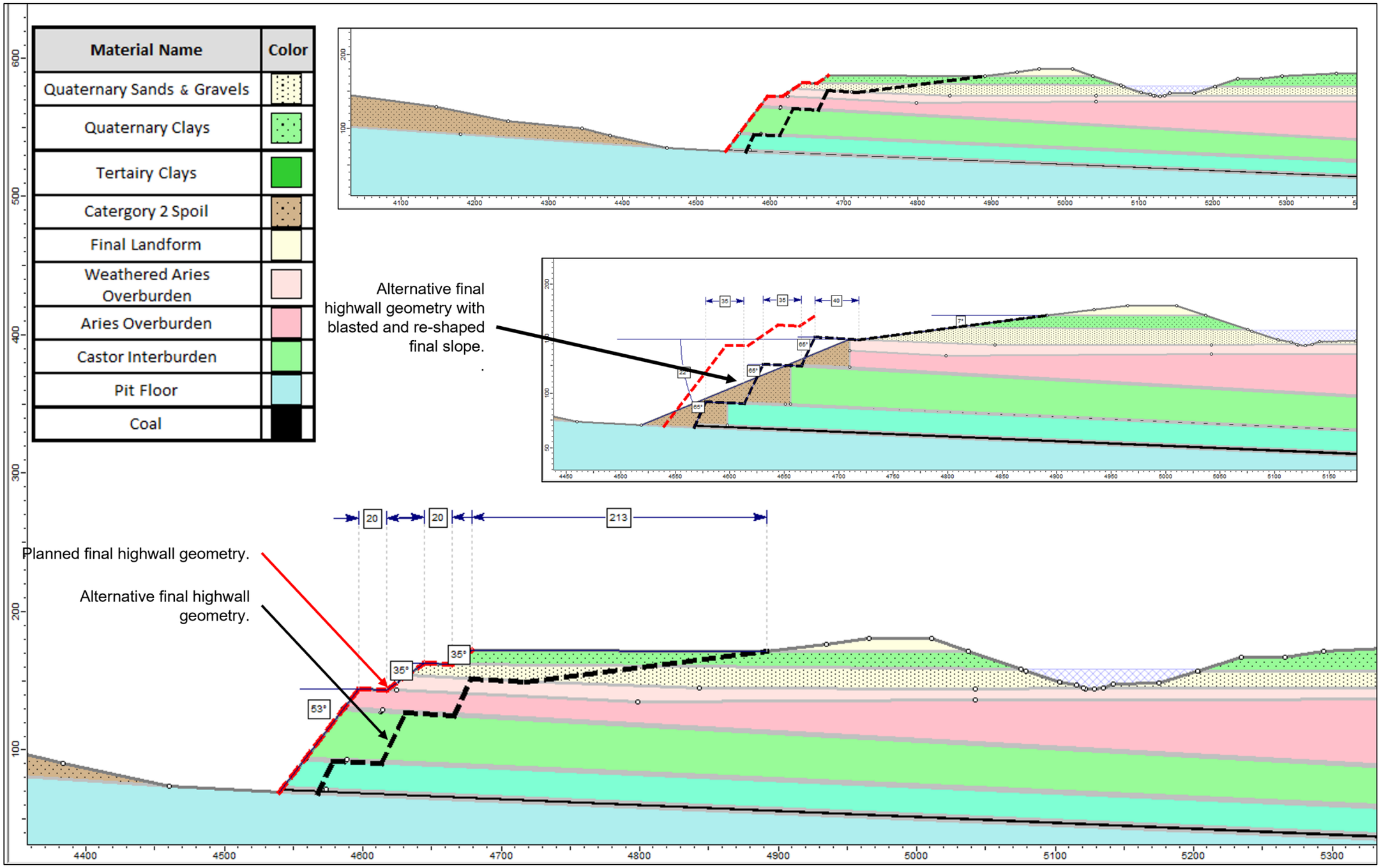


Figure 4-8 Cross Section 6 – Curragh Main K-Pit

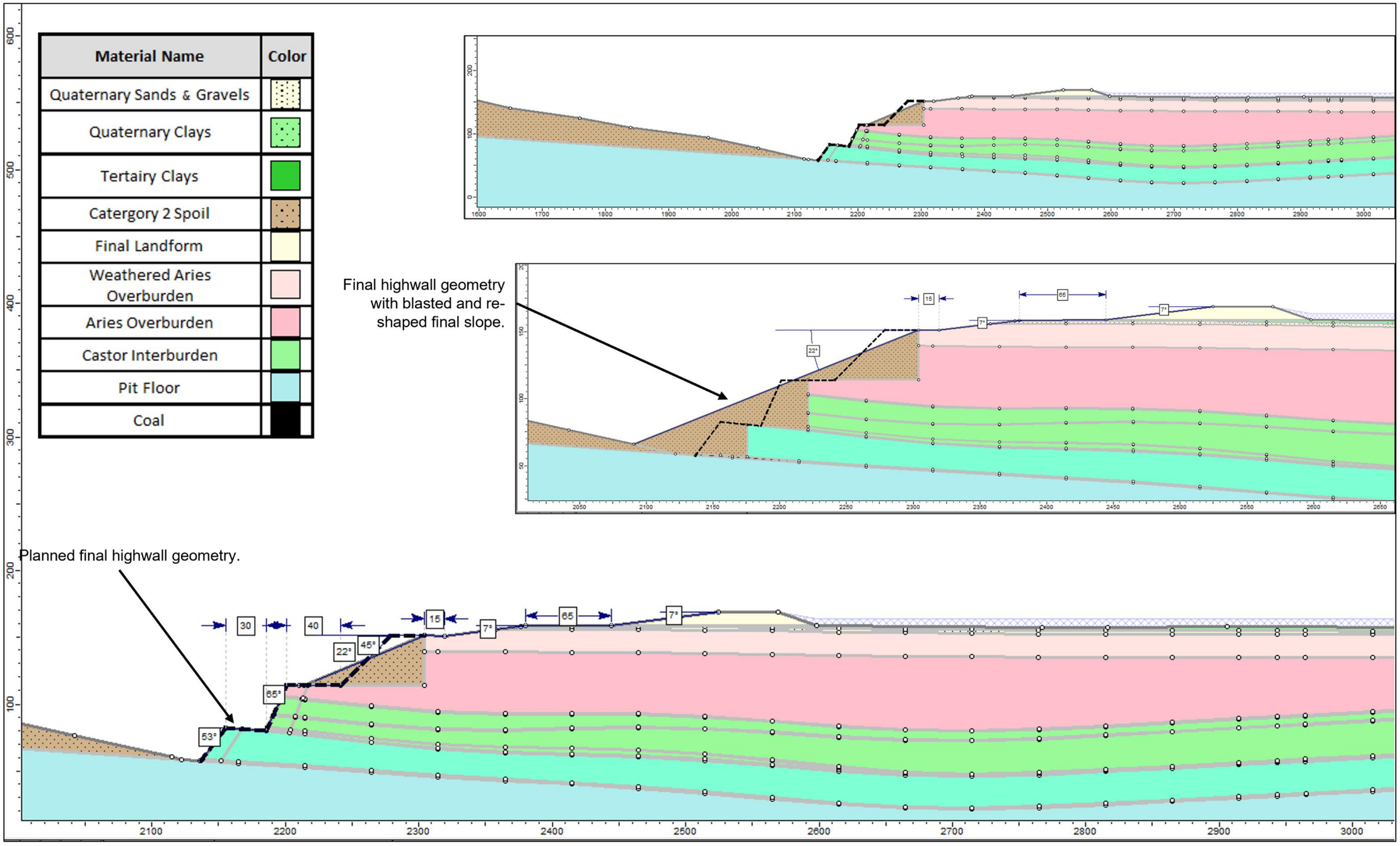
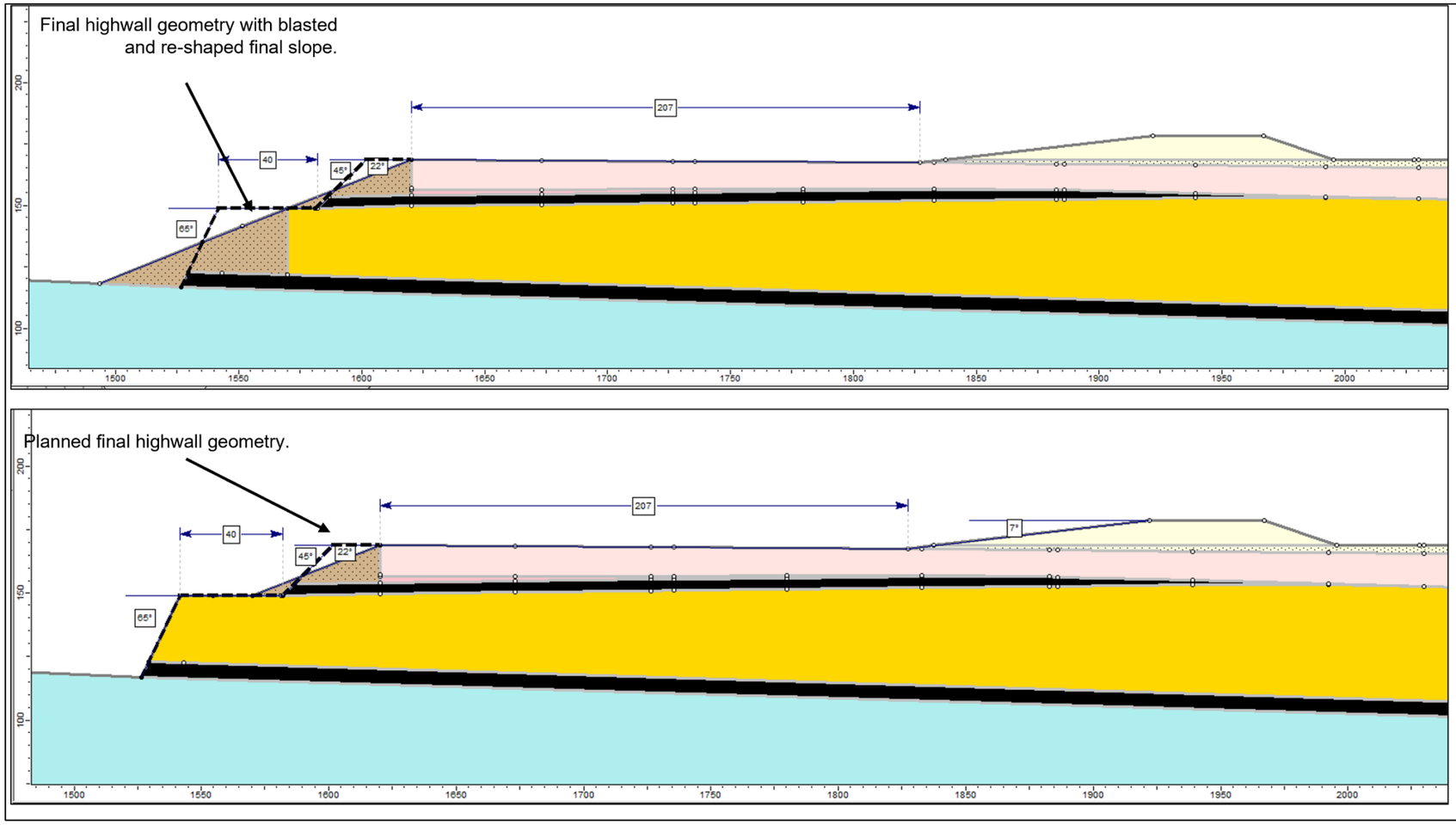


Figure 4-9 Cross Section 7 – Curragh Main J-Pit



Material Name	Color
Quaternary Sands & Gravels	
Catergory 2 Spoil	
Final Landform	
Weathered Aries Overburden	
Aries Overburden	
Pit Floor	
Coal	
Virgo Interburden	

Figure 4-10 Cross Section 8 – Y-Pit

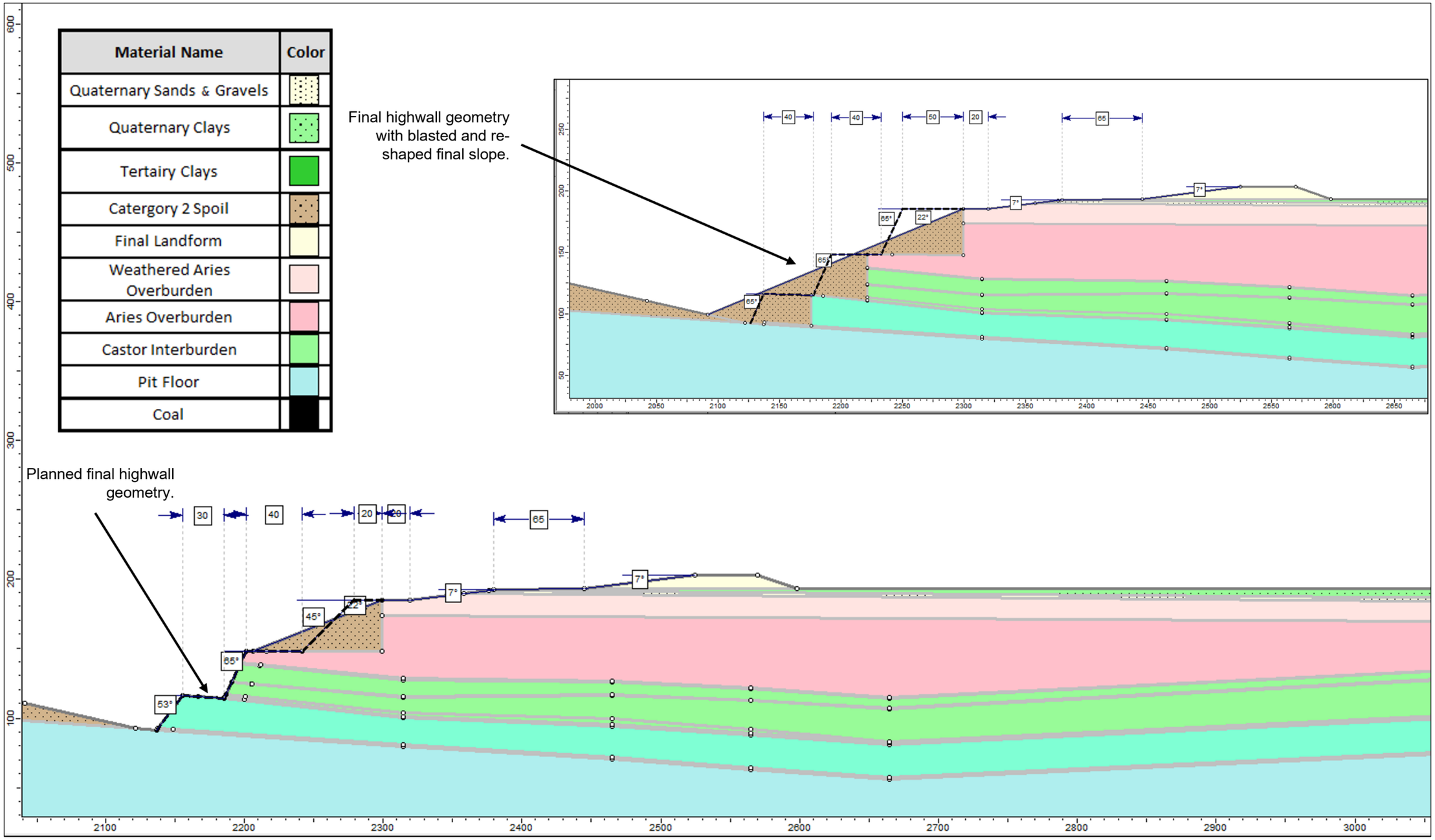


Figure 4-11 Cross Section 9 – Z-Pit

5. Slope Stability Analysis – Adopted Methodology

5.1 Adopted Geotechnical Ground Models

The adopted geotechnical ground models have been developed in Rocscience's proprietary software SLIDE 2.0 (SLIDE) and are based on the supplied final landform designs, flood levels and geological, geotechnical and hydrogeological data.

Two-dimensional limit equilibrium slope stability analysis has been completed for nine (9) cross-section final landform slope geometries, which are presented in Section 4.

5.2 Material Parameters

5.2.1 Spoil Dump Material Parameters

5.2.2 In-Pit Spoil Dumps

In general, the dragline spoil is observed to consist of spoil materials derived from fresh to weathered Permian rock. In considering the data presented in Simmons and McManus (2004) Hawley and Cunning (2017), and site observations, the spoil materials have been classified as Category 2 Spoil (refer to Figure 5-1 and Figure 5-2).

The truck dump terraces, which form the upper portions of the in-pit dumps, are considered to comprise materials similar to those described in Section 5.2.3 below.

5.2.3 Out-of-Pit Spoil Dumps

The out-of-pit dump composition appears to be highly variable with the following material types observed:

- Sands and Gravels;
- Clayey Sands;
- Low to High Plasticity Clays, Silty Clays and Sandy Clays; and,
- Highly Weathered to Slightly Weathered Permian Rock.

The adopted material strength parameters (Table 5-1) for the out-of-pit dump spoil have been taken from the following report:

- *RA002_201706_02_Rev0 Slope Stability Analysis for Out of Pit Dumps_Rev0*, dated November 2017.

Table 5-1 Adopted Out-of-Pit Spoil Dump Material Parameters

Material Name	Unit Weight (kN/m3)	Apparent Cohesion (kPa)	Friction Angle (°)
Spoil Dump Materials	18	3	28

Table 1
Shear Strength Parameters for Categories and Mobilisation Modes
(Parameter standard deviations in italicised parentheses)

Category	Unsaturated			Saturated			Remoulded
	γ (kN/m³)	c' (kPa)	ϕ' (deg)	γ (kN/m³)	c' (kPa)	ϕ' (deg)	c'=0 kPa, ϕ' (deg)
1	18 *(1)*	20 *(10)*	25 *(2.5)*	20 *(1)*	0 *(0)*	18 *(3)*	18 *(1.5)*
2	18 *(1)*	30 *(15)*	28 *(3)*	20 *(1)*	15 *(7.5)*	23 *(2.5)*	18 *(1.5)*
3	18 *(1)*	50 *(15)*	30 *(2)*	20 *(1)*	20 *(10)*	25 *(2.5)*	18 *(1.5)*
4	18 *(1)*	50 *(15)*	35 *(2.5)*	20 *(1)*	0 *(0)*	30 *(1.5)*	28 *(2)*

Figure 5-1 Shear Strength Parameters for Categories and Mobilisation Modes (Simmons & McManus, 2004).

Table 2
Spoil Categories and Attributes

CATEGORY		1	2	3	4
Description Attributes	**Weighting** *(excl. Age)*	Fine-grained clay-rich high plasticity	Fine-grained low plasticity with larger clasts	Larger clasts with fine matrix, low plasticity	Large blocks, minor fines, minor slaking
Predominant Particle Size	3/31=**9.7%** *(11.6%)*	Clay	Sand	Gravel	Cobbles
Consistency: cohesive cohesionless	7/31=**22.6%** *(26.9%)*	Soft to Firm Loose	Stiff Med. Dense	Hard Dense	XLS+ rock Very Dense
Structure	7/31=**22.6%** *(26.9%)*	Matrix only	Matrix supported	Framework supported	Framework only
Liquid Limit	9/31=**29.0%** *(34.6%)*	High (>50)	Intermediate (35 – 50)	Low (20 – 35)	Not Plastic (<20)
Age	5/31=**16.1%**	0 - 2y	2 - 10y	10 - 30y	>30y

(Note: XLS+ rock refers to rock of extremely low strength, or higher)

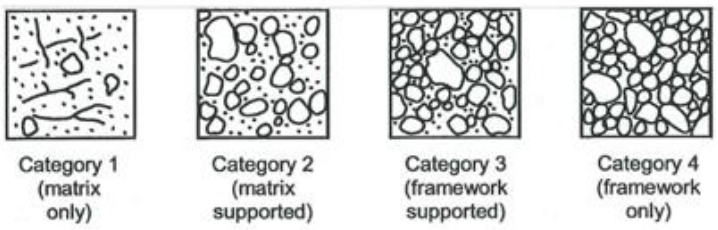


Figure 6 Spoil structure control ranking (use with Table 2)

Figure 5-2 Spoil Categories and Attributes (Simmons and McManus, 2004).

5.3 In-Situ Alluvial Material Parameters

5.3.1 Alluvial Clays

The material strength parameters adopted for in-situ clays have been based on available Atterberg Limits test data available for Curragh. Mesri (1993) calculations were undertaken to develop the material parameters presented in Table 5-2 and Table 5-3.

which represent a curved Mohr-Coulomb failure envelope, with friction angle reducing with increasing normal stress.

Table 5-2 Adopted Clay Material Parameters – Quaternary Clays

Normal Stress (kPa)	Shear Stress (kPa)
0.5	0.9
2	2.7
5	5.8
10	10.3
20	18.3
50	39.1
100	69.6
150	97.4
225	136.4
300	173.2
400	219.9
1000	470.5

Table 5-3 Adopted Clay Material Parameters – Tertiary Clays

Normal Stress (kPa)	Shear Stress (kPa)
0.5	1.5
2	4.3
5	8.6
10	14.5
20	24.4
50	48.5
100	81.6
150	110.7
225	150.0
300	186.1
400	230.9
1000	459.1

5.3.2 Alluvial Sands and Gravels

Consideration has been given to available laboratory test data and the observed pitwall performance associated with these materials. Adopted material strengths for the Sands and Gravels are provided in Table 5-4.

Table 5-4 Adopted Sand Material Parameters

Material Name	Unit Weight (kN/m3)	Apparent Cohesion (kPa)	Friction Angle (°)
Sands & Gravels	18	0	35

5.4 Permian Rock Mass Strength

The rock mass strength parameters presented in Table 5-8 and Table 5-9 have been developed from available geological and geotechnical data (i.e. geotechnical borehole data and laboratory test data) and field observations using Rocscience's proprietary software RocData incorporating disturbance factors (D) of 0 and 0.7, for a non-blast affected and a blast affect rock mass, respectively

5.4.1 Coal Material Strength

The adopted Coal material strength parameters were obtained from Martin & Stacey (2018) (Table 5-5).

Table 5-5 Adopted Coal Material Strength Parameters

Material	Unit Weight	Apparent Cohesion (kPa)	Friction Angle (°)
Coal	15	35	35

5.4.2 Tuff Material Strength

The adopted tuff material strength parameters are presented in Table 5-6 and have been derived from available direct shear test results.

Table 5-6 Adopted Tuff Material Strength Parameters

Material	Unit Weight	Apparent Cohesion (kPa)	Friction Angle (°)
Yarrabee Tuff	24	50	23

5.4.3 Adopted Hydraulic Conductivity

Adopted hydraulic conductivity values are presented in Table 5-7 and were provided by SLR for the presented analysis.

Table 5-7 Adopted hydraulic conductivity values for the considered material types

Material Name	Hydraulic Conductivity	
	K_h (m/s)	K_v/K_h (factor)
Quaternary Sands & Gravels	$1.509x10^{-5}$	0.0167
Quaternary Clays	$9.516x10^{-6}$	0.0167
Tertiary Clays	$3.617x10^{-8}$	0.0147
Weathered Permian Rock	$1.894x10^{-5}$	0.0474
Permian Rock	$9.00x10^{-10}$	0.0922
Coal Seams	$2.679x10^{-8}$	0.0156
Spoils	$1.736x10^{-4}$	0.246

Table 5-8 General Rock Mass Strength Parameters – Curragh Main

Parameter	Weathered Permian	Aries Overburden	Castor Interburden	Pollux Interburden	Pit Floor	Virgo Interburden
Unit Weight	22	24	24	24	24	24
Rock Strength (MPa)	3.62	15.73	17.96	23.59	23.96	16.85
GSI*	50	65	65	65	70	70
Mi	7	7	7	10	10	10
D	0	0	0	0	0	0
Apparent Cohesion (kPa)	87	549	537	633	1704	534
Friction Angle (°)	36	44	44	49	36	51
Parameter	Weathered Permian	Aries Overburden	Castor Interburden	Pollux Interburden	Pit Floor	Virgo Interburden
Unit Weight	22	24	24	24	24	24
Rock Strength (MPa)	3.62	15.73	17.96	23.59	23.96	16.85
GSI*	50	65	65	65	70	70
Mi	7	7	7	10	10	10
D	0.7	0.7	0.7	0.7	0.7	0.7
Apparent Cohesion (kPa)	58	309	364	437	-	372
Friction Angle (°)	28	39	39	44	-	47

*GSI is based on available geotechnical borehole data (Figure 5-3).

Table 5-9 General Rock Mass Strength Parameters – Curragh North

Parameter	Weathered Permian	Aries Overburden	Castor Interburden	Pisces Interburden	Pit Floor
Unit Weight	22	24	24	24	24
Rock Strength (MPa)	2.1	24.24	27.61	26.87	28.69
GSI*	50	65	65	65	70
Mi	7	7	7	10	10
D	0	0	0	0	0
Apparent Cohesion (kPa)	49	637	485	692	2040
Friction Angle (°)	36	47	42	49	36
Parameter	**Weathered Permian**	**Aries Overburden**	**Castor Interburden**	**Pisces Interburden**	**Pit Floor**
Unit Weight	22	24	24	24	24
Rock Strength (MPa)	2.1	24.24	27.61	26.87	28.69
GSI*	50	65	65	65	70
Mi	7	7	7	10	10
D	0.7	0.7	0.7	0.7	0.7
Apparent Cohesion (kPa)	33	414	740	473	-
Friction Angle (°)	29	42	46	45	-

*GSI is based on available geotechnical borehole data (Figure 5-3).

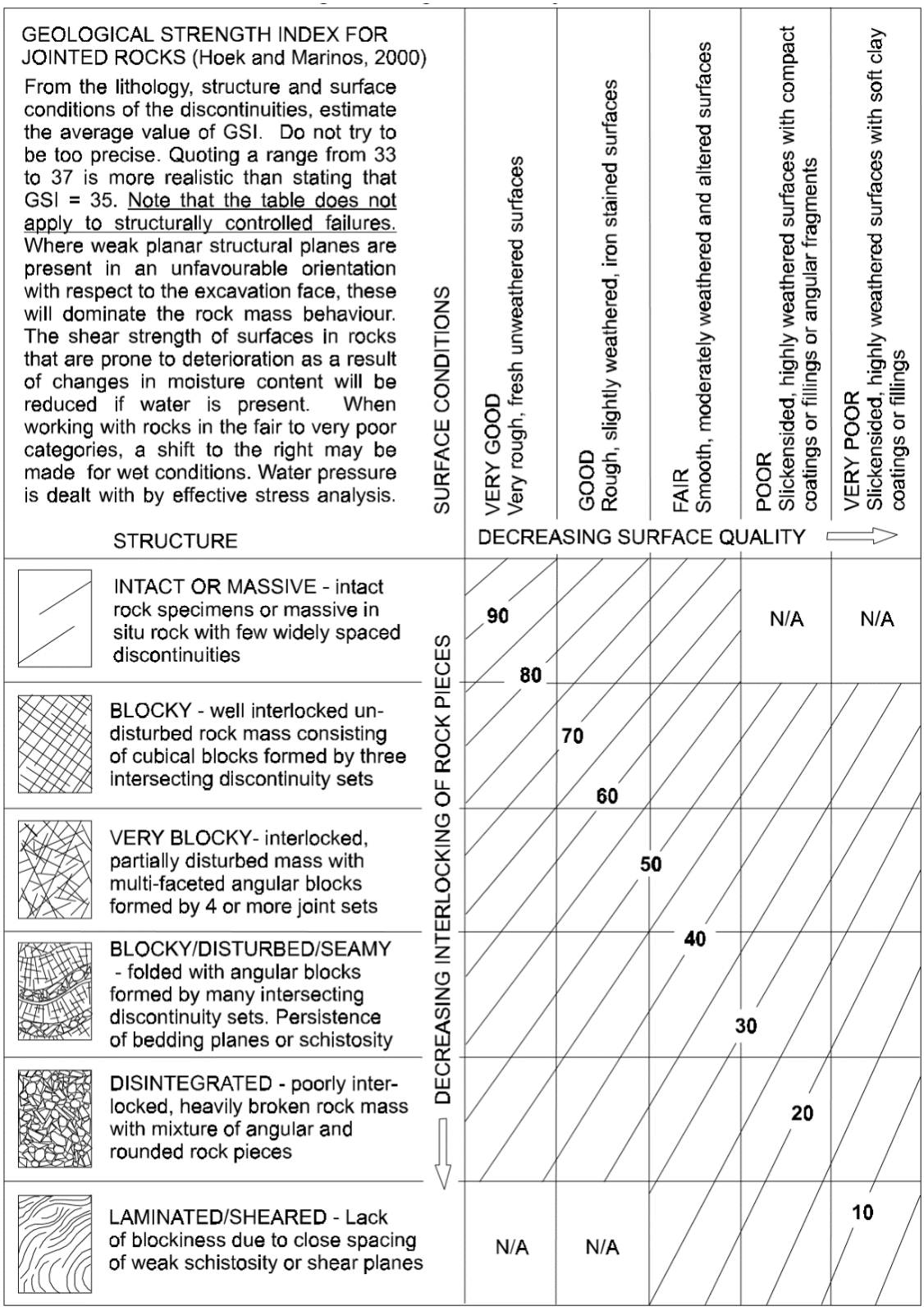


Figure 5-3 Summary of GSI classifications (Hoek and Marinos, 2000)

5.5 Adopted Slope Stability Analysis Methodology

Deterministic slope stability analysis, using two-dimensional limit equilibrium methods and Rocscience's proprietary software SLIDE 2.0 (SLIDE), has been undertaken for the nine (9) selected cross-section locations through the supplied final landform designs for Curragh.

The following assumptions, comments and qualifications are made in relation to the analyses completed:

- Static and dynamic scenarios have been considered. To consider the potential impacts of earthquakes (i.e. dynamic scenarios) a peak ground acceleration (g) of 0.02 has been applied, equivalent to an event with an exceedance probability of 2% in 50 years (refer to Section 2.3).
- For design acceptance criteria, a minimum factor of safety (FoS) of 1.5 for static conditions and 1.1 for dynamic conditions have been adopted for these analyses;
- The Spencer method has been adopted for these analyses;
- The Path Search search method has been adopted for these analyses;
- The slope stability analysis considers Global Stability of the slope;
- For the purpose of these analyses a slope angle of 7-degrees in the soil materials has been assumed. It is understood that this is to help prevent and minimise surface erosion, rather than to maintain long term stability of the relevant final landform slopes;
- A Disturbance (D) Factor of 0.7 has been applied when determining Hoek-Brown material parameters for a blast affect Permian rock mass;
- A Disturbance (D) Factor has been applied to a width equal to approximately half the bench height, where the final landform comprises final excavated pitwall geometries in the Permian rock;
- The analysis of final excavated pitwall geometries in the Permian rock only considers potential failures through the rock mass and does not consider the potential impact(s) of individual fault planes, fault orientation(s) and fault interaction(s);
- Groundwater and surface water can have a significant and adverse impact on the stability of pitwalls and must therefore be appropriately understood and considered. Limited groundwater and/or hydrogeological information is available.
    - The Steady State FEA tool provided in SLIDE has been utilised to model groundwater movement and hydrostatic pressures through the materials based on the adopted ground models, for the assumed water levels and adopted material hydraulic conductivities (Table 5-7).
    - Flood levels have been adopted as per Section 2.4. A 1m freeboard was added to the provided flood levels for the presented analysis. Values were converted to the CCPL mine grid coordinate system prior to use.
    - The final voids have been assumed to be dry for the presented analyses.
    - Perched water tables have not been considered.

6. Slope Stability Analysis Results

The analysis results for the critical failure surfaces analysed are provided in Table 6-1 to Table 6-9. Analysis outputs are provided in Appendix A.

Table 6-1 Analysis Results for the Adopted Geotechnical Ground Models -Section 1 U-Pit

Cross Section	Scenario	Estimated Static Factor of Safety	Estimated Dynamic Factor of Safety
Section 1: U-Pit	Planned Final Landform Option - Highwall Side	1.8	1.7

Table 6-2 Analysis Results for the Adopted Geotechnical Ground Models -Section 2 S-Pit South

Cross Section	Scenario	Estimated Static Factor of Safety	Estimated Dynamic Factor of Safety
Section 2: S-Pit South	Planned Final Landform Option - Highwall Side	1.8	1.7
	Planned Final Landform Option - Lowwall Side	1.7	1.6

Table 6-3 Analysis Results for the Adopted Geotechnical Ground Models -Section 3 X-Pit

Cross Section	Scenario	Estimated Static Factor of Safety	Estimated Dynamic Factor of Safety
Section 3: X-Pit	Planned Final Landform Option - Highwall Side	1.8	1.7

Table 6-4 Analysis Results for the Adopted Geotechnical Ground Models -Section 4 D-Pit

Cross Section	Scenario	Estimated Static Factor of Safety	Estimated Dynamic Factor of Safety
Section 4: D-Pit	Planned Final Landform Option - Highwall Side	2.4	2.3
	Alternative Final Landform Option - Highwall Side	3.2	2.7
	Alternative Final Highwall Re-Shaped Final Slope Option - Highwall Side	1.6	1.5

Table 6-5 Analysis Results for the Adopted Geotechnical Ground Models -Section 5 F-Pit

Cross Section	Scenario	Estimated Static Factor of Safety	Estimated Dynamic Factor of Safety
Section 5: F-Pit South	Planned Final Landform Option - Highwall Side	1.9	1.8
	Alternative Final Highwall Re-Shaped Final Slope Option - Highwall Side	1.8	1.7
	Planned Final Landform Out Board Slope	1.7	1.6
	Planned Final Landform Option - Lowwall Side	2.9	2.6

Table 6-6 Analysis Results for the Adopted Geotechnical Ground Models -Section 6 K-Pit

Cross Section	Scenario	Estimated Static Factor of Safety	Estimated Dynamic Factor of Safety
Section 6: K-Pit	Planned Final Landform Option - Highwall Side	2.5	2.4
	Alternative Final Landform Option - Highwall Side	3.2	3.1
	Alternative Final Highwall Re-Shaped Final Slope Option - Highwall Side	1.7	1.6

Table 6-7 Analysis Results for the Adopted Geotechnical Ground Models -Section 7 J-Pit

Cross Section	Scenario	Estimated Static Factor of Safety	Estimated Dynamic Factor of Safety
Section 7: J-Pit	Planned Final Landform Option - Highwall Side	1.7	1.6
	Planned Final Highwall Re-Shaped Final Slope - Highwall Side	1.6	1.5

Table 6-8 Analysis Results for the Adopted Geotechnical Ground Models -Section 8 Y-Pit

Cross Section	Scenario	Estimated Static Factor of Safety	Estimated Dynamic Factor of Safety
Section 8: Y-Pit	Planned Final Landform Option - Highwall Side	2.7	2.5
	Planned Final Highwall Re-Shaped Final Slope - Highwall Side	2.0	1.9

Table 6-9 Analysis Results for the Adopted Geotechnical Ground Models -Section 9 Z-Pit

Cross Section	Scenario	Estimated Static Factor of Safety	Estimated Dynamic Factor of Safety
Section 9: Z-Pit	Planned Final Landform Option - Highwall Side	1.8	1.7
	Planned Final Highwall Re-Shaped Final Slope - Highwall Side	1.6	1.5

7. Discussion and Recommendations

Two-dimensional limit equilibrium slope stability analysis has been completed with the estimated static and dynamic Factors of Safety (FoS) for the critical failure surface analysed presented for CCPL's consideration. The estimated FoS should only be used as a general guide for assessing potential geotechnical hazards and risks associated with the longer-term stability of the final landform designs.

Deterministic analysis results for the final landform designs, based on the adopted ground models and analysis methodology and assumptions, indicate that the final landform designs meet the adopted design acceptance criteria (Section 5.5).

It must be noted that the material parameters used in these analyses are consistent with those currently used for in-pit slope design. These are typically based on mean strength parameters, which lead to relatively high probabilities of failure when uncertainty is considered. For example, Table 9.7 in Read & Stacey (2009) suggests that for in-pit slope design a factor of safety of 1.5 may have a Probability of Failure (PoF) of up to 10 or 15%, and a factor of safety of 1.6 still has a PoF of up to 8%. These are unlikely to be acceptable in areas to which the public has access, where a factor of safety of 1.5 is expected to have a much lower PoF as a result of the use of more conservative design parameters. It is therefore necessary for CCPL to confirm that the adopted FoS are acceptable.

Past pitwall performance at Curragh indicates that geological structures are a key factor requiring consideration as part of the design process and CPS. The analysis of sections that include remnant pitwalls in the Permian rock only considers potential failures through the rock mass and does not consider the potential impact(s) of individual fault planes, fault orientation(s) and fault interaction(s). Where adverse fault orientations and interactions, relative to pitwall geometries and locations are present, the planned final pitwall geometries (as provided) may not be appropriate for CCPLs long-term final landform stability requirements. In such cases alternative design options such as the construction of softwalls in blasted Permian rock may be required. Due to potential surface erosion mitigation requirements and in order to meet the adopted design acceptance criteria for long-term slope stability, it may be necessary to re-shape softwalls to reduce slope angles. A re-shaped slope angle of approximately 22-degrees has been considered in the analysis undertaken for ground models that consider re-shaping of softwalls constructed in blasted Permian rock. The associated cut-fill balance of these options is to be further investigated as detailed design works are completed.

The ability to identify geological fault locations and geometries accurately for the final pitwall is limited by existing data coverage and density. Fault interpretations and geotechnical ground models for final pitwalls are to be developed as mining progresses and/or additional geology and geotechnical data is collected and obtained.

To consider the provided flood levels for X-Pit the proposed final landform has been raised by approximately 10m for the purpose of these analyses.

The slope stability analyses presented in this document should be reviewed and updated when new geological, geotechnical and/or hydrogeological data becomes available or as material changes are made to existing data or the design options are developed.

The following recommendations are provided in relation to detailed design of the final landforms:

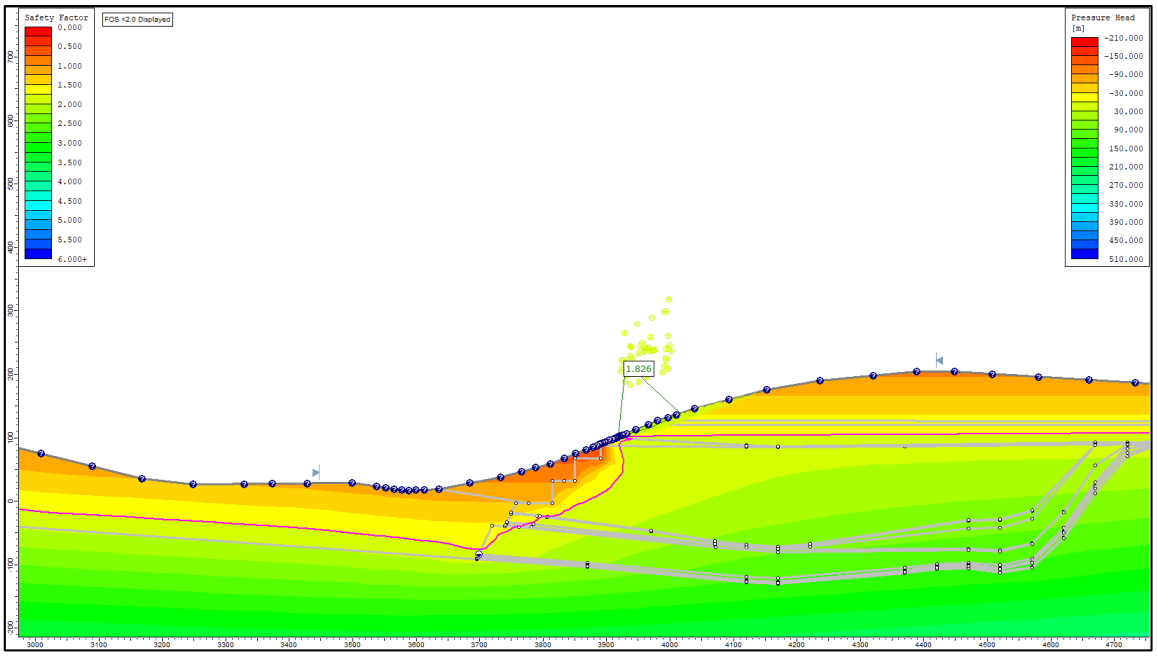
- The construction of the final landform designs, including cut-fill volumes, are to be reviewed and developed;
- An erosional assessment is necessary to confirm the maximum slope angles for the various soil strength materials (including spoil materials). The final landform designs, and if deemed necessary the slope stability analysis, are to be updated based on the outcomes of the erosion assessment;
- Geological, geotechnical and hydrogeological data collection strategies for the final pitwalls are to be developed and implemented to inform the detailed design process;
- The hydrogeological and hydrological models should be developed, and an associated groundwater investigation program implemented;
- Investigations and studies should be undertaken to identify the potential location and extent of Paleochannels in the alluvial soil profile; and,
- As the final landform designs are progressed, and additional geological, geotechnical, hydrogeological and/or hydrological data is obtained, more detailed and extensive slope stability analysis may be required. This should include assessment of all slope geometries, remnant pitwalls and final voids. It is recommended that detailed design include probabilistic slope stability analysis.

8. Qualification

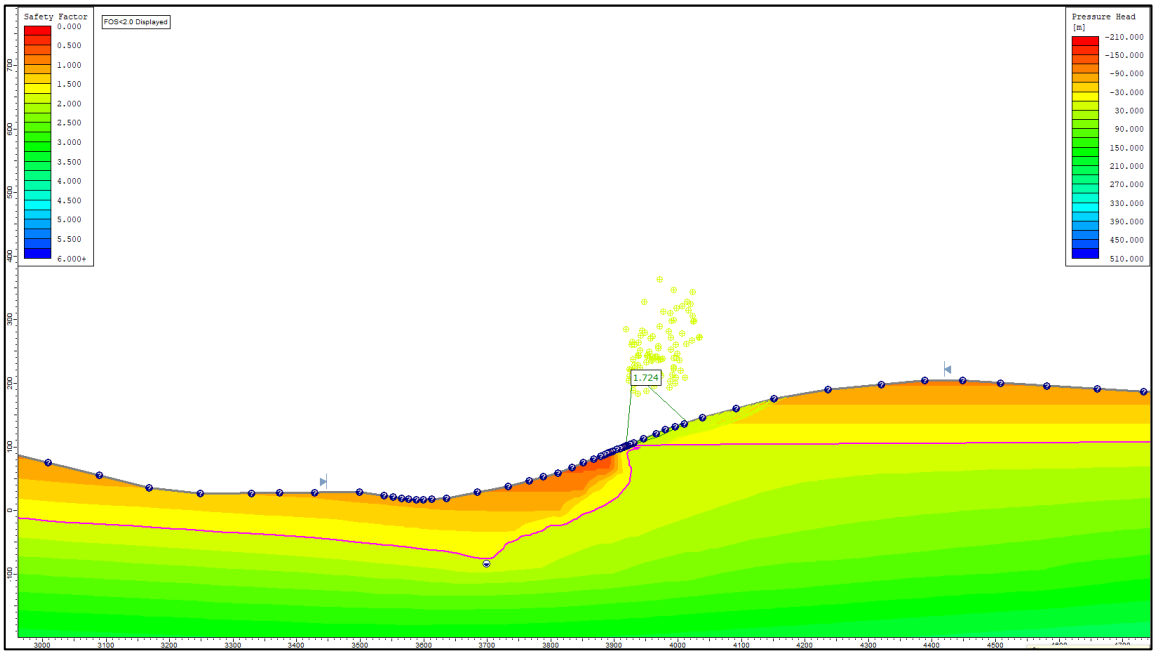
The following qualifications are made in relation to the analysis and recommendations presented in this report:

- This document has been prepared by R&A for CCPL and may only be used and relied upon by CCPL for the purpose agreed between R&A and CCPL as set out in relevant sections of this memorandum. R&A otherwise disclaims responsibility to any person other than CCPL arising in connection with this memorandum.
- It has been assumed that all data supplied by CCPL is true and accurate and that all available and relevant data has been supplied. R&A has not independently verified or validated the data supplied by CCPL and does not accept liability in connection with unverified information, including errors and omissions in this document which were caused by errors or omissions in that information.
- The outputs, opinions, conclusions and recommendations provided in this document are based on the adopted geotechnical ground models and analysis methods. The adopted geotechnical ground models presented in this report may be constrained by available data type, density and accuracy. Therefore there is potential for interpreted ground conditions to vary from those assumed in the adopted ground models. R&A assume that CCPL will undertake detailed design and risk analysis for the design option part of the design process.
- No geotechnical investigations or laboratory testing have been commissioned or undertaken as part of this work.
- The groundwater levels and phreatic surfaces adopted as per data supplied by SLR.
- If the content of this document, including the adopted methods and terminology, is unclear or not fully understood clarification should be sort.
- If it is known, or subsequently becomes known, that any of the qualifications, assumptions or interpretations made in this memorandum are incorrect, R&A must be notified immediately, and the applicability of the slope stability analysis and any associated recommendations reviewed. If considered necessary, the slope stability analysis and report may need to be updated.

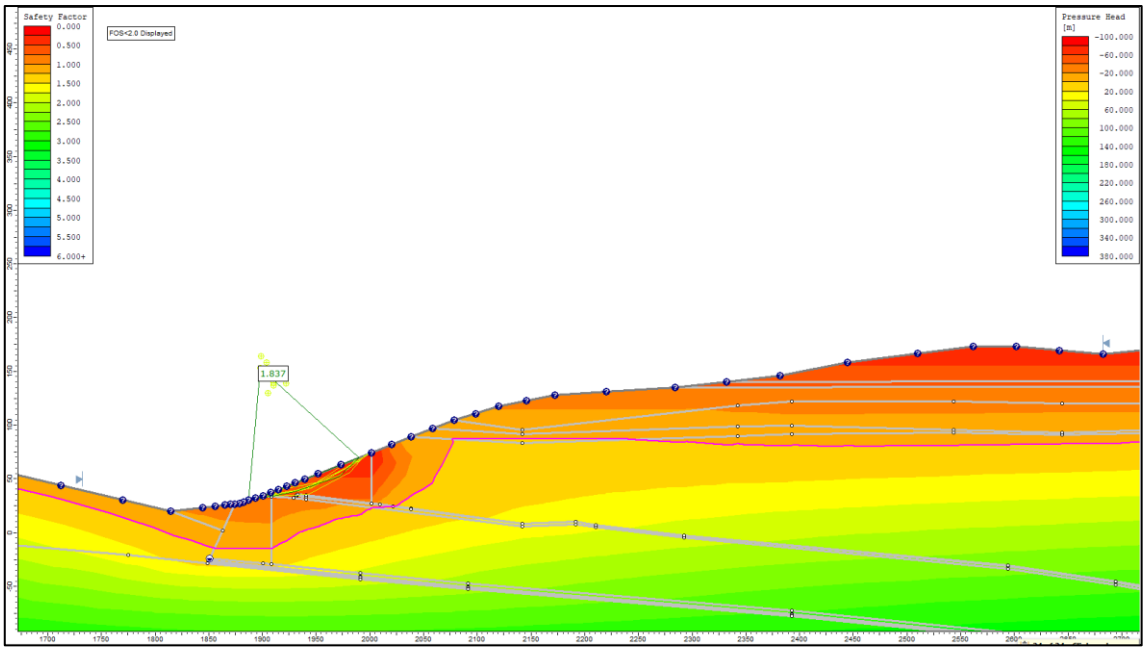
Appendix A – Limit Equilibrium Slope Stability Analysis Outputs



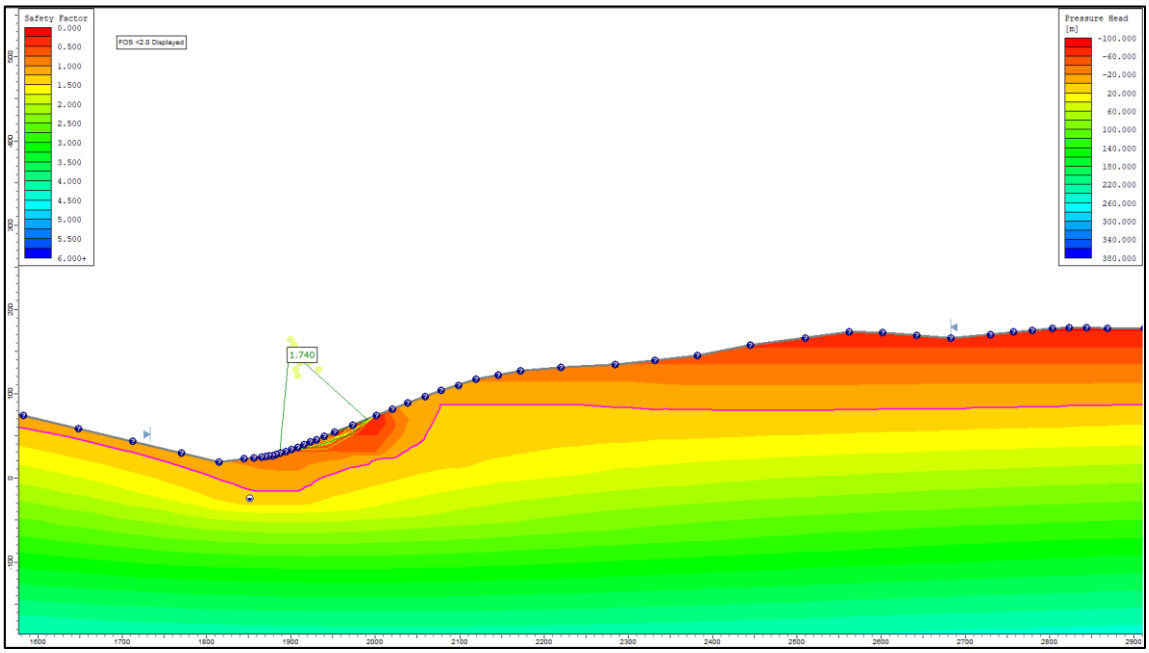
Appendix A 1 Cross Section 1 – Curragh North U-Pit - Static



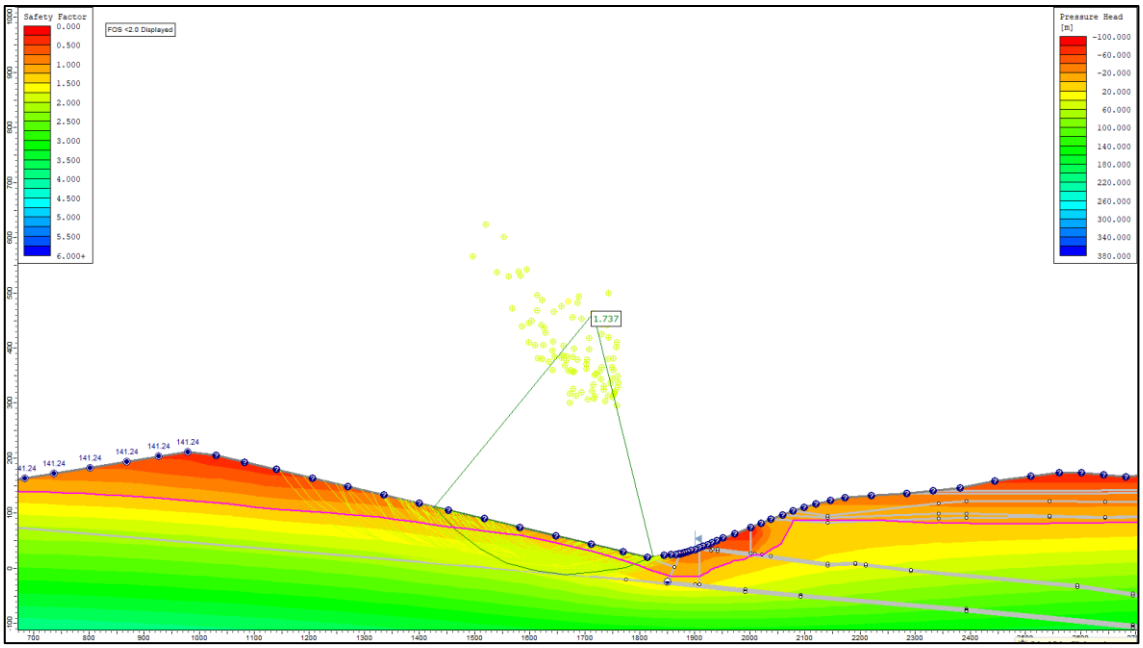
Appendix A 2 Cross Section 1 – Curragh North U-Pit - Dynamic



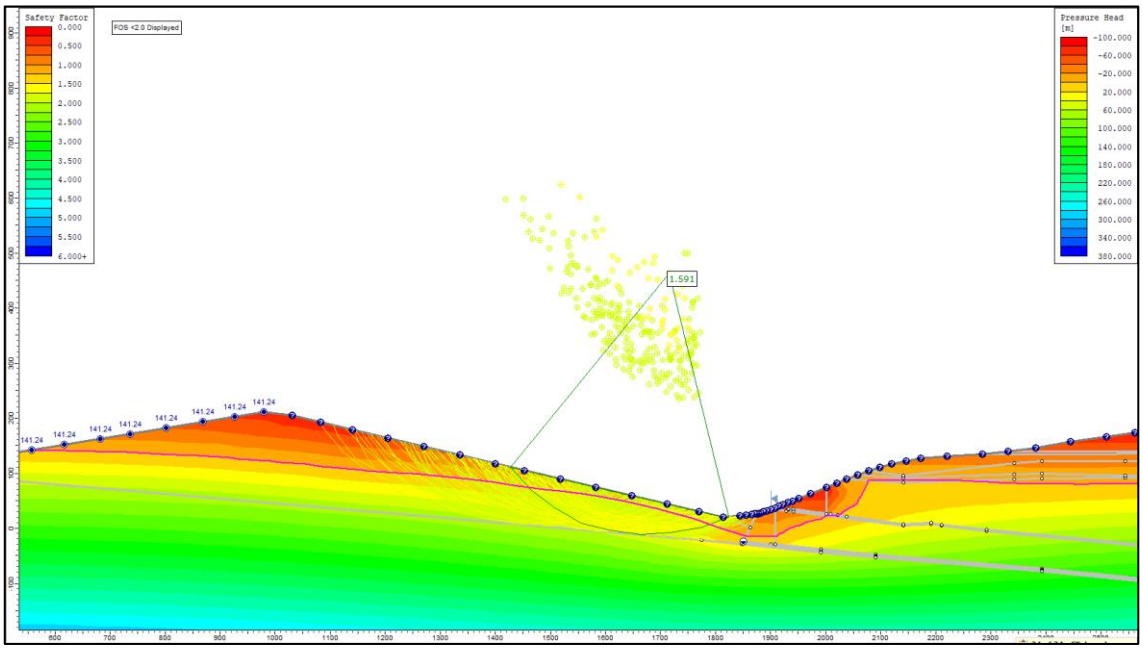
Appendix A 3 Cross Section 2 – Curragh North S-Pit South - Static



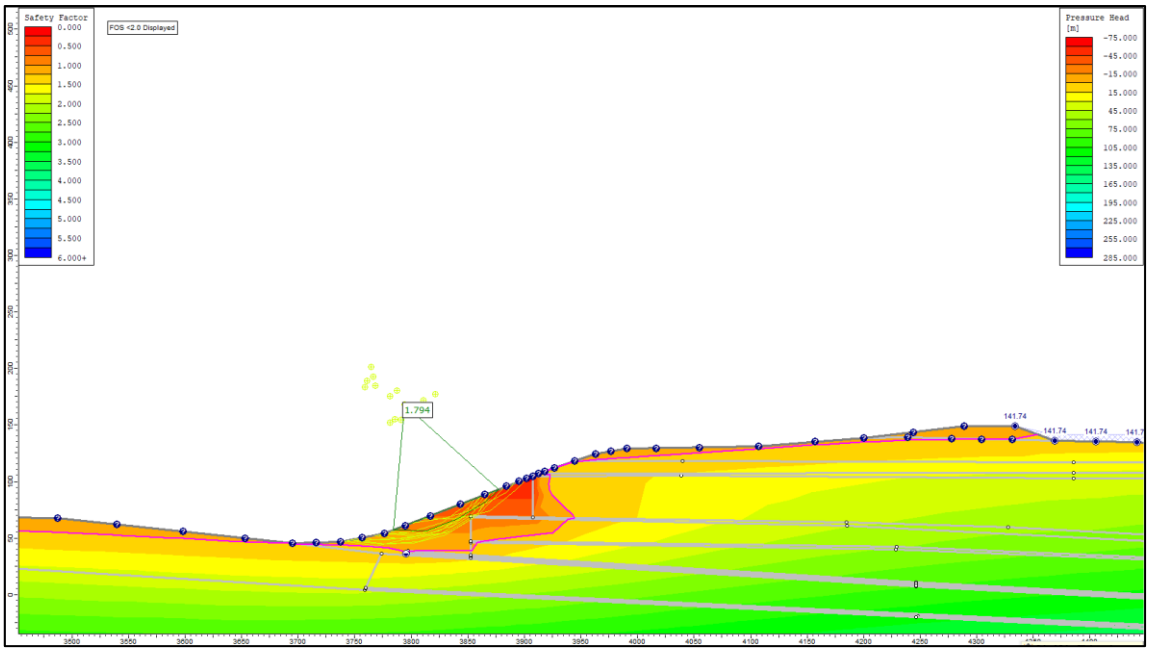
Appendix A 4 Cross Section 2 – Curragh North S-Pit South - Dynamic



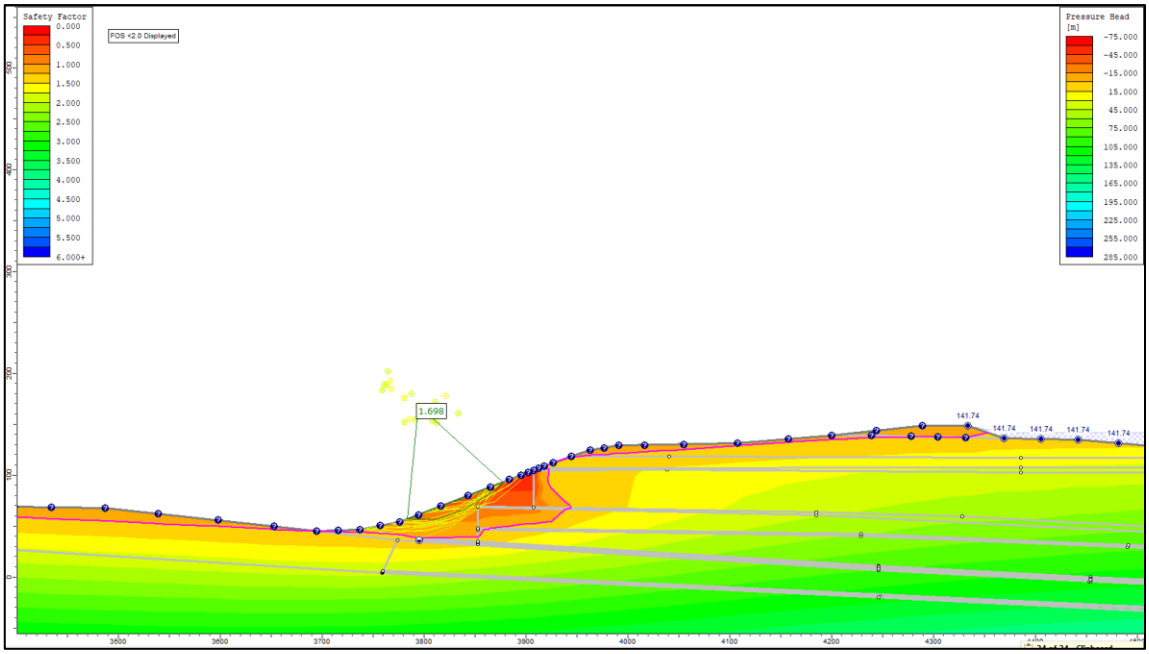
Appendix A 5 Cross Section 2 – Curragh North S-Pit South Lowwall – Static



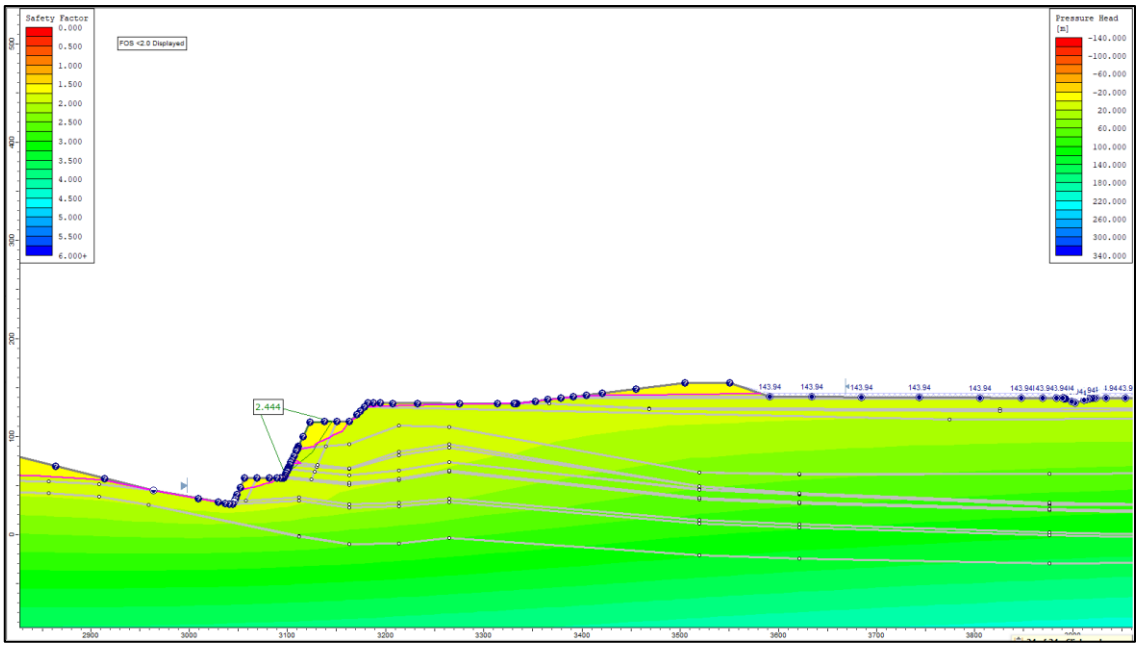
Appendix A 6 Cross Section 2 – Curragh North S-Pit South Lowwall - Dynamic



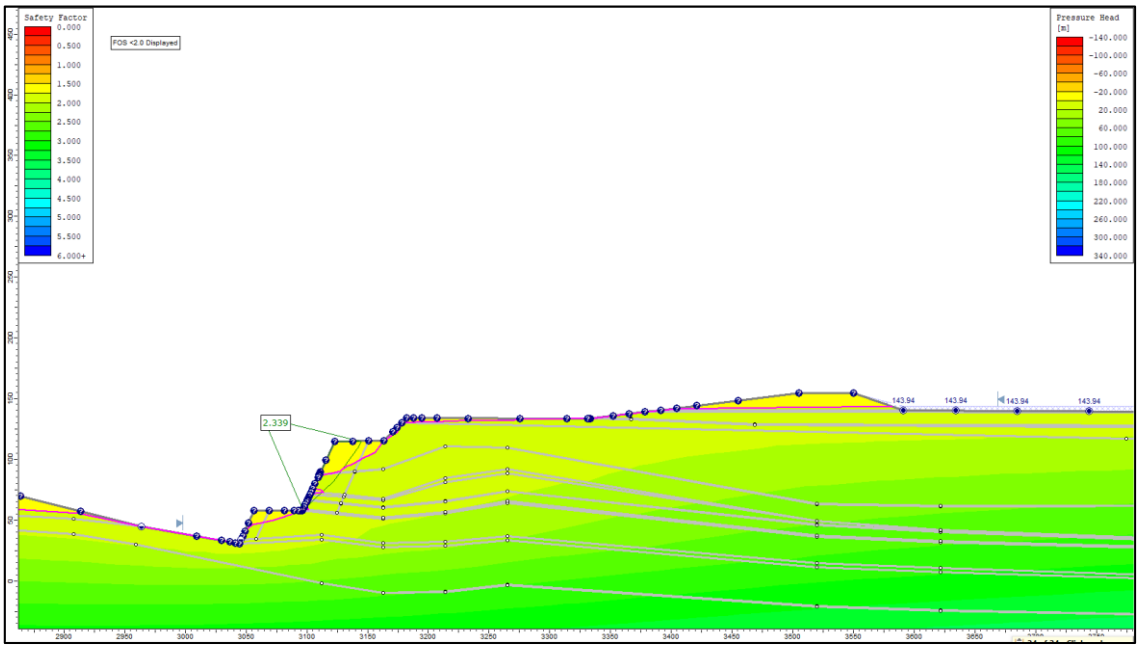
Appendix A 7 Cross Section 3 – X-Pit – Raised final landform to accommodate supplied flood levels - Static



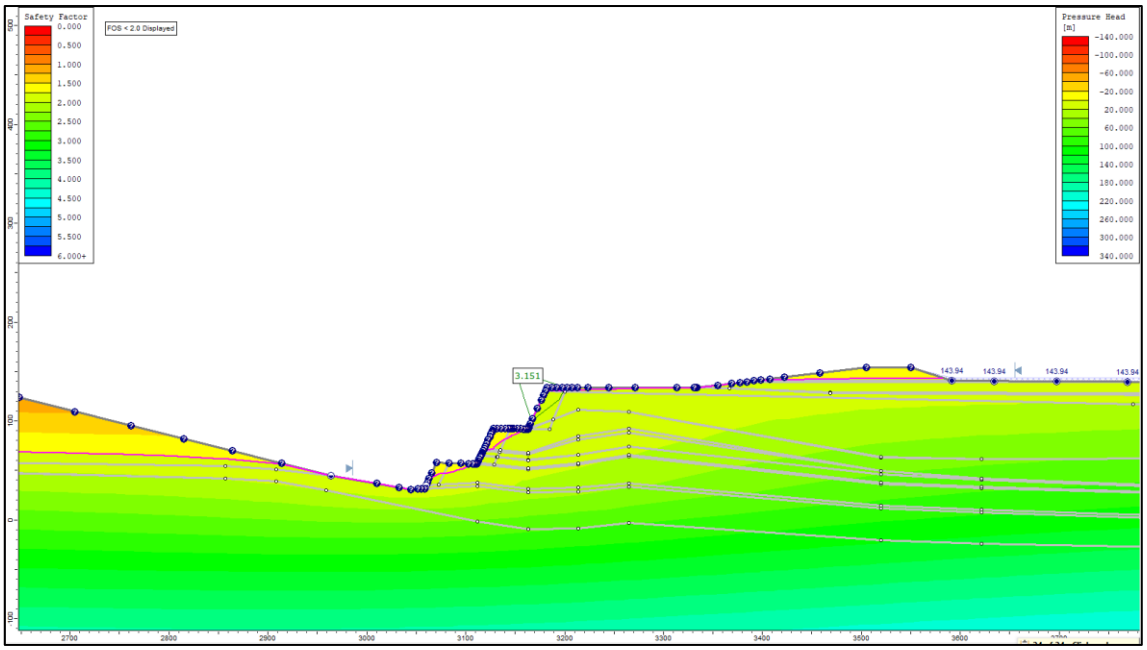
Appendix A 8 Cross Section 3 – X-Pit – Raised final landform to accommodate supplied flood levels - Dynamic



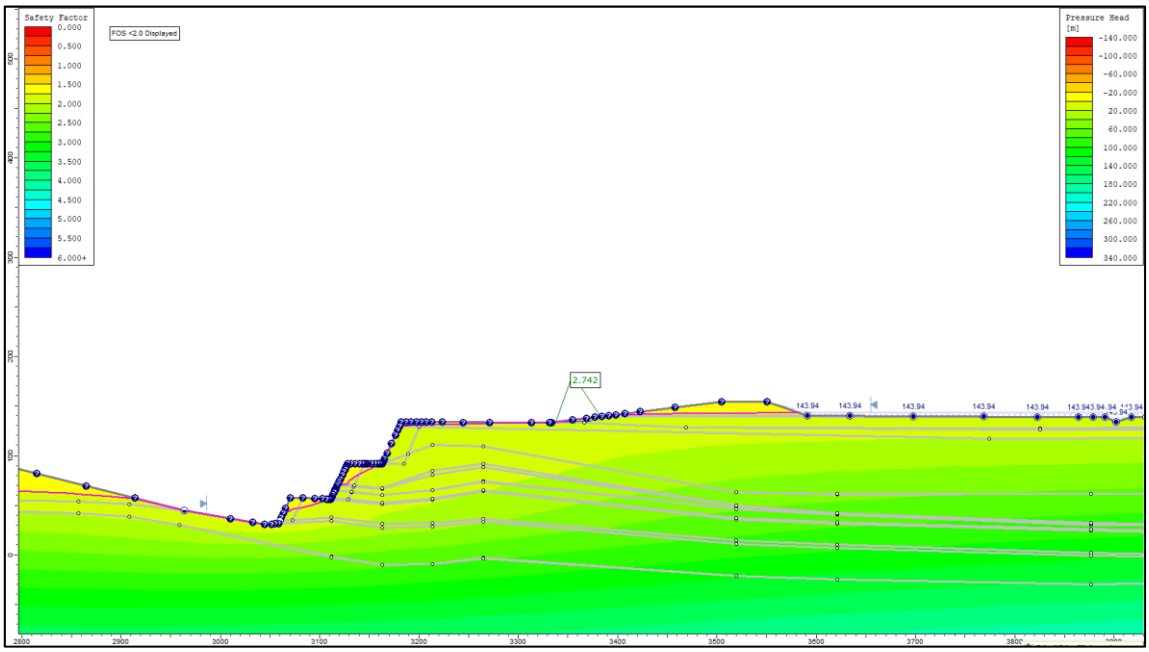
Appendix A 9 Cross Section 4 – Curragh Main D-Pit - Static



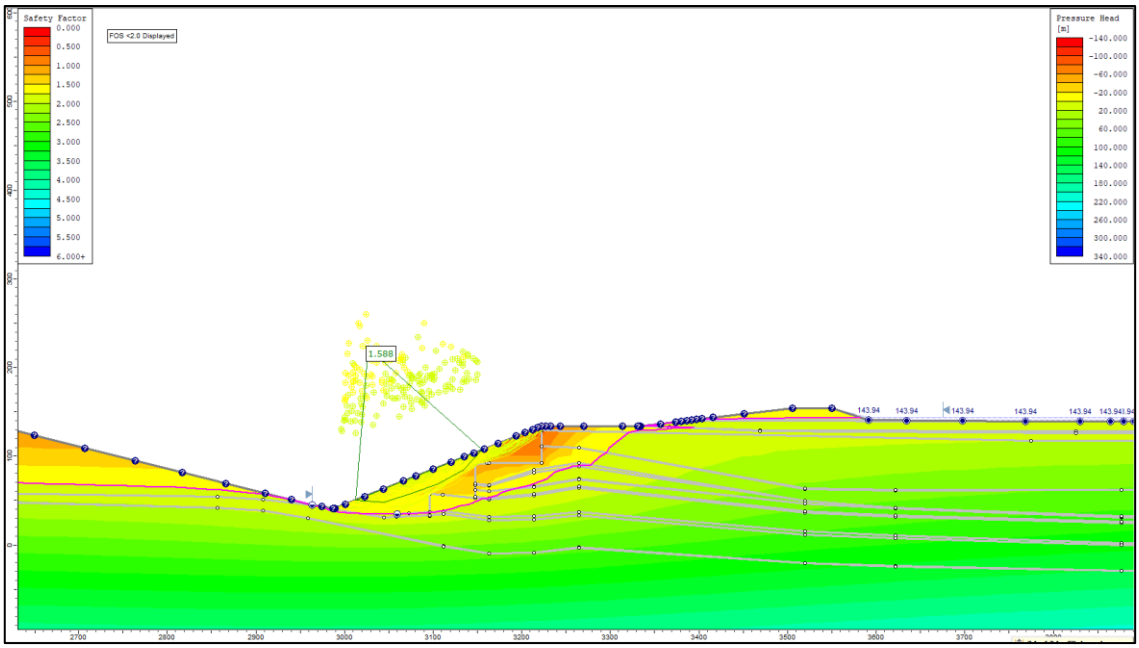
Appendix A 10 Cross Section 4 – Curragh Main D-Pit - Dynamic



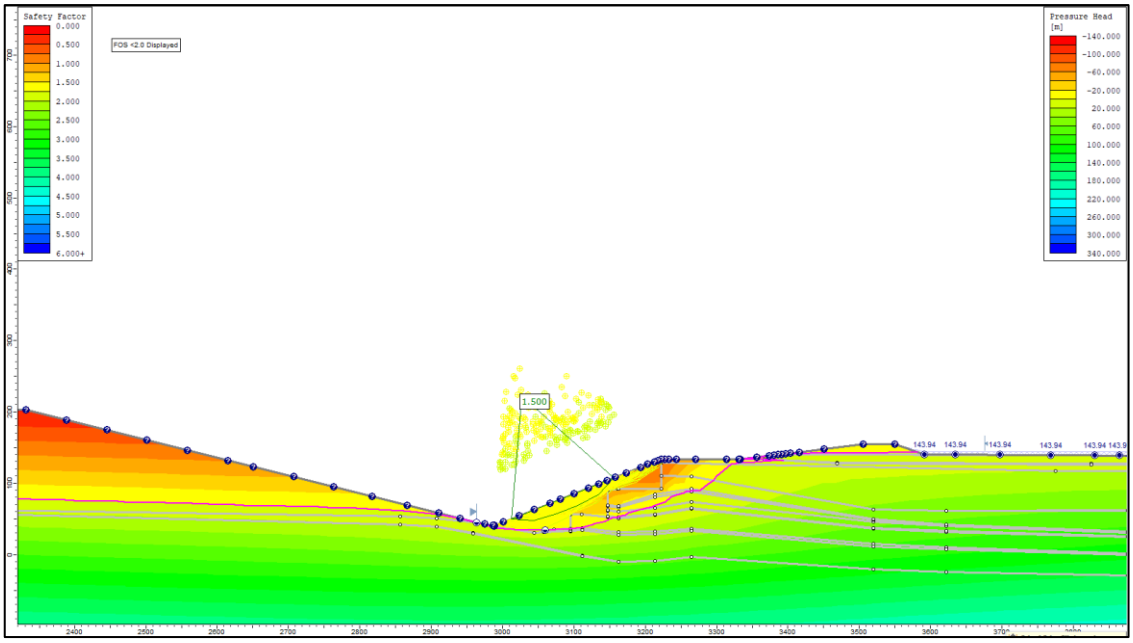
Appendix A 11 Cross Section 4 – Curragh Main D-Pit Alternative final highwall geometry – Static



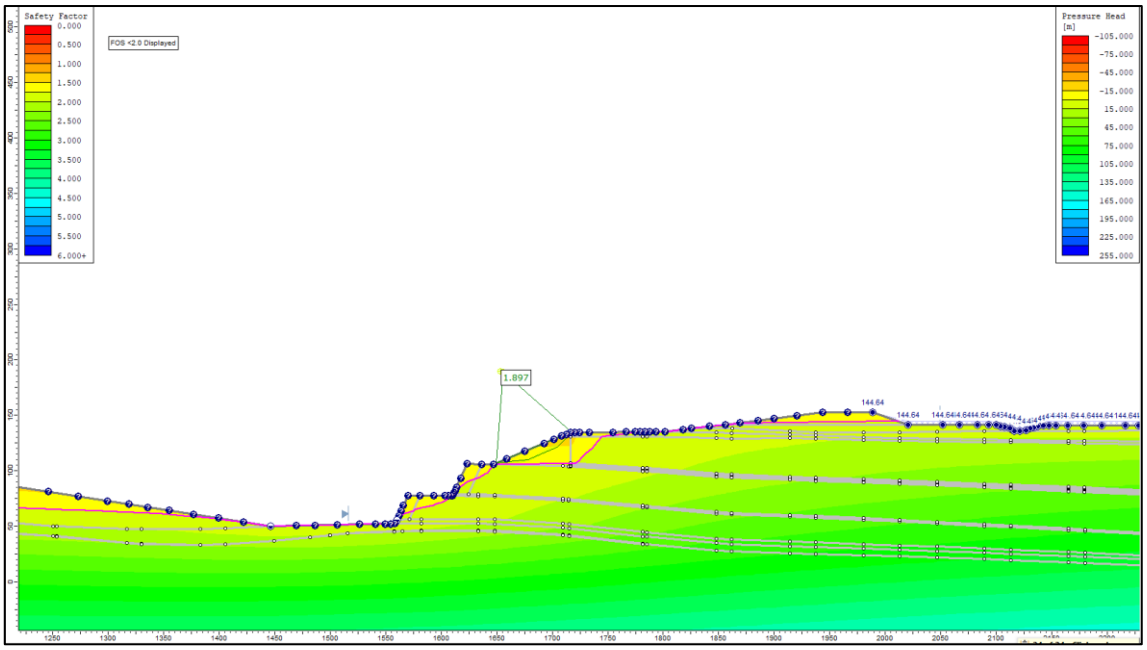
Appendix A 12 Cross Section 4 – Curragh Main D-Pit Alternative final highwall geometry – Dynamic



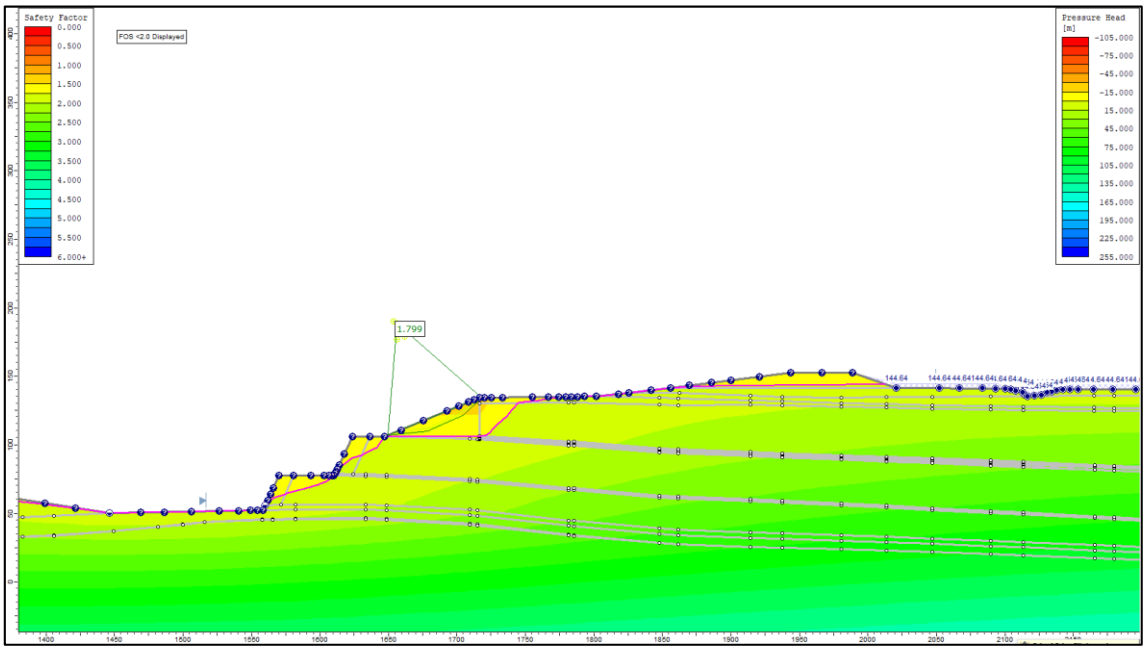
Appendix A 13 Cross Section 4 – Curragh Main D-Pit Alternative final highwall geometry with blasted and re-shaped final slope – Static



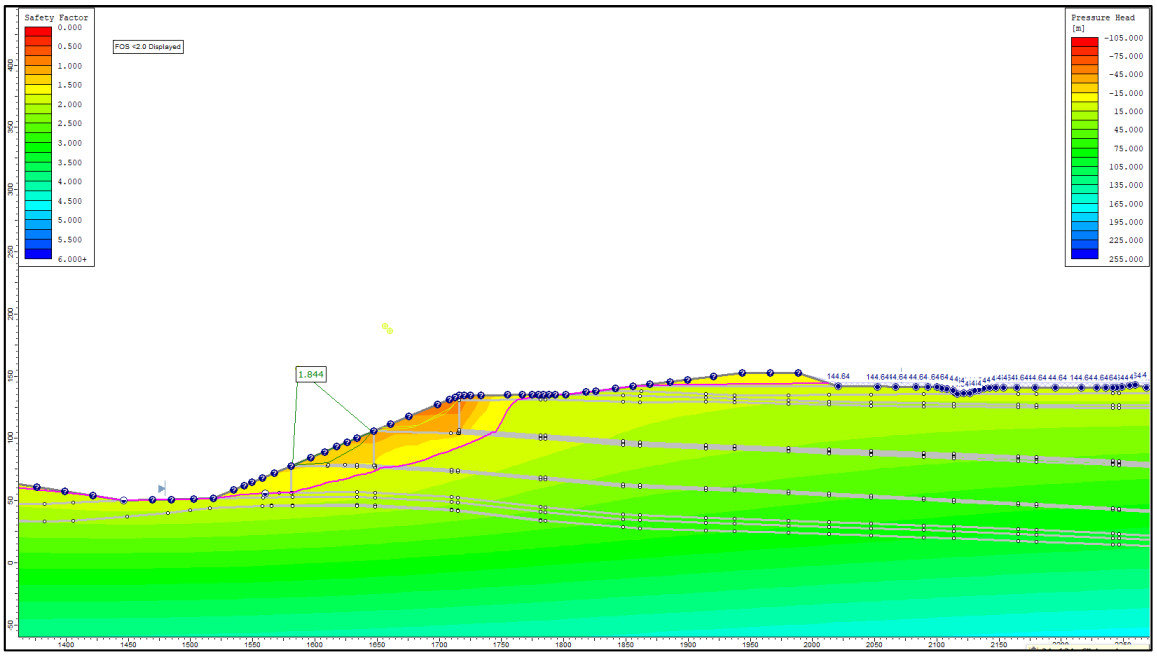
Appendix A 14 Cross Section 4 – Curragh Main D-Pit Alternative final highwall geometry with blasted and re-shaped final slope – Dynamic



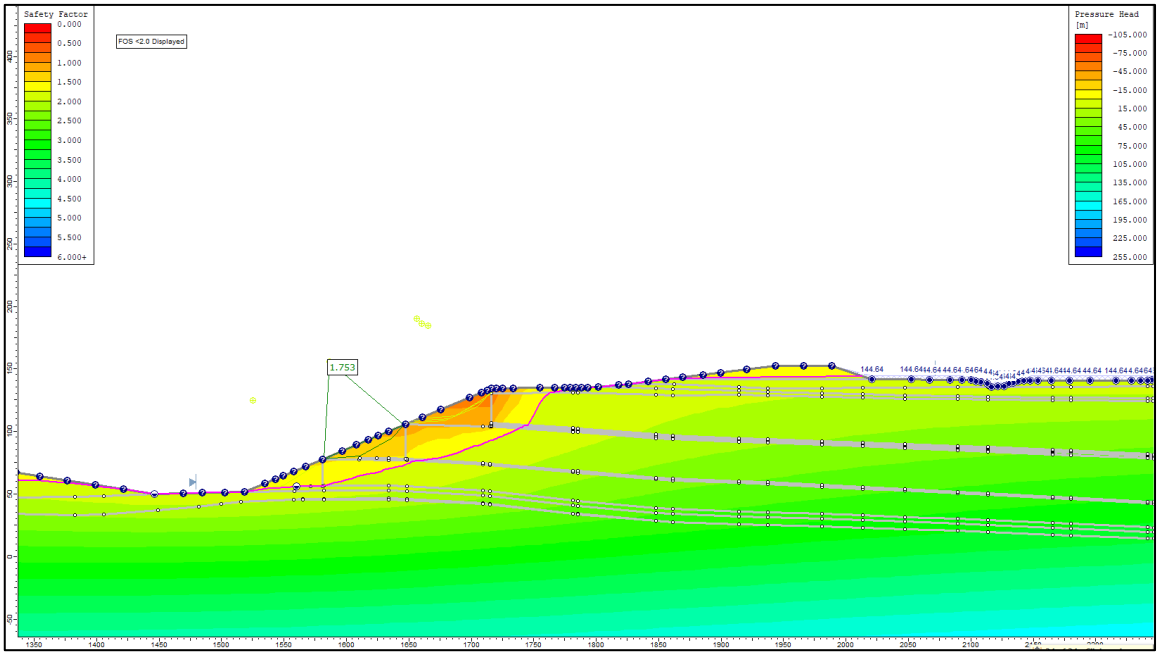
Appendix A 15 Cross Section 5 – Curragh Main F-Pit - Static



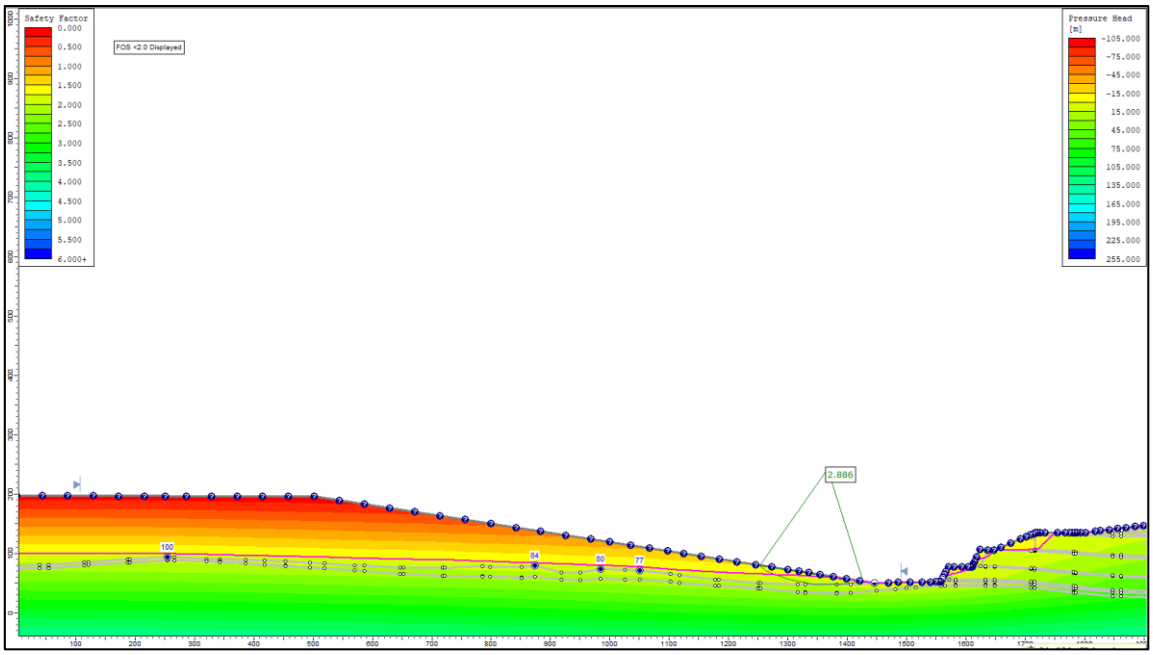
Appendix A 16 Cross Section 5 – Curragh Main F-Pit - Dynamic



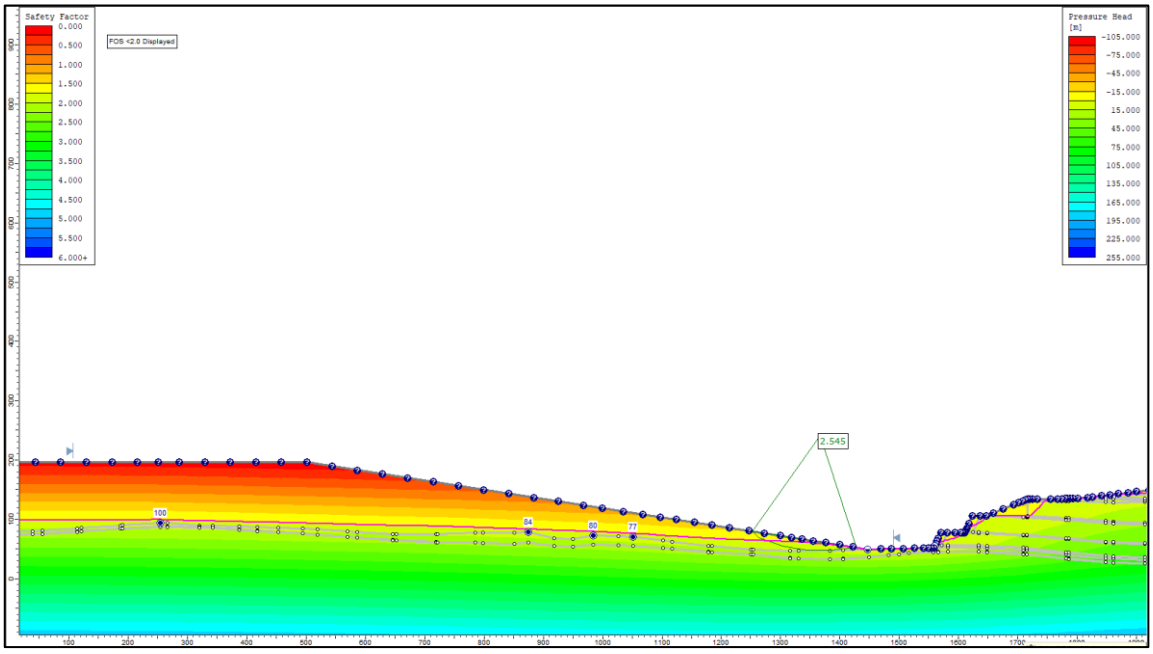
Appendix A 17 Cross Section 5 – Curragh Main F-Pit Final highwall geometry with blasted and re-shaped final slope – Static



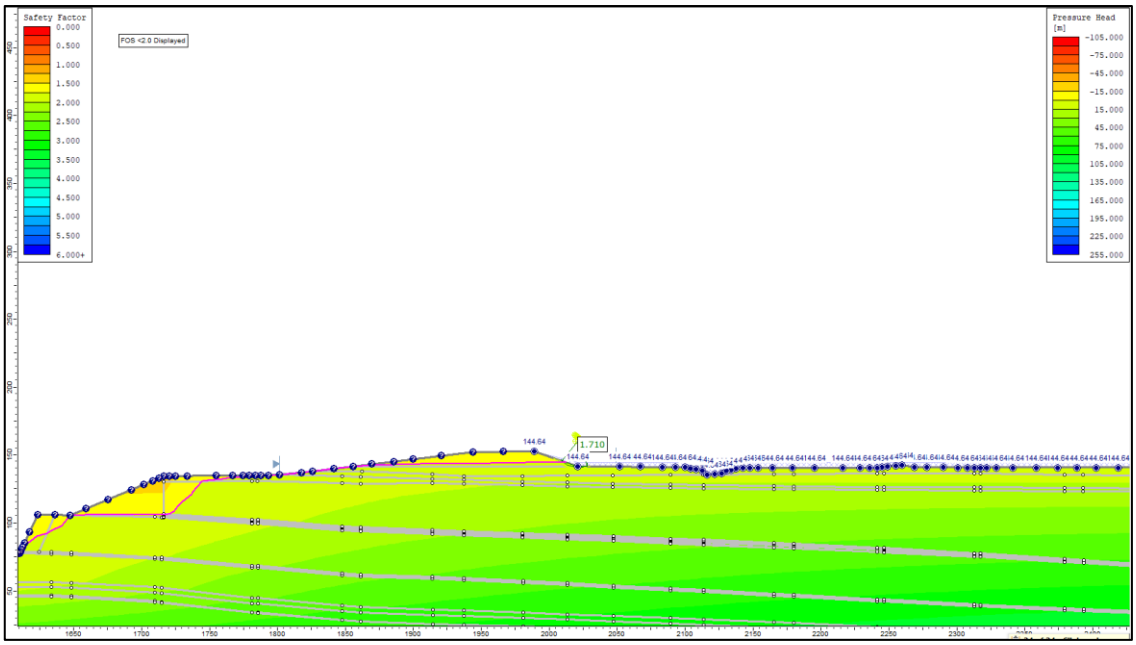
Appendix A 18 Cross Section 5 – Curragh Main F-Pit Final highwall geometry with blasted and re-shaped final slope – Dynamic



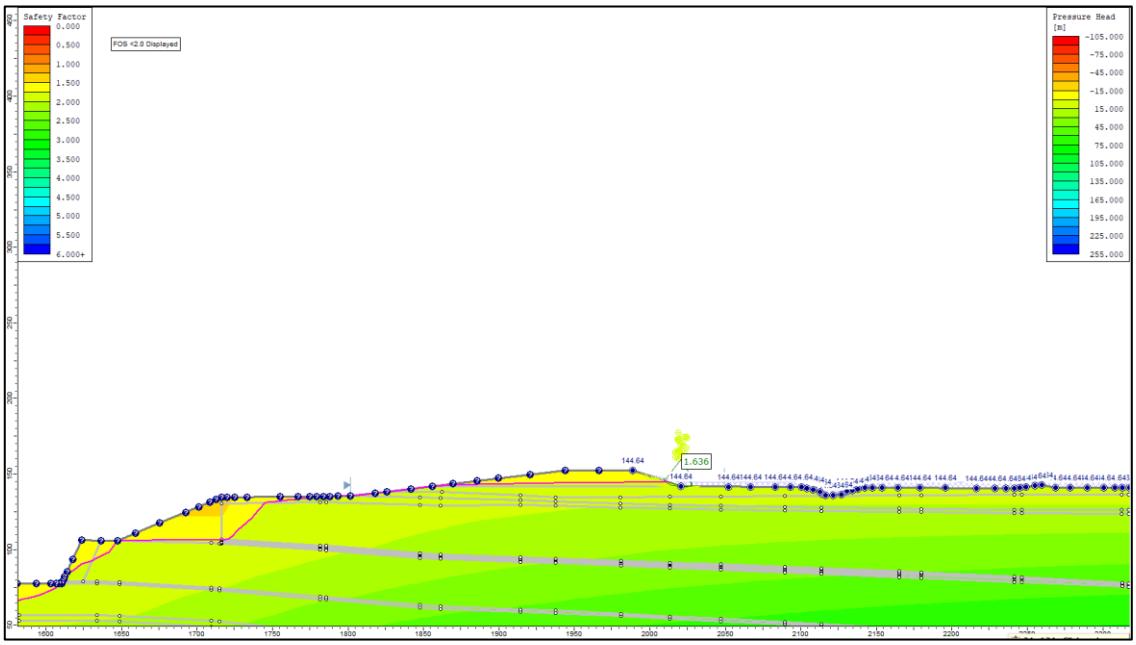
Appendix A 19 Cross Section 5 – Curragh Main F-Pit Lowwall - Static



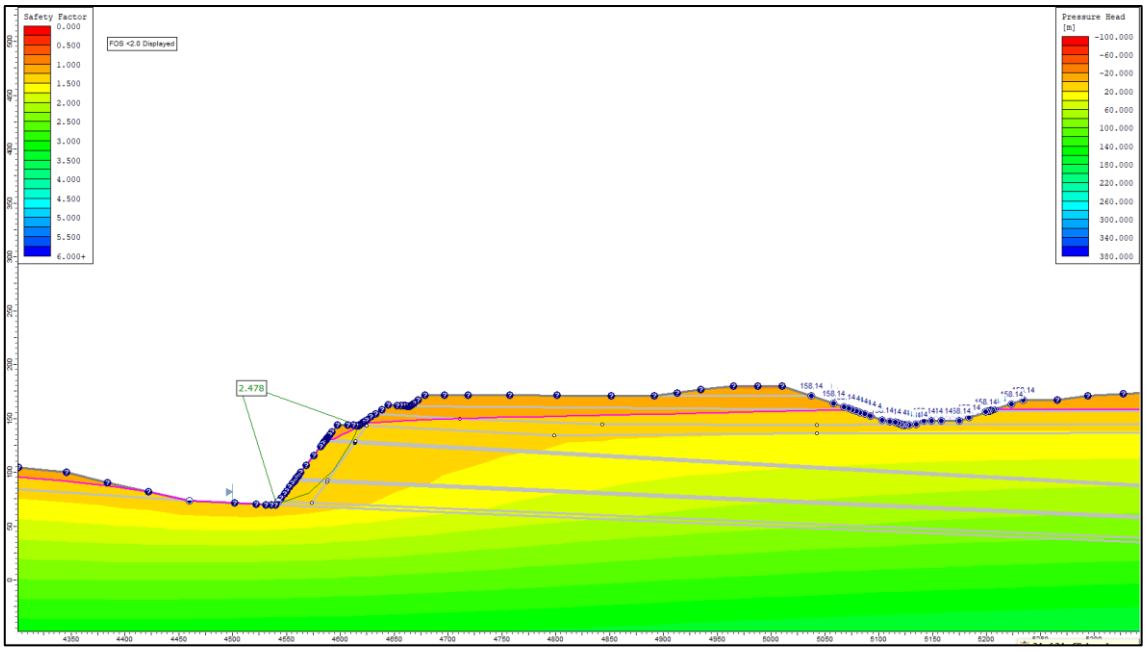
Appendix A 20 Cross Section 5 – Curragh Main F-Pit Lowwall – Dynamic



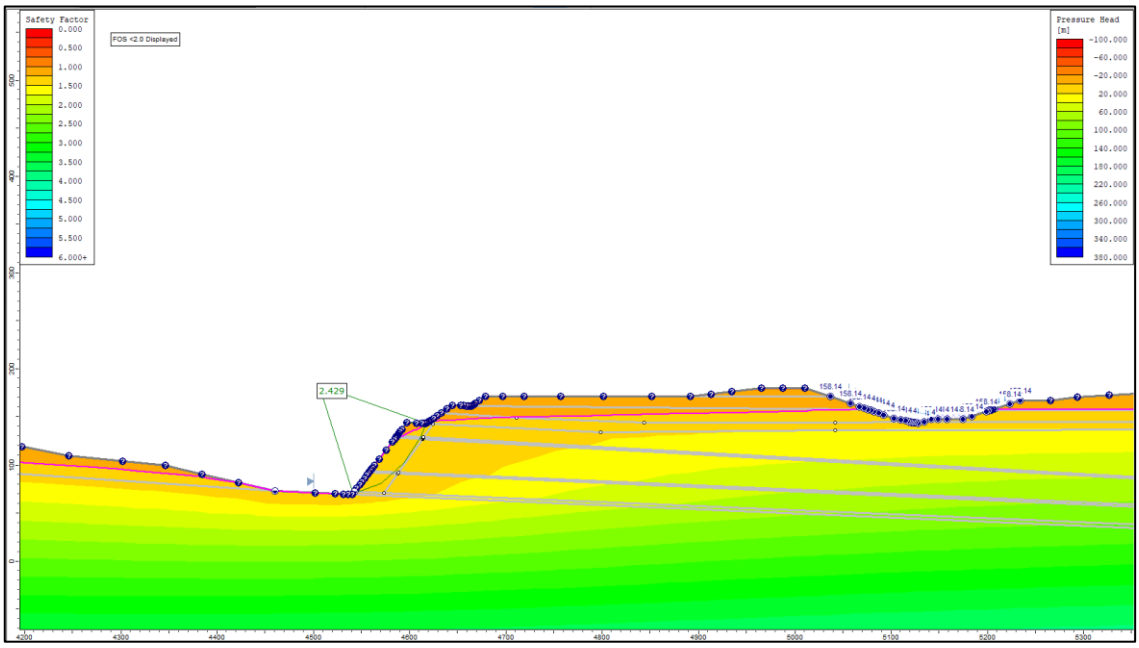
Appendix A 21 Cross Section 5 – Curragh Main F-Pit Final Landform Out Board Slope - Static



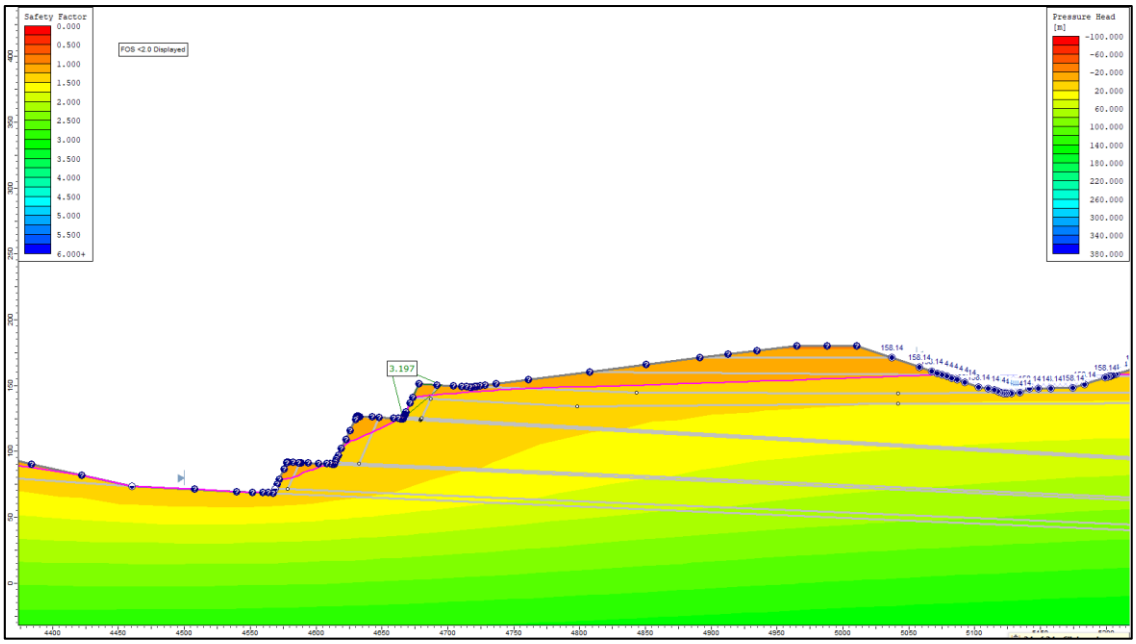
Appendix A 22 Cross Section 5 – Curragh Main F-Pit Final Landform Out Board Slope - Dynamic



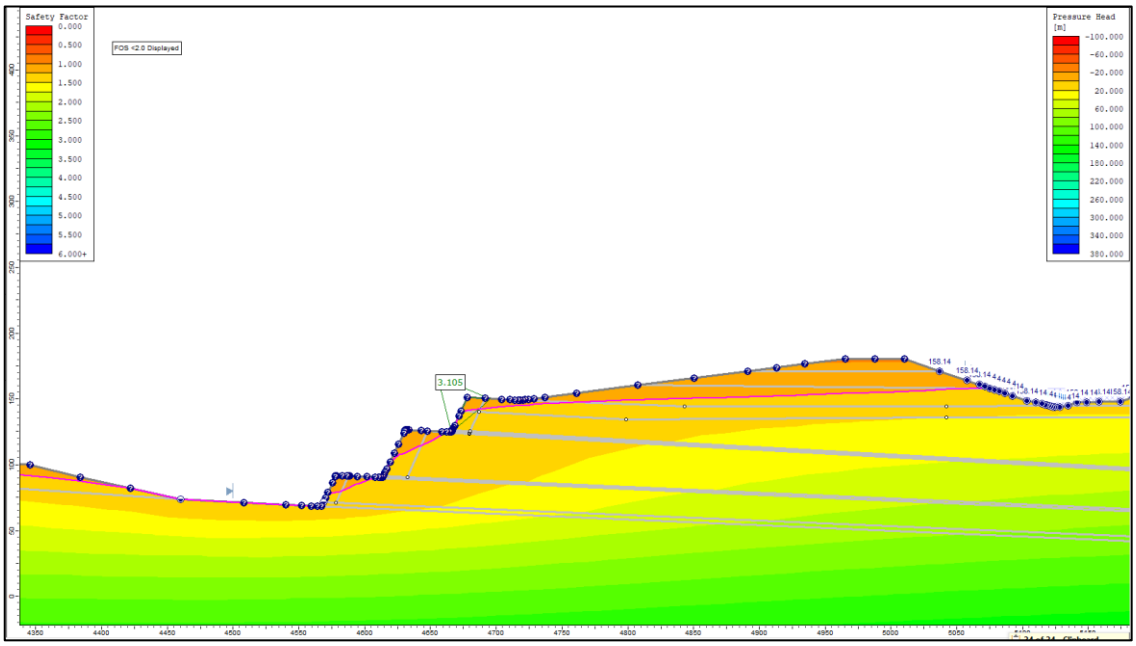
Appendix A 23 Cross Section 6 – Curragh Main K-Pit - Static



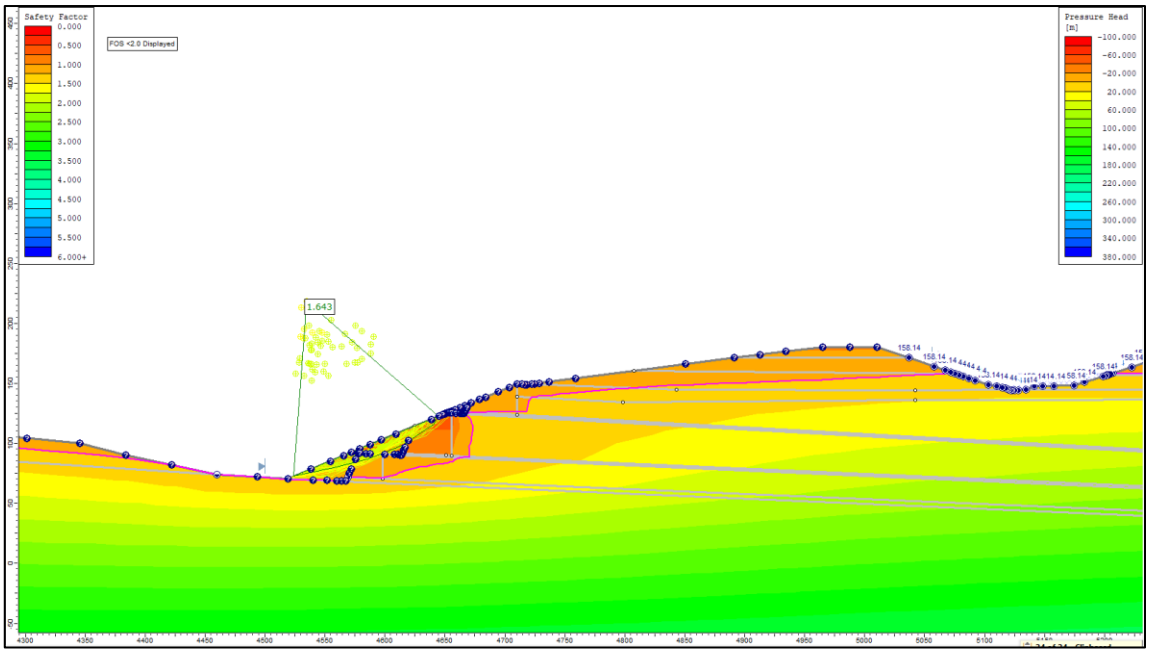
Appendix A 24 Cross Section 6 – Curragh Main K-Pit - Dynamic



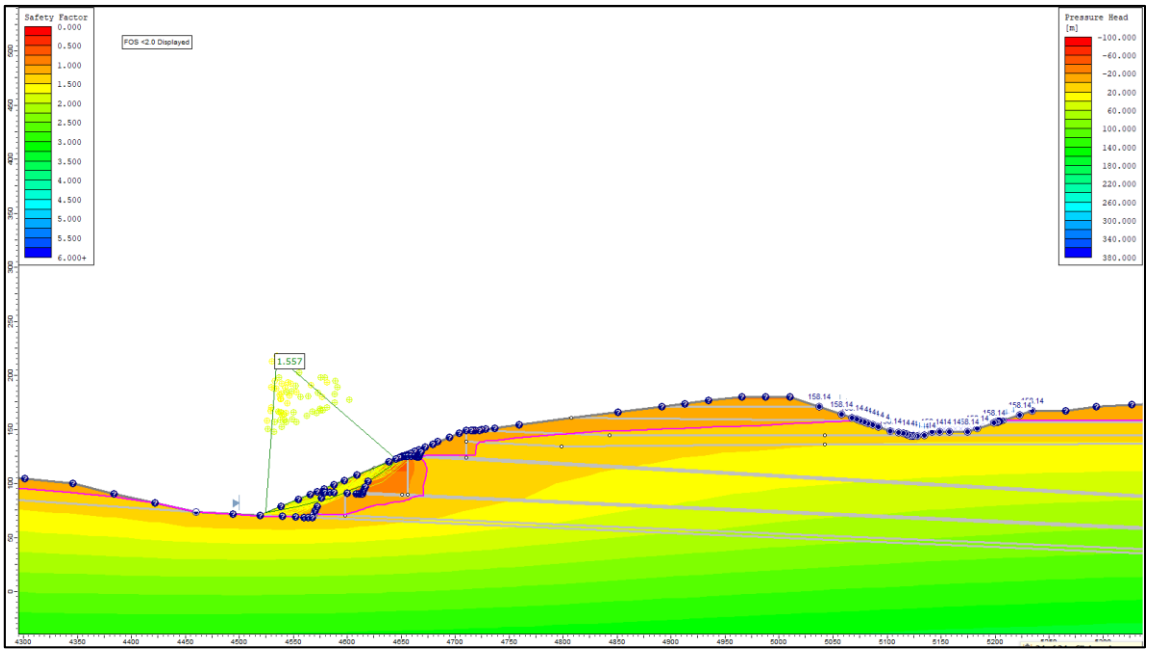
Appendix A 25 Cross Section 6 – Curragh Main K-Pit Alternative final highwall geometry – Static



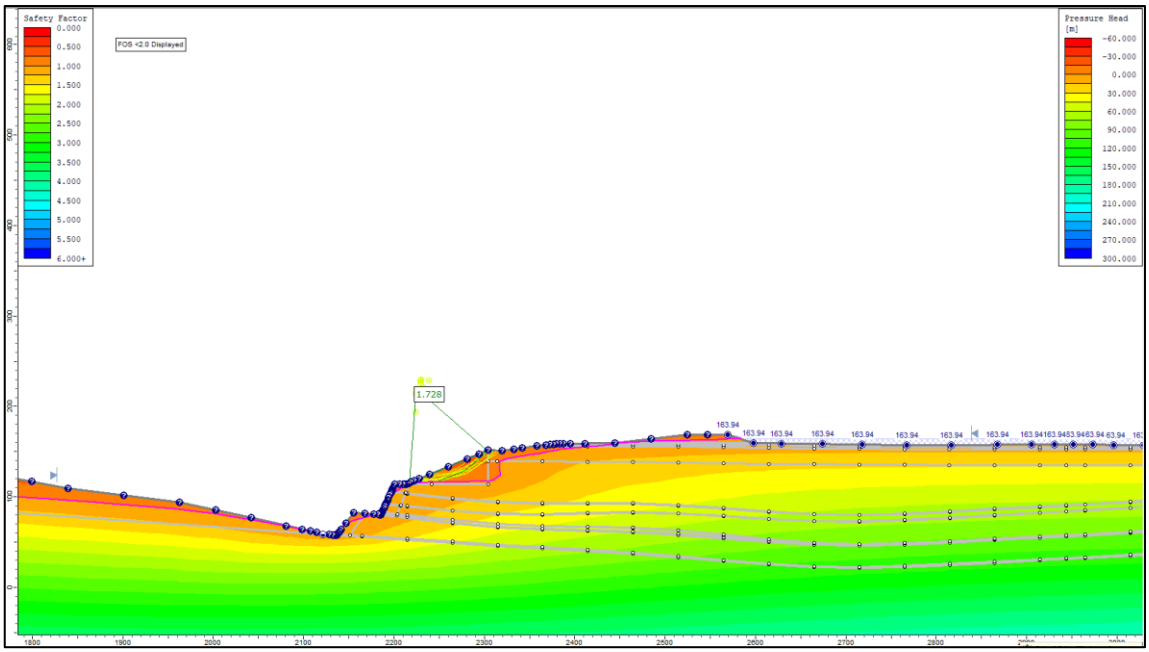
Appendix A 26 Cross Section 6 – Curragh Main K-Pit Alternative final highwall geometry – Dynamic



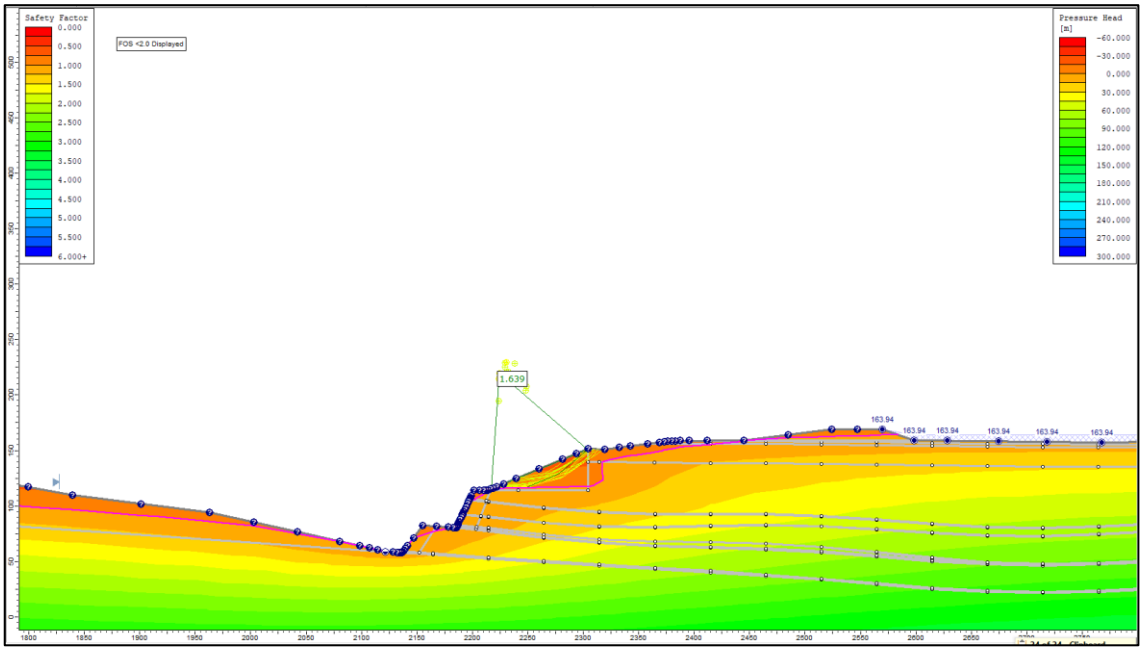
Appendix A 27 Cross Section 6 – Curragh Main K-Pit Alternative final highwall geometry with blasted and re-shaped final slope – Static



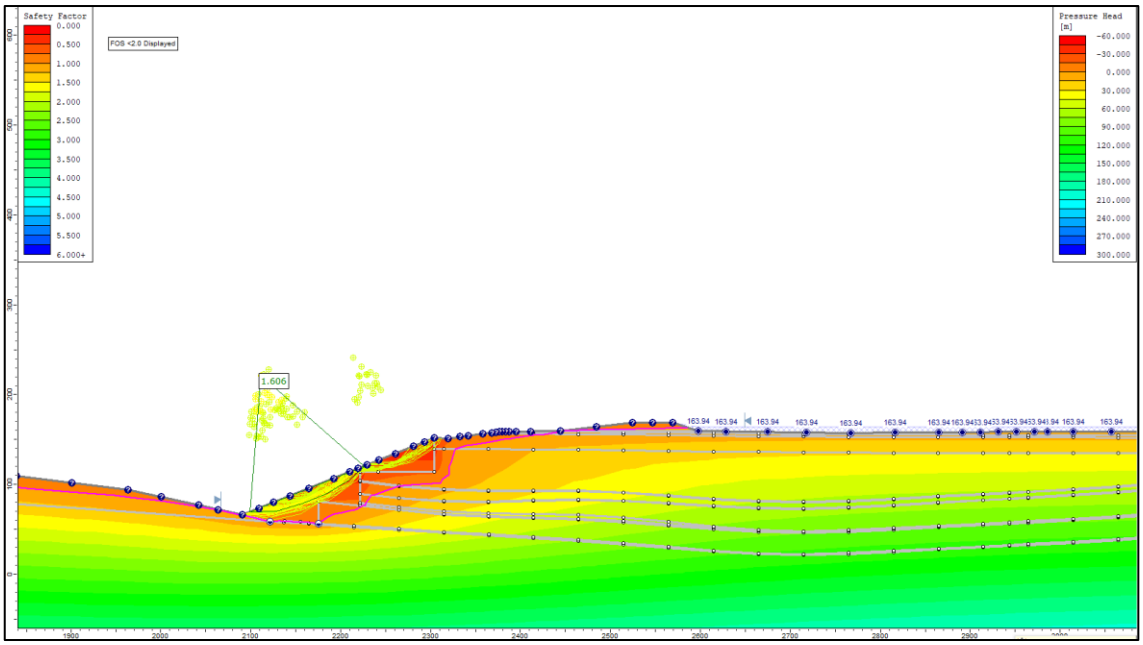
Appendix A 28 Cross Section 6 – Curragh Main K-Pit Alternative final highwall geometry with blasted and re-shaped final slope – Dynamic



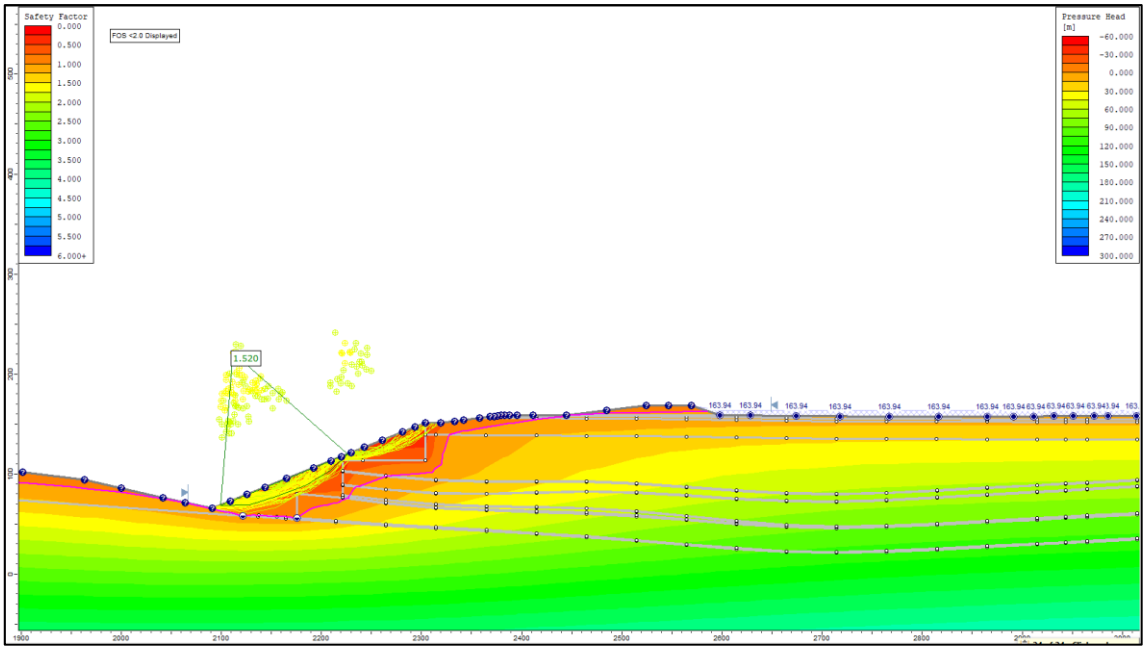
Appendix A 29 Cross Section 7 – Curragh Main J-Pit - Static



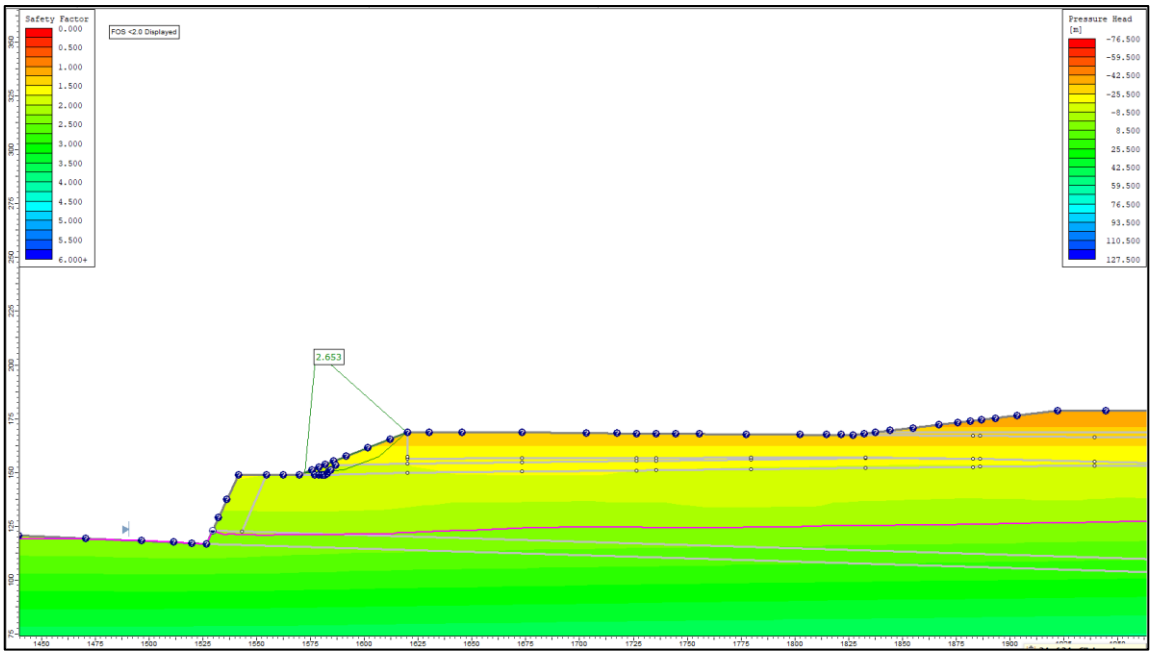
Appendix A 30 Cross Section 7 – Curragh Main J-Pit - Dynamic



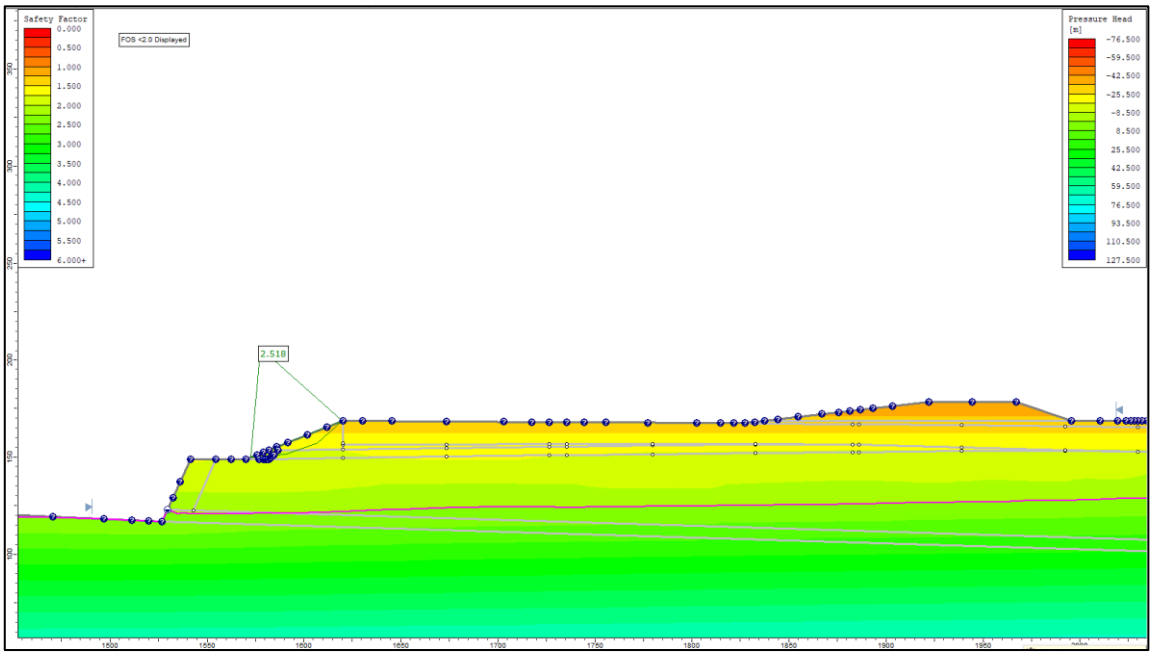
Appendix A 31 Cross Section 7 – Curragh Main J-Pit Final highwall geometry with blasted and re-shaped final slope – Static



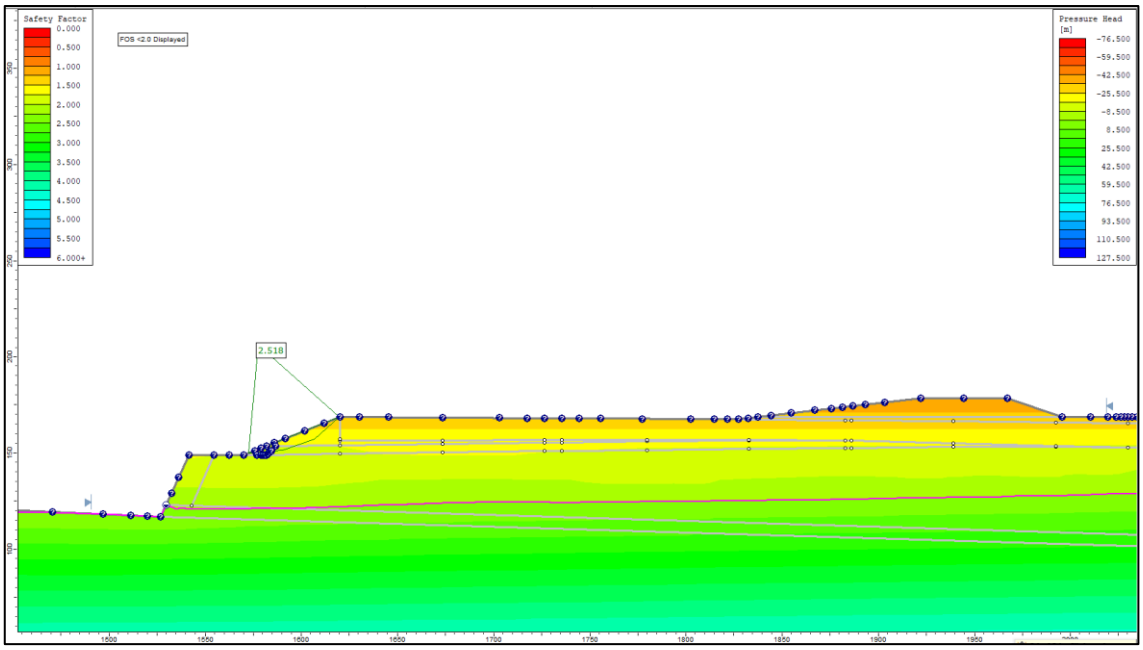
Appendix A 32 Cross Section 7 – Curragh Main J-Pit Final highwall geometry with blasted and re-shaped final slope – Dynamic



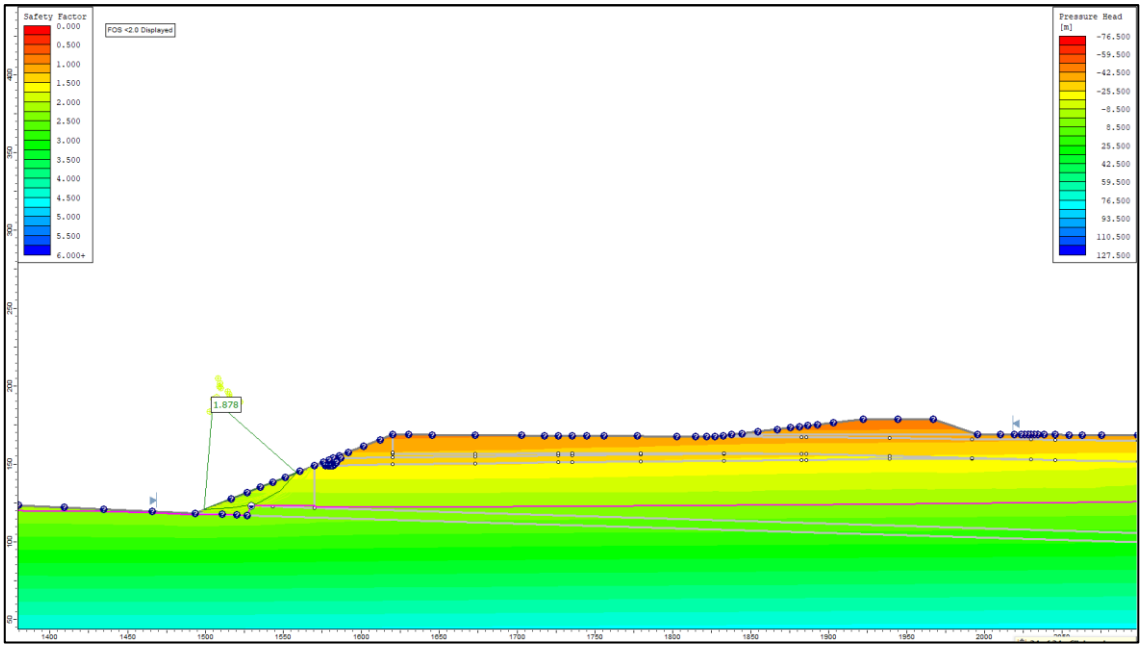
Appendix A 33 Cross Section 8 – Curragh Main Y-Pit - Static



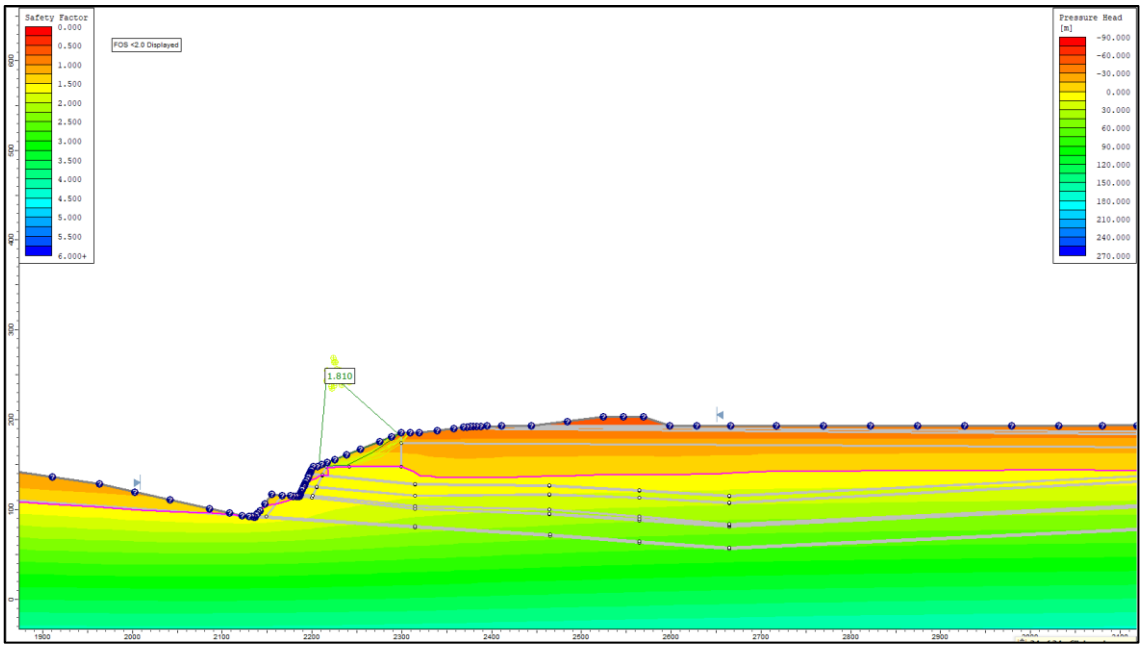
Appendix A 34 Cross Section 8 – Curragh Main Y-Pit - Dynamic



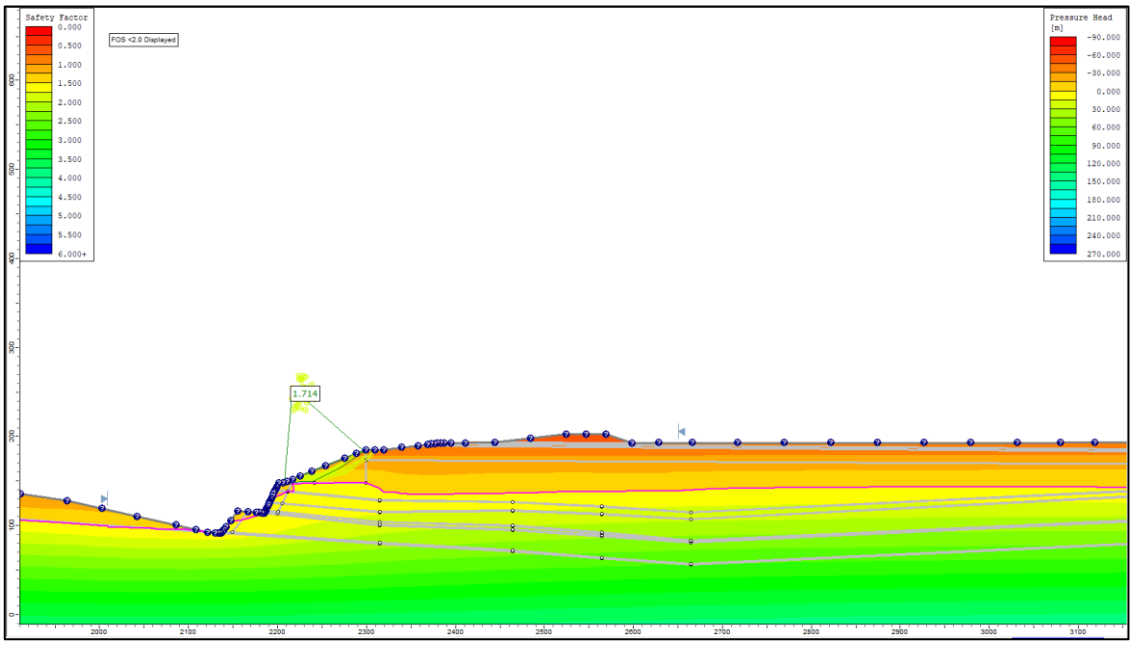
Appendix A 35 Cross Section 8 – Curragh Main Y-Pit Final highwall geometry with blasted and re-shaped final slope – Static



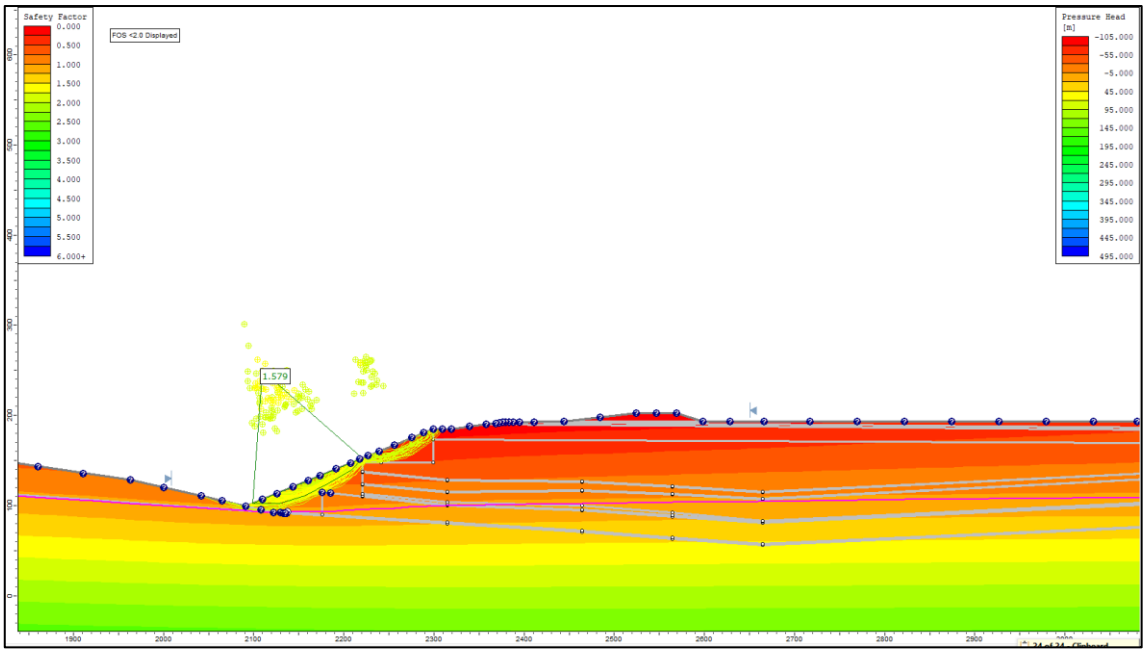
Appendix A 36 Cross Section 8 – Curragh Main Y-Pit Final highwall geometry with blasted and re-shaped final slope – Dynamic



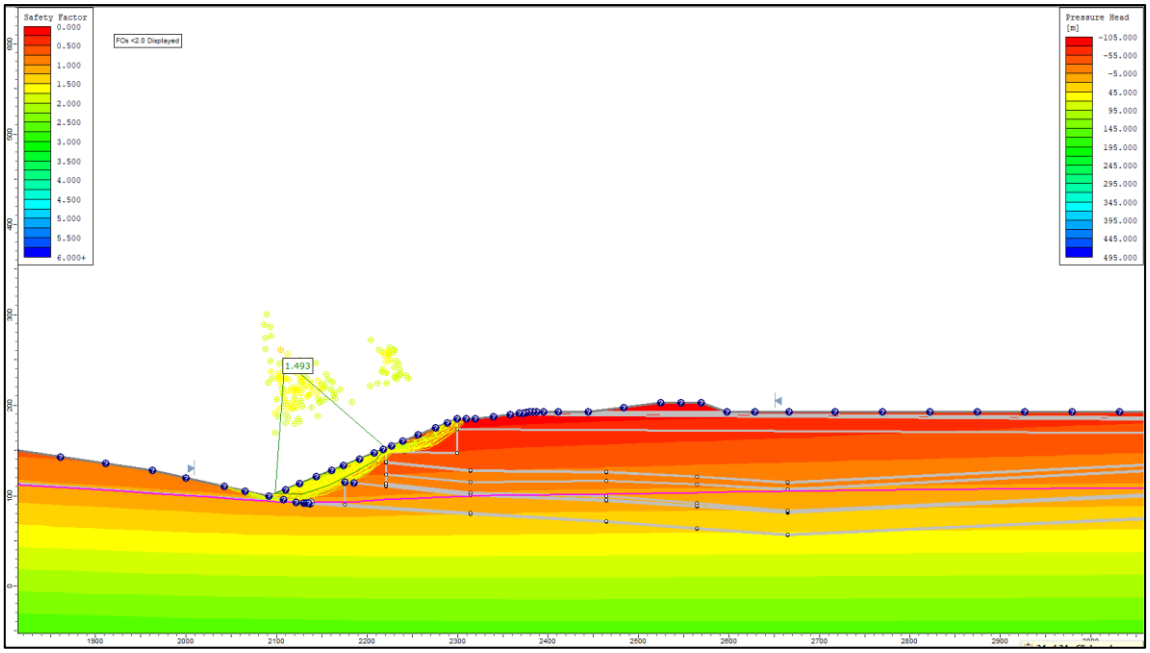
Appendix A 37 Cross Section 9 – Curragh Main Z-Pit - Static



Appendix A 38 Cross Section 9 – Curragh Main Z-Pit - Dynamic



Appendix A 39 Cross Section 9 – Curragh Main Z-Pit Final highwall geometry with blasted and re-shaped final slope – Static



Appendix A 40 Cross Section 9 – Curragh Main Z-Pit Final highwall geometry with blasted and re-shaped final slope – Dynamic

Appendix B – Design Risk & Opportunities Register

Item	Risk Scenario	Actions & Recommendations
1	Geological and geotechnical risk and uncertainty: • Variations in the geological and structural models resulting in changes to adopted lithological unit, unit thicknesses, geological structures (i.e. faults, joints etc.), rock mass conditions, material properties etc. impacting the final landform design option include pitwall crest and toe limits.	Geological and geotechnical data collection programs for the final pitwalls are to be developed and implemented. An erosion assessment is completed to define the required slope angles for the soil strength materials and inform the design development. The proposed final landform is to be updated based on the outcomes of the erosion study.
2	Hydrogeological and hydrological risk and uncertainty: • Variations in the hydrogeological and hydrological models resulting in changes to adopted lithological unit hydraulic properties, changes in groundwater levels, changes in flood water level etc. impacting the final landform design option.	The hydrogeological and hydrological models should be developed, and an associated ground water investigation program implemented, to further inform the slope stability analysis. Investigations and studies should be undertaken to identify the potential location and extent of Paleochannels.
3	Variations to the proposed final landform design options arising from: • Variations in the geological and structural model; • Variations in the hydrogeological and hydrological models; • Outcomes of erosion studies; • Changes to or limitations in the final pitwall construction methodology, crest and toe locations, and availability of materials.	The proposed final landform design option construction methodologies, and design options are developed. Undertake detailed design work to develop final pitwall construction methodologies.

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APPENDIX E

Rehabilitation Management and Monitoring Plan

REHABILITATION MANAGEMENT AND MONITORING PLAN

Document No:	EM PLAN 1.3	**Version:**	6
Applies to:	ALL	**Work Groups:**	Mining, Environment
RELEVANT LEGISLATION	Environmental Protection Act 1994	S126C, S126D, S318Z	
	Environmental Authority EPML00643713:	A4, D27–D28, G10-G12, G17-G19	

KEY RELATED DOCUMENTS

Plans	Procedures	Forms
EM PLAN 1.0	EMS PROC 1.3	
EM PLAN 1.1	EMS PROC 1.5	
EM PLAN 1.2	EMS PROC 1.6	

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Next Review Date:	**This document is scheduled for review 3 years from the Approval Date**		

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1	Creation of Document	07/2012	Amanda Dawson-Evenhuis	Ken Dunlop
2	Review and Update of Document	07/05/2014	Amanda Dawson-Evenhuis	Elmien Ballot
3	Basic review and update to encompass ES amendment	30/06/2015	Amanda Dawson-Evenhuis	Elmien Ballot
4	Organisational Changes and EA Amendment	28/06/2016	Helen Cooke	Elmien Ballot
5	Incorporation of rehabilitation requirements for heightened spoil dumps at Curragh North	24/09/2019	Steve Lyngcoln, Principal Ecologist, WSP	Elmien Ballot
6	Review and Update of Document	30/11/2021	Howard Rogers, Principal Ecologist, WSP	Kim Tuart

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1. LEGISLATIVE CONTEXT

1.1 Environmental Protection Act 1994

The *Environmental Protection Act 1994* (EP Act) is the key legislation for environmental management and protection in Queensland. The EP Act establishes a general environmental duty and a duty to notify environmental harm that applies to all persons and corporations.

The following sections of the EP Act are the key requirements for operations prior to closure:

- Chapter 5, Section 126C and 126D covers the requirements for a Progressive Rehabilitation and Closure Plan (PRCP), which provides for a rehabilitation program for land disturbed or proposed to be disturbed under each relevant lease; and the proposed amount of financial assurance (FA) for the environmental authority for the plan period;
- in November 2020 Curragh transitioned to the estimated rehabilitation cost (ERC) calculator. The ERC period for which the ERC is in force is between 3 November 2020 to 2 November 2022; and
- Section 318Z deals with progressive rehabilitation and certification.

1.2 Curragh Mine Environmental Authority

The Curragh Project operates under Environmental Authority (EA) EPML00643713, issued by Department of Environment and Science (DES) under Chapter 5 of the EP Act. Rehabilitation plans are captured in each ERC submission.

This Rehabilitation Management and Monitoring Plan has been developed to provide a framework and strategy for site rehabilitation work and has been developed to meet the legislative requirements under the EA. The following EA conditions are covered in this plan for landform, erosion and weed control:

Rehabilitation landform criteria

G10 All areas significantly disturbed by mining activities must be rehabilitated to a stable landform with a self-sustaining vegetation cover.

G11 Progressive rehabilitation must commence within three years when areas become available within the operational land.

G12 Areas that are, or are becoming, available for rehabilitation must be identified in the current Plan of Operations.

G13 and G14 relate to Residual Voids and are not addressed in this plan but covered specifically in the Concept Residual Void Assessment (CRVA).

Erosion

G15 Rehabilitated land must:

a. not have a rate of soil loss that exceeds that present in representative unmined areas within the mining leases that have the same chemical and physical characteristics including slope, slope length and fire regime; and

b. not exhibit any signs of continued erosion greater than that exhibited on representative unmined areas within the mining leases.

Weed control

G16 Class 1 and Class 2 declared plants as listed under the *Land Protection Pest and Stock Route Management Act 2002* and subordinate legislation must not be present in the rehabilitation in densities that prevent the revegetation criteria from being achieved.

Rehabilitation of Blackwater Creek diversion

G17 The rehabilitation of the Blackwater Creek diversion which is addressed in EM PLAN 1.4 Blackwater Creek Diversion Monitoring and Maintenance Plan.

Rehabilitation monitoring program

G18 The holder of the environmental authority must conduct a Rehabilitation Monitoring Program on a yearly basis, which must include sufficient spatial and temporal replication to enable statistically valid conclusions as established under the rehabilitation program.

G19 Upon commencement, a Rehabilitation Management and Monitoring Program must be developed describing:

a. how the rehabilitation objectives will be achieved; and

b. verification of rehabilitation success.

G20 and G21 relate to Post-Closure Management Plan and are not addressed in this plan.

2. INTRODUCTION

The Curragh Project is an open cut coal mine located approximately 200 kilometres west by road from Rockhampton and approximately six kilometres north of the town of Blackwater (Figure 1), within the Central Highlands Regional Council. It is located within the catchment of the Dawson / Fitzroy River drainage, which contains a number of ephemeral waterways such as Blackwater Creek and Sagittarius Creek (WBM, 2000). These waterways drain north and north-west to the Mackenzie River. The Dawson / Fitzroy system has been subjected to several direct and indirect pressures associated with the advent of agricultural practices and mining operations in the wider Bowen Basin.

The Curragh Project has been operating since 1983. In March 2018, Coronado Curragh Pty Ltd (CCPL) was acquired by Coronado Global Resources from previous operators, Wesfarmers Curragh Pty Ltd (WCPL). WCPL had managed the Curragh Project between 2000 and 2018, after the operation was purchased from ARCO and Mitsui.

The Curragh East Mine had been approved in 2000, extending the mine life to 2016. In 2003, WCPL won the competitive tender to develop an allocated section of the Curragh North Mine. Curragh North Mine commenced operation in 2004, extending the life of the Curragh Project to 2025.

In 2008, Curragh obtained approval to divert Blackwater Creek to the eastern edge of the Curragh East Mine mining lease, allowing WCPL to access the reserves located under the current creek alignment once the diversion was open. A pit west of the Curragh main operation, Curragh West, was approved in July 2015, effective 1 August 2015. This area has not yet been developed.

In 2016 WCPL converted parts of MDL162 to ML700006, ML700007, ML700008 and ML700009, increasing the total area and the life of the project past 2038.

In 2018, CCPL acquired “The Stanwell Reserved Area” at Curragh North, further increasing the life of the Curragh Project past 2042.

The Curragh Project open cut mine produces a variety of coking, PCI and steaming coal products for both export and domestic markets. CCPL holds a long-term domestic coal supply contract with Stanwell Corporation which is largely supplied by washed secondary product.

The Curragh Project comprises circa 19,650 hectares (Ha) of Mining Leases (MLs). The scale of the Curragh Project makes CCPL a significant landholder in the Central Highlands region. With a variety of historical and current land uses within the local and regional catchment CCPL recognises the importance of responsible land management.

To date a total of 1,545 hectares (Ha) of land has been rehabilitated using the techniques and processes described within this management plan.

Much of the criteria and techniques have been developed as results of extensive research and monitoring carried out at Curragh since 1990. Research work is considered a vital component of Curragh’s continual improvement process, the purpose of which is to understand key aspects of the rehabilitated ecosystem, improving rehabilitation techniques and determining whether the resulting vegetation and fauna communities will be sustainable and fulfil their ecosystem functions over the long term.

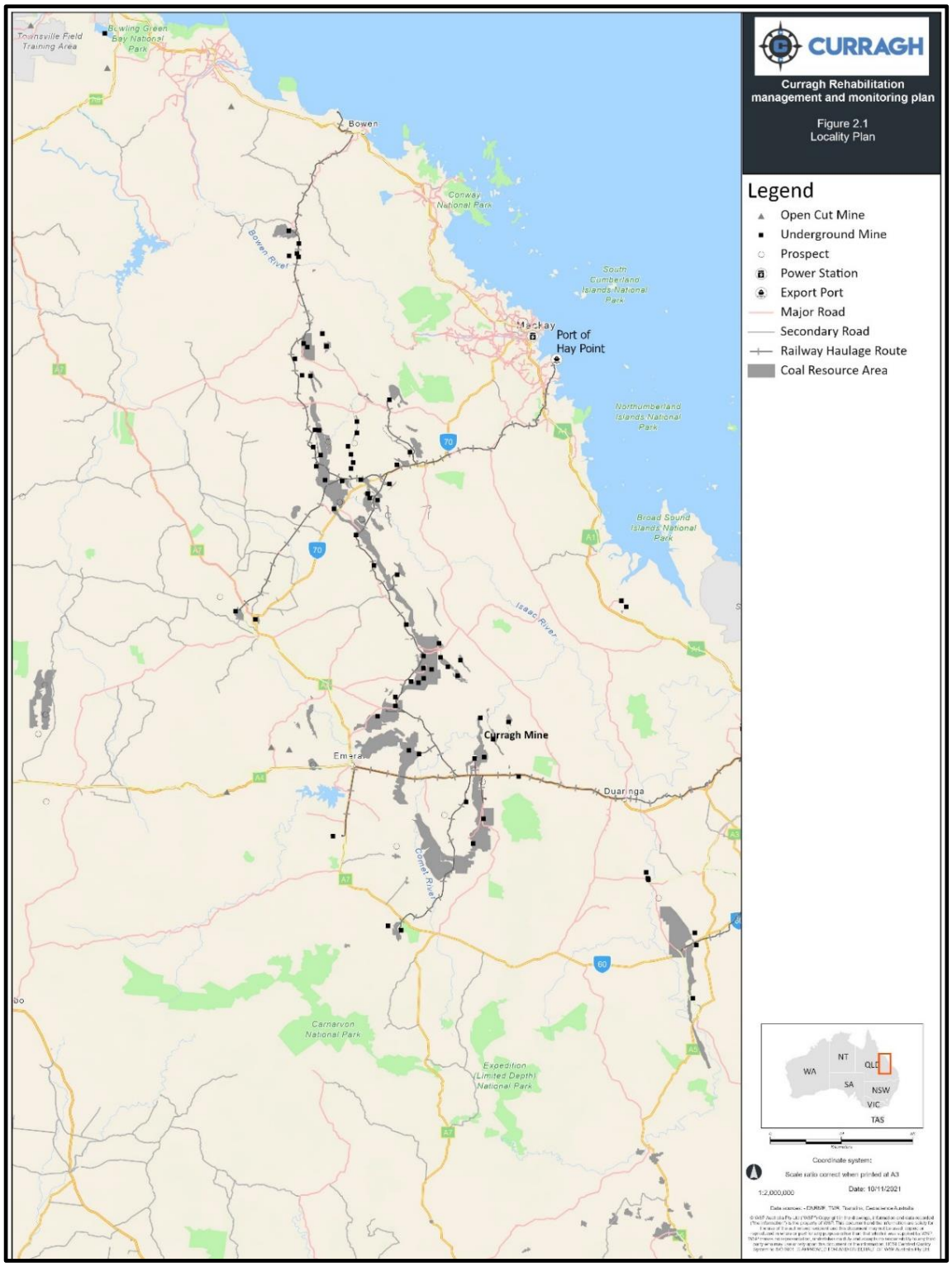


Figure 1: Locality map.

2.1 Background

Immediately prior to the commencement of open cut mining in the Curragh Project area the predominant land use was grazing and raising cattle. The area to the west of Blackwater Creek was comprised of beef cattle raising and mixed beef cattle/grain production systems (Hollingsworth, 1979). To the east of Blackwater Creek, beef cattle operations were carried out over approximately 80% of the land. This activity resulted in a major portion of the land area being significantly modified.

Overall, pre-mining land use consisted of beef cattle grazing (85%), conservation (11%) and disturbed areas (4%). The Curragh Project area conservation status before mining was Class 3. In addition, there is evidence of small-scale underground mining having taken place within parts of the lease area to the west of Blackwater Creek.

2.2 Rehabilitation Objectives

The rehabilitation objectives for the Curragh Project are:

i. To achieve a self-sustaining open pasture and woodland, capable of supporting both native fauna and pasture for light intensity grazing that requires minimal on-going maintenance.

ii. To ensure the land disturbed by mining activities will be made stable.

iii. Maintain downstream water quality at an acceptable standard consistent with ambient water quality conditions.

To avoid land degradation, grazing should be of a light intensity only. Light grazing is a condition with less than 30% grass utilization to produce slaughter steers. A 30% pasture utilization is considered the maximum to maintain land condition without degradation (Bowen and Chudleigh, 2017).

The basic elements essential to the attainment of these objectives are landform stability, topsoil management, revegetation, and control of run-off water. These objectives incorporate specific short-term and long-term objectives.

2.3 Short-Term Objectives

Short-term rehabilitation objectives including landform stabilisation, erosion control, and revegetation works aim:

i. To minimise clearing/vegetation disturbance consistent with operational requirements.

ii. To utilise coarse woody debris on rehabilitation area as habitat, where possible.

iii. To rehabilitate areas of disturbance no longer required for mining related operations in accordance with the Rehabilitation Management and Monitoring Plan.

iv. To apply soil (topsoil/subsoil) to the final landform based on material availability and post mining land use.

v. To stabilise all earthworks, drainage lines and disturbed areas required for mine-related activities to minimise erosion and sedimentation.

vi. To control pests, feral animals and noxious weeds.

vii. To implement fire management trials for the site.

viii. To reduce the visibility of activities from adjacent properties and the local road network, where appropriate.

2.3.1 Long-Term Objectives

Long-term rehabilitation objectives including achieving stable self-sustaining open pasture and woodland, capable of supporting both native fauna and pasture for light intensity grazing that requires minimal on-going maintenance aim:

i. To establish low maintenance, geotechnically stable, safe and vegetated landforms which blends in with the surrounding natural landscape and is acceptable to stakeholders.

ii. To control pests including feral animals and weeds.

iii. To monitor rehabilitation success in terms of physical and biological parameters.

iv. To decommission and remove all project-related infrastructure not required for the future use of final land use stakeholders.

v. To remediate any contaminated land.

vi. To re-establish open woodland and pasture capable of supporting both native fauna and pasture for light intensity grazing commensurate with land capability. Where land capability is low the emphasis will be on the re-establishment of woodland habitat).

vii. To relinquish Blackwater Creek back to the authorities by meeting its closure criteria.

2.4 Post-mine Land Capability

The post-mine land capability is likely to differ from the pre-mine land capability in places given the approximate 25% increase on in situ volume as a result of swell from mining activity that has taken place i.e. the land profile will be more undulating than pre-mining. However, with the exception of voids and slopes associated with voids; land capability will allow for a similar type (with decreased grazing intensity) of land use that occurred prior to mining.

It is expected that extensive areas of open predominantly native woodland will be nature positive, even though structure and species composition may differ from remnant Regional Ecosystems. The predominance of pasture grasses in the rehabilitated lands will allow for light grazing. Light grazing, while allowing for a return to the pre-mining land use should also minimise the risk of erosion and is considered compatible with nature positive outcomes, provided grazing levels as determined by pasture monitoring are not exceeded.

The main post-mine differences in land use capability will include:

- spoil slopes where the slope angle on average exceed the slope of the original topography;
- final voids where remnant high walls and end walls may be left; and
- infrastructure retained as agreed by stakeholders.

2.5 Rehabilitation Commitments

The following rehabilitation commitments have been adopted:

i. Infrastructure will be decommissioned unless arrangements have been made with underlying stakeholders.

ii. Landform design that will emulate the natural drainage and slopes in the mining area, where possible.

iii. Landform morphology will be developed and implemented to ensure an integrated final landform.

iv. Water and erosion will be managed though use of the appropriate water management structures e.g. contour banks, rock lining on waterways.

v. Final void studies will be continuously undertaken and updated during operations and prior to mine closure to ensure baseline data is available for updating the final void modelling. The baseline data will be inclusive of water and periodic soil monitoring.

vi. All final voids, including pits and ramps not backfilled, will be made safe with persons and stock excluded.

vii. Hydro-geological studies of tailings dams will be undertaken once operational life is reached to inform final rehabilitation design.

viii. Deep ripping of spoil/topsoil in conjunction with seeding will be utilised to minimise erosion.

ix. Revegetation will be surveyed on a regular basis as defined in Section 7 and maintenance will be carried out to meet rehabilitation success criteria.

x. Revegetation will be carried out predominantly using a seeder to broadcast seed.

xi. A rehabilitation schedule will be implemented and maintained.

xii. Rehabilitation areas will be restricted for access.

xiii. Haul roads and hardstand areas will be rehabilitated by removal of contaminated material and ripping of compacted areas, topsoiling and seeding.

2.5.1 Decommissioning of Infrastructure

The decommissioning and final rehabilitation will occur on a staged basis over several years. Where written agreement has not been obtained with stakeholders for infrastructure to remain, the rehabilitation will include:

- the treatment of exploration disturbance and drill holes according to the DES ESR-2016-1985 Eligibility criteria and standard conditions for exploration and mineral development projects—V2;
- the removal of buildings and structures;
- the breaking up and covering of concrete slabs and or/coal stockpile areas with a suitable depth of inert material;
- the removal of redundant roads by removal of contaminated material before ripping and seeding; and
- mine affected water management structures will be assessed for contamination and treated in accordance with specialist advice.

2.5.2 Post-mine Land Suitability

Based on current information, post-mine suitability at Curragh Project could sustain an open pasture woodland capable of supporting both native fauna and light intensity grazing. The only areas unable to be rehabilitated to a post mining land use will be the final voids and residual walls (Non-Use Mining Areas - NUMAs) identified in the CRVA as shown in Figure 2.

2.5.3 Post-mine Land Use

To achieve the Post Mining Land Use (PMLU), rehabilitation will include the use of a species mix incorporating exotic and native pasture grasses and native woodland species as discussed in Section 3.7 noting that the native woodland species seed mix may vary from year to year depending on seed availability and ongoing reviews of species performance to achieve the land use objectives.

2.5.4 Post-mine Landform

In general, visual amenity impacts will remain during the life of the mine. Out of pit spoil stockpiles will remain in the post-mining landform. The visual impacts of these stockpiles will be minimised through progressive rehabilitation activities, including revegetation.

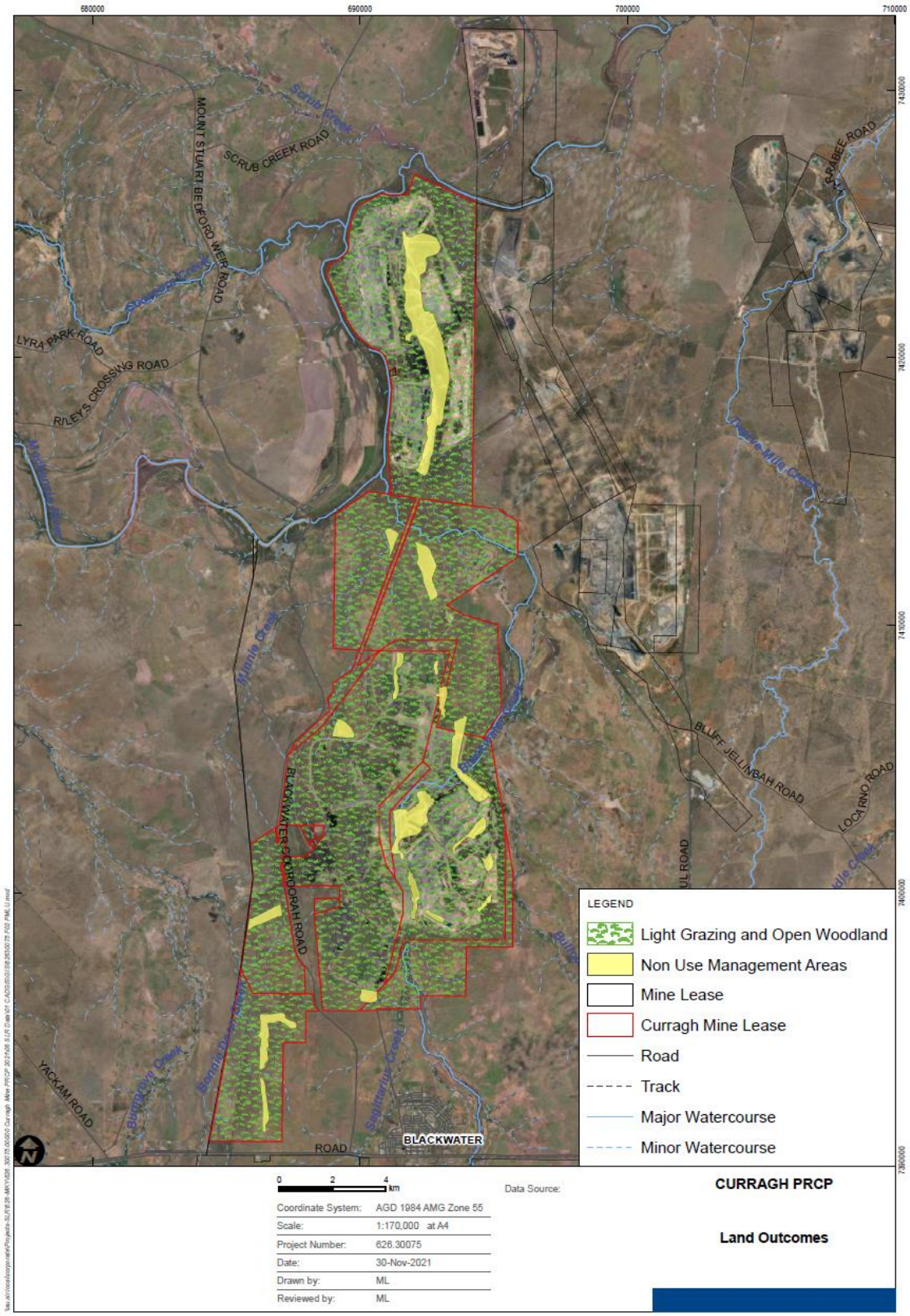


Figure 2: PLMU and NUMA Map.

3. REHABILITATION MANAGEMENT STRATEGY

The rehabilitation strategy is built around five benchmarks as follows:

- areas re-contoured (reshaped to final grade);
- areas topsoiled;
- areas seeded (ripped and seeded, irrespective of germination success);
- areas established (vegetation has established, although minor reseeding/ erosion repairs may be necessary); and
- areas successfully rehabilitated and certified (compliance with rehabilitation success criteria).

Conceptually re-contouring will occur circa 36 months after cessation of coal mining and re-topsoiling activities will complete 48 months after cessation of mining.

In general, all available (re-contoured and topsoiled) areas are seeded in October/November and February/March of each year. Seeding may also occur at other times to take advantage of predicted weather patterns.

3.1 Slope angles

The maximum slope criteria to be achieved by rehabilitation is provided in Table 1. Treatment proposed for voids and void ramps is discussed further in the Concept Residual Voids Assessment document (CRVA).

Table 1: Slope Criteria for Rehabilitation.

	Slope Criteria
Boxcut spoil	Typical slope 14%, Maximum slope 16%
Strip spoil	Typical slope 10%, Maximum slope 16%
Out of Pit	Typical slope 12%, Maximum slope 16%
Final void	As described in the CRVA document
Haulage ramps	Typical Slope 22%-27%
	Dip direction at coal dip 5%-9%

The Curragh Project will, throughout the life of the operation, continue to trial rehabilitation for varying slope angles within the ranges shown in Table 1 to identify the most appropriate treatment at each slope angle. This excludes Curragh North Spoil Dumps where near term trials are considering slopes of greater than 16 %. If monitoring proves that the rehabilitation of slope angles greater than 10 % (and greater than 16 % for Curragh North spoil dumps) are not performing, then suitable control strategies will be implemented, and design criteria will be modified accordingly.

3.2 Slope Length

For simplicity in design and construction, straight slopes, with a constant gradient are targeted for spoil reshaping at the Curragh Project. Straight slopes require their slope length to be limited to avoid runoff water velocity increasing above the erosive threshold. The criteria for the slope angle/length relationship adopted are provided in Table 2**.**

Table 2: Slope Length.

Slope %	Slope ratio (v:h)	Length Between Benches (m)
6	1:17	115
8	1:12	105
10	1:10	90
12	1:8	80
14	1:7	70
16	1:6	55
18	1:5.5	45
25	1:4	As required (not<45)

3.3 Contour Banks

Contour banks are earthen water management structures constructed at intervals down a slope to intercept run off and safely channel it into stable waterways. Contour banks reduce effective slope length and intercept the runoff before it can concentrate into an erosive force. Contour banks also trap sediment from overland flow. Contour banks are typically constructed on re-contoured spoil to minimise erosion.

CCPL will continue to produce a landform design that will emulate the natural drainage and slopes in the mining area, where possible. Landform design will incorporate natural and engineered structures to minimise erosion.

Contour bank design parameters would typically include consideration of:

- low gradient design of circa 0.5% along the flow alignment;
- low flow velocities, typically >1.0 m/sec (for nil vegetation case);
- adequate topsoil coverage (200-300 mm);
- bank invert left bare, no topsoil; and
- up slope bank face <1:2, down slope face <1:3.

Contour banks less than 400m long are built to a standard dimension of 1m high of spoil, plus a 200-300 mm topsoil cover.

Contour banks effectively minimise erosion on slopes but tend to produce concentrated high velocity flows at their discharge end. Contour banks are therefore arranged to discharge into a strategically placed energy dissipation basin or waterway.

Some waterways may require rock armouring due to the high flow velocities encountered. At Curragh Project, the Ishbash equation has been used to determine optimum rock size as appropriate.

If contour banks are left to remain in the longer term, after the establishment of a vegetative cover, they may increasingly be at risk of overtopping. This failure could cause a concentration of flow to occur and commencement of gully erosion. Consequently, after establishment of adequate vegetative cover, the potential will be assessed as to whether the contour banks will be removed to avoid that possibility. Removal could be carried out by a variety of methods depending on the height of the bank and its manner of construction.

3.4 Contamination Source Rehabilitation

Rehabilitation of the tailings dam will be in accordance with the technical Guideline for Tailings Management and the Guideline for Rehabilitation Requirements for Mining Lease Projects and subject to detailed hydro-geological studies at the appropriate time. For in-pit tailings storage, rehabilitation methods are expected to be the same as for the tailings dam.

3.5 Topsoil Management

The Curragh Project has an active topsoil management procedure (EMS PROC 1.3) to provide guidance for the ongoing management of topsoil and to ensure topsoil is managed as an important resource. This document provides direction for the management of topsoil from its removal, storage and its placement as part of the rehabilitation strategy. As outlined in Curragh Project's regulatory framework under the Environmental Authority EPML00643713 and EM PLAN 1.1 Topsoil Management Plan.

3.6 Deep Ripping

Deep ripping and the use of a winged tyne (Figure 3) after shaping has been completed, is required to improve rainfall/run-off infiltration, and to decrease erosion. The winged tyne facilitates improved sub soil loosening without having to drag a larger tyne through the soil profile.

Deep ripping is carried out to a depth of 60–75 cm with the rip-lines oriented across the slope at a gradient of 0.5% (1h: 200v) off the contour. The dozer operator uses the graded banks, which are also at 0.5% gradient, for alignment guidance. Deep ripping is carried out in conjunction with the seeding operation.



Figure 3: A winged tyne in use at Curragh.

3.7 Revegetation

The objective of revegetation is threefold:

i. To stabilise the re-contoured ground.

ii. To fit in and complement the surrounding flora and habitat.

iii. To enhance or increase species diversity.

Revegetation is predominantly carried out by seeding. which appears to perform better than tube stock planting, which has a high mortality rate.

3.8 Seeding

The seed mix employed at Curragh Project includes native Eucalypts, Acacias, other native shrubs and tree species, native grasses, exotic grasses and a range of legumes. A typical seed mix is provided in Table 3: . The seed mix is improved from year to year based on the results of the annual rehabilitation monitoring. The current seed mix (2019 – 2022 has an increased richness of other trees and shrubs to better reflect species present in the reference sites.

For 2019 to 2020 the combined seed mix included seven species of Acacia, six species of Eucalyptus, six native grass species, 12 species of other trees and shrubs, one legume species and three exotic pasture grass species.

Table 3: Past and Recent Seeding Mix**.**

Acacias	**2011**	**2019/2022**	***Native Grasses***	**2011**	**2019/2022**
Acacia bancroftii	x		*Astrebla lappacea*	x	
Acacia complanata	x		*Astrebla squarrosa*		x
Acacia cretata	x		*Bothriochloa bladhii*		x
Acacia decora		x	*Cynodon dactylon*	x	
Acacia excelsa		x	*Dichanthium serecium*	x	
Acacia harpophylla	x	x	*Digitaria didactyla*	x	
Acacia holosericea	x	x	*Digitaria sericeum*		x
Acacia macradenia	x		*Heteropogon contortus*	x	x
Acacia rhodoxylon		x	*Paspalidium caespitosum*	x	
Acacia salicina	x		*Themeda australis*	x	x
Acacia saligna	x		**Introduced / Exotic Grasses**		
Acacia shirleyi		x	*Bothriochloa insculpta*		x
Acacia stenophylla	x		*Cenchrus ciliaris*	x	
Acacia victoriae		x	*Chloris gayana*	x	x
Eucalyptus			*Echinochloa esculenta*		x
Corymbia citriodora variegata		x	*Panicum coloratum*	x	
Eucalyptus camaldulensis	x		*Panicum maximum*	x	
Eucalyptus cambageana	x	x	*Urochloa mosambicensis*	x	
Eucalyptus citriodora	x		**Legumes**		
Eucalyptus crebra	x	x	*Cassia brewsteri*		x
Eucalyptus drepanophylla	x		*Chamaecrista rotundifolia*	x	
Eucalyptus longirostrata	x		*Clitoria ternatea*	x	
Eucalyptus populnea	x	x	*Stylosanthes hamata*	x	
Eucalyptus punctata	x		*Stylosanthes scabra*	x	
Eucalyptus tereticornis	x	x			
Eucalyptus thozetiana	x	x			
Other Trees / Shrubs					
Atalaya hemiglauca	x	x			
Brachychiton rupestris	x	x			
Carissa ovata		x			
Casuarina crista	x				
Eremophila maculata		x			
Erythrina vespertilio		x			
Geijera parviflora		x			
Lysiphyllum carronii	x	x			
Lysiphyllum hookeri		x			
Owenia acidula		x			
Petalostigma pubescens		*x*			
Pittosporum angustifolium		*x*			
Salt Bush Mix		*x*			
Senna artemisioides	*x*				
Senna notabilis	*x*				

3.9 Rehabilitation Schedule for Heightened Spoil Dumps at Curragh North

Issues and risks that may affect the success and performance of revegetation on increased slope angles include:

- soil erosion and landform stability;
- adequacy of current species mixes for final landform and land use; and
- vegetation establishment on steeper slopes >16%.

Consequently, the following measures will be trialled for rehabilitation of the steeper slopes associated with the heighted Curragh North spoil dumps.

3.9.1 Erosion and landform stability

Contour banks / slope breaks

On the steeper slopes associated with the heighted spoil dumps at Curragh North, the regularity of contour banks and/or slope breaks will be increased (to approximately 55m apart for vegetated slopes up to 20%). The adequacy of these additional contour banks and slope breaks for maintaining erosion and landform stability, will be assessed through erosion and landform stability monitoring as outlined below.

Erosion analysis

For the heighted spoil dumps at Curragh North, field-based erosion monitoring will be undertaken at the same time as rehabilitation monitoring. Evidence of erosion will be assessed in accordance with the Australian Soil and Land Survey Field Handbook (National Committee on Soil and Terrain 2009) and includes:

a. type of erosion (wind, water, scald, sheet, rill, gully, tunnel and mass movement)

b. state of erosion (active, partially stabilised or stabilised)

c. severity of erosion (dependent upon type of erosion present – present/absent and if present either minor, moderate, severe or very severe)

d. for gullies - the depth and width of erosion

e. opportunistic identification of all areas of significant erosion encountered outside of the assessment areas.

Landform stability

Landform stability of the rehabilitation on the heightened spoil dumps will be assessed using current Light Detection and Ranging (LiDAR) data and remote sensing software to generate 1m digital elevation models (DEMs) of the landform. DEMs from previous years will be compared to assess stability as it relates to identifying areas of settlement, deposition, subsidence and erosion.

The DEM slope analysis will also be used to assess the as built landform against the landform design criteria with a maximum slope of 16% for the out of pit (OoP) dump slope tying into the final landform and with in-pit dump slopes of up to 27% for the internal rehabilitation batters.

Annual erosion and landform stability monitoring will enable early detection of instability of rehabilitated slopes >16%, particularly areas that may be developing deep rills or gullies and/or areas that are either subsiding or where run off is settling. Early detection will enable targeted rework as required to maintain overall landform stability.

3.9.2 Species mix

The following measures will be implemented to improve rehabilitation success on steeper slopes associated with the heightened spoil dumps at Curragh North:

- establishment of additional vegetation reference sites in surrounding vegetation communities on steep slopes (i.e. > 16%) to improve species data and vegetation data to inform rehabilitation on the steeper slopes;
- tree, shrub and grass species representative of the surrounding vegetation will be included in the species mix for steeper slopes; and
- to establish short-term groundcover, a cover crop such as millet or oats will be included with the revised native tree, shrub and grass seed mix.

3.9.3 Vegetation establishment on steeper slopes

The current rehabilitation method includes deep ripping, with the use of a winged tyne and direct seeding. For steeper slopes, (>16%) there is an increased risk of erosion. To reduce this risk, rehabilitation is focused on establishing a high ground cover to reduce rainfall impact on soils and on establishing deeper roots to stabilise slopes. To improve native tree and shrub establishment on steeper slopes all areas of rehabilitation that have been adequately topsoiled are seeded with the revised native species mix (outlined above).

In areas of rehabilitation lacking suitable topsoil, consideration will be given to hydro mulching slopes >16% to improve vegetation establishment to achieve >50% cover with revised species mix in less than one year to reduce the risk of erosion.

When preparing the soils for direct seeding, consideration will be given to the constraints associated with the material below the depth of ripping (i.e. poor structure from sodicity or subsoil salinity). The addition of soil ameliorants such as lime or gypsum or alternatively a calcium based soil conditioner in combination with recalcitrant carbon-based soil conditioner, a biologically active fertiliser blend including soil bacteria and mycorrhizal fungi developed for rehabilitation, and a soil binder product may be required to stabilise the soil prior to direct seeding and ripping.

4. COMPLETION CRITERIA

The EPA (2008) Guideline 18 and DES Guideline (ESR/2016/1875) on the rehabilitation requirements for mining projects provides assistance to mining companies when defining rehabilitation goals, objectives and setting appropriate completion criteria. This guideline details how the regulator will assess whether progressive or final rehabilitation is successful and eligible for sign off.

Assessment is based on different land management units called 'domains' which contain their own specific goals, objectives and indicators that can be monitored and measured to demonstrate that the completion criteria have been satisfied. Four broad rehabilitation goals are required for rehabilitation of areas disturbed by mining. These goals are presented in Table 4.

Table 4: General rehabilitation goals and objectives of areas disturbed by mining (EPA 2008, DES 2016).

Rehabilitation Goal	Possible Rehabilitation Objective
Long-term safety	The site is safe for humans and animals (including stock and wildlife), now and in the foreseeable future.
Non-polluting material	Hazardous material adequately managed.
	Acid mine drainage (if any) will not cause serious environmental harm.
	Polluted/ contaminated water will be contained on-site.
Stable landform	Very low probability of landform slumping, subsidence, slippage or rock falls with serious consequences to people, animals and/or the environment.
	Landform design achieves appropriate erosion rates.
	Vegetation cover to minimise erosion
Sustainable land use	Soil properties that support and will continue to support proposed post-mine land use.
	Specified self-sustaining vegetation and habitat established.
	Specified water body with low risk of environmental harm established.
	Land use with comparable management requirements to similarly used non- mined land established.

4.1 Pre-Mine Landform, Land Use, Habitat and Vegetation

The pre-mine landforms of the mining leases to the west of Blackwater Creek, the area's major drainage system, were gently undulating plains and lowlands with a mild gradient to the east over most of the area towards the creek, with mainly gentle 2-5% slopes (Coffey et al. 1979 in Orr and Bell 1990). A similar profile was exhibited to the east of the creek, but with gradients to the west and northwest. The predominant soil type is brown cracking clay soil which is associated with sandstone parent materials. Cattle grazing and minor grain production was the main land use.

As a result of land clearing activities prior to mining, only small areas of the original vegetation remain on the mine site (Coffey et al. 1979 in Orr and Bell 1990). These remnants were mainly Brigalow (Acacia harpophylla) communities with eucalypt species relatively uncommon. Several other native tree/shrub species were reported to be common to most communities, such as Carissa ovata, Geijera parviflora, Eremophila mitchellii and Acacia rhodoxylon. These native remnant habitats support a diverse fauna assemblage, including rare and threatened fauna species (See Section 5.6.1).

4.2 Final Landform and Land Use

Previous RMMPs for the Curragh Project have addressed three "Domains" consistent with the EPA's Guideline 18 on land disturbance types:

i. Domain 1, areas have been disturbed by mining activities i.e. reshaped spoil, roads and infrastructure suitable for an open woodland ecosystem with a slope range of <16 percent.

ii. Domain 2, areas which have been areas where water carrying capacity was required i.e. tailings storage facilities, tailings embankments & mine site ramps and will be suitable for open grassland with a slope range of <25 percent.

iii. Domain 3, will be all the active pit voids.

More specific land use description for each domain is shown in Table 5 which has been sourced from a combination of references including EPA Guideline 18 (2008), DES Guideline (ESR/2016/1875), Curragh Mine EMOS (2002), annual monitoring reports of the Curragh Project rehabilitation sites and a range of other draft plans regarding completion criteria.

Domain 3 is addressed in the CRVA.

Table 5: Proposed domains based on land use description for final land disturbance types.

Domain	Disturbance Type	Post Mine land Description	Maximum Slope (%)
1	Borrow Pits	Light grazing and open woodland	10
	Long Term Infrastructure	Light grazing and open woodland	0.5
	Main Haul Road	Light grazing and open woodland	6
	Short Term Infrastructure	Light grazing and open woodland	0.5
	Reject Dumps (e.g. out of pit)	Open woodland	16
	Topsoil Stripped	Light grazing and open woodland	0.5
	Available Strip Spoil	Light grazing and open woodland	10
2	Tailings Embankment	Open Grassland	22
	Tailings	Open Grassland	0.5
	Deferred Rehab (e.g. Ramps)	Open Grassland	22

4.3 Completion Criteria for Domains 1 and 2

Proposed completion criteria for Domains 1 and 2 and given in Tables 6 and 7 respectively.

Table 6: Curragh completion criteria for Rehabilitation of Disturbed Lands in Domain 1.

Goal	Objective	Parameter/Indicator	Completion Criteria
Safety	The site is safe for humans and animals (including stock and wildlife), now and in the foreseeable future.	Safety assessment of slopes that are >16% and >5 m in height (if any)	• Certification in rehabilitation report that slopes, including graded banks, waterways, and rock lined waterways are safe. Predictions/ risk assessment to be made about future safety.
		Exposure to and availability of heavy metals and other toxic materials (selection will be made based on relevance to site)	• Certification in rehabilitation report that soil, spoil and other cover materials are safe with details of predicted future changes.
		Technical design of landform	• Engineer's certification of construction and maintenance to specified geotechnical design performance.
		Low risk of fire	• Site management planning provide adequate measures for fire risk reduction (e.g. minimise accumulation of dry matters or other potential fuels for fire).
Non-polluting	Hazardous material/ contaminated land adequately managed.	Results of site contaminated land assessment report	• Contaminated sites remediated and removed from DES Environmental Management Register or Contaminated Land Register. • Tarmac, padding, footing, hardstand removed from site unless otherwise agreed with landholder(s). • Evidence that all infrastructures are removed from site except where agreed in writing by the post mining landowner/holder.
	Polluted/ contaminated water will be contained on-site.	Downstream groundwater/ surface water monitoring.	• Certification that drainage structures and sediment dams are effective in controlling surface water runoff, and minimising quantities of polluted water and containing it on site. • Certification that monitoring data meet specified criteria relevant to potential contaminants.
		Geochemical and hydrological minimisation of spoil	• Documented evidence that geochemical and hydrological minimisation of soil material has been incorporated into design of spoil dumps.
			• Evidence that appropriate risk assessment has been undertaken and control measures are in place.
Stable landform	Very low probability of landform slumping with serious consequences to people, animals and/or the environment	Past record of slope failure/slumping	• Evidence that appropriate risk assessment was undertaken, and control measures are in place to prevent recurrence.
		Slope Range	• Evidence in rehabilitation report that relevant EA conditions have been complied with according to – Landform Design (Table 5).
	Landform design achieves appropriate erosion rates	Engineered structures to control water flow	• Documented evidence that drainage structures are in place as per design requirements and functioning effectively.
	Vegetation ground cover to minimise erosion	Vegetation type and density	• Evidence that the vegetation type and density are of species suited to the spoil/waste composition, slope, aspect, climate and other factors, and that the measured erosion rates meet the limits set (Only relevant to stability where root systems are a major control of erosion).
		Foliage cover	• Evidence that the average percent vegetative ground cover on both topsoil and spoil ≥50%.
		Leaf litter, humus, depth of growing medium	• Evidence of litter breakdown and the development of humus.
Sustainable land use	**Ecosystem definition:** Area accomplishes and remains as a healthy open woodland, capable of supporting both native fauna and pasture for light intensity grazing.		
	Specified self-sustaining vegetation and habitat established.	Key Species Presence	Evidence in rehabilitation monitoring reports of the following: • Tree canopy cover (combined canopy and sub-canopy). Preliminary value to be determined from 2021 monitoring. • Presence of at least 1 *Eucalyptus* species. • Presence of at least 2 *Acacia* species.
		Native species recruitment	• Evidence of second-generation recruitment of tree/shrub species.
		Absence of weed species	• Certification that Class 2 declared pest plants are successfully managed in a weed management program.
		Fauna presence	• Evidence of active use of rehabilitated site by native fauna (e.g. bird nests, scats, etc.).

Goal	Objective	Parameter/Indicator	Completion Criteria
	Soil properties support and will continue to support proposed post- mine land use.	Chemical properties (e.g. pH, salinity, nutrients, trace elements) of topsoil and other subsoil/growth medium for vegetation.	Evidence in rehabilitation reporting that topsoil and spoil chemistry satisfies the following: • Soil salinity content is <800 dS/m with the aim of attaining <400 dS/m. • Soil pH is between 5.5 and 9. • Soil Exchangeable Sodium Percentage (ESP) is <15%.
		Physical properties (e.g. type, colour, texture, coherence, water infiltration, stability, etc.).	• Topsoil strips returned to a depth of >100 mm on spoil dumps. • Surface ripped before revegetated where appropriate. • Physical properties to be achieved to within 2 standard deviations of that in reference sites and determined by soil testing.
		Biological properties (e.g. nutrient cycling, microbial biomass, litter bags etc.).	• Evidence that nutrient accumulation and recycling processes are occurring by the presence and decomposition of a litter layer.

Table 7: Curragh completion criteria for Rehabilitation of Disturbed Lands in Domain 2**.**

Goal	Objective	Parameter/Indicator	Completion Criteria
Safe	The site is safe for humans and animals (including stock and wildlife), now and in the foreseeable future.	Safety assessment of slopes that are >22% and >5 m in height	• Certification in rehabilitation report that slopes are safe. Predictions/ risk assessment to be made about future safety.
		Exposure to and availability of heavy metals and other toxic materials (selection will be made based on relevance to site)	• Certification in rehabilitation report that TSF cover and Ramp material is safe with details of predicted future changes.
			• Leaching tests meet specified guideline values (using standard protocols such as US EPA Toxic Characteristic Leaching Procedure).
		Technical design of landform	• Engineers certification of construction and maintenance to specified geotechnical design performance.
		Low risk of fire	• Site management planning provide adequate measures for fire reduction (e.g. minimise accumulation of dry matter).
		Performance of Fencing	• Certification that fencing meets required safety standards and prevents stock from accessing TSF and Ramp slopes
Non-polluting	Hazardous material is adequately managed.	Technical design of capping	• Engineer's certification of construction and maintenance to design performance. • Cover for TSFs comprises a minimum of 1.5 m of insert cover material, must be sufficient to break capillary rise of solutes. • No acid leachate.
	Polluted/ contaminated water will be contained on-site.	Downstream groundwater/ surface water monitoring	• Certification that drainage structures and sediment dams are effective in controlling surface water runoff, and minimising quantities of polluted water and containing it on site. • Certification that monitoring data meet specified criteria relevant to potential contaminants.
Stable landform	Very low probability of landform slumping with serious consequences to people, animals and/or the environment	Past record of slope failure/slumping	• Evidence that appropriate risk assessment was undertaken and control measures are in place to prevent recurrence.
		Slope Range	• Evidence in rehabilitation report that relevant EA conditions have been complied with according to – Landform Design (Table 5).
		Geotechnical, geochemical and hydrological studies of existing slopes and TSFs	• Documented evidence that appropriate risk assessment has been undertaken and control measures are in place for existing TSFs. • Evidence that results of geotechnical, hydrological and geochemical assessment have been incorporated into design of TSFs as final landforms. • No mass failure of slopes. • Ramp walls not backfilled exhibit long-term geotechnical stability.
	Landform design achieves appropriate erosion rates	Engineered structures to control water flow	• Documented evidence that drainage structures are in place as per design requirements and functioning effectively.
		Foliage Cover	• Evidence that the average percent vegetative ground cover on both topsoil and spoil ≥50%.
	Vegetation Cover to Minimise Erosion	Leaf Litter, Humus, depth of Growing Medium	• Evidence of litter breakdown and the development of humus.
Sustainable land use	**Ecosystem definition:** Area accomplishes and remains as a healthy open grassland, capable of supporting pasture for light intensity grazing		
	Specified self-sustaining vegetation and habitat established.	Key Species Presence	• Presence of native grass and pasture species.
		Species Recruitment	• Evidence of second-generation recruitment of desirable pasture/legume species
		Absence of weed species	• Certification that Class 2 declared pest plants are successfully managed in weed management programs.
		Fauna presence	• Evidence of active use of rehabilitated site by native fauna (e.g. bird nests, scats, etc.).
	Soil properties support and will continue to support proposed post- mine land use.	Chemical properties (e.g. pH, salinity, nutrients, trace elements) of topsoil and other subsoil/growth medium for vegetation	Evidence in rehabilitation reporting that topsoil chemistry satisfies the following: • Soil salinity content is <800 dS/m with the aim of attaining <400 dS/m. • Soil pH is between 5.5 and 9. • Soil Exchangeable Sodium Percentage (ESP) is <15%.

Goal	Objective	Parameter/Indicator	Completion Criteria
		Physical properties (e.g. type, colour, texture, coherence, water infiltration, stability etc.)	• Topsoil strips returned to a depth of >100 mm. • Physical properties to be achieved to within 2 standard deviations of that in reference sites and determined by soil testing.
		Biological properties (e.g. nutrient cycling, microbial biomass etc.)	• Evidence that nutrient accumulation and recycling processes are occurring by the presence and decomposition of a litter layer.
	Land use is established with comparable management requirements to similarly used un-mined land.	Achieves agreed stocking capacity/capability on agreed areas (potential for erosion/damage to slopes which may be fenced off).	• Use of rehabilitated land meets specified yield (e.g. 75% of un-mined land).

4.3.1 Goal: Safety

The completion criteria for the safety aspect of the site are adopted from Guideline 18 (EPA 2008) and ensure that the slope, spoil and supporting structures are safe for humans and animals in the long-term and that there is a low risk of fire on the site.

4.3.2 Goal: Non-Polluting

The criteria for this rehabilitation goal ensure that the water leaving the site is not polluted or contaminated and the drainage structures and sediment dams are functioning effectively.

4.3.3 Goal: Stable Landform

Slope range

The slope range for various disturbed lands are meant to ensure that the rehabilitated spoil dumps comply with design requirements and function effectively. The suggested vegetation type and density of species are suited to the various landform and climate factors.

Foliage cover

An erosion rate of less than 1 tonne/hectare/year can be achieved at the Curragh Project on slopes less than 20%, provided surface vegetative cover reaches more than 50% (Caroll et al. 2003). Since this level of cover is achievable on rehabilitated sites over a short period of time (3 – 4 years) as shown in Figure 4, this value was adopted as the completion criteria for foliage cover in Domain 1. Figure 4 indicates that 50% vegetation cover (including litter cover) could be reached in as little as three years after seeding on topsoil media, and generally between six and ten years on spoil media.

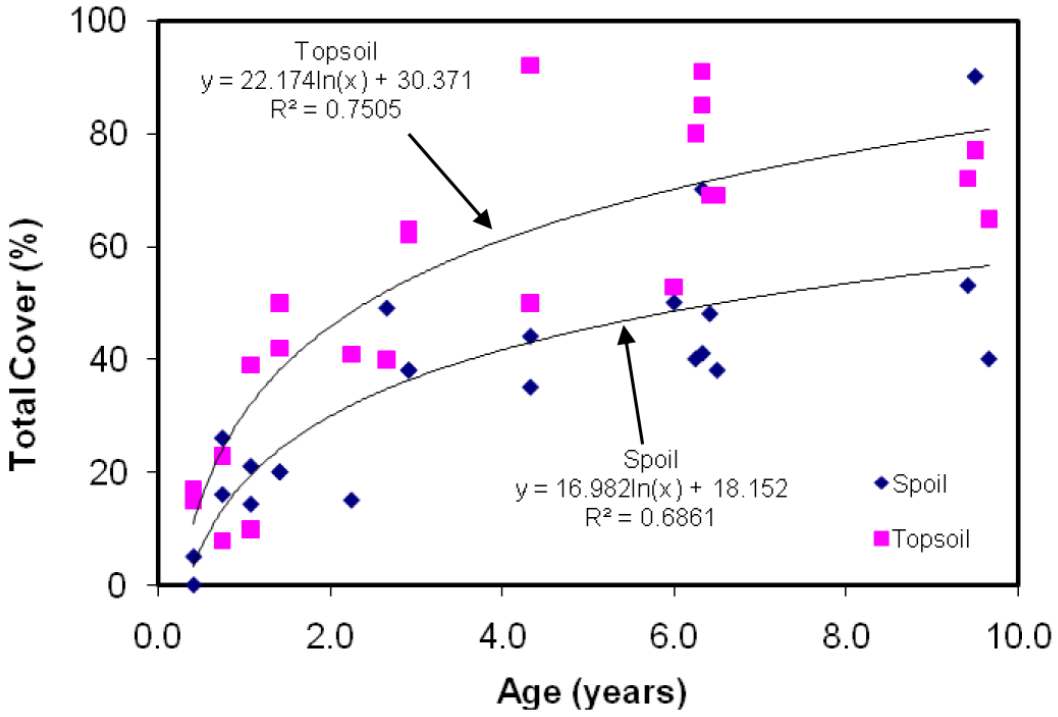


Figure 4: Vegetation covers by ages of rehabilitation at Curragh rehabilitation sites (as yearly monitored by CMLR-UQ from 2002 until 2007).

4.3.4 Goal: Sustainable Land use

Evidence of sustainable land use is determined from vegetation and habitat attributes and soil chemical properties.

Previously native tree and shrub species density was listed as a potential criterion, this has been replaced by canopy cover (combined canopy and sub-canopy cover). Provisional canopy cover targets will be determined from the 2021 monitoring data. Other land use criteria include the presence of key native species, the presence of native woody species recruitment, the absence of Class 2 declared weeds, and the presence of native fauna.

Soil EC and pH values follow a similar format to Guideline 18 and values are specific to Curragh based on 10 years of monitoring as well as previous studies completed on reference sites. Rehabilitated sites with topsoil have a lower mean pH, electrical conductivity (EC) and exchangeable sodium percentage (ESP) than sites with spoil growing media (Table 8).

Table 8: Range of soil chemical properties in different rehabilitation media.

Media	Range of values in rehabilitation		
	pH	**EC (uS/cm)**	**ESP**
Topsoil	7.7 – 8.8	94 – 757	0 – 8.4
Spoil	7.2 – 9.3	57 – 1568	0 – 9.2

4.3.5 Curragh North heighted spoil dumps success criteria

From a landform stability perspective, success criteria for the Curragh North heightened spoil dumps relates to a lack of evidence of instability associated with major rill and gully erosion and/or subsidence.

From a vegetation perspective, it is important that there is a minimum of 50% total cover including litter. From a vegetation performance perspective, the current reference sites are not suitable for assessing the performance of rehabilitation on steeper slopes >16%, therefore additional reference sites for native vegetation on slopes >16% will be established. Whilst it is unlikely there may be suitable reference sites in surrounding native vegetation on slopes >16% it is recommended that a “best on offer” reference site is considered in surrounding native vegetation.

Completion criteria for rehabilitation on the steep slopes will be aligned with achieving performance of vegetation that shows a trajectory towards achieving vegetation structural attributes such as tree canopy heights and canopy cover and species richness associated with reference communities.

In the absence of suitable reference sites, consideration will be given to taking completion criteria for tree canopy heights, canopy cover and ground cover from existing benchmark data for associated broad vegetation groups on steeper slopes >16% from the broader sub-region surrounding the mine.

5. REHABILITATION MONITORING

5.1 Introduction

The overall aim of the 2021-2025 program is to provide Curragh Project with accurate information about the performance and development of its rehabilitation over time.

Within this broad aim there are number of specific objectives:

i. To measure the density, richness and condition of canopy, shrub (overstorey) and shrub (understory) woody species established on rehabilitated land using plot-based methods, and to benchmark the results against completion criteria.

ii. To measure species richness in the rehabilitation and compare against completion criteria.

iii. To accurately assess foliage projective cover (FPC), canopy cover (canopy cover is the combined cover of the canopy and sub-canopy), shrub cover and ground cover across rehabilitated areas using plot-based methods and to assess against completion criteria.

iv. Assessment of slope stability, erosion 'hotspots' or slumping across the site using LiDAR.

v. To determine if any relationships exist between biophysical parameters, such as substrate quality, soil moisture and rainfall patterns at the time of sowing, and rehabilitation success.

5.1.1 Methodology

The methodology for the 2021 - 2025 program has been updated in this document to better align with more contemporary methodologies and to increase efficiency. However, the methods will still enable the same rehabilitation metrics to be assessed, quantified and compared for assessment against rehabilitation success criteria and ultimately progressive certification and relinquishment.

5.1.2 Site Selection

The extended five-year 2021 - 2025 program is based on monitoring at ages 1, 2, 3, 5, 7 and 10 years. From age 10, sites are monitored at five year intervals until certification.

Reference sites were selected and measured in October 2011, and these will be revisited in 2021 to capture any temporal variation and provide ongoing feedback to the completion criteria process. The 2021 - 2025 rehabilitation schedule is provided in Section 7 together with a summary of monitoring, establishment year (seeding) and rehabilitation performance.

5.1.3 Traditional Transect Based Assessment

A modified transect-based approach will continue at Curragh to provide continuity with previous monitoring of rehabilitation on site and to inform remotely sensed imagery interpretation. For 2021 - 2025, the method has been modified to focus on collecting data suitable for the current rehabilitation success criteria

5.1.4 Sites less than one year old

For sites less than one year old the following are recorded;

- plant species richness – native, pasture species and weeds;
- percentage cover; and
- rill and gully erosion.

A walk through of the site is undertaken to record all native and weed species observed across representative area of the site, ensuring variation across the site is assessed, e.g. areas of woodland species, pasture grasses, weedy areas and any area where there are obvious differences in vegetation cover. Following this, a representative location towards the centre of the site is chosen and a 1m x 1m quadrat is randomly placed in the four compass directions (north, east, south and west).

The species assemblage (including declared weeds) and the following groundcover percentages within the quadrats are recorded. Rill and gully formation are also noted and where significant gullies are forming a GPS waypoint is recorded so that gully stability can be assessed over time (Figure 5).

This assessment is undertaken for each site with a minimum of four quadrat samples per 10 hectares provided the site is relatively homogeneous. If there is substantial variation in vegetation cover across a site, the site will be stratified so that an additional four quadrats will be sampled for each strata, e.g. high cover areas, low cover areas, weed dominated areas.

For each quadrat the following are recorded:

- native grasses;
- non-native grasses;
- native forbs and others;
- woody species (saplings);
- non-native forbs and others; and
- bare ground/rock.

5.1.5 Sites greater than one year old

At each new site, three transects of 50m x 14m running downslope will be established and permanently marked for future re-assessment. At each (new and established) transect assessments are undertaken in 50m x 14m, 50m x 8m, 50m x 4m and in 1m x 1m quadrats (listed in Table 9), with the following parameters assessed:

- species richness – total number of different species in each life form layer as described in the BioCondition Methodology (Eyre et al., 2015);
- coarse woody debris – total length in metres of all woody debris over 0.5m length and 0.1m diameter; and
- tree species recruitment – regeneration of canopy and sub-canopy species.

Table 9: Data attributes collected in different quadrats.

50m x 4m quadrats	1m x 1m quadrats
Canopy cover, sub-canopy cover and shrub layer cover using the line intercept method along the transect centre line. Cover is recoded for each layer where it intercepts the tape measure laid out along the centre line	Native perennial grass cover, native other grass, native forbs and other species (non-grass), native shrubs (<1m height), non-native grass, non-native forbs and shrubs, litter, rock, bare ground and cryptograms.
stem counts identified into groupings – Eucalypt/Corymbia, Acacia, Other (tree), Shrub based on final life form, i.e. a young Eucalypt in the shrub layer is still recorded as a tree	
estimate of the mean height of the sub-canopy and shrub layer based on field measurements	
number of large trees. A large tree will be determined based on comparison with the relevant reference sites and measured against a DBH threshold	

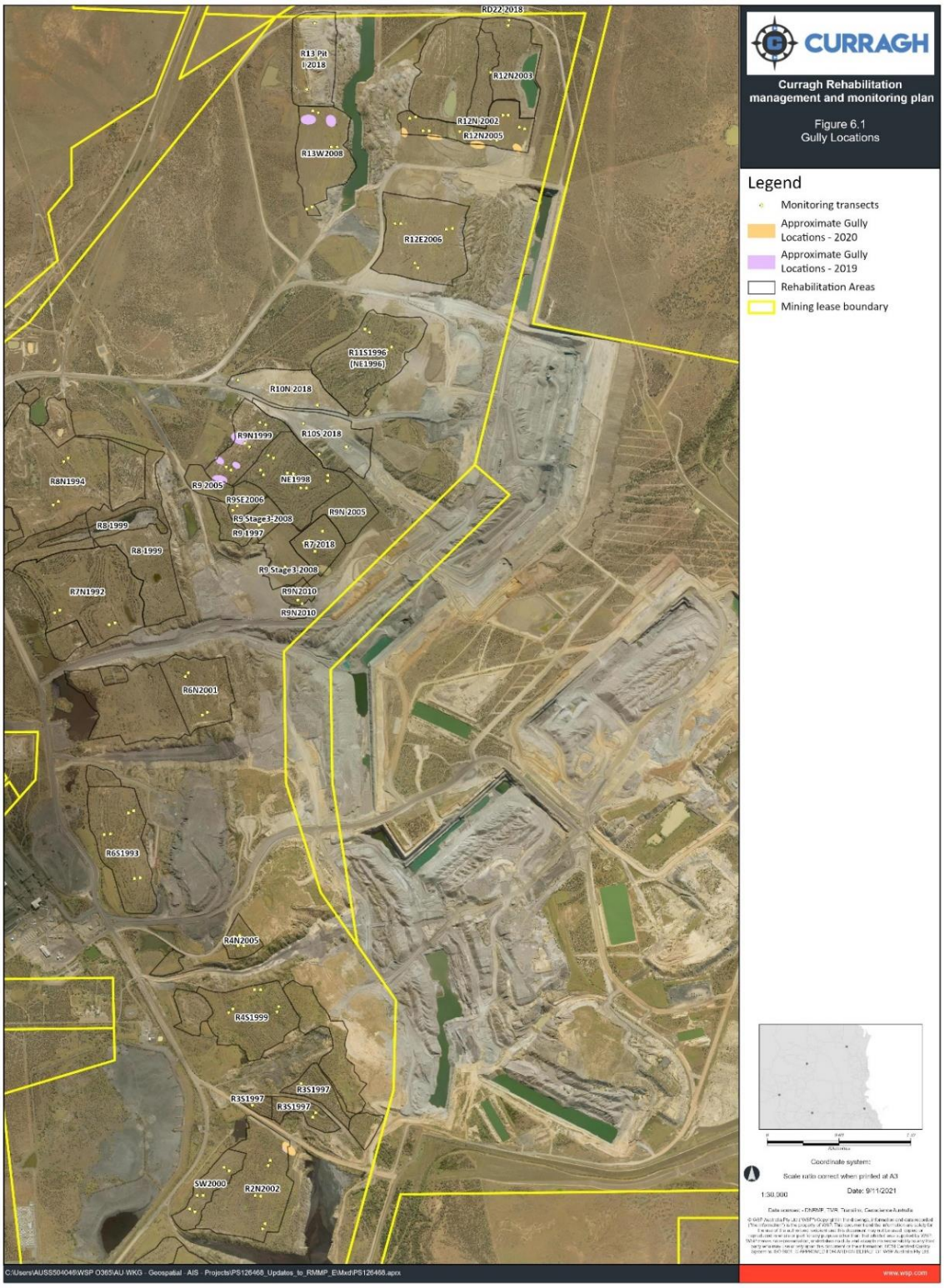


Figure 5: Gully Locations.

5.1.6 Soil Sampling

Soil sampling (0-10cm) at both ends of the transect on newly revegetated sites (or problem sites) across topsoil / spoil media for analysis of EC, pH and nutrient characteristics.

5.2 Reference Sites

Reference sites were established in remnant vegetation in 2011 as a requirement of the Environmental Authority (2011). The reference communities provide a basis for the generation and progressive review of the rehabilitation success criteria and form a part of the ongoing annual vegetation monitoring program at the Curragh Project.

5.3 The Use of Reference Communities

Guideline Mining (formally Guideline 18) (DERM 2011) suggests for the rehabilitation objective of establishing a native ecosystem, that unmined native reference communities may be used to guide criteria. Comparisons to the reference community can be used as an indirect indicator of how sustainable the rehabilitated ecosystem is likely to be. However, the selection of appropriate reference sites to which rehabilitated sites can be compared is a particular challenge within the mining industry. Typically, mining will alter the landscape to such an extent that the geology, soil physical and chemical profile and hydrology no longer resemble the unmined landscapes. Reddell and Hopkins (1994) also highlight the need to recognise the constraints associated with rehabilitating a heavily disturbed site and comparing it to a native, 'undisturbed' ecosystem.

Some guidelines on the selection of reference sites have been proposed, with Ruiz- Jaen and Aide (2005) suggesting that reference sites should:

- occur within the same life zone, close to the project; and
- should be exposed to similar natural disturbance regimes.

This allows for natural changes in vegetation to be identified over time, minimising the unknown variation within rehabilitated sites. Ruiz-Jaen and Aide (2005) also recommend that a number of reference communities need to be selected due to the natural variation within individual sites.

In many cases, mined land rehabilitation efforts have included seed mixes that only partially resemble the suite of species found within a reference community, as has been the case at Curragh Project. In these instances, it is highly unrealistic to expect the rehabilitation of the site to result in a vegetation community identical to that of a reference site (Erskine et al. 2008).

In these situations, reference sites can be used as a guide to spatial and temporal changes, as opposed to specific vegetation and soil parameters. Comparisons of indicators that can be safely made between rehabilitation and reference sites include ground cover and erosion, plant life form composition (e.g. the proportion of vines, herbs, trees and grasses), tree heights and seedling presence, soil nutrient levels and litter cover (Erskine 2008).

5.3.1 Reference site establishment and general descriptions

The Curragh Project is surrounded by a number of land uses, many of which are highly disturbed including grazing and agricultural land. The Regional Ecosystem (RE) Mapping (Queensland Herbarium 2009) indicates that vegetation within the mine leases and surrounding the mine is largely non-remnant, having been cleared for cropping and pasture. However, pre-clearing RE's list a large majority of the site as being RE 11.4.9 (Acacia harpophylla shrubby open forest) and a mixture of Acacia and Eucalypt dominated woodland / open forest. The RE maps have been utilised to locate and select appropriate reference sites.

In November 2011, three Eucalypt dominated vegetation communities were selected as reference sites:

i. RE: 11.10.12 Poplar Box Woodland.

ii. RE: 11.4.2 Napunyah Woodland (Gravel Pit).

iii. RE: 11.4.8 Dawson Gum Woodland.

The selected sites represent self-sustaining native ecosystems. Monitoring data from these sites is used to determine quantifiable vegetation attributes to assist in the development of completion criteria for rehabilitation at the Curragh Project. However, it is not expected that the rehabilitation will replicate the species composition or stand structure of the reference site communities.

Reference site selection was based on:

- remnant and representative vegetation types in the area;
- slopes, landforms and soil capability similar to the rehabilitation on the mine;
- A range of vegetation structure and cover from sparse to dense, and woodland to open forest; and
- access by field staff.

The location and extent of the Poplar Box Woodland and the Napunyah Woodland communities are mapped in Figure 6. Descriptions and GPS coordinates are provided in Table 10. Note the Dawson Gum Woodland reference site is no longer present due to mine expansion.

Further details of the vegetation attributes and soil characteristics of the reference sites, and comparison with monitoring data from the rehabilitation sites are provided in Appendix 2.

Table 10: Locations of permanently marked monitoring transects located within reference communities within the Curragh Project area.

Description	RE	Site	Transect	Start Points (AGD84)		Finish Points (AGD84)	
				Northing	Easting	Northing	Easting
Poplar Box Woodland	11.10.12	REF PB1	1	7399259	695458	7399269	695507
Poplar Box Woodland	11.10.12	REF PB 2	2	7399207	695489	7399212	695538
Napunyah Woodland (Gravel Pit)	11.4.2	REF GP1	1	7410458	693172	7410491	693134
Napunyah Woodland (Gravel Pit)	11.4.2	REF GP2	2	7410602	693141	7410575	693100
Dawson Gum Woodland*	11.4.8	REF EC 1	1	7405776	693938	7405792	693891
Dawson Gum Woodland*	11.4.8	REF EC 2	2	7405689	693963	7405734	693945

*no longer present due to mine expansion

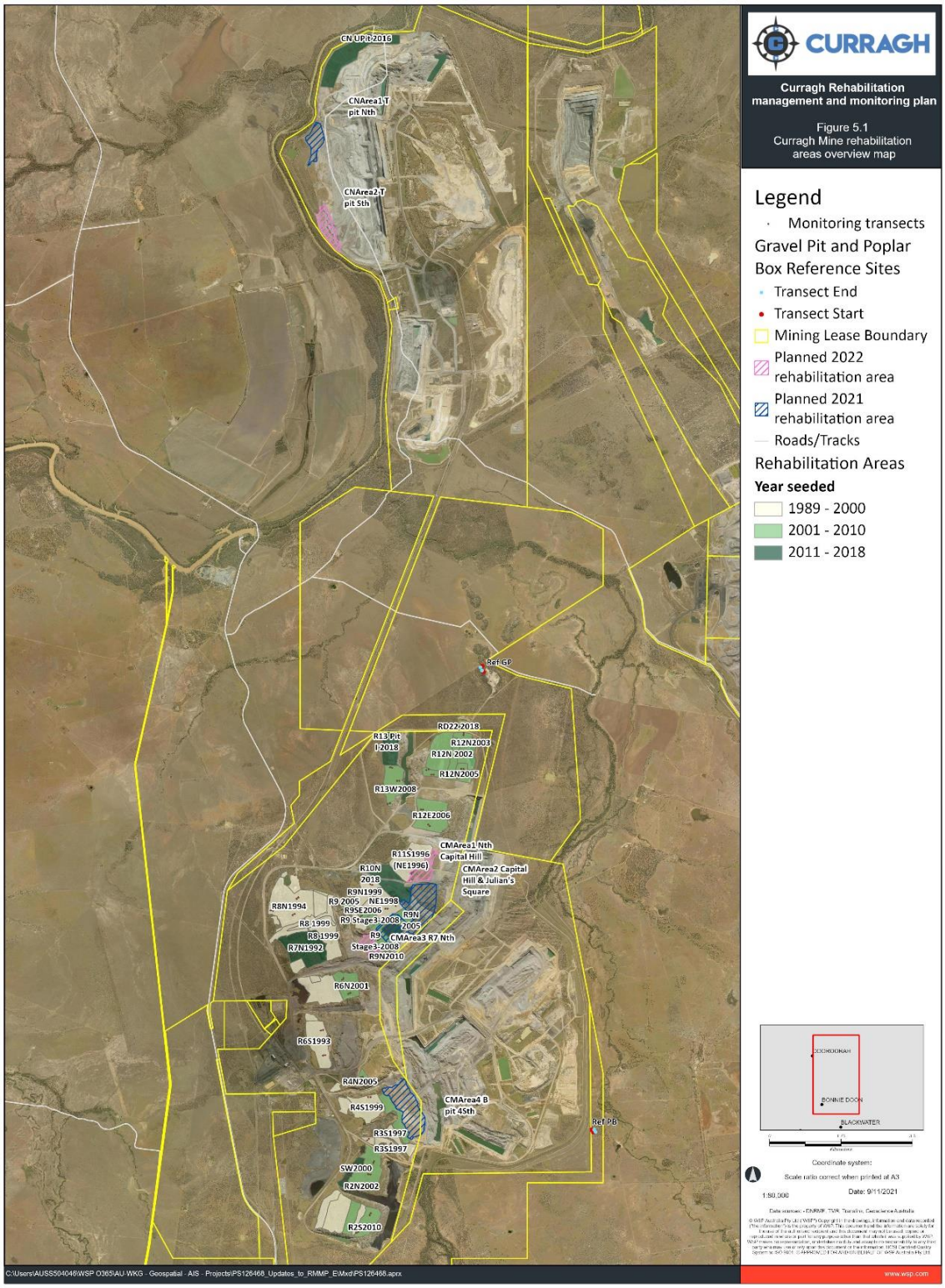


Figure 6: Curragh Project rehabilitation areas overview map.

5.4 Pasture Monitoring

Pasture monitoring will be undertaken to determine the dry season yield per hectare to determine the potential safe stocking capacity that will avoid land degradation. This assessment method is based on collecting pasture samples from 0.5m x 0.5m quadrats along each 50m monitoring transect as follows:

- select one of the five ground cover quadrat locations at random along each transect;
- harvest the grass from a 0.5m x 0.5m quadrat; The quadrat should be located adjacent to the centre line i.e., for quadrat one where ground cover is measured in a 1m x 1m quadrat at 9m to 10 m, the pasture monitoring quadrat should be located at 9m – 9.5m;
- using battery operated shears cut the herbage (grass & herbs) to within approximately 1cm of the ground level and bag all the harvested material in a large labelled paper bag. Note that if there are large amounts of old dead herbage (typically grey in colour) it should be separated from the sample and discarded to prevent over estimation of the pasture mass;
- determine the nett (wet) weight of each sample (nett weight = sample weight minus the bag weight. If the quadrat has no grass cover and this is not representative of the transect, another quadrat should be selected at random. The average weight of the two samples is entered in the final spreadsheet;
- sub-sample each of the 'wet' sample quadrats. The sub-sample should be of mostly leafy material since this is mostly what cattle feed on. Incorporating stem material will result in potentially artificially high nett weights;
- measure the wet weight of each of the five sub-samples in grams;
- oven dry the sub-sample (samples will be dried for 48 hours at approximately 70-80°C using a dehydrator);
- weigh the oven dried sub-sample (in grams);
- calculate dry matter percentage of the sub-sample;
- use this dry matter percentage figure to determine the dry matter weight of each quadrat;
- calculate the equivalent dry matter weight for each quadrat for one hectare (kg dry matter/hectare); and
- determine dry season pasture budget to provide a guide for the appropriate stocking rate for the proposed light grazing land use (for an example: Dry season pasture budget: a guide for stocking rates - FutureBeef).

Trials may be needed to determine the appropriate threshold for light grazing on rehabilitated landforms to prevent degradation of rehabilitated landforms, which is important for informing for post relinquishment grazing. For unmined land 30% use of pasture is considered the maximum sustainable land use to avoid degradation in Central Queensland (Bowen and Chudleigh, 2017). This equates to a stocking rate of approximately 0.6 steers per hectare or less for productive pastures. For rehabilitated mined lands the threshold is likely to be less to minimise land degradation, and associated erosion due to the sodic nature of some of the spoil material.

5.5 State and Transition Model

To determine the overall rehabilitation status for each transect, and to identify if rework, maintenance or ongoing monitoring is required, a simplified State and Transition Model will be used. The State and Transition Model identifies key landform and ecosystem changes in relation to the rehabilitation success criteria that have implications for management that can be easily mapped in relation to the potential management requirements, rework, maintenance and monitoring.

The states of rehabilitation are initially based on the rehabilitation success criteria that are ordered in a logical sequence to reflect progressive changes in ecosystem rehabilitation. These will be reviewed based on the 2021 rehabilitation monitoring. An example of potential rehabilitation age indicators is provided in Table 11 and the associated state and transition age model is provided in Figure 7. The applicability of the age indicators and age model will be trialled and refined from the 2021 monitoring.

Table 11: Rehabilitation transitional age indicators.

Indicator	Transitional Age
Stability	1
Ground cover	3
Percentage of native tree species (excluding Brigalow)	5
Native tree species density	7
Stem count of each native tree species (biodiversity) / Foliage Projective Cover (FPC) of native species	10

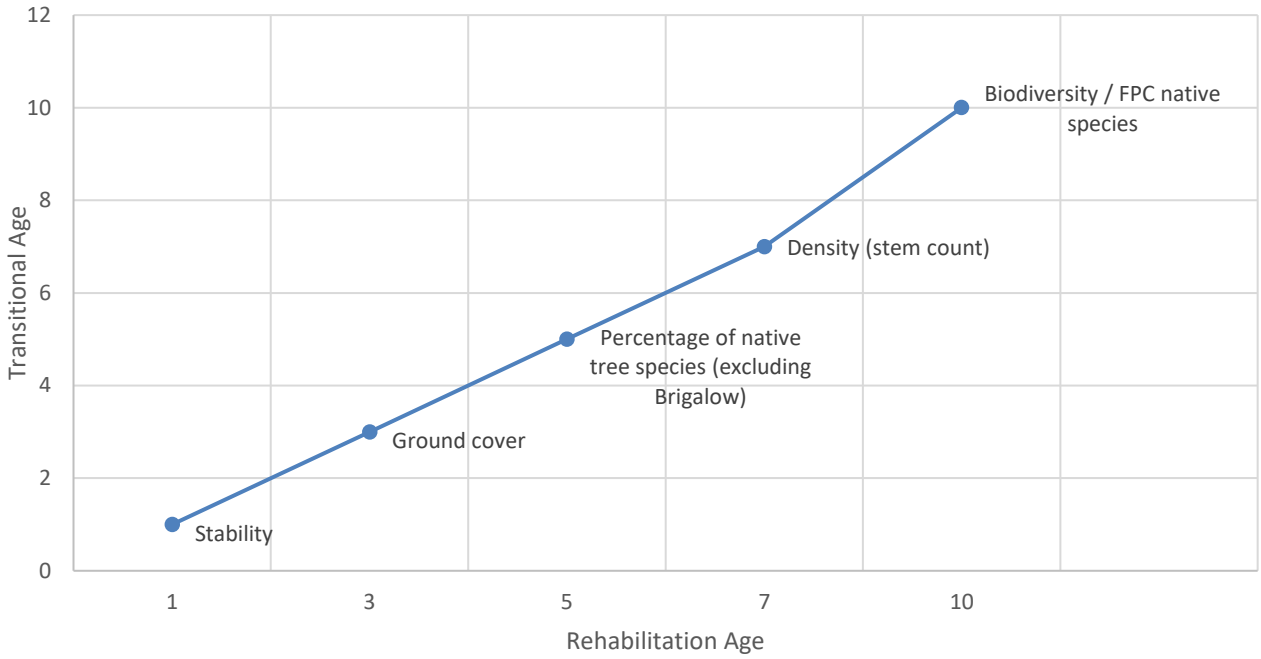


Figure 7: State and Transition Age Model.

A site that is not performing will fall below the line in the age model. For example, a 10-year-old site that does not meet the ground cover requirements will retain a transitional age of three, even if all other indicators have been met. Examples of compliant and non-compliant sites is provided in Figure 8.**Error! Reference source not found.** with different transitional age indicators.

A site that has attained the final stage of the transition age model has met all the performance monitoring criteria and would be recommended for progressive certification and relinquishment. A site that is not performing well will be recommended for rework, maintenance, or just to continue ongoing monitoring. The rehabilitation status and accompanying management action is provided in Table 12.

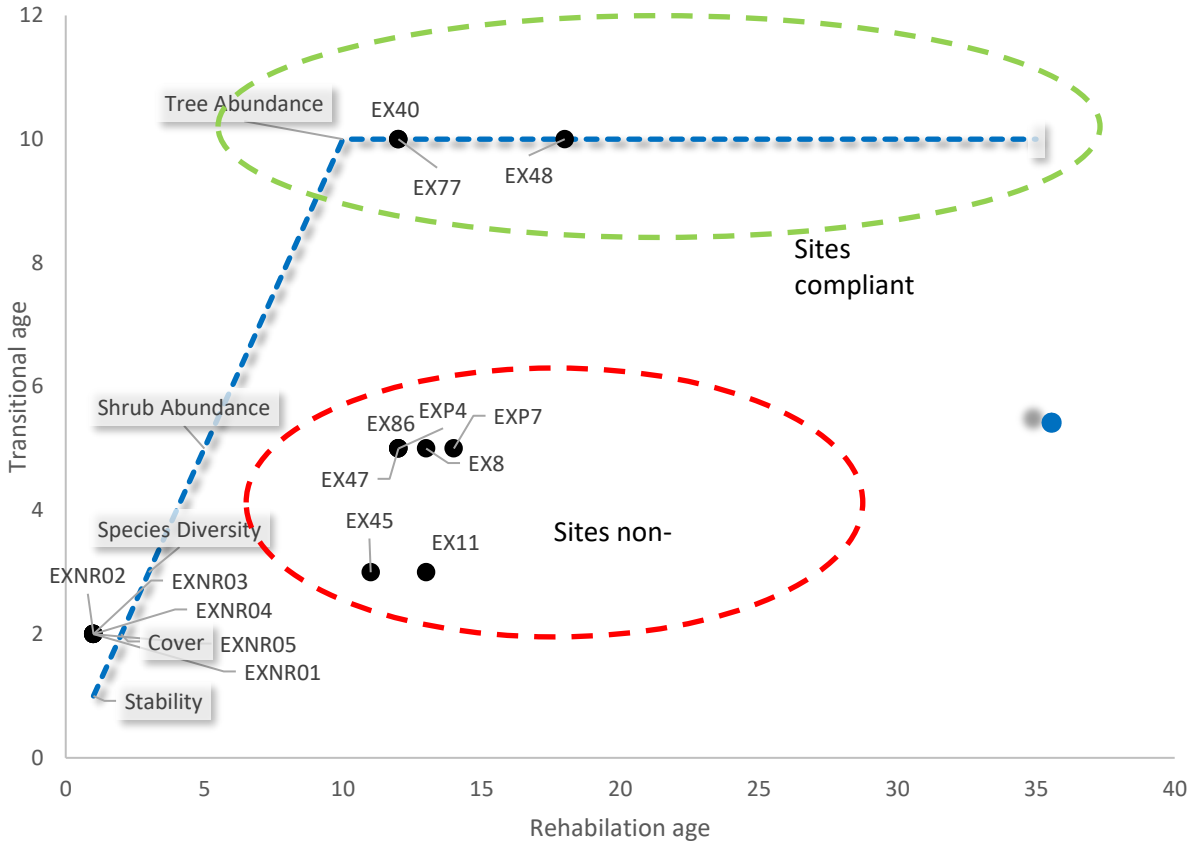


Figure 8: State and Transition Age Model Example.

Table 12: Rehabilitation Status.

Rehabilitation status	Recommended action
Rework	Major works associated with reshaping landforms and gully remediation
Maintenance	Minor works associated with gully remediation, groundcover maintenance, reseeding and planting
Monitor	Site is on a trajectory towards completion criteria and requires ongoing monitoring
Acceptable	Site meets all performance criteria. Recommend for progressive certification

5.6 Additional Monitoring and Control Measures

5.6.1 Flora and Fauna Protection

The pre-mining flora and fauna areas west of Blackwater Creek for Curragh Mine were reported by Hollingsworth (1979). For areas east of Blackwater Creek, pre-mining flora and fauna were reported by EH&S (1998) and ERM (2000b).

A three-season sampling program by the Central Queensland University (1994- 1996) surveyed areas for vertebrate fauna. Two hundred and twenty species of terrestrial vertebrates were identified including 149 bird, 23 mammal, 36 reptile (12 snakes and 24 lizards) and 12 frog species. Aquatic vertebrates were not targeted although the report by the Central Queensland University (1994-1996) mentions four species.

The pre-mining flora and fauna at areas for Curragh North Mine were reported during the EIS studies. Three flora and fauna surveys were undertaken during 1998, 2002 and 2003.

A total of 198 fauna species were observed or recorded including 14 butterflies, 15 amphibians, 22 reptiles, 120 birds and 27 mammals were identified.

The following species of conservation significance were recorded for the Curragh Project:

i. Brigalow Scaly-Foot Lizard (Paradelma orientalis) (no longer listed).

ii. Ornamental Snake (Denisonia maculata).

iii. Squatter Pigeon (Geophaps scripta scripta).

iv. Little Pied Bat (Chalinolobus picatus). (no longer listed).

Six vegetation communities were identified:

i. Fringing Red River Gum, tall woodland on alluvial plains.

ii. Open Coolabah, woodland with a predominately grassy under storey.

iii. Brigalow woodland and Yellowwood.

iv. Poplar Box and Dallachys Gum open woodland.

v. Lemon scented Gum woodland with Rosewood.

vi. Open grassland with Scattered Trees.

The main areas of conservation significance which have been identified:

i. Mackenzie River Riparian Vegetation.

ii. Brigalow community in the northern section of the Curragh Project.

iii. Brigalow community in the central section of the Curragh Project.

iv. Brigalow community in the southern section of the Curragh Project.

v. Poplar Box community in the eastern section of the Curragh Project.

The declared plants known to exist on the lease include:

i. Parthenium weed.

ii. Parkinsonia.

iii. Harrisia Cactus.

iv. Mother of Millions.

v. Rubbervine.

Fauna and flora surveys were carried out in late 2007 covering the area of the existing creek alignment and proposed Blackwater Creek diversion.

The assessment identified:

- a total of 108 fauna species including 71 birds, 19 mammals, 13 reptiles and 5 amphibians;
- five regional ecosystems (REs) as occurring within Curragh East Mine (ML 80086). Of these RE 11.3.1 and 11.4.9a are listed as Endangered under the Queensland Vegetation Management Act 1999 (VM Act) and the Commonwealth Environmental Protection and Biodiversity Conservation Act 1999 (EPBC Act) while 11.4.12 is also listed as Endangered under the VM Act;
- a total of 271 species of plant within the study area of which 41 (15 %) were introduced; and
- seven species of 'declared plants' under the Queensland Land Protection (Pest and Stock-route Management) Act 2002 during the field surveys for Curragh Project.

5.6.2 Declared Plants and Feral Animals

Weeds are an increasing cost to local graziers and the wider community. All Curragh mining leases are in close proximity to surrounding pastoralists. The potential impact from weeds is high and can include a loss of production, difficulty in establishment of rehabilitation, failure to meet completions criteria and degraded aesthetic qualities. The declared plants known to exist on the lease include Parthenium weed, Parkinsonia, Harrisia Cactus, Mother of Millions and Rubbervine. Local feral animals include pigs, cats and dogs and are a significant issue for the wider community. Feral animals including pigs, foxes, hares and cats are also particularly detrimental to native flora and fauna.

5.6.3 Description of Environmental Value

The environmental values to be protected or enhanced are:

- managing endangered and threatened ecosystems to ensure biodiversity values are retained;
- enhancing knowledge and data relating to all native fauna in the local area, with a particular focus on the species classified as threatened under the EPBC Act and/or NC Act; and
- managing declared pests and declared weeds to maximise the enduring value of the land.

5.6.4 Environmental Protection Objective

Objectives for the management of conservation values include:

- not introducing new weed species and preventing the spread of existing weed species;
- the protection of on-site flora and fauna;
- re-introducing flora and fauna to the mined area by undertaking a staged rehabilitation program;
- control of feral animal populations on site; and
- minimising the impact of mining on identified significant ecosystems.

5.6.5 Potential Impacts

Potential impacts on fauna and flora species may include:

- loss of habitat for the Brigalow Scaly-foot Lizard, Ornamental Snake, Squatter Pigeon and Little Pied Bat through clearing activities;
- fragmentation of the population and interception to dispersal / movement along existing corridors;
- an increase in weeds that may alter the structure of habitat and therefore reduce the quality of habitat

currently inhabited; and

- feral animals attracted to the Curragh Project.

5.6.6 Control Measures

Control measures include:

- the mine site weed eradication program is part of the Central Highlands Regional Council weed control strategy. Company or contractor vehicles are washed before leaving site. A specially designed wash down facility with under-body sprays is located at the Curragh Project industrial area. Contractor equipment is checked before being allowed onsite. Contractor equipment, if used in an infested weed area, is washed down before being transported away from the area;
- trees are to be inspected for fauna presence prior to removal where the potential for fauna presence exists and where inspections have not been undertaken for previous mining operations. Detected individuals will be flushed out or relocated prior to clearance; and
- in the event of any sick, injured or displaced animals being located during clearing activities, the Queensland Department of Environment and Science will be contacted when required.

5.6.7 Ongoing Surveys

Surveys will be carried out on an ongoing basis to gauge the occurrence, diversity and stability of flora and fauna species, and to determine appropriate directions for the progressive integration of mined areas into the surrounding ecosystems.

5.6.8 Weed Treatment Declared Plants and Feral Animal Control

Integrated weed and pest management is practised. Weed control methods include mechanical removal, herbicides and fire. A long term-approach to weed management is required to control weeds. A weed control management plan identifying locations of weeds by species is maintained and updated. Weed management as described in the following EMS documents are the basis of the annual weed control program.

Reference: EM PLAN 1.0 Land Management Plan and *EMS PROC 1.1 Declared Fauna and Flora Management Procedure.*

5.6.9 Vegetation Clearing

Prior to clearance of trees, areas are to be inspected for fauna presence detected individuals will be flushed out and/or relocated.

Reference: EM PLAN 1.0 Land Management Plan

5.6.10 Regional Ecosystems

The Curragh Project supports five environmental management areas (Figure 9). These areas are requirements of conditions of approval under two separate referrals under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

These environmental management areas and the relevant referrals involve:

i. Curragh North Coal Mine (EPBC 2003/1096)
   a. *Brigalow Management Area* (55 hectares) – Condition 2
   b. *Brigalow Rehabilitation Area* (37 hectares) – Condition 2
   c. *Transport Corridor Management Area* (17 hectares) – Condition 1

ii. Blackwater Creek Diversion and Coal Mine (EPBC 2007/3925)
   a. Northern Brigalow Area (44.9 hectares) – Condition 1

b. Northern Brigalow Revegetation Area (21.4 hectares) – Condition 1

Management plans have been prepared outlining the management actions to be undertaken to maintain and enhance the environmental values of each of these areas. These management plans have been combined into the Consolidated Environmental Management Plan (CEMP).

The management actions include measures to control weeds and pest animals, livestock and site access, erosion and sediment controls, fire management, methods for seed stock collection and planting techniques, as well as fauna management.

The CEMP also outlines a monitoring and reporting framework for noting the condition of each environmental management area over time.

5.6.11 Blackwater Creek Diversion

The rehabilitation plan for the Blackwater Creek diversion includes success criteria for the creek diversion, and ongoing monitoring requirements to ensure a stable and sustainable creek alignment is established and maintained.

Refer to document Place Design 'Blackwater Creek Diversion EMS-PROC-034 (Blackwater Creek Diversion – Vegetation and Rehabilitation Management Plan (2008)', for additional background information on rehabilitation design principles andoriginal process and the current EM PLAN 1.4 Blackwater Creek Diversion Monitoring and Maintenance Plan.

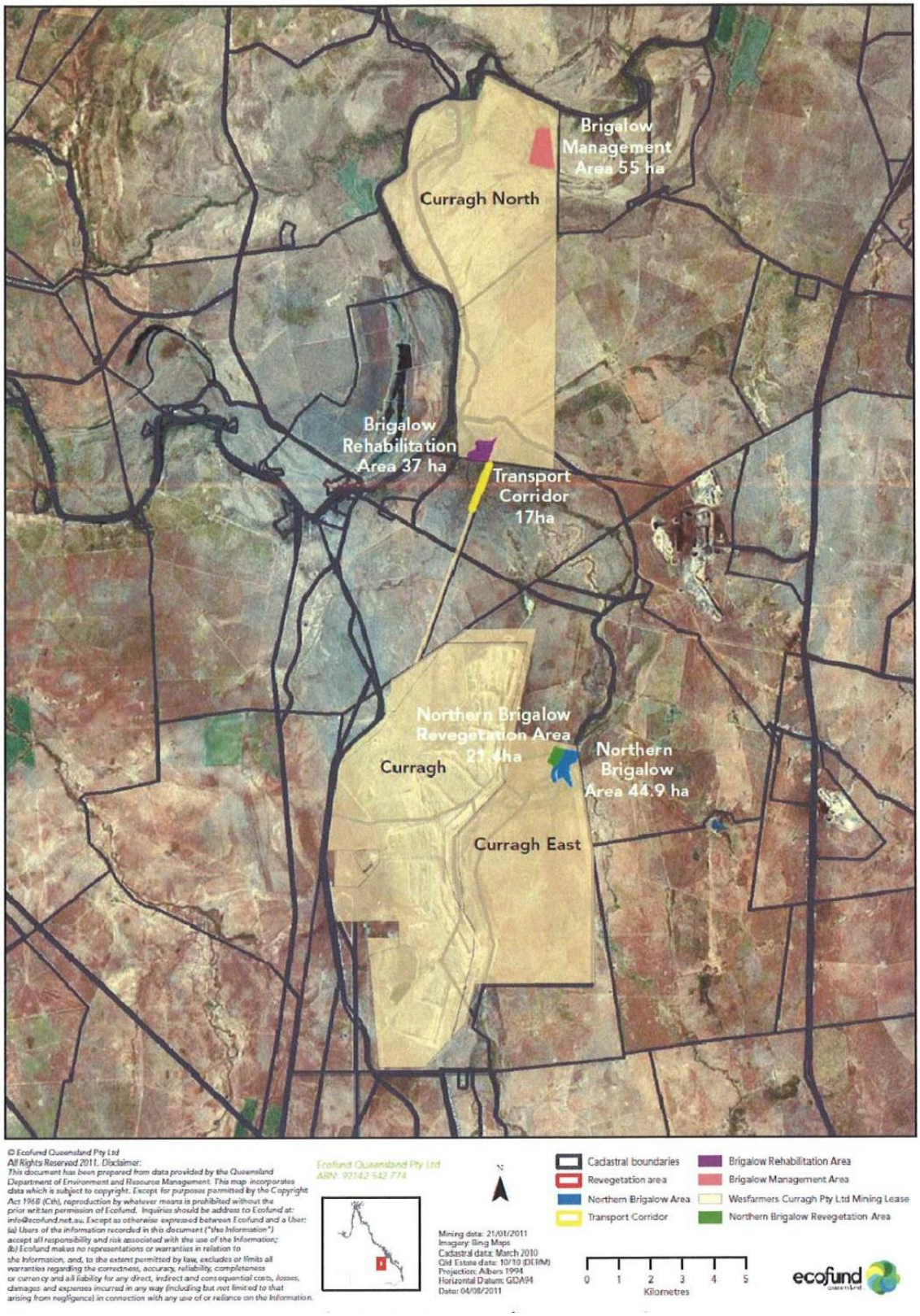


Figure 9: Curragh Mine Environmental Management Areas.

6. PROGRESSIVE CERTIFICATION

Curragh undertakes progressive targeted rehabilitation monitoring to identify rehabilitation areas that are performing at a level adequate to enable Coronado to apply for progressive certification. This involves targeted monitoring using the standard rehabilitation monitoring procedures as outlined in EMS PROC 1.6 Rehabilitation Monitoring Procedure.

The monitoring results are assessed against the completion criteria for the relevant domain (See section 4.3), based on a landform level assessment and a transect based assessment (Table 13,

Table 14 and Table 15).

Table 13: Safe, stable and non-polluting rehabilitated landform completion criteria performance matrix.

Performance Criteria	Completion criteria	
	Not yet conforming	**Acceptable**
Slope >10% with a maximum slope 16% unstable	Yes	**No**
Slope ≤ 10% with a maximum slope 16% stable	No	**Yes**
Landform design achieves appropriate erosion rates. Engineered structures to control water flow	No	**Yes**
Signs of continued erosion greater than that exhibited on representative unmined areas within the mining leases (i.e. active gully erosion)	Yes	**No**
Certification that Class 2 declared pest plants are successfully managed by weed management program	No	**Yes**
Fauna presence (Evidence of active use of rehabilitated site by native fauna (e.g. bird nests, scats, etc.)	No	**Yes**

Table 14: Light grazing and open woodland completion criteria performance matrix Domain 1.

Performance Criteria	Completion criteria	
	Not yet conforming	**Acceptable**
Tree canopy cover (%) (combined canopy and sub-canopy) *Preliminary value to be determined from 2021 monitoring*	TBA	**TBA**
Key Species Presence: • at least 1 *Eucalyptus* species • at least 2 *Acacia* species	No	**Yes**
Evidence of second-generation recruitment of native tree/shrub species	No	**Yes**
Mean ground cover requirement (≥50% total cover)	<50%	**≥50%**
Evidence of litter breakdown and nutrient recycling	No	**Yes**
Evidence in rehabilitation reporting that topsoil and spoil chemistry satisfies the following: • soil salinity content is <800 µS/m with the aim of attaining <400 µS/m • soil pH is between 5.5 and 9 • soil Exchangeable Sodium Percentage (ESP) is <15%.	No	**Yes**

Table 15: Open grassland completion criteria performance matrix Domain 2.

Performance Criteria	Completion criteria	
	Not yet conforming	**Acceptable**
Use of rehabilitated land meets specified yield *Preliminary value to be determined from 2021 monitoring*	TBA	**TBA**
Presence of native grass and pasture species	No	**Yes**
Evidence of second-generation recruitment of native tree/shrub species	No	**Yes**
Mean ground cover requirement (≥50% total cover)	<50%	**≥50%**
Evidence of litter breakdown and nutrient recycling	No	**Yes**
Evidence in rehabilitation reporting that topsoil and spoil chemistry satisfies the following: • soil salinity content is <800 µS/m with the aim of attaining <400 µS/m • soil pH is between 5.5 and 9 • soil Exchangeable Sodium Percentage (ESP) is <15%.	No	**Yes**

7. REHABILITATION MONITORING SCHEDULE 2021 – 2025

The proposed five rehabilitation monitoring schedule for 2021 – 2025 is presented in Table 16. The schedule is based on monitoring at age ≤1, 2, 3, 5, 7 and 10 years. After age 10 monitoring occurs at five-year intervals. Monitoring up to age one is based on a rapid assessment. From age one onwards permanent monitoring transects are established for newly rehabilitated areas.

A map of the existing monitoring sites is provided in Figure 10.

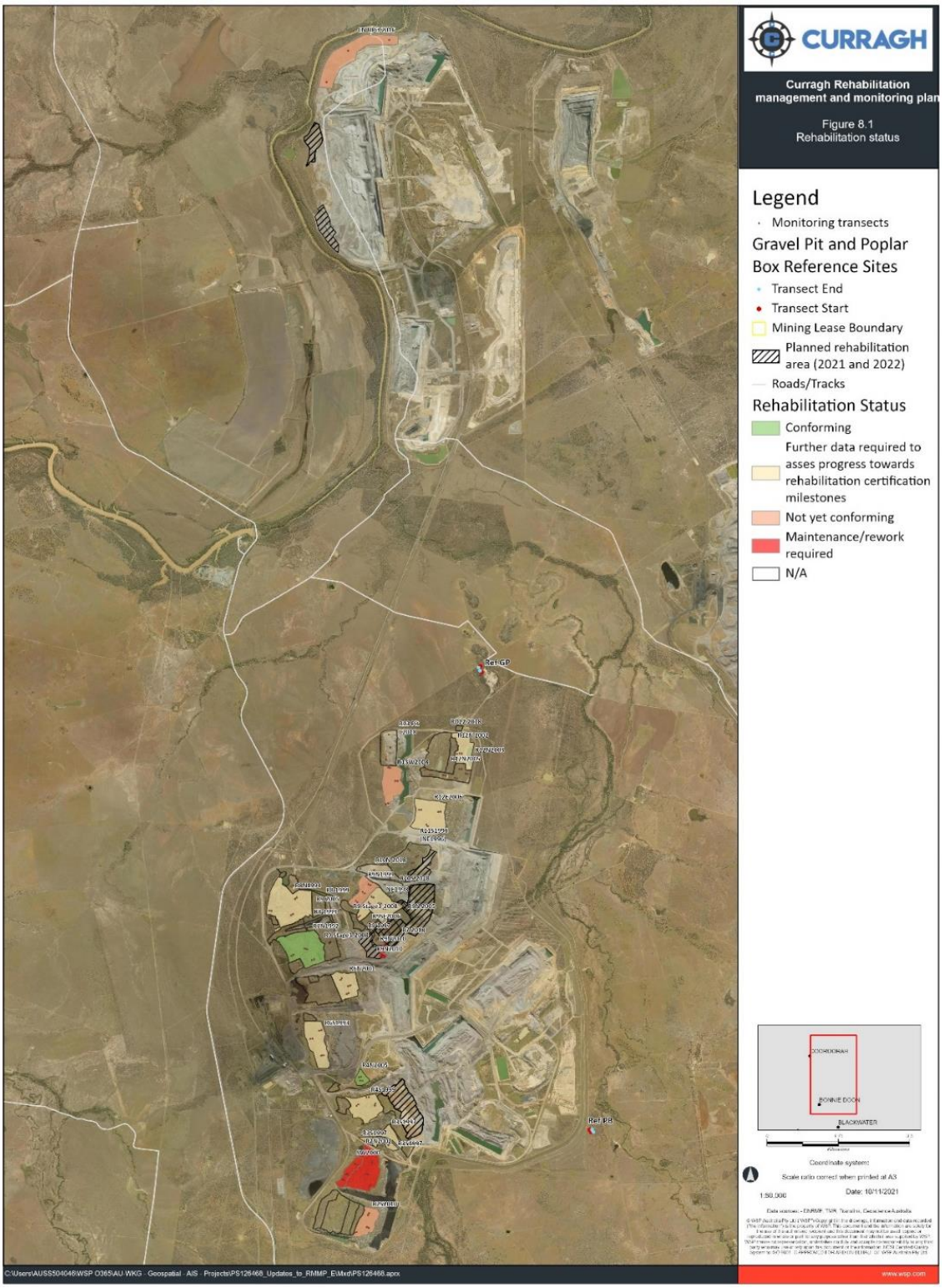


Figure 10: Rehabilitation status.

Table 16: Rehabilitation monitoring schedule 2021 – 2005.

Site Name	Site ID	Easting*	Northing*	Rehab Year	Years Monitored	Age 2021	Site Establishment	Rehab Status	2021	2022	2023	2024	2025
Reference Gravel Pit	REF GP1	7410641	693284		2011, 2014, 2016, 2019, 2020		Existing	-					
Reference Poplar Box	REF PB1	7399441	695571		2011, 2014, 2016, 2019, 2020		Existing	-					
Reference *E. cambageana*^	REF EC	-	-		2011, 2014, 2016		Mined	-	-	-	-	-	-
`Ramp 7 1992	R71992			1992		29 years	Existing	Conforming		Year 30			
Ramp 7 North 1992	R7N1992	7403663	689371	1992	2015, 2020	29 years	Existing	Further data required		Year 30			
Ramp 6 South 1993	R6S1993	7401938	689510	1993	2013, 2017	28 years	Existing	Further data required			Year 30		
Ramp 8 North 1994	R8N1994	7404794	688956	1994	2013	27 years	Existing	Further data required				Year 30	
Ramp 11 South 1996	R11S1996	7406310	691604	1996	2002, 2005, 2009, 2012	25 years	Existing	Further data required	Year 25				
Ramp 3 South 1997	R3S1997	7399131	691031	1997	2003, 2006, 2015	24 years	Existing	Further data required		Year 25			
North East 1998	NE1998	7405171	690778	1998	2002, 2004, 2007, 2011, 2015	23 years	Existing	Further data required			Year 25		
Ramp 4 South 1999	R4S1999	7400149	690756	1999	2003, 2005, 2008, 2012 ,2016	22 years	Existing	Not yet conforming				Year 25	
Ramp 9 North 1999	R9N1999	7405495	690667	1999	2003, 2005, 2008, 2012 ,2016,2019	22 years	Existing	Not yet conforming				Year 25	
South West 2000	SW2000	7398280	690024	2000	2002, 2006, 2009, 2013, 2019, 2020	21 years	Existing	Further data required					Year 25
Ramp 6 North 2001	R6N2001	7402852	690187	2001	2004, 2007 ,2010,2017	20 years	Existing	Not yet conforming	Year 20				
Ramp 2 North 2002	R2N2002	7398741	690667	2002	2003, 2005, 2008, 2015, 2019, 2020	19 years	Existing	Further data required		Year 20			
Ramp 12 North 2003	R12N2003	7409104	692811	2003	2004, 2006, 2009	18 years	Existing	Not yet conforming			Year 20		
Ramp 12 North 2005 (fresh)	R12N2005 (fresh)	7408055	692700	2005	2005, 2006,2008, 2020	16 years	Existing	Not yet conforming					Year 20
Ramp 12 North 2005 (old)	R12N2005 (old)	7408277	692018	2005	2005, 2006,2008, 2020	16 years	Existing	Conforming					Year 20
Ramp 4 North 2005	R4N2005	7400708	690468	2005	2012,2013,2019, 2020	16 years	Existing	Further data required					Year 20
Ramp 12 East 2006	R12E2006	7407302	691878	2006	2007, 2009, 2010	15 years	Existing	Not yet conforming	Year 15				
Ramp 9 South East 2006	R9SE2006	7404699	690426	2006	2007, 2009, 2010	15 years	Existing	Further data required	Year 15				
Ramp 13 West 2008	R13W2008	7407465	691132	2008	2008, 2019	13 years	Existing	Further data required			Year 15		
Ramp 9 Stage 3 2008	R9Stage3 2008	7404134	690827	2008	2008, 2016	13 years	Existing	Further data required			Year 15		
Western dump Curragh North 3	Western dump CN3			2009	n/a	12 years	Existing	Further data required				Year 15	
Ramp 2 South 2010	R2S2010	7397000	690246	2010	2012, 2020	11 years	Existing	Further data required					Year 15
Ramp 9 North 2010	R9N2010	7403948	690903	2010	2011, 2020	11 years	Existing	Not yet conforming					Year 15
Blackwater Creek Diversion	Blackwater Creek Diversion	-	-	2011	2012, 2013, 2014, 2015, 2016, 2017, 2018, 2020	10 years	Existing	Not yet conforming		Biennial monitoring		Biennial monitoring	

URGENT DRAFT

Site Name	Site ID	Easting*	Northing*	Rehab Year	Years Monitored	Age 2021	Site Establishment	Rehab Status	2021	2022	2023	2024	2025
Ramp 12 South 2014	R12S2014			2014	n/a	6 years	Existing	Further data required	Year 7			Year 10	
KyberPass Ramp 4 North	KyberPass R4N			2014	n/a	6 years	Existing	Not yet conforming	Year 7			Year 10	
Curragh North U Pit 2016	CN UPIT2016			2016	2020	5 years	Existing	Further data required	Year 5		Year 7		
Ramp 7 2018	R72018			2018	2020	3 years	Existing	Not yet conforming	Year 3		Year 5		Year 7
Ramp 10 North 2018	R10N2018			2018	2020	3 years	Existing	Not yet conforming	Year 3		Year 5		Year 7
Ramp 10 South 2018	R10S2018			2018	2020	3 years	Existing	Not yet conforming	Year 3		Year 5		Year 7
Ramp 13 Pit 1 2018	R13Pit1 2018			2018	2020	3 years	Existing	Not yet conforming	Year 3		Year 5		Year 7
Ramp D22 2018	RD22 2018			2018	2018	3 years	Existing	n/a	Year 3		Year 5		Year 7
Ramp 3 South 2018	R3S2018			2018	n/a	3 years	Existing	Not yet conforming	Year 3		Year 5		Year 7
Ramp 4 South B Pit	R4S B Pit	-	-	2021	-	-	Proposed	-		Year 1	Year 2	Year 3	
Capital Hill and Julian's Square	Capital Hill and Julian's Square	-	-	2021	-	-	Proposed	-		Year 1	Year 2	Year 3	
Nth Capital Hill	North Capital Hill	-	-	2021		-	Proposed	-		Year 1	Year 2	Year 3	
T pit North Curragh North	T Nth CN	-	-	2021	-	-	Proposed	-		Year 1	Year 2	Year 3	
T pit South Curragh North	T Sth CN	-	-	2022	-	-	Proposed	-			Year 1	Year 2	Year 3
Ramp 7 North	R7Nth	-	-	2022		-	Proposed	-			Year 1	Year 2	Year 3

*Easting and Northing coordinates are derived from the start of Transect 1 (T1) for each site.

^REF EC has been disturbed by mining and no longer exists.

URGENT DRAFT

8. RESEARCH AND DEVELOPMENT

Curragh maintains a strong commitment to rehabilitation research and development to refine rehabilitation methods, achieve rehabilitation success and ensure eventual bond release. Past research projects are listed here and are summarised in Appendix 3.

8.1 Previous Research Programs

Previous research programs conducted by WCPL include:

i. Mine rehabilitation erosion stage III (biophysical adjunct).
ii. Establishment of trees on topsoil.
iii. Soil micro-biology.
iv. Soil substitutes and native ecosystem development.
v. Establishment of native understorey.
vi. Terrestrial flora/fauna success criteria.
vii. Aquatic flora/fauna success factors.
viii. Risk assessment of rehabilitation stability.
ix. Tailing dam hydrogeology.

9. REFERENCES

ANZECC. (2000) Australian Guidelines for Fresh and Marine Water Quality 2000. National Water Quality Management Strategy, Australian and New Zealand Environment and Conservation Council, Canberra, ACT.

Baiquni, H. & McKenna, P. (2008) Curragh Coal Mine Rehabilitation Monitoring 2007 assessment. Final report to Curragh Queensland Mining Ltd. Centre for Mined land Rehabilitation, University of QLD. 24pp.

Bowen, D. (1996) Personal Communication. Centre for Mined Land Rehabilitation, The University of Queensland, St. Lucia, QLD.

Bowen, M.K. & Chudleigh, F. (2017). Productivity and profitability of a range of alternative steer growth paths resulting from manipulating the pasture feed base in central Queensland – a modelling approach. Department of Agriculture and Fisheries.

Carroll, C., Merton, L. and Berger, P. (2000). Impact of vegetative cover and slope on runoff, erosion, and water quality for field plots on a range of soil and spoil materials on central Queensland coal mines. *Australian Journal of Soil Research* 38, 313-327.

Carroll, C. & Tucker, A. (2000). Effects of pasture cover on soil erosion and water quality on central Queensland coal mine rehabilitation. *Tropical Grasslands* 34, 254- 262.

Carroll, C., Tucker, A., Burger, P. & Pink, L (2003) Sustainability indicators for coal mine rehabilitation. 2003 Curragh Final Report. QLD Natural Resources and Mines. 35pp

Central Queensland Cultural Heritage Management Pty Ltd, (June 2000), Curragh East Levee Bank Mitigation program, Summary Report of Field Work.

C.Q.M.L. (1996) Environmental Sampling Procedures Manual, Curragh Project, March 1991. Curragh Queensland Mining Limited, Blackwater, QLD.

Curragh Queensland Mining Ltd (2007) Curragh Project Plan of Operations, 1 July 2007 – 30 June 2008.

C.Q.U. (1996) Fauna of Curragh Coal Mine Blackwater Central Queensland. Centre for Land and Water Resource Development, Central Queensland University, Rockhampton, QLD.

CCPL EM PLAN 1.0 Land Management Plan

CCPL. EM PLAN 1.4 Blackwater Creek Diversion Monitoring and Maintenance Plan

CCPL EMS PROC 1.1 Declared Fauna and Flora Management Procedure

Department of the Environment and Heritage 2006, *EPBC Act Policy Statement*

1.1 Significant Impact Guidelines, Department of the Environment and Heritage, Canberra.

Curragh Queensland Mining Ltd, (2002), Curragh Project Environmental Management Overview Strategy, October 2002.

Department of Environment and Science, Guideline: Rehabilitation requirements for mining resources activities (ESR/2016/1875).

Department of Natural Resources and Mines, Central West Water Management and Use Regional Guideline: Watercourse Diversions – Central Queensland Mining Industry. Queensland Government.

EGI (1993), Geochemistry of Overburden and Implications for its Disposal, Curragh East Development Area.

EH&S Systems (1998), Description of Existing Environment, Curragh East Project,Brisbane.

Elsol, J. and Fletcher, G. (1995) Vegetation Studies - Curragh Queensland Mining Limited. Land Reclamation Services Pty Ltd, Emerald, QLD.

Emmerton, B. (1993) Characterisation of Dragline Dumped Spoil, Curragh Project. Land Reclamation Services Pty Ltd, Emerald, QLD.

EPA (2008) Rehabilitation requirements for mining projects. Guideline: Mining 18. http://www.epa.qld.gov.au/publications/p01673aa.pdf/Rehabilitation_requirements_ for_mining_projects.pdf

ERM (2000a), Curragh East Initial Advice Statement, Environmental Resources Management, Brisbane.

ERM (2000b) Curragh East Project Flora and Fauna Studies, Environmental Resources Management, Brisbane.

ERM (2000c) Curragh East Project Land Suitability Assessment, Environmental Resources Management, Brisbane.

ERM (2000d) Curragh East Project Weed Survey, Environmental Resources Management, Brisbane.

ERM (2000f) Curragh East Project Community Outcomes Report, Environmental Resources Management, Brisbane.

Franks, A., J. (2002). The ecological consequences of Buffel Grass Cenchrus ciliaris establishment within remnant vegetation of Queensland. Pacific Conservation Biology; 2002; 8, 2;

Hall, R. (2008) Soil Essentials Managing Your Farms Primary Asset. Landlinks Press 182 pp

Haydock, K.P. and Shaw, N.H. (1975). The comparative yield method for estimating dry matter yield of pasture. *Australian Journal of Experimental Agriculture and Animal Husbandry* 15, 663-670.

Hollingsworth P. and Associated Consultants. (1979) Preliminary Impact Assessment May 1979, Evaluation of the Coal Resources in Authority to Prospect 217C Curragh.

Land Reclamation Services Pty Ltd. (1984) Reclamation Planning Curragh Project Blackwater, Queensland. Emerald, QLD.

Land Reclamation Services Pty Ltd. (1990) Curragh Project Soil Survey. Emerald, QLD.

Land Reclamation Services, (1994), Selection of Native Species to Develop Natural Ecosystems on Open Cut Coal Mines in the Central Queensland Region Fletcher, G., LRS Pty Ltd, Emerald.

Land Reclamation Services, (1995), Vegetation Studies - Curragh Queensland Mining Limited., L Elsol, J, and Fletcher, G, LRS Pty Ltd, Emerald.

Longworth and McKenzie Pty Ltd. (1987) Curragh Tailings Dam Stage 3 - Construction Manual. Brisbane, QLD.

L'Oste-Brown, S (2007) Fieldwork summary report (No. 1) for the survey and mitigation of 2007 priority areas 2 & 5 (Curragh Main) and the survey and mitigation of 2007 priority areas 10-12 (Curragh East), September 2007, 20 September 2007.

Place Design (2008) Blackwater Creek Diversion Vegetation and Rehabilitation Management Plan. WCPL document no. EMS-PROC-034.

Stuart Miller & Associates, (1984), Waste Management and Rehabilitation Studies,Overburden Geochemical Investigations, Birchgrove, NSW.

Stuart Miller & Associates, (1990), Geochemical Characterisation of Course Rejects & Tailings, Balmian, NSW.

McKenna, P. & Baiquni, H (2008) Curragh Coal Mine Rehabilitation Monitoring 2008 assessment. Final report to Curragh Queensland Mining Ltd. Centre for Mined land Rehabilitation, University of QLD. 89pp.

McKenna, P. & Vickers, H (2009) Curragh Coal Mine Rehabilitation Monitoring 2009 assessment. Final report to Curragh Queensland Mining Ltd. Centre for Mined land Rehabilitation, University of QLD. 76pp.

Mulligan, D.R. and Bell, L.C. (1991). Tree and Shrub Growth on Land Rehabilitated After Mining at Curragh Coal Mine. Department of Agriculture, The University of Queensland, St. Lucia, QLD.

Orr, M.S. and Bell, L.C. (1990) Strategies for Site Stabilisation and Native Species Regeneration at the Curragh Open-Cut Coal Mine. Department of Agriculture, The University of Queensland, St. Lucia, QLD.

Orr, M.S, (1993), Strategies for Native Species Establishment at the Curragh Open-Cut Coal Mine, Central Queensland., University of Queensland, Brisbane.

PB (2007) Blackwater Creek Diversion Terrestrial Ecology Assessment. December2007, Brisbane

PB (2008) Addendum 1 to Blackwater Creek Diversion Hydrology and Hydraulic Report, February 2007, Brisbane.

Queensland Herbarium (2009). Regional Ecosystem Description Database (REDD). Version 6.0b Updated November 2009, (Department of Environment and Resource Management: Brisbane).

Rayment, G.E. and Higginson, F.R. (1992). *Australian laboratory handbook of soil and water chemical methods.* Inkata Press, Sydney.

Rosser, J., Swartz, G.L., Dawson, N.M. and Briggs, H.S. (1974) A Land Capability Classification for Agricultural Purposes. Division of Land Utilisation Technical Bulletin No. 14, Queensland Department of Primary Industries.

Scanlan, J.C., McKeon, G.M., Day, K.A., Mott, J.J. and Hinton, A.W. (1996). Estimating safe capacities in extensive cattle grazing properties within tropical semi- arid woodlands of north-eastern Australia. *Rangeland journal* 16, 64-76.

University of Queensland, Centre for Mined Land Rehabilitation, (1989), Strategies for Site Stabilisation and Native Species Regeneration at the Curragh Open-Cut Coal Mine - Progress Report.

University of Queensland, Centre for Mined Land Rehabilitation, (1991), Tree and Shrub Growth on Land Rehabilitated after Mining at Curragh Coal Mine.

University of Queensland, Centre for Mined Land Rehabilitation, (1993a), Strategies and Techniques for the Establishment of a Self-Sustaining Native Ecosystem on Mined Land at the Curragh Open-Cut Coal Mine.

University of Queensland, Centre for Mined Land Rehabilitation, (1993b), Assessment of Seed Content of Vacuum Collected Topsoil Litter Samples from Native Vegetation near Curragh.

University of Queensland, Centre for Mined Land Rehabilitation, (1998), Strategiesand Techniques for the Establishment of a Self-Sustaining Native Ecosystem on Mined Land at the Curragh Open-Cut Coal Mine, A summary of monitoring and investigation 1995-1998.

University of Queensland, Centre for Mined Land Rehabilitation (2000), InoculatingMycorrhizal Fungi into Mine Soils, Curragh Project, AMIRA Project P257B, Final Report.

WBM (2000), An investigation of the vertebrate fauna and habitat values of Curragh Project.

Willcocks, J. (1993). Climate. In *Farming Systems for Downs and Brigalow Soils in Central Queensland.* Proceedings of a workshop held at Emerald Pastoral College, September 1991 (Eds A.L. Garside, B.J. Radford and A.J. Carr.). Dept. Primary Industries, Brisbane.

WSP 2021, Coronado Curragh Offset Strategy. Curragh Extension Project EPBC 2015/7508.

APPENDIX 1 – Curragh Project Spoil and Soil Characterisation

In order to meet requirements under the Curragh Project Environmental Authority (Permit Number: EPML00643713) a rehabilitation management plan must be developed that specifies soil and spoil characteristics.

Appendix 1 summarises data gathered in the previous surveys of the Curragh, Curragh East and Curragh North mining tenements and makes recommendations on further spoil and soil analysis regimes that may be required to meet condition outlined in the Environmental Authority.

Previous Investigations

Previous soil and spoil investigation have been undertaken in all areas that are to be disturbed by mining activities.

Curragh Soil

A soil study by Land Reclamation Services (1990) identified 7 soil mapping units in the Curragh Project area. Table A1.1 gives a brief description of the soil units described by Land Reclamation Services and outlines the soils suitability for rehabilitation (Figure A1.1 shows the locality of the soil units). Care should be taken when using the table as 'there is considerable variation within these mapping units' and hence a more intensive survey should be completed before topsoil stripping commences.

Table A1.1: Curragh Soils and Suitability for Rehabilitation.

Soil Description	Suitability for Rehabilitation
Red brown melon hole clays	• Top 10cm chemically suitable for Rehab • Lower horizons are dispersive and have high chloride concentration • Melon hole relief makes striping top layer without contamination from lower horizons impossible • Therefore, this soil is not suitable for rehabilitation
Red brown non-cracking clays	• Top 20cm are suitable for rehabilitation • Lower horizons are dispersive and have moderate chloride concentrations • Topsoil should be carefully stripped to 20cm
Grey brown cracking clays	• High chloride concentrations throughout the profile • All horizons are potentially dispersive • Recommended that this soil is not used in rehabilitation
Grey brown cracking clays over calcareous material	• Well-structured cracking clay with low chlorides and dispersivity to at least 60cm • Soil should be stripped to 60cm depth • 0–30cm should be stockpiled separately to 30-60cm
Red brown cracking clays – acid sub soil	• Only the top 20cm is chemically suitable for rehabilitation
Mixed clays and texture contrast soils	• Only the top 15cm is suitable for rehabilitation • Lower horizons consist of impervious clays which are dispersive
Red texture contrast soils	• Only the A horizon should be used for rehabilitation as the lower clays are impervious and dispersive • Therefore, only the top 15cm should be stripped and stockpiled for rehabilitation

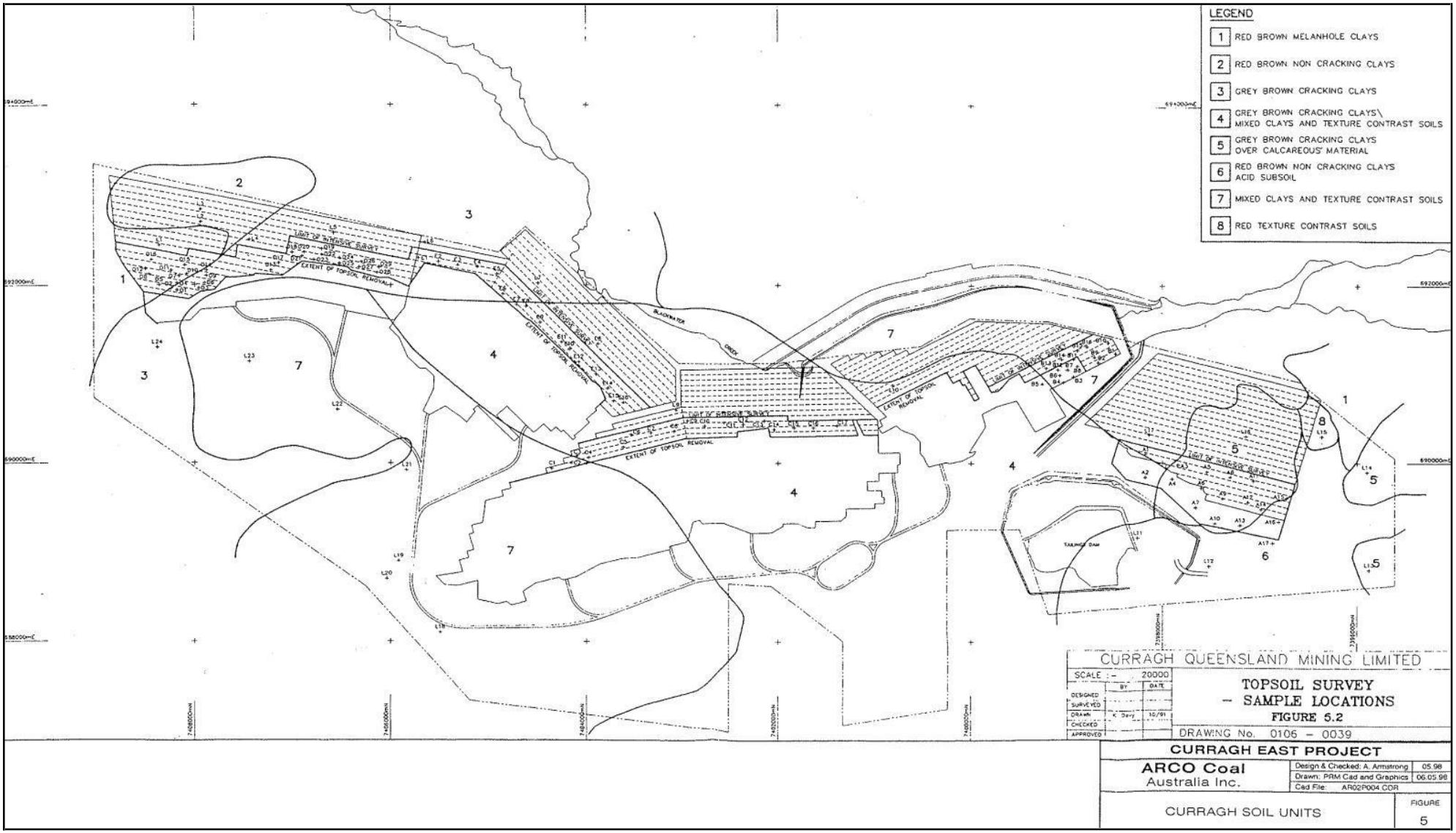


Figure A1.1: Curragh Soil Types.

Spoil

Various Spoil studies have been completed in the vicinity of the main Curragh area. Below is a brief description of the findings from each report.

Stuart Miller and Associates

Stuart Miller and Associates (1984) completed field and laboratory investigation to characterise overburden and identify management techniques that may be required to maximise rehabilitation success and preserve water quality. This report focuses on overburden samples taken from pits C and E (formerly known as pit E east) as well parts of Pits B and D. The results show that:

- the total sulphur content of samples ranged from 0.03 to 2.8%;
- the ANC is high in all samples – and hence sufficient to neutralise acid produced by oxidation of sulphur;
- the thin (<0.5m) inter burden layer between the Aries/Castor and Pollux seams is acid forming in places but shouldn't prove problematic in rehabilitation, provided that this strata is mixed with other layers;
- spoils were moderately to highly saline and were highly sodic; and
- coal seams are potentially acid forming and hence rejects generated from this area may be acidic in nature.

Land Reclamation Services

Land Reclamation Service completed a survey of dragline dumped spoil in 1993, 81 grab samples were analysed for pH and EC, with results from these samples used to select 41 samples for further analysis. The in-situ and laboratory results have shown that the majority of spoil is saline and sodic:

- Of the 81 grab samples only 6 returned an acidic pH with;
    - one of these samples came from coal reject material;
    - four samples contained oxidised coal material; and
    - one clay and grey shale material with slight acidity was found between ramps 7 and 8.

In addition to the dragline spoil sampling Land Reclamation Services also completed analysis of overburden chips from 5 drill holes within the mining lease. The samples were analysed for pH and EC (on a 1:5) and results show that:

- in general, weathered materials (ranging from 333 to 2270 µS/cm) appear to have higher salinities than that unweathered materials (EC between 293 and 945 µS/cm); and
- the majority of the chip samples were strongly alkaline with the exception being some near surface clay samples from the northern area of the Lease.

HLA-Envirosciences Pty Ltd

HLA-Envirosciences completed pH and NAG analysis on 20 samples from 5 bore holes in March 1998. Of the twenty samples only two had an acidic pH and a NAG of >0.1. The details of these two samples are shown below:

- sample 98137-13100 was taken from between the base of weathering and the Aries roof, a pH of 3.4 and NAG of 12.9 kg/t was recorded; and
- sample 98143-13118 was taken between Aries floor and Castor Roof, a pH of 2.9 and NAG of 4.5kg/t.

Unfortunately, the HLA report does not contain the location of the bore holes and hence this data may be of little use. Curragh East

Soils

A description of the existing environment of the Curragh East Project Area was completed by Environment Health and Safety Systems (1998). Soil samples were taken from 17 sites and soils were described in sufficient detail to classify into mapping units (Figure A1.2). In general, the report shows that:

- soil sample analyses show that the soils of the project area are poorly to moderately fertile;
- soils are potassium and nitrogen are deficient;
- soils are calcium and magnesium are moderately deficient; and
- sodicity of soils is low although deeper layers may prove more problematic.

In addition to the soil units already described in the Curragh Soil section the following soil units are also described in the (1998) report as existing in the Curragh East area:

Variable Texture Contrast Soils

Occur on the eastern and north-eastern part of the Curragh East area and are characterised by coarse textured sandy clay loams to sandy clay over-lying coarsely structured alkaline clay subsoil. The soils are associated with the ridge running north/south over the Curragh East area and support a range of vegetation from tall Poplar Box forest to short mixed forest.

Cracking Clays over Alluvial Parent Material

This mapping unit is associated with the undisturbed section of the Blackwater Creek streambed. This cracking heavy clay forms a deep layer over an alluvial parent material, the dark brown to grey soil has a coarse blocky structure and ranges from acid to neutral in the upper 0.5 metres to strongly alkaline below this depth.

Rehabilitation suitability for these two-soil mapping unit is not given in the Environment Health and Safety Systems report

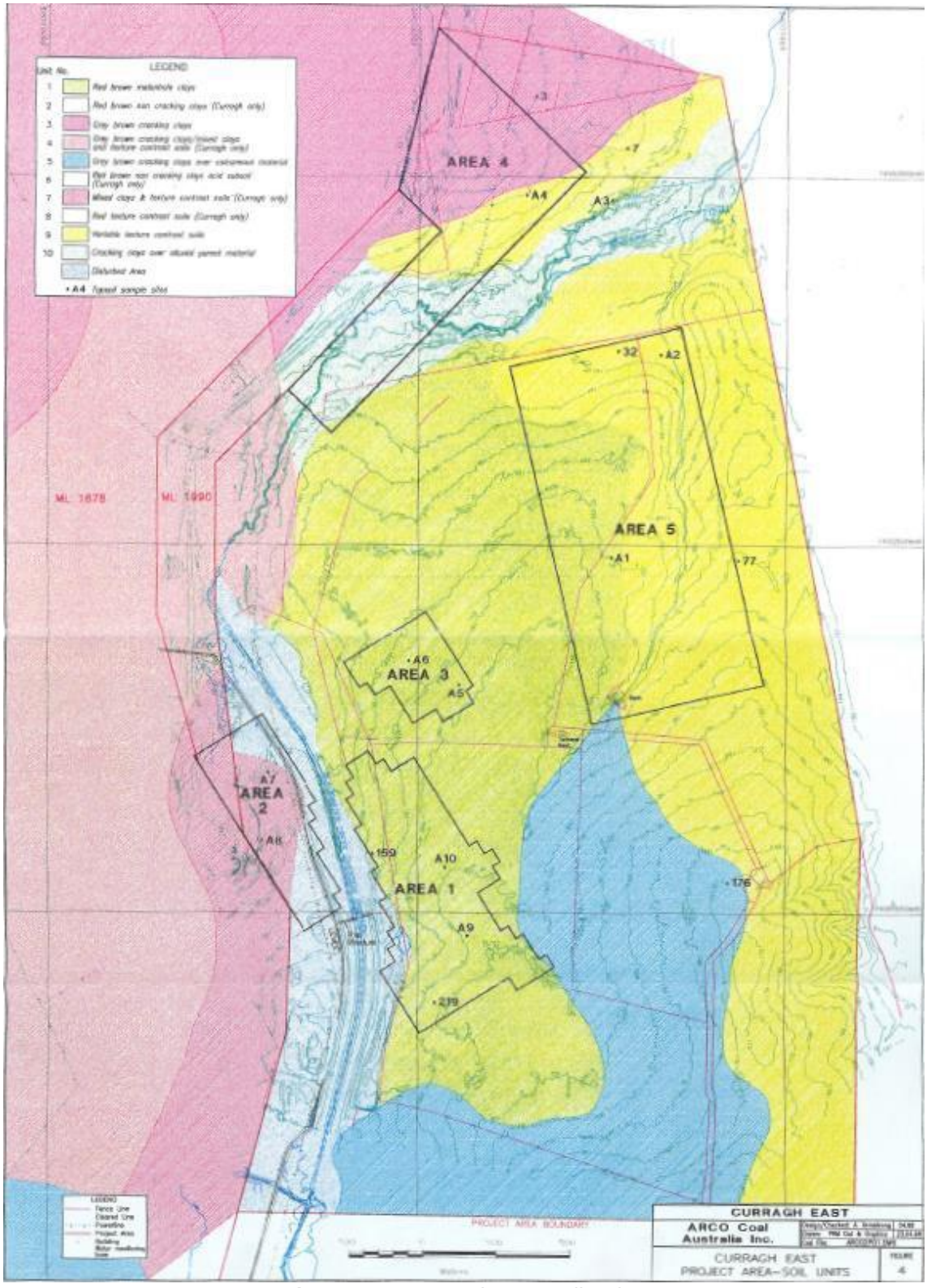


Figure A1.2: Curragh East Soil Units.

Spoil

As part of the Curragh East Project, Environmental Geochemistry International (EGI) was commissioned to investigate the Acid Forming Potential (AFP) and environmental geochemistry of the overburden in the Curragh East project area. Curragh Project personal supplied the EGI laboratory with 119 samples from varying depths within 16 drill holes. All samples were analysed for total sulphur content and ANC with subsequent calculations to determine NAPP being made. Selected samples then underwent Net Acid Generation NAG testing and a multi element analysis.

From the analysis the following conclusions were drawn:

- all samples had low sulphur contents (<0.01 to 0.36%), the samples with the greater than 0.15% Sulphur were almost exclusively from the roof or floor of the Aries and Castor seems;
- ANC were typically moderate to high, and generally increased with sample depth;
- in most cases the ANC is at least 20-times the acid production potential;
- NAPP results were all negative and therefore all samples are classified as non-acid forming;
- overburden is slightly to moderately enriched with Silver, Arsenic and Selenium; however concentrations are below levels which would limit rehabilitation of the overburden after mining.
- spoil was found to be generally sodic in nature; and
- 'The potential for generation of acidic leachates in all types of spoil from the Curragh East area is extremely low.'

Curragh North Soils

As part of the EIS process, AustralAsian Resource Consultants Pty Ltd (AARC) was commissioned to complete a *Supplementary Topsoil Survey for the Curragh North Mining Lease* (AARC 2004). The report used results from soil samples taken in previous surveys (1996, 1998 and 2003, 61 samples in total). As well as data taken from the analysis of 88 sites sampled in November 2003 by the consultants (Figure A1.3). Soil test results were statistically analysed by AARC with the relative levels of various parameters used to categorise soil against criteria provided in the Land Suitability Assessment Techniques Guideline (Department of Minerals and Energy 1995).

The AARC report concludes that:

- the Curragh North Project area contains 6 distinct soil types;
- the soil types have been mapped into 4 distinct management units (Figure A1.3); and
- each land management until has distinctive management requirements and is only suited to particular land uses (Table A1.2).

Table A1.2: Suitability of soil types for grazing and broad acre cropping – prior to mining activities (adapted from AARC 2004).

Management Unit	Grazing Suitability		Broadacre Cropping Suitability		Area to be disturbed (hectares)	% of disturbed area
	Class	Limitations	Class	Limitations		
Dee	3	Suitable for grazing with moderate limitations. Requires moderate inputs to ensure sustainable land use	3	Suitable for rain fed broadacre cropping with moderate limitations. Requires moderate inputs to ensure sustainable use	1371.5	29.7
Callide	2	Suitable for grazing with minor limitations. May require minor changes in management to ensure sustainable use.	3	Suitable for rain fed broadacre cropping with moderate limitations. Requires moderate inputs to ensure sustainable use	1865.9	40.4
Maculata	3	Suitable for grazing with moderate limitations. Requires moderate inputs to ensure sustainable land use	3	Suitable for rain fed broadacre cropping with moderate limitations. Requires moderate inputs to ensure sustainable use	275.8	6.0
Oombabee r	4	Suitable for grazing with severe limitations. Requires significant inputs to ensure sustainable land use.	4	Suitable for rain fed broadacre cropping with severe limitations. Requires significant inputs to ensure sustainable land use.	1100.1	23.8

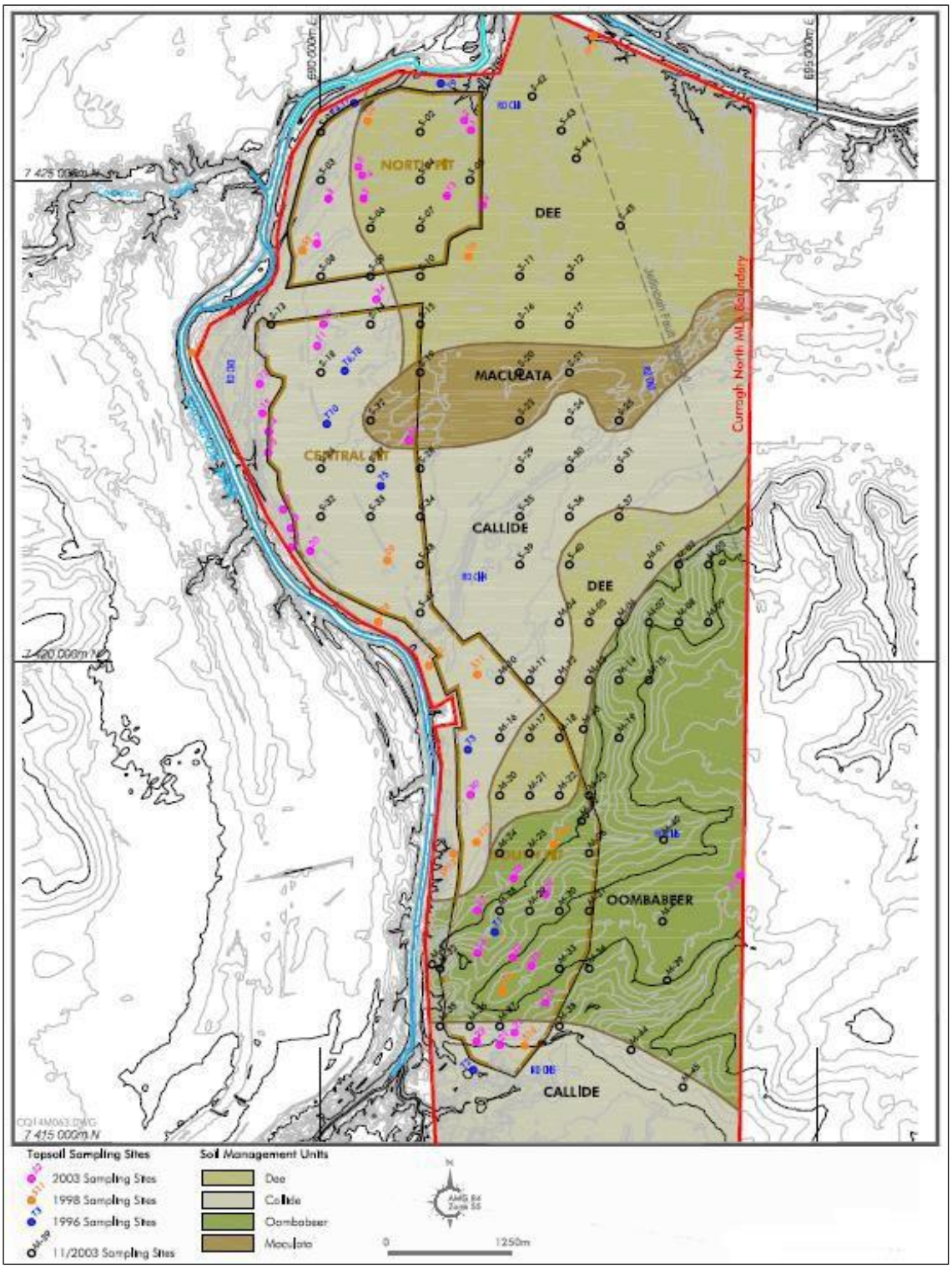


Figure A1.3: Location of soil sampling points and soil management units.

Spoil

As part of the Curragh North Project EIS, AARC was commissioned to compile an Overburden Characterisation Report (OCR) of the Curragh North project Site. AARC used analytical results from 33 overburden samples in order to "identify and evaluate potential management issues associated with the handling of overburden material at the Project site".

The following conclusions were drawn:

- acid Neutralising Capacity (ANC) and Net Acid Production Potential (NAPP) results have indicated AMD is unlikely to develop to be a management issue;
- sodicity levels for the overburden material are sufficiently high to warrant placement below the root zone;
- salinity levels are not sufficiently high to adversely affect plant growth; and
- ongoing characterisation of overburden is recommended to refine management strategies on an operational level.

2009 Spoil Sampling Regime

In 2009 Curragh Environmental personal undertook sampling of mine spoil from Curragh, Curragh East and Curragh North to further assess the risk of AMD. An experimental process outlined by Watling *et al.* was used; this involved measuring field pH (pH_F) and field pH peroxide (pH_{FOX}) on sub-samples of mine spoil.

The Guidelines for Sampling an Analysis of Lowland Acid Sulfate Soils in Queensland (Ahern *et al.* 1998) were used to interpret the experimental results. The guidelines use a combination of three factors to deduce a positive field sulphide identification, namely "a reaction with hydrogen peroxide, a much lower pH_{FOX} than field pH_F (ΔpH) and the actual value of pH_{FOX}.

In addition to field investigations, 11 samples were sent to a NATA accredited laboratory for further analysis. Results from both the field assessment and laboratory analysis are shown below:

The field assessment results were:

- one sample had a slightly acidic pHF (6.3 from the Permian material on the CN Eastern Spoil Dump) with the remaining samples returning pHF of between 7.4 and 9.4;
- three Samples had a ΔpH > 1 they were from mine spoils located on the CN Eastern Spoil Dump (both Tertiary and Permian material) and the CN levee access road;
- only two samples returned an acidic pHFOX (Tertiary and Permian materials from the Eastern Spoil Dump); and
- field assessment results indicate that the Permian material on the CN Eastern Spoil Dump has the highest PASS potential, as the pHFOX was 2.7 and the ΔpH was 3.6.

The laboratory analysis results were:

- pH of samples was alkaline, ranging from 7.8 to 9.4;
- as per the field assessment two samples returned an acidic pHOX these samples were the two samples from the eastern spoil dump;
- the Net Acid Generation (NAG) was <0.5 kg(H2SO4)/tonne for all except one sample, ESD2 (Permian Material) had a NAG of 3.5 kg(H2SO4)/tonne;
- acid Neutralisation Capacity ranged from 6.1 to 67 kg (H2SO4)/tonne for the 11 samples; and
- the Nett Acid Generation Potential (inc. ANC) was negative for all samples, suggesting that the samples have enough ANC to prevent acid generation.

CONCLUSIONS AND RECOMMENDATIONS

Spoil Acidity

Previous reports suggest that future spoil sampling may be required to facilitate successful spoil placement if isolated areas of PASS are discovered. A detailed spoil sampling regime should be developed in conjunction with a suitably qualified consultant, so spoil can be categorised prior to mining. Taking spoil samples during the exploration drilling program would allow enough time for samples to be analysed and an appropriate strategic placement plan to be developed if Potential Acid Sulphate Soil (PASS) were discovered. Using the exploration drill to obtain these samples would also allow for some synergies regarding project costing.

Sodicity and Salinity

Previous spoil characterisation reports indicate that the spoils in the Curragh and Curragh East lease areas are saline and sodic in nature. At Curragh North salinity is not sufficiently high to affect plant growth but sodicity is high enough to consider selective placement of spoils or amelioration techniques.

Soil Curragh North

The supplementary topsoil survey for the Curragh North Mining Lease (AARC 2004) Supplies a reasonably detailed map of soil management units. This map should be used by environmental personnel when advising on topsoil stripping (through the permit to disturb system) as each management unit should be stripped and stockpiled separately. The separate stockpiling of different management units would allow for the best management of each soil class once rehabilitation commenced. Once topsoil has been stockpiled it is important that relevant information is recorded into the topsoil database so as data relating to the stockpile can be easily recalled when rehabilitation works begin.

Curragh and Curragh East

Preliminary topsoil surveys of the Curragh and Curragh East give a good broad description of the soils in these areas. Higher resolution topsoil mapping would be required to optimise topsoil stripping and stockpiling techniques. To facilitate this, it is advisable that further topsoil sampling and categorisation should take place well in advance of mining activities.

REFERENCES

Ahern, C.R., Ahern, M.R., and Powell, B. (1998) Guidelines for Sampling and Analysis of Lowland Acid Sulphate Soils (ASS) in Queensland

Austral Asian Resource Consultants (2003) Curragh North Project - Environmental Impact Statement

Austral Asian Resource Consultants (2004) Supplementary Topsoil Survey for the Curragh North Mining Lease

Environmental Geochemistry International (1993) Curragh Queensland Mining – Curragh East Development Area: Geochemistry of Overburden and Implications for its Disposal

Environment Health and Safety Systems (1998) Description of Existing Environment Curragh East Project

HLA-Envirosciences (1998) Soil Analysis: Net Acid Generation and pH Curragh Mine Queensland

Land Reclamation Services (1990) Curragh Mine Soil Survey

Land Reclamation Services (1993) Characterisation of Dragline Dumped Spoil – Curragh Mine

Stuart Miller and Associates (1984) Curragh Queensland Mining Limited, Waste Management and Rehabilitation Studies Overburden Geochemical Investigations

Walting, K.M., Ahern, C.R, Hey, K.M., Acid Sulfate Soil Field pH Tests

APPENDIX 2 – Vegetation Reference Sites

Reference Site 1: Poplar Box Woodland (REF PB)

Regional Ecosystem: 11.10.12

RE Description: *Eucalyptus populnea* woodland on medium to coarse-grained sedimentary rocks (QLD Herbarium 2009).

The two REF PB transects are located in a remnant patch of *Eucalyptus populnea* open woodland on the southern area of the western boundary fence (Figure A2.1) run in an easterly direction away from the lease boundary. This is a sparse open woodland to a height of 15m with a sparse mid storey of *Eremophila spp.* and *Atalaya hemiglauca*. The ground layer is dominated by Buffel (*Cenchrus ciliaris*) and native grasses such as *Aristida spp.* and *Chrysopogon fallax*. The area has undergone recent rill and sheet erosion and there were many bare patches noted. Upon examination of the UAV images obtained at the time of monitoring, the area is obviously part of a larger easterly facing drainage line. Areas of remnant Poplar Box off the western and south western boundary had undergone extensive medium-high intensity fuel reduction burning in the weeks prior to the assessment in 2011.

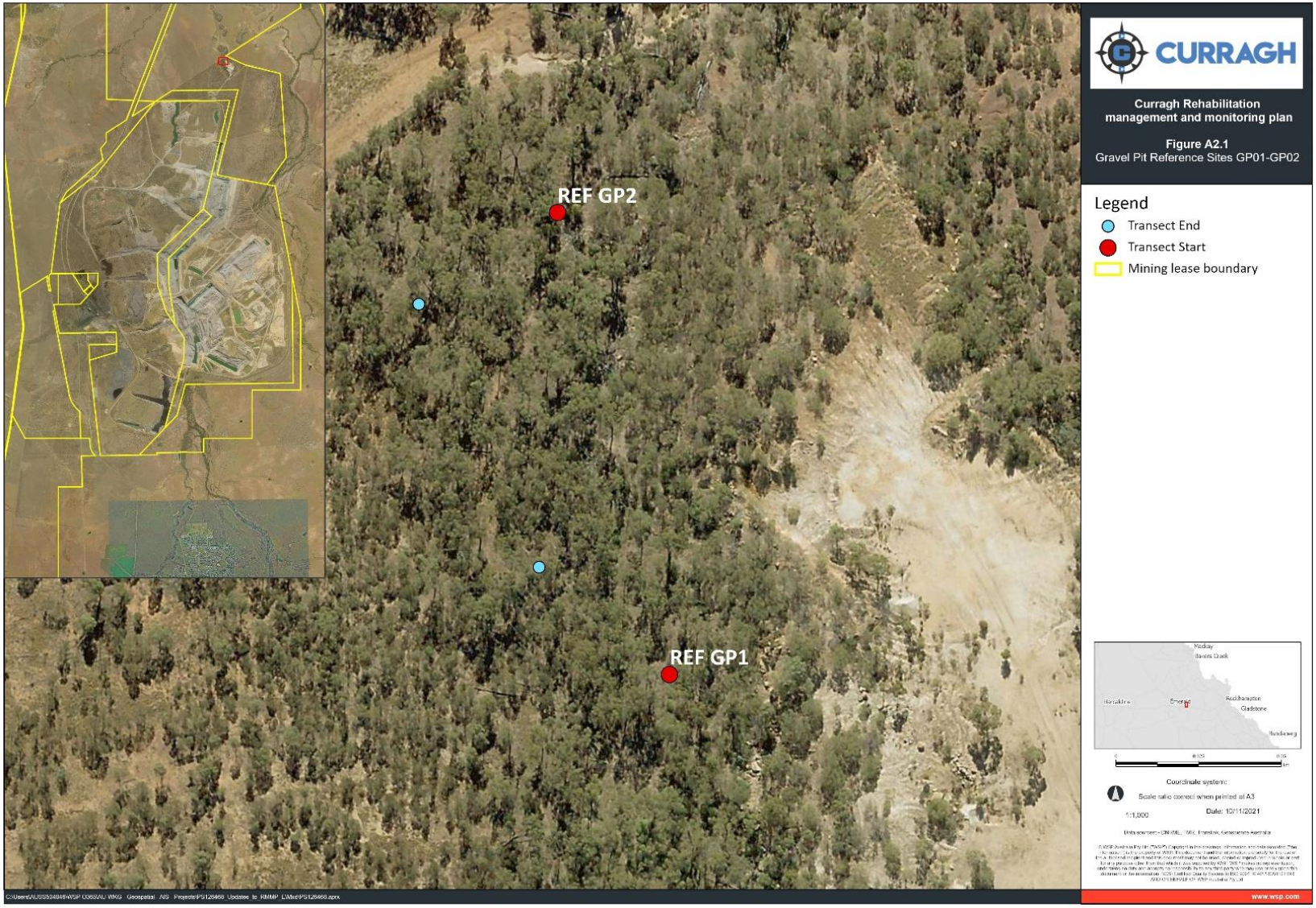


Figure A2.1: Poplar Box Reference Sites PB01-PB02.

Reference Site 2: Napunyah Woodland Gravel Pit (REF GP)

Regional Ecosystem: 11.4.2

RE Description: *Eucalyptus* spp. and/or *Corymbia* spp. grassy or shrubby woodland on Cainozoic clay plains.

The two REF GP transects are located to the north of the mine boundary in the area known as the 'gravel pit' which is an old quarry (Figure A2.2). Surrounding the quarry is a remnant patch of *Eucalyptus thozetiana* woodland which grades into *Acacia harpophylla* woodland on the lower slopes. This general area was the location of the original reference sites listed in Curragh EMOS 2002 as 'Site C', however the exact location of the 2002 plots is unknown. The current transects are positioned within the area dominated by *Eucalyptus thozetiana* before the community grades into *Acacia harpophylla. Eucalyptus thozetiana* forms a dominant moderate-dense canopy to a height of 15m, while the sparse midlayer consists of the shrub species *Carissa ovata*, *Croton phebalioides*, and *Erythroxylum australe*. Groundlayer is a dense combination of native grasses such as *Paspalidium spp*., *Aristida spp*., and *Leptochloa decipiens ssp. decipiens*. Historical timber harvesting is evident with cut timbers noted, and the area has obviously undergone considerable disturbance as a result of the quarry workings.

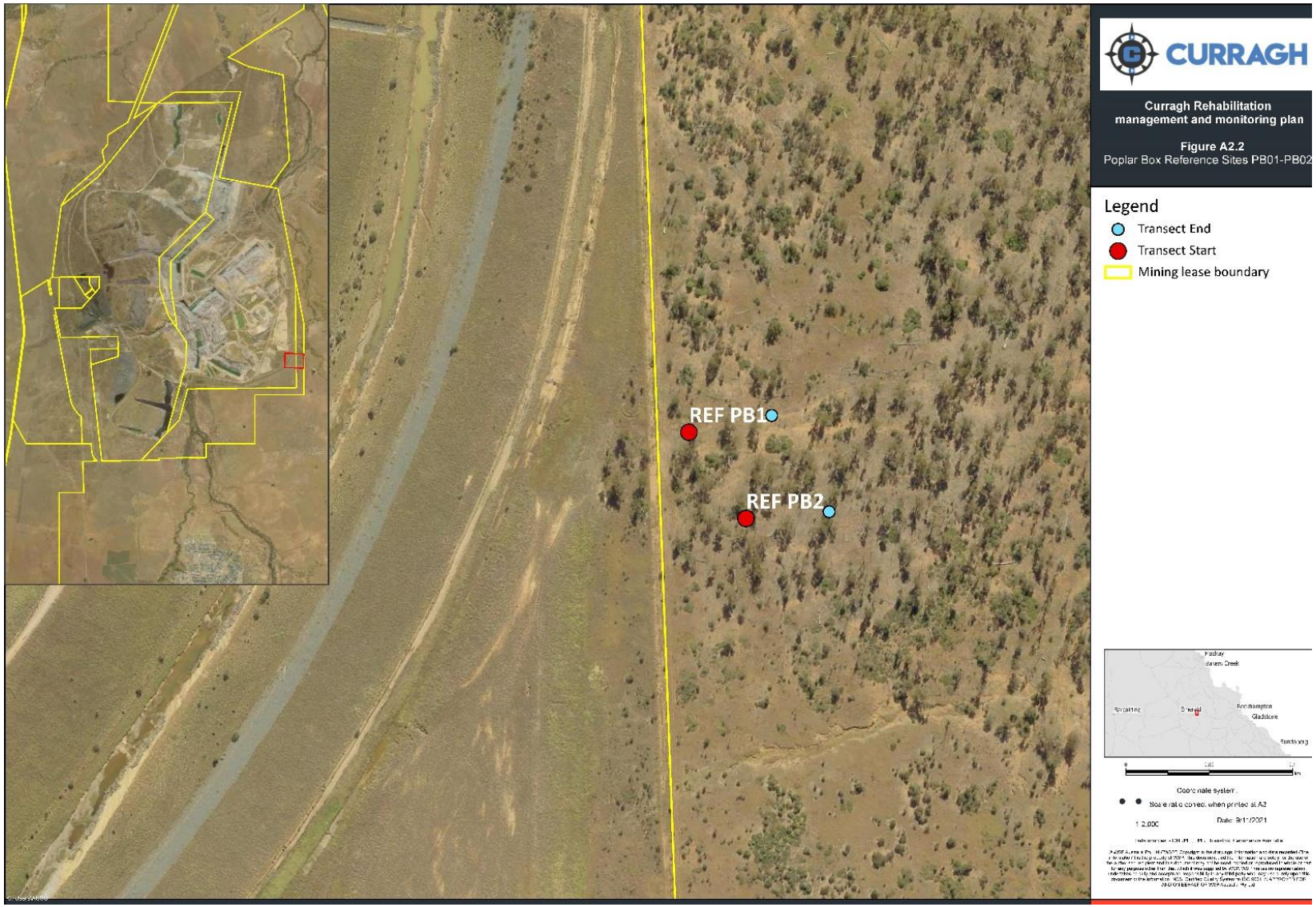


Figure A2.2: Gravel Pit Reference Sites GP01-GP02

Reference Site 3:

Regional Ecosystem: 11.4.8

RE Description: *Eucalyptus cambageana* woodland to open forest with Ac*acia harpophylla* or A*. argyrodendron* on Cainozoic clay plains.

The two REF EC transects are located within a small patch of remnant *Eucalyptus cambageana woodland* within the mine lease on the northwestern boundary. The open canopy is dominated by *Eucalyptus cambageana* and *Acacia harpophylla* to a height of 12m, with some sparse, older dead *Eucalyptus cambageana* stags present. The mid layer is composed of *Carissa ovata*, *Eremophila mitchellii* and *Alectryon diversifolius* in a moderate to sparse density. The moderate to dense groundlayer is dominated by patches of Buffel Grass (*Pennisetum ciliare*) and other grasses such as *Paspalidium spp.*, *Aristida spp.* and *Enteropogon unispiceus* are more dominant in areas of dense Brigalow canopy shading

This reference site is no longer in use due to mine progression in the area.

A2.1 Methods – Vegetation assessment

The methods used followed previous methods employed when assessing rehabilitated sites at Curragh Project.

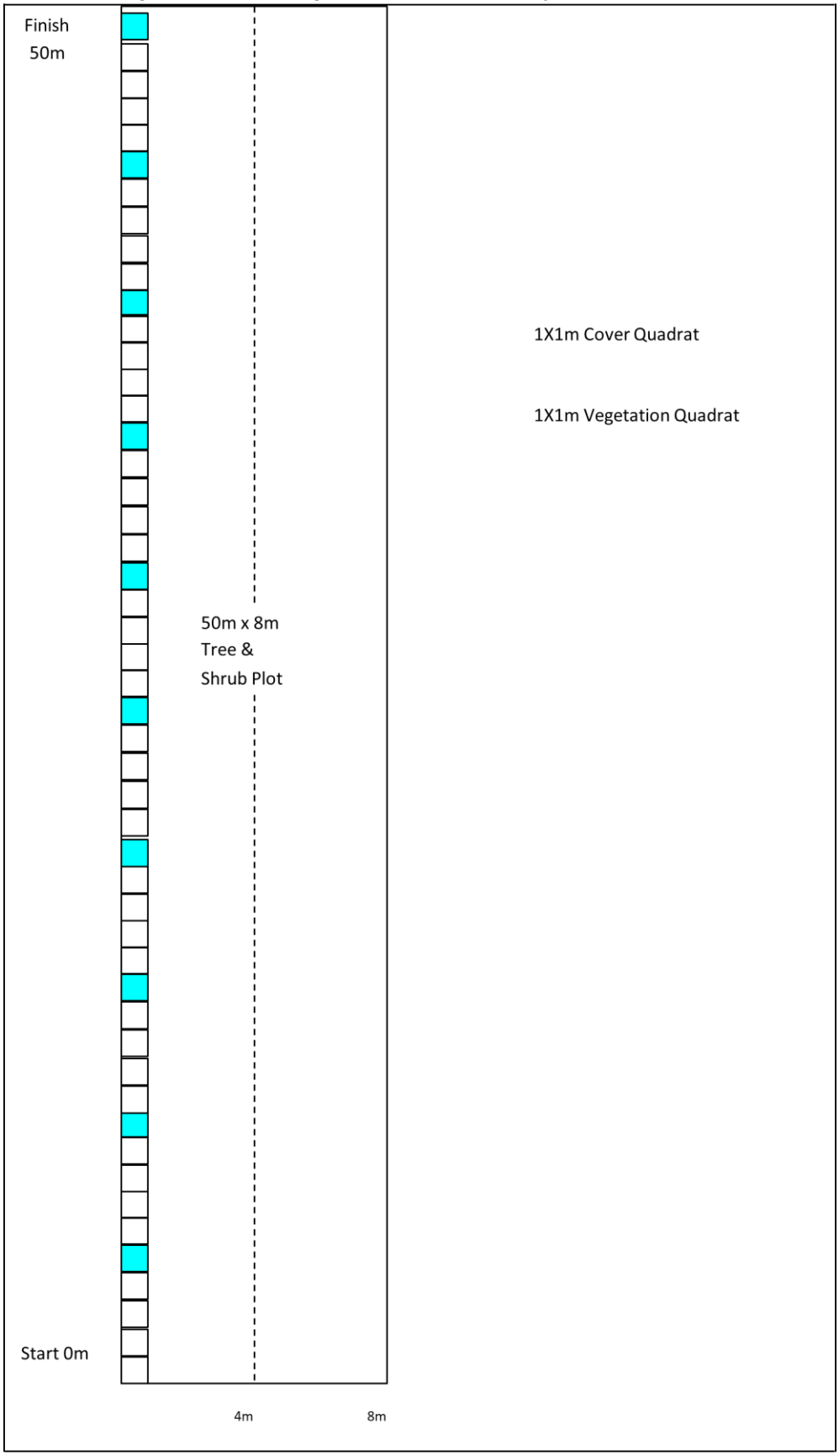
A measuring tape was extended along each of the 50m transects, and the number and height of woody tree and shrub species were recorded for each of 50 (1m x 1m) quadrats located along the right-hand side of the tape. Any forbs (herbaceous and sub shrub) and grass species present in each quadrat were also recorded. Tree and shrub species and heights were also recorded in an area of 7m x 50m immediately adjacent to the 1m x 1m quadrats, in 5m x 10m sections. Individuals within 4m of the measuring tape were recorded separately to enable future comparisons with previous data. Grass and herbaceous species present but not already encountered in the 1m quadrats were also recorded in this way. Thus, species richness was assessed for 1200m^2 at each site, comprising 3 x 400m^2 areas (Figure A2.3).

At one metre intervals along the transect, foliage projective cover (FPC) was assessed for the cover of canopy vegetation (>2m), understorey vegetation (0.5-2m), and ground vegetation (<0.5m), noting at each interval if the vegetation cover was by native grass (n), introduced grass (i), shrub (s) or tree (t). At each metre interval groundcover was also assessed for bare, rock, litter or vegetation. This resulted in measures of vegetation in three strata (canopy, understorey and ground layer) at each point along the transect, and four categories of soil surface cover at each point along the transect.

At 5m intervals along each transect ground cover characteristics (live standing material, detached or fallen litter, and rock) were visually assessed within the 1m x 1m quadrats (*i.e*. a total of 10 quadrat locations for the whole 50m transect), used for recording species presence detailed above. The proportion of bare ground was also assessed by default. The proportional contribution to total standing cover from up to three of the most prevalent species was recorded.

Photographs were taken from both ends of transect as a permanent visual record of the development of the site providing an interesting visual snapshot of the changes that are occurring over time.

Figure A2.3: Diagram of monitoring methods conducted by CMLR at Reference sites 2011.



A2.1.1 Soil sampling and analysis

At each transect, two surface (0-10cm) soil samples was collected, one at each end of the transect. All samples were air-dried, ground to pass through a 2mm sieve and initially analysed for pH and electrical conductivity (EC) to determine the occurrence of any significant differences in soil characteristics. The samples were analysed according to methods described in Rayment and Higginson (1992). Total N and Total C are measured by combustion in an automated LECO CNS Analyser. Unlike in previous years, samples for C analysis were not pre-treated with 5 M HCl to remove any inorganic carbonates present (Method 6B3) and hence only Total C values are provided in this report. Available P was determined by ICPAES following 0.5 M $NaHCO_3$ (1:30) extraction (Method 9B1). Exchangeable cations (Ca, Mg, K and Na) were analysed by ICPAES following alcoholic 1 M NH_4Cl extraction, with pre- treatment to remove soluble salts (Method 15A2). Cation exchange capacity (CEC), a measure of soil ability to hold nutrients, and exchangeable sodium percentage (ESP), indicating how prone a soil is to dispersion and structural problems, were calculated from exchangeable cations data. Chloride was determined colorimetrically using a Pharmacia Ultrospec 2000 spectrophotometer on 1:10 soil solution extracts in 0.1 M nitric acid (Method 5A2), and extractable S by ICPAES from 1:5 soil solution extracts in 0.01M calcium monophosphate (Method 10B3).

A2.1.2 Site characteristics

At each site, general descriptions of the area were recorded, including dominant vegetation for each strata, evidence of grazing, clearing, erosion or any other disturbance. Average slope gradient, the angle between the beginning and the end of transect, was measured using a hand-held clinometer.

A2.2 Survey results

A2.2.1 Vegetation

Species Richness

Species richness across the three reference sites ranged from 18 (REF PB), 25.5 (REF EC) to 26 (REF GP). Figure A2.4 a) and b) details the richness for each site with a breakdown of the lifeforms, indicating that grass species are making up a significant proportion of the richness component at REF EC and REF GP, while tree species makes up a higher proportion at REF PB.

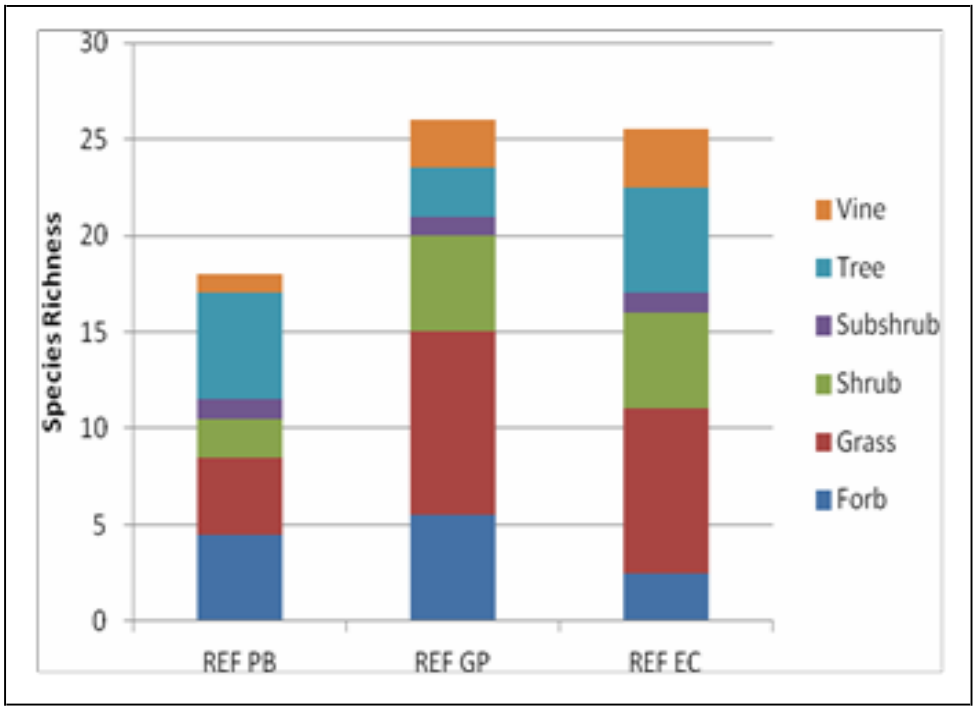


Figure A2.4 a: Species richness lifeforms recorded within three native sites in 2011. Lifeform richness as a proportion.

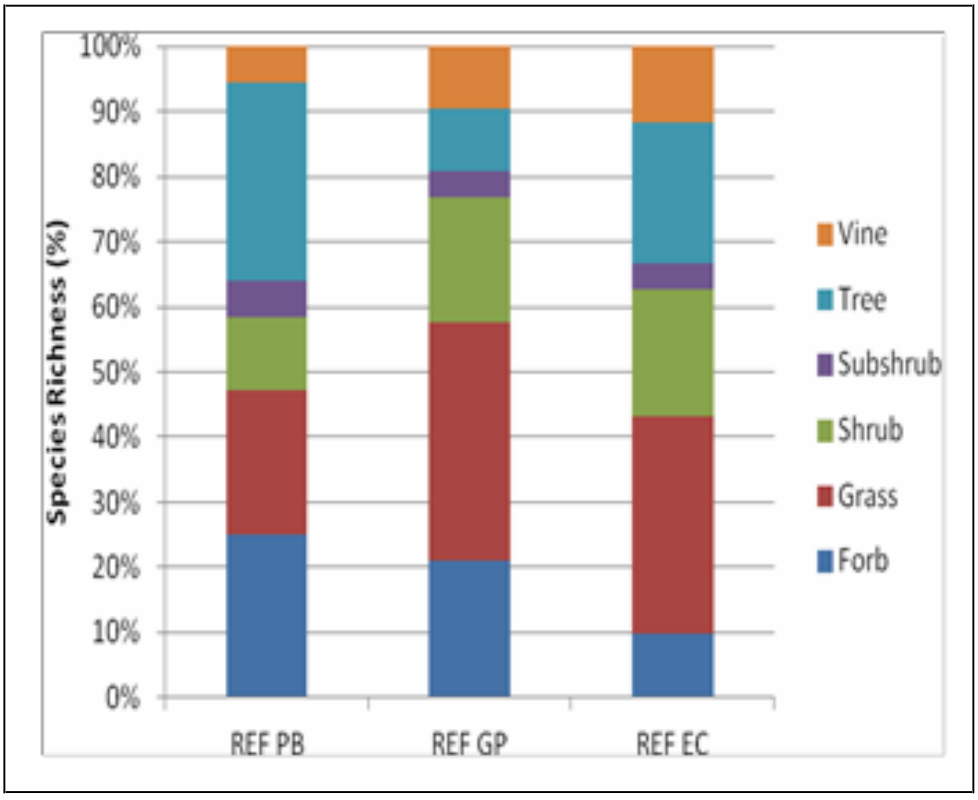


Figure A2.5 b: Species richness as a percentage (calculated as an average from two transects within each area (400m2).

A2.2.2 Tree & shrub density and heights

The total tree density at the reference sites ranged from 400 (REF PB), 425 (REF GP) to 775 (REF EC). A breakdown of Eucalypts, Acacias and 'Other' tree species is provided in Figure A2.6 The high proportion of Acacias at REF EC represents a high number of *Acacia harpophylla* (Brigalow) individuals, while the high number of 'Other' tree species at REF PB reveals a relatively high number of species such as *Atalaya hemiglauca* (Whitewood), *Eremophila* spp, and *Ventilago viminalis* (Supple Jack). The dominance of *Eucalyptus thozetiana* is demonstrated by the high number of Eucalypts at REF GP.

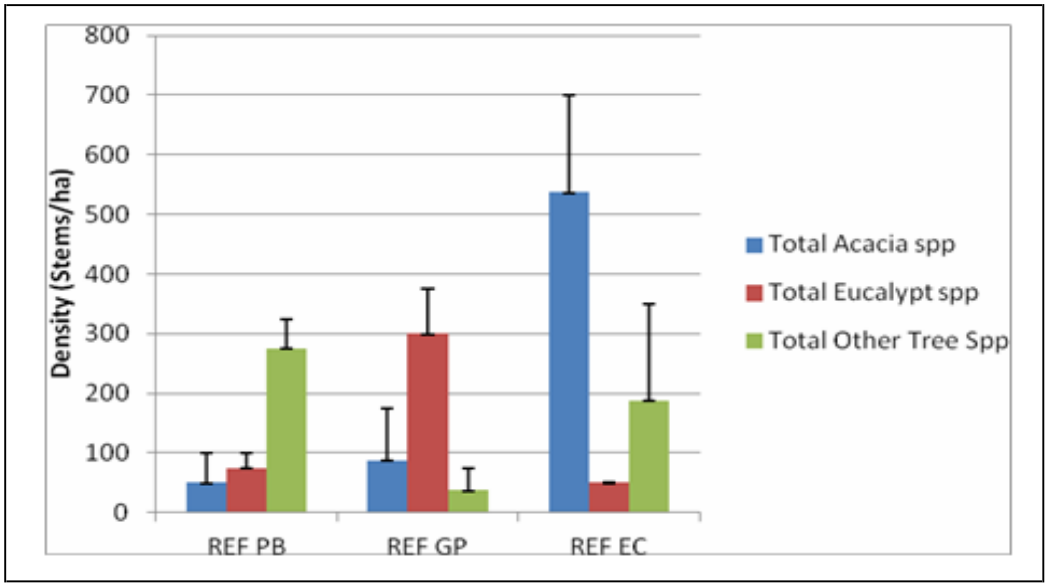


Figure A2.6: Tree densities at three reference sites monitored at Curragh, November 2011. Data taken from sum of 2 transects (800m^2).

Analysis of height class shows that the greatest densities are found in the <2m category with REF GP and REF EC dominated by shrubs such as *Carissa ovata* and *Indigophora brevidens*, while REF PB is dominated by Other Tree species such as *Atalaya hemiglauca* and *Eremophila spp*. At all reference sites, Eucalypt species are dominant in the >10 m height class representing the dominant canopy species for each site (Figure A2.7). These charts indicate that structurally the reference sites have a sparse to moderate upper storey, a sparse midstory and moderate to dense ground layer.

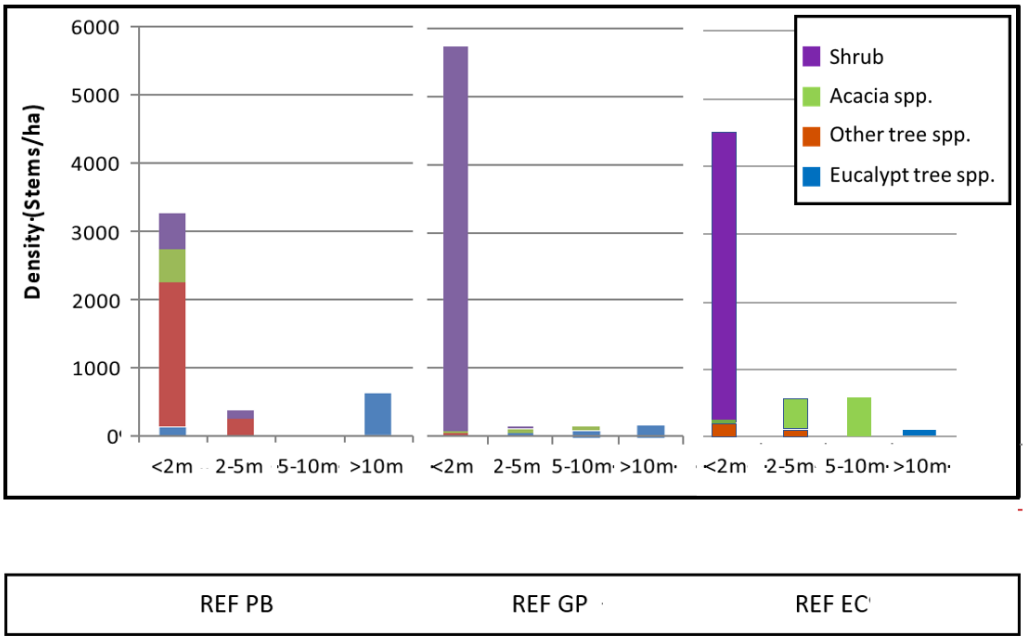


Figure A2.7: Height class density plots for three reference sites monitored November 2011, Curragh Project. Data taken from sum of 2 transects (800m^2).

A2.2.3 Cover

Foliage projective cover across the three reference communities shows the variation observed, with canopy cover REF GP (66%), REF EC (46%) and REF PB (16%). Ground cover was dominated by introduced grasses (mostly Buffel) at REF PB with a cover score of over 70%, while the ground layer was dominated by mostly native grasses at REF GP (53%) and at REF EC a mixture of introduced grass (39%) and shrubs (28%). Mid layer was largely absent at REF PB with small contributions by shrubs and trees at the other two reference sites (Figure

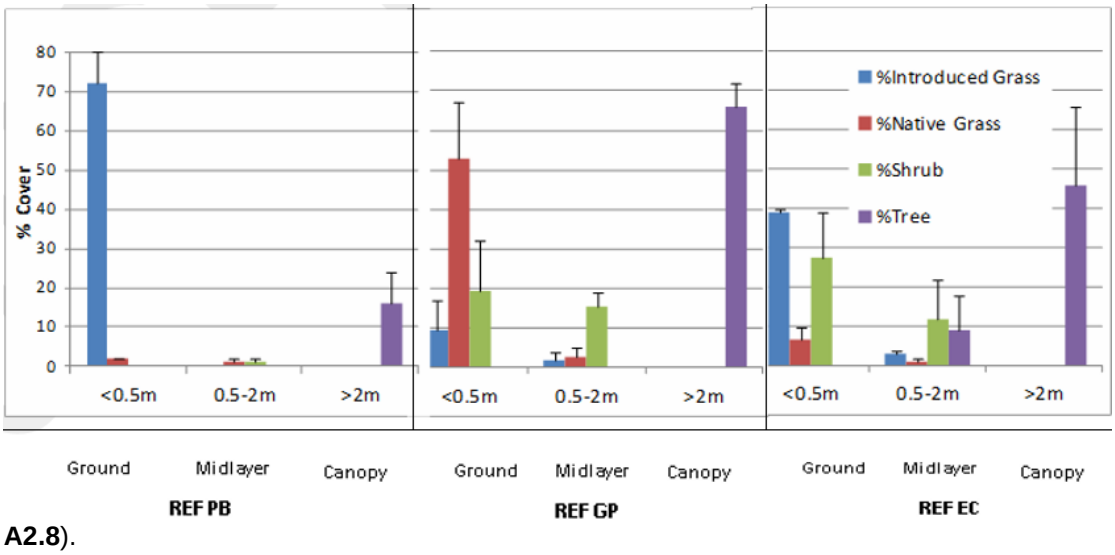


Figure A2.8).

Figure A2.8: Foliage Projective Cover (FPC) along 50m transect. Each reference site is a coverage of two transects.

Cover measurements from the quadrat assessment shows that the quadrats are dominated by standing vegetation (60%); litter contributes a large proportion of the cover component at REF GP (33%) and REF EC (30%), while bare earth contributes a significant cover component of 27% at REF PB (Figure A2.9).

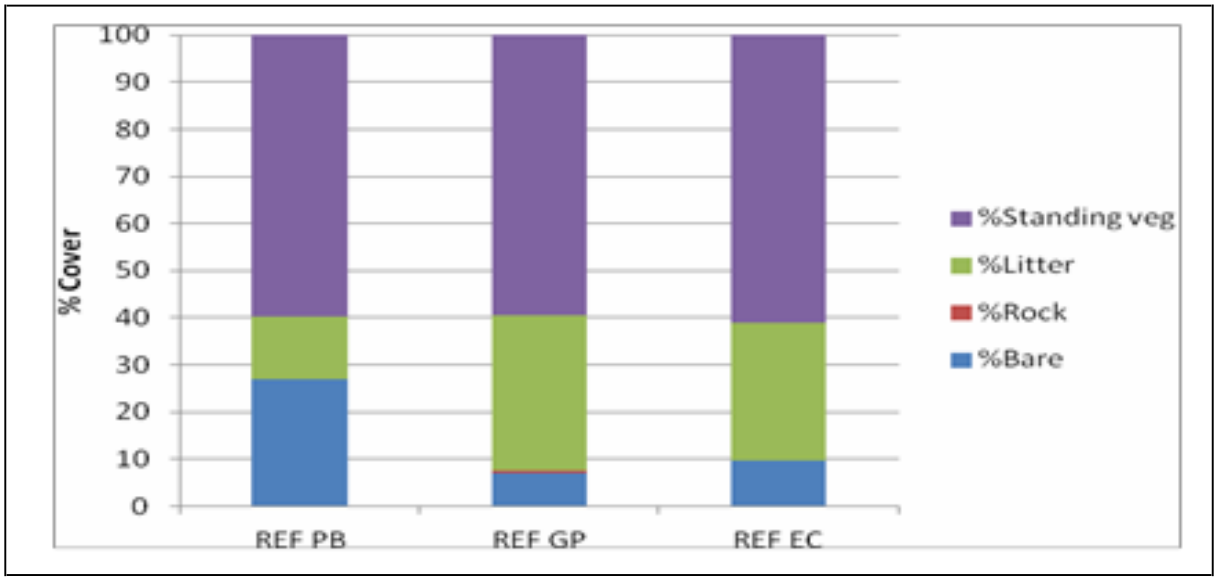


Figure A2.9: Quadrat Cover for the three reference sites. Each reference site is an average of two transects.

A2.2.4 Soil Properties

Site-specific soil data taken across all reference sites from November 2011 is provided in sodic. Table A2.1 For sampling and analysis methods please refer to Section A2.1.1.

The topsoil across all monitored sites is generally considered to be non-saline, neutral (pH) and non-sodic. Table A2.1: Soil results (0-10cm) from monitoring from each transect at the three reference sites. Values are an average of two samples, one taken at the start and one at the end of each transect.

Table A2.1 Soil results from monitoring.

Parameter	REF PB1	REF PB2	REF GP1	REF GP2	REF EC1	REF EC2
EC (uS/cm) (1:5 H_20)	18.32	21.01	68.10	66.57	121.40	78.87
pH	7.12	7.15	6.83	7.11	6.55	6.67
Total C (%Wt)	1.00	1.34	2.58	3.49	2.55	2.83
Total N (%Wt)	0.05	0.09	0.16	0.21	0.17	0.18
Cl (mg/kg)	11.25	7.38	68.81	35.14	53.59	18.61
Available P (mg/kg)	7.07	8.05	29.55	32.28	26.74	44.11
SO_4-S (mg/kg)	6.47	5.64	14.15	14.27	13.57	13.12
Ca (cmol(+)/kg)	2.69	4.49	5.68	7.08	13.31	14.07
K (cmol(+)/kg)	0.36	0.58	0.80	1.06	0.67	1.40
Mg (cmol(+)/kg)	0.89	1.13	3.28	2.75	1.49	1.68
Na (cmol(+)/kg)	0.19	0.19	0.24	0.26	0.23	0.18
CEC (calculated)	4.12	6.39	10.00	11.15	15.70	17.33
Cu (mg/kg)	0.33	0.49	1.04	1.09	0.88	0.92
Fe (mg/kg)	24.72	36.21	43.64	51.26	45.72	64.17
Mn (mg/kg)	8.54	13.17	4.96	5.45	15.65	22.99
Zn (mg/kg)	0.99	0.51	3.19	4.99	2.38	3.46

Total N values are considered low-medium across topsoil media while levels of sulphate-sulphur (SO_4-S) vary across the sites with REF PB considered to be low while REF GP and REF EC are at medium levels. Similarly, for available phosphorus, REF PB is considered low while REF GP and REF EC are at medium levels. All soils were low-moderate for CEC values, with PB in particular showing values that indicate a susceptible and fragile reduced soil structure.

The relative proportions of cations across the sites indicate that REF PB is well balanced; REF GP demonstrates low, but not deficient calcium levels, while REF EC is low, but not deficient in magnesium (Figure A2.10.)

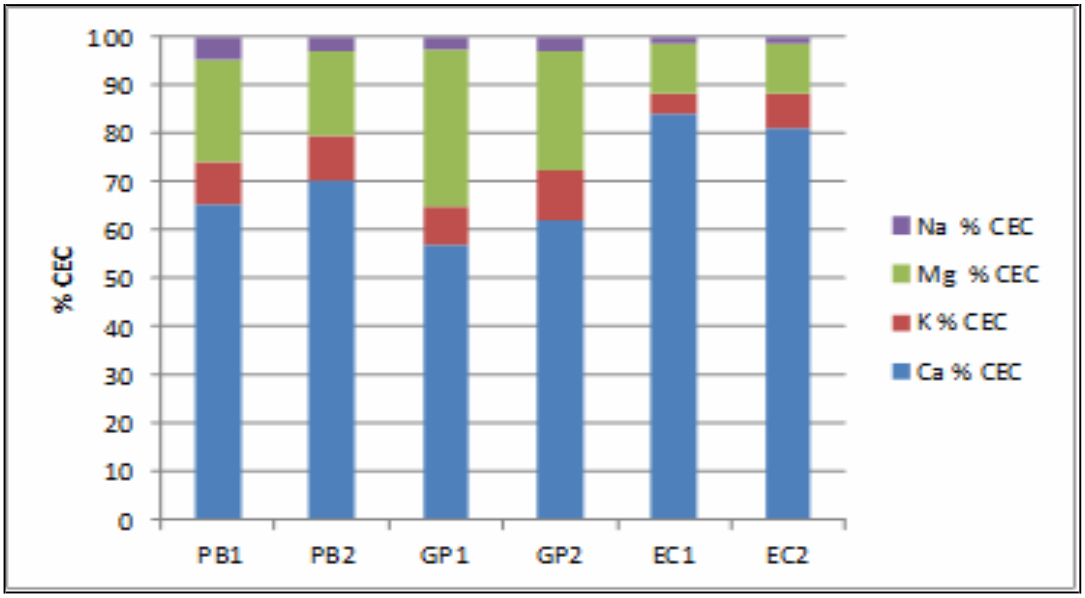


Figure A2.10: Relative proportions of cations across each transect. Values are an average of two samples.

A2.2.5 Rainfall Patterns for 2020

Annual rainfall totals from 1983-2020 recorded on site at the Curragh Project are shown in Figure A2.11. With an average rainfall of 530 mm (1983-2020), the 2020 rainfall represents a total rainfall just under the long-term average.

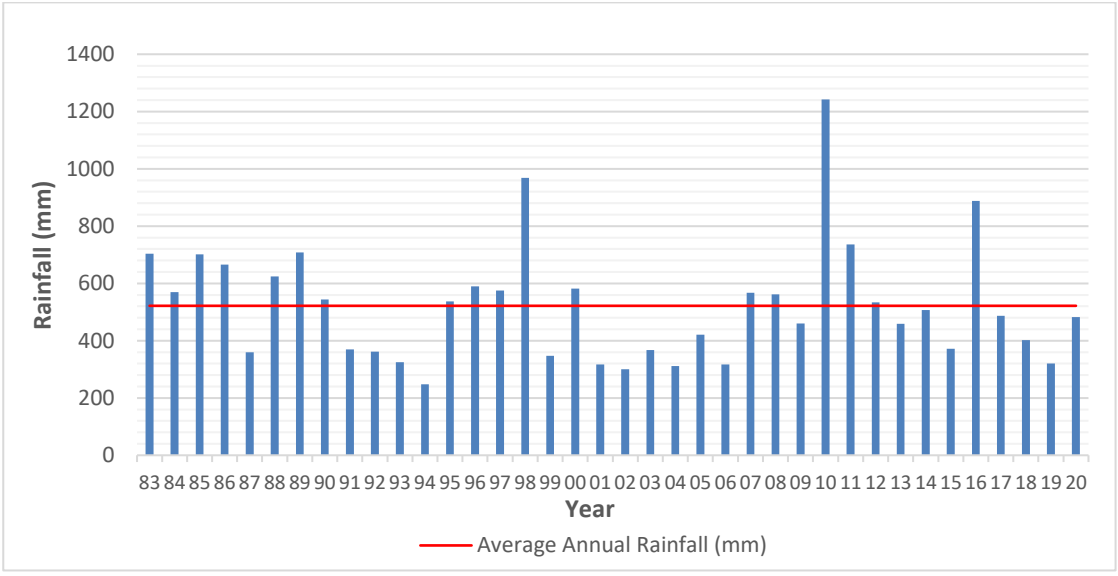


Figure A2.11: Annual rainfall totals recorded at Curragh Project 1983-2020 Red line indicates Curragh Project long term average.

Monthly rainfall totals recorded at the Curragh mine site in 2020 are shown in Figure A2.12. The majority of the monthly rainfall actually fell in January, February and October (95 – 98 mm) compared with the long-term average of 43.6mm.

Daily weather data throughout 2011 provides daily values for the parameters expressed in the monthly summary in Figure A2.12.

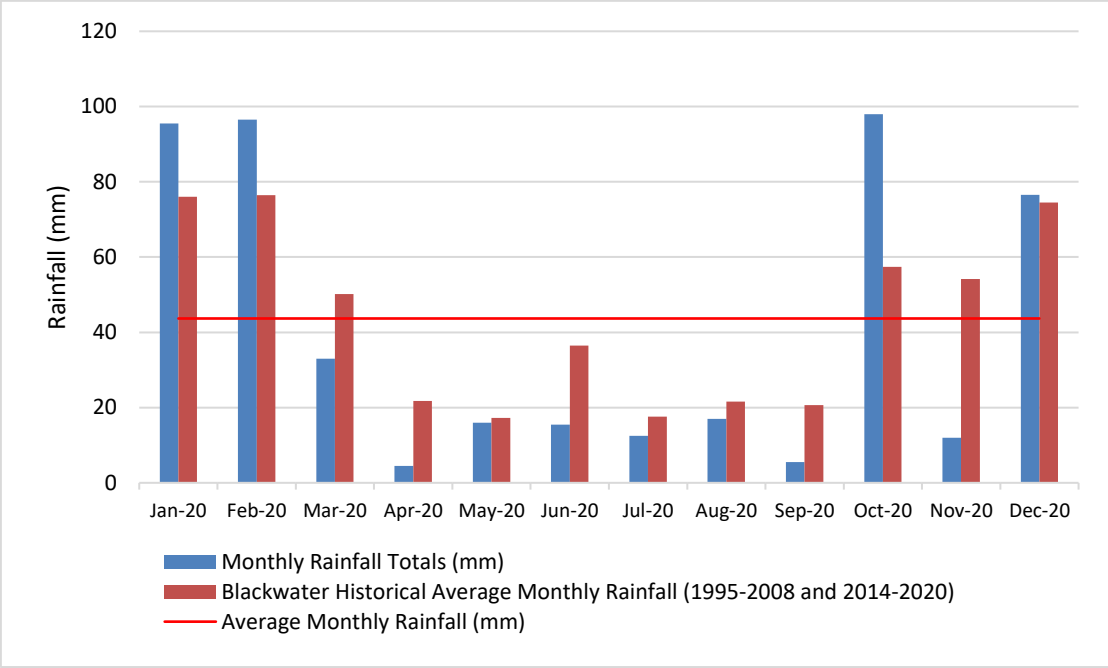


Figure A2.12: Monthly rainfall totals for the year 2020 recorded at Curragh Project against Blackwater average.

A2.3 Comparison with Curragh rehabilitation data

A2.3.1 Species Richness

The relationship between reference sites, rehabilitation age and species richness (all species) from 1996 - 2010 is illustrated in Figure A2.13. The majority of rehabilitated sites have been monitored on three separate occasions and many sites show an initial decline in species richness before stabilising or slightly increasing over time. A general decline in richness could be attributed to the establishment and subsequent cover dominance of grass species such as *Cenchrus ciliaris* which are able to successfully out compete other understory species and is known to compete out native species (Franks 2002). Species richness in the reference communities are high in comparison to the rehabilitated sites with REF GP and REF EC recording the highest values (0.07 and 0.06 species/m^2 respectively) while REF PB showed a significantly lower richness of 0.05 species/m^2.

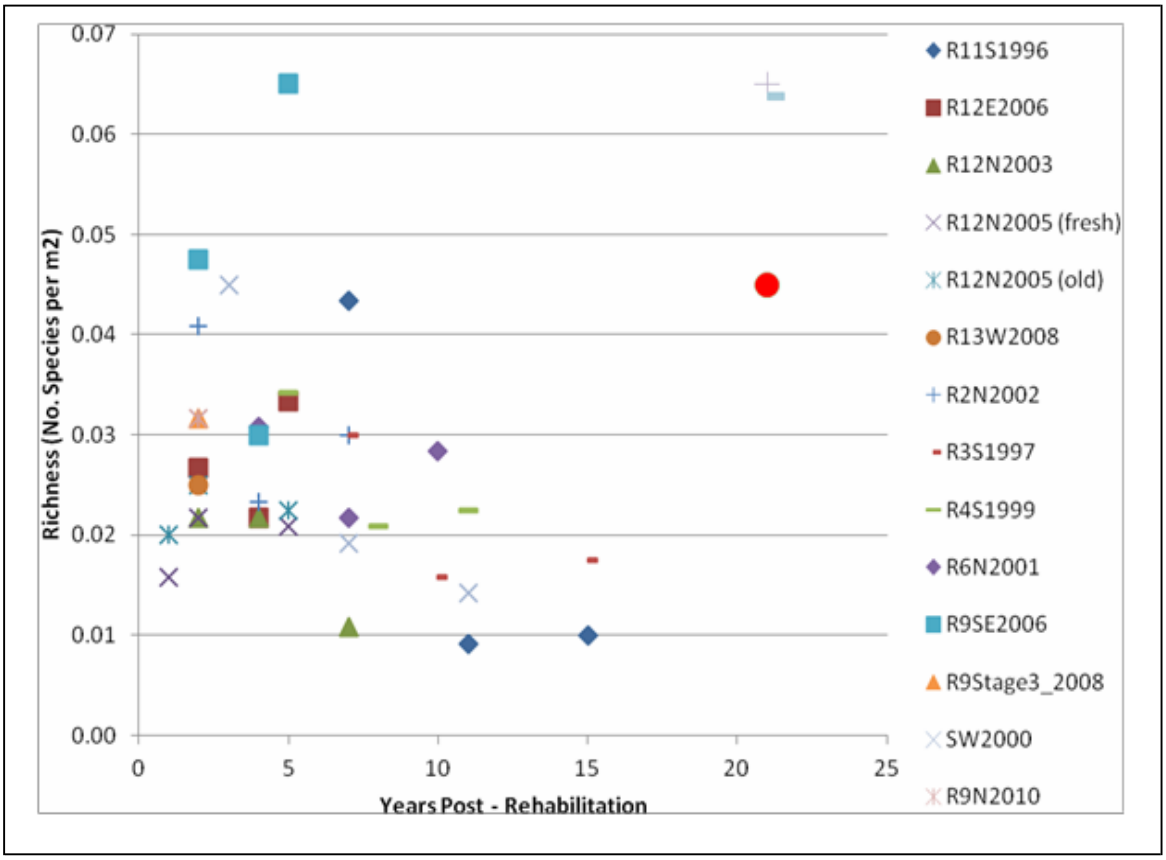


Figure A2.13: The relationship between species richness (all species) for rehabilitated and native sites. Values are numbers of species per m^2.

Still to be provided as part of this assessment is:

- Comparisons of native, introduced and exotic richness between sites; and
- PRIMER MDS analysis between rehab vs reference sites.

A2.3.2 Tree & Shrub Density

The chrono sequence of tree and shrub density data for each rehabilitated site against values for the reference communities REF EC, REF GP and REF PB is provided in Figure A2.14 (a, b, c, d & e). Most rehabilitated sites show a general trend of increasing density over time with the best performing sites being R3S1997, R11S1996 and NE1998. Many of the rehabilitated sites are trending towards values obtained within the reference communities with REF EC being an obvious outlier at 1112.5 stems per ha (Figure A2.14a). While *Acacia harpophylla* (Brigalow) was only present at two native sites REF EC and REF GP and one rehabilitated site (R3S1997), the removal of this species from the data demonstrates its dominance, particularly at site REF EC (reduced to 225 stems per ha) (Figure A2.14b). Many rehabilitated sites are on a trajectory towards Acacia densities (Figure A2.14d) (note this figure includes Brigalow)), however Eucalypt (Figure A2.14c) and shrub (Figure A2.14e) densities in the reference communities are significantly higher than those found within the rehab sites, particularly shrub densities which were off the chart for the sites REF EC (4525 stems per ha) and REF GP (5640 stems per ha). This result shows the significant density of understorey species such as *Carissa ovata, Alectryon diversifolius, Indigophora spp.* etc. found within the native communities and subsequently lacking in the rehabilitated sites, most likely due to the competitive dominance of grass species such as Buffel and poor seed germination and success of understorey species within rehabilitated sites.

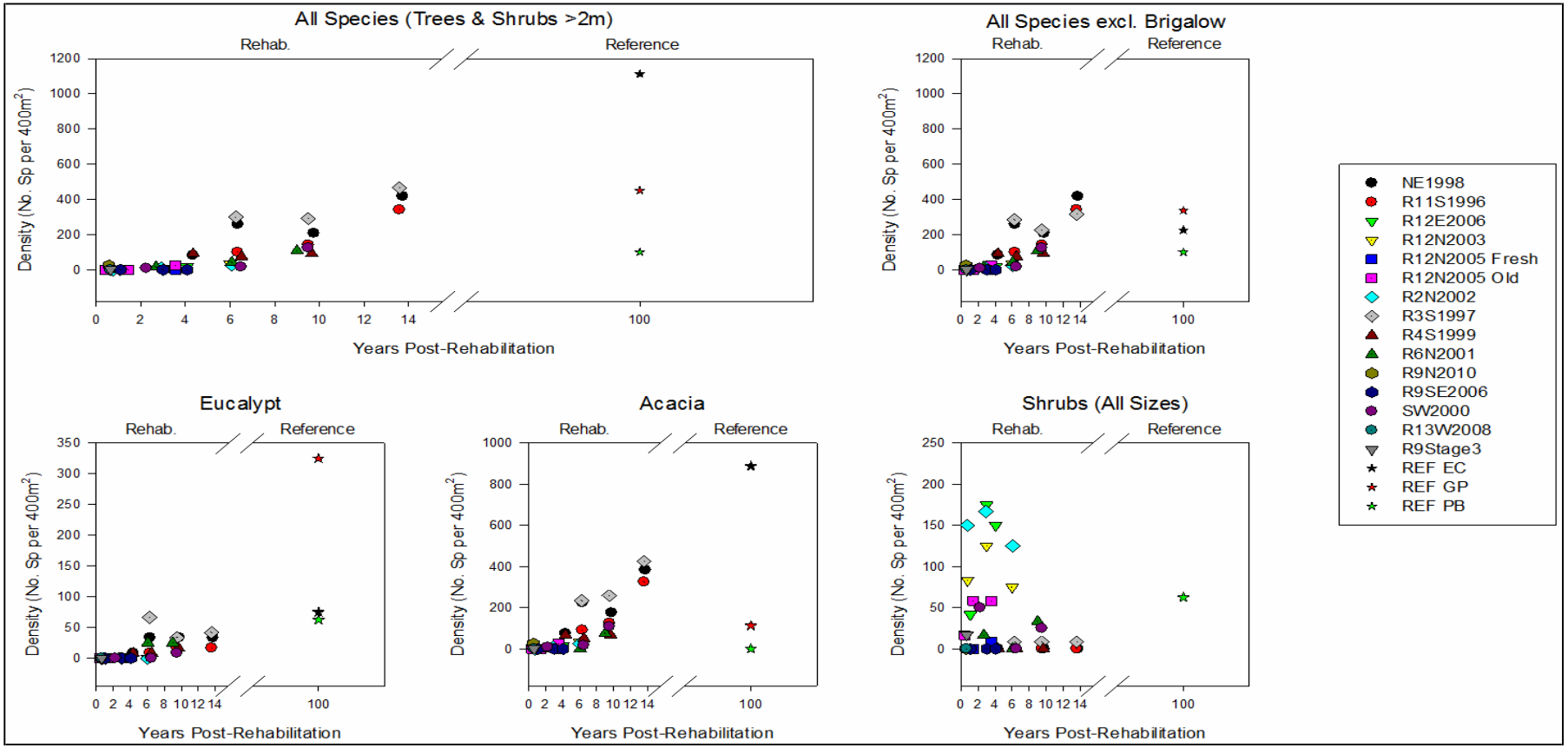


Figure A2.14: The relationship between tree and shrub density on rehabilitated sites vs native sites. a) All Species>2m, b) All Species>2m excluding *Acacia harpophylla* (Brigalow), c) Eucalypt density >2m, d) Acacia density>2m and e) Shrubs (all sizes). Each data point represents average numbers of individuals per 400 m^2 (8mX50m transect).

A2.3.3 Vegetative Cover

Monitoring data for the past ten years consistently shows that total vegetative cover tends to increase over time for both media levelling off as the sites approach 14 years of age. Topsoiled areas generally show a greater per cent cover as compared to the spoil media due largely to management practices of sowing faster growing pasture species in the topsoil media and tree & shrub species in the spoil media. The chemical and physical characteristics of the topsoil media are also more favourable to faster growing ground cover species. The inclusion of reference site data indicates that rehabilitated areas are on a trajectory towards, and in some cases surpassing values obtained in the reference sites (Figure A2.15). Trend lines indicate that topsoiled media could achieve reference site values within 10 years, while spoil media may take between 15-20 years.

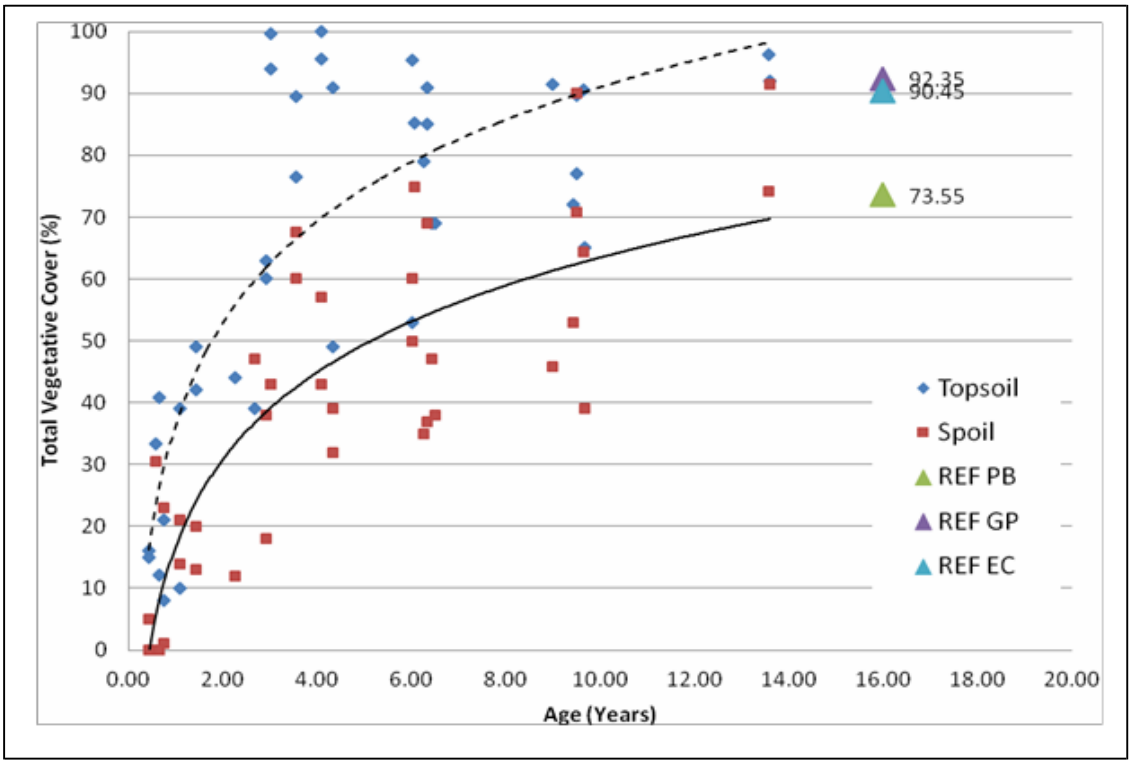


Figure A2.16: Cover development with rehabilitation age at Curragh Project on replaced topsoil and spoil compared with values from reference communities. Data are from 2002 until 2011 monitoring campaigns.

Data showing further comparisons such as litter cover between sites is currently being processed and will be provided within the review of this document. Note that this is cover measured through quadrat method only. Cover analysis by FPC as reported earlier has *not* traditionally occurred on rehabilitated sites at Curragh. This method will however be included in the extended monitoring period so that future comparisons can be made on the structural variability between reference and rehabilitated communities.

APPENDIX 3 – Past Research and Development Projects

A3.1 Completed research programs

Final Void Research – to allow planning for closure to be undertaken on the basis of sound understanding of final void hydrology and post-closure processes. (AECOM, 2012)

The use of high resolution remote sensed imagery generated via GPS- guided Unmanned Aerial Vehicles (UAVs) to assist ground-based assessments. Centre for Mined Land Rehabilitation, University of Queensland (CMLR-UQ), 2002-2016

Develop success criteria from ongoing monitoring of reference and rehabilitated areas. CMLR-UQ, 2002-2016

Measuring Rehabilitation Responses to Fire: Implications for long term resilience and mine closure. CMLR-UQ, 2015-2017

A3.2 Other relevant research

A3.2.1 Mine Rehabilitation Erosion Process

An industry wide erosion research program: "Post-Mining Landscape Parameters for Erosion And Water Quality Control" managed by the Centre for Mined Land Rehabilitation, CMLR, at the University of Queensland commenced in 1992 (ACARP C4011). The program investigated soil erosion processes and water quality issues relating to mine rehabilitation. It is a Queensland coal industry research program aiming to develop erosion prediction models for use in post mining landform design as well as a better understanding of water quality issues.

The project was sponsored by 15 open cut coalmines in Central Queensland, including Curragh. Onsite environmental officers as well as researchers fromthe University of Queensland, the University of Newcastle, ACIRL and the DNR, (formally DPI), provided technical expertise. The program was due to be completed by the end of 1997, although further funding allowed it to continue into year 2002.

A3.2.2 Mine Rehabilitation Erosion Stage II

An extension to ACARP 4011, this project (ACARP 1629), undertaken by the Department of Natural Resources, focused on the long-term monitoring of erosion and water quality from rehabilitated land. Biophysical indicators for rehabilitation and the effect or reject on enhancing infiltration and vegetative growth were investigated.

A3.2.3 Mine Rehabilitation Erosion Stage III (biophysical adjunct)

Central Queensland University undertook a *Pilot study investigating the use of invertebrate assemblages to gauge rehabilitation success*. Samples were taken from 3 reference sites, 5 contour strip sites, 3 full soil sites and 3 early rehabilitation sites. The assessment indicated that the older contour strip sites were following a similar successional pathway and showed similar grouping characteristics to reference sites. At the order taxonomic level, contour strip sites had a similar order composition to reference sites.

A3.2.4 Establishment of Trees on Topsoil

Land Reclamation Services set up an herbicide/cultivation trial at Curragh Mine in 1992. Its aim was to determine the advantages and costs of applying various herbicide/cultivation treatments to topsoil areas to overcome Buffel competition and establish native species.

This project was affected by the drought and because it was never completed, the outcomes were inconclusive. The progress of the uniformly topsoiled rehabilitation area between Ramps 1 and 2, established as part of this project, is monitored.

A3.2.5 Soil Micro-Biology

Curragh was a member company that supported the AMIRA project: “Soil Microbiology for Rehabilitation P257A conducted by the University of Western Australia, 1991-1994”. It focused on defining soil microbiology at a range of mine sites, specifically the presence and benefits of mycorrhizal fungi. A number of Curragh natural isolates were identified and used for pot and greenhouse cultivation, refinements of inoculation production and storage techniques and assessment of stockpiled topsoil health from mycorrhiza bioassays and microbial biomass measurement.

Curragh sponsored an extension to the above AMIRA project: “Inoculating VA Mycorrhizal Fungi into Mine Soils P257B”, specifically targeting methods of cost-effective introduction of isolates into mine soil. The first field trial at Curragh commenced in May 1997 and concluded in February 2000.

A3.2.6 Soil Substitutes and native Ecosystem Development

The CMLR (University of Qld) undertook a project entitled “Soil Substitutes and Native Ecosystem Development at the Curragh Open-Cut Coal Mine”. Two main sub-programs cover the issues encompassed:

Properties of Coarse Coal Reject - Laboratory and glasshouse studies examining the chemical, physical and microbiological properties of a range of coarse coal reject samples to assess their short- and long-term impacts on native species establishment, native community sustainability, and the surrounding groundwater environments in general.

Monitoring of Media, Vegetation and Ecosystem Development – measurement of the growth, nutritional and ecological status of existing rehabilitation and natural control areas. Field sampling and surveys, followed by laboratory analyses, were undertaken to supplement data previously collected from Curragh as well as aid in the development of rehabilitation success indicators. A significant proportion of the project is devoted to the study of litter fauna and decomposition within an area not previously focused on.

Reports on outcomes include UQ CMLR (1991), UQ CMLR (1993a), UQ CMLR (1993b) and UQ CMLR (1998). The University of Central Queensland conducted a further study of invertebrates during May 1999. Seventeen sites were studied including Reference Site B. The results suggest that the Contour Strip plots are showing similar assemblages of invertebrates to each other but distinct from the Reference sites.

A3.2.7 Establishment of Native Understorey

Curragh has been successful in establishing upper storey trees and shrubs and also pasture grasses. Current and future efforts are also being directed into the development of native understorey flora and fauna. The CMLR commenced a research project which remains uncompleted; however, Curragh has continued introducing *Acacia cretata* and *Acacia ampliceps*, two native understorey species, since the beginning of 1999.

A3.3 Terrestrial Flora/Fauna Success Criteria

An assessment of terrestrial flora and fauna success criteria was carried out by WBM in February 2000. The object of the research was to identify success factors evident in reference sites around Curragh, and contrast these with similar factors in spoil rehabilitation.

A3.4 Aquatic Flora/Fauna Success Factors

In conjunction with field tests detailed in Section 7, WBM undertook surveys of water ponds (2 in rehabilitation, 1 in a retention dam, 1 in a natural creek site and 1 in a creek diversion site) to establish success indicators for aquatic species.

A3.5 Risk Assessment of Rehabilitation Stability

A University of Queensland administered ACARP project (C8039), comprising a risk assessment model of rehabilitation geomorphology and final land use stability, has used Curragh Mine as a reference site, among a

number of others in the Bowen Basin.

A3.6 Tailings Dam Hydrogeology Study

In March 2000, negotiations commenced on a study of tailings dam hydrogeology, as the first steps towards fulfilling closure requirements discussed in Section 7. ACARP C9030, a general stability study across Bowen Basin mines, is programmed for February 2000 to year 2003.

APPENDIX F

Erosion Assessment

PROGRESSIVE REHABILITATION AND CLOSURE PLAN

Curragh Project
Erosion Risk Assessment

Prepared for:

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SLR Ref: 630.30341-R01
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BASIS OF REPORT

This report has been prepared by SLR Consulting Australia Pty Ltd (SLR) with all reasonable skill, care and diligence, and taking account of the timescale and resources allocated to it by agreement with Coronado Curragh Pty Ltd (the Client). Information reported herein is based on the interpretation of data collected, which has been accepted in good faith as being accurate and valid.

This report is for the exclusive use of the Client. No warranties or guarantees are expressed or should be inferred by any third parties. This report may not be relied upon by other parties without written consent from SLR.

SLR disclaims any responsibility to the Client and others in respect of any matters outside the agreed scope of the work.

DOCUMENT CONTROL

Reference	Date	Prepared	Checked	Authorised
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APPENDICES

Appendix A: Sample Site Logs
Appendix B: Certificate of Analysis

1 Introduction

The Curragh Project is located within the Central Highlands Regional Council, approximately 6 km north of the town of Blackwater and approximately 200 km west of Rockhampton. The total mining lease area is about 19,650 ha.

The Curragh Project consists of:

- Curragh Central (Pit X-west);
- Curragh Central Extended (Pit X-east & Pit D);
- Curragh Extended (Pit J);
- Curragh South (Pit Z);
- Curragh West (Pit Y);
- Curragh East (Pit A-C, Pit E—I, Pit K-L); and
- Curragh North (Pit s, Pit T and Pit U).

The Curragh Project is an open cut operation producing a variety of coking, PCI and steaming coal products for both the export and domestic markets. The operation is a mix of dragline and truck and shovel fleets. The site is predominantly divided into mining areas 'Curragh Main' and the more recent 'Curragh North'. Curragh Main consists of Curagh East, West and Extended and mining commenced in this area in approximately 1983. Curragh North is a satellite mining operation which commenced operations in 2005 and is connected to Curragh Main by a haul road for supply and servicing and a conveyor for coal transport to the Curragh Main Coal Handling and Preparation Plant (CHPP).

The approved annual run of mine (ROM) production is 18 million tonnes per annum (Mtpa). Coal extraction has been ongoing since 1983, entirely through surface mining methods. Coal is transported from the mine to Gladstone via the Central Rail Line also known as the Blackwater Line. The Project is currently estimated to run until 2044.

2 Objectives

The objectives of the erosion assessment are as follows:

- Calculate the soil erodibility (K) factors for the topsoil, subsoil and spoil material.
- Determine appropriate cover management (C) and support practice (P) factors from local and international literature.
- Calculate the rainfall erosivity (R) factor for the site.
- Calculate soil loss (A) for a set of slope angles (as provided by the landform design engineer) for the proposed final landform.
- Provide guidance / recommendations on optimal waste rock dump slope angles and cover management based on soil loss estimates.

3 Methodology

3.1 Methods of data analysis

The **Revised Universal Soil Loss Equation (RUSLE)** is used to determine long term safe, stable and non-polluting landform design at OCC. RUSLE is commonly used to predict the long term, average, annual soil loss from sheet and rill flow under specific management conditions. The predicted losses are empirically derived. Given that the RUSLE takes into consideration all major components likely to affect erosion, it is the most widely used soil loss predictive tool available. Inputs include rainfall erosivity, soil erodibility, slope length, gradient, erosion control practices, ground cover and management. The output is the predicted average annual soil loss per unit area. The estimated annual soil loss expected is based on the following equation (USDA-ARS, 2016):

$$A = R \times K \times LS \times C \times P \qquad \text{Eq. 1}$$

where, A = computed spatial average soil loss (ton per hectare per year (t ha−1.yr-1)), R is the rainfall-runoff erosivity factor, K is the soil erodibility factor, LS = topographic factor, C is the cover management factor (unitless) and P is the support practice factor.

For the rainfall erosivity (R-factor) the value determined for Emerald as per the IECA (2009) *Best Practice Erosion and Sediment Control* was used. The soil erodibility was determined from representative soil and spoil samples collected from Curragh Main and Curragh North. Laboratory estimation of the K-factor considers the topsoil soil organic matter, very fine sand, silt, soil structure and permeability. The slope length and gradients were sourced from the maximum values specified in the Curragh Rehabilitation Plan (Curragh, 2019).

3.2 Data source

A summary of the input data is provided in the below table.

Table 1. Description of data sources for soil loss estimation for Curragh Project

RUSLE Input parameter	Description
Soil erodibility K-factor	Laboratory results for K-factors are available for soil and spoil samples collected from Curragh Main and Curragh North. Spoil samples are subdivided into Permian and Quaternary spoil.
Rainfall erosivity R-factor	The annual erosivity factor was determined from the IECA (2008) *Best Practice Erosion & Sediment Control. Book 2 – Appendices A-G* Table E1.
Slope % & slope length LS-factor	Slope length and gradients were based on the maximum slope criteria specified in the Curragh Rehabilitation Plan (2019) Table 2.
Cover management C-factor	Cover management was based on guidance provided in the Curragh Rehabilitation Plan (2019) and additional cover management practices were included where required.
Support practices P-factor	The P factor was sourced from the IECA (2008) *Best Practice Erosion & Sediment Control. Book 2 – Appendices A-G* Table E11.

4 Results and discussion

4.1 Soil erodibility (K-factor)

The K-factor is a measure of the susceptibility of soil particles to detachment and transport by rainfall and runoff. Soil texture is the principal component affecting K-factor, but soil structure, organic matter and profile permeability also contribute.

SLR provided Curragh with a topsoil and spoil sampling plan. Samples were collected from 20 selected topsoil and 20 spoil stockpiles. Details of the sample sites are provided in **Appendix A.** All the samples were submitted to a NATA accredited laboratory for testing including determination of the K-factor. The laboratory certificates are provided in **Appendix B.**

4.1.1 Topsoil

Detailed information on the soil mapping units is provided in the Curragh Topsoil Management Plan. Multiple soil characterisation studies have been undertaken at Curragh, Curragh East and Curragh North:

- Soil study for the original Curragh Project by LRA (1990) identified 7 soil mapping units in the Curragh mine area.
- Additional mapping at Curragh East was undertaken by EHSS (1998) where two additional mapping units were identified.
- A soil survey of the Curragh North Project site was conducted by ARC (2003) which included the results of previous investigations. Four mapping units were identified at Curragh North.

Samples were collected from topsoil stockpiles at Curragh North and Curragh Main. Topsoil samples generally have a smaller range of K-factors compared to the spoil. The median K-factors were used in the RUSLE and are provided in **Table 4**.

Table 2 K-factors topsoil

Site area	Number of sites	Median K-factor
Curragh North	10	0.021
Curragh Main	9	0.028

K-factor for Curragh North is lower than Curragh Main indicating that topsoil material from Curragh North is less erodible.

4.1.2 Spoil

Overburden at the project site can be characterised by three main types of material as shown in **Table 3** (AARC, 1999).

Table 3 Overburden summary (AARC, 1999)

Rock type	Description
Quaternary alluvium	A mixture of brown clay and silt, and sand and river gravel
Tertiary alluvium	Reddish claystone with sub-rounded gravels and claystone matrices

Rock type	Description
Permain Rangal Coal Measures	A broadly fining upward sequence of fine-grained sandstone, siltstone and mudstone

Characteristically, Tertiary material is yellow/brown in colour, has high proportions of silt and clay and is alkaline and sodic. Tertiary materials experience a marked loss of strength when they are wet up. Because of the composition and moisture-sensitivity, many Tertiary materials are prone to instability and severe erosion. Permian material is characterised by grey colours. Compared to Tertiary materials, Permain materials contain less clay, is similarly alkaline and less sodic (ACARP, 2006).

Previous spoil characterisation reports indicate that the spoils in the Curragh and Curragh East lease areas are saline and sodic in nature. At Curragh North, salinity is not sufficiently high to affect plant growth but sodicity is high enough to consider selective placement of spoils or amelioration.

The median K-factor was used in the RUSLE. The K-factor was adjusted for inclusion of surface stone cover as per the methodology provided by Panagos *et al.* (2014). The K-factors calculated for individual lithologies are provided in **Table 4**.

Table 4 K-factors spoil

Site area	Lithology	Number of sites	Median K-factor	Adjusted K-factor (K_{st})
Curragh North	Permian	7	0.034	0.025
	Tertiary	1	0.037	0.027
	Quaternary	1	0.023	0.017
Curragh Main	Permian	5	0.034	0.025
	Tertiary	1	0.022	0.016
	Quaternary	5	0.019	0.014

K-factors for the Permian spoil from both sites are equal to 0.025 with values for Quaternary materials also similar for both sites (CN is 0.017 and CM is 0.014). There is a marked difference in the K-factors for Tertiary spoil from the two sites. Only one Tertiary sample was tested for each site. Based on information from previous studies (see **Section 4.1.2**) the higher of the two values will be used to determine the soil loss on Tertiary spoil. The following K-factors will be used to represent the spoil types in the RUSLE:

- Tertiary spoil 0.027
- Permian spoil 0.025
- Quaternary spoil 0.017.

4.2 Rainfall erosivity (R-factor)

The rainfall erosivity factor, R, is a measure of the ability of rainfall to cause erosion. It is a constant parameter based on the location of the site. The erosivity factor for Emerald (1,804) from the IECA (2008) *Best Practice Erosion & Sediment Control. Book 2 – Appendices A-G* Table E1 was used.

4.3 Cover management (C-factor)

The cover factor, C, is the ratio of soil loss from land under specified crop or mulch conditions to the corresponding loss from continuously tilled, bare soil.

The Curragh Rehabilitation Plan (2019) includes the following guidance in terms of cover management practices:

- Revegetation will be carried out by seeding which appears to perform better than tube stock
- Vegetation species mix will include Eucalypts, Acacias, other native shrubs and tree species, native grasses, exotic grasses and range of legumes
- Potential use of straw mulch with cover crop.

In addition to the above rehabilitation, heightened spoil dumps at Curragh North may require the following cover management practices:

- Contour banks approximately 55 m apart for vegetated slopes up to 20%
- Cover crop such as millet or oats will be included with revised native tree, shrub and seed mix
- Consideration of hydromulch on slopes >16% to improve vegetation establishment to achieve >50% cover in less than one year.

An additional cover management tool to be evaluated is the application of stone with a cover crop on embankments where slope gradients of 34.4% are proposed.

The C-factors used in the RUSLE are outlined in **Table 5.**

Table 5 C-factors

Description	C-factor	Source
Newly established grass cover no canopy (0%)	1.0	IECA (2008) Table E8
Newly established grass cover no canopy (20%)	0.45	IECA (2008) Table E8
Newly established grass cover no canopy (40%)	0.2	IECA (2008) Table E8
Newly established grass cover no canopy (50%)	0.15	Calculated based on graph of data presented in IECA (2008) Table E8
Newly established grass cover no canopy (60%)	0.10	IECA (2008) Table E8
Newly established grass cover no canopy (80%)	0.03	IECA (2008) Table E8
Hydromulch	0.07	IECA (2008) Table E6
Cover crop with 2.5 t/ha straw mulch	0.20	IECA (2008) Table E8
Cover crop with 3.8 t/ha straw mulch	0.12	IECA (2008) Table E8
Cover crop with 330 t/ha stone	0.05	IECA (2008) Table E8
Cover crop with 600 t/ha stone	0.02	IECA (2008) Table E8

4.4 Support Practice (P-factor)

The erosion control practice factor, P, is the ratio of soil loss with a nominated surface condition ploughed up and down the slope. It is reduced by practices that reduce both the velocity of runoff and the tendency of runoff to flow directly downhill. P-factor was selected given that mined landforms are largely unconsolidated materials.

Section 2.5 of the Curragh Rehabilitation Plan (2019) includes the following adopted support practice:

Deep ripping of spoil/topsoil in conjunction with seeding will be utilised to minimise erosion.

Therefore, a K-factor of 0.8 is applied in the RUSLE, corresponding to 'Ripped - Loose soil to 300 mm Depth' in accordance with the IECA Guideline.

4.5 Topographic factor (LS factor)

The LS-factor describes the combined effect of slope length and gradient on soil loss. It is the ratio of soil loss per unit area at any site to the corresponding loss from a specific experimental plot of known length and gradient.

Slope length and gradients were based on the maximum slope criteria specified in the Curragh Rehabilitation Plan (2019) Table 2 and the Curragh Concept Residual Void Assessment (SLR, 2021). The LS associated with the slope length and gradients were determined using the LS lookup table provided in *Queensland Landform Erosion Risk Evaluation for Pit Void Closure Planning - Desktop Review and Void Landform Guidelines* (Landloch, 2016).

Table 6 LS factors (Curragh, 2019) and (SLR, 2021)

Slope %	Slope length (m)	LS (Landloch, 2016)
6	115	1.06
8	105	1.45
10	90	1.93
12	80	2.44
14	70	2.94
16	55	3.06
18	45	3.24
25	45	5.68
35	31	6.07

4.6 Estimated Soil Loss (A-factor)

There is currently no broad agreement on what constitutes an 'acceptable rate of erosion' on a rehabilitated landform. Spatial data available from CSIRO (2020) provide estimates of broad scale and in situ soil erosion in Australia. The soil erosion estimate provided for the Curragh site range from 0.026 to 31.4 t/ha/y which can be interpreted as low to high based on the Food and Agricultural Organisation (FAO) soil loss classes in **Table 7** (Teng, et al., 2016)**.** The Curragh Rehabilitation Plan specifies that a soil loss of <1 t/ha/yr on slopes less than 20% with 50% vegetative cover can be obtained in 3-4 years. The RUSLE parameters used to calculate this soil loss were not available and as such the FAO soil loss classes were adopted to inform acceptable soil loss criteria for Curragh.

The low-risk soil loss threshold range applicable for an agricultural setting is estimated at 5 to 12 t/ha/yr. According to the DRI *Guidelines for Rehabilitation of Central Queensland Coal Mines* (DRI, undated) post mining landforms should be designed so that lost sediment will be less than 20 t/ha/yr and preferably less than 12.5 t/ha/yr.

A target average erosion rate of <12 t/ha/yr (very low or low) has been adopted for this study.

Table 7 FAO soil loss classes after Bergma et al (1991)

Soil loss (t/ha/yr)	Class
< 5	very low
5 – 12	low
12 – 25	moderate
25 – 60	high
60 – 150	very high
> 150	extremely high

The results of the RUSLE calculations are provided in **Table 8** for Permian, Quaternary and Tertiary spoil and **Table 9** for topsoil from Curragh North and Curragh Main. The results indicate the following:

- Stable 16% slope gradients can be achieved on all spoil types by applying hydromulch
- Permian and Quaternary spoil with 16% slope gradients will be stable once 50% cover is established
- Tertiary spoil will only be stable when at least 80% cover is established
- Spoil stability is increased as a result of stone fragments which provide additional cover
- Stone cover offer the best protection against erosion with soil losses classified as very low to low where this is applied
- Topsoil from Curragh North is less erodible and will reach a low annual soil loss once 60% cover is established
- Stable slopes of >25 % can be achieved when cover crops are used with stone mulch
- Topsoil from Curragh Main is more erodible and gentler slopes should be considered.

Table 8 Soil loss (t/ha/yr) spoil

Lithology			Slope angle (%)	35%	25%	18%	16%	14%	12%	10%	8%	6%
			Slope length (m)	31	45m	45m	55m	70m	80m	90m	105m	115m
	Cover management					Calculated annual soil loss (t/ha/yr)						
Permian	Newly established grass cover no canopy	0		219.0	204.9	116.9	110.4	106.1	88.0	69.6	52.3	38.2
		20		98.6	92.2	52.6	49.7	47.7	39.6	31.3	23.5	17.2
		40		43.8	41.0	23.4	22.1	21.2	17.6	13.9	10.5	7.6
		50		32.9	30.7	17.5	16.6	15.9	13.2	10.4	7.8	5.7
		60		21.9	20.5	11.7	11.0	10.6	8.8	7.0	5.2	3.8
		80		6.6	6.1	3.5	3.3	3.2	2.6	2.1	1.6	1.1
	Hydromulch			15.3	14.3	8.2	7.7	7.4	6.2	4.9	3.7	2.7
	Cover crop with 2.5 t/ha straw mulch			43.8	41.0	23.4	22.1	21.2	17.6	13.9	10.5	7.6
	Cover crop with 3.8 t/ha straw mulch			26.3	24.6	14.0	13.2	12.7	10.6	8.4	6.3	4.6
	Cover crop with 330 t/ha stone			11.0	10.2	5.8	5.5	5.3	4.4	3.5	2.6	1.9
	Cover crop with 600 t/ha stone			4.4	4.1	2.3	2.2	2.1	1.8	1.4	1.0	0.8
Quaternary	Newly established grass cover no canopy	0		148.9	139.4	79.5	75.1	72.1	59.9	47.4	35.6	26.0
		20		67.0	62.7	35.8	33.8	32.5	26.9	21.3	16.0	11.7
		40		29.8	27.9	15.9	15.0	14.4	12.0	9.5	7.1	5.2
		50		22.3	20.9	11.9	11.3	10.8	9.0	7.1	5.3	3.9
		60		14.9	13.9	7.9	7.5	7.2	6.0	4.7	3.6	2.6
		80		4.5	4.2	2.4	2.3	2.2	1.8	1.4	1.1	0.8
	Hydromulch			10.4	9.8	5.6	5.3	5.0	4.2	3.3	2.5	1.8
	Cover crop with 2.5 t/ha straw mulch			29.8	27.9	15.9	15.0	14.4	12.0	9.5	7.1	5.2
	Cover crop with 3.8 t/ha straw mulch			17.9	16.7	9.5	9.0	8.7	7.2	5.7	4.3	3.1
	Cover crop with 330 t/ha stone			7.4	7.0	4.0	3.8	3.6	3.0	2.4	1.8	1.3
	Cover crop with 600 t/ha stone			3.0	2.8	1.6	1.5	1.4	1.2	0.9	0.7	0.5
Tertiary	Newly established grass cover no canopy	0		236.5	221.3	126.3	119.2	114.6	95.1	75.2	56.5	41.3
		20		106.4	99.6	56.8	53.7	51.6	42.8	33.8	25.4	18.6
		40		47.3	44.3	25.3	23.8	22.9	19.0	15.0	11.3	8.3
		50		35.5	33.2	18.9	17.9	17.2	14.3	11.3	8.5	6.2
		60		23.7	22.1	12.6	11.9	11.5	9.5	7.5	5.7	4.1
		80		7.1	6.6	3.8	3.6	3.4	2.9	2.3	1.7	1.2
	Hydromulch			16.6	15.5	8.8	8.3	8.0	6.7	5.3	4.0	2.9
	Cover crop with 2.5 t/ha straw mulch			47.3	44.3	25.3	23.8	22.9	19.0	15.0	11.3	8.3
	Cover crop with 3.8 t/ha straw mulch			28.4	26.6	15.2	14.3	13.7	11.4	9.0	6.8	5.0
	Cover crop with 330 t/ha stone			11.8	11.1	6.3	6.0	5.7	4.8	3.8	2.8	2.1
	Cover crop with 600 t/ha stone			4.7	4.4	2.5	2.4	2.3	1.9	1.5	1.1	0.8

Table 9 Soil loss (t/ha/yr) topsoil

Lithology			Slope angle (%)	35%	25%	18%	16%	14%	12%	10%	8%	6%
			Slope length (m)	31	45m	45m	55m	70m	80m	90m	105m	115m
	Cover management					Calculated annual soil loss (t/ha/yr)						
Curragh North	Percentage newly established grass cover no canopy	0		184.0	172.1	98.2	92.7	89.1	73.9	58.5	43.9	32.1
		0.2		82.8	77.5	44.2	41.7	40.1	33.3	26.3	19.8	14.5
		0.4		36.8	34.4	19.6	18.5	17.8	14.8	11.7	8.8	6.4
		0.5		27.6	25.8	14.7	13.9	13.4	11.1	8.8	6.6	4.8
		0.6		18.4	17.2	9.8	9.3	8.9	7.4	5.8	4.4	3.2
		0.8		5.5	5.2	2.9	2.8	2.7	2.2	1.8	1.3	1.0
	Hydromulch			12.9	12.1	6.9	6.5	6.2	5.2	4.1	3.1	2.2
	Cover crop with 2.5 t/ha straw mulch			36.8	34.4	19.6	18.5	17.8	14.8	11.7	8.8	6.4
	Cover crop with 3.8 t/ha straw mulch			22.1	20.7	11.8	11.1	10.7	8.9	7.0	5.3	3.9
	Cover crop with 330 t/ha stone			9.2	8.6	4.9	4.6	4.5	3.7	2.9	2.2	1.6
	Cover crop with 600 t/ha stone			3.7	3.4	2.0	1.9	1.8	1.5	1.2	0.9	0.6
Curragh Main	Percentage newly established grass cover no canopy	0		245.3	229.5	130.9	123.7	118.8	98.6	78.0	58.6	42.8
		0.2		110.4	103.3	58.9	55.6	53.5	44.4	35.1	26.4	19.3
		0.4		49.1	45.9	26.2	24.7	23.8	19.7	15.6	11.7	8.6
		0.5		36.8	34.4	19.6	18.5	17.8	14.8	11.7	8.8	6.4
		0.6		24.5	23.0	13.1	12.4	11.9	9.9	7.8	5.9	4.3
		0.8		7.4	6.9	3.9	3.7	3.6	3.0	2.3	1.8	1.3
	Hydromulch			17.2	16.1	9.2	8.7	8.3	6.9	5.5	4.1	3.0
	Cover crop with 2.5 t/ha straw mulch			49.1	45.9	26.2	24.7	23.8	19.7	15.6	11.7	8.6
	Cover crop with 3.8 t/ha straw mulch			29.4	27.5	15.7	14.8	14.3	11.8	9.4	7.0	5.1
	Cover crop with 330 t/ha stone			12.3	11.5	6.5	6.2	5.9	4.9	3.9	2.9	2.1
	Cover crop with 600 t/ha stone			4.9	4.6	2.6	2.5	2.4	2.0	1.6	1.2	0.9

5 Model limitations

The following limitations of the RUSLE model are noted:

- The RUSLE model was formulated based on soil erosion studies on agricultural land in the USA and when applied to different climate regimes and land cover conditions it may lead to over- or under-prediction of actual average annual soil loss
- RUSLE ideally requires long-term data to develop the parameters for climate (R factor) and erodibility (K factor) for locations and soils outside the USA
- RUSLE estimates soil loss through sheet and rill erosion, but not from other types of erosion (gully, channel, bank, or from mass wasting events such as landslides)
- The model also does not account for deposition, extent of outcrops or soil depth
- Given the absence of long-term data for some factors (R and P factors in particular), the model relies on expert opinion. The RUSLE estimates average annual soil loss by sheet and rill erosion on those portions of landscape profiles where erosion, but not deposition is occurring.
- The RUSLE provides a high-level indication of landform performance.
- The RUSLE is not a Landform Evolution Model (LEM) but provides sufficient guidance to compare the performance of final landform construction (slope length and grade) and stabilization/amelioration methods (hydromulching, cover crops etc.).
- The rainfall erosivity factor does not consider individual storm or extreme weather events but presents an average over the year
- The rate of soil loss provided may vary significantly depending upon climate patterns, climate change and storm events particularly when the ground is bare.
- Incorporation of soil ameliorants (eg. gypsum on dispersive materials) may further improve stability and, therefore reduce predicted soil loss. Beneficial use of soil ameliorants have not been included in the calculated outcomes. RUSLE does not account for incorporation of ameliorants and the potential reduction in K-factors.

6 References

AARC. (1999). *Waste Characterisation Report.*

ACARP. (2006). *Rehabilitation of Highwalls ACARP Project C14048.*

ARC. (2004). *Supplementary Topsoil Survey for the Curragh North Mining Lease.* Austrlasian Resource Consultants.

Curragh. (2019). *Rehabilitation Management and Monitoring Plan. EM PLan 1.3. Version 6.* Curragh.

DRI. (undated). *Guidelines for Rehabilitation of Central Queensland Coal Mines.* Brisbane: Department of Resource Industries.

FAO. (2022, 07 25). *Food and Agriculture Organisation of the United States*. Retrieved from Land & Water: https://www.fao.org/land-water/land/land-governance/land-resources-planning-toolbox/category/details/zh/c/1236444/

IECA. (2008). *Best Practice Erosion & Sediment Control. Book 2 Appendices A - G.* Australasia: International Erosion Control Association.

Landloch. (2016). QLD Landform Erosion Risk Evaluation for Pit Void Closure Planning - Desktop Review and Void Landform Guidelines. Newcastle, Queensland, Australia.

LRS. (1990). *Curragh Mine Soil Survey.* Land Reclamation Services Pty Ltd.

Panagos, P., Meusburger, K., Ballbio, C., Borelli, P., & Alewell, C. (2014). Soil erodibility in Europe: A high-resolution dataset based on LUCAS. *Science of the Total Environment, 479-480*, 189-200.

SLR. (2021). *Curragh Project Concept Residual Void Assessment.* Mackay, QLD: SLR Consulting Australia Pty Ltd.

Teng, H., Viscarra Rossel, R., Shi, Z., Behrens, T., Chappell, A., & Bui, E. (2016). Assimilating satellite imagery and visible-near infrared spectroscopy to model and map soil loss by water erosion in Australia. *Environmental Modelling & Software, 77*, 156-167.

USDA-ARS. (2016, 08 13). *Revised Universal Soil Loss Equation*. Retrieved from USDA Agricultural Research Service U.S. Department of Agriculture: https://www.ars.usda.gov/southeast-area/oxford-ms/national-sedimentation-laboratory/watershed-physical-processes-research/docs/revised-universal-soil-loss-equation-106-current-version/

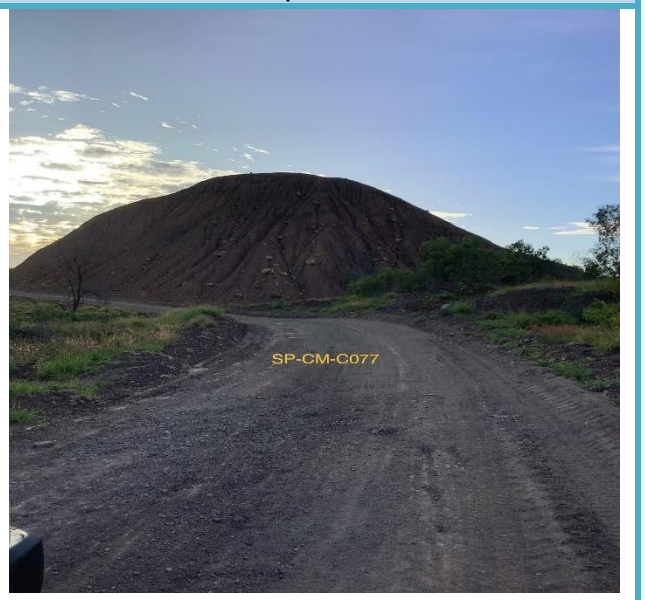
Appendix A:

Sample Site Logs

Sample Photo		Sample Photo		Sample Photo	
					
Site information		**Site information**		**Site information**	
Material Type	Spoil	**Material Type**	Spoil	**Material Type**	Spoil
Sample ID	SP-CN-C418	**Sample ID**	SP-CN-C16	**Sample ID**	SP-CM-C07
Sample date	02-08-2022	**Sample date**	02-08-2022	**Sample date**	02-08-2022
Coordinates	55k 0693826 / 7419717	**Coordinates**	55k 0693298 / 7416586	**Coordinates**	55K 0692819 / 7407579
Project Location	Curragh North	**Project Location**	Curragh North	**Project Location**	Curragh Main
Stockpile dominant lithology	Permian Rangal coal measures/Quaternary alluvium mix	**Stockpile dominant lithology**	Quaternary Alluvium	**Stockpile dominant lithology**	Quaternary / tertiary alluvium
Dominant surface rock	Coal stone/sandstone	**Dominant surface rock**	Sandstone	**Dominant surface rock**	Sandstone
Surface rock >60mm	>10%	**Surface rock >60mm**	>10%	**Surface rock >60mm**	>10%
Vegetation	0%	**Vegetation**	0%	**Vegetation**	0-2%
Surface Condition	Weathered slopes with heavy rill erosion evident	**Surface Condition**	No vegetation present. Heavy rill erosion evident on slopes.	**Surface Condition**	Weathered surface. Active rill erosion. Some surface crusting
Texture	Sand/Sandy Loam	**Texture**	Sand	**Texture**	Sand. Borderline sandy loam.
Signs of salinity	No vegetation present. Dark, wet, greasy patches. Clear water pooled nearby.	**Signs of salinity**	Bare patches of soil. Wet, dark, greasy patches.	**Signs of salinity**	Bare patches of soil. Salt tolerable plant species present
Signs of sodicity	Nil	**Signs of sodicity**	Surface crusting. Cloudy water in puddles. Hard/dense subsoil.	**Signs of sodicity**	Some surface crusting. Soapy feel to sample when wetting.
Consistence strength	Weak/Firm	**Consistence strength**	Loose/very friable	**Consistence strength**	Friable
Consistence stickiness	Sligh	**Consistence stickiness**	Non-sticky	**Consistence stickiness**	Non-sticky
Slope	30%	**Slope**	36%	**Slope**	36%

Sample Photo	Sample Photo	Sample Photo
		

Site information		Site information		Site information	
Material Type	Spoil	**Material Type**	Spoil	**Material Type**	Spoil
Sample ID	SP-CM-C126	**Sample ID**	SP-CM-C042	**Sample ID**	SP-CM-C152
Sample date	01-08-2022	**Sample date**	01-08-2022	**Sample date**	01-08-2022
Coordinates	55k 0692183 / 7404550	**Coordinates**	55k 0690452 / 7404134	**Coordinates**	55k 0694176 / 74021634
Project Location	Curragh Main	**Project Location**	Curragh Main	**Project Location**	Curragh East
Stockpile dominant lithology	Quaternary Alluvium	**Stockpile dominant lithology**	Permian rangal coal measures	**Stockpile dominant lithology**	Permian rangal coal measures / quaternary alluvium mix
Dominant surface rock	Nil	**Dominant surface rock**	Coalstone	**Dominant surface rock**	Sandstone/coal stone mix
Surface rock >60mm	0%	**Surface rock >60mm**	2-10%	**Surface rock >60mm**	>10%
Vegetation	0-2%	**Vegetation**	50%	**Vegetation**	5%
Surface Condition	Not Provided	**Surface Condition**	Stable surface. Evidence of minor rill erosion	**Surface Condition**	Heavy presence of active rill erosion.
Texture	Silty Loam	**Texture**	Sandy Loam	**Texture**	Sand
Signs of salinity	Evidence of vegetation dieback	**Signs of salinity**	Bare patches of soil	**Signs of salinity**	Bare patches of soil. Growth of salt tolerant plant species.
Signs of sodicity	Poor water infiltration. Poor crop growth. Crusting on surface.	**Signs of sodicity**	Hard subsoil	**Signs of sodicity**	Poor vegetation growth. Some surface crusting.
Consistence strength	Firm	**Consistence strength**	Loose	**Consistence strength**	Firm
Consistence stickiness	Sticky	**Consistence stickiness**	Non-sticky	**Consistence stickiness**	Sticky
Slope	45%	**Slope**	35%	**Slope**	45%

Sample Photo	Sample Photo	Sample Photo
		

Site information		Site information		Site information	
Material Type	Spoil	**Material Type**	Spoil	**Material Type**	Spoil
Sample ID	SP-CM-C100	**Sample ID**	SP-CM-C38/38	**Sample ID**	SP-CM-C077
Sample date	01-08-2022	**Sample date**	01-08-2022	**Sample date**	01-08-2022
Coordinates	55K 0690921 / 740118432	**Coordinates**	55K 0688902 / 7396824	**Coordinates**	55k 0688902 / 73968243
Project Location	Curragh Main	**Project Location**	Curragh East	**Project Location**	Curragh Main
Stockpile dominant lithology	Permian rangal coal measures	**Stockpile dominant lithology**	Permian rangal coal measures	**Stockpile dominant lithology**	Permian dominant with tertiary mix
Dominant surface rock	Sandstone	**Dominant surface rock**	Sandstone/coal stone mix	**Dominant surface rock**	Permian/sandstone
Surface rock >60mm	>10%	**Surface rock >60mm**	>10%	**Surface rock >60mm**	>10%
Vegetation	0.4	**Vegetation**	>5%	**Vegetation**	0
Surface Condition	Evidence of moderate rill and piping erosion.	**Surface Condition**	Little vegetation. Coal present. Weathered surface.	**Surface Condition**	No vegetation growth. Heavy rill erosion
Texture	Sand	**Texture**	Sandy loam/borderline sand	**Texture**	Silty Loam
Signs of salinity	Bare patches of soil	**Signs of salinity**	Bare surface. Patches of salt bush. Salt crust in some spots.	**Signs of salinity**	Surface completely bare of vegetation
Signs of sodicity	Dense subsoil	**Signs of sodicity**	Poor vegetation growth. Surface crusting.	**Signs of sodicity**	Surface crusting. Dense subsoil. Soapy feel when wetting.
Consistence strength	Loose	**Consistence strength**	Very friable	**Consistence strength**	Very friable
Consistence stickiness	Non-sticky	**Consistence stickiness**	Slightly sticky	**Consistence stickiness**	Non-sticky
Slope	32%	**Slope**	31%	**Slope**	38%

Sample Photo	Sample Photo	Sample Photo
		

Site information		Site information		Site information	
Material Type	Spoil	**Material Type**	Spoil	**Material Type**	Spoil
Sample ID	SP-CN-C369/370	**Sample ID**	SP-CN-CN93	**Sample ID**	SP-CN-CN320
Sample date	02-08-2022	**Sample date**	04-08-2022	**Sample date**	04-08-2022
Coordinates	55k 0694122 / 7417627	**Coordinates**	55K 0691906 / 7423051	**Coordinates**	55k 0692073 / 7422194
Project Location	Curragh North	**Project Location**	Curragh North	**Project Location**	Curragh North
Stockpile dominant lithology	Permian spoil, coalstone dominant	**Stockpile dominant lithology**	Tertiary Alluvium	**Stockpile dominant lithology**	Quaternary alluvium
Dominant surface rock	Coalstone	**Dominant surface rock**	Claystone	**Dominant surface rock**	Sand / river gravel
Surface rock >60mm	0-2%	**Surface rock >60mm**	2-10%	**Surface rock >60mm**	>10%
Vegetation	25%	**Vegetation**	15%	**Vegetation**	5%
Surface Condition	Stable surface. Minimal erosion evident. Some grass vegetation.	**Surface Condition**	Heavy rill erosion. Some tree & grass vegetation.	**Surface Condition**	Very little vegetation. Minor rill erosion.
Texture	Sand	**Texture**	Sandy loam	**Texture**	Sand
Signs of salinity	Bare patches of soil	**Signs of salinity**	Bare patches of soil. Salt tolerant species present.	**Signs of salinity**	Bare patches of soil. Dieback of some species evident.
Signs of sodicity	Poor vegetation growth. Poor water infiltration. Hard subsoil.	**Signs of sodicity**	Poor vegetation growth.	**Signs of sodicity**	Cloudy water in nearby puddle. Surface crusting.
Consistence strength	Loose	**Consistence strength**	Very friable	**Consistence strength**	Loose
Consistence stickiness	Non-sticky	**Consistence stickiness**	Sticky	**Consistence stickiness**	Non-sticky
Slope	34%	**Slope**	30%	**Slope**	32%

Sample Photo	Sample Photo	Sample Photo
		

Site information		Site information		Site information	
Material Type	Spoil	**Material Type**	Spoil	**Material Type**	Spoil
Sample ID	SP-CN-CN342	**Sample ID**	SP-CN-CN413	**Sample ID**	SP-CN-CN334
Sample date	04-08-2022	**Sample date**	04-08-2022	**Sample date**	03-08-2022
Coordinates	55K 0690064 / 7422367	**Coordinates**	55K 0689752 / 7421690	**Coordinates**	55k 0692011 / 7425941
Project Location	Curragh North	**Project Location**	Curragh North	**Project Location**	Curragh North
Stockpile dominant lithology	Quaternary alluvium	**Stockpile dominant lithology**	Permian. Coalstone/Shale dominant	**Stockpile dominant lithology**	Permian
Dominant surface rock	Riverstone/siltstone/shale	**Dominant surface rock**	Coalstone / shale	**Dominant surface rock**	Coalstone / shale
Surface rock >60mm	>10%	**Surface rock >60mm**	>10%	**Surface rock >60mm**	>10%
Vegetation	Nil	**Vegetation**	5%	**Vegetation**	il
Surface Condition	Nil vegetation. Evidence of active rill erosion.	**Surface Condition**	Heavy rill erosion. Most surface rocks >100m. Little vegetation	**Surface Condition**	New spoil dump. No signs of active rill erosion
Texture	Sand	**Texture**	Sandy loam	**Texture**	Sandy loam
Signs of salinity	Dark greasy patches.	**Signs of salinity**	Bare patches of soil	**Signs of salinity**	New dump (no signs)
Signs of sodicity	No vegetation. Some surface crusting.	**Signs of sodicity**	Poor vegetation growth. Surface crusting. Dense subsoil.	**Signs of sodicity**	New dump (no signs)
Consistence strength	Loose	**Consistence strength**	Very friable	**Consistence strength**	Loose / very friable
Consistence stickiness	Non-sticky	**Consistence stickiness**	Sticky	**Consistence stickiness**	Slightly sticky
Slope	30%	**Slope**	25%	**Slope**	38%

Sample Photo	Sample Photo	Sample Photo
		

Site information		Site information		Site information	
Material Type	Spoil	**Material Type**	Spoil	**Material Type**	Spoil
Sample ID	SP-CN-CN364	**Sample ID**	SP-CM-C051	**Sample ID**	SP-CN-CN223
Sample date	02-08-2022	**Sample date**	02-08-2022	**Sample date**	Not Provided
Coordinates	55k 0691659 / 7417538	**Coordinates**	55K 0689735 / 7400989	**Coordinates**	55K 0691737 / 7418661
Project Location	Curragh North	**Project Location**	Curragh Main	**Project Location**	Curragh North
Stockpile dominant lithology	Permian	**Stockpile dominant lithology**	Permian	**Stockpile dominant lithology**	Permian
Dominant surface rock	Shale	**Dominant surface rock**	Sandstone / coalstone mix	**Dominant surface rock**	Coalstone / shale
Surface rock >60mm	>10%	**Surface rock >60mm**	Nil	**Surface rock >60mm**	>10%
Vegetation	Nil	**Vegetation**	Nil	**Vegetation**	Nil
Surface Condition	Rill erosion evident. Nil vegetation	**Surface Condition**	Heavy rill erosion. Nil vegetation	**Surface Condition**	Nil vegetation. Minimal rill erosion. New dump
Texture	Sand	**Texture**	Silty loam	**Texture**	Fine Clay
Signs of salinity	Nil vegetation	**Signs of salinity**	Bare patches of soil. Surface salt crust in some places	**Signs of salinity**	Nil
Signs of sodicity	Hard subsoil	**Signs of sodicity**	Slight surface crusting	**Signs of sodicity**	Nil
Consistence strength	Very firm	**Consistence strength**	Very friable	**Consistence strength**	Friable
Consistence stickiness	Slightly sticky	**Consistence stickiness**	Slightly sticky	**Consistence stickiness**	Slightly sticky
Slope	40%	**Slope**	45%	**Slope**	35%

Sample Photo		Sample Photo		Sample Photo	
					
Site information		**Site information**		**Site information**	
Material Type	Spoil	**Material Type**	Spoil	**Material Type**	Topsoil
Sample ID	SP-CM-C142	**Sample ID**	SP-CM-C10	**Sample ID**	TS-CM-C07
Sample date	05-08-2022	**Sample date**	01-08-2022	**Sample date**	02-08-2022
Coordinates	Not Provided	**Coordinates**	55k 0691489/7406642	**Coordinates**	55k 0693129 / 7407704
Project Location	Curragh Main	**Project Location**	Curragh Main	**Project Location**	Curragh Main
Stockpile dominant lithology	Tertiary spoil dominant	**Stockpile dominant lithology**	Quaternary alluvium	**Stockpile dominant lithology**	Quaternary alluvium
Dominant surface rock	Claystone/siltstone	**Dominant surface rock**	Permian/sandstone mix	**Dominant surface rock**	Dark grey shale
Surface rock >60mm	>10%	**Surface rock >60mm**	>10%	**Surface rock >60mm**	0-2%
Vegetation	20%	**Vegetation**	20%	**Vegetation**	95%
Surface Condition	Hard rocky surface. Minimal erosion. Established and mature trees and some grass.	**Surface Condition**	Weathered surface. Evidence of intensifying rill erosion.	**Surface Condition**	Stable. Well established buffel grass.
Texture	sand	**Texture**	Sand	**Texture**	Sandy Loam
Signs of salinity	Bare patches of soil.	**Signs of salinity**	Salt tolerant plant species are dominant. Areas/patches of bare soil.	**Signs of salinity**	Nil
Signs of sodicity	Poor grass growth. Dense/hard subsoil	**Signs of sodicity**	Surface crusting. Hard subsoil	**Signs of sodicity**	Nil
Consistence strength	Firm	**Consistence strength**	Very firm	**Consistence strength**	Very friable
Consistence stickiness	Sticky	**Consistence stickiness**	Slightly sticky	**Consistence stickiness**	Sticky
Slope	18%	**Slope**	12%	**Slope**	Flat

Sample Photo	Sample Photo	Sample Photo
		

Site information		Site information		Site information	
Material Type	Topsoil	**Material Type**	Topsoil	**Material Type**	Topsoil
Sample ID	TS-CM-C10	**Sample ID**	TS-CM-C126	**Sample ID**	TS-CM-C042
Sample date	01-08-2022	**Sample date**	01-08-2022	**Sample date**	01-08-2022
Coordinates	55k 0691401 / 7406704	**Coordinates**	55k 0691865 / 7405070	**Coordinates**	55k 0690139 / 7405150
Project Location	Curragh Main	**Project Location**	Curragh Main	**Project Location**	Curragh Main
Stockpile dominant lithology	Quaternary alluvium	**Stockpile dominant lithology**	Quaternary alluvium	**Stockpile dominant lithology**	Quaternary alluvium
Dominant surface rock	Nil	**Dominant surface rock**	Nil	**Dominant surface rock**	Nil
Surface rock >60mm	Nil	**Surface rock >60mm**	Nil	**Surface rock >60mm**	Nil
Vegetation	95%	**Vegetation**	50%	**Vegetation**	95%
Surface Condition	Stable surface. Well established buffel grass.	**Surface Condition**	Well established vegetation. Minimal signs of erosion.	**Surface Condition**	Established vegetation. No signs of active erosion.
Texture	Loam	**Texture**	Silty Loam	**Texture**	Silty Loam
Signs of salinity	Nil	**Signs of salinity**	Heavy presence of saltbush.	**Signs of salinity**	Nil
Signs of sodicity	Nil	**Signs of sodicity**	Surface crusting.	**Signs of sodicity**	Nil
Consistence strength	Friable	**Consistence strength**	Friable	**Consistence strength**	Very friable
Consistence stickiness	Sticky	**Consistence stickiness**	Very Sticky	**Consistence stickiness**	Sticky
Slope	Flat	**Slope**	Flat	**Slope**	Flat

Sample Photo	Sample Photo	Sample Photo
		

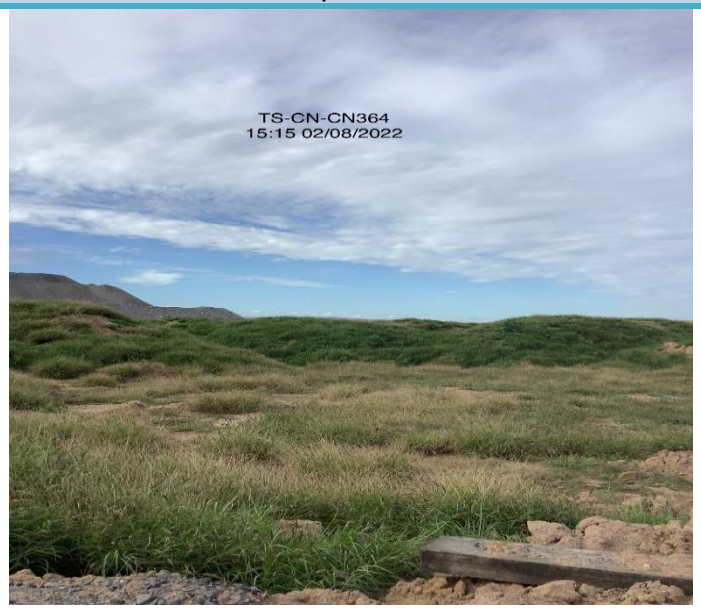
Site information		Site information		Site information	
Material Type	Topsoil	**Material Type**	Topsoil	**Material Type**	Topsoil
Sample ID	TS-CM-C152	**Sample ID**	TS-CM-C100	**Sample ID**	TS-CM-C38/38
Sample date	01-08-2022	**Sample date**	01-08-2022	**Sample date**	01-08-2022
Coordinates	55K 0694472 / 7402527	**Coordinates**	55k 0691006 / 7401101	**Coordinates**	55K 0688902 / 7396824
Project Location	Curragh East	**Project Location**	Curragh Main	**Project Location**	Curragh East
Stockpile dominant lithology	Quaternary alluvium	**Stockpile dominant lithology**	Quaternary alluvium	**Stockpile dominant lithology**	Quaternary alluvium
Dominant surface rock	Nil	**Dominant surface rock**	river gravel	**Dominant surface rock**	river gravel
Surface rock >60mm	Nil	**Surface rock >60mm**	2-10%	**Surface rock >60mm**	0-2%
Vegetation	95%	**Vegetation**	35-40%	**Vegetation**	95%
Surface Condition	Established buffel grass. Stable surface	**Surface Condition**	Evidence of minor rill erosion.	**Surface Condition**	Established buffel grass. Some localized Parkinsonia.
Texture	Silty Loam	**Texture**	Loam	**Texture**	Silty Loam
Signs of salinity	Nil	**Signs of salinity**	Nil	**Signs of salinity**	Nil
Signs of sodicity	Nil	**Signs of sodicity**	Nil	**Signs of sodicity**	Hard/dense subsoil
Consistence strength	Friable	**Consistence strength**	Very friable	**Consistence strength**	Firm
Consistence stickiness	Sticky	**Consistence stickiness**	Sticky	**Consistence stickiness**	Slightly sticky
Slope	Nil	**Slope**	Flat	**Slope**	Flat

Sample Photo	Sample Photo	Sample Photo
		

Site information		Site information		Site information	
Material Type	Topsoil	**Material Type**	Topsoil	**Material Type**	Topsoil
Sample ID	TS-CM-C077	**Sample ID**	TS-CN-CN93	**Sample ID**	TS-CN-CN320
Sample date	01-08-2022	**Sample date**	04-08-2022	**Sample date**	04-08-2022
Coordinates	55K 0688902 / 7396824	**Coordinates**	55k 0691842 / 7423036	**Coordinates**	55K 0691995 / 7422159
Project Location	Curragh Main	**Project Location**	Curragh North	**Project Location**	Curragh North
Stockpile dominant lithology	Quaternary alluvium	**Stockpile dominant lithology**	Quaternary alluvium	**Stockpile dominant lithology**	Quaternary alluvium
Dominant surface rock	river gravel	**Dominant surface rock**	Siltstone	**Dominant surface rock**	Nil
Surface rock >60mm	2-10%	**Surface rock >60mm**	0-2%	**Surface rock >60mm**	Nil
Vegetation	80%	**Vegetation**	80%	**Vegetation**	95%
Surface Condition	Well established grass vegetation. Some bare patches	**Surface Condition**	Established tree & grass vegetation. Some bare patches & surface cracking.	**Surface Condition**	Established grass & tree vegetation. No evidence of active erosion.
Texture	Clayey loam	**Texture**	Silty Loam	**Texture**	Silty Loam
Signs of salinity	Nil	**Signs of salinity**	Bare patches of soil	**Signs of salinity**	Nil
Signs of sodicity	Nil	**Signs of sodicity**	Surface cracking	**Signs of sodicity**	Nil
Consistence strength	Very friable	**Consistence strength**	Firm	**Consistence strength**	Firm
Consistence stickiness	Non-sticky	**Consistence stickiness**	Slightly sticky	**Consistence stickiness**	Slightly sticky
Slope	0.25	**Slope**	Flat	**Slope**	Flat

Sample Photo	Sample Photo	Sample Photo
		

Site information		Site information		Site information	
Material Type	Topsoil	**Material Type**	Topsoil	**Material Type**	Topsoil
Sample ID	TS-CN-CN342	**Sample ID**	TS-CN-CN413	**Sample ID**	TS-CN-CN334
Sample date	04-08-2022	**Sample date**	04-08-2022	**Sample date**	03-08-2022
Coordinates	55k 0689436 / 7422656	**Coordinates**	55k 0689676 / 7421754	**Coordinates**	55K 0692385 / 7426088
Project Location	Curragh North	**Project Location**	Curragh North	**Project Location**	Curragh North
Stockpile dominant lithology	Quaternary alluvium	**Stockpile dominant lithology**	Quaternary alluvium	**Stockpile dominant lithology**	Quaternary alluvium
Dominant surface rock	Siltstone	**Dominant surface rock**	Nil	**Dominant surface rock**	River gravel
Surface rock >60mm	0-2%	**Surface rock >60mm**	Nil	**Surface rock >60mm**	0-2%
Vegetation	80%	**Vegetation**	95%	**Vegetation**	90%
Surface Condition	Established vegetation. Some bare patches	**Surface Condition**	Established grass vegetation. No signs of active erosion.	**Surface Condition**	Established vegetation. Evidence of minor rill erosion
Texture	Silty Loam	**Texture**	Sandy loam	**Texture**	Clayey loam
Signs of salinity	Bare patches of soil.	**Signs of salinity**	Nil	**Signs of salinity**	Nil
Signs of sodicity	Nil	**Signs of sodicity**	Nil	**Signs of sodicity**	Dense subsoil. Surface cracking in some areas.
Consistence strength	Firm	**Consistence strength**	Very friable	**Consistence strength**	Firm
Consistence stickiness	Slightly sticky	**Consistence stickiness**	Slightly sticky	**Consistence stickiness**	sticky
Slope	Flat	**Slope**	Flat	**Slope**	Flat

Sample Photo		Sample Photo		Sample Photo	
					
Site information		**Site information**		**Site information**	
Material Type	Topsoil	**Material Type**	Topsoil	**Material Type**	Topsoil
Sample ID	TS-CN-CN223	**Sample ID**	TS-CN-CN364	**Sample ID**	TS-CM-C051
Sample date	02-08-2022	**Sample date**	02-08-2022	**Sample date**	02-08-2022
Coordinates	55K 0691320 / 7419798	**Coordinates**	55k 0691478 / 7416979	**Coordinates**	55k 0689187 / 7401020
Project Location	Curragh North	**Project Location**	Curragh North	**Project Location**	Curragh Main
Stockpile dominant lithology	Quaternary alluvium	**Stockpile dominant lithology**	Quaternary alluvium	**Stockpile dominant lithology**	Quaternary alluvium
Dominant surface rock	River gravel	**Dominant surface rock**	River gravel	**Dominant surface rock**	Nil
Surface rock >60mm	0-2%	**Surface rock >60mm**	0-2%	**Surface rock >60mm**	Nil
Vegetation	95%	**Vegetation**	95%	**Vegetation**	95%
Surface Condition	Established vegetation. No evidence of active erosion.	**Surface Condition**	Established vegetation. No evidence of active erosion.	**Surface Condition**	Established grass vegetation. No evidence of active erosion.
Texture	Loam	**Texture**	Sandy loam	**Texture**	Loam
Signs of salinity	Nil	**Signs of salinity**	Nil	**Signs of salinity**	Nil
Signs of sodicity	Nil	**Signs of sodicity**	Nil	**Signs of sodicity**	Nil
Consistence strength	friable	**Consistence strength**	Weak	**Consistence strength**	Very friable
Consistence stickiness	Slight / sticky	**Consistence stickiness**	Non-sticky	**Consistence stickiness**	Slightly sticky
Slope	Flat	**Slope**	Flat	**Slope**	Flat

Sample Photo	Sample Photo	Sample Photo
		

Site information		Site information		Site information	
Material Type	Topsoil	**Material Type**	Topsoil	**Material Type**	Topsoil
Sample ID	TS-CN-CN369/370	**Sample ID**	TS-CM-C142	**Sample ID**	TS-CN-C16
Sample date	02-08-2022	**Sample date**	05-08-2022	**Sample date**	02-08-2022
Coordinates	55K 0693817 / 7417549	**Coordinates**	None given	**Coordinates**	55k 0692264 / 7414818
Project Location	Curragh North	**Project Location**	Curragh Main	**Project Location**	Curragh North
Stockpile dominant lithology	Quaternary alluvium	**Stockpile dominant lithology**	Quaternary alluvium	**Stockpile dominant lithology**	Topsoil
Dominant surface rock	Nil	**Dominant surface rock**	river gravel	**Dominant surface rock**	Nil
Surface rock >60mm	Nil	**Surface rock >60mm**	Nil	**Surface rock >60mm**	Nil
Vegetation	95%	**Vegetation**	95%	**Vegetation**	95%
Surface Condition	Established grass vegetation. No evidence of active erosion.	**Surface Condition**	Established grass and tree vegetation. No signs of active erosion.	**Surface Condition**	Well established buffel grass. No signs of erosion. Near 100% vegetation cover.
Texture	Sandy loam	**Texture**	Sandy loam	**Texture**	Silty Loam
Signs of salinity	Nil	**Signs of salinity**	Nil	**Signs of salinity**	Nil
Signs of sodicity	Dense subsoil	**Signs of sodicity**	Nil	**Signs of sodicity**	Nil
Consistence strength	Very friable	**Consistence strength**	Friable	**Consistence strength**	Friable
Consistence stickiness	Non sticky / slightly sticky	**Consistence stickiness**	Slightly sticky	**Consistence stickiness**	Sticky
Slope	Flat	**Slope**	Flat	**Slope**	Flat

Appendix B:

Certificate of Analysis

GRAIN SIZE ANALYSIS (hydrometer and sieving techniques)

39 samples supplied by SLR Consulting Australia Pty Ltd on 25/08/2022. Lab Job No. N2045
Analysis requested by Michelle Papenfus. Your Job: SLR 630.30341 Curragh
10 Kings Road NEW LAMBTON NSW 2305

	Method	Sample 1 SP-CN-C418	Sample 2 SP-CN-C16	Sample 3 SP-CM-C07	Sample 4 SP-CM-C10	Sample 5 SP-CM-C126	Sample 6 SP-CM-C042	Sample 7 SP-CM-C152	Sample 8 SP-CM-C100	Sample 9 SP-CM-C38/38	Sample 10 SP-CM-C077	Sample 11 SP-CN-C369/370	Sample 12 SP-CN-CN93
	Job No.	*N2045/1*	*N2045/2*	*N2045/3*	*N2045/4*	*N2045/5*	*N2045/6*	*N2045/7*	*N2045/8*	*N2045/9*	*N2045/10*	*N2045/11*	*N2045/12*
Emerson Dispersion Class	*Emerson Aggregate Test (EAT)*	2	2	2	2	2	2	2	2	2	2	4	2
Total Organic Carbon (%C)	*HCL treatment- LECO Analyser*	0.56	0.24	0.32	2.12	2.17	1.27	0.48	0.23	1.37	0.96	17.20	0.25
Organic Matter (%)	*** Calculation*	0.96	0.41	0.55	3.65	3.73	2.18	0.83	0.40	2.36	1.65	29.58	0.43
K Factor	*Revised Universal Soil Loss Equation (RUSLE)*	0.058	0.016	0.022	0.022	0.039	0.037	0.034	0.034	0.025	0.022	0.028	0.043
K Factor + 20% (EAT Class 1&2 soils only)	*Revised Universal Soil Loss Equation (RUSLE)*	0.070	0.019	0.026	0.027	0.047	0.044	0.041	0.041	0.030	0.026	..	0.052

Notes:

1. All results as dry weight DW - samples were dried at 40 oC for 24-48 h prior to crushing and analysis.
2. Methods from Rayment and Lyons, Soil Chemical Methods - Australasia.
3. K Factor determined for RUSLE; Organic matter calculation as per RUSLE - where the TOC > 4% the 4% value has been used to determine K Factor; K Factor determined using client provided information for structure and permeability.
4. Analysis conducted between sample arrival date and reporting date.
5. ** NATA accreditation does not cover the performance of this service.
6. .. Denotes not requested.
7. This report is not to be reproduced except in full.
8. All services undertaken by EAL are covered by the EAL Laboratory Services Terms and Conditions (refer scu.edu.au/eal or on request).
9. Results relate only to the samples tested.
10. This report was issued on 14/10/2022 and replaces the previous report issued on 5/10/2022. The K Factor + 20% has been corrected for EAT Class 2 soils.

checked: .....
Graham Lancaster (Nata signatory)
Laboratory Manager

GRAIN SIZE ANALYSIS (hydrometer and sieving techniques)

39 samples supplied by SLR Consulting Australia Pty Ltd on 25/08/2022. Lab Job No. N2045
Analysis requested by Michelle Papenfus. Your Job: SLR 630.30341 Curragh
10 Kings Road NEW LAMBTON NSW 2305

	Method	Sample 13 SP-CN-CN320	Sample 14 SP-CN-CN342	Sample 15 SP-CN-CN413	Sample 16 SP-CN-CN334	Sample 17 SP-CN-CN364	Sample 18 SP-CM-C051	Sample 19 SP-CN-CN223	Sample 20 SP-CM-C142	Sample 21 TS-CM-C077	Sample 22 TS-CM-C142	Sample 23 TS-CM-C100	Sample 24 TS-CM-C051
	Job No.	*N2045/13*	*N2045/14*	*N2045/15*	*N2045/16*	*N2045/17*	*N2045/18*	*N2045/19*	*N2045/20*	*N2045/21*	*N2045/22*	*N2045/23*	*N2045/24*
Emerson Dispersion Class	*Emerson Aggregate Test (EAT)*	2	4	2	2	2	2	2	4	3	4	2	4
Total Organic Carbon (%C)	*HCL treatment- LECO Analyser*	0.15	0.31	1.15	16.10	1.03	2.62	0.89	0.89	1.35	6.09	1.06	2.77
Organic Matter (%)	*** Calculation*	0.26	0.53	1.98	27.69	1.77	4.51	1.53	1.53	2.32	10.47	1.82	4.76
K Factor	*Revised Universal Soil Loss Equation (RUSLE)*	0.006	0.008	0.042	0.028	0.029	0.020	0.022	0.022	0.021	0.019	0.018	0.016
K Factor + 20% (EAT Class 1&2 soils only)	*Revised Universal Soil Loss Equation (RUSLE)*	0.007	..	0.050	0.034	0.035	0.024	0.026	..	..	..	0.022	..

Notes:

1. All results as dry weight DW - samples were dried at 40 oC for 24-48 h prior to crushing and analysis.
2. Methods from Rayment and Lyons, Soil Chemical Methods - Australasia.
3. K Factor determined for RUSLE; Organic matter calculation as per RUSLE - where the TOC > 4% the 4% value has be
4. Analysis conducted between sample arrival date and reporting date.
5. ** NATA accreditation does not cover the performance of this service.
6. .. Denotes not requested.
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9. Results relate only to the samples tested.
10. This report was issued on 14/10/2022 and replaces the previous report issued on 5/10/2022. The K Factor + 20%

checked: .....
Graham Lancaster (Nata signatory)
Laboratory Manager

GRAIN SIZE ANALYSIS (hydrometer and sieving techniques)

39 samples supplied by SLR Consulting Australia Pty Ltd on 25/08/2022. Lab Job No. N2045
Analysis requested by Michelle Papenfus. Your Job: SLR 630.30341 Curragh
10 Kings Road NEW LAMBTON NSW 2305

	Method	Sample 25 TS-CM-C042	Sample 26 TS-CM-C07	Sample 27 TS-CM-C10	Sample 28 TS-CM-C38/38	Sample 29 TS-CM-C152	Sample 30 TS-CN-C16	Sample 31 TS-CN-CN364	Sample 32 TS-CN-CN223	Sample 33 TS-CN-CN342	Sample 34 TS-CN-CN413	Sample 35 TS-CN-CN334	Sample 36 TS-CN-CN93
	Job No.	*N2045/25*	*N2045/26*	*N2045/27*	*N2045/28*	*N2045/29*	*N2045/30*	*N2045/31*	*N2045/32*	*N2045/33*	*N2045/34*	*N2045/35*	*N2045/36*
Emerson Dispersion Class	*Emerson Aggregate Test (EAT)*	4	3	4	3	4	4	3	4	3	3	3	3
Total Organic Carbon (%C)	*HCL treatment- LECO Analyser*	1.69	1.51	1.53	1.28	1.17	1.60	0.47	0.87	1.23	0.74	1.26	1.92
Organic Matter (%)	*** Calculation*	2.91	2.60	2.63	2.20	2.01	2.75	0.81	1.50	2.12	1.27	2.17	3.30
K Factor	*Revised Universal Soil Loss Equation (RUSLE)*	0.021	0.034	0.021	0.029	0.030	0.018	0.020	0.026	0.032	0.026	0.024	0.022
K Factor + 20% (EAT Class 1&2 soils only)	*Revised Universal Soil Loss Equation (RUSLE)*	..	..	..	..	..	..	..	..	..	..	..	..

Notes:

1. All results as dry weight DW - samples were dried at 40 oC for 24-48 h prior to crushing and analysis.
2. Methods from Rayment and Lyons, Soil Chemical Methods - Australasia.
3. K Factor determined for RUSLE; Organic matter calculation as per RUSLE - where the TOC > 4% the 4% value has be
4. Analysis conducted between sample arrival date and reporting date.
5. ** NATA accreditation does not cover the performance of this service.
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9. Results relate only to the samples tested.
10. This report was issued on 14/10/2022 and replaces the previous report issued on 5/10/2022. The K Factor + 20%

checked: .....
Graham Lancaster (Nata signatory)
Laboratory Manager

GRAIN SIZE ANALYSIS (hydrometer and sieving techniques)

39 samples supplied by SLR Consulting Australia Pty Ltd on 25/08/2022. Lab Job No. N2045
Analysis requested by Michelle Papenfus. Your Job: SLR 630.30341 Curragh
10 Kings Road NEW LAMBTON NSW 2305

	Method	Sample 37 TS-CN-CN320	Sample 38 TS-CN-CN369/370	Sample 39 TS-CM-C26
	Job No.	*N2045/37*	*N2045/38*	*N2045/39*
Emerson Dispersion Class	*Emerson Aggregate Test (EAT)*	3	3	2
Total Organic Carbon (%C)	*HCL treatment- LECO Analyser*	1.20	0.42	1.12
Organic Matter (%)	*** Calculation*	2.06	0.72	1.93
K Factor	*Revised Universal Soil Loss Equation (RUSLE)*	0.028	0.015	0.030
K Factor + 20% (EAT Class 1&2 soils only)	*Revised Universal Soil Loss Equation (RUSLE)*	..	..	0.036

Notes:

1. All results as dry weight DW - samples were dried at 40 oC for 24-48 h prior to crushing and analysis.
2. Methods from Rayment and Lyons, Soil Chemical Methods - Australasia.
3. K Factor determined for RUSLE; Organic matter calculation as per RUSLE - where the TOC > 4% the 4% value has be
4. Analysis conducted between sample arrival date and reporting date.
5. ** NATA accreditation does not cover the performance of this service.
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8. All services undertaken by EAL are covered by the EAL Laboratory Services Terms and Conditions (refer scu.edu.au
9. Results relate only to the samples tested.
10. This report was issued on 14/10/2022 and replaces the previous report issued on 5/10/2022. The K Factor + 20%



checked: .....
Graham Lancaster (Nata signatory)
Laboratory Manager

GRAIN SIZE ANALYSIS (hydrometer and sieving techniques)

39 soil samples supplied by SLR Consulting Australia Pty Ltd on 25th August, 2022 - Lab Job No. N2045
Analysis requested by Michelle Papenfus. Job Ref SLR 630.30341 Curragh
10 Kings Road NEW LAMBTON NSW 2305

SAMPLE ID	Lab Code	MOISTURE CONTENT (% of water in sample)	GRAVEL > 2 mm (% of total oven-dry equivalent)	COARSE SAND 200-2000 µm (0.2-2.0 mm) (% of total oven-dry equivalent)	FINE SAND 100-200 µm (0.1-0.2 mm) (% of total oven-dry equivalent)	V. FINE SAND 20 - 100 µm (0.02-0.1 mm) (% of total oven-dry equivalent)	SILT 2-20 µm ISSS (% of total oven-dry equivalent)	CLAY < 2 µm (% of total oven-dry equivalent)
SP-CN-C418	N2045/1	8.2%	17.3%	4.5%	3.2%	26.6%	27.4%	20.9%
SP-CN-C16	N2045/2	8.0%	5.3%	32.4%	3.6%	8.4%	4.0%	46.3%
SP-CM-C07	N2045/3	11.2%	10.9%	7.3%	4.7%	18.6%	17.5%	41.0%
SP-CM-C10	N2045/4	9.6%	2.4%	7.5%	7.6%	28.2%	15.2%	39.2%
SP-CM-C126	N2045/5	9.8%	0.7%	3.4%	3.0%	31.4%	32.8%	28.7%
SP-CM-C042	N2045/6	9.2%	22.8%	6.8%	5.5%	22.1%	18.8%	24.1%
SP-CM-C152	N2045/7	7.6%	3.0%	10.8%	6.4%	20.3%	23.6%	35.8%
SP-CM-C100	N2045/8	8.8%	15.5%	21.1%	13.4%	17.2%	11.5%	21.3%
SP-CM-C38/38	N2045/9	9.9%	15.5%	23.4%	6.7%	17.8%	17.3%	19.3%
SP-CM-C077	N2045/10	12.1%	5.0%	6.8%	3.0%	14.0%	33.5%	37.8%
SP-CN-C369/370	N2045/11	13.0%	51.7%	4.1%	0.5%	5.9%	17.1%	20.8%
SP-CN-CN93	N2045/12	11.5%	0.5%	4.8%	13.6%	44.3%	10.1%	26.7%
SP-CN-CN320	N2045/13	6.4%	8.6%	60.2%	5.2%	8.8%	3.2%	13.9%
SP-CN-CN342	N2045/14	6.5%	20.9%	41.2%	6.8%	11.2%	4.2%	15.7%
SP-CN-CN413	N2045/15	11.3%	14.2%	13.7%	5.9%	28.1%	19.1%	19.0%
SP-CN-CN334	N2045/16	8.3%	31.1%	13.2%	3.2%	14.1%	19.1%	19.3%
SP-CN-CN364	N2045/17	4.5%	24.9%	24.1%	5.6%	16.7%	10.9%	17.7%
SP-CM-C051	N2045/18	13.7%	3.2%	9.6%	3.1%	12.1%	34.7%	37.2%
SP-CN-CN223	N2045/19	12.9%	24.8%	29.6%	6.7%	9.1%	10.7%	19.0%
SP-CM-C142	N2045/20	12.3%	47.0%	23.6%	3.1%	6.4%	6.5%	13.4%
TS-CM-C077	N2045/21	14.2%	5.4%	9.5%	9.8%	17.9%	9.9%	47.5%
TS-CM-C142	N2045/22	16.0%	13.9%	15.1%	5.9%	17.2%	8.1%	39.9%
TS-CM-C100	N2045/23	17.0%	0.5%	10.8%	7.6%	15.7%	14.6%	50.9%
TS-CM-C051	N2045/24	16.3%	6.7%	9.7%	7.9%	28.4%	8.3%	39.1%
TS-CM-C042	N2045/25	21.4%	1.4%	3.8%	4.2%	12.8%	18.0%	59.8%
TS-CM-C07	N2045/26	15.8%	1.6%	3.3%	5.9%	25.7%	21.0%	42.5%
TS-CM-C10	N2045/27	18.5%	0.7%	11.5%	6.6%	22.4%	3.2%	55.7%
TS-CM-C38/38	N2045/28	12.6%	3.0%	17.1%	11.1%	21.4%	9.7%	37.8%
TS-CM-C152	N2045/29	13.2%	0.1%	17.1%	13.3%	18.3%	13.5%	37.7%
TS-CN-C16	N2045/30	23.2%	0.3%	2.1%	1.4%	8.0%	19.3%	69.0%
TS-CN-CN364	N2045/31	3.4%	8.7%	57.9%	6.9%	14.8%	1.5%	10.2%
TS-CN-CN223	N2045/32	9.3%	0.0%	41.6%	8.7%	21.4%	5.6%	22.8%
TS-CN-CN342	N2045/33	11.0%	0.4%	22.2%	10.7%	25.0%	9.3%	32.4%
TS-CN-CN413	N2045/34	9.4%	0.0%	37.5%	12.4%	26.7%	3.2%	20.2%
TS-CN-CN334	N2045/35	21.0%	0.1%	1.3%	3.2%	27.6%	9.0%	58.9%
TS-CN-CN93	N2045/36	21.2%	0.6%	2.6%	1.5%	11.1%	25.0%	59.1%
TS-CN-CN320	N2045/37	18.6%	0.2%	5.7%	3.9%	23.5%	16.0%	50.7%
TS-CN-CN369/370	N2045/38	5.6%	2.9%	58.7%	7.5%	13.7%	3.6%	13.6%
TS-CM-C26	N2045/39	20.2%	1.1%	5.2%	5.7%	15.7%	14.9%	57.4%

Note:

1. The Hydrometer Analysis method was used to determine the percentage sand, silt and clay,
modified from SOP meth004 (California Dept of Pesticide Regulation), using method of Gee & Bauder (1986)," &
in Methods of Soil Analysis. Part 1 Agron. Monogr. 9 (2nd Ed). Klute, A., American Soc. of Agronomy Inc., Soil Sci. Soc. America Inc., Madison WI: 383-411.
2. The texture classification was based on the hydrometer results and the appropriate texture triangle.
3. All services undertaken by EAL are covered by the EAL Laboratory Services Terms and Conditions (see EAL website: scu.edu.au/eal).
4. This report is not to be reproduced except in full.
5. This report was issued on 05/10/2022.

checked: .....
Graham Lancaster (Nata signatory)
Laboratory Manager

GRAIN SIZE ANALYSIS (hydrometer and sieving techniques)

39 soil samples supplied by SLR Consulting Australia Pty Ltd on 25th August, 2022 - Lab Job No. N2045
Analysis requested by Michelle Papenfus. Job Ref SLR 630.30341 Curragh
10 Kings Road NEW LAMBTON NSW 2305

SAMPLE ID	Lab Code	MOISTURE CONTENT (% of water in sample)	COARSE SAND 200-2000 µm (0.2-2.0 mm) (% < 2 mm oven-dry equivalent)	FINE SAND 100-200 µm (0.1-0.2 mm) (% < 2 mm oven-dry equivalent)	V. FINE SAND 20 - 100 µm (0.02-0.1 mm) (% < 2 mm oven-dry equivalent)	SILT 2-20 µm (% < 2 mm oven-dry equivalent)	CLAY < 2 µm (% < 2 mm oven-dry equivalent)
SP-CN-C418	N2045/1	8.2%	5.5%	3.9%	32.2%	33.2%	25.3%
SP-CN-C16	N2045/2	8.0%	34.2%	3.8%	8.9%	4.3%	48.9%
SP-CM-C07	N2045/3	11.2%	8.2%	5.3%	20.8%	19.7%	46.0%
SP-CM-C10	N2045/4	9.6%	7.7%	7.8%	28.9%	15.5%	40.1%
SP-CM-C126	N2045/5	9.8%	3.4%	3.1%	31.6%	33.0%	28.9%
SP-CM-C042	N2045/6	9.2%	8.7%	7.1%	28.6%	24.3%	31.2%
SP-CM-C152	N2045/7	7.6%	11.1%	6.6%	20.9%	24.3%	37.0%
SP-CM-C100	N2045/8	8.8%	25.0%	15.9%	20.3%	13.6%	25.2%
SP-CM-C38/38	N2045/9	9.9%	27.7%	7.9%	21.1%	20.5%	22.8%
SP-CM-C077	N2045/10	12.1%	7.1%	3.1%	14.7%	35.3%	39.7%
SP-CN-C369/370	N2045/11	13.0%	8.5%	1.0%	12.1%	35.3%	43.1%
SP-CN-CN93	N2045/12	11.5%	4.9%	13.7%	44.5%	10.1%	26.8%
SP-CN-CN320	N2045/13	6.4%	65.9%	5.7%	9.6%	3.5%	15.2%
SP-CN-CN342	N2045/14	6.5%	52.1%	8.6%	14.2%	5.3%	19.8%
SP-CN-CN413	N2045/15	11.3%	16.0%	6.8%	32.8%	22.3%	22.1%
SP-CN-CN334	N2045/16	8.3%	19.1%	4.6%	20.4%	27.8%	28.1%
SP-CN-CN364	N2045/17	4.5%	32.1%	7.5%	22.2%	14.6%	23.6%
SP-CM-C051	N2045/18	13.7%	10.0%	3.2%	12.5%	35.8%	38.5%
SP-CN-CN223	N2045/19	12.9%	39.4%	8.9%	12.1%	14.2%	25.3%
SP-CM-C142	N2045/20	12.3%	44.5%	5.9%	12.0%	12.2%	25.3%
TS-CM-C077	N2045/21	14.2%	10.0%	10.3%	18.9%	10.5%	50.3%
TS-CM-C142	N2045/22	16.0%	17.6%	6.8%	20.0%	9.4%	46.3%
TS-CM-C100	N2045/23	17.0%	10.9%	7.6%	15.7%	14.6%	51.1%
TS-CM-C051	N2045/24	16.3%	10.4%	8.5%	30.4%	8.9%	41.9%
TS-CM-C042	N2045/25	21.4%	3.9%	4.3%	13.0%	18.2%	60.6%
TS-CM-C07	N2045/26	15.8%	3.3%	6.0%	26.1%	21.4%	43.2%
TS-CM-C10	N2045/27	18.5%	11.6%	6.6%	22.5%	3.2%	56.0%
TS-CM-C38/38	N2045/28	12.6%	17.7%	11.4%	22.0%	10.0%	38.9%
TS-CM-C152	N2045/29	13.2%	17.1%	13.4%	18.3%	13.5%	37.7%
TS-CN-C16	N2045/30	23.2%	2.1%	1.4%	8.0%	19.3%	69.2%
TS-CN-CN364	N2045/31	3.4%	63.4%	7.5%	16.2%	1.7%	11.2%
TS-CN-CN223	N2045/32	9.3%	41.6%	8.7%	21.4%	5.6%	22.8%
TS-CN-CN342	N2045/33	11.0%	22.3%	10.8%	25.1%	9.3%	32.6%
TS-CN-CN413	N2045/34	9.4%	37.5%	12.4%	26.7%	3.2%	20.3%
TS-CN-CN334	N2045/35	21.0%	1.3%	3.2%	27.6%	9.0%	58.9%
TS-CN-CN93	N2045/36	21.2%	2.7%	1.5%	11.2%	25.2%	59.4%
TS-CN-CN320	N2045/37	18.6%	5.7%	3.9%	23.5%	16.0%	50.8%
TS-CN-CN369/370	N2045/38	5.6%	60.4%	7.7%	14.1%	3.7%	14.0%
TS-CM-C26	N2045/39	20.2%	5.1%	1.3%	29.3%	12.4%	51.9%

Note:

1. The Hydrometer Analysis method was used to determine the percentage sand, silt and clay,
modified from SOP meth004 (California Dept of Pesticide Regulation), using method of Gee & Bauder (1986)," &
in Methods of Soil Analysis. Part 1 Agron. Monogr. 9 (2nd Ed). Klute, A., American Soc. of Agronomy Inc., Soil Sci. Soc. America Inc., Madison WI: 383-411.
2. The texture classification was based on the hydrometer results and the appropriate texture triangle.
3. All services undertaken by EAL are covered by the EAL Laboratory Services Terms and Conditions (see EAL website: scu.edu.au/eal).
4. This report is not to be reproduced except in full.
5. This report was issued on 05/10/2022.

Environmental Analysis Laboratory, Southern Cross University,
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Graham Lancaster (Nata signatory)
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AGRICULTURAL SOIL ANALYSIS REPORT

39 samples supplied by SLR Consulting Australia Pty Ltd on 25/08/2022. Lab Job No.N2045
Analysis requested by Michelle Papenfus. Your Job: SLR 630.30341 Curragh
10 Kings Road NEW LAMBTON NSW 2305

			Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
		Sample ID:	SP-CN-C418	SP-CN-C16	SP-CM-C07	SP-CM-C10	SP-CM-C126
		Crop:	soil	soil	soil	soil	soil
		Client:	SLR Consulting Australia Pty Ltd	SLR Consulting Australia Pty Ltd	SLR Consulting Australia Pty Ltd	SLR Consulting Australia Pty Ltd	SLR Consulting Australia Pty Ltd
	Parameter		Method reference	N2045/1	N2045/2	N2045/3	N2045/4	N2045/5
	Phosphorus (mg/kg P)		**Rayment & Lyons 2011 - 9B2 (Colwell)	10	4.9	5.6	8.2	8.2
	Nitrate Nitrogen (mg/kg N)		**Inhouse S37 (KCl)	0.8	0.8	9.6	6.6	9.6
	pH		Rayment & Lyons 2011 - 4A1 (1:5 Water)	9.5	8.9	8.7	9.5	8.3
	Electrical Conductivity (dS/m)		Rayment & Lyons 2011 - 3A1 (1:5 Water)	0.143	0.178	1.977	0.500	2.674
	Exchangeable Calcium	(cmol+/kg)	Rayment & Lyons 2011 - 15D3 (Ammonium Acetate)	10	3.1	18	15	6.4
		(kg/ha)		4,588	1,409	8,001	6,801	2,854
		(mg/kg)		2,048	629	3,572	3,036	1,274
	Exchangeable Magnesium	(cmol+/kg)		8.8	3.9	8.6	8.6	8.6
		(kg/ha)		2,395	1,059	2,330	2,332	2,341
		(mg/kg)		1,069	473	1,040	1,041	1,045
	Exchangeable Potassium	(cmol+/kg)		0.31	<0.12	0.13	0.14	0.30
		(kg/ha)		272	<112	115	125	262
		(mg/kg)		121	<50	51	56	117
	Exchangeable Sodium	(cmol+/kg)		1.4	1.8	11	5.7	13
		(kg/ha)		734	940	5,896	2,926	6,553
		(mg/kg)		328	420	2,632	1,306	2,925
	Exchangeable Aluminium	(cmol+/kg)	**Inhouse S37 (KCl)	<0.01	<0.01	<0.01	<0.01	<0.01
		(kg/ha)		1.1	1.8	1.1	1.4	1.3
		(mg/kg)		<1	<1	<1	<1	<1
	Exchangeable Hydrogen	(cmol+/kg)	**Rayment & Lyons 2011 - 15G1 (Acidity Titration)	<0.01	<0.01	<0.01	<0.01	<0.01
		(kg/ha)		<1	<1	<1	<1	<1
		(mg/kg)		<1	<1	<1	<1	<1
	Effective Cation Exchange Capacity (ECEC) (cmol+/kg)		**Calculation: Sum of Ca,Mg,K,Na,Al,H (cmol+/kg)	21	9.0	38	30	28
	Calcium (%)		**Base Saturation Calculations - Cation cmol+/kg / ECEC x 100	49	35	47	51	23
	Magnesium (%)			42	43	23	29	31
	Potassium (%)			1.5	1.1	0.35	0.48	1.1
	Sodium - ESP (%)			6.9	20	30	19	45
	Aluminium (%)			0.03	0.10	0.01	0.02	0.02
	Hydrogen (%)			0.00	0.00	0.00	0.00	0.00
	Calcium/Magnesium Ratio		**Calculation: Calcium / Magnesium (cmol+/kg)	1.2	0.81	2.1	1.8	0.74

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AGRICULTURAL SOIL ANALYSIS REPORT

39 samples supplied by SLR Consulting Australia Pty Ltd on 25/08/2022. Lab Job No.N2045
Analysis requested by Michelle Papenfus. Your Job: SLR 630.30341 Curragh
10 Kings Road NEW LAMBTON NSW 2305

		Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
	Sample ID:	SP-CN-C418	SP-CN-C16	SP-CM-C07	SP-CM-C10	SP-CM-C126
	Crop:	soil	soil	soil	soil	soil
	Client:	SLR Consulting Australia Pty Ltd	SLR Consulting Australia Pty Ltd	SLR Consulting Australia Pty Ltd	SLR Consulting Australia Pty Ltd	SLR Consulting Australia Pty Ltd
	Parameter	Method reference	N2045/1	N2045/2	N2045/3	N2045/4	N2045/5
	Zinc (mg/kg)	Rayment & Lyons 2011 - 12A1 (DTPA)	0.9	<0.5	<0.5	<0.5	19.3
	Manganese (mg/kg)		3	1	4	2	3
	Iron (mg/kg)		18	2	3	3	8
	Copper (mg/kg)		3.0	0.2	0.4	0.4	8.7
	Boron (mg/kg)	**Rayment & Lyons 2011 - 12C2 (Hot $CaCl_2$)	0.23	1.19	1.89	0.97	0.81
	Total Carbon (%)	Inhouse S4a (LECO Trumac Analyser)	0.63	0.29	0.63	2.30	2.17
	Total Nitrogen (%)		0.09	0.03	0.05	0.14	0.15
	Total Phosphorus (mg/kg)	Rayment & Lyons 2011 - 17C1 Aqua Regia	793	73	305	579	436
	Chloride (mg/kg)	**Rayment & Lyons 2011 - 5A3a	561	148	1,672	647	1,687
	pH	**Rayment & Lyons 2011 - 4B4 ($CaCl_2$)	8.2	8.0	8.3	8.6	7.9
	Emerson Aggregate Test (EAT)	**AS1289.3.8.1-2017	2	2	2	2	2

Notes:

1. All results presented as a 40°C oven dried weight. Soil sieved and lightly crushed to < 2 mm.
2. Methods from Rayment and Lyons, 2011. *Soil Chemical Methods - Australasia.* CSIRO Publishing: Collingwood.
3. Soluble Salts included in Exchangeable Cations - NO PRE-WASH (unless requested).
4. 'Morgan 1 Extract' adapted from 'Science in Agriculture', 'Non-Toxic Farming' and LaMotte Soil Handbook.
5. Guidelines for phosphorus have been reduced for Australian soils.
6. Indicative guidelines are based on 'Albrecht' and 'Reams' concepts.
7. Total Acid Extractable Nutrients indicate a store of nutrients.
8. National Environmental Protection (Assessment of Site Contamination) Measure 2013, Schedule B(1) - Guideline on Investigation Levels for Soil and Groundwater. Table 5-A Background Ranges.
9. Information relating to testing colour codes is available on sheet 2 - 'Understanding your agricultural soil results'.
10. Conversions for 1 cmol$_+$/kg = 230 mg/kg Sodium, 390 mg/kg Potassium, 122 mg/kg Magnesium, 200 mg/kg Calcium
11. Conversions to kg/ha = mg/kg x 2.24
12. The chloride calculation of Cl mg/L = EC x 640 is considered an estimate, and most likely an over-estimate
13. ** NATA accreditation does not cover the performance of this service.
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17. This report was issued on 5/10/2022 and replaces the report published 14/09/2022. Total carbon data has been amended.

NATA
WORLD RECOGNISED ACCREDITATION
Accreditation No. 14960
Accredited for compliance with ISO/IEC 17025 - Testing

Quality Checked: Kris Saville
Agricultural Co-Ordinator KS

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			Sample 6	Sample 7	Sample 8	Sample 9	Sample 10
		Sample ID:	SP-CM-C042	SP-CM-C152	SP-CM-C100	SP-CM-C38/38	SP-CM-C077
		Crop:	soil	soil	soil	soil	soil
		Client:	SLR Consulting Australia Pty Ltd	SLR Consulting Australia Pty Ltd	SLR Consulting Australia Pty Ltd	SLR Consulting Australia Pty Ltd	SLR Consulting Australia Pty Ltd
	Parameter	Method reference	N2045/6	N2045/7	N2045/8	N2045/9	N2045/10
	Phosphorus (mg/kg P)	**Rayment & Lyons 2011 - 9B2 (Colwell)	5.9	6.2	10	5.6	9.2
	Nitrate Nitrogen (mg/kg N)	**Inhouse S37 (KCl)	0.8	7.1	0.8	1.4	24.5
	pH	Rayment & Lyons 2011 - 4A1 (1:5 Water)	9.8	8.8	9.4	10.0	9.2
	Electrical Conductivity (dS/m)	Rayment & Lyons 2011 - 3A1 (1:5 Water)	0.222	3.221	0.117	0.420	0.738
	Exchangeable Calcium (cmol+/kg)	Rayment & Lyons 2011 - 15D3 (Ammonium Acetate)	14	10	8.9	10	16
	Exchangeable Calcium (kg/ha)		6,062	4,694	4,007	4,652	7,148
	Exchangeable Calcium (mg/kg)		2,706	2,096	1,789	2,077	3,191
	Exchangeable Magnesium (cmol+/kg)		14	9.2	6.5	6.3	6.1
	Exchangeable Magnesium (kg/ha)		3,817	2,494	1,773	1,728	1,658
	Exchangeable Magnesium (mg/kg)		1,704	1,113	791	771	740
	Exchangeable Potassium (cmol+/kg)		0.30	0.15	0.14	0.17	0.14
	Exchangeable Potassium (kg/ha)		259	134	126	151	121
	Exchangeable Potassium (mg/kg)		116	60	56	67	54
	Exchangeable Sodium (cmol+/kg)		2.5	17	3.3	4.0	4.9
	Exchangeable Sodium (kg/ha)		1,276	8,498	1,685	2,040	2,503
	Exchangeable Sodium (mg/kg)		569	3,794	752	911	1,117
	Exchangeable Aluminium (cmol+/kg)	**Inhouse S37 (KCl)	<0.01	<0.01	<0.01	<0.01	<0.01
	Exchangeable Aluminium (kg/ha)		1.0	1.4	1.2	<1	<1
	Exchangeable Aluminium (mg/kg)		<1	<1	<1	<1	<1
	Exchangeable Hydrogen (cmol+/kg)	**Rayment & Lyons 2011 - 15G1 (Acidity Titration)	<0.01	<0.01	<0.01	<0.01	<0.01
	Exchangeable Hydrogen (kg/ha)		<1	<1	<1	<1	<1
	Exchangeable Hydrogen (mg/kg)		<1	<1	<1	<1	<1
	Effective Cation Exchange Capacity (ECEC) (cmol+/kg)	**Calculation: Sum of Ca,Mg,K,Na,Al,H (cmol+/kg)	30	36	19	21	27
	Calcium (%)	**Base Saturation Calculations - Cation cmol+/kg / ECEC x 100	45	29	47	50	59
	Magnesium (%)		46	25	35	30	23
	Potassium (%)		0.98	0.42	0.76	0.83	0.51
	Sodium - ESP (%)		8.2	45	17	19	18
	Aluminium (%)		0.02	0.02	0.03	0.02	0.01
	Hydrogen (%)		0.00	0.00	0.00	0.00	0.00
	Calcium/Magnesium Ratio	**Calculation: Calcium / Magnesium (cmol+/kg)	0.96	1.1	1.4	1.6	2.6

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10 Kings Road NEW LAMBTON NSW 2305

			Sample 6	Sample 7	Sample 8	Sample 9	Sample 10
		Sample ID:	SP-CM-C042	SP-CM-C152	SP-CM-C100	SP-CM-C38/38	SP-CM-C077
		Crop:	soil	soil	soil	soil	soil
		Client:	SLR Consulting Australia Pty Ltd	SLR Consulting Australia Pty Ltd	SLR Consulting Australia Pty Ltd	SLR Consulting Australia Pty Ltd	SLR Consulting Australia Pty Ltd
	Parameter	Method reference	N2045/6	N2045/7	N2045/8	N2045/9	N2045/10
	Zinc (mg/kg)	Rayment & Lyons 2011 - 12A1 (DTPA)	<0.5	<0.5	<0.5	0.8	<0.5
	Manganese (mg/kg)		0	0	1	2	2
	Iron (mg/kg)		1	<0.5	2	4	2
	Copper (mg/kg)		0.1	<0.1	0.2	0.2	0.5
	Boron (mg/kg)	**Rayment & Lyons 2011 - 12C2 (Hot $CaCl_2$)	0.35	1.17	0.47	0.29	0.78
	Total Carbon (%)	Inhouse S4a (LECO Trumac Analyser)	2.30	0.54	0.23	2.04	1.63
	Total Nitrogen (%)		0.11	0.06	0.06	0.09	0.11
	Total Phosphorus (mg/kg)	Rayment & Lyons 2011 - 17C1 Aqua Regia	784	540	165	656	1,065
	Chloride (mg/kg)	**Rayment & Lyons 2011 - 5A3a	669	2,001	794	168	544
	pH	**Rayment & Lyons 2011 - 4B4 ($CaCl_2$)	8.3	8.4	7.7	8.3	8.4
	Emerson Aggregate Test (EAT)	**AS1289.3.8.1-2017	2	2	2	2	2

Notes:

1. All results presented as a 40°C oven dried weight. Soil sieved and lightly crushed to < 2 mm.
2. Methods from Rayment and Lyons, 2011. *Soil Chemical Methods - Australasia.* CSIRO Publishing: Collingwoo
3. Soluble Salts included in Exchangeable Cations - NO PRE-WASH (unless requested).
4. 'Morgan 1 Extract' adapted from 'Science in Agriculture', 'Non-Toxic Farming' and LaMotte Soil Handbook.
5. Guidelines for phosphorus have been reduced for Australian soils.
6. Indicative guidelines are based on 'Albrecht' and 'Reams' concepts.
7. Total Acid Extractable Nutrients indicate a store of nutrients.
8. National Environmental Protection (Assessment of Site Contamination) Measure 2013, Schedule B(1) - Guideline on Investigation Levels for Soil and Groundwater. Table 5-A Background Ranges.
9. Information relating to testing colour codes is available on sheet 2 - 'Understanding your agricultural soil resu
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			Sample 11	Sample 12	Sample 13	Sample 14	Sample 15
		Sample ID:	SP-CN-C369/370	SP-CN-CN93	SP-CN-CN320	SP-CN-CN342	SP-CN-CN413
		Crop:	soil	soil	soil	soil	soil
		Client:	SLR Consulting Australia Pty Ltd	SLR Consulting Australia Pty Ltd	SLR Consulting Australia Pty Ltd	SLR Consulting Australia Pty Ltd	SLR Consulting Australia Pty Ltd
	Parameter		Method reference	N2045/11	N2045/12	N2045/13	N2045/14	N2045/15
	Phosphorus (mg/kg P)		**Rayment & Lyons 2011 - 9B2 (Colwell)	38	20	6.9	12	6.9
	Nitrate Nitrogen (mg/kg N)		**Inhouse S37 (KCl)	0.8	0.7	<0.1	<0.1	0.7
	pH		Rayment & Lyons 2011 - 4A1 (1:5 Water)	5.7	9.2	9.2	3.4	9.3
	Electrical Conductivity (dS/m)		Rayment & Lyons 2011 - 3A1 (1:5 Water)	0.118	0.180	0.036	1.336	0.122
	Exchangeable Calcium	(cmol+/kg)	Rayment & Lyons 2011 - 15D3 (Ammonium Acetate)	6.2	11	2.2	6.4	12
		(kg/ha)		2,799	5,098	999	2,854	5,382
		(mg/kg)		1,250	2,276	446	1,274	2,403
	Exchangeable Magnesium	(cmol+/kg)		6.7	6.3	2.4	3.9	7.6
		(kg/ha)		1,837	1,727	662	1,056	2,064
		(mg/kg)		820	771	296	471	921
	Exchangeable Potassium	(cmol+/kg)		0.20	0.28	<0.12	<0.12	0.26
		(kg/ha)		178	241	<112	<112	226
		(mg/kg)		79	108	<50	<50	101
	Exchangeable Sodium	(cmol+/kg)		0.24	2.2	0.47	0.30	0.69
		(kg/ha)		125	1,141	241	152	354
		(mg/kg)		56	510	108	68	158
	Exchangeable Aluminium	(cmol+/kg)	**Inhouse S37 (KCl)	0.19	<0.01	<0.01	2.8	0.03
		(kg/ha)		37	1.6	<1	571	6.9
		(mg/kg)		17	<1	<1	255	3.1
	Exchangeable Hydrogen	(cmol+/kg)	**Rayment & Lyons 2011 - 15G1 (Acidity Titration)	0.18	<0.01	<0.01	1.2	<0.01
		(kg/ha)		4.0	<1	<1	28	<1
		(mg/kg)		1.8	<1	<1	12	<1
	Effective Cation Exchange Capacity (ECEC) (cmol+/kg)		**Calculation: Sum of Ca,Mg,K,Na,Al,H (cmol+/kg)	14	20	5.2	15	21
	Calcium (%)		**Base Saturation Calculations - Cation cmol+/kg / ECEC x 100	45	56	43	43	58
	Magnesium (%)			49	31	47	26	37
	Potassium (%)			1.5	1.4	0.83	0.29	1.3
	Sodium - ESP (%)			1.8	11	9.0	2.0	3.3
	Aluminium (%)			1.3	0.04	0.07	19	0.17
	Hydrogen (%)			1.3	0.00	0.00	8.4	0.00
	Calcium/Magnesium Ratio		**Calculation: Calcium / Magnesium (cmol+/kg)	0.92	1.8	0.91	1.6	1.6

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	Parameter	Method reference	Sample 11 SP-CN-C369/370 soil SLR Consulting Australia Pty Ltd N2045/11	Sample 12 SP-CN-CN93 soil SLR Consulting Australia Pty Ltd N2045/12	Sample 13 SP-CN-CN320 soil SLR Consulting Australia Pty Ltd N2045/13	Sample 14 SP-CN-CN342 soil SLR Consulting Australia Pty Ltd N2045/14	Sample 15 SP-CN-CN413 soil SLR Consulting Australia Pty Ltd N2045/15
	Zinc (mg/kg)	Rayment & Lyons 2011 - 12A1 (DTPA)	0.6	<0.5	<0.5	1.0	2.7
	Manganese (mg/kg)		18	2	1	8	2
	Iron (mg/kg)		20	3	2	16	9
	Copper (mg/kg)		0.9	0.4	0.2	0.1	2.5
	Boron (mg/kg)	**Rayment & Lyons 2011 - 12C2 (Hot $CaCl_2$)	0.26	0.69	<0.1	0.27	0.19
	Total Carbon (%)	Inhouse S4a (LECO Trumac Analyser)	17.20	0.25	0.15	0.31	1.36
	Total Nitrogen (%)		0.53	0.03	0.03	0.04	0.10
	Total Phosphorus (mg/kg)	Rayment & Lyons 2011 - 17C1 Aqua Regia	761	469	109	183	510
	Chloride (mg/kg)	**Rayment & Lyons 2011 - 5A3a	66	59	15	43	16
	pH	**Rayment & Lyons 2011 - 4B4 ($CaCl_2$)	5.2	8.3	8.2	3.3	8.5
	Emerson Aggregate Test (EAT)	**AS1289.3.8.1-2017	4	2	2	4	2

Notes:

1. All results presented as a 40°C oven dried weight. Soil sieved and lightly crushed to < 2 mm.
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			Sample 16	Sample 17	Sample 18	Sample 19	Sample 20
		Sample ID:	SP-CN-CN334	SP-CN-CN364	SP-CM-C051	SP-CN-CN223	SP-CM-C142
		Crop:	soil	soil	soil	soil	soil
		Client:	SLR Consulting Australia Pty Ltd	SLR Consulting Australia Pty Ltd	SLR Consulting Australia Pty Ltd	SLR Consulting Australia Pty Ltd	SLR Consulting Australia Pty Ltd
	Parameter		Method reference	N2045/16	N2045/17	N2045/18	N2045/19	N2045/20
	Phosphorus (mg/kg P)		**Rayment & Lyons 2011 - 9B2 (Colwell)	20	13	21	15	6.9
	Nitrate Nitrogen (mg/kg N)		**Inhouse S37 (KCl)	0.8	6.3	9.1	4.7	1.3
	pH		Rayment & Lyons 2011 - 4A1 (1:5 Water)	9.5	9.7	9.1	9.5	9.1
	Electrical Conductivity (dS/m)		Rayment & Lyons 2011 - 3A1 (1:5 Water)	0.273	0.426	0.696	0.194	0.108
	Exchangeable Calcium	(cmol+/kg)	Rayment & Lyons 2011 - 15D3 (Ammonium Acetate)	7.5	10	16	9.8	30
		(kg/ha)		3,366	4,541	7,346	4,416	13,680
		(mg/kg)		1,503	2,027	3,279	1,971	6,107
	Exchangeable Magnesium	(cmol+/kg)		5.5	6.0	9.8	7.7	5.3
		(kg/ha)		1,485	1,646	2,662	2,085	1,446
		(mg/kg)		663	735	1,188	931	645
	Exchangeable Potassium	(cmol+/kg)		0.19	0.25	0.16	0.24	0.14
		(kg/ha)		166	215	138	213	123
		(mg/kg)		74	96	62	95	55
	Exchangeable Sodium	(cmol+/kg)		2.8	3.6	5.0	1.9	0.64
		(kg/ha)		1,425	1,872	2,589	975	330
		(mg/kg)		636	836	1,156	435	147
	Exchangeable Aluminium	(cmol+/kg)	**Inhouse S37 (KCl)	<0.01	<0.01	<0.01	<0.01	0.01
		(kg/ha)		<1	<1	<1	<1	2.6
		(mg/kg)		<1	<1	<1	<1	1.1
	Exchangeable Hydrogen	(cmol+/kg)	**Rayment & Lyons 2011 - 15G1 (Acidity Titration)	<0.01	<0.01	<0.01	<0.01	<0.01
		(kg/ha)		<1	<1	<1	<1	<1
		(mg/kg)		<1	<1	<1	<1	<1
	Effective Cation Exchange Capacity (ECEC) (cmol+/kg)		**Calculation: Sum of Ca,Mg,K,Na,Al,H (cmol+/kg)	16	20	31	20	37
	Calcium (%)		**Base Saturation Calculations - Cation cmol+/kg / ECEC x 100	47	50	52	50	83
	Magnesium (%)			34	30	31	39	15
	Potassium (%)			1.2	1.2	0.50	1.2	0.38
	Sodium - ESP (%)			17	18	16	9.6	1.8
	Aluminium (%)			0.02	0.02	0.00	0.01	0.03
	Hydrogen (%)			0.00	0.00	0.00	0.00	0.00
	Calcium/Magnesium Ratio		**Calculation: Calcium / Magnesium (cmol+/kg)	1.4	1.7	1.7	1.3	5.7

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		Sample ID:	SP-CN-CN334	SP-CN-CN364	SP-CM-C051	SP-CN-CN223	SP-CM-C142
		Crop:	soil	soil	soil	soil	soil
		Client:	SLR Consulting Australia Pty Ltd	SLR Consulting Australia Pty Ltd	SLR Consulting Australia Pty Ltd	SLR Consulting Australia Pty Ltd	SLR Consulting Australia Pty Ltd
	Parameter	Method reference	N2045/16	N2045/17	N2045/18	N2045/19	N2045/20
	Zinc (mg/kg)	Rayment & Lyons 2011 - 12A1 (DTPA)	5.8	3.5	<0.5	0.7	<0.5
	Manganese (mg/kg)		12	8	0	1	4
	Iron (mg/kg)		30	16	<0.5	2	5
	Copper (mg/kg)		3.2	2.1	<0.1	0.2	0.2
	Boron (mg/kg)	**Rayment & Lyons 2011 - 12C2 (Hot $CaCl_2$)	0.16	0.32	0.91	0.36	0.18
	Total Carbon (%)	Inhouse S4a (LECO Trumac Analyser)	18.50	1.67	3.23	1.25	1.71
	Total Nitrogen (%)		0.45	0.09	0.14	0.07	0.06
	Total Phosphorus (mg/kg)	Rayment & Lyons 2011 - 17C1 Aqua Regia	655	617	897	626	1,550
	Chloride (mg/kg)	**Rayment & Lyons 2011 - 5A3a	71	156	273	62	34
	pH	**Rayment & Lyons 2011 - 4B4 ($CaCl_2$)	8.8	8.4	8.5	8.1	8.2
	Emerson Aggregate Test (EAT)	**AS1289.3.8.1-2017	2	2	2	2	4

Notes:

1. All results presented as a 40°C oven dried weight. Soil sieved and lightly crushed to < 2 mm.
2. Methods from Rayment and Lyons, 2011. *Soil Chemical Methods - Australasia.* CSIRO Publishing: Collingwoo
3. Soluble Salts included in Exchangeable Cations - NO PRE-WASH (unless requested).
4. 'Morgan 1 Extract' adapted from 'Science in Agriculture', 'Non-Toxic Farming' and LaMotte Soil Handbook.
5. Guidelines for phosphorus have been reduced for Australian soils.
6. Indicative guidelines are based on 'Albrecht' and 'Reams' concepts.
7. Total Acid Extractable Nutrients indicate a store of nutrients.
8. National Environmental Protection (Assessment of Site Contamination) Measure 2013, Schedule B(1) - Guideline on Investigation Levels for Soil and Groundwater. Table 5-A Background Ranges.
9. Information relating to testing colour codes is available on sheet 2 - 'Understanding your agricultural soil resu
10. Conversions for 1 cmol$_+$/kg = 230 mg/kg Sodium, 390 mg/kg Potassium, 122 mg/kg Magnesium, 200 mg/kg Calcium
11. Conversions to kg/ha = mg/kg x 2.24
12. The chloride calculation of Cl mg/L = EC x 640 is considered an estimate, and most likely an over-estimate
13. ** NATA accreditation does not cover the performance of this service.
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Agricultural Co-Ordinator KS

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ABN: 41 995 651 524

AGRICULTURAL SOIL ANALYSIS REPORT

39 samples supplied by SLR Consulting Australia Pty Ltd on 25/08/2022. Lab Job No.N2045
Analysis requested by Michelle Papenfus. Your Job: SLR 630.30341 Curragh
10 Kings Road NEW LAMBTON NSW 2305

			Sample 21	Sample 22	Sample 23	Sample 24	Sample 25
		Sample ID:	TS-CM-C077	TS-CM-C142	TS-CM-C100	TS-CM-C051	TS-CM-C042
		Crop:	soil	soil	soil	soil	soil
		Client:	SLR Consulting Australia Pty Ltd	SLR Consulting Australia Pty Ltd	SLR Consulting Australia Pty Ltd	SLR Consulting Australia Pty Ltd	SLR Consulting Australia Pty Ltd
	Parameter		Method reference	N2045/21	N2045/22	N2045/23	N2045/24	N2045/25
	Phosphorus (mg/kg P)		**Rayment & Lyons 2011 - 9B2 (Colwell)	12	7.2	17	13	8.5
	Nitrate Nitrogen (mg/kg N)		**Inhouse S37 (KCl)	9.6	1.8	25.6	95.7	11.0
	pH		Rayment & Lyons 2011 - 4A1 (1:5 Water)	8.9	8.5	8.9	8.4	8.8
	Electrical Conductivity (dS/m)		Rayment & Lyons 2011 - 3A1 (1:5 Water)	0.177	0.075	0.375	0.301	0.142
	Exchangeable Calcium	(cmol+/kg)	Rayment & Lyons 2011 - 15D3 (Ammonium Acetate)	27	30	24	38	41
		(kg/ha)		11,980	13,323	10,805	17,041	18,426
		(mg/kg)		5,348	5,948	4,824	7,608	8,226
	Exchangeable Magnesium	(cmol+/kg)		6.9	7.6	7.8	2.6	9.4
		(kg/ha)		1,872	2,063	2,130	721	2,565
		(mg/kg)		836	921	951	322	1,145
	Exchangeable Potassium	(cmol+/kg)		0.51	0.35	0.45	1.1	0.76
		(kg/ha)		444	302	390	941	669
		(mg/kg)		198	135	174	420	299
	Exchangeable Sodium	(cmol+/kg)		1.5	0.53	3.4	0.49	0.78
		(kg/ha)		765	272	1,731	251	404
		(mg/kg)		341	121	773	112	180
	Exchangeable Aluminium	(cmol+/kg)	**Inhouse S37 (KCl)	<0.01	<0.01	<0.01	<0.01	<0.01
		(kg/ha)		1.4	<1	<1	<1	<1
		(mg/kg)		<1	<1	<1	<1	<1
	Exchangeable Hydrogen	(cmol+/kg)	**Rayment & Lyons 2011 - 15G1 (Acidity Titration)	<0.01	<0.01	<0.01	<0.01	<0.01
		(kg/ha)		<1	<1	<1	<1	<1
		(mg/kg)		<1	<1	<1	<1	<1
	Effective Cation Exchange Capacity (ECEC) (cmol+/kg)		**Calculation: Sum of Ca,Mg,K,Na,Al,H (cmol+/kg)	36	38	36	42	52
	Calcium (%)		**Base Saturation Calculations - Cation cmol+/kg / ECEC x 100	75	78	67	90	79
	Magnesium (%)			19	20	22	6.3	18
	Potassium (%)			1.4	0.91	1.2	2.5	1.5
	Sodium - ESP (%)			4.2	1.4	9.4	1.2	1.5
	Aluminium (%)			0.02	0.01	0.01	0.01	0.01
	Hydrogen (%)			0.00	0.00	0.00	0.00	0.00
	Calcium/Magnesium Ratio		**Calculation: Calcium / Magnesium (cmol+/kg)	3.9	3.9	3.1	14	4.4

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10 Kings Road NEW LAMBTON NSW 2305

			Sample 21	Sample 22	Sample 23	Sample 24	Sample 25
		Sample ID:	TS-CM-C077	TS-CM-C142	TS-CM-C100	TS-CM-C051	TS-CM-C042
		Crop:	soil	soil	soil	soil	soil
		Client:	SLR Consulting Australia Pty Ltd	SLR Consulting Australia Pty Ltd	SLR Consulting Australia Pty Ltd	SLR Consulting Australia Pty Ltd	SLR Consulting Australia Pty Ltd
	Parameter	Method reference	N2045/21	N2045/22	N2045/23	N2045/24	N2045/25
	Zinc (mg/kg)	Rayment & Lyons 2011 - 12A1 (DTPA)	<0.5	<0.5	<0.5	<0.5	<0.5
	Manganese (mg/kg)		6	4	5	4	3
	Iron (mg/kg)		9	3	9	7	7
	Copper (mg/kg)		1.6	0.7	1.3	0.7	1.2
	Boron (mg/kg)	**Rayment & Lyons 2011 - 12C2 (Hot $CaCl_2$)	0.55	0.41	0.98	0.31	0.54
	Total Carbon (%)	Inhouse S4a (LECO Trumac Analyser)	1.48	6.69	1.10	4.29	1.69
	Total Nitrogen (%)		0.12	0.22	0.10	0.25	0.13
	Total Phosphorus (mg/kg)	Rayment & Lyons 2011 - 17C1 Aqua Regia	388	513	259	464	360
	Chloride (mg/kg)	**Rayment & Lyons 2011 - 5A3a	32	30	290	69	20
	pH	**Rayment & Lyons 2011 - 4B4 ($CaCl_2$)	8.0	7.7	8.1	7.8	8.0
	Emerson Aggregate Test (EAT)	**AS1289.3.8.1-2017	3	4	2	4	4

Notes:

1. All results presented as a 40°C oven dried weight. Soil sieved and lightly crushed to < 2 mm.
2. Methods from Rayment and Lyons, 2011. *Soil Chemical Methods - Australasia.* CSIRO Publishing: Collingwoo
3. Soluble Salts included in Exchangeable Cations - NO PRE-WASH (unless requested).
4. 'Morgan 1 Extract' adapted from 'Science in Agriculture', 'Non-Toxic Farming' and LaMotte Soil Handbook.
5. Guidelines for phosphorus have been reduced for Australian soils.
6. Indicative guidelines are based on 'Albrecht' and 'Reams' concepts.
7. Total Acid Extractable Nutrients indicate a store of nutrients.
8. National Environmental Protection (Assessment of Site Contamination) Measure 2013, Schedule B(1) - Guideline on Investigation Levels for Soil and Groundwater. Table 5-A Background Ranges.
9. Information relating to testing colour codes is available on sheet 2 - 'Understanding your agricultural soil resu
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11. Conversions to kg/ha = mg/kg x 2.24
12. The chloride calculation of Cl mg/L = EC x 640 is considered an estimate, and most likely an over-estimate
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10 Kings Road NEW LAMBTON NSW 2305

			Sample 26	Sample 27	Sample 28	Sample 29	Sample 30
		Sample ID:	TS-CM-C07	TS-CM-C10	TS-CM-C38/38	TS-CM-C152	TS-CN-C16
		Crop:	soil	soil	soil	soil	soil
		Client:	SLR Consulting Australia Pty Ltd	SLR Consulting Australia Pty Ltd	SLR Consulting Australia Pty Ltd	SLR Consulting Australia Pty Ltd	SLR Consulting Australia Pty Ltd
	Parameter		Method reference	N2045/26	N2045/27	N2045/28	N2045/29	N2045/30
	Phosphorus (mg/kg P)		**Rayment & Lyons 2011 - 9B2 (Colwell)	8.2	6.9	10	7.9	27
	Nitrate Nitrogen (mg/kg N)		**Inhouse S37 (KCl)	4.2	3.8	4.2	3.1	2.7
	pH		Rayment & Lyons 2011 - 4A1 (1:5 Water)	8.9	8.8	9.1	8.8	8.9
	Electrical Conductivity (dS/m)		Rayment & Lyons 2011 - 3A1 (1:5 Water)	0.127	0.141	0.154	0.103	0.156
	Exchangeable Calcium	(cmol+/kg)	Rayment & Lyons 2011 - 15D3 (Ammonium Acetate)	26	28	25	23	34
		(kg/ha)		11,473	12,692	11,266	10,179	15,405
		(mg/kg)		5,122	5,666	5,029	4,544	6,877
	Exchangeable Magnesium	(cmol+/kg)		7.7	9.9	4.9	5.1	10
		(kg/ha)		2,097	2,686	1,342	1,392	2,825
		(mg/kg)		936	1,199	599	621	1,261
	Exchangeable Potassium	(cmol+/kg)		0.43	1.5	0.41	0.38	0.91
		(kg/ha)		378	1,291	357	335	801
		(mg/kg)		169	576	160	150	358
	Exchangeable Sodium	(cmol+/kg)		1.9	0.56	1.4	0.22	1.5
		(kg/ha)		979	291	711	111	784
		(mg/kg)		437	130	317	50	350
	Exchangeable Aluminium	(cmol+/kg)	**Inhouse S37 (KCl)	<0.01	<0.01	<0.01	<0.01	<0.01
		(kg/ha)		<1	<1	<1	<1	<1
		(mg/kg)		<1	<1	<1	<1	<1
	Exchangeable Hydrogen	(cmol+/kg)	**Rayment & Lyons 2011 - 15G1 (Acidity Titration)	<0.01	<0.01	<0.01	<0.01	<0.01
		(kg/ha)		<1	<1	<1	<1	<1
		(mg/kg)		<1	<1	<1	<1	<1
	Effective Cation Exchange Capacity (ECEC) (cmol+/kg)		**Calculation: Sum of Ca,Mg,K,Na,Al,H (cmol+/kg)	36	40	32	28	47
	Calcium (%)		**Base Saturation Calculations - Cation cmol+/kg / ECEC x 100	72	70	79	80	73
	Magnesium (%)			22	25	15	18	22
	Potassium (%)			1.2	3.7	1.3	1.3	1.9
	Sodium - ESP (%)			5.3	1.4	4.3	0.76	3.2
	Aluminium (%)			0.01	0.01	0.00	0.02	0.01
	Hydrogen (%)			0.00	0.00	0.00	0.00	0.00
	Calcium/Magnesium Ratio		**Calculation: Calcium / Magnesium (cmol+/kg)	3.3	2.9	5.1	4.4	3.3

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			Sample 26	Sample 27	Sample 28	Sample 29	Sample 30
		Sample ID:	TS-CM-C07	TS-CM-C10	TS-CM-C38/38	TS-CM-C152	TS-CN-C16
		Crop:	soil	soil	soil	soil	soil
		Client:	SLR Consulting Australia Pty Ltd	SLR Consulting Australia Pty Ltd	SLR Consulting Australia Pty Ltd	SLR Consulting Australia Pty Ltd	SLR Consulting Australia Pty Ltd
	Parameter	Method reference	N2045/26	N2045/27	N2045/28	N2045/29	N2045/30
	Zinc (mg/kg)	Rayment & Lyons 2011 - 12A1 (DTPA)	<0.5	<0.5	<0.5	<0.5	<0.5
	Manganese (mg/kg)		5	6	5	8	4
	Iron (mg/kg)		11	7	7	5	7
	Copper (mg/kg)		1.3	2.0	1.1	1.0	1.1
	Boron (mg/kg)	**Rayment & Lyons 2011 - 12C2 (Hot $CaCl_2$)	0.66	0.61	0.93	0.48	0.96
	Total Carbon (%)	Inhouse S4a (LECO Trumac Analyser)	1.59	1.57	1.36	1.20	1.63
	Total Nitrogen (%)		0.14	0.14	0.11	0.12	0.14
	Total Phosphorus (mg/kg)	Rayment & Lyons 2011 - 17C1 Aqua Regia	211	212	161	187	657
	Chloride (mg/kg)	**Rayment & Lyons 2011 - 5A3a	16	16	19	4.6	15
	pH	**Rayment & Lyons 2011 - 4B4 ($CaCl_2$)	7.9	8.0	8.2	8.0	8.1
	Emerson Aggregate Test (EAT)	**AS1289.3.8.1-2017	3	4	3	4	4

Notes:

1. All results presented as a 40°C oven dried weight. Soil sieved and lightly crushed to < 2 mm.
2. Methods from Rayment and Lyons, 2011. *Soil Chemical Methods - Australasia.* CSIRO Publishing: Collingwoo
3. Soluble Salts included in Exchangeable Cations - NO PRE-WASH (unless requested).
4. 'Morgan 1 Extract' adapted from 'Science in Agriculture', 'Non-Toxic Farming' and LaMotte Soil Handbook.
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			Sample 31	Sample 32	Sample 33	Sample 34	Sample 35
		Sample ID:	TS-CN-CN364	TS-CN-CN223	TS-CN-CN342	TS-CN-CN413	TS-CN-CN334
		Crop:	soil	soil	soil	soil	soil
		Client:	SLR Consulting Australia Pty Ltd	SLR Consulting Australia Pty Ltd	SLR Consulting Australia Pty Ltd	SLR Consulting Australia Pty Ltd	SLR Consulting Australia Pty Ltd
	Parameter	Method reference	N2045/31	N2045/32	N2045/33	N2045/34	N2045/35
	Phosphorus (mg/kg P)	**Rayment & Lyons 2011 - 9B2 (Colwell)	8.2	38	58	41	49
	Nitrate Nitrogen (mg/kg N)	**Inhouse S37 (KCl)	1.3	81.4	10.0	3.5	5.7
	pH	Rayment & Lyons 2011 - 4A1 (1:5 Water)	8.8	7.5	7.6	8.4	8.3
	Electrical Conductivity (dS/m)	Rayment & Lyons 2011 - 3A1 (1:5 Water)	0.066	0.259	0.079	0.072	0.090
	Exchangeable Calcium (cmol+/kg)	Rayment & Lyons 2011 - 15D3 (Ammonium Acetate)	6.6	10	13	11	21
	Exchangeable Calcium (kg/ha)		2,942	4,615	5,727	4,933	9,642
	Exchangeable Calcium (mg/kg)		1,314	2,060	2,557	2,202	4,304
	Exchangeable Magnesium (cmol+/kg)		0.93	3.3	5.4	2.4	9.3
	Exchangeable Magnesium (kg/ha)		254	893	1,460	646	2,543
	Exchangeable Magnesium (mg/kg)		113	398	652	288	1,135
	Exchangeable Potassium (cmol+/kg)		<0.12	0.44	0.99	0.36	0.62
	Exchangeable Potassium (kg/ha)		<112	381	864	316	540
	Exchangeable Potassium (mg/kg)		<50	170	386	141	241
	Exchangeable Sodium (cmol+/kg)		0.12	0.54	0.36	0.17	1.3
	Exchangeable Sodium (kg/ha)		60	278	187	87	652
	Exchangeable Sodium (mg/kg)		27	124	83	39	291
	Exchangeable Aluminium (cmol+/kg)	**Inhouse S37 (KCl)	<0.01	<0.01	<0.01	<0.01	<0.01
	Exchangeable Aluminium (kg/ha)		<1	<1	<1	<1	<1
	Exchangeable Aluminium (mg/kg)		<1	<1	<1	<1	<1
	Exchangeable Hydrogen (cmol+/kg)	**Rayment & Lyons 2011 - 15G1 (Acidity Titration)	<0.01	<0.01	<0.01	<0.01	<0.01
	Exchangeable Hydrogen (kg/ha)		<1	<1	<1	<1	<1
	Exchangeable Hydrogen (mg/kg)		<1	<1	<1	<1	<1
	Effective Cation Exchange Capacity (ECEC) (cmol+/kg)	**Calculation: Sum of Ca,Mg,K,Na,Al,H (cmol+/kg)	7.7	15	19	14	33
	Calcium (%)	**Base Saturation Calculations - Cation cmol+/kg / ECEC x 100	85	71	66	79	66
	Magnesium (%)		12	23	28	17	29
	Potassium (%)		1.5	3.0	5.1	2.6	1.9
	Sodium - ESP (%)		1.5	3.7	1.9	1.2	3.9
	Aluminium (%)		0.05	0.02	0.01	0.02	0.01
	Hydrogen (%)		0.00	0.00	0.00	0.00	0.00
	Calcium/Magnesium Ratio	**Calculation: Calcium / Magnesium (cmol+/kg)	7.0	3.1	2.4	4.6	2.3

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10 Kings Road NEW LAMBTON NSW 2305

			Sample 31	Sample 32	Sample 33	Sample 34	Sample 35
		Sample ID:	TS-CN-CN364	TS-CN-CN223	TS-CN-CN342	TS-CN-CN413	TS-CN-CN334
		Crop:	soil	soil	soil	soil	soil
		Client:	SLR Consulting Australia Pty Ltd	SLR Consulting Australia Pty Ltd	SLR Consulting Australia Pty Ltd	SLR Consulting Australia Pty Ltd	SLR Consulting Australia Pty Ltd
	Parameter	Method reference	N2045/31	N2045/32	N2045/33	N2045/34	N2045/35
	Zinc (mg/kg)	Rayment & Lyons 2011 - 12A1 (DTPA)	<0.5	<0.5	<0.5	<0.5	<0.5
	Manganese (mg/kg)		3	6	6	4	6
	Iron (mg/kg)		12	12	9	4	10
	Copper (mg/kg)		0.4	0.5	0.8	0.5	0.9
	Boron (mg/kg)	**Rayment & Lyons 2011 - 12C2 (Hot $CaCl_2$)	0.35	0.39	0.36	0.31	1.05
	Total Carbon (%)	Inhouse S4a (LECO Trumac Analyser)	0.47	0.87	1.23	0.77	1.28
	Total Nitrogen (%)		0.05	0.08	0.09	0.06	0.09
	Total Phosphorus (mg/kg)	Rayment & Lyons 2011 - 17C1 Aqua Regia	138	356	432	439	405
	Chloride (mg/kg)	**Rayment & Lyons 2011 - 5A3a	10	124	38	11	11
	pH	**Rayment & Lyons 2011 - 4B4 ($CaCl_2$)	8.2	7.1	7.0	7.8	7.4
	Emerson Aggregate Test (EAT)	**AS1289.3.8.1-2017	3	4	3	3	3

Notes:

1. All results presented as a 40°C oven dried weight. Soil sieved and lightly crushed to < 2 mm.
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13. ** NATA accreditation does not cover the performance of this service.
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16. All services undertaken by EAL are covered by the EAL Laboratory Services Terms and Condit
17. This report was issued on 5/10/2022 and replaces the report published 14/09/2022. Total ca

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AGRICULTURAL SOIL ANALYSIS REPORT

39 samples supplied by SLR Consulting Australia Pty Ltd on 25/08/2022. Lab Job No.N2045
Analysis requested by Michelle Papenfus. Your Job: SLR 630.30341 Curragh
10 Kings Road NEW LAMBTON NSW 2305

			Sample 36	Sample 37	Sample 38	Sample 39
		Sample ID:	TS-CN-CN93	TS-CN-CN320	TS-CN-CN369/370	TS-CM-C26
		Crop:	soil	soil	soil	soil
		Client:	SLR Consulting Australia Pty Ltd	SLR Consulting Australia Pty Ltd	SLR Consulting Australia Pty Ltd	SLR Consulting Australia Pty Ltd
	Parameter	Method reference	N2045/36	N2045/37	N2045/38	N2045/39
	Phosphorus (mg/kg P)	**Rayment & Lyons 2011 - 9B2 (Colwell)	26	58	16	20
	Nitrate Nitrogen (mg/kg N)	**Inhouse S37 (KCl)	0.7	0.9	1.2	4.4
	pH	Rayment & Lyons 2011 - 4A1 (1:5 Water)	8.9	8.1	7.7	9.0
	Electrical Conductivity (dS/m)	Rayment & Lyons 2011 - 3A1 (1:5 Water)	0.123	0.088	0.035	0.266
	Exchangeable Calcium (cmol+/kg)	Rayment & Lyons 2011 - 15D3 (Ammonium Acetate)	23	19	2.9	24
	Exchangeable Calcium (kg/ha)		10,251	8,334	1,288	10,810
	Exchangeable Calcium (mg/kg)		4,576	3,720	575	4,826
	Exchangeable Magnesium (cmol+/kg)		12	8.0	1.2	8.6
	Exchangeable Magnesium (kg/ha)		3,192	2,187	336	2,352
	Exchangeable Magnesium (mg/kg)		1,425	976	150	1,050
	Exchangeable Potassium (cmol+/kg)		0.51	1.3	0.29	0.57
	Exchangeable Potassium (kg/ha)		445	1,176	250	497
	Exchangeable Potassium (mg/kg)		199	525	112	222
	Exchangeable Sodium (cmol+/kg)		1.7	0.76	0.11	3.5
	Exchangeable Sodium (kg/ha)		883	392	57	1,819
	Exchangeable Sodium (mg/kg)		394	175	26	812
	Exchangeable Aluminium (cmol+/kg)	**Inhouse S37 (KCl)	<0.01	<0.01	<0.01	<0.01
	Exchangeable Aluminium (kg/ha)		<1	<1	<1	<1
	Exchangeable Aluminium (mg/kg)		<1	<1	<1	<1
	Exchangeable Hydrogen (cmol+/kg)	**Rayment & Lyons 2011 - 15G1 (Acidity Titration)	<0.01	<0.01	<0.01	<0.01
	Exchangeable Hydrogen (kg/ha)		<1	<1	<1	<1
	Exchangeable Hydrogen (mg/kg)		<1	<1	<1	<1
	Effective Cation Exchange Capacity (ECEC) (cmol+/kg)	**Calculation: Sum of Ca,Mg,K,Na,Al,H (cmol+/kg)	37	29	4.5	37
	Calcium (%)	**Base Saturation Calculations - Cation cmol+/kg / ECEC x 100	62	65	64	65
	Magnesium (%)		32	28	27	23
	Potassium (%)		1.4	4.7	6.3	1.5
	Sodium - ESP (%)		4.7	2.6	2.5	9.6
	Aluminium (%)		0.00	0.00	0.01	0.00
	Hydrogen (%)		0.00	0.00	0.00	0.00
	Calcium/Magnesium Ratio	**Calculation: Calcium / Magnesium (cmol+/kg)	1.9	2.3	2.3	2.8

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Crop:		soil	soil	soil	soil
Client:		SLR Consulting Australia Pty Ltd	SLR Consulting Australia Pty Ltd	SLR Consulting Australia Pty Ltd	SLR Consulting Australia Pty Ltd
	Parameter	Method reference	N2045/36	N2045/37	N2045/38	N2045/39
	Zinc (mg/kg)	Rayment & Lyons 2011 - 12A1 (DTPA)	0.6	<0.5	<0.5	<0.5
	Manganese (mg/kg)		2	5	5	5
	Iron (mg/kg)		6	11	8	9
	Copper (mg/kg)		1.1	0.9	0.4	1.2
	Boron (mg/kg)	**Rayment & Lyons 2011 - 12C2 (Hot $CaCl_2$)	0.85	0.67	0.34	1.38
	Total Carbon (%)	Inhouse S4a (LECO Trumac Analyser)	2.17	1.20	0.42	1.27
	Total Nitrogen (%)		0.11	0.09	0.05	0.09
	Total Phosphorus (mg/kg)	Rayment & Lyons 2011 - 17C1 Aqua Regia	726	492	278	309
	Chloride (mg/kg)	**Rayment & Lyons 2011 - 5A3a	25	8.4	19	82
	pH	**Rayment & Lyons 2011 - 4B4 ($CaCl_2$)	8.1	7.4	7.1	8.3
	Emerson Aggregate Test (EAT)	**AS1289.3.8.1-2017	3	3	3	2

Notes:

1. All results presented as a 40°C oven dried weight. Soil sieved and lightly crushed to < 2 mm.
2. Methods from Rayment and Lyons, 2011. *Soil Chemical Methods - Australasia*. CSIRO Publishing: Collingwo
3. Soluble Salts included in Exchangeable Cations - NO PRE-WASH (unless requested).
4. 'Morgan 1 Extract' adapted from 'Science in Agriculture', 'Non-Toxic Farming' and LaMotte Soil Handbook.
5. Guidelines for phosphorus have been reduced for Australian soils.
6. Indicative guidelines are based on 'Albrecht' and 'Reams' concepts.
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APPENDIX G

Groundwater Report

CURRAGH MINE PRCP

Groundwater Technical Appendix

Prepared for:
Coronado Curragh Pty Ltd
Blackwater, QLD, 4717



SLR Ref: 626.30075.00000 -R01
Version No: -v2.0
September 2022

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BASIS OF REPORT

This report has been prepared by SLR Consulting Australia Pty Ltd (SLR) with all reasonable skill, care and diligence, and taking account of the timescale and resources allocated to it by agreement with Coronado Curragh Pty Ltd (the Client). Information reported herein is based on the interpretation of data collected, which has been accepted in good faith as being accurate and valid.

This report is for the exclusive use of the Client. No warranties or guarantees are expressed or should be inferred by any third parties. This report may not be relied upon by other parties without written consent from SLR.

SLR disclaims any responsibility to the Client and others in respect of any matters outside the agreed scope of the work.

DOCUMENT CONTROL

Reference	Date	Prepared	Checked	Authorised
626.30075 -R01-v1.0	14 September 2022	Dariarne Edwards Arash Mohajeri Maryam Kahe John Barlow	Arash Mohajeri John Barlow	Emma Williams

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APPENDICES

Appendix A Groundwater Quality
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1 Introduction

In September 2021 SLR was engaged by Coronado Curragh Pty Ltd (CCPL) to provide a Progressive Rehabilitation and Closure Plan (PRCP) for the Curragh Mine Complex (the mine). In support of the PRCP a groundwater assessment of the mine and final landforms has been undertaken including two key components, a conceptual hydrogeological model and numerical groundwater modelling. The objective of the groundwater assessment is to understand the post closure groundwater regime around the mine, and specifically to:

- present an understanding of the hydrogeological setting of the mine including potential groundwater receptors
- Simulate the post mining groundwater level recovery using the final landform (mine void backfill levels) developed by Coronado to understand whether the final voids act as groundwater sinks or sources; and;
- Understand the long-term effect of the proposed post mining landform on local groundwater levels i.e., the residual drawdown, and post-mining groundwater flux.

This assessment is based partly on the Groundwater Technical Report prepared for Wesfarmers Resources Pty Ltd by WSP prepared for approval of the Curragh Extension Project (WSP 2016). The WSP assessment includes a comprehensive hydrogeological conceptualisation for the mine which was peer reviewed by HydroSimulations (2016). A new numerical model has been developed for the site by SLR as part of the PRCP submission and includes the proposed expansion pits as well as incorporating the final landforms that were designed in 2021 for the Concept Residual Void Assessment (SLR 2021).

Section 2 of this report presents a summary of the hydrogeological setting of the mine and conceptual hydrogeological model. Section 3 presents an overview of the numerical groundwater model setup and development, including model calibration and prediction. Section 4 describes the post closure modelling and groundwater recovery including the long term post-closure groundwater levels compared to pre mining conditions i.e., the residual drawdown. Conclusions, recommendations, and limitations are presented in Section 5.

2 Conceptual Hydrogeological Model

2.1 Physical Setting

The Curragh Mine is located in Central Queensland within the Fitzroy Basin in an area dominated by grazing, farming and coal mining. The mine extends across an area from approximately 3 km to 35 km north of the township of Blackwater, with one of the proposed expansion pits (Pit Z) located 5km to the WNW of Blackwater. Neighbouring mines include Blackwater to the southwest of Blackwater Township, Mackenzie South located approximately 2.5 km east of Curragh and Jellinbah Central located approximately 5.5 km east of Curragh.

Figure 2-1 shows the mine location in the context of the local area, drainage, surrounding mines, topography as well as the general mine layout and pit configuration.

The site is broadly divided into Curragh North (Pits S, T, U and associated spoil dumps); Curragh Main (Pits A & B (both TSFs), C, D, E, F, G, H and I), and the expansion areas (Pits X, Y, Z, J and Ramp 9), where mining has not yet commenced. Mining at Curragh is projected to end in 2038.

2.1.1 Topography and land use

The land surrounding the mine is typically gently undulating and partly sits within the floodplain of Mackenzie River. The topography of the area is dominated by the major drainage features (Mackenzie River and tributaries), ephemeral drainage lines, and the open cut pits and spoil dumps of Curragh Mine and neighbouring mines. Topography and drainage near the Project area is shown on Figure 2-1.

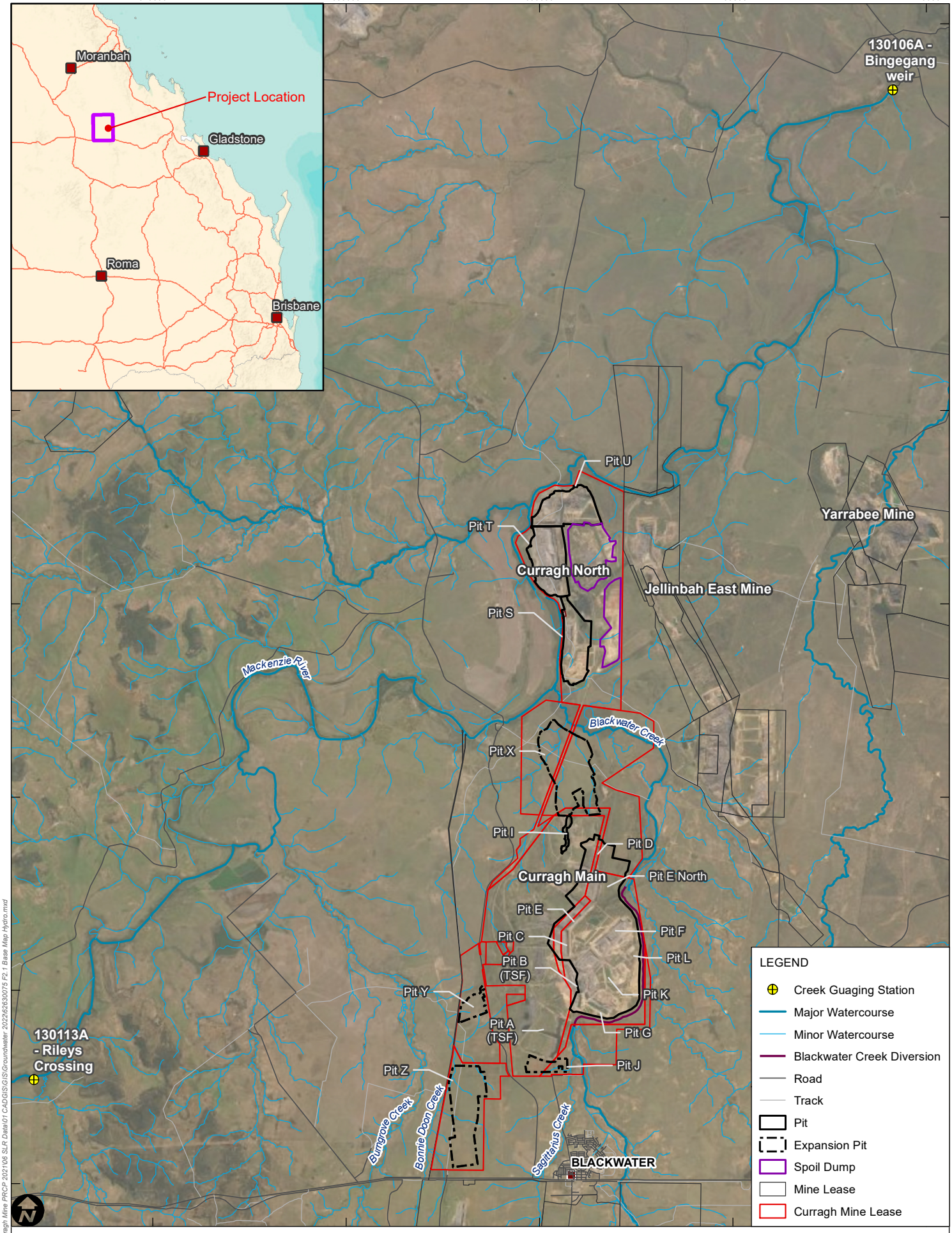
Aside from the Township of Blackwater to the south of Curragh, and the surrounding mines, land use is rural with large areas predominantly turned over to livestock grazing with some dryland cropping and minor irrigated cropping adjacent to Mackenzie River.

2.1.2 Climate

The climate of the region is subtropical with the highest rainfall and evaporation occurring from October through till March (BoM, 2021). Historical climate data was obtained for the period January 1900 to September 2021 from the Scientific Information for Landowners (SILO) database (Queensland Government, 2021) for the location of the Project area (latitude -23.5, longitude 148.9). Table 2-1 outlines the total monthly average rainfall and evaporation. The data shows that the total potential average annual evaporation (2,054 mm/yr) is almost four times annual rainfall (565 mm/yr). The high annual evaporation rates are strongly related to seasonal temperatures (Figure 2-2).

Table 2-1 Total Monthly Rainfall and Evaporation (January 1900 to August 2021)

Average Total Monthly (mm)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Rainfall	93	88	58	30	29	29	24	16	21	42	56	80	565
Evaporation	229	184	190	151	118	94	103	132	173	214	226	240	2,054



H:\Projects-SLR\626-MKY\626.30075.00000 Curragh Mine PRCP 2021106 SLR Data\01 CAD\GIS\GIS\Groundwater 20226263075 F2.1 Base Map Hydro.mxd

SLR

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0 5 10 km

Coordinate System:	AGD 1984 AMG Zone 55
Scale:	1:250,000 at A4
Project Number:	626.30075
Date:	17-Oct-2022
Drawn by:	ML
Reviewed by:	ML

CURRAGH PRCP GROUNDWATER ASSESSMENT

Curragh Mine Location and Layout

FIGURE 2-1

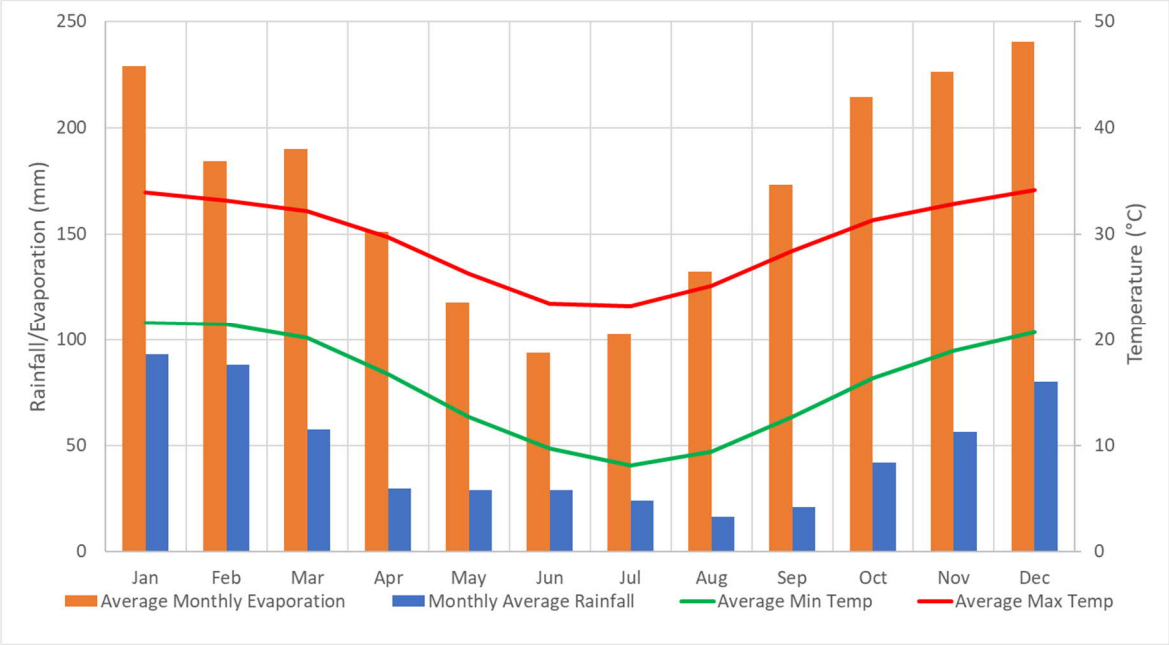


Figure 2-2 Average Monthly Evaporation, Rainfall and Temperature (January 1900 to August 2021)

In order to assess rainfall over recent years within a longer term context, the cumulative rainfall departure (CRD) was calculated for the data period 1900 to 2021 (Figure 2-3). The CRD is a summation of difference between the actual monthly rainfall compared to the average monthly for the same period. A rising slope in the CRD indicates periods of rainfall above the long term average (e.g., 2010 to 2012), and a falling slope indicates periods when rainfall is below the long term average (e.g., 1999 to 2007). Rainfall volumes over more recent years of the record (2017 to 2021) have been lower than average, as is indicated by the falling slope in the CRD.

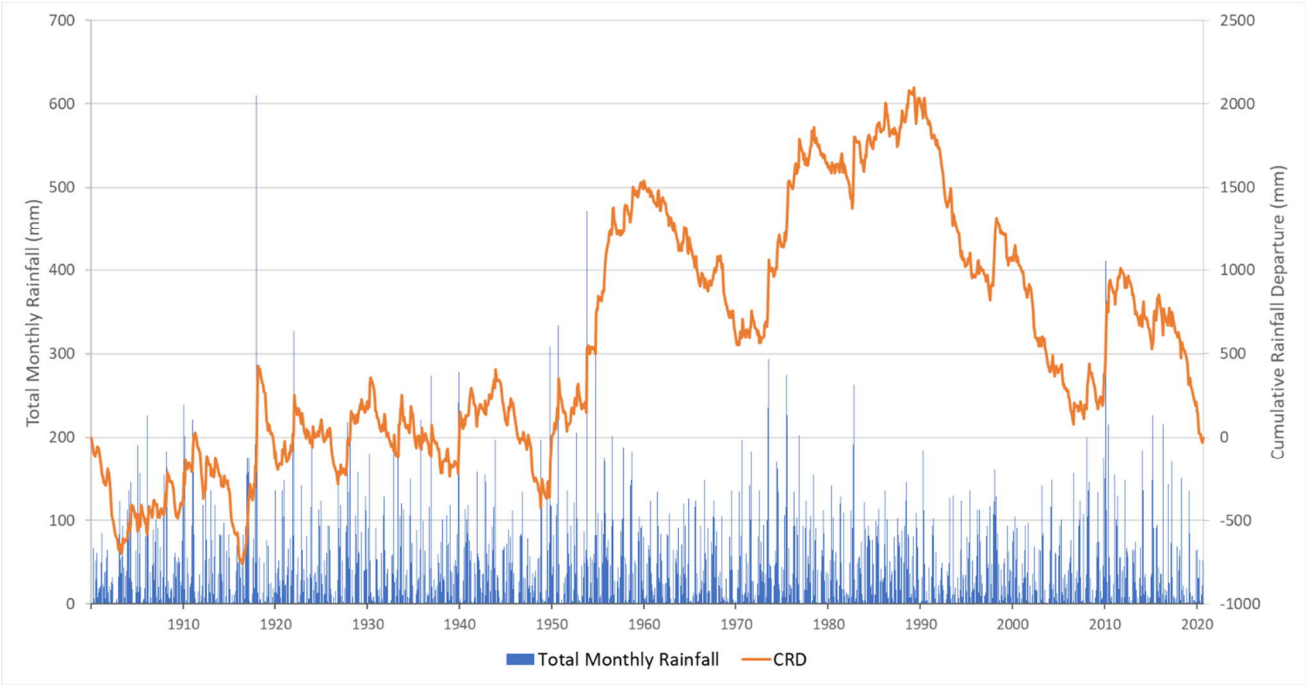


Figure 2-3 Cumulative Rainfall Departure and Total Monthly Rainfall (1900-2021)

Since the start of mining in 1983 the area has generally seen lower than average rainfall except for the remainder of the 1980s and significant wet seasons in late 1998 and 2010/11.

2.1.3 Hydrology

2.1.3.1 Mackenzie River

The mine extends across the floodplain of the Mackenzie River and its tributaries. The Mackenzie River forms at the confluence of the Nogoa and Comet rivers, 30km west of Blackwater and is the main watercourse in the area and a major tributary of the Fitzroy River. The total catchment area of Mackenzie River to Bingegang Weir (25km downstream of the mine), is approximately 51,000 square km. To the northwest of the mine the Mackenzie River floodplain is a relatively flat, with the current course of the river meandering through a tract of alluvium approximately 3 to 8 km wide.

Fairbairn Dam located upstream on the Nogoa River approximately 80km WSW of Blackwater stores 1,300 gigalitres (GL) when full. Releases from the dam maintain levels downstream so that various towns, mines and irrigators can be supplied. This regulation of the Mackenzie River has altered the natural flow regime.

Figure 2-4 presents flow duration curves for the gauge at Riley's Crossing (130113A) 25km west of Blackwater, and for Bingegang weir (130106A) 25km north-west (downstream) of the northern extent of the mine. The data indicates that higher flows mostly driven by rainfall over the catchment naturally result in increasing flows downstream with Bingegang recording higher flows than Riley's Crossing upstream when flows at both gauges are above ~200 ML/d. Below ~200 ML/d the effects of river regulation by releases from Fairburn Dam and downstream extraction / losses appear to be apparent with perennial flow recorded at Riley's Crossing whilst downstream at Bingegang there appears to be no flow over the weir 70% of the time.

The main tributaries of Mackenzie River in the study area include Blackwater Creek, Burngrove Creek, Cooroora Creek and Scrub Creek.

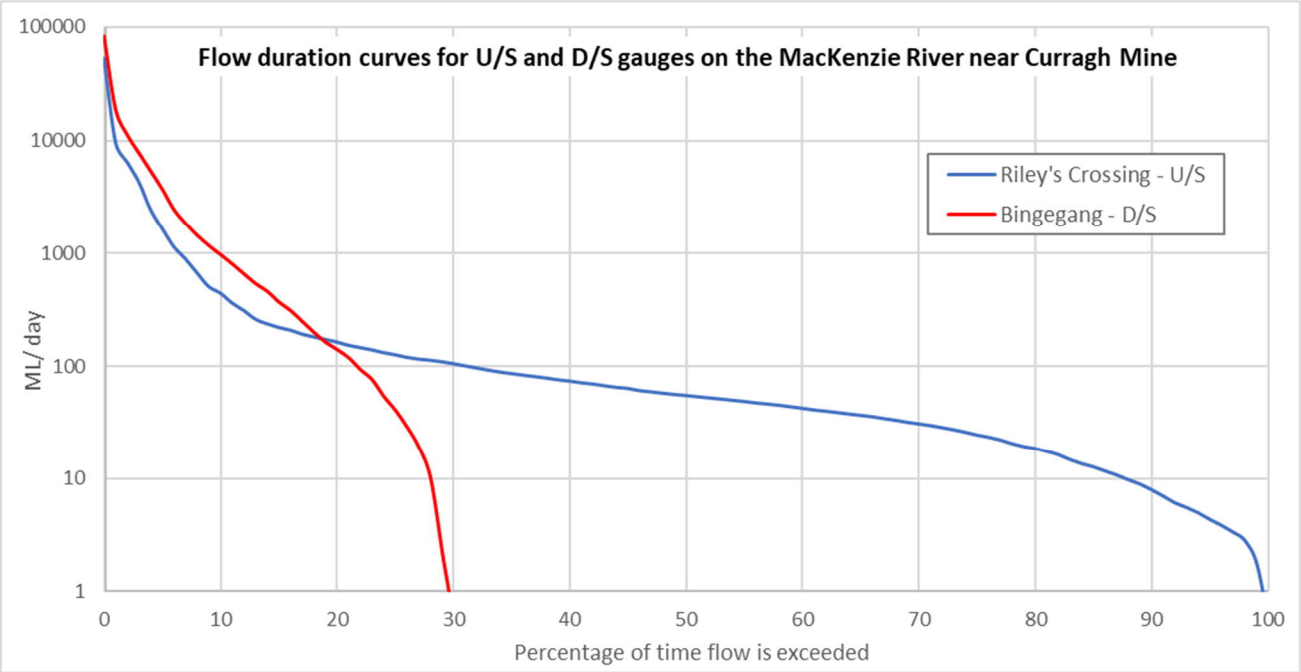


Figure 2-4 Flow Duration Curves for Gauging Stations on the Mackenzie River in the Vicinity of Curragh Mine (Nov 2013 – Oct 2021)

2.1.3.2 Blackwater Creek and tributaries

The main tributary of Mackenzie River in the study area is Blackwater Creek, which flows in a northerly direction to the east of Curragh Main via a major diversion around Pits J, K, L, F, and E. Blackwater Creek is naturally ephemeral although at its upstream end, it constantly flows due to discharge of treated effluent from Blackwater Wastewater Treatment Plant into Sagittarius Creek between Blackwater and the mine (PB 2016).

Blackwater Creek is highly modified having been diverted several times to accommodate mining at Curragh. The current Blackwater Creek diversion is a 9 km long engineered drainage structure made of compacted earth vegetated with grasses and shrubs. The discharge from Blackwater WTP is observed along the extent of the diversion although not north of the diversion (PB 2016).

Just downstream of the diversion around Curragh Main and to the east of the proposed Pit X Blackwater Creek becomes an ephemeral braided channel system.

Tributaries of Blackwater Creek include Taurus Creek, Sagittarius Creek, Minnie Creek and Bullock Creek, all of which are ephemeral. Minnie Creek flows through the proposed Pit X area and will be subject to a 5.3 km diversion near its confluence with Blackwater Creek plus a 2.9 km diversion of one of its unnamed tributaries around the western side of the pit prior to the commencement of mining in this area (PB 2016).

2.1.3.3 Burngrove Creek and tributaries

Other tributaries of Mackenzie River in the Project area include Burngrove Creek. A tributary of Burngrove Creek is Bonnie Doon Creek, which flows in a northerly direction to the west of proposed Pit Z and will be subject to a diversion. Both Burngrove Creek and Bonnie Doon Creek are ephemeral.

2.1.4 Geology

The surface geology across the study area (based on 1:100,000 published mapping), is presented in Figure 2-5 and the regional (solid) geology is presented in Figure 2-6

The study area is underlain by gently folded Permo-Triassic strata within the Bowen Basin overlain by Tertiary and Quaternary sediments. The Permo-Triassic strata, which are heavily faulted in places, dip eastward and include the Triassic Rewan Formation and the underlying Permian Blackwater Group, which includes the Rangal Coal Measures, Burngrove Formation and Fair Hill Formation. The overlying sediments comprise unconsolidated Quaternary alluvium associated with creeks, rivers and floodplains and the poorly consolidated Tertiary sediments of the Duaringa and Emerald formations. The Back Creek Group underlies the Blackwater Group and forms the basement of the area.

The stratigraphic sequence underlying the area is presented in Table 2-2 and summarised below.

2.1.4.1 Quaternary and Tertiary alluvium

Alluvium associated with the main watercourses of the Mackenzie River and Blackwater Creek (and their tributaries) is present across much of Curragh North and parts of Curragh Main and the proposed expansion pits.

In the proposed Pit X area, exploration drilling indicates the alluvium is typically less than 12m thick and predominantly comprised of clay with occasional sand and gravel lenses / channels at depth. Alluvium in the vicinity of proposed Pit J and Pit Z is generally thin (typically 2m but up to 4m) and comprised of clay and silt. Alluvium occurs in the southeast corner of proposed Pit D extension and is typically less than 2m (and up to 10m) and comprised of clay and sand (WSP 2016).

Floodplain alluvium associated with the Mackenzie River occurs extensively at Curragh North and exhibits an overall fining upwards sequence and significant lateral variability with an average thickness of 18 - 20m. Drilling data indicates the alluvium may be up to 35 m thick and the base of the alluvium is deepest close to the Mackenzie River (WSP 2016).

Table 2-2 Regional Stratigraphy

Age	Group	Stratigraphic Unit	Description
Quaternary		Alluvium	Soils, unconsolidated silts, sands, gravels and clays,
Cenozoic (Tertiary)		Duaringa Formation/ Emerald Formation	Claystone, siltstone, sandstone, conglomerate (often poorly consolidated), lignite, basalt
Triassic	Mimosa	Rewan Formation	Mudstone, interbeds of lithic sandstone.
Upper Permian	Blackwater Group	Rangal Coal Measures	Coal seams calcareous sandstone, calcareous shale, mudstone, calcareous tuff in places. Main coal seams include Aries, Castor, Pollux, Orion, Pisces.
		Burngrove Formation	Siltstone, carbonaceous shales and mudstone, fine lithic sandstone, calcareous lithic and feldspathic sandstone, tuffaceous shales and thin coal seams.
		Fair Hill Formation	Lithic and feldspathic labile sandstone, quartzose sublabile sandstone, siltstone, mudstone, calcareous and tuffaceous sandstone, volcanic conglomerate, carbonaceous mudstone, coal
Permian	Back Creek Group	Macmillan Formation	Interbedded mudstone and sandstone, prominent dark grey basal unit.

2.1.4.2 Cenozoic sediments

The Duaringa Formation is present in the proposed Pit X and Pit D extension areas and outcrops extensively in the north, east and south of the study area. In the north of the study area the Cenozoic sediments have been eroded by the Mackenzie River. The Emerald Formation is present in the western section of the proposed Pit X area and outcrop in the west of the study area (WSP 2016).

The Cenozoic sediments consist of interbedded stiff to hard clayey sands, gravels and thick beds of ferruginous clays of medium to high plasticity. They are fluvial and colluvial in origin and partially consolidated. The sequence unconformably overlies Permian coal measures with an indistinct boundary due to the clay rich and ferruginous composition of both horizons caused by in-situ weathering (WSP 2016).

2.1.4.3 Triassic sediments

The Rewan Formation overlies the Rangal Coal Measures and outcrops / subcrops directly east of the mined areas. It typically comprises thinly interbedded mudstones, lithic sandstones and siltstones. Drilling in the Minyango mine area recorded Rewan Formation up to 350m thick with a depth of weathering between 30 and 70 m (WSP 2016).

2.1.4.4 Permian sediments

The Permian Rangal Coal Measures (RCM) is the uppermost sequence in the Blackwater Group and comprises predominantly fine grained to occasionally medium grained lithic sandstone, siltstone, mudstone, carbonaceous mudstone and coal.

The RCM contain seams of high quality PCI coal, high quality medium-to-low ash coals suitable for prime coking coal, anthracite, semi-anthracite, and high energy thermal coals. The Cancer, Aries, Castor, Pollux, Orion and Pisces seams within the RCM are mined at Curragh. The strata generally dip to the east at less than 3°, with dips increasing locally in fault zones. The Rangal Coal Measures outcrop / subcrop in Curragh North and Curragh Main areas. The Rangal Coal Measures also subcrop east (the upthrow side) of the Jellinbah Fault where they are extracted at Jellinbah Mine (WSP 2016).

The boundary between the Burngrove Formation and the overlying RCM is the Yarrabee Tuff Bed, a distinctive marker horizon. The tuff lies between the target Pisces seam in the RCM and the Pisces Lower seam. The upper part of the Burngrove Formation (below the Yarrabee Tuff Bed and Pisces Lower seam), comprise dark grey to grey mudstones grading to siltstones. The Burngrove Formation outcrops/subcrops in the proposed Pit X, Y and Z locations and to the west of Curragh Mine (WSP 2016).

The Fair Hill Formation underlies the Burngrove Formation and outcrops/subcrops to the west of the mine. The formation comprises lithic sandstone, conglomerate, mudstone, carbonaceous shale, coal, tuff and tuffaceous mudstone and includes the Fort Cooper Coal Measures.

The upper Permian sediments are weathered. The depth of weathering in the study area is approximately 14 metres below ground level (mbgl), except where Quaternary erosion and deposition has resulted in the replacement of Permian sediments by Quaternary alluvium. Where this occurs deeper weathering up to 35 mbgl is observed (WSP 2016).

2.1.5 Structural geology

The mine is located within an area of the Bowen Basin subject to faulting and gentle folding. The study area lies on the eastern limb of the Comet Ridge, adjacent to the Folded Zone within the Bowen Basin. This ridge was formed over an existing basement platform, creating a regional anticlinal structure with low amplitude and gentle folds (WSP 2016).

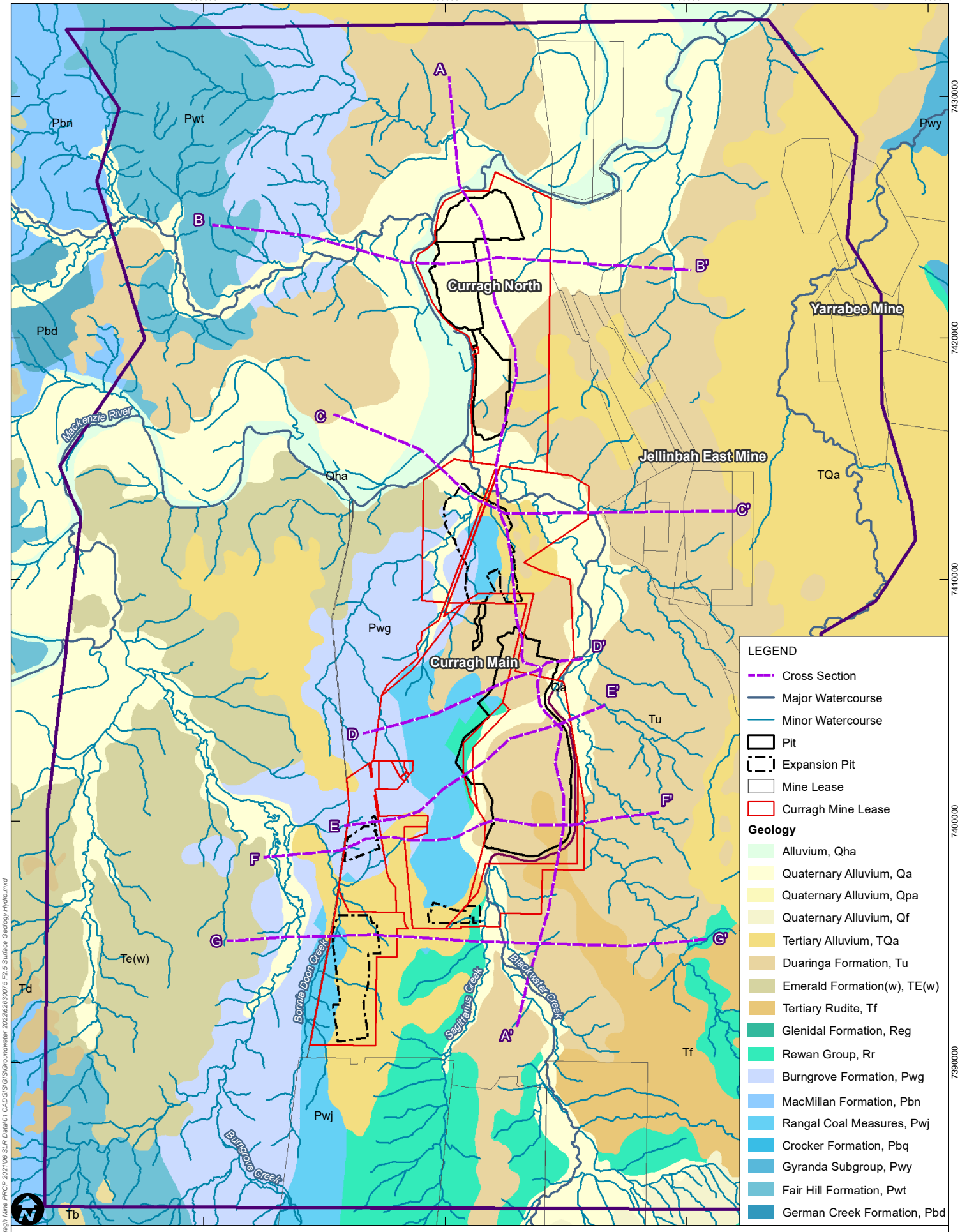
The NNW-SSE trending Jellinbah Fault is located directly east of Curragh North and approximately 5 km east of Curragh Main. It is the major fault structure in the Curragh Mine region. The fault has an approximate vertical displacement of 120 m brining the RCM back up to depths that allows the Jellinbah Mine to target the associated coal seams.

The RCM in the vicinity of the mine have been affected by low angle thrust faulting from the north-east and results in seam displacements up to 20 m vertically. Fault deformation has resulted in seam thinning, seam repetitions and absenting occurring throughout the Curragh Mine (PB 2016).

2.1.5.1 Geological Cross-sections

Cross-sections showing the geology of the study area have been developed using the geological model for the site together with LiDAR (current and pre mining). The sections also show and final landforms / voids, approximate pre-mining and post-mining groundwater levels / void lake levels, tailings storages and the locations of other potentially sources of groundwater contamination (landfills and infrastructure areas).

The locations of the cross-sections are shown on Figure 2-5, and comprise a north-south long section (A-A' Figure 2-7), and several east-west sections (B-B' Figure 2-8, C-C' Figure 2-9, and D-D' Figure 2-10, E-E' Figure 2-11, F-F' Figure 2-12, G-G' Figure 2-13)



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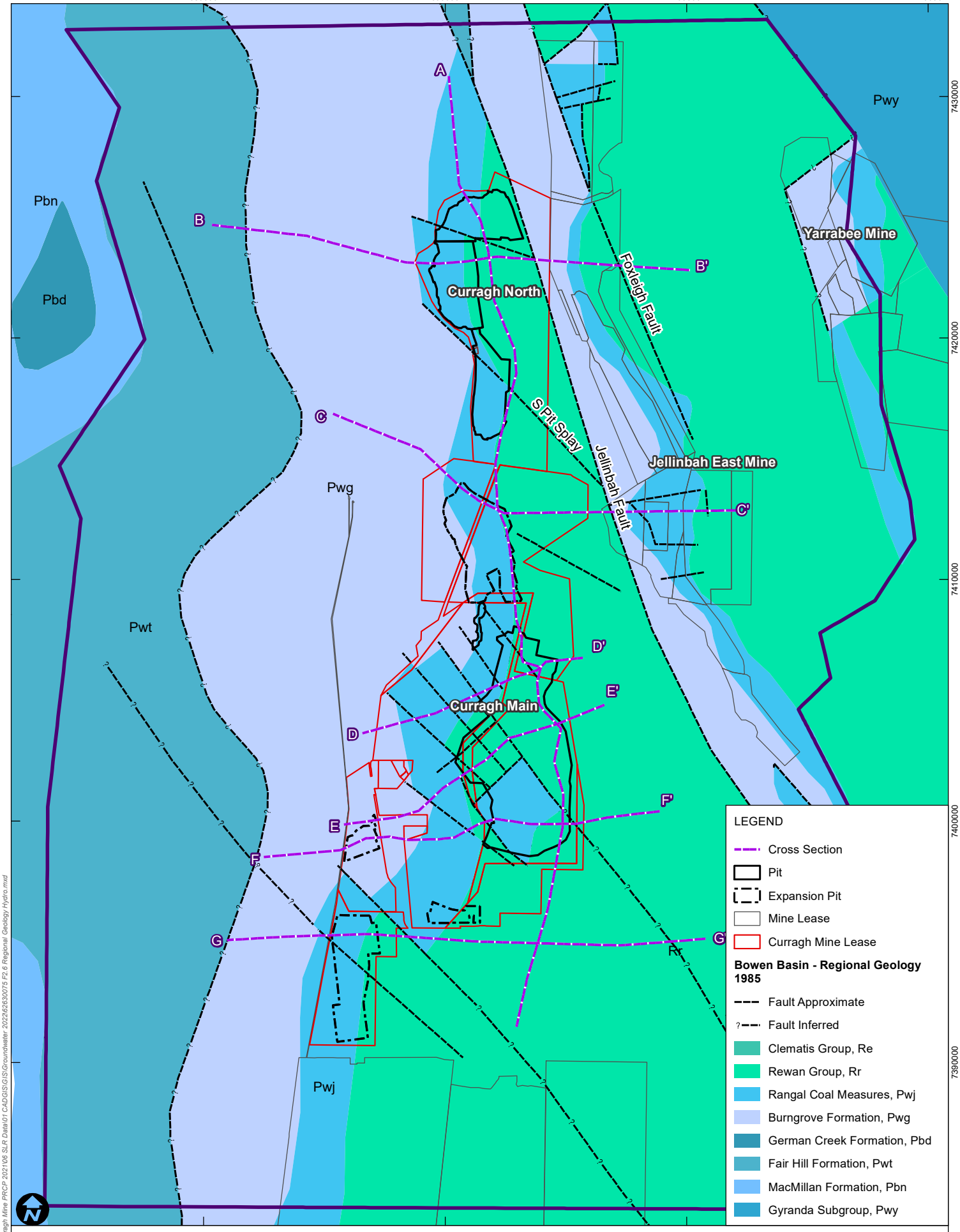
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Scale:	1:200,000 at A4
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Date:	17-Oct-2022
Drawn by:	ML
Reviewed by:	ML

CURRAGH PRCP GROUNDWATER ASSESSMENT

Surface Geology

FIGURE 2-5

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CURRAGH PRCP GROUNDWATER ASSESSMENT

Regional Geology

FIGURE 2-6

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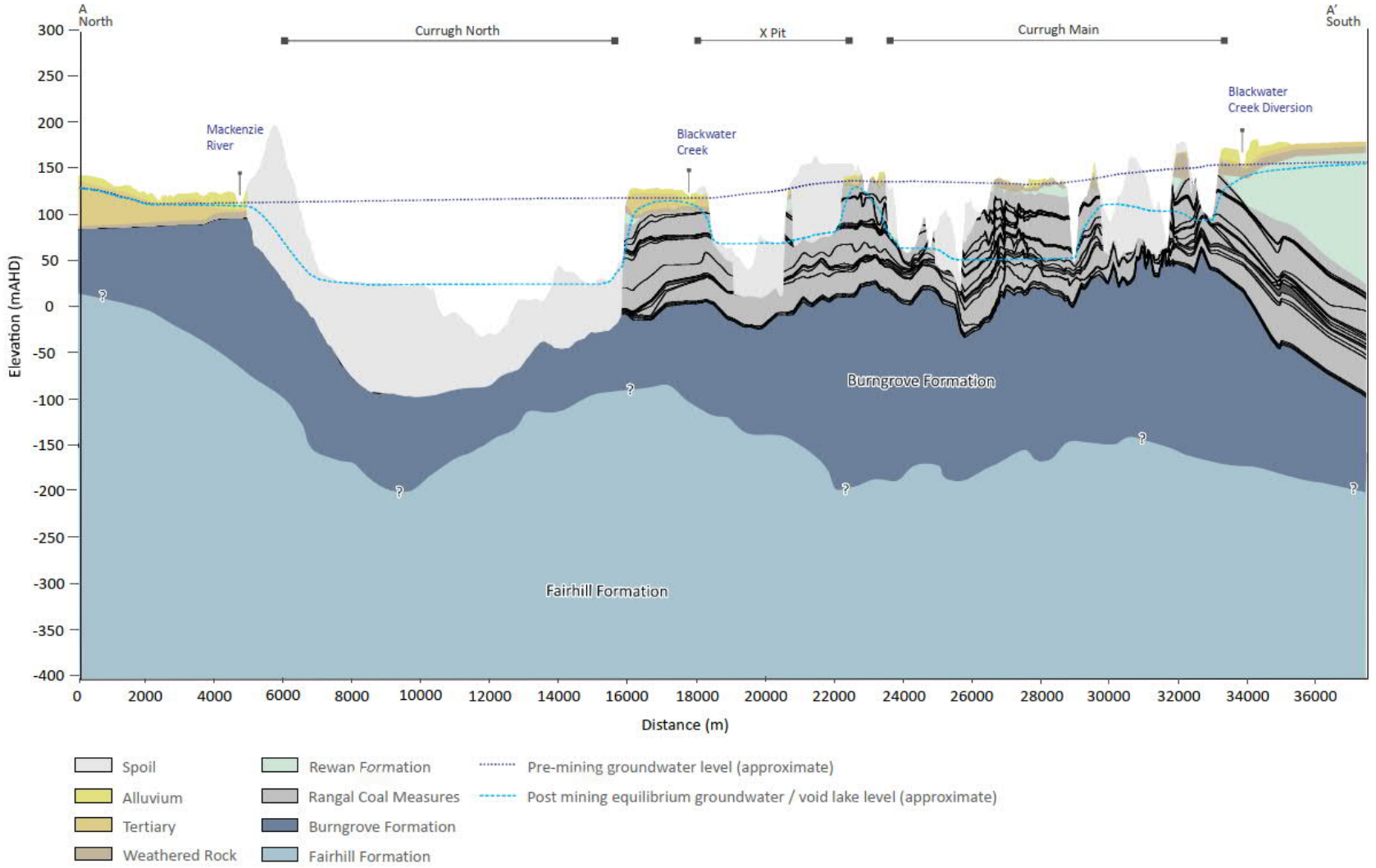


Figure 2-7 Geological cross-section A-A' of Curragh Mine Complex showing final landforms/voids and groundwater levels

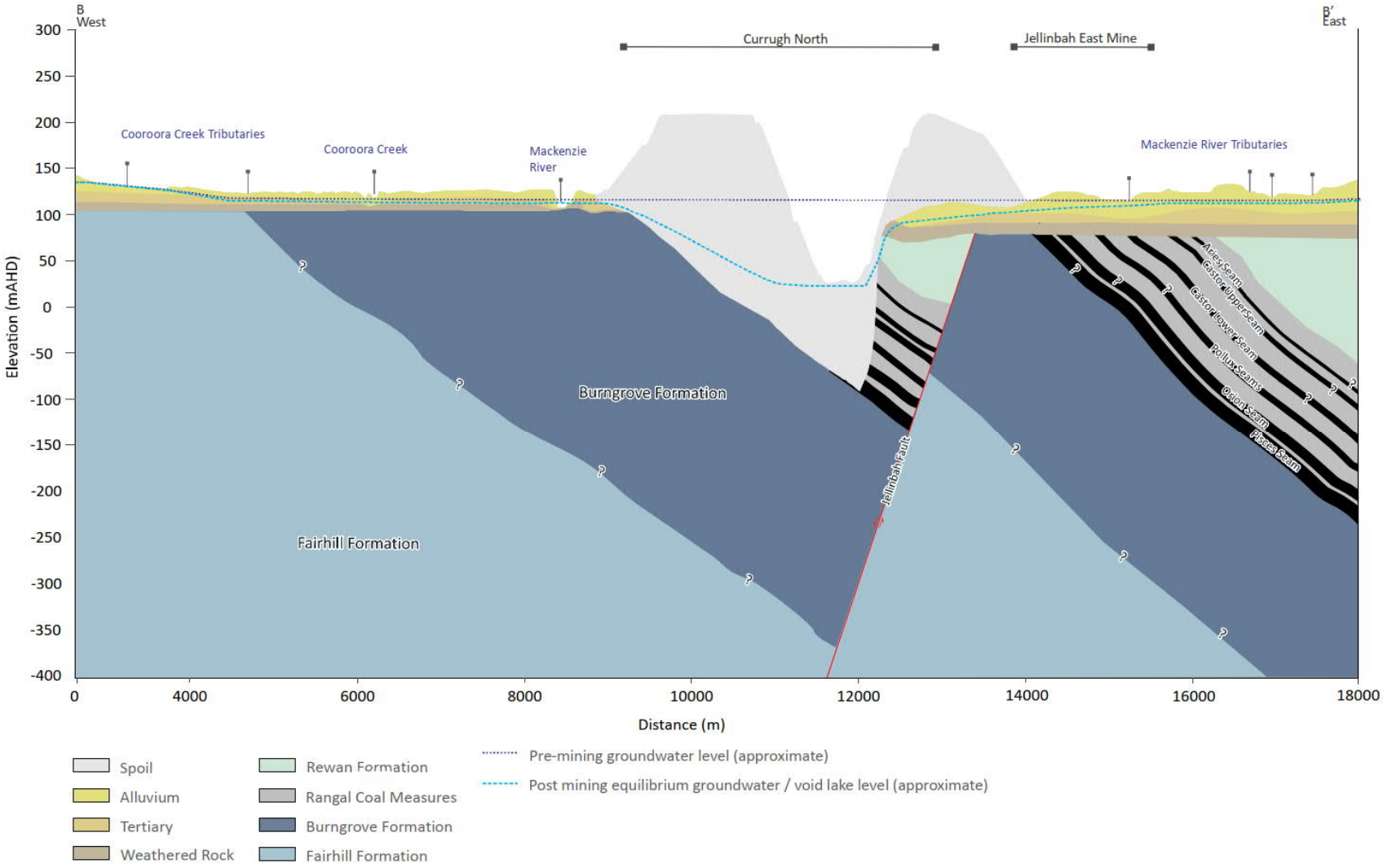


Figure 2-8 Geological cross-section B-B' of Curragh Mine Complex showing final landforms/voids and groundwater levels

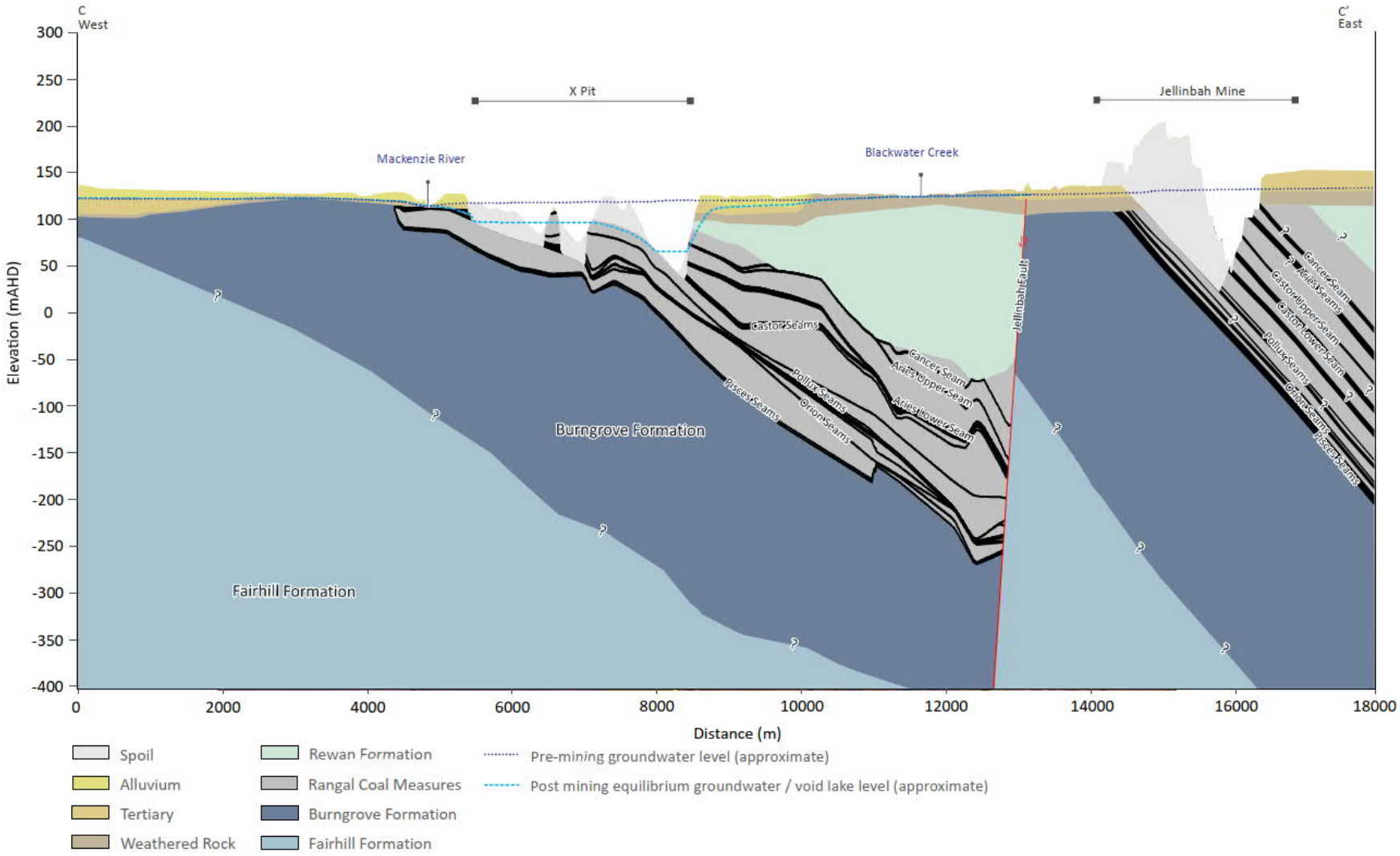


Figure 2-9 Geological cross-section C-C' of Curragh Mine Complex showing final landforms/voids and groundwater levels

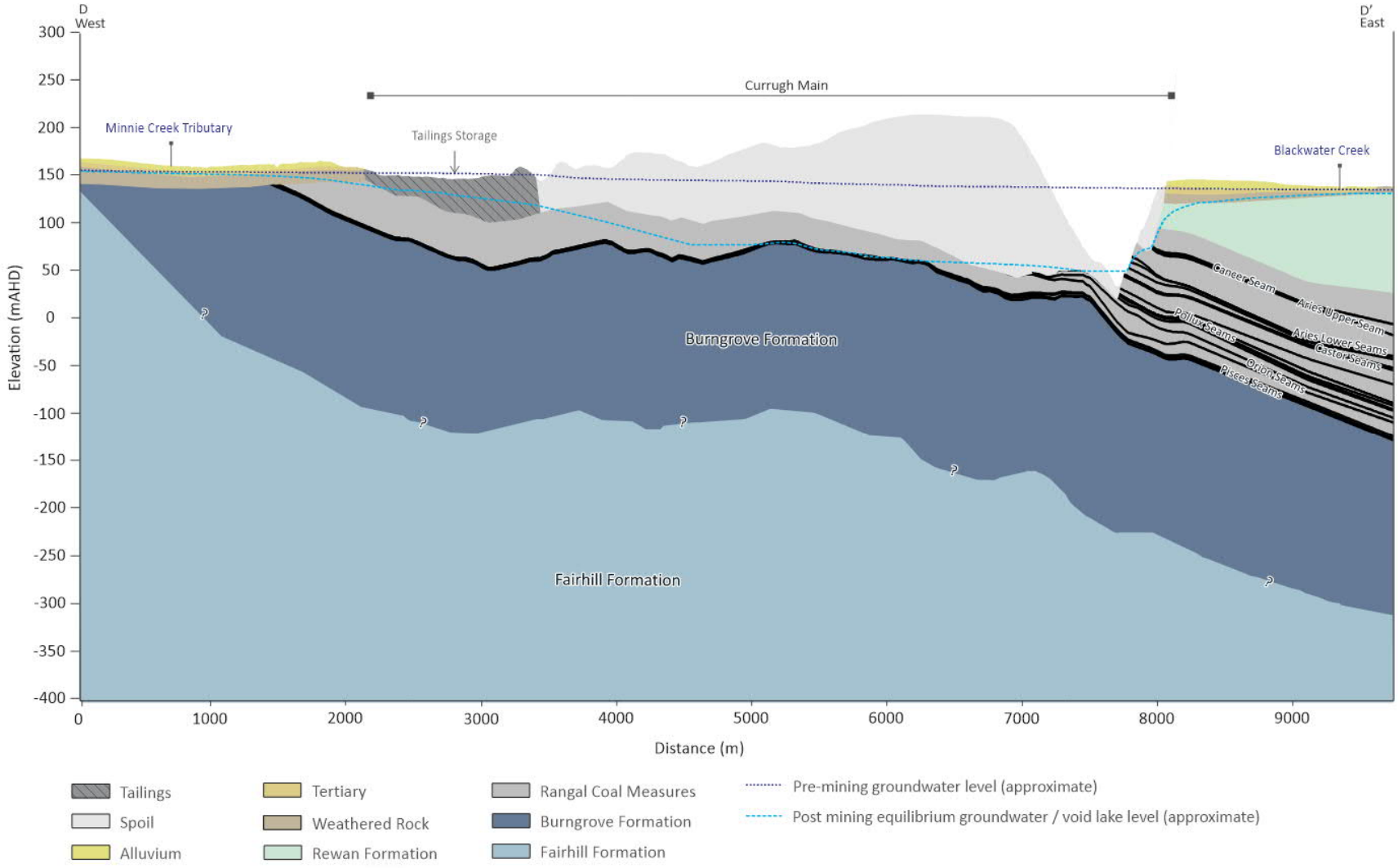


Figure 2-10 Geological cross-section D-D' of Curragh Mine Complex showing final landforms/voids and groundwater levels

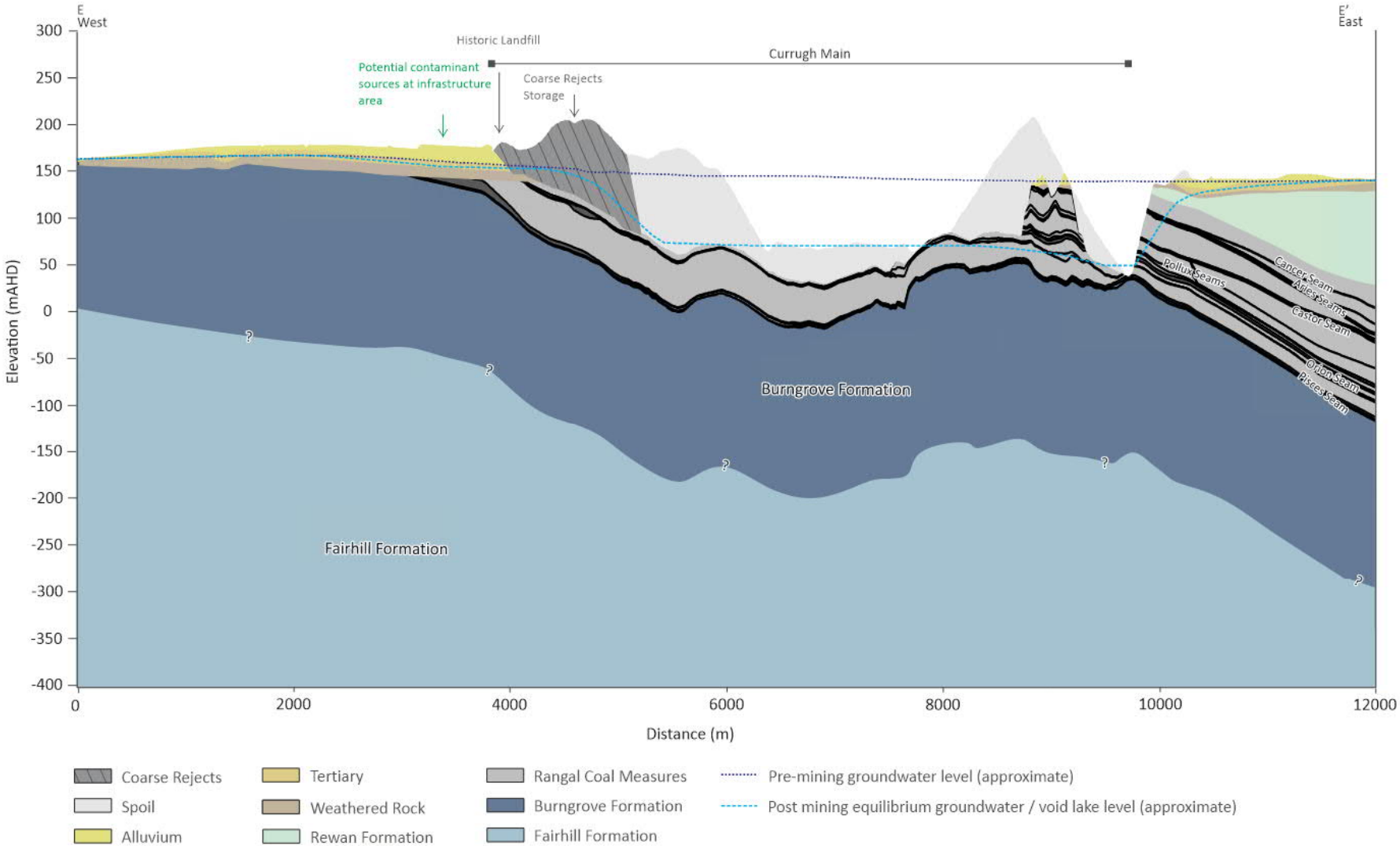


Figure 2-11 Geological cross-section E-E' of Curragh Mine Complex showing final landforms/voids and groundwater levels

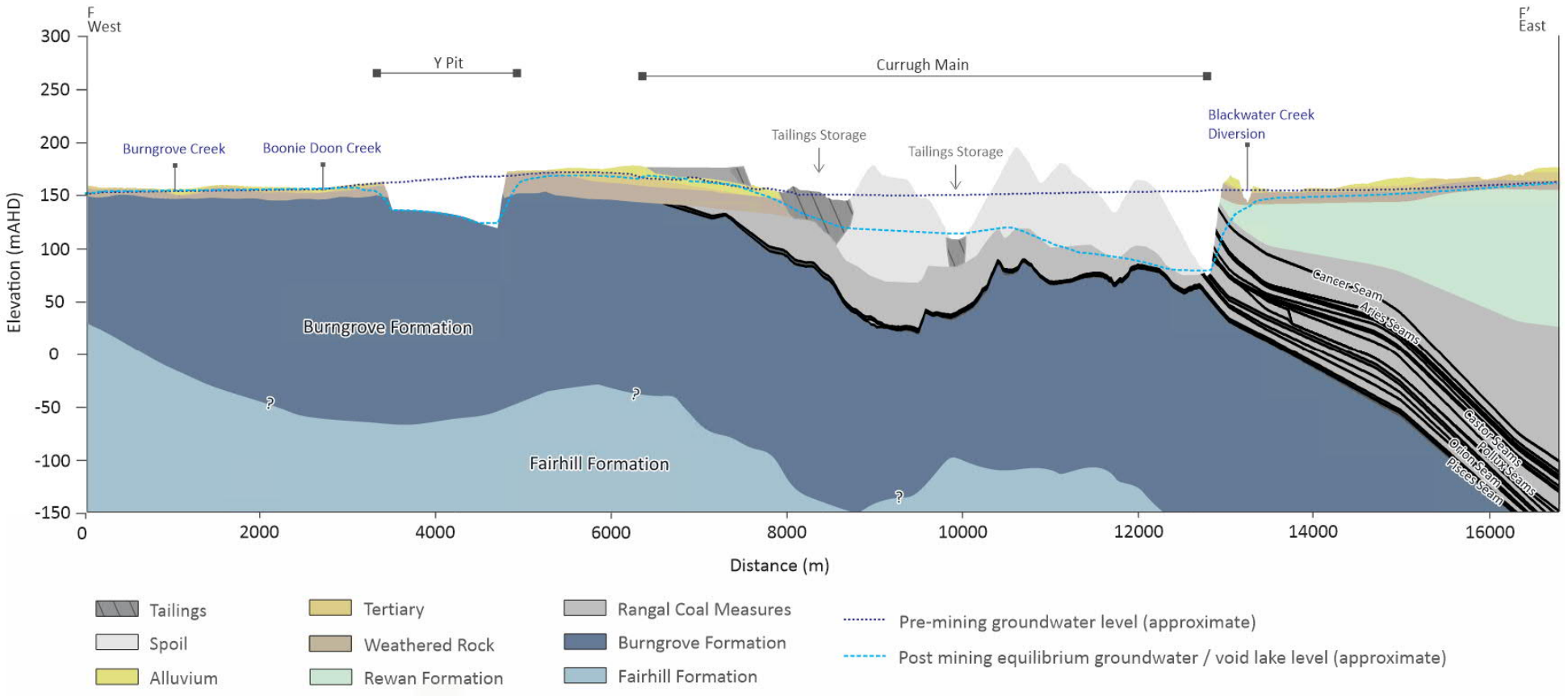


Figure 2-12 Geological cross-section F-F' of Curragh Mine Complex showing final landforms/voids and groundwater levels

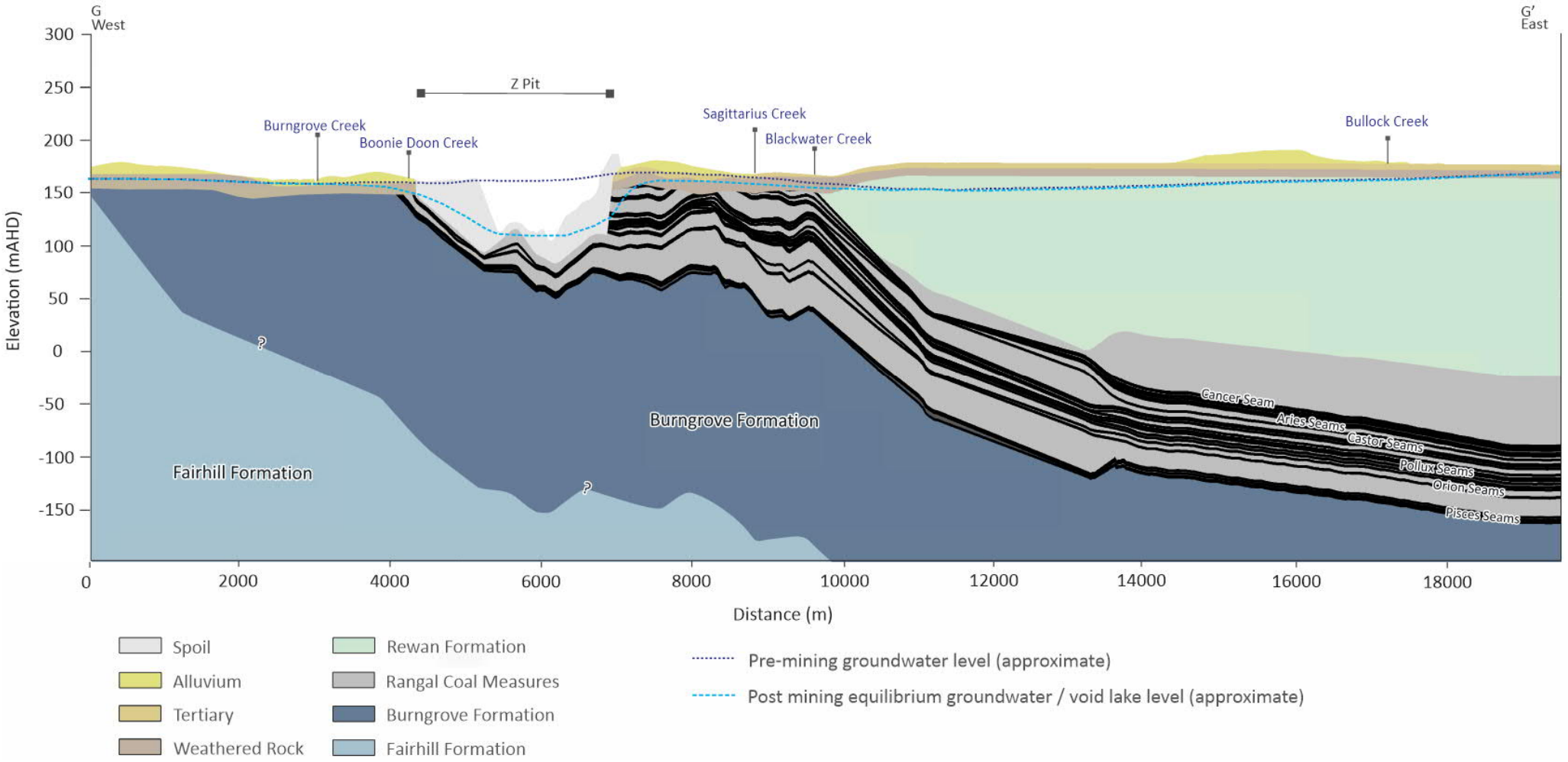


Figure 2-13 Geological cross-section G-G' of Curragh Mine Complex showing final landforms/voids and groundwater levels

2.2 Groundwater Monitoring Data

2.2.1 Groundwater Monitoring Network

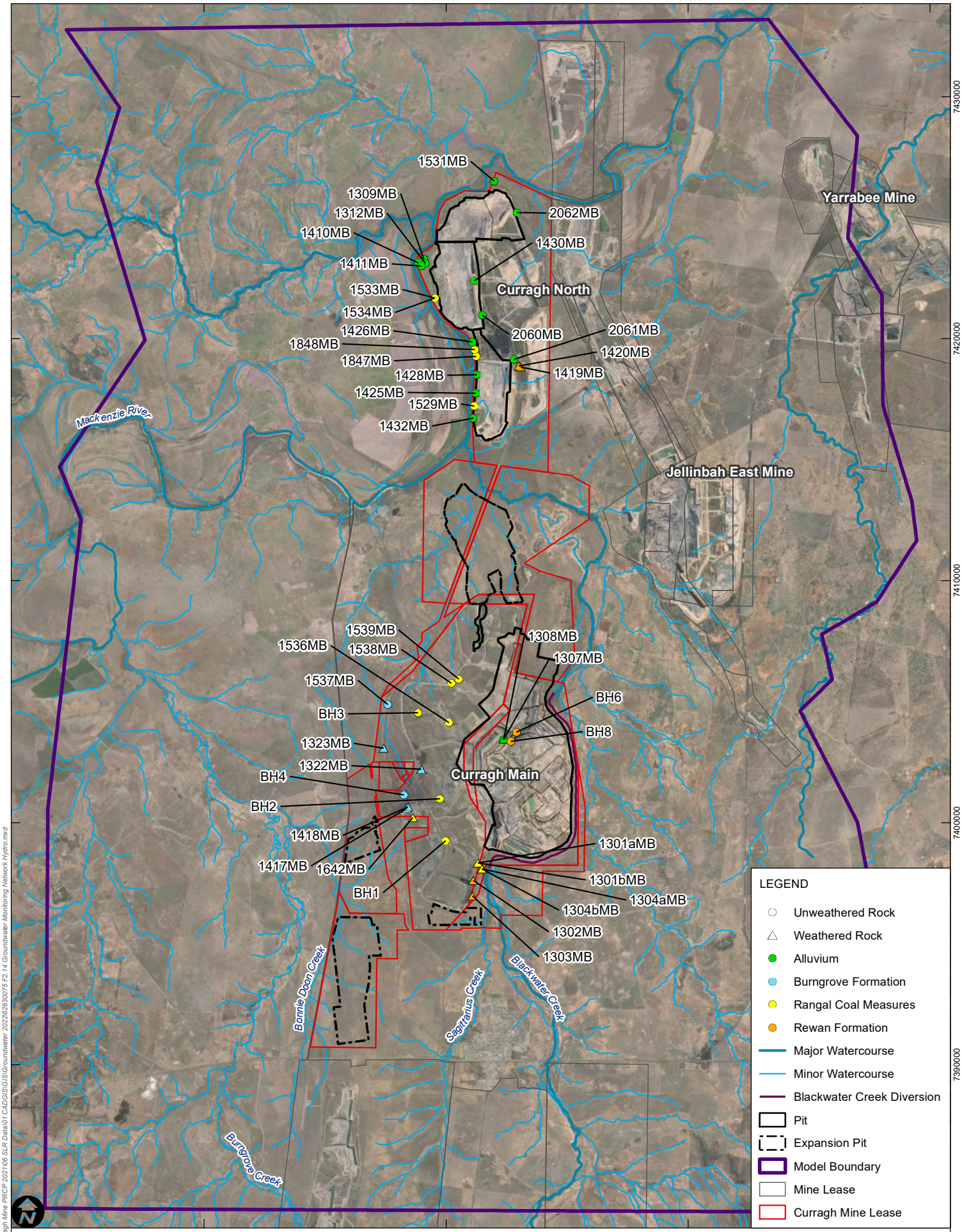
The groundwater monitoring network at Curragh Mine has progressively developed since the 1990s. The available monitoring data indicates that there are 36 bores from which data is currently collected with 22 used for groundwater quality monitoring and 23 used for groundwater level monitoring. The monitoring bore network for the mine is shown in Figure 2-14. Details of the monitoring bores, including bore construction, target formation and date of installation, are provided in Table 2-3.

Groundwater monitoring bores across the mine have been installed in the alluvium, Duaringa Formation, Rewan Formation, Rangal Coal Measures and the Burngrove Formation, with emphasis on water bearing units. The network has been designed to improve the understanding of the hydrogeological conditions in the area surrounding the mine and identify impacts associated within mining operations. Monitoring bore locations have been chosen to:

- provide spatial coverage across the mine area
- provide hydrogeological data on the range of formations and hydrogeological environments
- identify potential impacts to sensitive features such as groundwater dependent ecosystems (GDEs) and areas of potential surface water-groundwater interaction
- detect changes in groundwater conditions due to seepage from site infrastructure, including tailings storage facilities (TSFs), landfills, fuel farms and water storage dams
- establish a baseline of undisturbed groundwater conditions so that trigger levels can be developed to detect impacts associated with mining.

The Groundwater Monitoring Plan for the site identifies three categories of monitoring bore:

- compliance bores - monitored to assess potential impacts from mining activity on sensitive receptors
- reference bores - monitored to establish baseline groundwater conditions so that appropriate trigger levels for the detection of impacts associated with mining can be developed
- observation bores - monitored to improve the understanding of the hydrogeological conditions in the area surrounding the mine.



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Reviewed by:	ML

CURRAGH PRCP GROUNDWATER ASSESSMENT

Groundwater Monitoring Network

FIGURE 2-14

H:\Projects-SLR\626-MKY\626.30075.00000 Curragh Mine PRCP 20211106 SLR Data\01 CAD\GIS\GIS\Groundwater 20226263075 F2.14 Groundwater Monitoring Network Hydro.mxd

Table 2-3 Groundwater Monitoring Bores

Bore	Easting	Northing	Ground RL (mAHD)	Screen Depth (mbgl)	Formation description	Date installed	Location	Available data	
								Water Quality	Water Level
Alluvium									
1307MB*	692378	7403433	143.16	4 – 7	Alluvium	08-07-2013	Dam A	no	yes
1308MB*	692387	7403452	143.30	10 – 14	Alluvium / weathered Tertiary (Duaringa Fm.)	09-07-2013	Dam A	no	no
1309MB”	689082	7423302	124.43	12 – 18	Alluvium	10-07-2013	CN3 (between pit and Mackenzie R)	yes	yes
1312MB*	689148	7423118	125.93	11 – 17	Alluvium	11-07-2013	CN3 (between pit and Mackenzie R)	yes	yes
1426MB”	691085	7419864	128.79	12 – 26	Alluvium	25-11-2014	S Pit West - below levee north	yes	yes
1428MB*	691266	7418518	127.9	13 – 26	Alluvium	26-11-2014	S Pit West - below levee central	no	no
1531MB*	691987	7426518	125.53	21 – 27	Alluvium	16-07-2015	U Pit extension - north near levee	yes	yes
1533MB”	689529	7421689	132.36	21 – 27	Alluvium	15-07-2015	T Pit - West levee	no	no
1410MB”	688842	7423144	126.05	10 – 18	Alluvium	27-11-2014	CN3	yes	yes
1430MB*	691169	7422399	127.56	22 – 27	Alluvium	21-11-2014	T Pit - East (palaeochannel)	no	no
1432MB*	691123	7416724	134.75	2 – 5	Alluvium	25-11-2014	S Pit Tertiary Ridge	no	no
1411MB”	688974	7423011	128.23	9 – 20	Alluvium	21-11-2014	CN3	yes	yes
1425MB	691229	7417747	125.12	16 – 19	Alluvium	24-11-2014	S Pit West - below levee south	no	yes
2060MB	691488.4	7420977	123.88	18 – 24	Alluvium	-	Dam A	no	yes
2061MB	692800.1	7419144	129.75	26.5 – 32.5	Alluvium	-	Dam A	no	yes
2062MB	692921.8	7425213	123.77	13 – 19	Alluvium	-	Dam A	no	yes
Tertiary									
1301aMB*	691313	7398339	151.83	4 – 11	Tertiary (weathered)	06-07-2013	New TSF (formerly Pit A R2)	yes	no
1302MB*	691118	7397611	153.64	3 – 6	Tertiary (weathered)	05-07-2013	New TSF (formerly Pit A R2)	yes	no
1303MB*	691086	7396966	156.9	3 – 6	Tertiary (weathered)	05-07-2013	New TSF (formerly Pit A R2)	yes	no
1304aMB*	691481	7398090	153.35	6 – 9	Tertiary (weathered)	04-07-2013	New TSF (formerly Pit A R2)	yes	no
1419MB^	693083	7418830	137.96	1.2 – 15	Tertiary (weathered Duaringa Fm.)	19-11-2014	Curragh North Fuel Farm	yes	no
1420MB”	693004	7418881	138.43	1.2 - 15	Tertiary (weathered Duaringa Fm.)	20-11-2014	Curragh North Fuel Farm	yes	no
Rewan Formation									

Bore	Easting	Northing	Ground RL (mAHD)	Screen Depth (mbgl)	Formation description	Date installed	Location	Available data	
								Water Quality	Water Level
BH6*	692902	7403743	141.98	n/a	Rewan Fm	n/a	Dam A and B	no	no
BH8*	692678	7403357	142.90	n/a	Rewan Fm	n/a	Dam A	no	no
Rangal Coal Measures									
BH1"	689978	7399250	157.70	n/a	RCM	n/a	Crib hut 3	yes	no
BH2"	689746	7400993	169.8	n/a	RCM	n/a	R5 landfill	yes	no
BH3"	688846	7404539	176.52	n/a	RCM	n/a	R8 landfill	yes	no
1301bMB*	691308	7398335	151.69	14 – 18	RCM (weathered)	06-07-2013	New TSF (formerly Pit A R2)	yes	no
1304bMB*	691481	7398084	153.33	14 – 17	RCM (weathered)	02-07-2013	New TSF (formerly Pit A R2)	yes	yes
1529MB"	691161	7417212	123.81	33 – 39	RCM	17-07-2015	S Pit West - below levee south	yes	yes
1534MB^	689540	7421687	132.52	27 – 33	RCM	13-07-2015	T Pit - West levee	yes	yes
1536MB"	690116	7404141	148.504	35.5 – 41.5	RCM	02-07-2015	Landfill - east	yes	yes
1538MB^	690217	7405768	153.18	73 – 79	RCM	29-06-2015	Ramp 10/11	yes	yes
1539MB*	690523	7405931	152.2	53 – 59	RCM	03-07-2015	Ramp 10/11 - second site	yes	yes
1642MB	688631	7400213	174.587	1.4 – 18.5	RCM (weathered)	n/a		no	yes
1847MB	691245.7	7419276	129.169	76.5 – 85.5	RCM (Pisces)	n/a		no	yes
1848MB	691184.3	7419553	128.902	85 – 94.5	RCM (Pisces)	n/a		no	yes
Burngrove Formation									
BH4"	688260	7401147	170.19	n/a	Burngrove Fm.	n/a	CHPP landfill	yes	no
1322MB*	688976	7402204	162.69	2 – 25	Burngrove Fm. (weathered)	26-07-2013	Down gradient of industrial process area	no	yes
1323MB^	687417	7403078	164.44	11 – 25	Burngrove Fm. (weathered)	25-07-2013	Up gradient of mining ops	yes	yes
1417MB^	688376	7400592	175.56	1.2 – 15	Burngrove Fm. (weathered)	18-11-2014	Curragh Fuel Farm	yes	no
1418MB"	688428	7400647	175.56	1.2 – 16	Burngrove Fm. (weathered)	18-11-2014	Curragh Fuel Farm	yes	no
1537MB^	687589	7404885	157.71	30.5 – 36.5	Burngrove Fm. (coal seam)	27-06-2015	SAR	yes	yes

*Observation bore, ^Reference bore, "Compliance bore

2.3 Hydrogeology

2.3.1 Hydrostratigraphy

The main hydrostratigraphic units in the vicinity of the mine are described below, from the shallowest to the deepest/oldest:

- Alluvium – up to 30m thick in the north associated with the floodplain / channel deposits of the Mackenzie River. Thinner (up to 12 m), near extension Pit X and comprises clay, sand and gravel. At Curragh Main and the southern extension pits, up to 10 m thick but generally much thinner and predominantly clay and silt. The alluvium is dry in many areas. Unconfined water bearing sand and gravel may occur at the base of the alluvial sequence around Curragh North and near the proposed Pit X, but it is considered unlikely to be significantly water bearing where present across the south of the mine.
- Regolith - unconsolidated surface layer of weathered rock which may provide a preferential shallow flow pathway for groundwater. Occurs across the Project area at thicknesses between 5 and 15 m. Includes weathered residual rocks of the Duaringa and Emerald formations, Rewan Formation, Rangal Coal Measures and Burngrove Formation in areas of outcrop and below the alluvium. Variable permeability.
- Cenozoic (Tertiary Duaringa and Emerald formations) - Occurs around Curragh Main extension Pits X and D. Comprises cemented sands and gravels and sandstones, siltstones and mudstones. Water bearing zones may occur in more permeable layers, unconfined to semi-confined.
- Rewan Group - is a regional aquitard comprising mudstones interbedded with siltstone and fine to medium grained labile sandstone.
- Rangal Coal Measures - Occurs along the strike of the mine and is overlain to the east by the Rewan. Groundwater flow is primarily within the coal seams (via interconnected cleats and fractures), which are confined by low permeability overburden and interburden. The coal measures are highly faulted resulting in “compartmentalisation” with coal seams juxtaposed against lower permeability interburden limiting the lateral continuity of flow. Faults themselves may form barriers to flow or provide conduits.
- Burngrove Formation – outcrops/subcrops to the west of the mine dipping east below the Rangal Coal Measures. Groundwater flow occurs primarily via coal seams and fractured sandstone units with low permeability siltstone and claystone forming aquitards. As with the RCM sequence it is considered to be highly faulted with coal seams juxtaposed against lower permeability interburden limiting the lateral continuity of groundwater flow. This Formation is considered “basement” for the purposes of this assessment.

2.3.1.1 Alluvium

The alluvium comprises coarse sands, gravels, silt, and clay. Groundwater present within the sand and gravel units is generally regarded as unconfined. Floodplain alluvium associated with the Mackenzie River and Blackwater Creek occurs extensively across Curragh North and the northern part of the extension Pit X.

For the 2016 expansion project hydrogeological assessment PB undertook a review of bore logs from the exploration drilling program which identified that Curragh North is underlain by a paleochannel system of significant thickness (12 - 30 m), predominantly comprising sand and gravel. The Pit X extension area is underlain by a thinner alluvial sequence (typically less than 12 m) predominantly comprising clay with sand and gravel lenses, generally occurring at depth. The alluvium in the southern areas of the mine is generally thin (<10m but typically much thinner) and comprised predominantly of clay and silt (PB 2016).

The Mackenzie River channel has migrated across the floodplain over time resulting in coarse sediments (sands and gravels) being deposited as point bar/channel deposits and lenses with overlying finer floodplain sediments. There is significant lateral variability and discontinuity in the coarser alluvial deposits which is likely to control/limit connectivity to the Mackenzie River (PB 2016). The permeability of the sands and gravels horizons within the alluvium will be variable and depend on the fines content (silt and clay).

Groundwater studies undertaken at Curragh North prior to the commencement of mining found the majority of monitoring bores installed in alluvium were dry. Where intersected, groundwater occurred within coarse basal sands and gravels (PB 2016).

Potential impacts from mining activities will depend on intersection of the alluvium by mining and connectivity between pits and watercourses via the alluvium with the main receptors being landholder bores and GDEs.

2.3.1.2 Rangal Coal Measures

Coal seams are typically the most permeable horizons within the Rangal Coal Measures and are considered fractured rock aquifers with groundwater flow occurring via joints and cleats. The coal measures have also been extensively faulted which is likely to restrict flow through the coal seams due to the lateral discontinuity. The faults themselves may present barriers to flow or provide pathways for groundwater flow.

To the east of the mining activity the coal seam aquifers are confined by the interburden layers of low permeability shale, siltstone and mudstone.

2.3.1.3 Burngrove Formation

The Burngrove Formation comprises an interbedded fractured rock aquifer system with water bearing units comprising fractured or weathered sandstone and coal seams. These fractured rock aquifer units are confined by low permeability sequences of siltstone, mudstone and tuff. The fractured rock aquifers are heterogeneous in properties and distribution over their spatial extent.

2.3.2 Groundwater Levels and Flow Direction

Groundwater level data was provided by the mine for late 2015 onward and is presented in hydrographs below for the alluvium, RCM and Burngrove Formation. Earlier groundwater level data presented in the 2016 PB groundwater assessment for the mine expansion is also described below.

2.3.2.1 Alluvium

The alluvium associated with Mackenzie River is dry in many areas and where water is present it generally occurs in coarse channel deposits at the base of the alluvium. Perched groundwater in sand and gravel lenses within low permeability fines (silt and clay) has also been recorded in previous investigations (PB, 2016).

Pre-mining groundwater levels in the alluvium at Curragh North were generally 18 to 22 mbgl with groundwater levels recorded since commencement of mining ranging from approximately 16 to 26 mbgl (PB, 2016).

The alluvium associated with Blackwater Creek in the southern area of the mine is dry in many areas.

More recent groundwater level data for the alluvium is presented in Figure 2-15. The data appears to show clear responses to rainfall variations through 2016 and 2017 and a slight declining trend apparent in some bores (in line with low rainfall since early 2018).

Most of the current alluvial monitoring is focused on the Mackenzie River alluvial deposits directly west of Curragh North. The only current alluvial monitoring south of this is at 1307MB within Curragh Main with the alluvial groundwater level reflecting the higher elevation of this area.

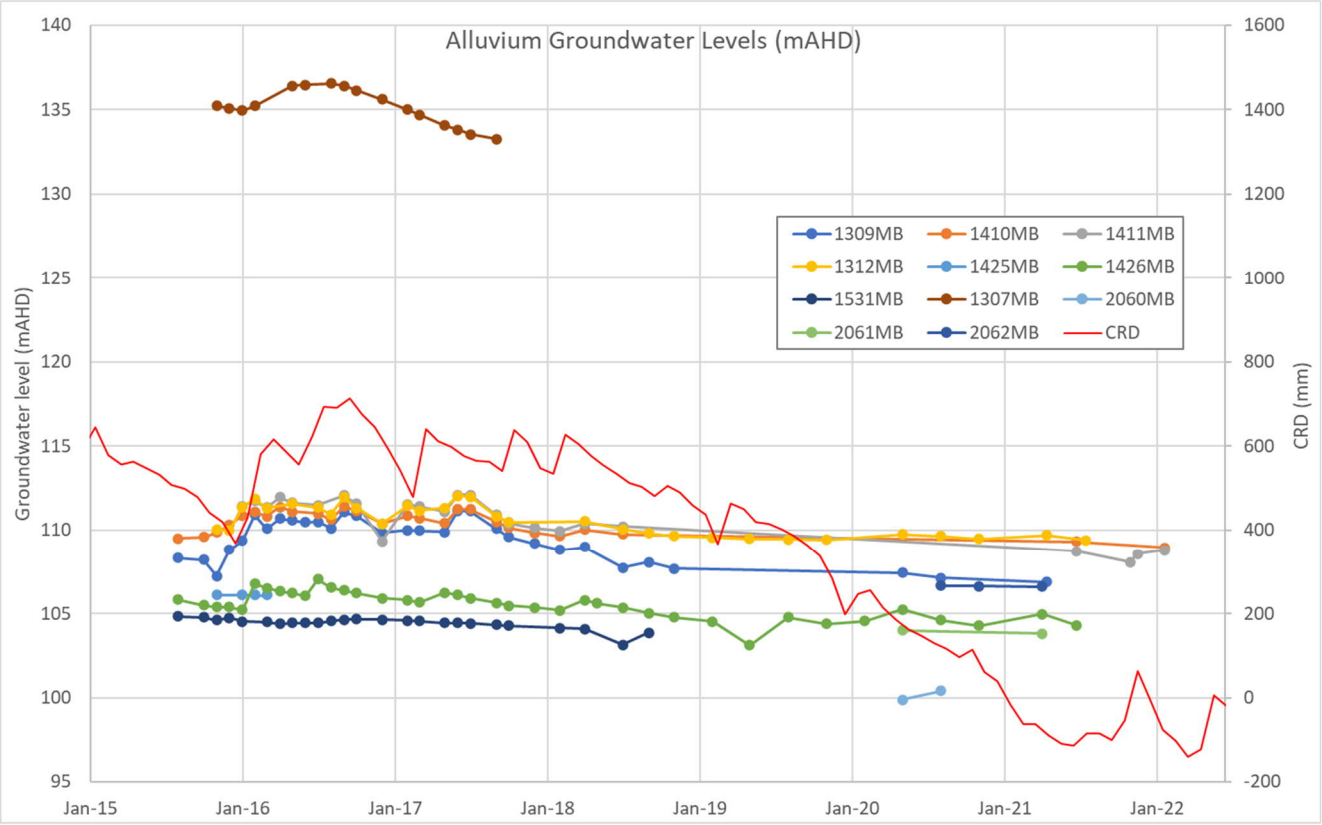


Figure 2-15 Alluvium Groundwater Levels and Cumulative Rainfall Departure

Overall, the alluvial groundwater levels clearly reflect a northerly flow direction along the Mackenzie River west of Curragh North. The 2016 PB assessment numerical modelling indicated that groundwater flow in the alluvium followed topography and drainage lines to the north and northeast. Data for 1309MB and 1312MB for July 2013 to the end of 2015 is consistent with subsequent data obtained from these bores.

2.3.2.2 Rangal Coal Measures

Monitoring of the Pisces seam at Curragh North prior to the commencement of mining indicated pressure heads of 0 to 78 m above the seam. Groundwater levels in RCM outcrop areas were observed to respond to rainfall variations seen in the CRD and groundwater level recovery was also observed at some locations where mining progression had moved away from certain bores (PB, 2016).

Prior to mining, groundwater flow direction in the Permian strata was to the north-east at a very gentle gradient of 1 in 400 (Douglas Partners 2014). Since commencement of mining, groundwater flow direction in the Permian strata has been influenced locally by dewatering in the active pit areas of Curragh and Jellinbah mines.

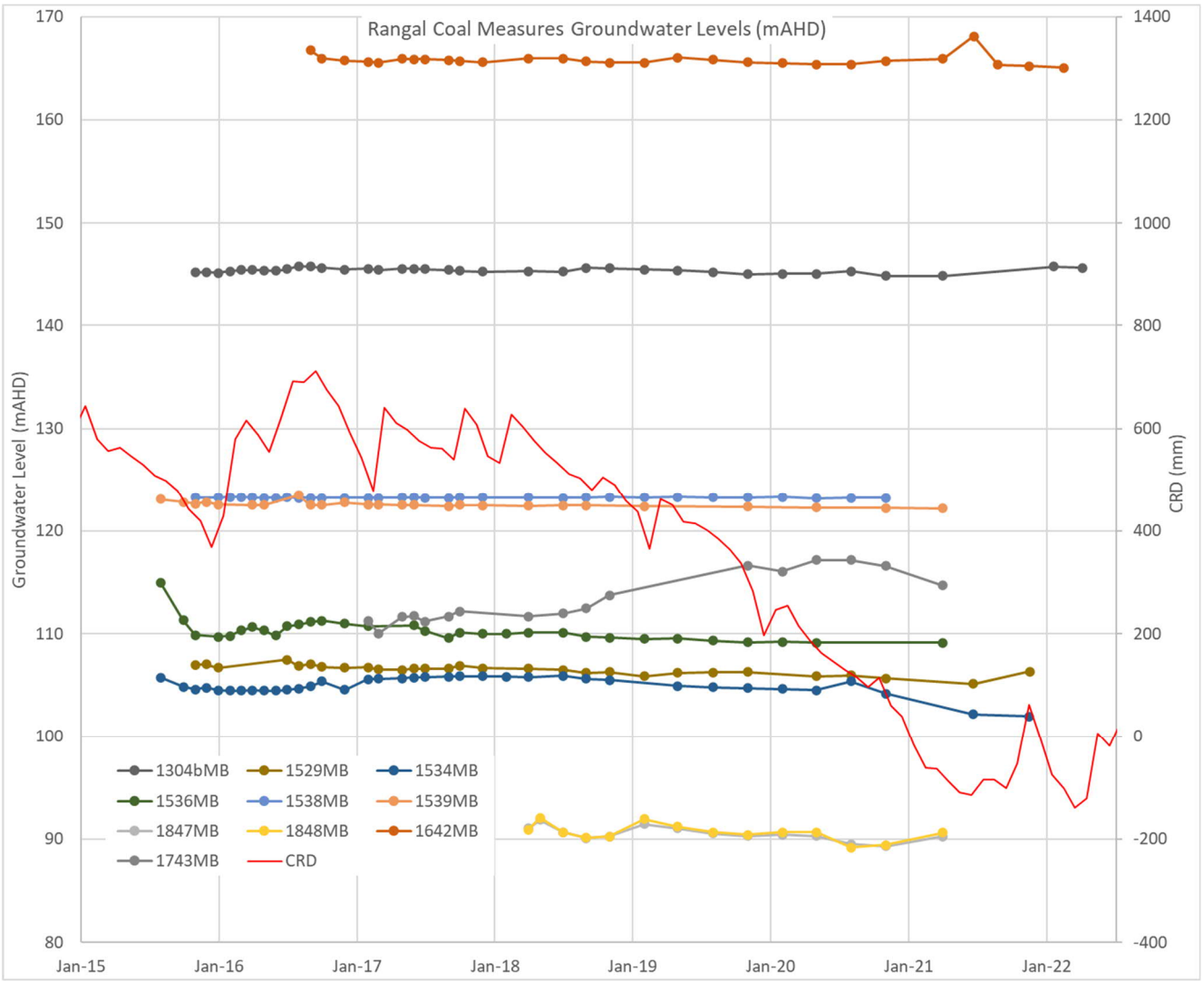


Figure 2-16 RCM Groundwater Levels and Cumulative Rainfall Departure

Recent groundwater level monitoring data for RCM bores is presented in Figure 2-16 and generally shows very steady levels with little or no response to the CRD although several bores show slight declining trends from 2017 onward in line with lower than average rainfall although this may also be due to the influence of mining. Bore 1743MB shows a rising trend from 2017 onward, contrary to the CRD. This bore is located to the east of the Pit A TSF and south of Pit B TSF and screened at shallow depth (14-17 m bgl). It is possible that the rising groundwater level trend in this bore relates to the filling of the adjacent TSFs.

2.3.2.3 Burngrove Formation

Groundwater levels recorded in the Burngrove Formation since commencement of mining have ranged from approximately 6 to 29 mbgl with shallow bores in unconfined outcrop areas showing levels that correspond to long term rainfall trends. (PB, 2016).

Recent groundwater level monitoring data for the four bores installed in the Burngrove Formation are presented in Figure 2-17 All four bores are installed on the west side of Curragh Main to depths of less than 35m bgl. 1417MB shows a slight declining trend over time and possibly some response to the CRD over this period. 1537MB and to a lesser extent 1322MB show a slight rising trend over the monitoring period, possibly due to the progression of mining activity away from these locations. Recovery responses may also be somewhat masked by lower than average rainfall over the monitoring period.

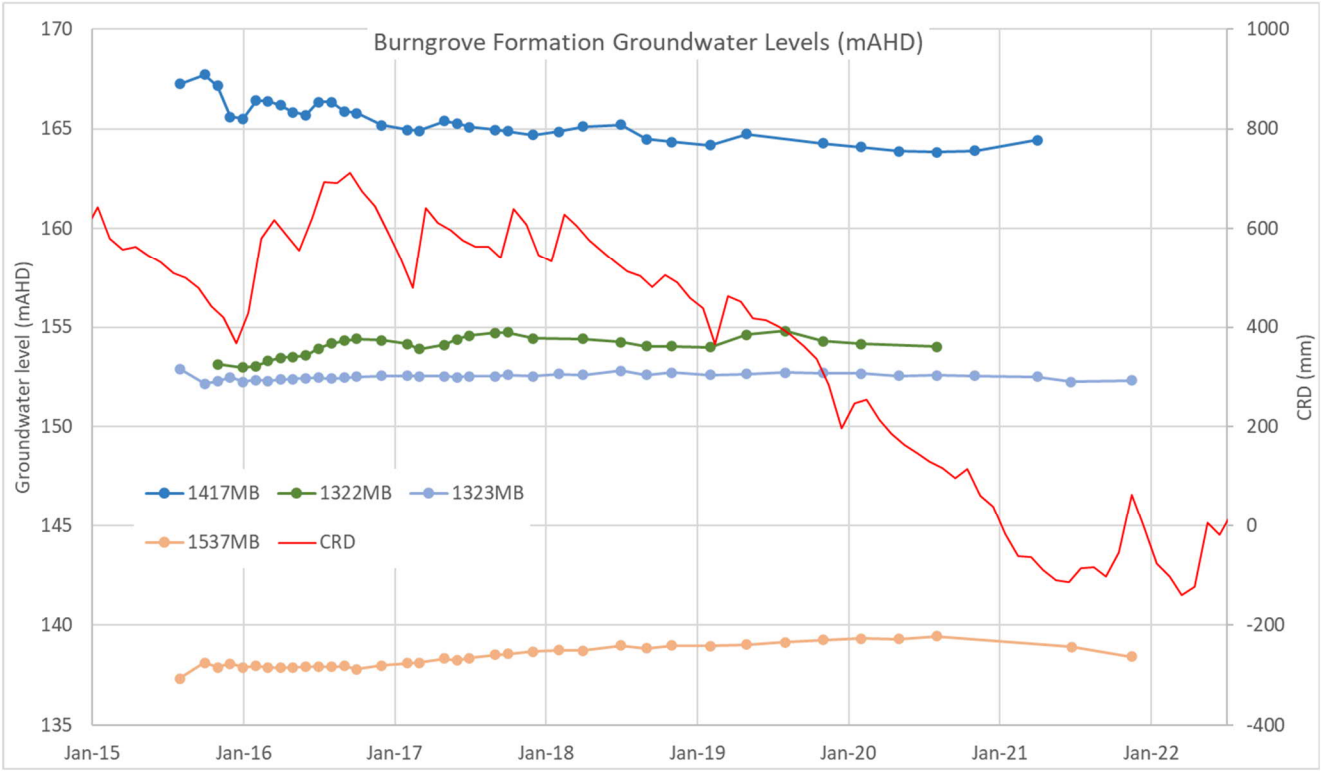


Figure 2-17 Burngrove Formation Groundwater Levels and Cumulative Rainfall Departure

2.3.3 Pre-mining groundwater flow

Modelled pre-mining groundwater levels simulated in the revised numerical model are presented in Error! Reference source not found. and show a generally northerly flow of groundwater across the southern area of the model domain, turning more towards the north-east in the northern part of the model domain, essentially aligned with the Mackenzie River which flows in the same direction.

2.3.4 Effects of faulting on groundwater flow

As well as the larger mapped faults referred to in Section 2.1.5, the many minor faults will be present throughout the Permian strata.

A seismic survey across an area approximately 4x4km directly south of Blackwater was completed for the Minyango Project in 2011 (Velseis, 2012). The aim was to map the roof of the Aries and Pollux seams, mapping structures / faulting including characterisation of displacement, orientation and fault type. A total of 709 structural features were interpreted within the 16 sq km survey area for all seams.

Most structures (faults) interpreted from the survey were high angle with two main faulting trends identified striking either NNW-SSE or approximately E-W. No dominant fault type was identified with a similar number of faults characterised as reverse, normal and undefined. Many of the structures classified as undefined appear as if they may have been reactivated as they display both normal and reverse characteristics. The largest vertical displacements interpreted across the Aries and Pollux seams were 53.5m and 38m respectively. However, most faults interpreted across both horizons had displacements of less than 15m.

The high degree of faulting within the Rangal Coal Measures identified locally by the Velseis survey will have will have resulted in "compartmentalisation" with the faulting juxtaposing the more permeable coal seams against interburden along fault planes. This will limit the coal seams exposed in the pit highwalls from acting as continuous pathways for potential seepage migration with abrupt discontinuation of seams where they are displaced by faulting against lower permeability interburden.

Whilst faulting around Curragh is considered likely to have resulted in strong compartmentalisation within the coal measures, some faults may act as conduits for groundwater flow.

2.3.5 Hydraulic Properties

Hydraulic property data obtained from the Curragh site and surrounding mines and other relevant sources for the key formations of interest was collated by PB for the 2016 Curragh expansion project and has been reproduced in Table 2-4.

The parameter ranges presented in Table 2-4 indicates the highly variable hydraulic conductivity in the alluvium depending on the silt / clay content. The coal seams within the Rangal Coal Measures exhibit variably moderate permeability, and typically significantly higher than the interburden strata.

Table 2-4 Hydraulic Parameter Estimates (reproduced from PB, 2016)

Age / Formation	Lithology	Kh (m/d)	Kv (m/d)	Ss (m^{-1})	Sy	Source	Project	Source
Quaternary Alluvium	Mackenzie River alluvium - silty clay	0.0009 – 0.001				Falling head test	Curragh North	1
	Mackenzie River alluvium - sand	0.09 – 9				Falling head test	Curragh North	1
	Mackenzie River alluvium - sand/gravel	0.9 – 9				Falling head test	Curragh North	1
	Mackenzie River alluvium - gravel	10				Constand rate test	Mackenzie South	2
	Blackwater Creek alluvium	0.4				Rising head test	Minyango	3
	Blackwater Creek alluvium	0.6	0.018			Calibrated model parameters	Minyango	3
	Floodplain/ river alluvium	1 – 40	0.1 – 2	0.0005	0.05 – 0.18	Calibrated model parameters	Arrow Energy	7
	Not specified0.00	100	10	0.001	0.25	Unknown	Ensham Central	6
	Not specified	0.7 – 1.5		0.0001		Unknown	Barabala North	13
	Not specified	10	1		0.2		Millenium expansion	8
	Not specified	0.088 – 0.38		0.00001		Unknown	Caval Ridge	9
	Not specified	10	1	0.00005	0.1	Unknown	Springsure Creek	11
Tertiary	Duaringa Fm. - unspecified	0.05	0.005	0.00005	0.12	Calibrated model parameters	Arrow Energy	7
		0.6	0.018				Minyango	3
	Weathered – sandy gravels	0.9				Unknown	Curragh North	1
	Weathered – claystone / cemented strata	0.43				Unknown	Curragh North	1
Triassic Rewan Fm.	Sedimentary strata	0.00075	0.0000001	0.00005	0.05	Calibrated model parameters	Arrow Energy	7
		0.00015 – 0.055				Falling head tests	Minyango	3
		0.0009	0.000054			Calibrated model parameters	Minyango	3
		0.00001 – 0.0001	0.000001 – 0.00001	0.000001	0.005	Unknown	Ensham Central	6
		0.1	0.00001	0.000005	0.05	Unknown	Daunia	10
		0.0001	0.0000007	0.00001	0.01	Unknown	Springsure Creek	11

Age / Formation	Lithology	Kh (m/d)	Kv (m/d)	Ss (m^{-1})	Sy	Source	Project	Source
		0.000007				Calibrated model parameters	Carmichael	12
Permian Rangal Coal Measures	Overlying units	0.04	0.001			Packer tests	Curragh North	1
	Fractured coal	0.009 – 0.09				Packer tests	Curragh North	1
	Intact coal	0.017				Packer tests	Curragh North	1
	Aries coal seam	0.003				Falling head test	Minyango	3
		0.14				Drill stem test	Minyango	4
	Aries / Castor coal seam	0.00014				Packer leak-off test	Cook Colliery	5
	Castor coal seam	0.06				Drill stem test	Minyango	4
	Pollux coal seam	0.017				Drill stem test	Minyango	4
		0.9				Constant rate test	Mackenzie South	2
	Pisces coal seam	0.003				Drill stem test	Minyango	4
	Interburden	0.0001	1×10^{-8}	8.5×10^{-6}	0.05	Calibrated model parameters	Arrow Energy	7
		0.00009	1.8×10^{-6}			Calibrated model parameters	Minyango	3
		0.1		5×10^{-6}	0.05	Unknown	Daunia	10
		0.001	0.00001	0.00001	0.01	Unknown	Springsure Creek	11
Permian Burngrove	Coal and interburden	0.00044	8.8×10^{-6}	0.00005	0.12	Calibrated model parameters	Minyango	3
		0.000009	9.9×10^{-7}			Calibrated model parameters		
Permian Fair Hill Fm.	Fort Cooper coal seams (Virgo/ Leo/ Aquarius)	0.000017				Packer leak-off test	Cook Colliery	5

1 Minserve (1998), cited in Parsons Brinckerhoff (2003), 2 ERM (2002), cited in AGE (2006), 3 AGE (2013a), 4 Polymetra (2009), cited in AGE (2013a), 5 North Queensland Energy (1993), cited in AGE (2013a), 6 AGE (2006), cited in HydroSimulations (2014), 7 Ausenco-Norwest (2012), 8 Matrix Plus (2010), 9 URS (2009), cited in HydroSimulations (2014), 10 BHP Billiton Mitsubishi Alliance, cited in HydroSimulations (2014), 11 CDM Smith (2013), cited in HydroSimulations (2014), 12 GHD (2013), 13 JBT (2012), cited in HydroSimulations (2014)

2.3.6 Groundwater Quality

Groundwater quality data has been provided for the bores listed in Table 2-5 and which are shown on Figure 2-14. Data is generally available from late 2015 onward with limited data provided from before this time. Historically, groundwater quality monitoring was infrequent between 1997 to 2012 with the frequency increasing thereafter. Samples were analysed for electrical conductivity (EC), pH, major ions, nutrients, dissolved metals and hydrocarbons. Water quality statistics for selected analytes are shown in Table 2-6.

Table 2-6 also includes data for three water samples taken in 2022 from the Pit B tailings storage facility. As there are no monitoring bores installed in the tailings these samples have been taken as providing indicative water quality for water within the tailings.

Table 2-5 Currently available groundwater quality data

Screened Formation	Bore ID	Data availability	
		From	To
Alluvium	1309MB	28-10-2015	01-04-2020
Alluvium	1312MB	03-10-2019	03-10-2019
Alluvium	1426MB	30-10-2015	10-11-2020
Alluvium	1531MB	28-10-2015	13-05-2020
Alluvium	1410MB	03-03-2016	29-06-2018
Alluvium	1411MB	28-04-2016	11-06-2019
Tertiary (weathered)	1301aMB	30-01-2020	06-01-2021
Tertiary (weathered)	1302MB	03-10-2019	07-01-2021
Tertiary (weathered)	1303MB	03-10-2019	07-01-2021
Tertiary (weathered)	1304aMB	18-09-2013	13-06-2016
Tertiary (weathered Duaringa Fm.)	1419MB	06-08-2015	28-06-2018
Tertiary (weathered Duaringa Fm.)	1420MB	30-12-2016	20-06-2017
RCM	BH1	26-06-2000	09-11-2020
RCM	BH2	09-02-2000	16-11-2020
RCM	BH3	09-02-2000	11-11-2020
RCM (weathered)	1301bMB	03-10-2019	06-01-2021
RCM (weathered)	1304bMB	04-09-2013	06-01-2021
RCM	1529MB	06-08-2015	10-11-2020
RCM	1534MB	06-08-2015	09-12-2020
RCM	1536MB	16-04-2018	14-05-2020
RCM	1538MB	19-08-2015	11-11-2020
RCM	1539MB	29-10-2015	20-08-2018
Burngrove Fm.	BH4	09-02-2000	09-12-2020
Burngrove Fm. (weathered)	1323MB	07-01-2014	09-11-2020
Burngrove Fm. (weathered)	1417MB	05-08-2015	09-11-2020
Burngrove Fm. (weathered)	1418MB	22-06-2015	11-11-2020
Burngrove Fm. (coal seam)	1537MB	30-10-2015	10-11-2020

Table 2-6 Groundwater quality (recent data) for the Mackenzie River Alluvium, Rangal Coal Measures, Burngrove Formation and Tailings at Curragh

Analyte	95% Species protection for freshwater [1]	Livestock (ANZECC)	ADWG [A]	Groundwater Quality Objectives for the Fitzroy River Basin						Mackenzie River Alluvium				Tertiary				Rangal Coal Measures				Burngrove Fm.				Tailings Water Samples (3 samples from Pit B TSF (2022))			
				Deep (Zone 34)			Shallow (Zone 13)																						
				20th	50th	80th	20th	50th	80th	No.	20th	50th	80th	No.	20th	50th	80th	No.	20th	50th	80th	No.	20th	50th	80th	No.	Min	Mean	Max
pH	-	-	6.5 – 8.5 [C]	7.4	7.8	8.03	7.5	8.0	8.3	45	6.92	7.19	7.65	17	7.33	7.51	7.71	122	7.1	7.4	7.7	82	7.31	7.59	7.91	3	8.33	8.39	8.43
TDS	-	See Table 2-7	600 [C]	-	-	-	-	-	-	34	334	378	640	25	1,132	2,350	9,596	134	1,090	8,434	9,674	114	2242	4710	8366	3	4480	6717	8260
EC (µS/cm)	-	-	-	3,419	6,100	16,000	630	1,150	2,509	45	484.6	573	3468	17	1,702	3,290	13,420	118	1,620	14,250	16,000	80	5718	10900	14560	3	6890	10330	12700
Aluminium (mg/L)	0.055	5	0.2 [C]	-	-	-	-	-	-	34	0.01	0.01	0.01	25	0.01	0.01	0.024	139	0.01	0.01	0.019	116	0.01	0.01	0.01	3	0.01	0.01	0.01
Arsenic (mg/L)	0.013	0.5	0.01	-	-	-	-	-	-	34	0.001	0.003	0.0104	25	0.001	0.001	0.0016	138	0.001	0.001	0.005	118	0.001	0.001	0.001	3	0.004	0.005	0.007
Antimony (mg/L)	0.009	-	0.003	-	-	-	-	-	-	32	0.001	0.001	0.001	14	0.001	0.001	0.001	64	0.001	0.001	0.001	78	0.001	0.001	0.001	3	0.002	0.003	0.006
Boron (mg/L)	0.37	5	4	-	-	-	-	-	-	0	-	-	-	1	-	0.87	-	23	0.938	1.1	1.36	11	0.63	0.78	0.85	3	0.26	0.37	0.47
Cadmium (mg/L)	0.0002	0.01	0.002	-	-	-	-	-	-	0	-	-	-	1	-	0.0001	-	23	0.0001	0.0001	0.0001	11	0.0001	0.0001	0.0001	3	0.0001	0.0001	0.0001
Calcium (mg/L)	-	1,000	-	46	145	442	21	40	73	15	34.8	41	51	8	142	150	182	128	70	130	170	59	74	110	212	3	80	113	156
Chloride (mg/L)	-	-	250 [C]	753	1,900	5,505	30	110	400	21	49	67	771	14	1,895	2,800	4,356	139	1,292	4,300	5,140	86	580	2000	4060	3	1960	2897	3680
Chromium (mg/L)	0.0033 (CrIII)	1	0.05 (as CrVI)	-	-	-	-	-	-	0	-	-	-	1	-	0.001	-	23	0.001	0.016	0.0268	11	0.001	0.006	0.013	3	0.001	0.001	0.001
Cobalt (mg/L)	0.0014	1	-	-	-	-	-	-	-	0	-	-	-	1	-	0.001	-	23	0.001	0.001	0.0068	11	0.001	0.001	0.001	3	0.001		0.002
Copper (mg/L)	0.0014	0.4 (sheep) 1 (cattle) 5 (pigs & poultry)	2	0.017	0.030	0.03	0	0.01	0.03	0	-	-	-	1	-	0.001	-	23	0.0014	0.004	0.006	11	0.001	0.004	0.005	3	0.001	0.001	0.001
Iron (mg/L)	-	not sufficiently toxic	0.3 [C]	0	0.05	0.246	0	0.01	0.04	34	0.376	2.12	5.82	25	0.05	0.05	0.554	138	0.05	0.17	1.2	119	0.05	0.05	0.29	3	0.05	0.05	0.05
Lead (mg/L)	0.0034	0.1	0.01	-	-	-	-	-	-	0	-	-	-	1	-	0.001	-	25	0.001	0.001	0.001	13	0.001	0.001	0.001	3	0.001	0.001	0.001
Magnesium (mg/L)	-	2,000	-	35	115	491	21	54	119	9	14	18	21.4	10	198	296	335	67	51	148	400	42	47	100	483	3	118	173	229
Mercury (mg/L)	0.0006	0.002	0.001	-	-	-	-	-	-	28	0.0001	0.0001	0.0001	18	0.0001	0.0001	0.0005	131	0.0001	0.0001	0.0005	104	0.0001	0.0001	0.0001	3	0.0001	0.0001	0.0001
Manganese (mg/L)	1.9	not sufficiently toxic	0.5	0.000	0.05	0.291	0	0.01	0.02	0	-	-	-	1	-	1.2	-	23	0.022	0.19	0.634	11	0.23	0.27	0.3	3	0.002	0.022	0.062
Nickel (mg/L)	0.011	1	0.02	-	-	-	-	-	-	0	-	-	-	1	-	0.003	-	38	0.0044	0.008	0.013	17	0.0012	0.003	0.005	3	0.003	0.004	0.005
Potassium (mg/L)	-	-	-	-	-	-	-	-	-	21	3	4	6	13	7.5	11	12	82	6	8	13	60	2	5	11	3	12.0	15.3	17.0
Selenium (mg/L)	0.005	0.02	0.01	-	-	-	-	-	-	33	0.01	0.01	0.01	19	0.01	0.01	0.01	112	0.01	0.01	0.01	103	0.01	0.01	0.01	3	0.01		0.01
Silver (mg/L)	0.00005	-	0.1	-	-	-	-	-	-	0	-	-	-	1	-	0.001	-	23	0.001	0.001	0.0016	11	0.001	0.001	0.001	3	0.001	0.001	0.001
Sodium (mg/L)	-	-	180 [2]	480	1100	2565	56	135	326	21	36	42	648	13	1,800	2,100	2,700	135	1,400	2,600	3,336	85	580	1150	1890	3	1500	2053	2540
SO_4 (mg/L)	-	1,000	250 [C]	25	138	398	5	24	125	21	5	48	150	14	599	1,100	1,690	140	3	529	801	87	28	194	398	3	784	1369	2330
Uranium (mg/L)	ID	0.2	0.017	-	-	-	-	-	-	0	-	-	-	1	-	0.005	-	23	0.001	0.007	0.008	11	0.001	0.001	0.001	3	0.005	0.006	0.007
Zinc (mg/L)	0.008	20	3	0.01	0.025	0.317	0	0.015	0.05	0	-	-	-	1	-	0.024	-	23	0.0038	0.012	0.0246	11	0.005	0.014	0.02	3	0.011	0.017	0.022
Total Hardness as CaCO3 (mg/L)	-	-	200 [C]	359	919	3,208	145	350	650	18	140	192	576	9	352	403	444	65	232	830	980	52	396	651	797	3	686	994	1330

Metals concentrations presented for groundwater are dissolved. Greyed out values for groundwater quality represent method detection limits

1 Australian and New Zealand Guidelines for Fresh and Marine Water Quality (2018) - for dissolved metals and metalloids, guideline value relates to slightly-moderately disturbed systems, 95% species protection.

2 Natural component of water - guideline value is taste threshold.

A ADWG are recommended guidelines for human consumption of water (i.e. post-treatment), NHMRC (2011)

ID - insufficient data

C Aesthetic guideline / Insufficient data to set a guideline value based on health considerations.

Table 2-7 Total dissolved solids (mg/L) - livestock water quality guidelines and groundwater quality

Livestock	Low range	Medium range	High range
Beef Cattle	0 – 4,000	4,000 – 5,000	5,000 – 10,000
Dairy Cattle	0 – 2,400	2,400 – 4,000	4,000 – 7,000
Sheep	0 – 4,000	4,000 – 10,000	10,000 – 13,000
Horses	0 – 4,000	4,000 – 6,000	6,000 – 7,000
Pigs	0 – 4,000	4,000 – 6,000	6,000 – 8,000
Poultry	0 – 2,000	2000 – 3,000	3,000 – 4,000
Formation	**20th %ile**	**50th %ile**	**80th %ile**
Mackenzie Alluvium	334	378	640
Tertiary	1,132	2,350	9,596
Rangal Coal Measures	1,090	8,434	9,674
Burngrove Fm.	2,242	4,710	8,366
Tailings Water Samples (3 samples from Pit B TSF 2022))	4,480 (min)	6,717 (mean)	8,260 (max)

Low range - No adverse effects expected
Medium Range - Animals may have initial reluctance to drink, but stock should adapt without loss of production.
High range - Loss of production and a decline in animal condition and health would be expected. Stock may tolerate these levels for short periods if introduced gradually.

To provide a broad picture of groundwater quality in the vicinity of the mine Table 2-6 and Table 2-7 presents water quality statistics (20th, 50th and 80th percentiles) for each of the main formations monitored together with the following relevant water quality guidelines:

- Livestock drinking water guidelines (ANZECC, 2000) – given the rural agricultural setting of the mine the stock watering guidelines are considered relevant to assessing local groundwater values.
- Australian Drinking Water Guidelines (ANZECC, NRMMC 2011) – given the rural setting of the mine and the potential presence of local stock and domestic bores the drinking water guidelines are considered relevant to assessing local groundwater values.
- Australian and New Zealand Guidelines for Fresh and Marine Water Quality (2018) – these guidelines, originating from the ANZECC & ARMCANZ (2000) water quality guidelines, provide guideline values for the protection of fresh and marine water habitats. The values selected from this guidance relates to slightly-moderately disturbed freshwater systems for 95% species protection. These guidelines are considered relevant for protection of the Mackenzie River and its tributaries.
- Groundwater Quality Objectives for the Fitzroy River Basin (Zone 13 & 34) (DEHP 2011) - These guidelines are intended to be protective of surface waters where there is the potential for groundwater surface water interaction i.e., groundwater quality should not compromise identified EVs and WQOs for those waters. This guidance groundwater quality objectives i.e., background groundwater quality statistics that should be maintained for groundwaters, for 44 zones and depths (shallow and deep) across the Fitzroy Basin. The mine lies within Zone 13 which is categorised as Low-Moderate salinity alluvial groundwater – reflective of the Mackenzie River Alluvium. In addition, guideline values for Zone 34 (deep) have been included which is regarded as saline groundwater and considered more representative of deeper groundwater within the RCM and Burngrove Formation.

A summary of general groundwater quality compared these to guideline values is presented below.

- Livestock drinking water guidelines (ANZECC, 2000) – except for sulphate in Tertiary strata at the 50th and 80th percentile none of the guideline values for stock watering in Table 2-6 are exceeded in any lithology even at the 20th percentile. TDS is considered separately in Table 2-7:
    - Mackenzie River Alluvium – Salinity/TDS is suitably low for stock watering.
    - Tertiary – salinity is generally low and suitable for most stock although higher salinities/TDS are observed around the 80th percentile rendering it suitable for beef cattle and sheep only.
    - RCM – salinity/TDS is elevated with concentrations around the 50th percentile becoming unsuitable for more sensitive livestock. 80th percentile TDS exceeds the high range guidelines for most livestock except sheep and beef cattle.
    - Burngrove Formation – salinities/TDS around the 50th percentile concentration are generally still suitable for all but the most sensitive livestock (poultry and dairy cattle) but increase to similar concentrations seen in the Tertiary and RCM at the 80th percentile. 80th percentile TDS exceeds the high range guidelines for most livestock except sheep and beef cattle.
    - Pit B tailings water – the three samples collected show mean and maximum salinities similar to but lower than the RCM with the mean TDS being generally unsuitable for more sensitive livestock. Maximum TDS exceeds the high range guidelines for most livestock except sheep and beef cattle.
- Australian Drinking Water Guidelines (ANZECC, NRMMC 2011) – groundwater quality in the Mackenzie River Alluvium to the west of Curragh North is considered generally suitable for drinking water based on chemical quality noting the exceedances below. The composition of groundwater in the Tertiary, RCM, and Burngrove Fm. Is considered unsuitable for drinking water, primarily due to its generally high salinity. The following exceedances of guideline values are noted:
    - Mackenzie River Alluvium - The (aesthetic) guidelines for TDS, Na and total hardness are exceeded at the 80th percentile and the (aesthetic) guideline for Fe is exceeded at all percentiles. In addition, the guideline for As is fractionally exceeded at the 80th percentile.
    - Tertiary - The (aesthetic) guidelines for TDS, Cl, Na, SO4 and hardness are exceeded at the 20th percentile. In addition, the guidelines for Al, As and Fe are exceeded at the 80th percentile and one analysis for Mn also exceeds the guideline.
    - RCM - The (aesthetic) guidelines for TDS, Cl, Na and hardness are exceeded at the 20th percentile, and SO4 at the 50th percentile. In addition, the guidelines for As, Fe and Mn are exceeded at the 80th percentile.
    - Burngrove Formation - The (aesthetic) guidelines for TDS, Cl, Na and hardness are exceeded at the 20th percentile, and SO4 at the 80th percentile.
    - Pit B tailings water – The (aesthetic) guidelines for TDS, Cl, Na, hardness and SO4 are exceeded. and SO4 at the 50th percentile. In addition, the maximum concentration of Sb exceeds guideline value.
- Australian and New Zealand Guidelines for Fresh and Marine Water Quality (2018) – 95% species protection. With regard to the potential impacts on surface water ecosystems local groundwater the following exceedances identified:
    - Mackenzie River Alluvium – none of the guideline values are exceeded at the 20th percentile.
    - Tertiary – The guideline for B and Zn is exceeded although the sample count for these analytes is just 1.

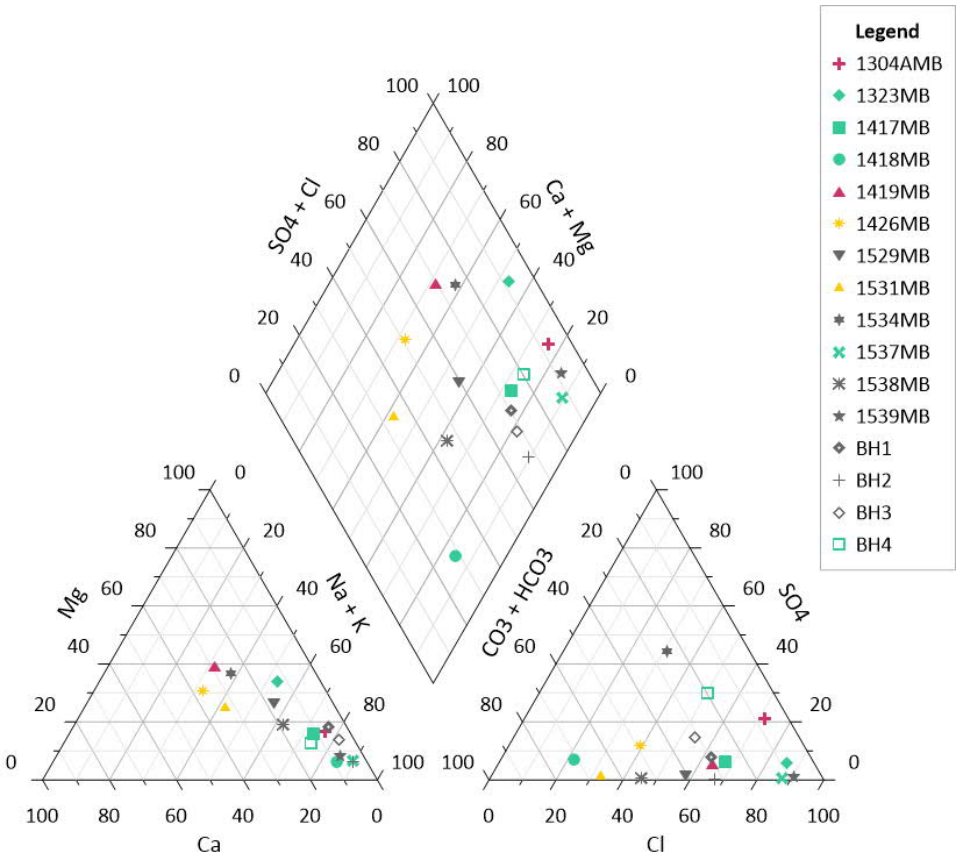
  - RCM - The guideline for B is exceeded at the 20th percentile; Cr, Cu and Zn at the 50th percentile and, Co, K and Ag at the 80th percentile.
  - Burngrove Formation - The guideline for B is exceeded at the 20th percentile; Cu and Zn at the 50th percentile and, Cr at the 80th percentile.
  - Pit B tailings water - The guideline for B, Co and Se is exceeded by the maximum concentration; and the guideline for Zn by all three samples.

- Groundwater Quality Objectives for the Fitzroy River Basin (Zone 13 & 34) (DEHP 2011) - These guidelines are intended to be protective of surface waters where there is the potential for groundwater - surface water interaction. The Mackenzie River Alluvium has been compared to Zone 13 (shallow) guidelines which are intended for low salinity alluvial groundwater. The Tertiary, RCM and Burngrove Formation groundwater has been compared to guidelines for Zone 34 (deep) which are considered more appropriate for the deeper geology across the mine:
  - Mackenzie River Alluvium – pH (slightly lower than the 20th %ile guideline); and exceedances for EC (80th %ile), Ca (20th and 50th %iles), Fe (20th, 50th and 80th %iles), Na (80th %ile), and SO4 (50th and 80th %iles).
  - Tertiary – pH (slightly lower than the 20th %ile guideline); and exceedances for Ca (20th and 50th %iles), Mg (20th and 50th %iles), Mn (20th, 50th and 80th %iles), Na and SO4 (20th, 50th and 80th %iles).
  - RCM - pH (slightly lower than the 20th and 50th %ile guideline); and exceedances for Fe (50th and 80th %iles), Mg (20th %ile), Mn, Na and SO4 (20th, 50th and 80th %iles).
  - Burngrove Formation - pH (slightly lower than the 20th %ile guideline); and exceedances for EC (20th and 50th %iles), Fe (80th %ile), Mg (20th %iles), Mn (20th, 50th and 80th %iles), Na and SO4 (50th and 80th %iles).
  - Pit B tailings water –
    - exceedances of the “shallow” guideline values for pH (slightly higher) and EC, Ca, Cl, Mg, Mn, Na, SO4 and total hardness (20th, 50th and 80th %iles); Zn (20th and 50th %iles);
    - exceedances of the “deep” guideline values for pH (slightly higher) and SO4 (20th, 50th and 80th %iles); EC, Cl, Mg, Na, and total hardness (20th, 50th %iles); Ca, Mn, Zn (20th %ile).

The quality of tailings water obtained from the Pit B TSF is considered to be broadly very similar to the groundwater samples obtained from the RCM. The tailings water has trace concentrations of As and Sb and a significantly higher SO4 concentrations compared to the RCM groundwater. Whereas RCM groundwater contains trace concentrations of Cu and Cr which the tailings water samples do not.

For bores with sufficient data on major ion chemistry, the mean major ion concentrations have been plotted on a Piper Diagram (Figure 2-18), to determine key differences in the hydrochemical facies of groundwater sampled from different strata. The Piper Plot displays individual bores colour coded for the different formations: Mackenzie River Alluvium (yellow), Tertiary (red), RCM (grey) and Burngrove Formation (green).

The fresher groundwater of the Mackenzie River Alluvium (yellow), fall within the Mg-HCO3 field while the RCM bores plot mostly within the Na-Cl field as does groundwater sampled from the Burngrove Formation. The two bores screened in the Tertiary plot separately in the Na-Cl field and the adjacent mixed Ca-Mg-Cl field.



*Mackenzie River Alluvium (yellow), Tertiary (red), RCM (grey) and Burngrove Formation (green)

Figure 2-18 Piper plot of groundwater major ion chemistry

2.3.7 Groundwater Recharge and Discharge

2.3.7.1 Recharge

Recharge of the alluvial aquifers occurs via stream flow, particularly during periods of high flow and flooding, as well as via rainfall infiltration. Most creeks in the region are ephemeral, although flow in the Mackenzie River is controlled by releases from Fairbairn Dam and the upper reach of Blackwater Creek flows due to discharge from the Blackwater Wastewater Treatment Plant. These streams may provide a constant source of recharge to the underlying alluvial and weathered rock groundwater systems. Groundwater studies undertaken at Curragh North prior to the commencement of mining found the alluvium was dry in many areas which may be related to clays and silts in the upper part of the alluvial profile restricting direct recharge and streamflow infiltration (PB 2003).

In the initial phases of mining at Pit S at Curragh North in late 2014, conceptual understanding was that Mackenzie River may provide recharge to the alluvium with a hydraulic gradient in the alluvium towards Pit S (Douglas and Partners, 2014). However, the 2016 PB assessment indicates that very minor inflow from the alluvium in the wall buttress on the Mackenzie River side of the pit has been observed and no change in water levels in Mackenzie River during mining (PB 2016). This may be due to the disconnected nature of the permeable channel deposits and the presence of clay and silt layers limiting the connectivity between the alluvium and mining operations directly east of the Mackenzie River at Curragh North (PB 2016).

From a review of available monitoring data Parsons Brinckerhoff (2003) identified a limited response in alluvial groundwater levels to rainfall events and subsequent river level rises and suggest this was due to the monitored alluvial groundwater being perched, and the high fines content of the alluvial sand and gravel lenses.

Following a review of alluvial bore logs between the Mackenzie River and proposed Pit X, and Blackwater Creek and proposed extension Pits D and J which identified a relatively high proportion of clay, PB (2016) again suggest that recharge to alluvium in these areas may be limited.

Recharge to the aquifer units within the RCM and Burngrove Formation is likely to occur predominantly through rainfall infiltration in outcrop areas, and via vertical leakage, particularly where coal seams subcrop permeable alluvium. Some recharge may also occur via stream flow where formations outcrop / subcrop along creek lines, for example where the RCM outcrops Bonnie Doon Creek.

2.3.7.2 Discharge

The major discharge from the RCM in the vicinity of the mine is direct inflow to the mine pits. Regional groundwater flow is also a discharge mechanism with the general direction of groundwater flow being toward the north-east.

Evapotranspiration from the water table is also a significant discharge mechanism in areas where the water table is shallow and within the rooting depth of vegetation.

The BOM GDE Atlas indicates that Mackenzie River, Blackwater Creek and Cooroora Creek have a moderate potential for groundwater interaction. There is potential that groundwater in alluvium may discharge to Mackenzie River at times, particularly during the wet season when groundwater levels may rise. This is discussed further below.

Local extraction of groundwater by landholders is also a discharge mechanism although this appears to be limited in the vicinity of the mine (Section 2.4.2).

Other streams in the study area, including Blackwater Creek, Minnie Creek, Sagittarius Creek and Bonnie Doon Creek, are considered unlikely to receive baseflow from groundwater. This is consistent with site observations which indicate these streams are dry during the dry season and only flow following rainfall runoff during the wet season (PB 2016).

2.3.8 Surface Water Groundwater Interaction

2.3.8.1 Mackenzie River (including Cooroora Creek)

The Mackenzie River is the main watercourse in the vicinity of the mine with regulation and releases from Fairburn Dam having altered the natural flow regime. Cooroora Creek is a tributary of Mackenzie River to the west of Curragh North.

2.3.8.1.1 Occurrence of groundwater

Groundwater studies undertaken by Parsons Brinckerhoff (2003) at Curragh North prior to the commencement of mining found that most monitoring bores installed in alluvium were dry. Where water was present in monitoring bores, it occurred within the basal palaeochannel deposits of gravel and coarse sands.

2.3.8.1.2 Pre-mining groundwater levels

Groundwater studies undertaken by Parsons Brinckerhoff (2003) at Curragh North prior to the commencement of mining included installation of a groundwater monitoring network in the Mackenzie River alluvium and monitoring levels in the Mackenzie River.

Monitoring was undertaken from November 2001 to May 2003 at three alluvial bores located immediately adjacent to Mackenzie River (near current Pit U and Pit T). Hydrographs for these bores and levels in the Mackenzie River are presented in Figure 2-19 and show that groundwater levels in the alluvium were 3-5 m below the Mackenzie River stage. The monitoring also shows that high flow events captured in the monitoring data with river stage increases of over 1m had little or no impact on groundwater levels in the neighbouring alluvial groundwater bores. The data was interpreted as an indication that prior to mining at Curragh North, there was limited leakage from the river to the alluvium, and no discharge of groundwater from the alluvium to the river.

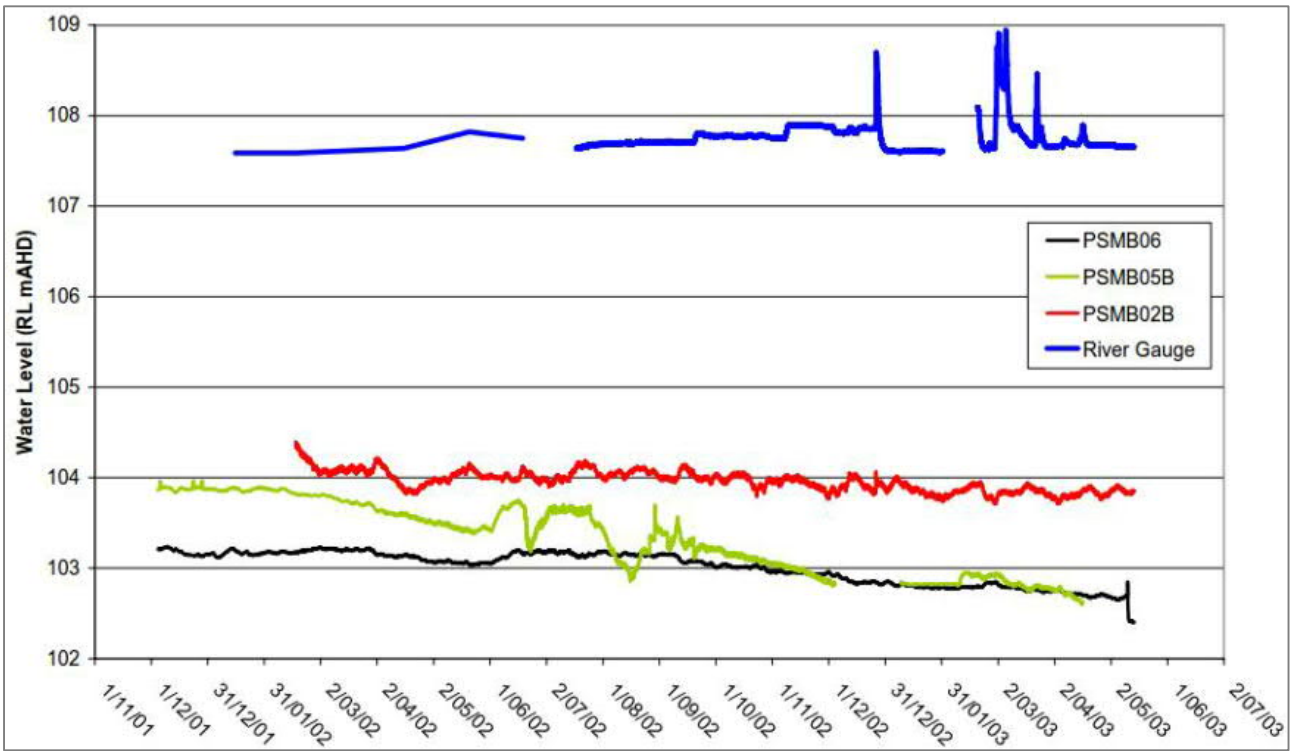


Figure 2-19 Mackenzie River stage and Mackenzie alluvium groundwater levels (reproduced from AGE, 2006)

Groundwater monitoring undertaken for the Mackenzie South Project observed a similar relationship with groundwater levels in an alluvial bore (MSP0203), immediately adjacent to the Mackenzie River 4.2 m below the river stage prior to the commencement of mining (AGE, 2006). It is noted that the monitoring undertaken for the Curragh North and Mackenzie South projects was undertaken during a period of low rainfall.

2.3.8.1.3 Observations of mining adjacent to the river

Curragh North pits (S, T and U) experience inflows from the alluvium, which, in this area is relatively thick and comprised of sand and gravel. Average daily inflow from the alluvium to these pits is estimated to be 3.5 Ml/d (40 l/s), with the bulk of this inflow occurring at Pit U (3 Ml/d) (PB 2016).

A review of inflows to Pit S by Douglas Partners (2014) indicated that at the start of mining in late 2014, inflows were observed from sand and gravel at the base of the alluvium. Curragh Mine also reported that saturated alluvium was encountered in Pit S at approximately 5 to 10 mbgl with initial inflow/dewatering rates of approximately 6.5 Ml/day (PB 2016).

Two months after mining started in Pit S, the alluvium on the western pit face adjacent to Mackenzie River was dewatered and the majority of inflow was observed from the east pit face and monitoring bores screened to the base of the alluvium between the Mackenzie River and Pit S were dry or recorded water levels near the base (PB 2016).

Site observations of limited seepage from west buttress wall of Pit S suggest there is limited hydraulic connection between the Mackenzie River and the alluvium intersected in Pit S. This may be due to low permeability alluvial silt and clay between the river and pit, combined with low permeability riverbed material. Curragh Mine personnel have observed that pit inflows have not changed in relation to changing water levels in the Mackenzie River or wet season rainfall conditions (PB 2016).

2.3.8.1.4 Riverbed materials

Inspection of the Mackenzie River by AGE (2006) immediately downstream of Curragh North, found the material exposed in the banks to be clay bound gravels suggesting the Mackenzie River stream bed is of relatively low permeability, limiting seepage of water from the river to the alluvium. Similar stream bed materials were observed in the Nogoa River upstream, where a detailed study of connectivity between the river and underlying alluvium was undertaken for Ensham Mine (AGE, 2006). The study involved installation of 23 monitoring bores in alluvium along both sides of the Nogoa River and excavation of pits in the stream bed and showed that there was no connection between the alluvium and river (AGE, 2006). The findings of this study were supported by investigations undertaken by the Queensland government on the Nogoa River floodplain which concluded 'it is unlikely that there is any connection between the river system and groundwater. Groundwater is restricted to the deeper section of the alluvium and there are large tracts of dry alluvium' (cited in AGE 2006).

2.3.8.2 Blackwater Creek

Blackwater Creek is a tributary of Mackenzie River. It is a highly modified system having undergone three previous channel alterations due to Curragh Mine workings including a 9.4 km diversion in 2010.

The field investigation program for the Minyango project found the Blackwater Creek alluvium was only saturated in areas where there is a significant thickness of deeper alluvial sediment (AGE 2013). Within the study area, the Blackwater Creek alluvium forms a relatively thin heterogeneous system, with lenses of poorly connected clean sand separated by lower permeability clayey facies and bedrock highs (PB 2016). The constant flow in the upstream section of Blackwater Creek is understood to be from the Blackwater Wastewater Treatment Plant (WTP) which discharges effluent via Sagittarius Creek.

Depth to groundwater (based the PB 2016 calibrated numerical groundwater model) indicates that Blackwater Creek is unlikely to receive baseflow from groundwater, with groundwater levels more than three metres below the stream bed. This is supported by observation of the downstream end of Blackwater Creek being dry except following rainfall.

Blackwater Creek was conceptualised by PB in 2016 to be a losing stream that is disconnected from the water table.

2.4 Groundwater Related Values

2.4.1 Groundwater dependent ecosystems (GDEs)

A Groundwater Dependent Ecosystem (GDE) is one in which the plant and/ or animal community is dependent on the availability of groundwater to maintain its structure and function. The BoM Groundwater Atlas (BoM, 2021) indicates areas of primarily low potential terrestrial GDEs / IDEs (inflow dependent ecosystems associated with the riparian corridor of the Mackenzie River and, to a lesser extent, Blackwater Creek (Figure 2-20). These terrestrial GDEs are vegetation ecosystems that rely on the subsurface presence of groundwater.

The 2016 PB assessment (due to its objective of assessing impacts associated with expansion), considered the potential for impacts on GDEs in considerable detail. The area of potential subsurface GDEs was assumed to be restricted to areas of saturated alluvium based on the results from the numerical groundwater modelling. It was also assumed that within the areas of saturated alluvium that groundwater dependence was related to the depth to the water table and vegetation rooting depth. The following criteria were used to refine the areas of likely and potential subsurface GDEs in the vicinity of the site:

- Where field verified and Queensland Herbarium mapped regional ecosystems associated with likely and potential GDEs intersected with modelled areas of saturated alluvium
- The likelihood or potential for groundwater dependence of a terrestrial GDE was based on the depth to groundwater within the area of saturated alluvium as follows:
    - High likelihood of groundwater dependence – depth to groundwater <10 m
    - Possible groundwater dependence – depth to groundwater between 10 and 20 m
    - Groundwater dependence unlikely – depth to groundwater >20 m.

The assessment (PB, 2016) identified that much of the reach of the Mackenzie River and Cooroora Creek (tributary of the Mackenzie), within the model domain, and the northern reaches of Blackwater Creek, had a high potential to host terrestrial GDEs along the riparian corridor with a likely depth to groundwater of <10 m.

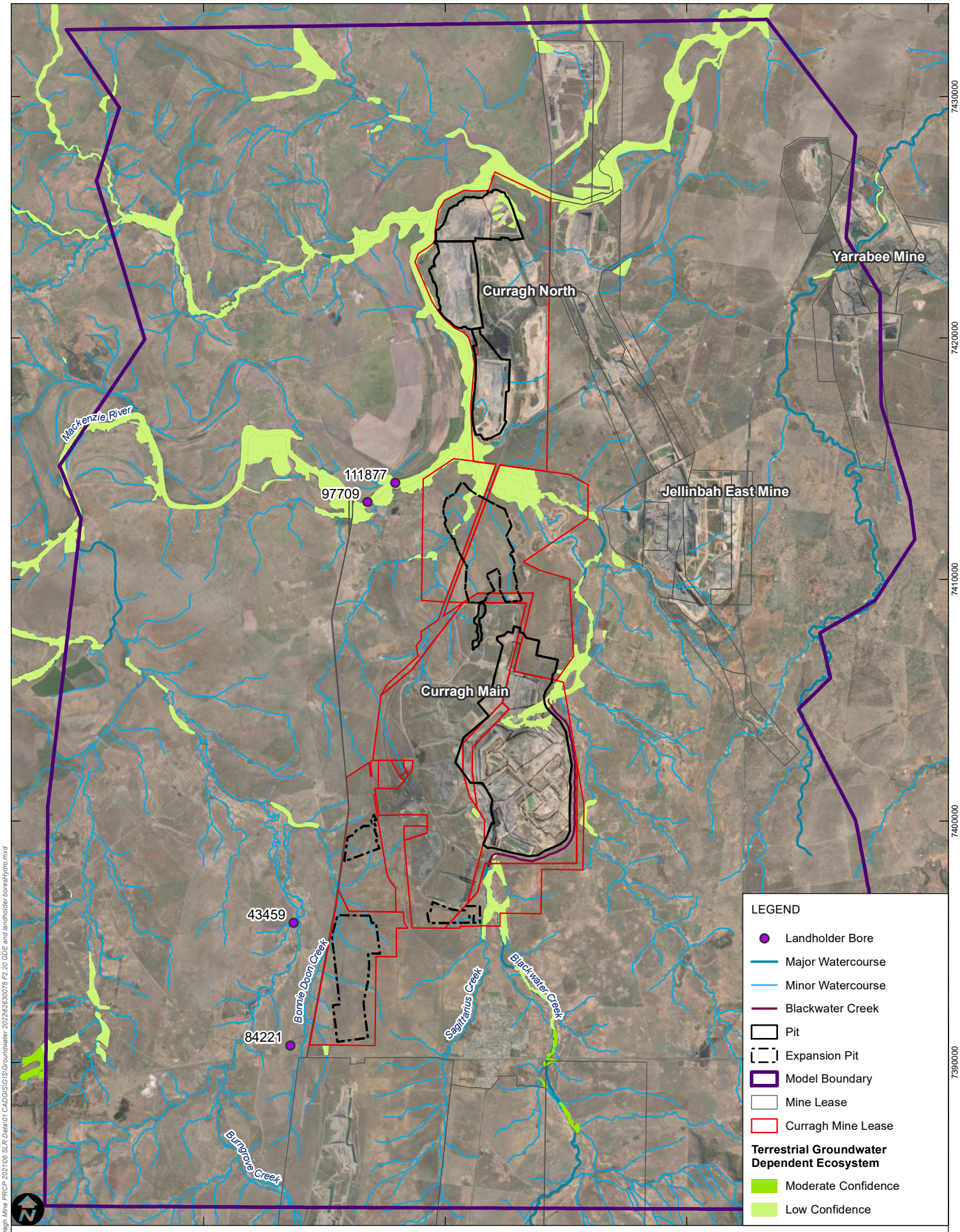
2.4.2 Local groundwater use

There are four registered bores within 3km of Curragh mining operations (existing or proposed); details are presented in Table 2-8 and their locations are shown on Figure 2-20.

Table 2-8 Registered bores within 3km of Curragh mining operations

RN		Depth (m)	SWL (mbgl)	Water quality	Yield (L/s)	Installed
43459	-	-	-	-	-	-
84221	Burngrove Formation	31	30	salty	0.12	1988
97709	-	57	13	Fresh	3.2	1998
111877	Mackenzie River Alluvium	23	15			2002

RN111877 is owned by Central Highlands Regional Council and located at the campground approximately 150 m south of Bedford Weir on the Mackenzie River. The Council have indicated the bore is used to irrigate grass near and in the toilet block at the campground and that the groundwater is relatively saline. The bore is used to fill a 45,000 L tank 2 to 3 times each week (PB, 2016).



SLR

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0 5 10 km

Coordinate System:	AGD 1984 AMG Zone 55
Scale:	1:200,000 at A4
Project Number:	626.30075
Date:	17-Oct-2022
Drawn by:	ML
Reviewed by:	ML

CURRAGH PRCP GROUNDWATER ASSESSMENT

Landholder Bores and Groundwater Dependent Ecosystems

FIGURE 2-20

H:\Projects-SLR\626-MKY\626.30075.00000 Curragh Mine PRCP 20211106 SLR Data\01 CAD\GIS\GIS\Groundwater 20226263075 F2.20 GDE and landholder bores\Hydro.mxd

2.5 Potential Sources of Groundwater Contamination

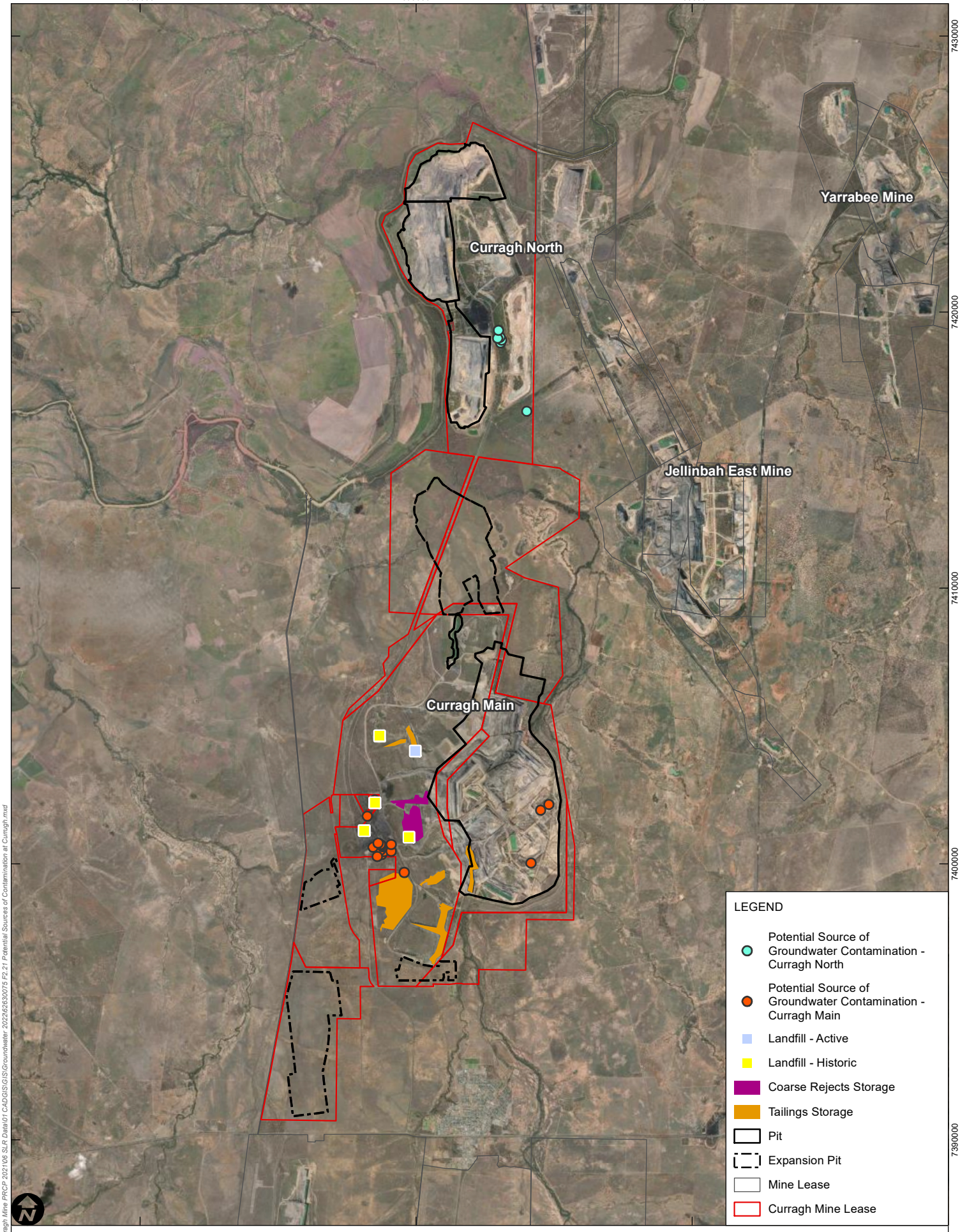
A number of sources of potential contamination to groundwater have been identified at Curragh. These sources include:

- tailings and coarse reject storages
- on site landfills (historic and current)
- Locations identified by Curragh staff – mostly focussed around infrastructure areas (workshop areas, vehicle washdown areas, bulk fuel storage / fuelling points, historic diesel spill site)

The locations of these potential sources are shown on Figure 2-21. Detailed evaluation of these locations, the presence of actual contamination and the likelihood or potential of these sites to contaminate groundwater is beyond the scope of this study. However, they have been identified at this stage to understand the local post mining groundwater flow regime and whether shallow groundwater at these locations is likely to be moving off site or continually towards the final voids if the final voids are generally acting as groundwater sinks. This has been evaluated through the use of "particle tracking" modelling and the post-mining shallow groundwater surface determined by numerical modelling (Section 4.3).

The tailings storage facilities (TSFs) are large volumes of material extending below the water table which have the potential to locally affect groundwater quality. However, limited sampling of water from the Pit B TSF suggests that the water quality is similar to that of the Rangal Coal Measures (Section 2.3.6). However, the destination of groundwater at or around the TSFs has also been evaluated using particle tracking and the post-mining groundwater levels (Section 4.3).

Shallow groundwater in the vicinity of the TSFs and the sources of potential groundwater contamination would migrate towards the final voids (which act as groundwater sinks), rather than migrate off site (Section 4.3)



H:\Projects-SLR\626-MKY\626.30075.00000 Curragh Mine PRCP 20211106 SLR Data\01 CAD\GIS\GIS\Groundwater 20226263075 F2.21 Potential Sources of Contamination at Curragh.mxd

SLR

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0 5 10 km

Coordinate System:	AGD 1984 AMG Zone 55
Scale:	1:175,000 at A4
Project Number:	626.30075
Date:	19-Oct-2022
Drawn by:	ML
Reviewed by:	ML

CURRAGH PRCP GROUNDWATER ASSESSMENT

Potential Sources of Groundwater Contamination at Curragh

FIGURE 2-21

3 Numerical Groundwater Modelling

3.1 Model History and Current Objectives

A numerical groundwater model for Curragh Mine was developed in 2016 by Parsons Brinckerhoff for Wesfarmers Resources Pty Ltd. The model was constructed and calibrated with the primary objective of quantifying the potential impacts of the Curragh Extension Project (X, Y and Z Pits) on groundwater resources and associated environmental values. The model was independently peer reviewed and audited by HydroSimulations in 2016. The peer review found the modelling design, model calibration and predictions to be fit for the purpose of quantifying impacts from proposed mining for the Curragh Extension Project.

The 2016 model was provided to SLR Consulting by CCPL in 2021 and was updated for use in a preliminary assessment of post-closure groundwater related issues for the Curragh Concept Residual Void Assessment (CRVA) (SLR, 2021). For the CRVA, the 2016 model temporal datasets were extended. Post-mining recovery simulation with detailed final void modelling was added to facilitate estimation of the effect of mine closure on the local groundwater regime. There were however some limitations with the 2021 model and a number of key updates were considered necessary to accurately simulate mine closure and groundwater level recovery including updating the model grid to add refinement where needed, incorporation of the most recent geological model including the extension pit areas; and representation of the final voids and tailings storages.

The key changes to the model design from that reported for the 2021 CRVA model (SLR, 2021) include:

- Model extent and grid – extended model domain, unstructured Voronoi grid with refinement in key areas;
- Model layers – constructed layers to capture significant displacement faults within Curragh Mine area and incorporate the most recent geological model for the Curragh Mine Complex;
- Boundary conditions – set model boundary conditions with revised grid and regional flows;
- Stresses – model inputs updated with recent and site-specific data;
- Calibration – the new model has been calibrated with an updated calibration data set.

The primary objective of this work is to develop an understanding of the post closure hydrogeological regime at Curragh as part of the closure planning process. The key objectives of this modelling exercise have been to:

- Develop a calibrated model with mine progression, final voids, tailings storages in line with the current closure landform design developed by Coronado;
- Simulate the post-mining groundwater level recovery to assess whether the final voids will generally act as groundwater sinks or sources; and;
- Understand the long-term effect of the proposed post-mining landform on local groundwater levels by comparing the long-term post closure case to a null case (no mining scenario).

Section 3 of this report sets out the design and construction of the new model and calibration. Section 4 presents the model set up for post closure recovery and the results.

3.2 Model Design Summary

3.2.1 Model Code

MODFLOW-USG Transport was used as the model code (Panday *et al.* 2013). MODFLOW-USG is a recent version of industry standard MODFLOW code and was considered the most suitable modelling code for accomplishing the model objectives. MODFLOW-USG optimises the model grid and increases numerical stability by using unstructured, variably sized cells. These cells take any polygonal shape, with variable size constraints allowing for refinement in areas of interest (i.e., geological or mining features).

Where previous MODFLOW versions restricted interlayer flow to vertical connectivity, MODFLOW-USG offers lateral connectivity between model layers. Lateral connectivity enables more accurate representations of hydrostratigraphic units, particularly those that pinch out, outcrop, or cross geological faults. MODFLOW-USG is also able to simulate unsaturated conditions, allowing progressive mine dewatering and post closure rewetting to be represented by the model.

Fortran code and a MODFLOW-USG edition of the Groundwater Data Utilities (Watermark Numerical Computing) were used to construct the MODFLOW-USG input files.

3.2.2 Model Extent and Mesh Design

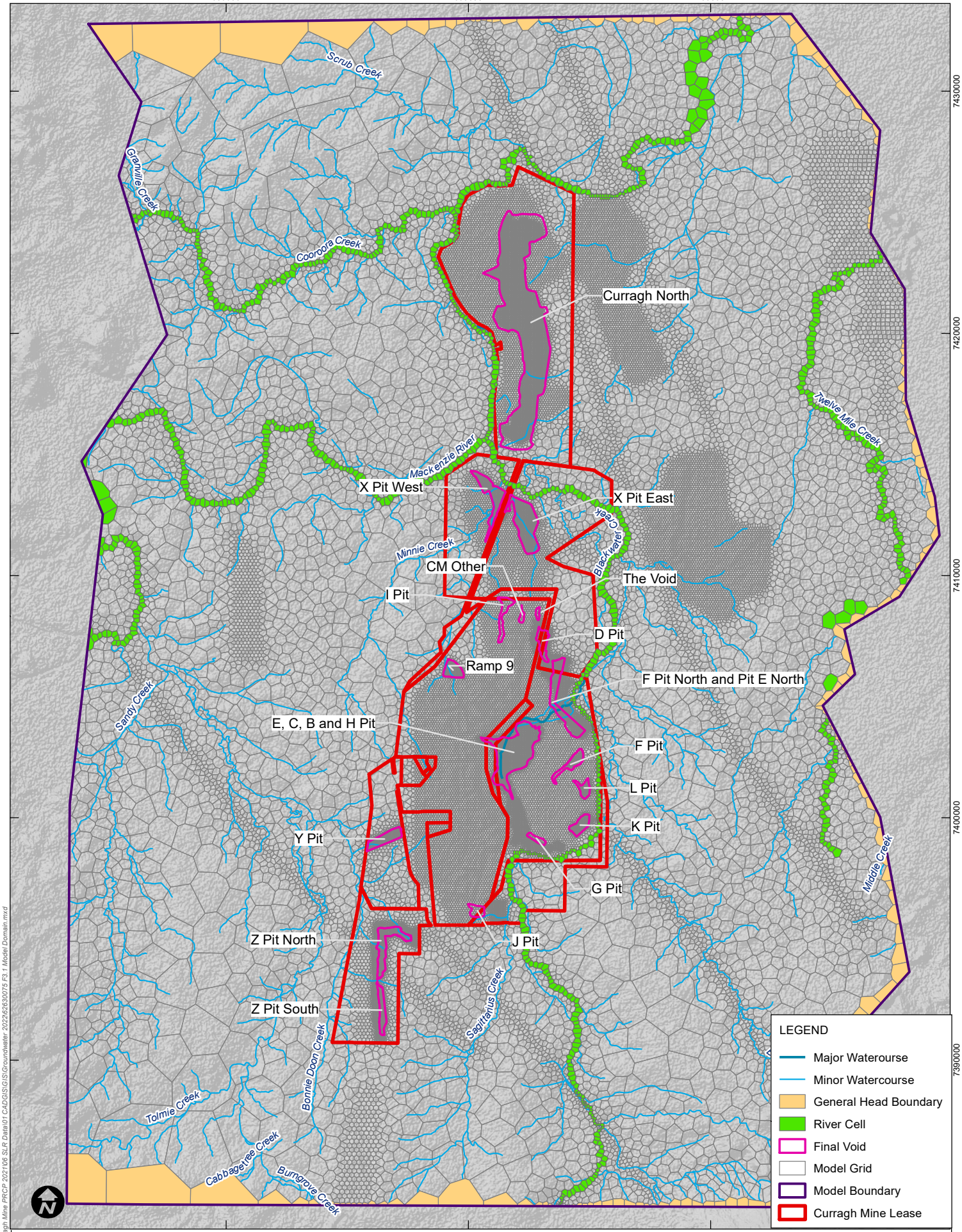
The model geometry including the grid and layering have been changed from the 2021 groundwater model update by SLR. The model domain is presented in Figure 3-1. The horizontal and vertical extent of the numerical model was set up to cover all historical and future mining operations at Curragh Mine (approximately 49.3 km N-S and 34.8 km W-E).

The model domain is intended to place boundary conditions sufficiently distant from Curragh Complex to allow the extent of potential impacts from mining activities on the groundwater system to be assessed without being impacted by model boundary conditions, on the basis of the predicted extent of residual drawdown for Curragh Complex reported by the SLR (2021) model. The western boundary follows the sub-crop line at the base of the Fairhill Formation and the eastern boundary has been set along a combination of major faults and the geological boundary between the RCM and the Rewan Formation.

To optimise model run times by reducing the total cell count, an unstructured grid with varying Voronoi cell sizes was designed using AlgoMesh (HydroAlgorithmics, 2014). Varying Voronoi cell sizes allow areas of interest to be refined, while a coarser resolution elsewhere reduces the total cell count and model run times. The model domain was vertically discretised into 23 layers, each layer comprising a cell count of up to 41,111. The total number of cells in the model is 395,021 after pinching out layers across those parts of the model domain where these geological units are not present.

The following features have been included in the grid design:

- The McKenzie River is represented in the model with a 200 m cell size constraint;
- Open cut mining at Curragh is represented with a 100 m cell size constraint;
- Other open cut mine areas included in the model have a 100 m cell size constraint;
- Final voids at Curragh are represented with a 50 m cell size constraint; and
- Tailings storage facilities at Curragh are represented with a 50 m or 100 m cell size constraint;



H:\Projects-SLR\626-MKY\626.30075.00000 Curragh Mine PRCP 2021\06 SLR Data\01 CAD\GIS\GIS\Groundwater 20226263075 F3.1 Model Domain.mxd

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0 5 10 km

Coordinate System:	AGD 1984 AMG Zone 55
Scale:	1:200,000 at A4
Project Number:	626.30075
Date:	13-Sep-2022
Drawn by:	AN
Reviewed by:	AN

CURRAGH PRCP GROUNDWATER ASSESSMENT

Model Domain

FIGURE 3-1

The model was developed with 23 layers to represent the regional stratigraphy and capture key coal seams mined at site and surrounding operations. The model layers are presented in Table 3-1, detailing the average thickness and maximum thickness for each relevant unit included in the model. Model layer extents (lateral and vertical) have been defined using the Curragh Mine geological model with the support of exploration data from Queensland Globe for geological data beyond the extent of the Curragh Mine geological model.

Consistent with the 2021 model, the RCM are represented over three model layers, upper, middle and lower RCM, with coal seams aggregated into a total thickness at the base of each of these layers.

Major regional faults are included in the model together with a number of smaller scale local faults. The Jellinbah Fault, a regional thrust fault running in a north-westerly direction to the east of the Project resulting in up to 400 m of displacement, has been incorporated into the model by representing separate model layers (the repeated geological sequence) on either side of the fault, with lateral connection simulated between adjacent units along the fault line. Layers 3 to 11 represent geological units to the west of the Jellinbah Fault with the equivalent geological units represent by layers 12 to 23 on the eastern side of the fault. Other faults within the model domain have been represented only through model layer elevations.

To represent the geological structure pinched out layers were used from Layer 3 to Layer 23.

Table 3-1 Model Layers and Thicknesses

Model Layer	Formation	Unit	Average Thickness (m)	Maximum Thickness (m)
1	Alluvium/Gravel	Surface cover	15.5	42.4
1	Alluvium (Sand-Clay)		9.2	18.0
1	Alluvium-Clay		9.2	18.0
1	Weathered Rock /Rewan		6.6	15.1
1	Weathered Rock-RCM		13.0	38.3
1	Weathered Rock		9.3	31.0
2	Weathered	Tertiary and minor Triassic Clematis, weathered Permian	13.0	64.2
3	Rewan WEST	Triassic sandstone, siltstone, mudstone	46.3	515.9
4	RCM Overburden West		29.5	316.3
5	RCM Upper Seams West	Cancer, Aries, Castor seams	15.2	428.0
6	RCM Interburden West	Sandstone, siltstone	36.7	131.4
7	RCM Middle Seams West		2.5	5.0
8	RCM Interburden West	Sandstone, siltstone	18.5	57.0
9	RCM Lower Seams West	Pisces seam	3.4	4.0
10	Burngrove West	Sandstone, siltstone, mudstone, coal seams	159.2	277.6
11	Fairhill Formation West	Sandstone, mudstone, coal seams	50.0	57.2
12	Rewan EAST	Triassic sandstone, siltstone, mudstone	169.6	641.2

Model Layer	Formation	Unit	Average Thickness (m)	Maximum Thickness (m)
13	RCM Overburden East		4.6	20.2
14	RCM Upper Seams East	Cancer, Aries, Castor seams	1.0	2.2
15	RCM Interburden East	Sandstone, siltstone	33.8	54.6
16	RCM Middle Seams East		3.2	3.3
17	RCM Interburden East	Sandstone, siltstone	10.0	33.4
18	RCM Lower Seams East	Pisces seam	2.8	2.8
19	Burngrove East	Sandstone, siltstone, mudstone, coal seams	203.9	647.7
20	Fairhill Formation East	Sandstone, mudstone, coal seams	125.0	125.0
21	Fairhill Formation East	Sandstone, mudstone, coal seams	125.0	125.0
22	Fairhill Formation East	Sandstone, mudstone, coal seams	125.0	125.0
23	Fairhill Formation East	Sandstone, mudstone, coal seams	125.0	125.0

3.2.3 Temporal discretisation

Consistent with the simulated time periods in the 2021 model (SLR), the model uses a steady-state stress period to represent the pre-mining conditions. The calibration period comprised 11 time slices (i.e., stress periods) of 3 years followed by 6 annual stress periods representing historical mining between January 1983 and January 2022. Together, the initial steady-state and transient calibration was split into 18 stress periods. The predictive period comprised 23 transient annual stress periods, representing future mining at Curragh Complex between January 2022 and January 2045. The predictive period was followed by a recovery period from January 2045 to January 2132, discretised into 3 annual, 14 biennial and 7 eight-year transient stress periods.

The temporal discretisation of the model has been updated from that previously used in the Curragh Model (SLR, 2021), to allow for the active mining simulation to extend to 2045. Table 3-2 and Table 3-3 summarise the calibration and predictive model stress periods respectively, alongside simulated timing of active mining. Mining simulated at Curragh has been summarised into the following areas:

- Curragh North - U, T and S Pits;
- Curragh Main – A, B, C, D, E, F, G, H, I, J, K and L Pits; and
- Curragh Expansion Areas - X Pit (East and West), Y Pit, Z Pit, and Ramp 9.

Table 3-2 Calibration Model Stress Period Setup

Calibration Period	Interval	Stress Period	Date (from)	Date (to)	Mackenzie (North & South) (OC)	Curragh North (OC)	Jellinbah (Plains & Central) (OC)	Washpool Coal (OC)	Curragh Main (OC)	Curragh Expansion Areas (OC)	Blackwater (OC)
Steady-state		1	Steady-state								
Transient	3-yearly	2	01/01/1983	31/12/1985					x		
	3-yearly	3	01/01/1986	31/12/1988					x		
	3-yearly	4	01/01/1989	31/12/1991					x		
	3-yearly	5	01/01/1992	31/12/1994			x		x		
	3-yearly	6	01/01/1995	31/12/1997			x		x		
	3-yearly	7	01/01/1998	31/12/2000			x		x		x
	biennial	8	01/01/2001	31/12/2003	x	x	x		x		x
	3-yearly	9	01/01/2004	31/12/2006	x	x	x		x		x
	3-yearly	10	01/01/2007	31/12/2009	x	x	x		x		x
	3-yearly	11	01/01/2010	31/12/2012	x	x	x		x		
	3-yearly	12	01/01/2013	31/12/2015	x	x	x		x		x
	Annual	13	01/01/2016	31/12/2016	x	x	x	x	x		x
	Annual	14	01/01/2017	31/12/2017	x	x	x	x	x		
	Annual	15	01/01/2018	31/12/2018	x	x	x	x	x		
	Annual	16	01/01/2019	31/12/2019		x	x	x	x		
	Annual	17	01/01/2020	31/12/2020		x	x	x	x		
	Annual	18	01/01/2021	31/12/2021		x	x	x	x		

Table 3-3 Predictive Model Stress Period Setup

Predictive Interval	Stress Period	Date (from)	Date (to)	Mackenzie (North & South) (OC)	Curragh North (OC)	Jellinbah (Plains & Central) (OC)	Curragh Main (OC)	Expansion Areas (OC)
Annual	19	01/01/2022	31/12/2022	x	x	x	x	x
Annual	20	01/01/2023	31/12/2023	x	x	x	x	x
Annual	21	01/01/2024	31/12/2024	x	x	x	x	x
Annual	22	01/01/2025	31/12/2025	x	x	x	x	x
Annual	23	01/01/2026	31/12/2026	x	x	x	x	x
Annual	24	01/01/2027	31/12/2027	x	x	x	x	x
Annual	25	01/01/2028	31/12/2028	x	x	x	x	x
Annual	26	01/01/2029	31/12/2029	x		x	x	x
Annual	27	01/01/2030	31/12/2030	x		x	x	x
Annual	28	01/01/2031	31/12/2031	x		x	x	x
Annual	29	01/01/2032	31/12/2032	x		x	x	x
Annual	30	01/01/2033	31/12/2033	x		x	x	x
Annual	31	01/01/2034	31/12/2034	x		x	x	x
Annual	32	01/01/2035	31/12/2035	x		x	x	x
Annual	33	01/01/2036	31/12/2036	x		x	x	x
Annual	34	01/01/2037	31/12/2037	x		x	x	x
Annual	35	01/01/2038	31/12/2038	x		x	x	x
Annual	36	01/01/2039	31/12/2039	x		x		x
Annual	37	01/01/2040	31/12/2040	x				x
Annual	38	01/01/2041	31/12/2041	x				x
Annual	39	01/01/2042	31/12/2042					x
Annual	40	01/01/2043	31/12/2043					x
Annual	41	01/01/2044	30/12/2044					

3.2.4 Model Stresses and Boundary Conditions

Stresses and boundary conditions used in the model have been adopted from the 2021 CRVA model (SLR, 2021) as follows.

3.2.4.1 Rainfall Recharge

The dominant mechanism for recharge to the groundwater system is through diffuse infiltration of rainfall through the soil profile and subsequent deep drainage to underlying groundwater systems. Diffuse rainfall recharge to the model was represented using the MODFLOW-USG Recharge package (RCH).

The recharge rates were established through the calibration process, with bounds based on the conceptual understanding of the system and comparing them with other groundwater models prepared for the region. The starting values adopted in the calibration process were from the Curragh Mine model (SLR, 2021). Rainfall recharge was imposed as a percentage of actual rainfall, calculated from the SILO Grid Point observations.

The model included 9 recharge zones, based on surface geology, as listed below:

- Quaternary Alluvium (Northern);
- Quaternary Alluvium (Central);
- Quaternary Alluvium (Southern);
- Weathered Permian units;
- Weathered Triassic units;
- Emerald Formation;
- Duaringa Formation;
- Weathered Tertiary and Quaternary units; and
- Basalt.

3.2.4.2 Evapotranspiration

MODFLOW evapotranspiration package (EVT) was used to simulate evapotranspiration in the model. The 9 recharge zones were used for construction of the EVT package to simulate varied evapotranspiration rates across the model domain.

The evapotranspiration rates were established through the calibration process, with starting values adopted based on the long-term average, annual, actual evapotranspiration for the Curragh Mine area. Evapotranspiration rates were adopted for the 9 zones as a calibrated factor applied to an approximate annual rate of 800 mm/year, set to an extinction depth of 2 m.

3.2.4.1 Fixed head boundaries

General Head Boundary (GHB) conditions have been specified along the northern, southern and the eastern model boundaries. The GHB boundary condition is used to represent the regional flow into and out of the model area and has been assigned using GHB cells in all layers using pre-mining head elevations. Groundwater will enter the model where the head set in the GHB is higher than the modelled water levels in the adjacent cell and will leave the model when the water level is lower in the GHB. GHB conductance is calculated using the hydraulic conductivity and the dimensions of each GHB cell and is therefore variable in this model due to variable cell-size.

A no flow boundary was applied to the western boundary of the model that represents the outcrop of the Fair Hill Formation.

3.2.4.2 Rivers

MODFLOW river package (RIV) was used to simulate significant watercourses in the model domain. The model includes the Mackenzie River and some tributaries of Mackenzie River, including Blackwater Creek. The Mackenzie River was represented at a constant level using the RIV package. The smaller tributaries to the Mackenzie River were represented using the RIV package, with stage elevations set equal to the minimum surface elevation in each cell, making these RIV cells act as drains.

3.2.4.3 Mining

MODFLOW drain package (DRN) was used to simulate historical and future open pit mining within the model domain. The simulated future mine progression in the model was primarily based on the 2016 study with updates to reflect historical mining that occurred after 2016, and more recent updates to future mine progression plans.

3.2.4.4 Variation in Hydraulic Properties - Open Cut Mining

Hydraulic properties were varied with time using the Time-variant materials (TVM) package of MODFLOW-USG Transport.

For open cut mining, Hawkins (1998) and Mackie (2009) indicate that spoil and waste rock are more permeable than the undisturbed strata. Completed open cut mining areas will be backfilled with waste overburden as the extraction proceeds. Backfilling of open cut mine areas with spoil was also modelled using TVM package. The model cell properties were updated to spoil properties guided by operational mine plans, and satellite imagery. Horizontal hydraulic conductivity of 0.3 m/day and vertical hydraulic conductivity of 0.1 m/day is applied to the spoil. The storage parameters used for the spoil were a specific yield of 0.1 and a specific storage of 1.0×10^{-5} m-1.

3.3 Model Calibration

Transient calibration was previously undertaken on the existing Curragh Model (SLR, 2021) and the calibrated parameters have been used as a starting point for calibration of the updated model. Automated calibration utility PEST ++ (Doherty 2019) and manual calibration were used to match the available transient water level data.

The calibration dataset groundwater level measurements recorded from August 1997 until June 2021. Most of this calibration dataset was derived from the original PB model (PB, 2016). The calibration consists of 980 target heads established for 65 bores from the following sites:

- Jellinbah Coal Mine: 19 groundwater level observations sites;
- Curragh Mine: 45 groundwater monitoring bores located across the Curragh, Curragh East and Curragh North mining areas; and
- Other bores: 1 water resource investigation bore.

Groundwater bores used for the calibration were weighted as 1 each in the calibration where data was considered reliable. Curragh monitoring bores BH3 and BH4 were weighted as 0.5, BH5 was weighted as 0.1, and BH2 was weighted as 0, reflective of data reliability. Consistent with the SLR (2021) recalibration data set, bore 1314MB was excluded from the calibration as the observed data indicated significant measurements errors. The observation points and their average residuals are presented in Appendix B.

The hydraulic properties (horizontal and vertical conductivity, specific yield and specific storage), and recharge rates were adjusted during the transient recalibration to provide best match between the measurements and model simulated heads. Manual parameter adjustment was undertaken to ensure the calibrated parameters were consistent with the conceptual understanding of the hydrogeological system. Vertical hydraulic conductivity was calibrated as a factor of horizontal conductivity (K_z/K_x). Reduced vertical hydraulic conductivity is typically observed due to sedimentary layering throughout the sequence, and by aggregation of strata in a numerical model.

3.3.1 Calibration Statistics

One of the industry standard methods to evaluate the calibration of the model is to examine the statistical parameters associated with the calibration. This is done by assessing the error between the modelled and observed (measured) water levels in terms of the root mean square (RMS). A root mean square (RMS) is expressed as:

$$RMS = \left[1/n \sum (h_o - h_m)_i^2\right]^{0.5}$$

Where:

- n = number of measurements
- h_o = observed water level
- h_m = simulated water level

RMS is considered to be the best measure of error, if errors are normally distributed. The weighted RMS error for the calibrated model is 6.09 m.

The acceptable value for the calibration criterion depends on the magnitude of the change in heads over the model domain. If the ratio of the RMS error to the total head change in the system is small, the errors are only a small part of the overall model response. Scaled RMS (SRMS) error is the RMS divided by the range of measured heads. The weighted SRMS is 7.48% which indicates a good calibration well within the Australian guideline indicator of 10% SRMS error (MDBC, 2001; Barnett *et al*., 2012). Figure 3-2 shows the observed and simulated groundwater levels graphically for all bores used in the calibration. The current model shows a consistent match to the observations when compared to the SLR (2021) model calibration.

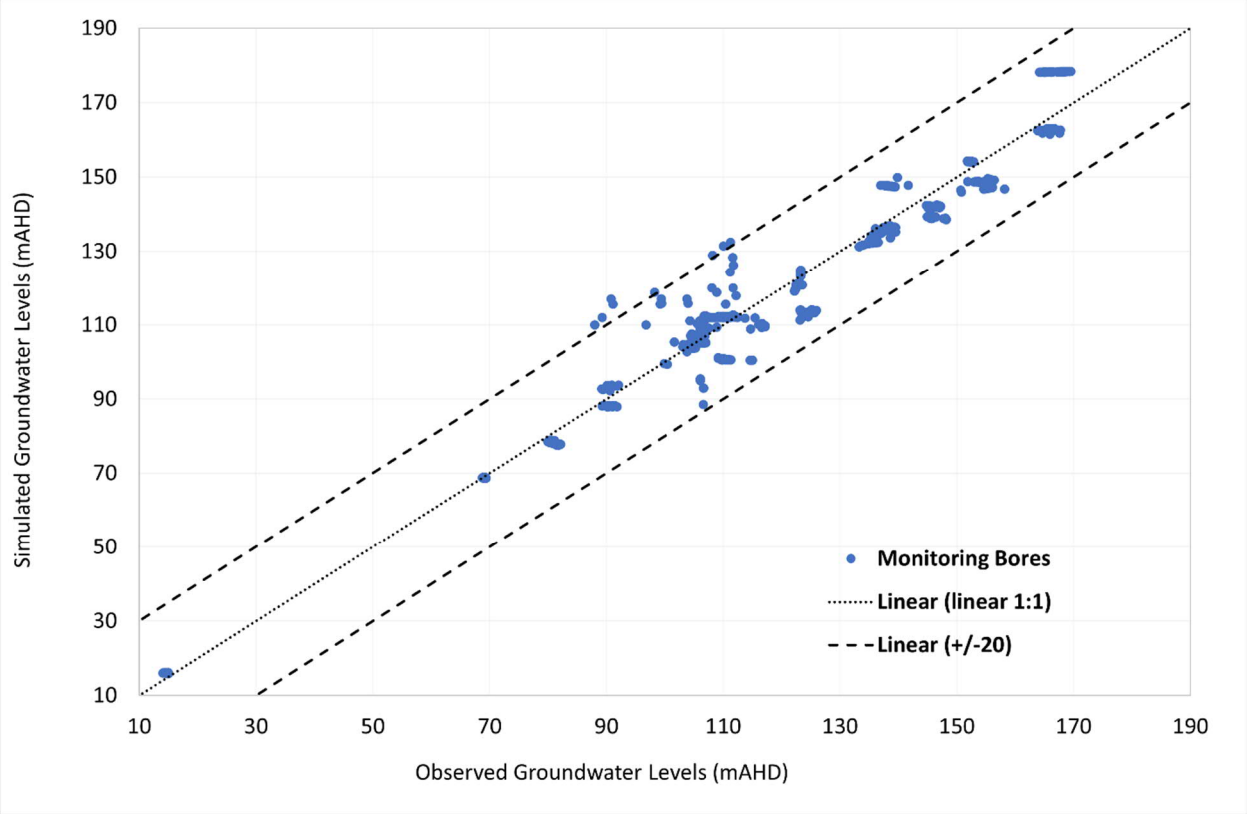


Figure 3-2 Calibration Scattergram – Modelled vs Observed Groundwater Levels (all bores)

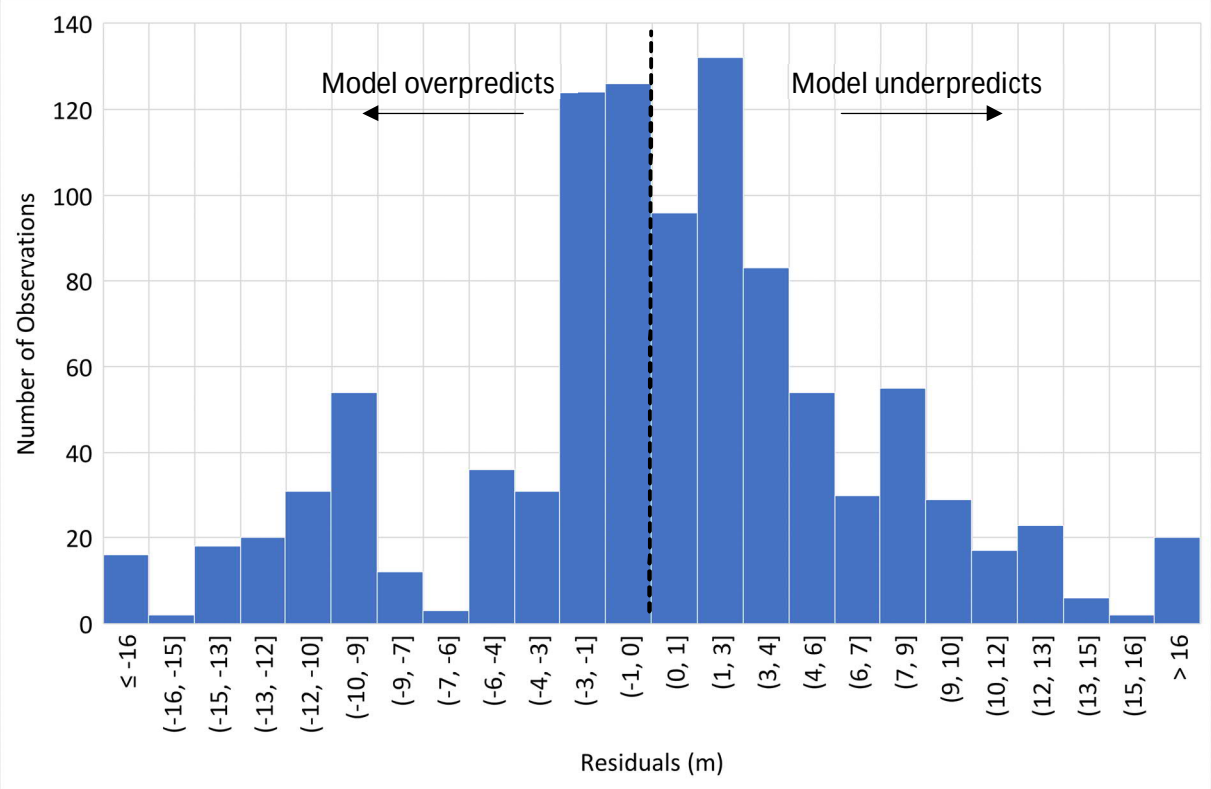


Figure 3-3 Calibration Residual Histogram

Figure 3-3 shows the distribution of calibration residuals. As shown in the figure, all calibration residuals for calibration data points are within ± 20 m. A negative residual represents an over estimation of water levels, while a positive residual represents an underestimate. The calibration residual distribution indicates that overall, the model tends to under-predict groundwater levels. The model slightly under-predicts groundwater levels within the model domain.

The overall transient calibration statistics are presented in Table 3-4. As shown in the table, all calibration targets are calibrated within ±20 m of the observed measurements. This provides an indication of sufficient fit for the regional dataset; however, further discussion on the fit between modelled and observed trends is included in Section 3.3.2.

Table 3-5 and Figure 3-4 show the average calibration residual and absolute average residual per model layer and the spatial distribution of residuals, respectively. The residual is the difference between the measured and the modelled water level at each bore. Table 3-5 shows an overall under-estimation of water levels in the model layers across the model domain. The table shows Layer 6 has the largest average residual, and Layer 15 has the largest absolute average residual. Appendix B contains a table of average, maximum and minimum residuals for each bore in the transient calibration.

Table 3-4 Calibration Statistics

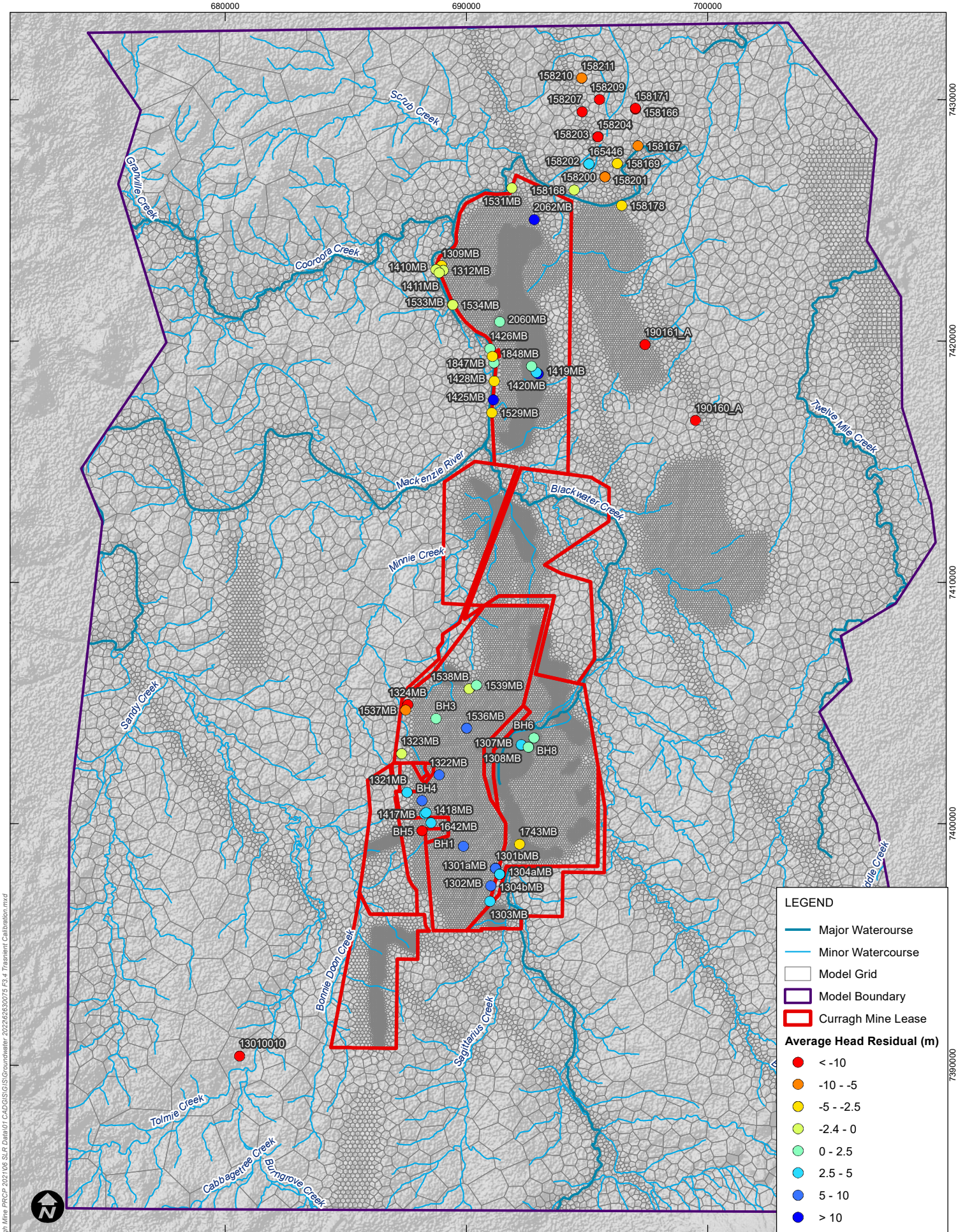
Statistic	Value
Sum of Squares (m2)	33,980
Mean of Squares (m)	37.1
Square Root of Mean of Squares (RMS) (m)	6.1
Scaled Root Mean Square (SRMS) (%)	7.4%
Root Mean Fraction Square (RMFS) (%)*	4.6%
Scaled Root Mean Fraction Square (SRMFS) (%) **	7.5%
Sum of Residuals (m)	4,179
Mean Residual (m)	4.1
Scaled Mean Residual (%)	5.0
Coefficient of Determination (tend to unity)	1.0
Targets within ±2m	412
Targets within ±5m	731
Targets within ±20m	1,012

*RMFS represents the sample standard deviation of the differences between predicted values and observed values as a fraction of the observed value expressed as a percentage.

** SRMFS scales the RMFS error by the ratio of the mean observed value to the range of the observed values expressed as a percentage.

Table 3-5 Average Residual by Model Layer

Model Layer	Formation	Unit	Average Residual (m)	Average Absolute Residual (m)	Number of Observation Targets	Number of bores
1	Alluvium, Weathered Rock	Surface cover	1.18	3.72	412	37
2	Regolith	Tertiary and minor Triassic Clematis, weathered Permian	1.34	4.10	117	10
3	Rewan Formation (West of Fault)	Triassic sandstone, siltstone, mudstone	2.08	2.08	29	2
4	RCM Overburden (West of Fault)	Sandstone, siltstone	-	-	-	-
5	RCM Upper Seams (West of Fault)	Cancer, Aries, Castor seams	-	-	-	-
6	RCM Interburden (West of Fault)	Sandstone, siltstone	5.33	6.51	62	3
7	RCM Middle Seams (West of Fault)	Pollux (Upper and Lower), Orion (Upper and Lower)	-	-	-	-
8	RCM Interburden (West of Fault)	Sandstone, siltstone Pisces seam	4.66	4.67	65	2
9	RCM Lower Seams (West of Fault)	Pisces seam	-	-	-	-
10	Burngrove (West of Fault)	Sandstone, siltstone, mudstone, coal seams	-4.42	6.44	292	8
11	Fairhill Formation (West of Fault)	Sandstone, mudstone, coal seams	-	-	-	-
12	Rewan Formation (East of Fault)	Triassic sandstone, siltstone, mudstone	-	-	-	-
13	RCM Overburden (East of Fault)	Sandstone, siltstone	-	-	-	-
14	RCM Upper Seams (East of Fault)	Cancer, Aries, Castor seams	-	-	-	-
15	RCM Interburden (East of Fault)	Sandstone, siltstone	-20.80	20.80	1	1
16	RCM Middle Seams (East of Fault)	Pollux (Upper and Lower), Orion (Upper and Lower)	-	-	-	-
17	RCM Interburden (East of Fault)	Sandstone, siltstone	-	-	-	-
18	RCM Lower Seams (East of Fault)	Pisces seam	-	-	-	-
19	Burngrove (East of Fault)	Sandstone, siltstone, mudstone, coal seams	-4.21	7.76	2	2
20 to 23	Fairhill Formation (East of Fault)	Sandstone, mudstone, coal seams	-	-	-	-



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0 5 10 km

Coordinate System:	AGD 1984 AMG Zone 55
Scale:	1:200,000 at A4
Project Number:	626.30075
Date:	27-Sep-2022
Drawn by:	AN
Reviewed by:	AN

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Transient Calibration Average Head Residuals (m)

FIGURE 3-4

H:\Projects-SLR\626-MKY\626.30075.00000 Curragh Mine PRCP 2021\06 SLR Data\01 CAD\GIS\GIS\Groundwater 20226263075 F3.4 Trasnient Calibration.mxd

3.3.2 Calibration Fit

3.3.2.1 Groundwater levels

This section provides discussion on the match between modelled and observed groundwater level trends (calibration hydrographs) for key bores across the Curragh Mine Complex. Calibration hydrographs, showing modelled and observed groundwater levels are presented in Appendix C. The hydrographs show that generally the model has replicated the groundwater transient trends in the bores.

Reproducing historical changes in groundwater levels at Curragh Complex requires accurate data for mining progression (spatial extent and depth), backfilling and void water levels as well as the screening depth interval (or targeted geological unit) for each bore. In many cases, this information was incomplete or not available. Considering these limitations, the response to the historical mining at Curragh Complex were reasonably well simulated at most locations around the historical mining areas. This includes close matches to mining response in bores in Layer 1 (1307MB, 1425MB, 1426MB), Layer 3 (BH6, BH8). Layer 6 (1848MB) and Layer 10 (1534MB).

Within the mine area, the model overpredicts groundwater levels for bores in the Burngrove Formation (Layer 10) such as seen in the calibration hydrographs for bores 1537MB and BH5. Underprediction can be seen in the hydrographs for bores screened in the regolith (Layer 2) in the calibration hydrographs for 1301MB, 1302MB, 1303MB and 1304MB.

Water levels in the alluvium and shallow regolith in the vicinity of the mine are generally well simulated and are within 5m of the measured water level (1308MB, 1309MB, 1312MB, 1322MB, 1410MB, 1411MB and 1531MB).

Groundwater levels in regional bores to the far north and south of the model domain are overestimated by 10 to 15 m. Only one measurement is available for each bore located to the north. These bores target the alluvium (158166 and 158209) and the RCM (158171, 158207, 158208, 158210). The difference in groundwater level between observed and simulated likely relate to the simplification of the geological units into discrete model layers away from the project area, where limited data is available.

3.3.2.2 Mine Pit Inflows

Measured average groundwater inflows to Curragh North and Curragh Main pits (derived for the PB 2016 work), were available for 2015 and were used to assess the performance of the model in simulating mine pit inflows. Manual calibration was undertaken to match the magnitude of groundwater inflow.

Table 3-6 summarises the average observed and simulated inflows to the mine workings over different periods. Overall, the model provides a reasonable fit to measured pit inflows for 2015. The modelled pit inflows are underpredicted at Curragh Main, Curragh pit U & T, and overpredicted at Curragh North pit S. It should be noted however that that there will be inaccuracies in the measured inflows and that the magnitude of the modelled inflows for 2015 will be heavily influenced by the accuracy of mine progression built into the model. Choosing a slightly longer period (3 years from 2014-2016) and averaging the inflow rates generally provides a better match to the observed 2015 inflow rates for individual pits / mine areas and a closer match to the total measured inflow for the four areas in Table 3-6.

The average inflows for the full calibration period (2002-2016) are much higher for Pit T and Pit S and reflect higher initial inflows to these pits in the early phases of mining.

Table 3-6 Mine Pit Inflows

	Curragh Main (C, D, E, F, H Pits)	Curragh North (U Pit)	Curragh North (T Pit)	Curragh North (S Pit)	Total
2015 Measured Inflow (ML/d)	2.3	5.60	1.00	0.60	9.5
2015 Modelled Inflow (ML/d)	0.79	3.61	0.62	0.84	5.86
2014-2016 Modelled Inflow (ML/d)	1.45	3.7	0.85	1.34	7.34
Model calibration period (2002-2016), average inflow (ML/d)	2.36	6.38	3.59	1.32	13.64

3.3.3 Water Balance

The water balance for the steady-state and transient calibration simulations are presented in Table 3-7 and Table 3-8, respectively. The water balance for the steady-state model indicates that regional groundwater flow (GHB) was the largest inflow contributor to the model (48.4 ML/d). In the transient simulation, the largest net contribution to the model was also regional groundwater flow (GHB) (48.4 ML/d). Regional net groundwater inflows were 39.7 and 39.9 ML/day for the steady state and transient runs respectively, indicating that more than half the total groundwater inflow enters the model domain through this boundary.

Net outflows of 10.6 ML/d (steady state) and 7.3 ML/d (transient) from the model occur due to seepage from the Mackenzie River (i.e., surface water and groundwater interaction in the Mackenzie River). Also contributing to outflow from the groundwater system is evapotranspiration (43.8 and 42.8 ML/d outflow for the steady state and transient simulations, respectively). The mass balance error for the steady state and transient calibrations are 0.00 %, within the error threshold recommended by the Australian Groundwater Modelling Guidelines (Barnett et al., 2012), and indicating the model is stable and achieves an accurate numerical solution.

Table 3-7 Steady State Model Mass Balance

Component	Inflow (ML/day)	Percent of Total Inflow (%)	Outflow (ML/day)	Percent of Total Outflow (%)
Recharge (RCH)	14.76	23.13	-	-
ET (from GW) (EVT)	-	-	43.80	68.66
SW-GW Interaction (RIV) *	0.65	1.02	11.26	17.65
Regional GW Flow (GHB)	48.39	75.85	8.73	13.69
Mines (DRN)	-	-	-	-
Storage	-	-	-	-
Total	63.80	100.00	63.79	100.00

Table 3-8 Transient Model Water Balance

Component	Inflow (ML/day)	Percent of Total Inflow (%)	Outflow (ML/day)	Percent of Total Outflow (%)
Recharge (RCH)	14.11	18.05	-	-
ET (from GW) (EVT)	-	-	42.82	54.79
SW-GW Interaction (RIV) *	2.11	2.69	9.42	12.05
Regional GW Flow (GHB)	48.44	61.96	8.56	10.95
Mines (DRN)	-	-	11.99	15.34
Storage	13.52	17.30	5.37	6.87
Total	78.17	100.00	78.16	100.00

3.3.4 Calibrated Hydraulic Parameters

Table 3-9 summarises the calibrated values for horizontal and vertical hydraulic conductivity used in the model.

Table 3-9 Calibrated Hydraulic Parameters

Model Layer	Formation	Unit	Horizontal Hydraulic Conductivity (m/day)*	Anisotropy Kz/Kx
1	Alluvium (Gravel)	Surface cover	4.1×10^{01}	4.43×10^{-03}
1	Alluvium (Sand-Clay)		1.11×10^{-01}	1.63×10^{-02}
1	Alluvium (Clay)		5.00	4.67×10^{-03}
1	Weathered Rock (Rewan)		5.47×10^{-02}	1.84×10^{-02}
1	Weathered Rock (RCM)		1.40	2.65×10^{-01}
1	Weathered Rock (Fairhill/Burngrove)		1.47	1.53×10^{-01}
2	Weathered Rock (Other)	Tertiary and minor Triassic Clematis, weathered Permian	1.46×10^{-01}	2.30×10^{-01}
3	Rewan Formation (West of Fault)	Triassic sandstone, siltstone, mudstone	1.62×10^{-02}	1.22×10^{-02}
4	RCM Overburden (West of Fault)	Sandstone, siltstone	8.63×10^{-04}	3.04×10^{-02}
5	RCM Upper Seams (West of Fault)	Cancer, Aries, Castor seams	5.72×10^{-02}	1.69×10^{-01}
6	RCM Interburden (West of Fault)	Sandstone, siltstone	7.87×10^{-04}	9.69×10^{-03}
7	RCM Middle Seams (West of Fault)	Pollux (upper and lower), Orion (upper and lower)	5.52	1.14×10^{-02}
8	RCM Interburden (West of Fault)	Sandstone, siltstone	5.48×10^{-01}	5.0×10^{-03}
9	RCM Lower Seams (West of Fault)	Pisces seam	9.30×10^{-03}	3.27×10^{-02}
10	Burngrove (West of Fault)	Sandstone, siltstone, mudstone, coal seams	1.22×10^{-04}	1.62×10^{-02}
11	Fairhill Formation (West of Fault)	Sandstone, mudstone, coal seams	1.26×10^{-04}	1.19×10^{-01}
12	Rewan Formation (East of Fault)	Triassic sandstone, siltstone, mudstone	3.73×10^{-02}	2.24×10^{-02}
13	RCM Overburden (East of Fault)	Sandstone, siltstone	2.04×10^{-03}	2.50×10^{-02}
14	RCM Upper Seams (East of Fault)	Cancer, Aries, Castor seams	1.39	3.41×10^{-01}
15	RCM Interburden (East of Fault)	Sandstone, siltstone	6.36×10^{-03}	8.34×10^{-02}
16	RCM Middle Seams (East of Fault)	Pollux (upper and lower), Orion (upper and lower)	2.51	2.94×10^{-02}
17	RCM Interburden (East of Fault)	Sandstone, siltstone	3.99×10^{-01}	1.47×10^{-02}
18	RCM Lower Seams (East of Fault)	Pisces seam	2.20	4.66×10^{-01}
19	Burngrove (East of Fault)	Sandstone, siltstone, mudstone, coal seams	2.05×10^{-04}	1.04×10^{-01}
20	Fairhill Formation (East of Fault)	Sandstone, mudstone, coal seams	8.32×10^{-05}	4.26×10^{-01}
21	Fairhill Formation (East of Fault)		1.45×10^{-04}	2.70×10^{-01}
22	Fairhill Formation (East of Fault)		8.09×10^{-04}	1.57×10^{-01}
23	Fairhill Formation (East of Fault)		1.78×10^{-03}	4.77×10^{-01}

Note: * upper hydraulic conductivity derived from depth of 20 m below surface and using depth formula

The hydraulic conductivity of the Permian interburden material and coal seams in the model reduces with depth. This relationship of depth and permeability has been based on data SLR have analysed from other Bowen Basin coal mines. The hydraulic conductivity of the interburden/overburden and coal seam layers decreases with depth according to the following equation (exponential):

Coal/Interburden: $HC = HC_0 \times e(-0.012 \times depth)$

Where:

- HC is horizontal hydraulic conductivity at specific depth;
- HC_0 is horizontal hydraulic conductivity at depth of 0 m (intercept of the curve);
- depth is depth of the floor of the layer (thickness of the cover material);
- slope is a term representing slope of the formula (steepness of the curve).

HC_0 was estimated in the calibration. It varies for the coal seams and for the interburden and overburden units in the model. The final calibrated parameters used in the revised model are consistent with the range of field and literature derived hydraulic parameters compiled for the conceptual model in the Groundwater Technical Report for the Curragh Extension Project (SLR, 2021).

3.3.5 Calibrated Storage Properties

Table 3-10 summarises the calibrated values for specific storage and specific yield.

Table 3-10 Calibrated Storage Parameters

Model Layer	Formation	Unit	Specific Yield	Specific Storage SS (m^{-1})
1	Alluvium (Gravel)	Surface cover	4.49×10^{-02}	1.44×10^{-06}
1	Alluvium (Sand-Clay)		2.92×10^{-02}	4.02×10^{-06}
1	Alluvium (Clay)		2.10×10^{-03}	9.98×10^{-06}
1	Weathered Rock (Rewan)		5.32×10^{-03}	4.42×10^{-06}
1	Weathered Rock (RCM)		4.69×10^{-02}	3.14×10^{-06}
1	Weathered Rock (Fairhill/Burngrove)		1.71×10^{-03}	7.19×10^{-06}
2	Weathered Rock (Other)	Tertiary and minor Triassic Clematis, weathered Permian	4.69×10^{-02}	2.93×10^{-06}
3	Rewan Formation (West of Fault)	Triassic sandstone, siltstone, mudstone	7.91×10^{-03}	1.59×10^{-06}
4	RCM Overburden (West of Fault)	Sandstone, siltstone	6.96×10^{-03}	2.39×10^{-06}
5	RCM Upper Seams (West of Fault)	Cancer, Aries, Castor seams	4.51×10^{-03}	5.51×10^{-07}
6	RCM Interburden (West of Fault)	Sandstone, siltstone	7.07×10^{-03}	4.80×10^{-06}
7	RCM Middle Seams (West of Fault)	Pollux (upper and lower), Orion (upper and lower)	3.28×10^{-03}	1.03×10^{-07}
8	RCM Interburden (West of Fault)	Sandstone, siltstone	1.98×10^{-03}	4.44×10^{-07}
9	RCM Lower Seams (West of Fault)	Pisces seam	7.23×10^{-03}	2.65×10^{-06}
10	Burngrove (West of Fault)	Sandstone, siltstone, mudstone, coal seams	5.05×10^{-03}	8.43×10^{-07}
11	Fairhill Formation (West of Fault)	Sandstone, mudstone, coal seams	2.57×10^{-03}	7.15×10^{-07}
12	Rewan Formation (East of Fault)	Triassic sandstone, siltstone, mudstone	8.37×10^{-03}	2.15×10^{-06}
13	RCM Overburden (East of Fault)	Sandstone, siltstone	7.29×10^{-03}	6.95×10^{-07}
14	RCM Upper Seams (East of Fault)	Cancer, Aries, Castor seams	6.55×10^{-03}	2.35×10^{-07}
15	RCM Interburden (East of Fault)	Sandstone, siltstone	6.13×10^{-03}	5.00×10^{-06}
16	RCM Middle Seams (East of Fault)	Pollux (upper and lower), Orion (upper and lower)	7.75×10^{-03}	3.86×10^{-07}
17	RCM Interburden (East of Fault)	Sandstone, siltstone	1.60×10^{-03}	2.43×10^{-07}
18	RCM Lower Seams (East of Fault)	Pisces seam	1.00×10^{-02}	3.02×10^{-06}
19	Burngrove (East of Fault)	Sandstone, siltstone, mudstone, coal seams	1.58×10^{-03}	2.94×10^{-07}
20	Fairhill Formation (East of Fault)	Sandstone, mudstone, coal seams	1.73×10^{-03}	1.07×10^{-07}
21	Fairhill Formation (East of Fault)		1.61×10^{-03}	1.23×10^{-07}
22	Fairhill Formation (East of Fault)		2.68×10^{-03}	1.35×10^{-07}
23	Fairhill Formation (East of Fault)		1.08×10^{-03}	1.97×10^{-07}

3.3.6 Calibrated Recharge

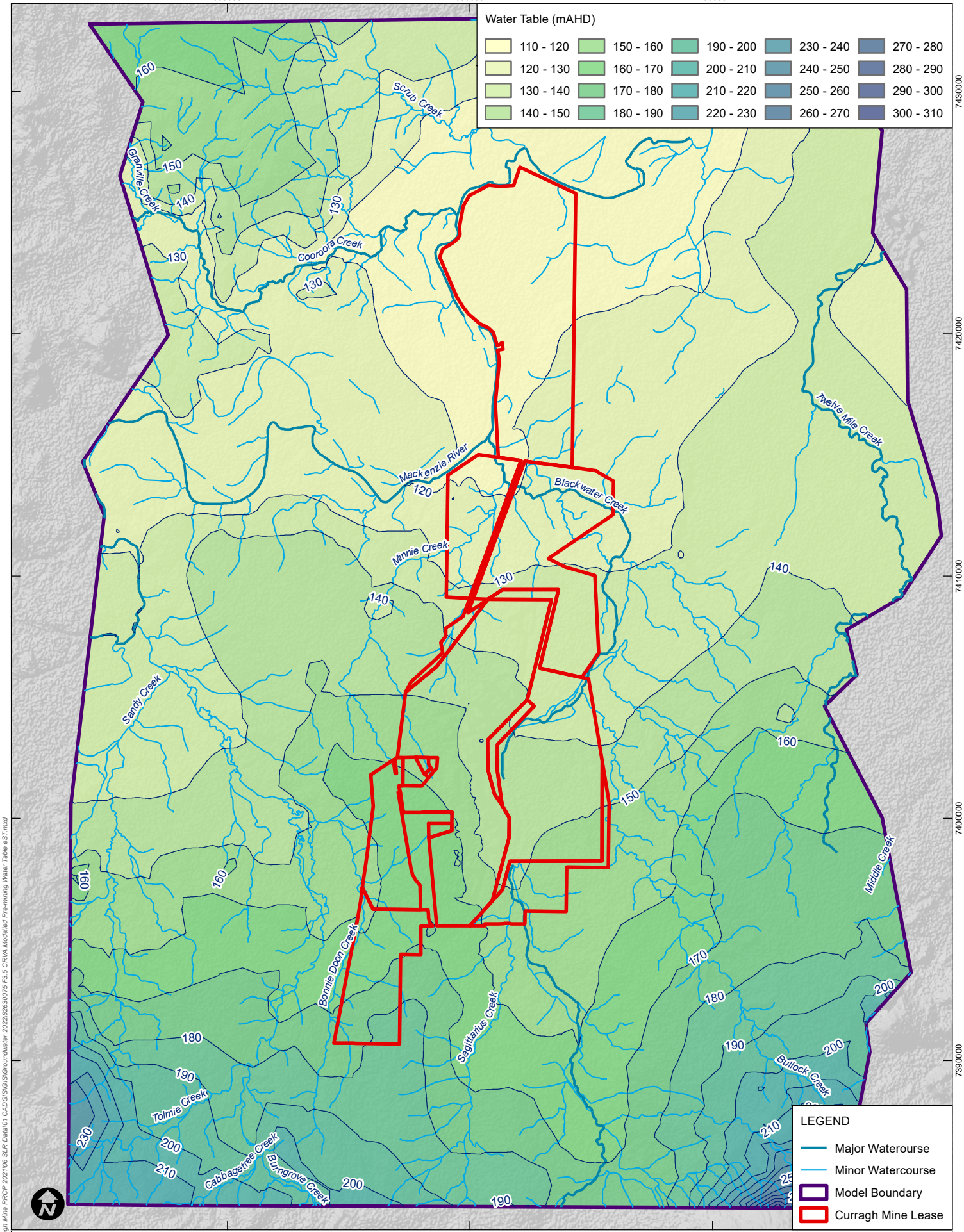
Recharge is predominantly through direct rainfall infiltration through the soil profile, and along the ephemeral drainage lines. The rate of recharge infiltration depends on the location, topography and geology at each model cell. Initial estimates of recharge were adopted from the previous Curragh Model (SLR, 2021). As discussed in Section 3.2.4, the MODFLOW-USG recharge package simulated diffuse rainfall recharge across the model domain. For the steady state simulation, the model calculated the recharge rate as a percentage of long-term annual rainfall (565.4 mm/year) for each geological unit outcropping at the surface and for the transient simulation, the model calculated the recharge rate as a percentage of actual annual rainfall. The model then adjusted these initial percentages through the calibration process. Table 3-11 presents the calibrated recharge rate to each geological unit in the model.

Table 3-11 Calibrated Rainfall Recharge

Model Surface Geology Zone	Long-term Average Recharge (mm/year)	% Annual Rainfall
Quaternary Alluvium (Northern)	3.61	0.64
Quaternary Alluvium (Central)	10.65	1.88
Quaternary Alluvium (Southern)	9.11	1.61
Weathered Permian	0.94	0.17
Weathered Triassic	0.29	0.05
Emerald Formation	0.16	0.03
Duaringa Formation	0.12	0.02
Weathered Tertiary/Quaternary	10.92	1.93
Basalt	0.21	0.04

3.3.7 Calibrated Pre-Mining Groundwater Levels

Figure 3-5 shows the calibrated pre-mining water table (defined as the shallowest groundwater level below surface, regardless of the geological unit / model layer). As shown in Figure 3-5, the simulated water levels reflect the flow regime prior to commencement of any mining within the model domain and indicate a general flow of groundwater towards the north to north-west discharging through the RIV boundary condition in the north of the model (Mackenzie River). The simulated water table broadly reflects topography across the model domain.



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Modelled Pre-mining Water Table (End of Steady State Simulation)

FIGURE 3-5

H:\Projects-SLR\626-MKY\626.30075.00000 Curragh Mine PRCP 20211106 SLR Data\01 CAD\GIS\GIS\Groundwater 20226263075 F3.5 CRVA Modelled Pre-mining Water Table eST.mxd

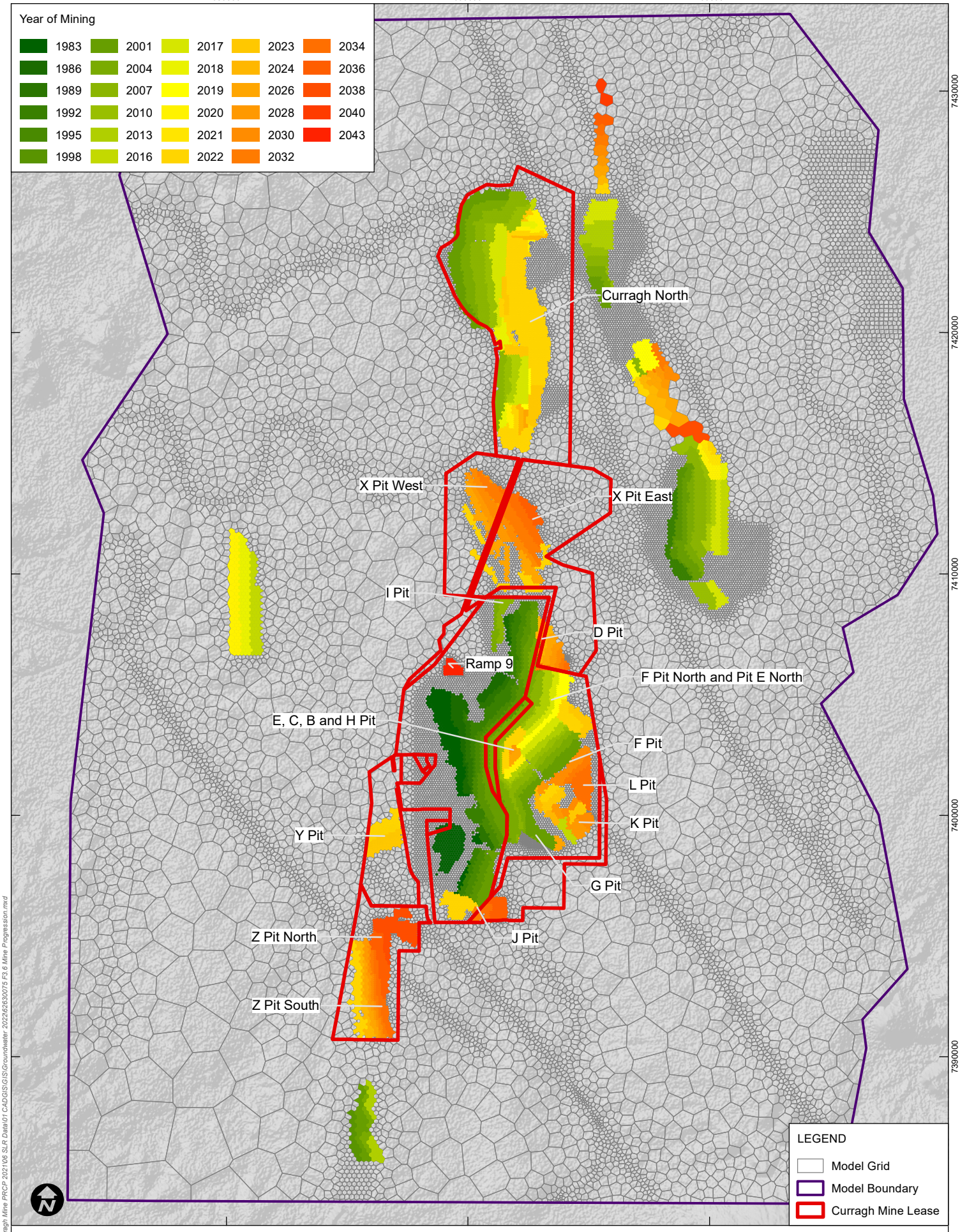
3.4 Predictive Model

Transient predictive modelling was used to simulate the proposed future mining at Curragh (Curragh North, Curragh Main, expansion pits X, Y, Z, and Ramp 9), as well as mining at other approved and foreseeable mines within the model domain. The predictive model stress period setup is detailed in Section 3.2.3, and the mine progression simulated in the model is presented in Figure 3-6.

All mining areas included in the model were simulated using the MODFLOW Drain (DRN) package. A nominally high drain conductance of 100 square metres per day (m^2/day) was applied to drain cells to simulate rapid removal of water from the system. Drain cells simulating mining were projected down to the base of the target coal seams. A two-year operational window was assumed for open-cut mine cells, after which time the drains were removed and the MODFLOW Time Varying Materials (TVM) package was used to assign spoil or void properties to the cells.

As discussed in Section 3.2.4.4, the properties of model cells representing the backfilled pits were updated to spoil properties guided by the backfill elevations in the final landform. Horizontal hydraulic conductivity of 0.3 m/day and vertical hydraulic conductivity of 0.1 m/day is applied to the spoil. The storage parameters used for the spoil were a specific yield of 0.05 and a storage coefficient of 1.0×10^{-5} m.

The model cells representing residual voids as informed by the final landform were assigned void properties upon removal of the drains representing active mining at those cells. High horizontal and vertical hydraulic conductivities (1000 m/day) and storage parameters based on the compressibility of water (specific yield of 1.0, storage coefficient of 5.0×10^{-6} m^{-1}) were applied to void cells, to simulate free water movement within the void.



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0 5 10 km

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Modelled Mine Progression

FIGURE 3-6

H:\Projects-SLR\626-MKY\626.30075.00000 Curragh Mine PRCP 2021106 SLR Data\01 CAD\GIS\GIS\Groundwater 20226263075 F3.6 Mine Progression.mxd

3.4.1 Predictive Water Balance

The water balance for the predictive simulation is presented in Table 3-12. The water balance for the predictive model indicates that Regional GW Flow (GHB) was the largest net inflow contributor to the model (48.46 ML/d). Regional groundwater inflow and outflow are 48.46 ML/day and 8.61 ML/day respectively, indicating that groundwater enters the model domain through this boundary.

The largest net contributor to outflow from the model during the predictive simulation beside evapotranspiration (41.70 ML/d outflow) were the drain cells, used to simulate mining activity (9.67 ML/d). A net outflow of 3.16 ML/d from the model occurs due to baseflow to the Mackenzie River. The mass balance error for the predictive calibration is 0.00%.

Table 3-12 Predictive Model Water Balance

Component	Inflow (ML/day)	Percent of Total Inflow (%)	Outflow (ML/day)	Percent of Total Outflow (%)
Recharge (RCH)	15.32	18.91	-	-
ET (from GW) (EVT)	-	-	41.70	51.47
SW-GW Interaction *	3.63	4.48	6.79	8.38
Regional GW Flow (GHB)	48.46	59.81	8.61	10.63
Mines (DRN)	-	-	9.67	11.94
Storage	13.61	16.80	14.25	17.58
Total	81.02	100.00	81.02	100.00

* The other tributaries or drainage lines in the model are set as drains to the groundwater system and do not result in any recharge.

3.4.2 Predicted Mine Inflows

Simulated mine pit inflows were extracted using MODFLOW-USG ZONBUD utility and calculated as time weighted averages for model Drain cells, for the predictive simulation period (January 2022 to January 2045). The total inflow rate predicted for the Curragh Complex averaged 8.19 ML/day over the predictive model simulation.

4 Recovery Model

4.1 Recovery Model Setup

Post mining impacts were investigated with a recovery model, commencing at the end of active mining. A preliminary transient recovery model consisting of 24 stress periods of varying length (annual, biennial, 8-yearly and an extended final stress period of 500 years) was developed initially to assess the relationship between the final voids' lake elevations and groundwater inflow. At the start of the recovery model, all remaining model drain cells (representing pit dewatering in areas of active mining) were removed from pits and the properties of the final void cells were converted to values representative of a void as described in Section 3.4.

The relationship between groundwater inflows to the voids and void lake level was extracted from the preliminary recovery model and incorporated into the site water balance model (WBM) developed for the Curragh PRCP (SLR, 2022). The WBM predicts the equilibrium lake levels that will be reached in each void and these final void lake levels are used in the final groundwater recovery model. Further information relating to the Curragh Complex WBM can be found in Section 3 of the Curragh Mine Complex Surface Water Residual Void Modelling (SLR, 2022).

The final recovery model uses the MODFLOW river package (RIV) to simulate increasing void lake elevations in each of the final voids over the recovery period, with stage elevations vs time applied according to the WBM predictions for each void, up to the final equilibrium lake levels predicted by the WBM. The WBM predicted water levels in the final voids to reach equilibrium conditions after approximately 50 to 80 years, dependent on void structure and interaction with the regional groundwater system.

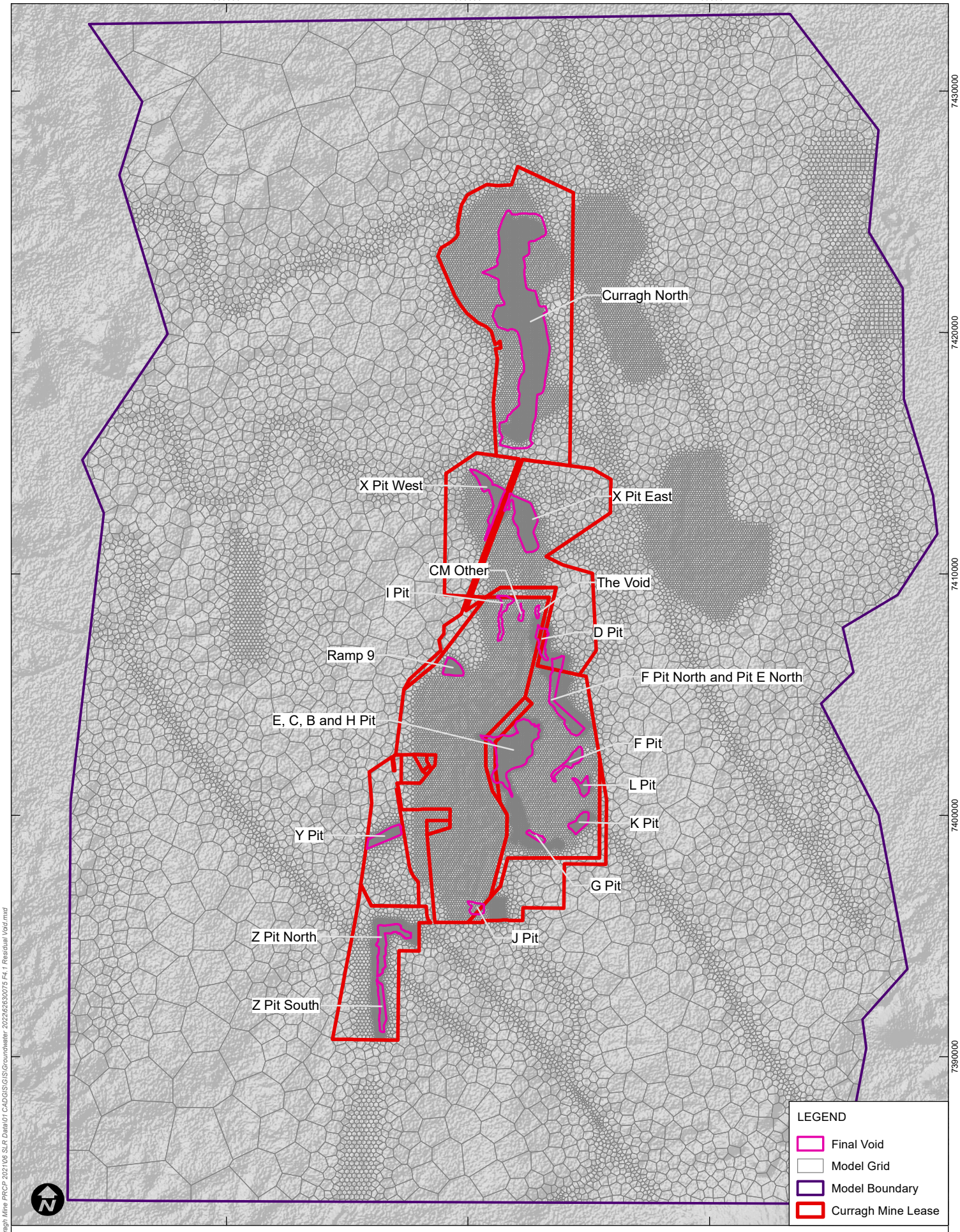
Tailings Storage Facilities (TSFs) and Coarse Reject Storage areas (CRSs) were represented in the recovery model based on the available mapping of storage areas. An isotropic hydraulic conductivity of 1 x 10^{-5} m/day, specific yield of 0.01 and storage coefficient of 5 x 10^{-6} m were assigned to the model cells representing TSF and CRS, using the MODFLOW Time Varying Materials (TVM) package.

The RIV package was used to represent increasing sediment levels of tailings and course reject material, with final fill levels defined by final landform elevation. The sediment levels in TSF and CRS were increased from the mined layer to the final fill level at a constant rate over a 10-year period, to represent the gradual filling of sediment storage facilities during mine operation. Sediments were assigned a vertical conductivity of 5 x 10^{-2} m/day. The water levels in TSF and CRS were increased at a corresponding rate, at 1 m above the sediment level.

The layout of the final voids across the Curragh Mine Complex is presented in Figure 4-1.

Void recovery graphs in each of the voids over the recovery period are presented in Appendix D.

A summary of predictions from the recovery model, including final void water levels and groundwater flux (at equilibrium) are presented in Section 4.2.



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Final Landform Voids

FIGURE 4-1

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4.2 Post-mining Equilibrium

Simulated post-mining groundwater fluxes to the final voids at equilibrium conditions were extracted using MODFLOW-USG ZONBUD utility. The net groundwater flux has been calculated as a cumulative void flux for each area at Curragh Complex (Curragh North, X Pit, Curragh Main, Ramp 9, Y Pit and Z Pit) to account for interaction between the adjacent voids within each area, where spoil connects the voids. The simulated average groundwater takes at the end of recovery (December 2132) at each of the site areas are presented in Table 4-1.

The groundwater fluxes to the final voids presented in Table 4-1 are total fluxes, including throughflow from spoil (higher recharge over the spoil and drainage into the final void), and groundwater inflow from the Rangal Coal Measures (RCM). An equilibrium groundwater flux of 6.14 ML/day was predicted at Curragh North, where the minimum elevation of the final landform is 74.6 m lower than the other voids. The relative depth of the residual void at Curragh North is likely accountable for the higher predicted groundwater flux to the void in this area. Equilibrium total groundwater flux to the voids in X Pit, Curragh Main, Ramp 9, Y Pit and Z Pit are predicted to be 0.57, 1.44, 0.02, 0.08 and 0.64 ML/day respectively, indicating all simulated voids are predicted to be groundwater sinks with net groundwater flow into the voids. The simulated fluxes to the voids in the groundwater model are consistent with groundwater fluxes in the surface WBM developed for simulating final landforms for Curragh Mine (SLR, 2022).

Based on the geological data reviewed for this assessment it appears that equilibrium void lake levels are generally below the level of base of weathering (Table 4-1). The equilibrium void lake levels in Pit I and Ramp 9 exceed the approximate minimum base of weathering at the voids by about 5 m. Where the base of weathering levels are exceeded by the void lake level, the alluvium and weathered rock profile could potentially present preferential pathways for outward seepage of water from the void lakes. However, lower lake levels in adjacent voids will likely act as sinks for any such seepage.

The predicted water salinity results presented in Table 4-1 have been derived from the surface water balance modelling (SLR,2022). The predicted salinities indicate that all voids are expected to exceed hypersaline EC levels (>50,000 µS/cm) within approximately 200 years of closure.

Table 4-1 Post-Mining Equilibrium Residual Void Summary

Curragh Area:		Curragh N	X Pit		Curragh Main											Ramp 9	Y Pit	Z Pit	
Residual Void[1]:		UTS	X West	X East	I Pit	Main Other	The Void	D Pit	F Pit	F Pit North & E Pit	L Pit	K Pit	ECBH Pits	G Pit	J Pit			Z Pit North	Z Pit South
Final landform minimum elevation (mAHD)		-48	78.373	33.503	133.1	120	93	29.13	91.6	26.6	64.6	63.11	40.6	130.1	92.6	77.1	116	78.1	87.11
Post-mining equilibrium void lake level (mAHD)*		23.1	98.2	67.3	134.3	127.4	125.7	62.2	110.5	49.3	102.3	77.1	70.3	136.4	111.2	131.4	123.2	107.8	104.6
Approximate base of weathering (mAHD)**		75	110	105	130	130	130	125	125	130	140	135	130	140	145	125	155	155	160
Void lake salinity (uS/cm), as predicted by the water balance model.[2]	~10 years	13,900	19,200	15,600	171,200	11,700	10,200	16,500	18,200	27,500	13,800	28,400	15,700	40,700	23,300	17,300	40,600	19,800	23,400
	~30 years	20,100	39,600	27,500	319,000	25,700	15,600	28,800	38,600	55,400	24,200	67,800	33,700	121,700	49,300	25,600	121,800	37,600	48,500
	~200 years	99,400	259,200	181,700	520,900	123,500	83,900	165,200	25,2500	276,500	150,200	416,900	228,600	484,800	324,800	99,800	500,700	237,800	317,000
Net groundwater flux to void at equilibrium (ML/day)***		6.14	0.57		1.44											0.02	0.08	0.64	

Notes:
1 The residual voids have been grouped where a void may act as a source of water to an adjacent void, but where collectively they act as a groundwater sink.
2 532,836 µS/cm is the maximum salinity limit set in the surface water balance model (SLR 2022)
* Final lake levels were derived from the surface water model.
** Approximate elevation of base of weathering estimated from available data.
*** Total flux, including drainage from the spoil and groundwater inflow from the RCM.

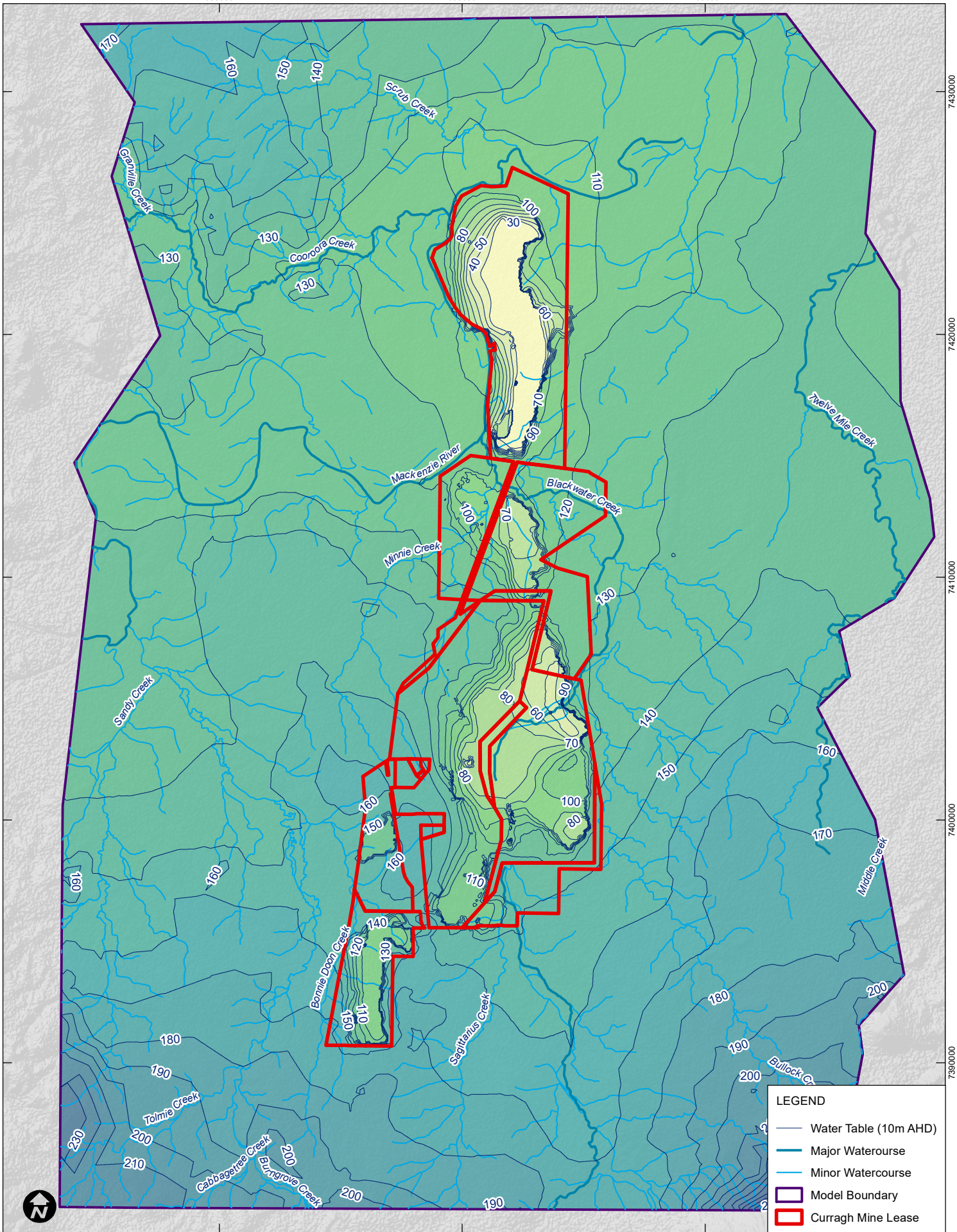
4.3 Post-mining Gradients and Residual Drawdown

The predicted post-mining water table at equilibrium (end of recovery) is shown in Figure 4-2. Hydraulic gradients at equilibrium indicate an overall flow direction toward residual voids at Curragh Main and Curragh North. All residual voids show hydraulic heads decreasing with proximity to the void, indicating all voids are predicted to act as local groundwater sinks.

Residual drawdown refers to the remaining drawdown after full post-mining recovery compared to pre-mining groundwater levels and is obtained by subtracting the predicted equilibrium post-closure groundwater levels from a 'null-mining' model scenario. The 'null-mining' model run does not include any historical or future mining at Curragh Complex, but all other stresses (including surrounding mine activity) and boundary conditions remain unchanged from the model simulating mining at Curragh Complex. The residual drawdown is therefore a comparison of groundwater levels between a 'mining and closure' scenario, and a 'no mining' scenario.

Predicted drawdown figures (Figure 4-3 and Figure 4-4) show where residual drawdown impacts are predicted to exceed 1 m. Figure 4-3 presents the residual drawdown within the alluvium only, at post-mining equilibrium. Predicted recovered heads in the alluvium west of Curragh North show residual drawdowns of 1 to 2 m extending up to 4 km from mined pits at Curragh North although drawdowns at the very edge of the voids are higher (10-20 m). Figure 4-4 presents the residual drawdown of the water table at post-mining equilibrium.

To investigate the potential movement of groundwater to or from the voids and spoil at post-mining equilibrium, the post-mining water table predicted for the end of recovery was used to infer potential flow pathways in and around the spoil at each area of mining. The post-mining hydraulic gradients around the mine were used to predict groundwater movement relative to the voids and areas of spoil. Figure 4-5 shows the inferred flow pathways around the residual voids interpreted from the particle tracking simulation at post-mining equilibrium. The flow paths from the outer edges of the voids or spoil dumps informed by the recovered head levels indicate groundwater flow is toward the residual voids i.e., none of the voids act as sources to the wider groundwater system (although some voids may act as sources to adjacent voids with lower final landform elevations or predicted equilibrium water levels). Particle tracking also indicates that indicates that groundwater in the vicinity of the TSFs and sources of potential groundwater contamination (infrastructure area, landfills) would move towards the final voids rather than migrate off site.



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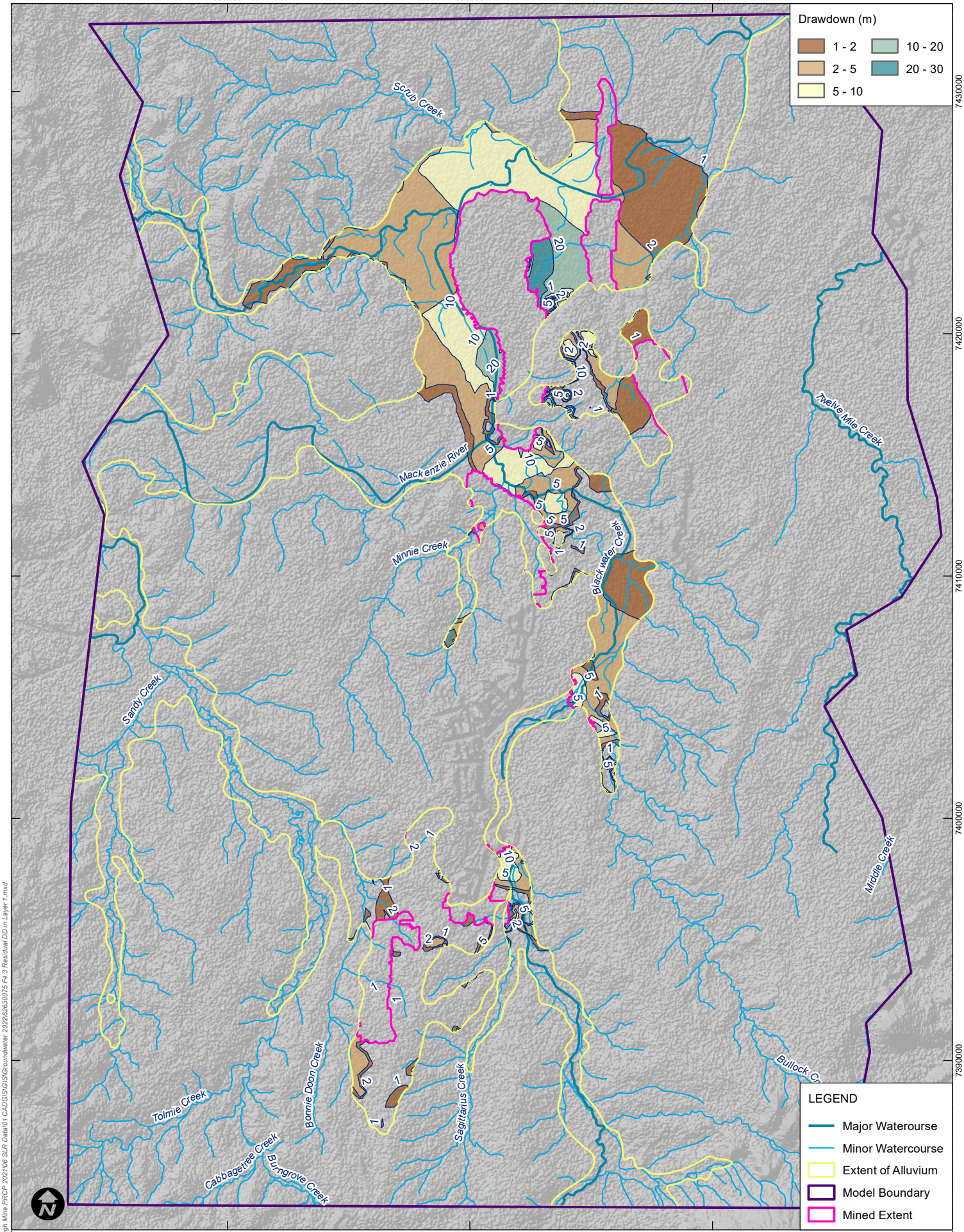
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Predicted Water Table (End of Recovery)

FIGURE 4-2

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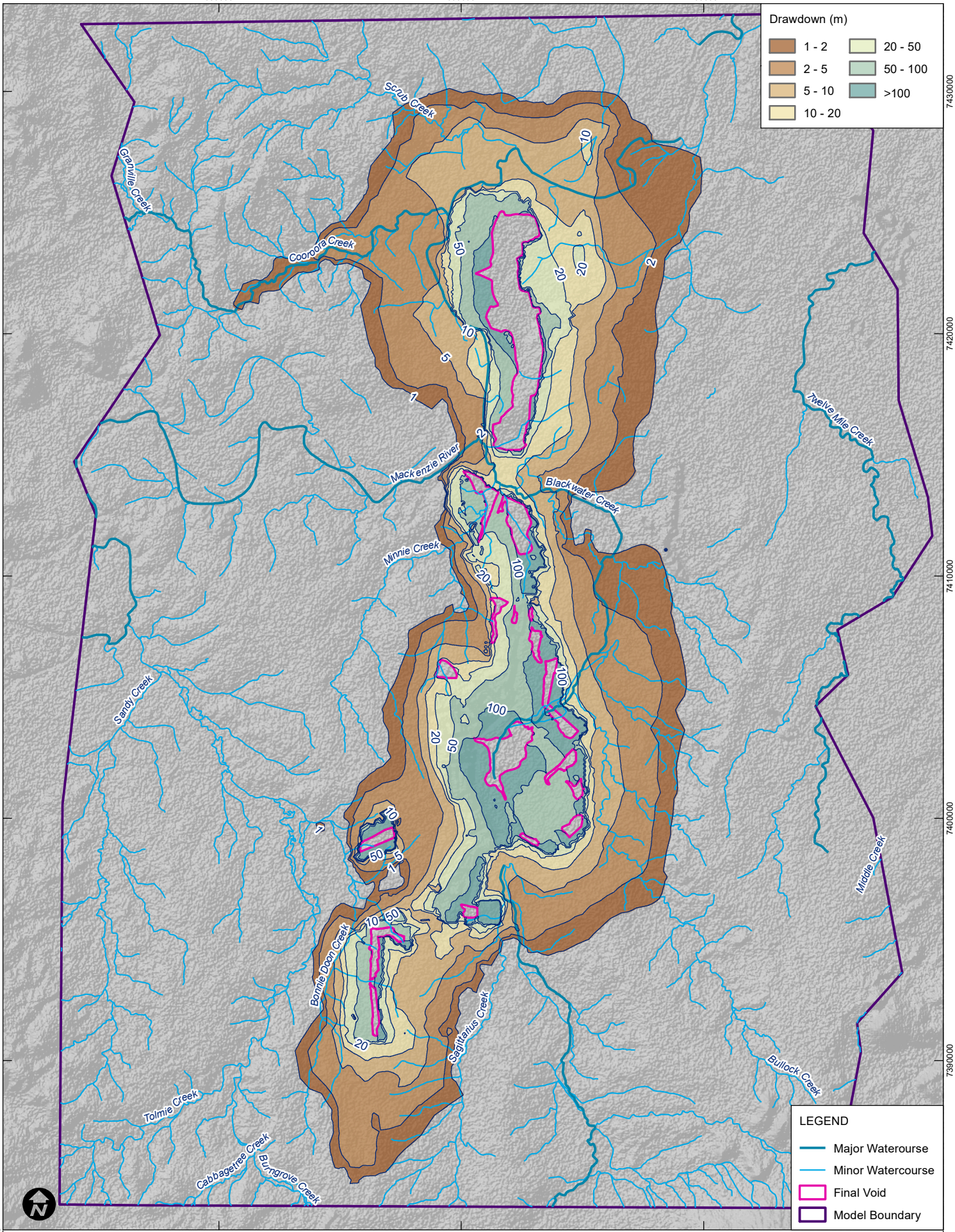
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Project Number:	626.30075
Date:	13-Sep-2022
Drawn by:	AN
Reviewed by:	AN

CURRAGH PRCP GROUNDWATER ASSESSMENT

Predicted Residual Drawdown in Alluvium (End of Recovery)

FIGURE 4-3

H:\Projects-SLR\626-MKY\626.30075.00000 Curragh Mine PRCP 20211106 SLR Data\01 CAD\GIS\GIS\Groundwater 20226263075 F4.3 Residual DD in Layer 1.mxd



0 5 10 km

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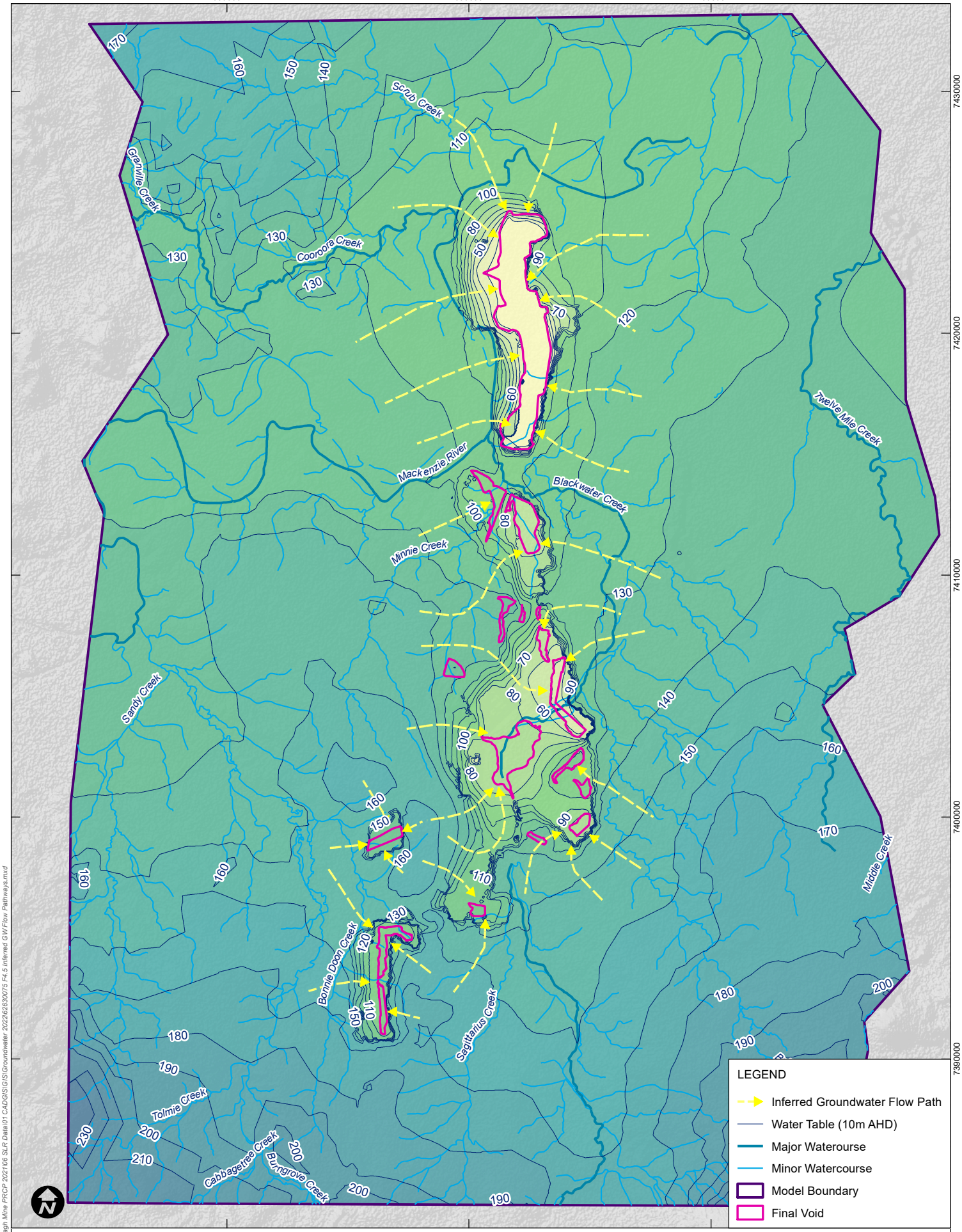
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Project Number:	626.30075
Date:	14-Sep-2022
Drawn by:	AN
Reviewed by:	AN

CURRAGH PRCP GROUNDWATER ASSESSMENT

Water Table Residual Drawdown at End of Recovery

FIGURE 4-4

H:\Projects-SLR\626-MKY\626.30075.00000 Curragh Mine PRCP 20211106 SLR Data\01 CAD\GIS\GIS\Groundwater 20226263075 F4.4 Predicted Residual WT EoR.mxd



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0 5 10 km

Coordinate System:	AGD 1984 AMG Zone 55
Scale:	1:200,000 at A4
Project Number:	626.30075
Date:	19-Oct-2022
Drawn by:	AN
Reviewed by:	AN

CURRAGH PRCP GROUNDWATER ASSESSMENT

Inferred Groundwater Flow Pathways at Post-Mining Equilibrium

FIGURE 4-5

H:\Projects-SLR\626-MKY\626.30075.00000 Curragh Mine PRCP 20211106 SLR Data\01 CAD\GIS\GIS\Groundwater 20226263075 F4.5 Inferred GW Flow Pathways.mxd

5 Conclusions

5.1 Conclusions

The Curragh Complex numerical groundwater model achieved the modelling objectives, as outlined in Section 3.1. Model calibration statistics are within suggested guidelines (MDBC, 2001) and mass balance errors were 0%, through the model calibration and predictive modelling. The model considers all available data relevant to calibration, including the updated geological model, pit shells, tailings storage facilities, groundwater level database, and the final landforms. The following key conclusions are drawn from the numerical modelling assessment of the post-mining groundwater environment at the Curragh Complex:

- The modelling indicates that lakes will form within the final voids of the proposed post-mining landform. These lakes will act as local groundwater 'sinks' with groundwater within mining disturbed areas (including the TSFs, CRS and shallow groundwater at the location of potential sources of contamination) migrating towards these sinks.
- Post-mining residual drawdown in the Mackenzie River Alluvium to the west of Curragh North will generally be in the order of 1-2m (but up to 20m near the mine voids), noting that the Mackenzie River is regarded as a "losing" watercourse with pre-mining groundwater levels in the alluvium 3-5m below the river stage in the vicinity of the mine (Section 2.3.8.1).
- Based on the geological data reviewed for this assessment, it appears that equilibrium void lake levels are generally below the base of the alluvium and the base of weathering (potential preferential pathways for outward seepage of water from the void lakes). Where the minimum base of weathering elevation is potentially exceeded by the predicted equilibrium void lake levels at Ramp 9 and Pit G, particle tracking shows that any seepage from these voids will migrate to adjacent voids with lower void lake levels.
- Post-mining, the total estimated "groundwater" inflow to all voids is approximately 8.89 ML/d although the majority of this is water derived from infiltration to the spoil and drainage into the void lake rather than inflow from the Rangal Coal Measures or Alluvium.

5.2 Model Limitations

It is important to note that groundwater models have inherent uncertainties which should be quantified and reduced where required and possible. The limitations and uncertainty associated with the model are discussed below. The IESC *Uncertainty analysis – Guidance for groundwater modelling within a risk management framework* (2018) identifies four key sources of scientific uncertainty affecting groundwater model simulations:

- Structural/conceptual.
- Parameterisation.
- Measurement error.
- Scenario uncertainties.

These four sources of uncertainty have been qualitatively assessed with regards key aspects of the Curragh Mine groundwater model, as presented in Table 5-1.

Overall, the model is considered fit for purpose to achieve the objectives of the PRCP groundwater assessment outlined in Section 1 based on the data provided and the project timeframe. The table includes a detailed summary of the model setup and capabilities, demonstrating that the model is fit for purpose, as well as some recommendations if future updates to the model should be required.

Table 5-1 Groundwater Model and Data Limitations and Recommended updates for more Detailed Assessment of Closure

Type	Part	Status	Comment
Structural/ Conceptual	Grid and Model Extent	Fit for purpose.	The model has an unstructured Voronoi grid that includes detailed cell refinement around the final voids, the tailings at the site, neighbouring mines and along drainage features such as Mackenzie River The model extent encompasses Curragh Complex with boundaries set to subcrop and outcrop lines in the solid geology.
	Layers	Fit for purpose	Top of layer 1 incorporates site LiDAR data Representation of alluvium and regolith refined based on CSIRO (2015) regolith mapping and available geology. Extent of modelled alluvium consistent with mapped extent of alluvium near pits and along Mackenzie River. Model vertical resolution sufficient to represent relevant geological units and unstructured grid allows layer pinch out where units not present. Model structure refined based on the most up to date site geology model.
	Conceptualisation – Geological Structure	Fit for purpose	The structure of the geology is based on site geology model. Major fault (Jellinbah thrust) has been included in the model through duplicate layers representing disconnected sections of each unit to either side of the fault. Minor faults have been included through layer displacements from site geological model.
	Conceptualisation – GDEs	Fit for purpose. Potential for further assessment.	The risk to potential GDE's was assessed in 2016 for approval of the mining expansion. Closure and the associated partial recovery of the groundwater system will represent an improved groundwater level condition for potential GDEs compared to the approved maximum extent of mining. Post closure risks to potential GDEs has not been explicitly evaluated.
	Conceptualisation – Surface Water Groundwater Interactions	Fit for purpose.	Key groundwater–surface water interaction is related to drainage features and associated alluvium and the main drainage feature within the model of the Mackenzie River and the associated alluvial deposits. Investigations and monitoring undertaken by PB indicate the alluvium is largely dry and creeks are ephemeral / losing. Monitoring of the Mackenzie River Alluvium found that groundwater levels were 3-5 m below the Mackenzie River stage.

Type	Part	Status	Comment
	Conceptualisation – Saturated Extent of Alluvium and Regolith	Fit for purpose. Future improvements could be made.	The model provides a close fit to groundwater levels in alluvium, generally within 2 m of observed levels. Additional monitoring would verify the presence/absence of groundwater in the Alluvium at key locations i.e., west of Curragh North.
Parameterisation	Hydraulic Conductivity – Depth Dependence	Fit for purpose. Future improvements could be made.	Limited site specific hydraulic conductivity data (horizontal and to a lesser extent vertical) obtained in 1998. The data shows a general decline in hydraulic conductivity with depth that is replicated in the model. Additional data (if available) should be utilised to verify and update the modelled change with depth, and to refine model calibration and predictions.
	Spoil and Tailings Properties	Fit for purpose. Future improvements possible.	No site-specific data is available for the spoil and tailings. Spoil properties were adopted from existing studies. Measurements of spoil and tailings hydraulic properties could be utilised to verify and refine the model calibration and predictions in updates of the model.
	Rivers	Fit for purpose. Improvements possible.	Mackenzie River stage height is assigned a long term annual average level assumed in the previous version of the model. Monitoring of the Mackenzie River Alluvium found that groundwater levels were 3-5 m below the Mackenzie River stage so variable stage height at times might increase leakage to the alluvium temporarily. Major flood events may have a significant impact on alluvial groundwater recharge but are difficult to replicate within the model. Future modelling could attempt to represent significant flood events as periods of enhanced recharge to the alluvium. No site-specific information on surface water discharge, flow monitoring or water storage has been included in the model but could be considered in future model updates. Blackwater Creek and other minor tributaries within the vicinity of Curragh Complex are ephemeral and only flow briefly after rainfall. Therefore, river stage height of zero was assigned to these watercourses in the model.
	Recharge	Fit for purpose	Recharge zonation is based on mapped surface geology and calibrated recharge rates. Soil mapping and site water quality data could be further utilised to base recharge rates.

Type	Part	Status	Comment
Measurement Error	Observation Data Quality	Fit for purpose Future improvements possible.	Further review of bore construction details and screening of groundwater level data / formations monitored could be undertaken as well as incorporation of any new groundwater level monitoring to refine the groundwater model in future.
	Landholder Bore Data Quality	Fit for purpose	Further detailed review of impacts at the locations of landholder bores should be undertaken with the updated model for PRCP
	Temporal spread	Fit for purpose. Future improvements possible.	Timeseries water level data with varying resolution has been used in the calibration from the site as well as the neighbouring mine Jellinbah Coal Mine. Model temporal discretisation of annual stress periods temporal behaviour of the groundwater system to be simulated in the model. Temporal resolution could be increased to quarterly stress periods to allow climate seasonality to be included.
Scenario Uncertainties Future stresses/ conditions	Calibration	Fit for purpose	A transient calibration model was run and calibrated to observed groundwater levels (1983-June 2021) using PEST and observed mine inflows (2015) with manual calibration. Using shorter time slices in the model would allow climate seasonality to be better represented in the model. The model calibration could be further refined if additional monitoring bores are installed.
	Predictive	Fit for purpose Future improvements possible.	Model captures open cut mining progression and timing at Curragh Complex, based on the 2016 groundwater study with minor updates made to reflect recent changes in mine progression. The model includes some future mining at surrounding mines based on publicly available data and the information from the previous version of the model. The simulated mining progression and the timing for the pits could be improved if an updated mine progression plan is provided. This may require changes to the predictive model temporal discretisation.
	Sensitivity and uncertainty	Fit for purpose. Future improvements may be required.	Predictive uncertainty analysis was not considered necessary for the purpose of this assessment. Additional work to test the uncertainty of the model parameters may be required. This includes differences in the properties spoil properties and hydraulic properties of the in-situ strata. As well the influence of streamflow and recharge on model predictions and recovery.

6 References

Ausenco-Norwest, 2012. Groundwater Model, Northern Bowen Basin Regional Model Impact Predictions, Queensland, Australia. Prepared for Arrow Energy Pty Ltd. Available at: http://www.arrowenergy.com.au/__data/assets/pdf_file/0018/3870/Appendix- Model-Technical-Report.pdf.

Barnett, B., Townley, L.R., Post, V., Evans, R.E., Hunt, R.J., Peeters, L., Richardson, S., Werner, A.D., Knapton, A. and Boronkay, A., 2012. Australian Groundwater Modelling Guidelines. Waterlines Report Series No. 82, June 2012.

AGE 2006. Ensham Central Project EIA - Groundwater Impact Assessment. Prepared for Hansen Consulting, cited in HydroSimulations, Baralaba North Continued Operations (BNCOP) for Cockatoo Coal Ltd, April 2014.

AGE, 2013. Minyango Project Groundwater. Proj G1562. Report for Hansen Bailey. April 2013.

Bureau of Meteorology (BOM). (2021). Map of Climate Zones Australia. Retrieved August 20, 2021, from http://www.bom.gov.au/climate/how/newproducts/images/zones.shtml

Doherty, J., 2010. PEST - Model Independent Parameter Estimation. User Manual 5th Edition. Watermark Numerical Computing.

Douglas Partners 2014. Report on S Pit Groundwater Study Review, Curragh Coal Mine via Blackwater, Central Queensland, Project 80724.00, November 2014.

HydroAlgorithmics 2014. AlgoMesh 2. Released 1 September 2020, from http://www. hydroalgorithmics.com /algomesh-version-2-released.

HydroSimulations, 2016. Curragh Extension Project Groundwater Model: Final Review (Ref: HC2016/26).

MDBC (Middlemis, H., Merrick, N., and Ross, J.), 2001. Murray-Darling Basin Commission – Groundwater Flow Modelling Guideline. Report for MDBC. January 2001.

Parsons Brinckerhoff 2003. Curragh North Coal Mine – Hydrology, flooding and groundwater report, Project No. 2132105A-PR001Ebt (Appendix G of Curragh North Mine Environmental Impact Statement). August 2003.

Parsons Brinkerhoff (PB), 2016. Curragh Extension Project – Groundwater Technical Report (2172652H-WAT-REP-002 RevB)

Queensland Government. (2021). *Scientific Land Owners (SILO) database – Australian climate data from 1889 to yesterday*. Retrieved August, 23, 2021, from https://www.longpaddock.qld.gov.au/silo/point-data/

Panday, S., Langevin, C.D., Niswonger, R.G., Ibaraki, M., and Hughes, J.D., 2013., MODFLOW–USG version 1: An unstructured grid version of MODFLOW for simulating groundwater flow and tightly coupled processes using a control volume finite-difference formulation: USGS Techniques and Methods 6-A45.

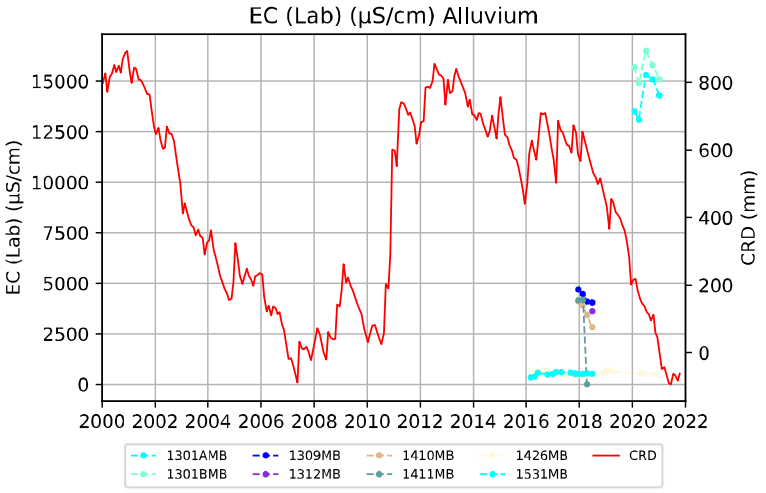
SLR, 2021a. Curragh Mine Complex, Concept Residual Void Assessment Groundwater Technical Appendix, November 2021.

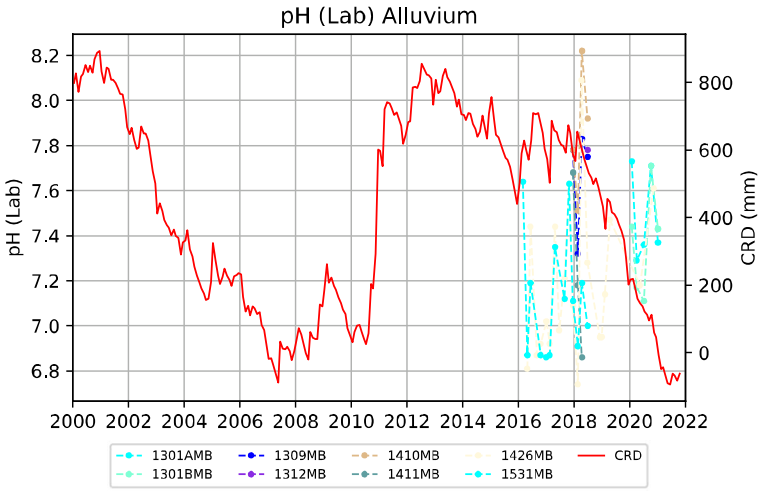
SLR, 2021b. Curragh Mine Complex, Concept Residual Void Assessment (626.30075.00000), November 2021.

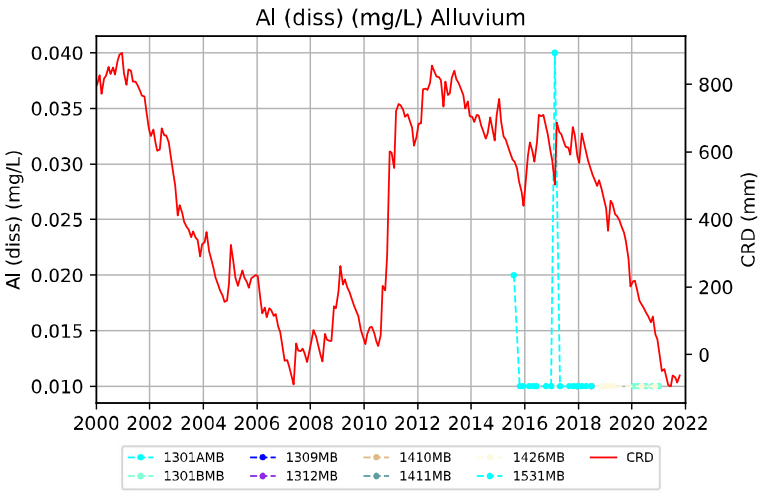
Velseis Processing Pty Ltd (2012). 2011 Minyango 3D Seismic Survey, Minyango Project Area, Qld. Final Report, Interpretation and Data Processing.

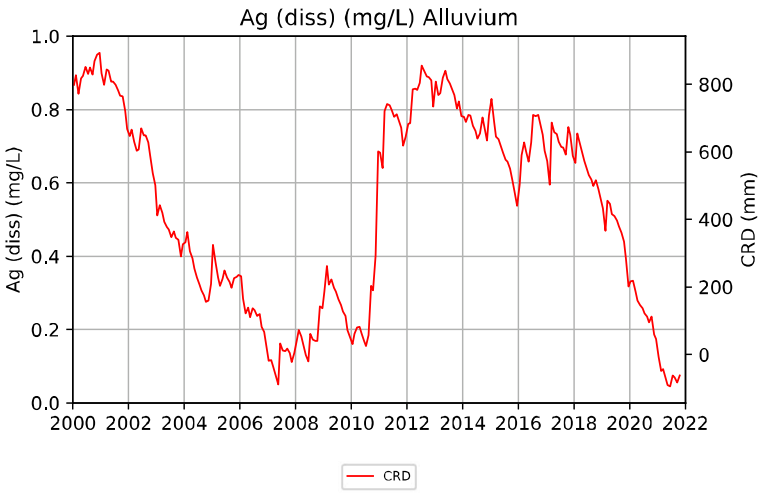
APPENDIX A

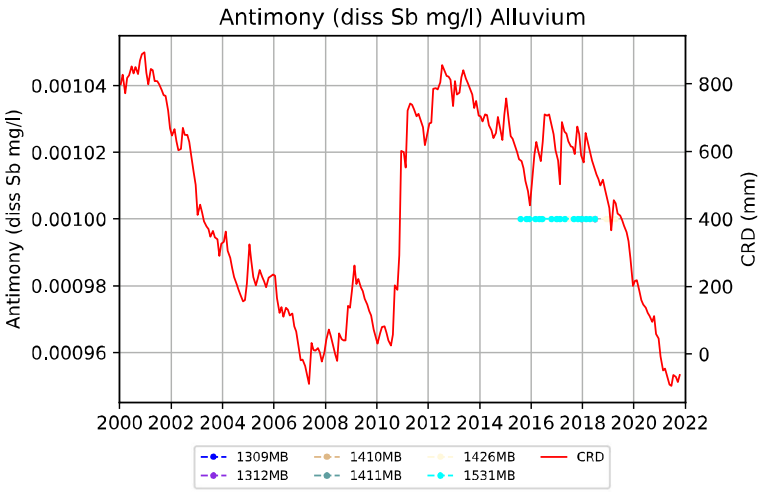
Groundwater quality charts

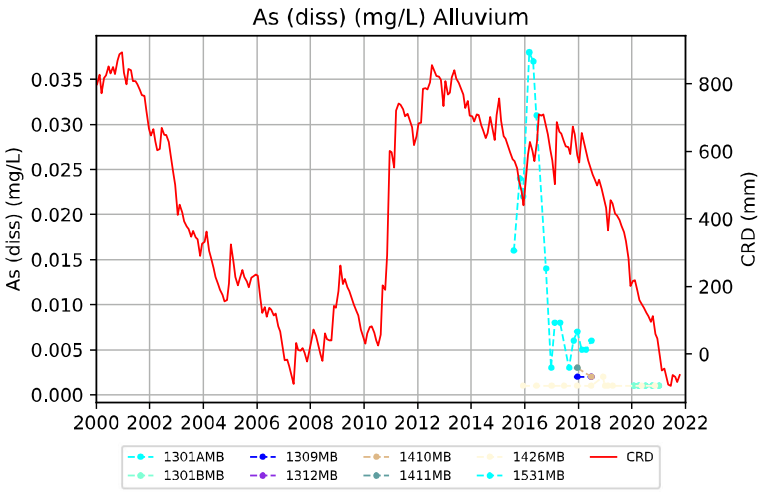

EC (Lab) (µS/cm) Alluvium
EC (Lab) (µS/cm)
CRD (mm)
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1531MB
CRD

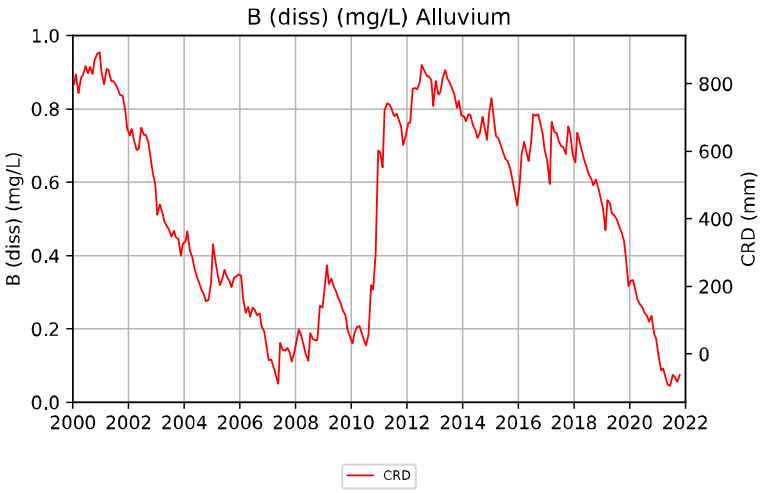

pH (Lab) Alluvium
pH (Lab)
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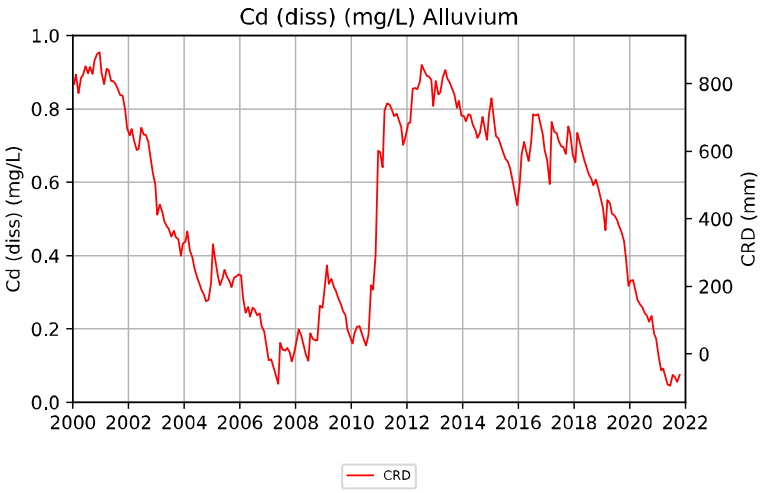

Al (diss) (mg/L) Alluvium
Al (diss) (mg/L)
CRD (mm)
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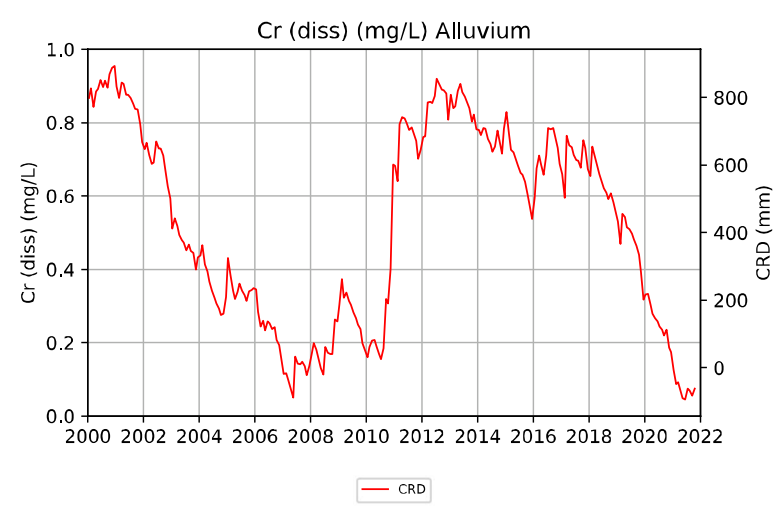

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Ag (diss) (mg/L)
CRD (mm)
CRD

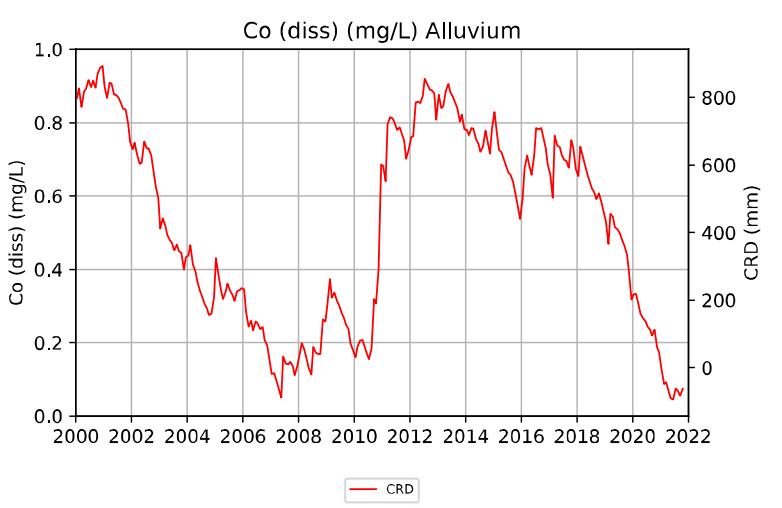

Antimony (diss Sb mg/l) Alluvium
Antimony (diss Sb mg/l)
CRD (mm)
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CRD

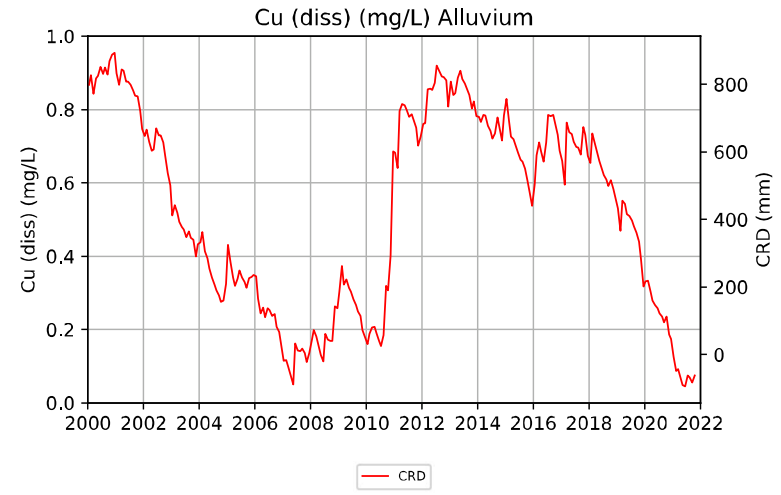

As (diss) (mg/L) Alluvium
As (diss) (mg/L)
CRD (mm)
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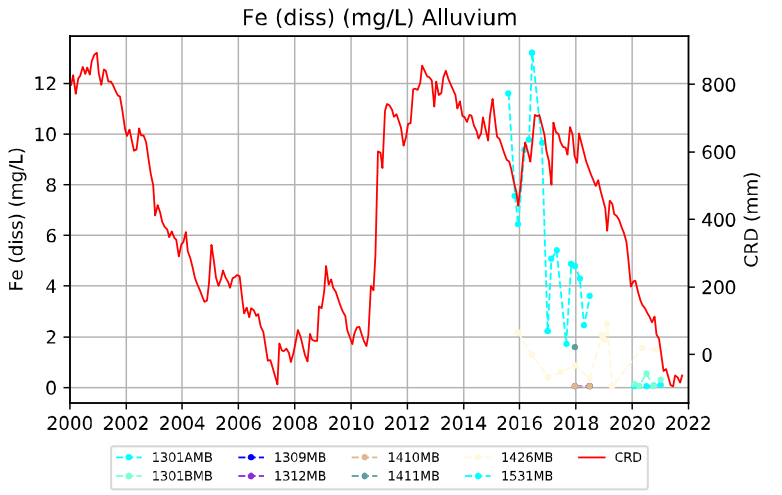

B (diss) (mg/L) Alluvium
B (diss) (mg/L)
CRD (mm)
CRD

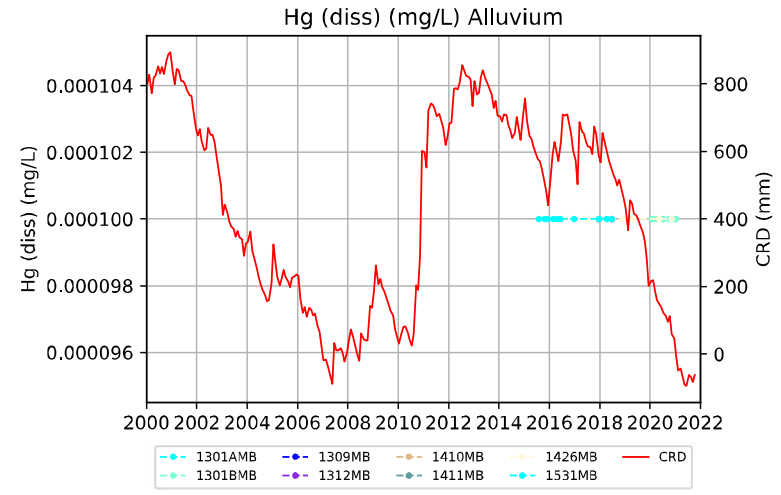

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Cd (diss) (mg/L)
CRD (mm)
CRD

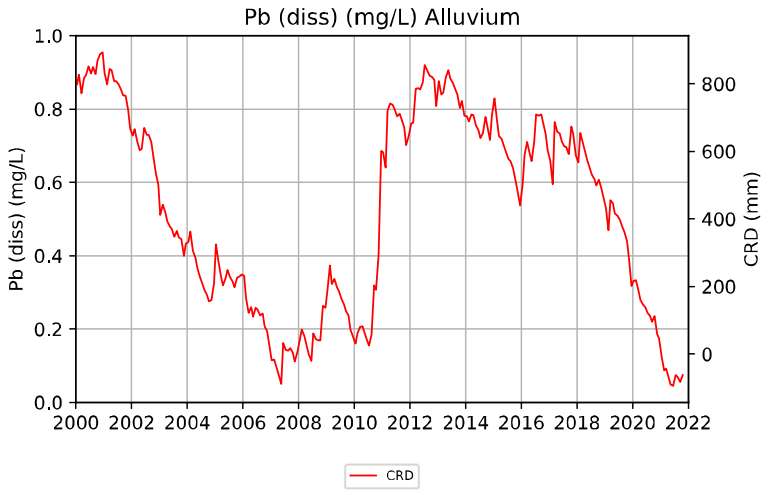

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Cr (diss) (mg/L)
CRD (mm)
CRD

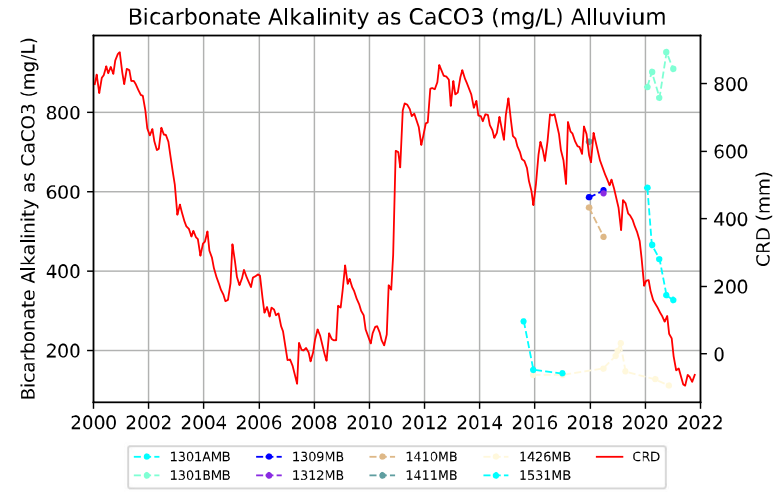

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Co (diss) (mg/L)
CRD (mm)
CRD

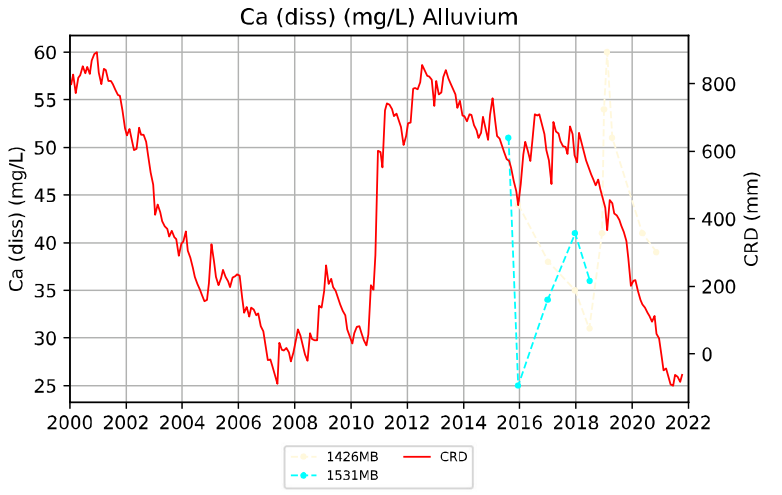

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Cu (diss) (mg/L)
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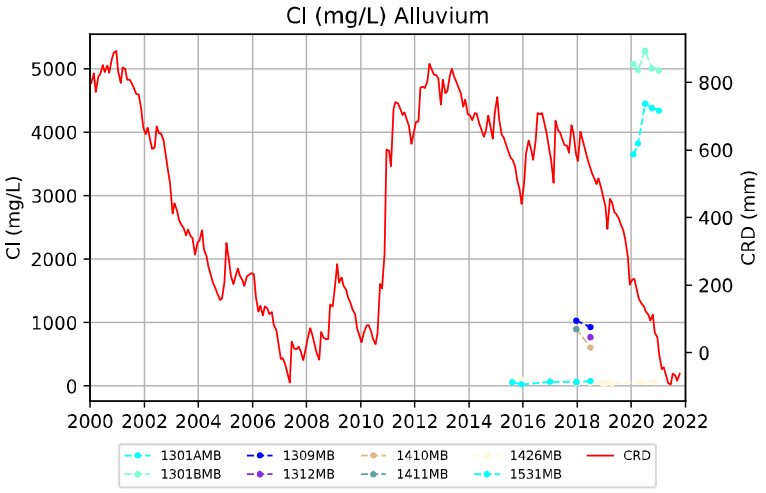

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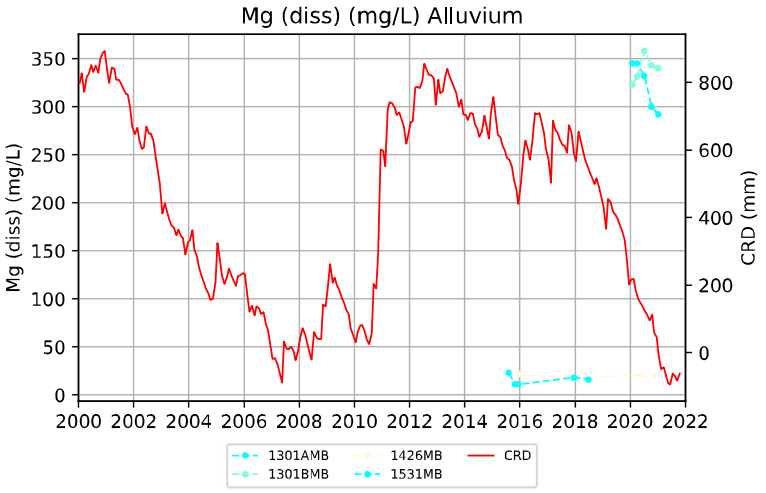

Hg (diss) (mg/L) Alluvium
Hg (diss) (mg/L)
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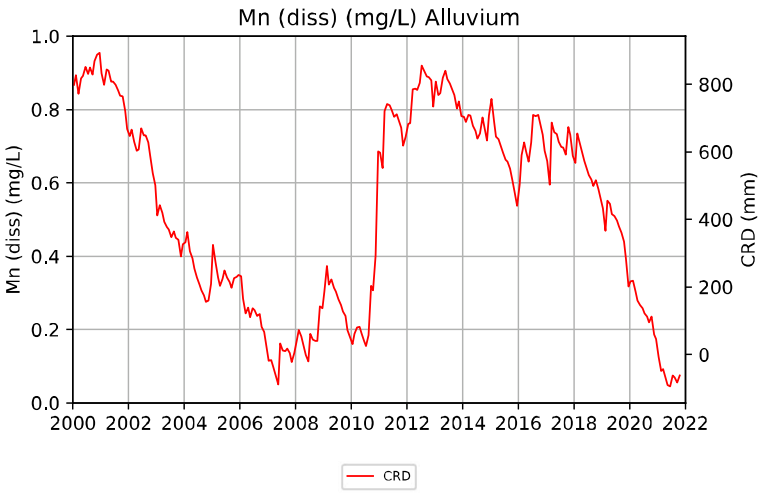

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CRD (mm)
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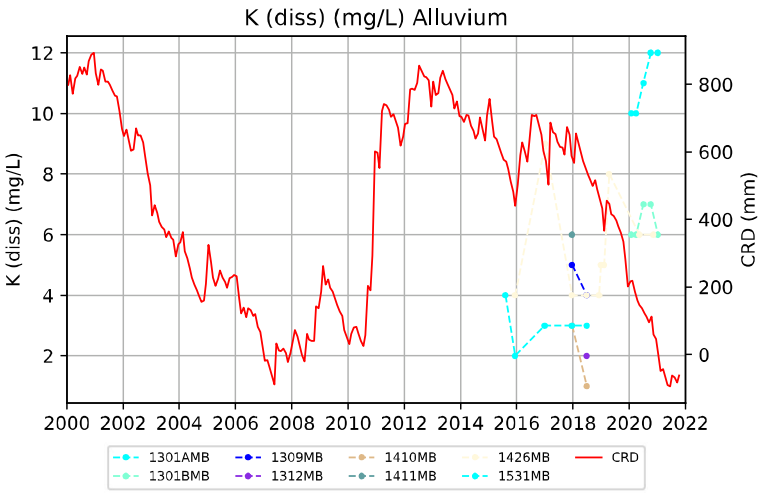

Bicarbonate Alkalinity as CaCO3 (mg/L) Alluvium
Bicarbonate Alkalinity as CaCO3 (mg/L)
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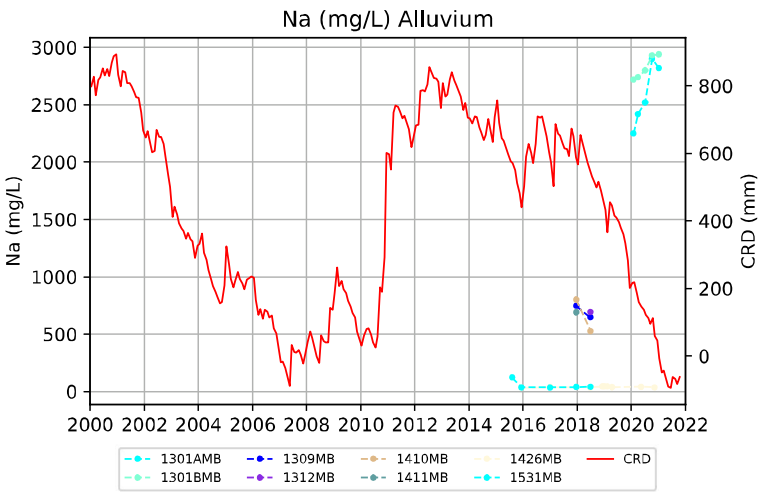

Ca (diss) (mg/L) Alluvium
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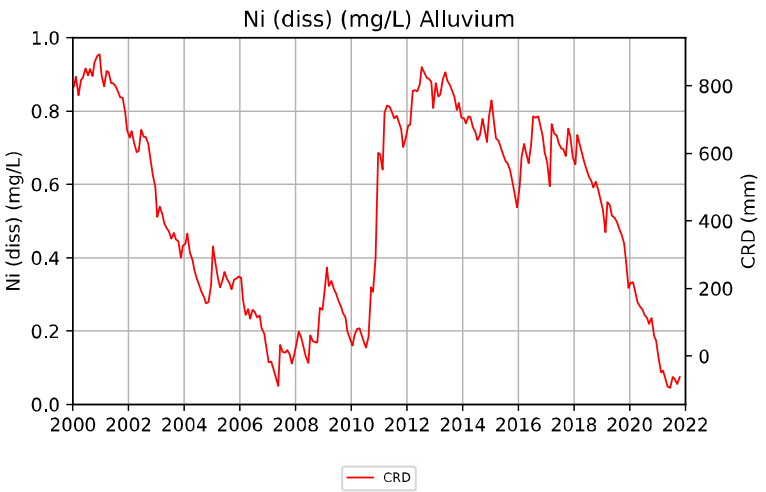

Cl (mg/L) Alluvium
Cl (mg/L)
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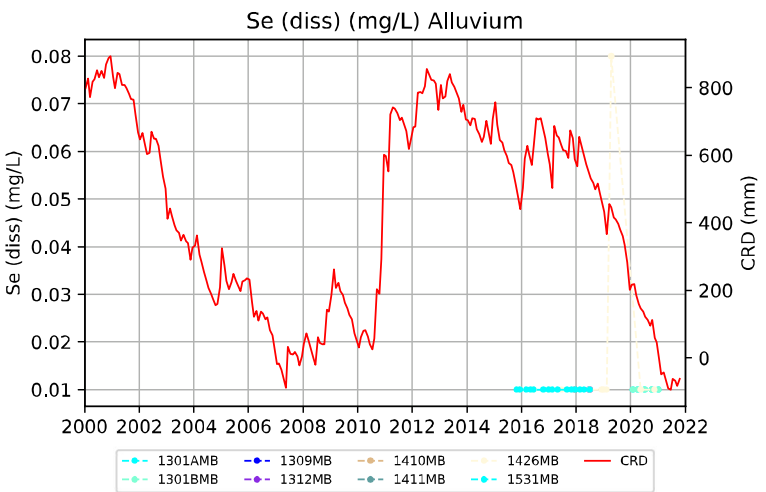

Mg (diss) (mg/L) Alluvium
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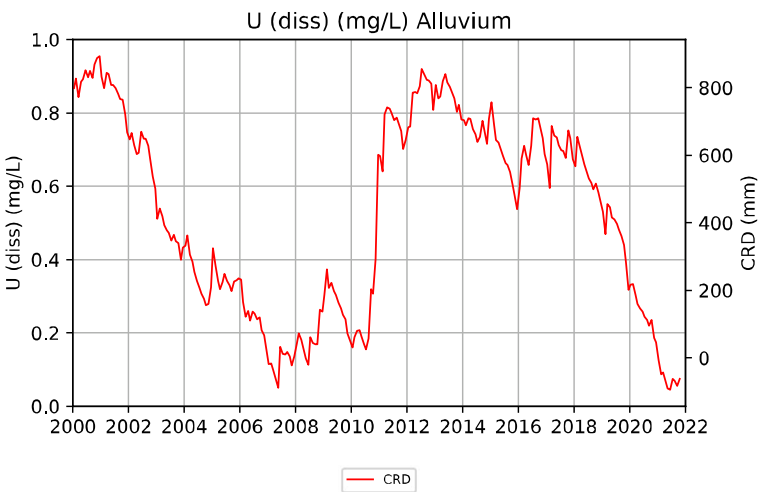

Mn (diss) (mg/L) Alluvium
Mn (diss) (mg/L)
CRD (mm)
CRD

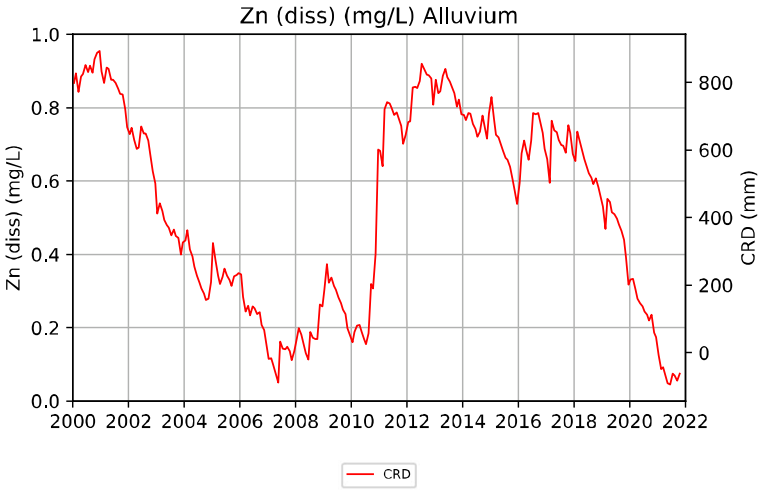

K (diss) (mg/L) Alluvium
K (diss) (mg/L)
CRD (mm)
1301AMB
1301BMB
1309MB
1312MB
1410MB
1411MB
1426MB
1531MB
CRD

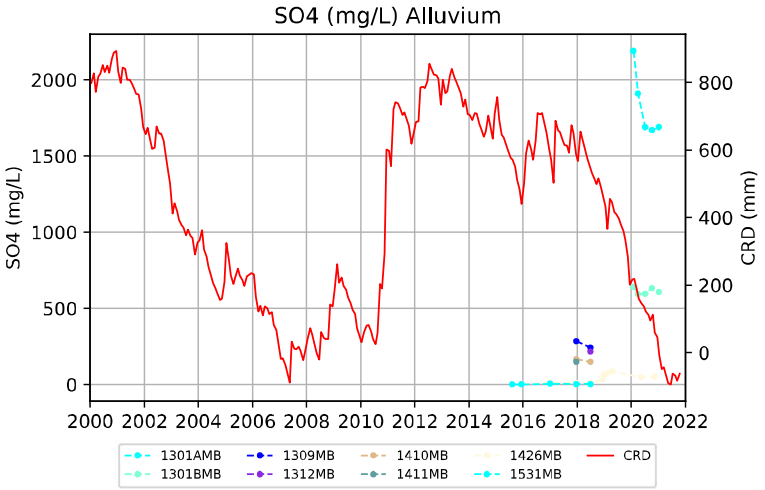

Na (mg/L) Alluvium
Na (mg/L)
CRD (mm)
1301AMB
1301BMB
1309MB
1312MB
1410MB
1411MB
1426MB
1531MB
CRD

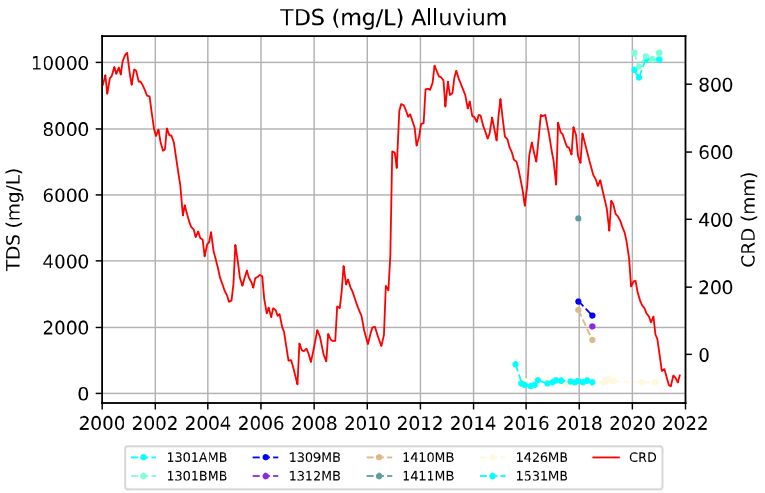

Ni (diss) (mg/L) Alluvium
Ni (diss) (mg/L)
CRD (mm)
CRD

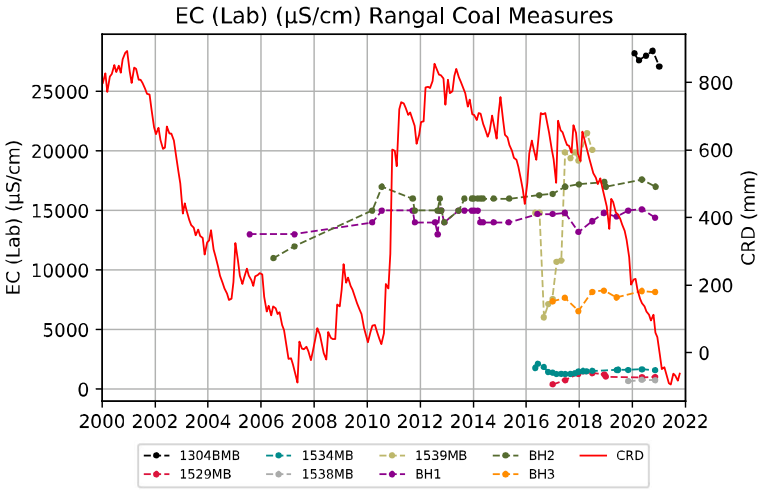

Se (diss) (mg/L) Alluvium
Se (diss) (mg/L)
CRD (mm)
1301AMB
1301BMB
1309MB
1312MB
1410MB
1411MB
1426MB
1531MB
CRD

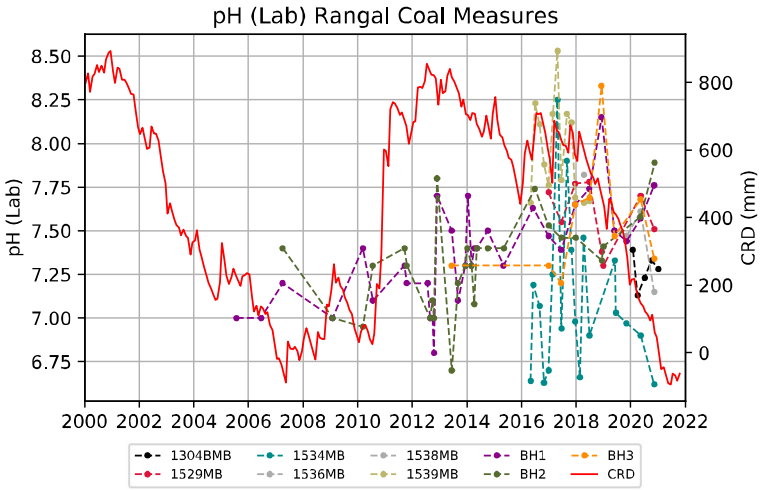

U (diss) (mg/L) Alluvium
U (diss) (mg/L)
CRD (mm)
CRD

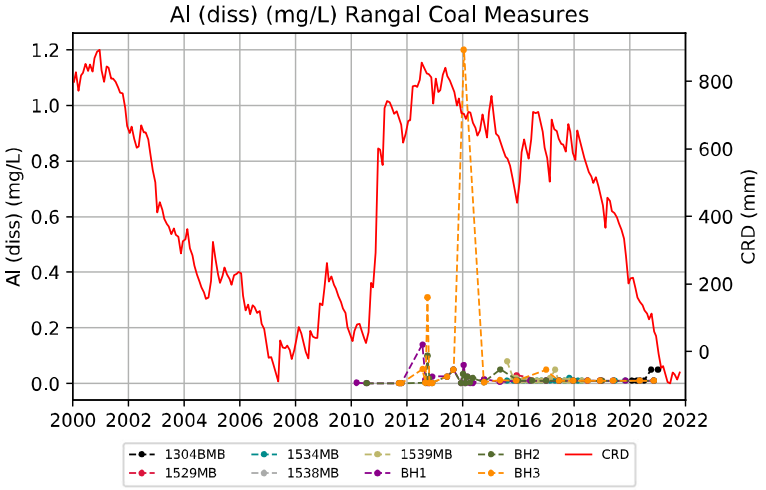

Zn (diss) (mg/L) Alluvium
Zn (diss) (mg/L)
CRD (mm)
CRD

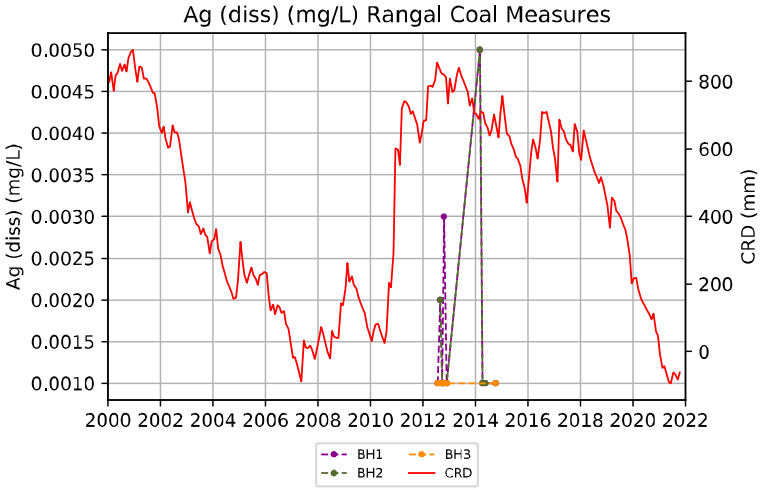

SO4 (mg/L) Alluvium
SO4 (mg/L)
CRD (mm)
1301AMB
1301BMB
1309MB
1312MB
1410MB
1411MB
1426MB
1531MB
CRD

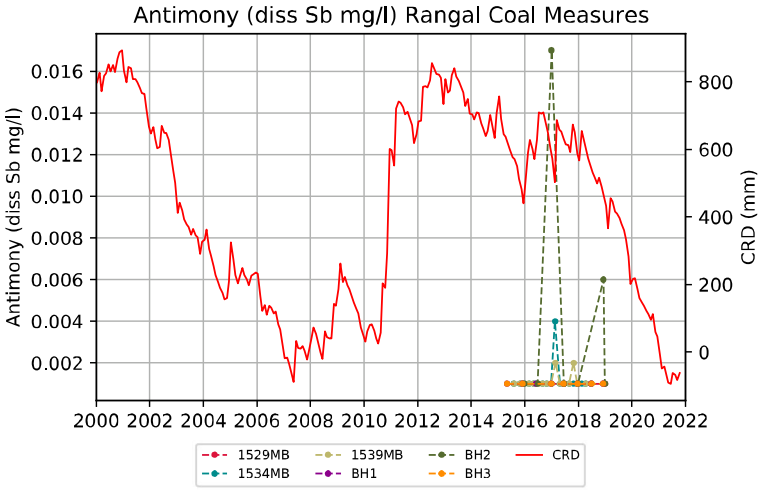

TDS (mg/L) Alluvium
TDS (mg/L)
CRD (mm)
1301AMB
1301BMB
1309MB
1312MB
1410MB
1411MB
1426MB
1531MB
CRD

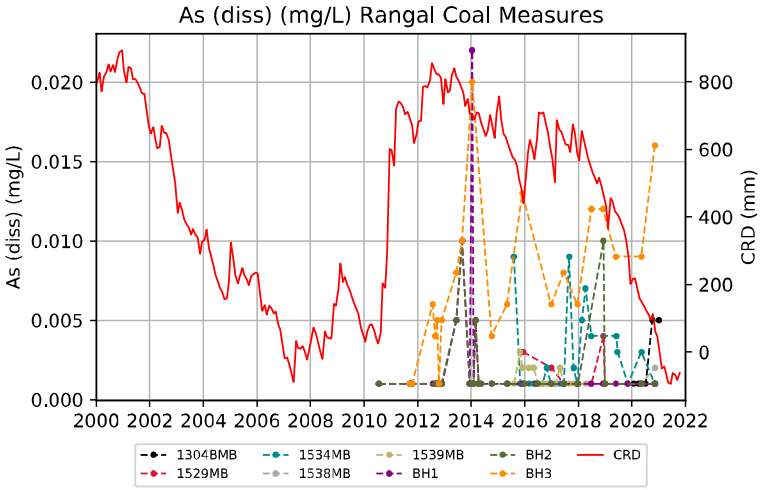

EC (Lab) (µS/cm) Rangal Coal Measures
EC (Lab) (µS/cm)
CRD (mm)
1304BMB
1529MB
1534MB
1538MB
1539MB
BH1
BH2
BH3
CRD

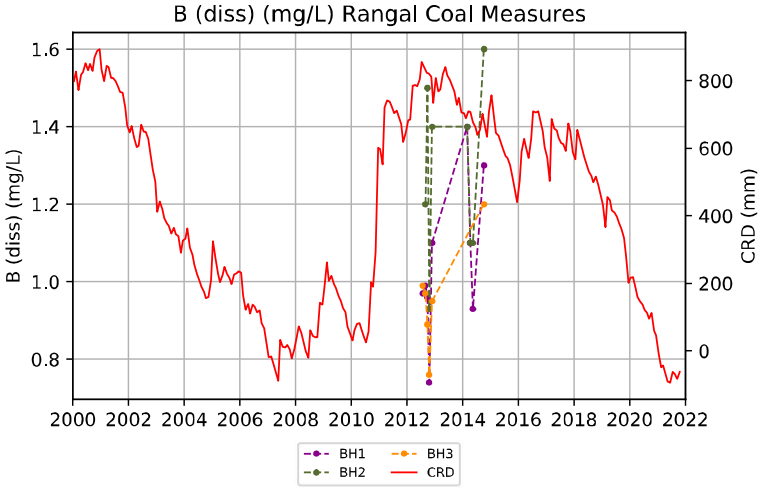

pH (Lab) Rangal Coal Measures
pH (Lab)
CRD (mm)
1304BMB
1529MB
1534MB
1536MB
1538MB
1539MB
BH1
BH2
BH3
CRD

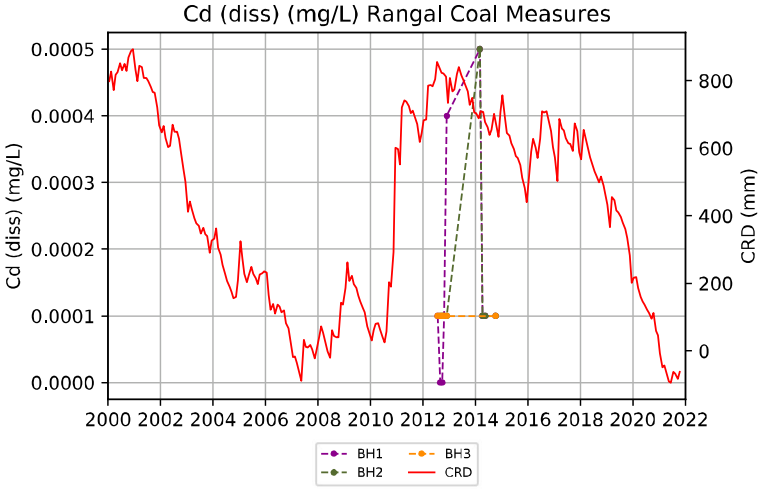

Al (diss) (mg/L) Rangal Coal Measures
Al (diss) (mg/L)
CRD (mm)
1304BMB
1529MB
1534MB
1538MB
1539MB
BH1
BH2
BH3
CRD

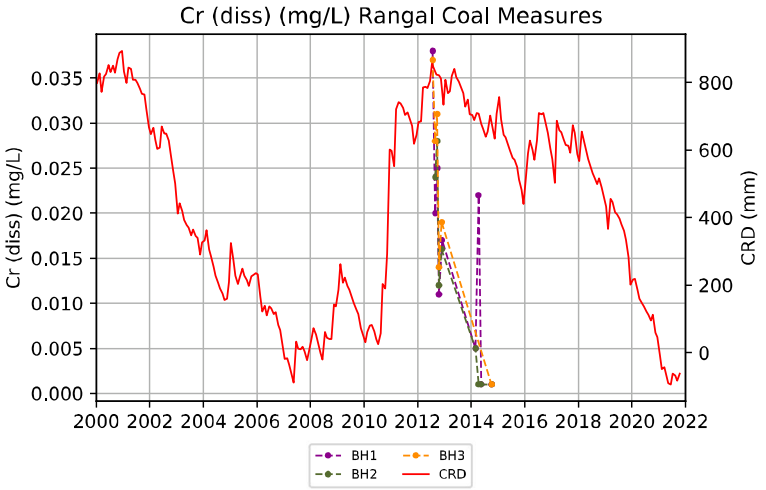

Ag (diss) (mg/L) Rangal Coal Measures
Ag (diss) (mg/L)
CRD (mm)
BH1
BH2
BH3
CRD

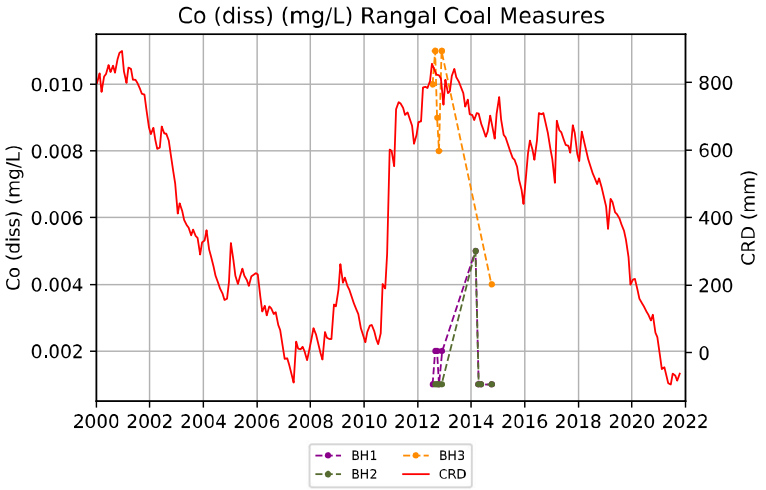

Antimony (diss Sb mg/l) Rangal Coal Measures
Antimony (diss Sb mg/l)
CRD (mm)
1529MB
1534MB
1539MB
BH1
BH2
BH3
CRD

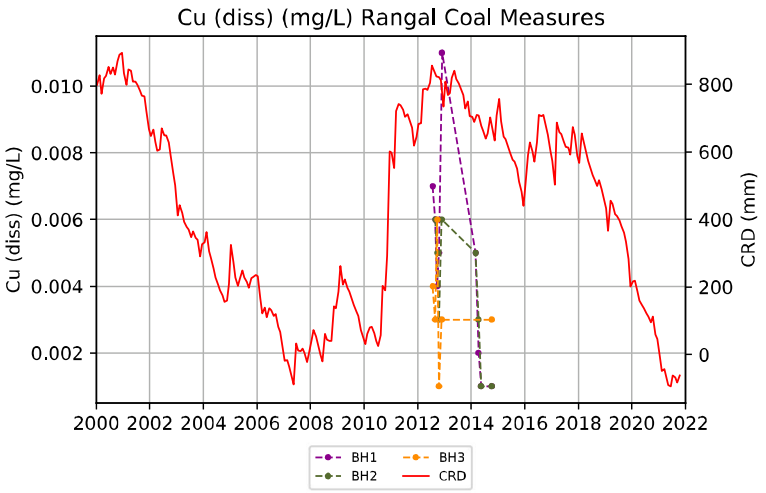

As (diss) (mg/L) Rangal Coal Measures
As (diss) (mg/L)
CRD (mm)
1304BMB
1529MB
1534MB
1538MB
1539MB
BH1
BH2
BH3
CRD

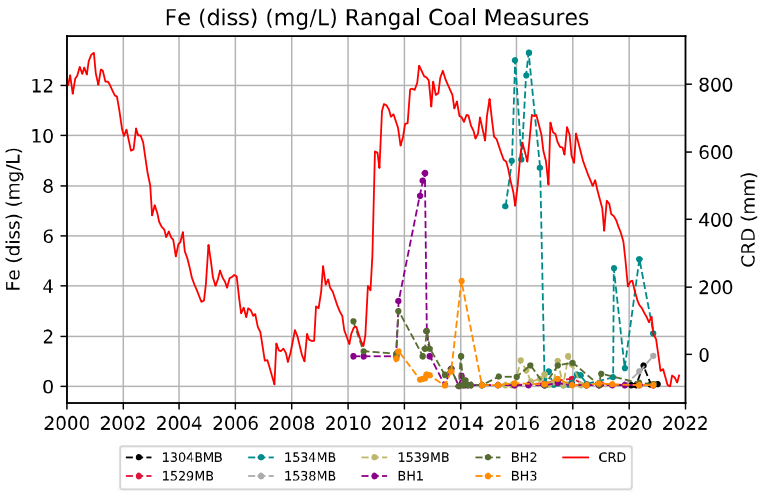

B (diss) (mg/L) Rangal Coal Measures
B (diss) (mg/L)
CRD (mm)
BH1
BH2
BH3
CRD

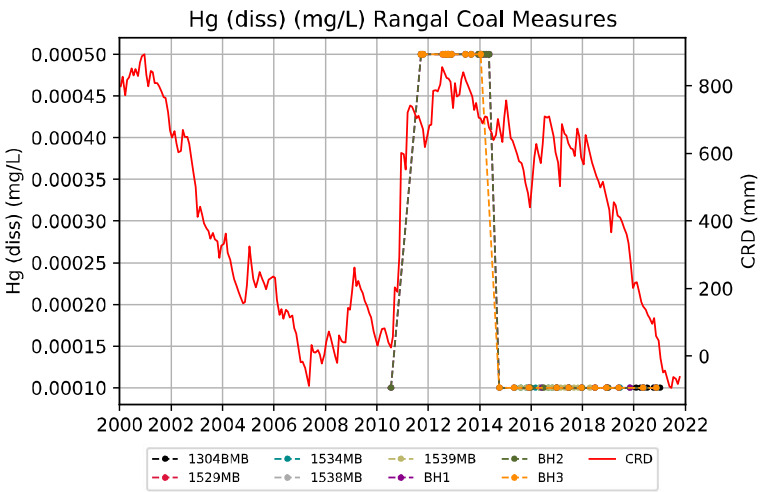

Cd (diss) (mg/L) Rangal Coal Measures
Cd (diss) (mg/L)
CRD (mm)
BH1
BH2
BH3
CRD

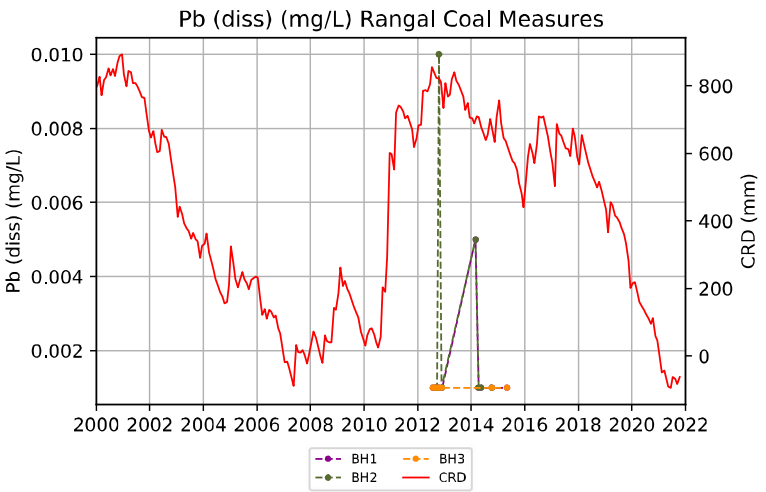

Cr (diss) (mg/L) Rangal Coal Measures
Cr (diss) (mg/L)
CRD (mm)
BH1
BH2
BH3
CRD

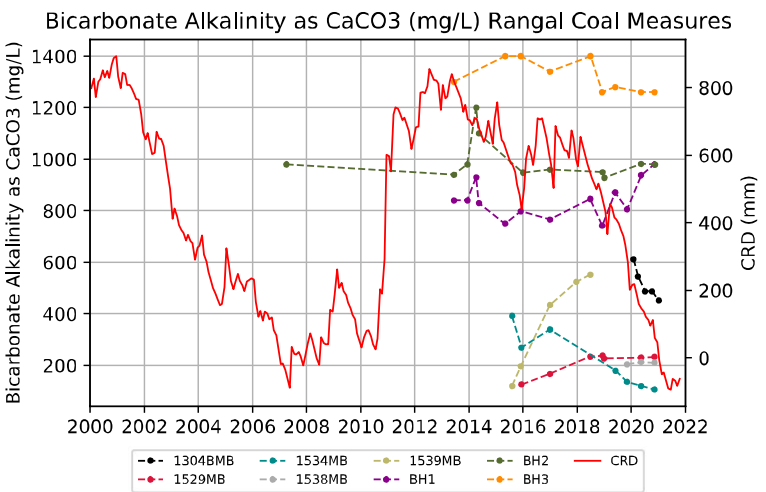

Co (diss) (mg/L) Rangal Coal Measures
Co (diss) (mg/L)
CRD (mm)
BH1
BH2
BH3
CRD

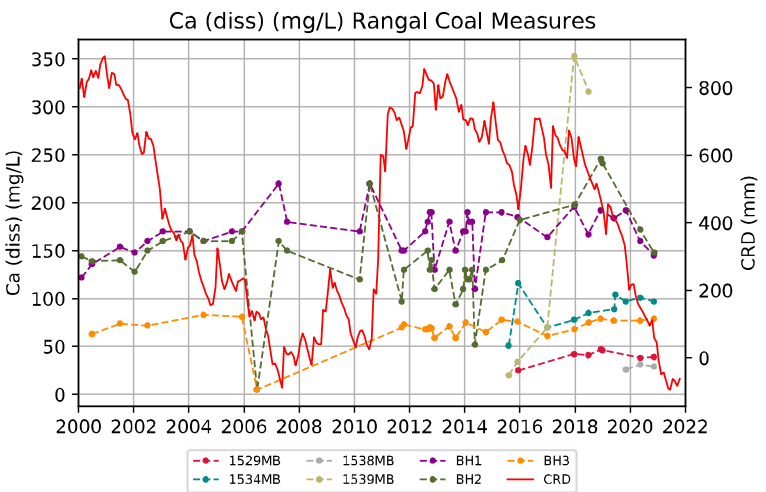

Cu (diss) (mg/L) Rangal Coal Measures
Cu (diss) (mg/L)
CRD (mm)
BH1
BH2
BH3
CRD

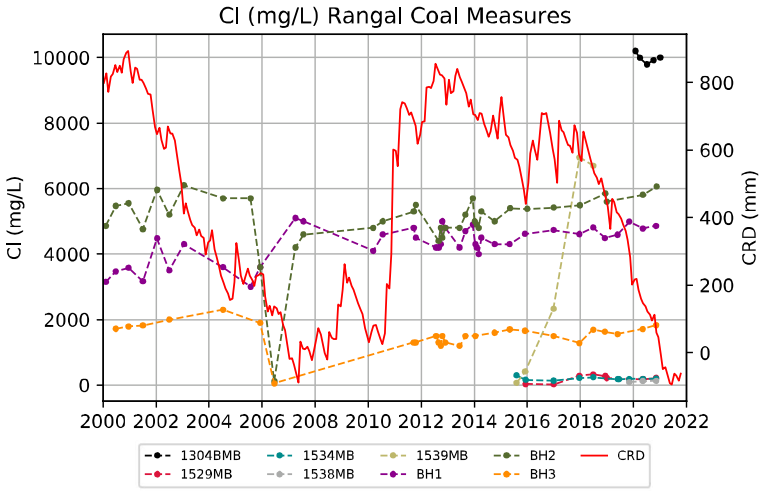

Fe (diss) (mg/L) Rangal Coal Measures
Fe (diss) (mg/L)
CRD (mm)
1304BMB
1529MB
1534MB
1538MB
1539MB
BH1
BH2
BH3
CRD

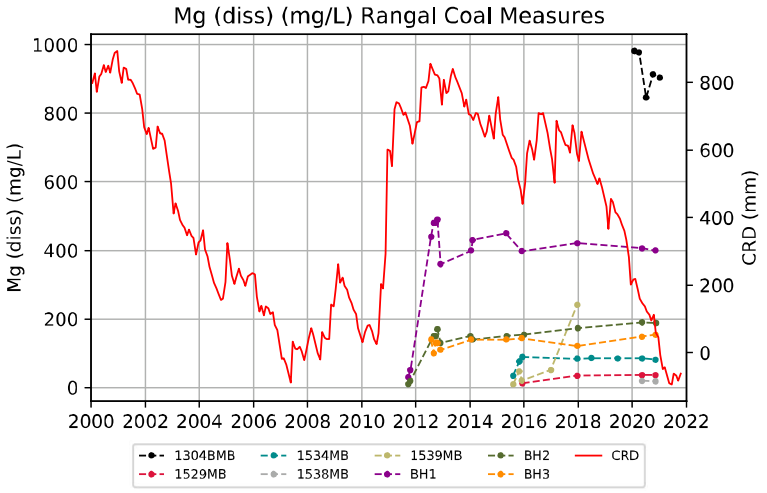

Hg (diss) (mg/L) Rangal Coal Measures
Hg (diss) (mg/L)
CRD (mm)
1304BMB
1529MB
1534MB
1538MB
1539MB
BH1
BH2
BH3
CRD

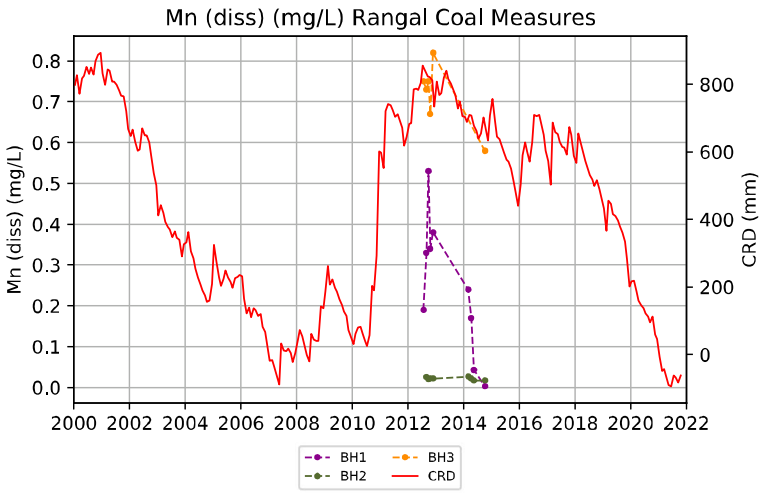

Pb (diss) (mg/L) Rangal Coal Measures
Pb (diss) (mg/L)
CRD (mm)
BH1
BH2
BH3
CRD

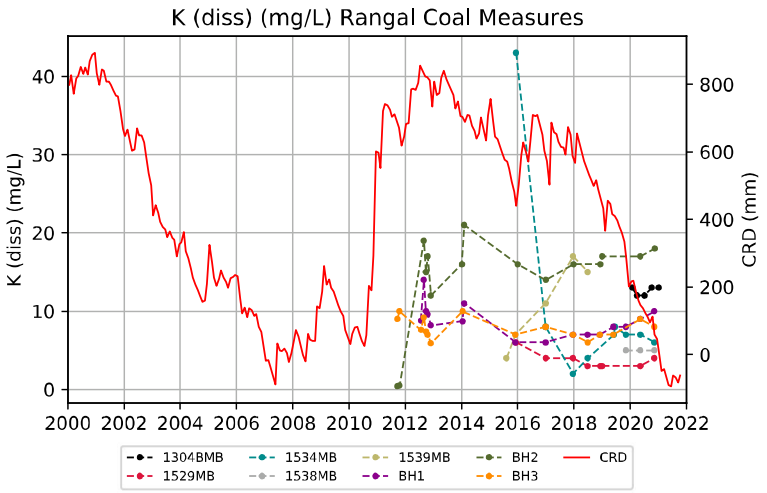

Bicarbonate Alkalinity as CaCO3 (mg/L) Rangal Coal Measures
Bicarbonate Alkalinity as CaCO3 (mg/L)
CRD (mm)
1304BMB
1529MB
1534MB
1538MB
1539MB
BH1
BH2
BH3
CRD

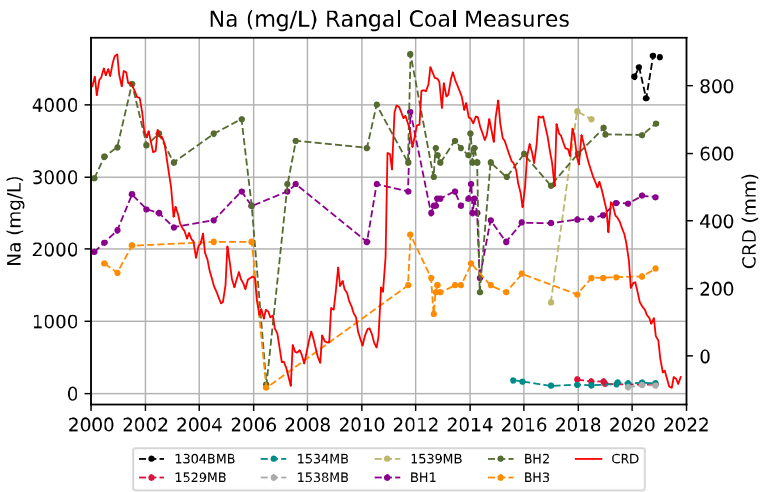

Ca (diss) (mg/L) Rangal Coal Measures
Ca (diss) (mg/L)
CRD (mm)
1529MB
1534MB
1538MB
1539MB
BH1
BH2
BH3
CRD

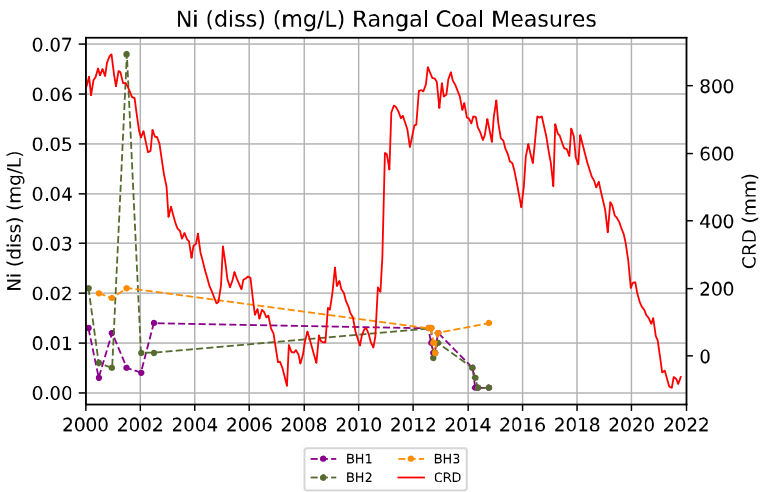

Cl (mg/L) Rangal Coal Measures
Cl (mg/L)
CRD (mm)
1304BMB
1534MB
1539MB
BH2
CRD
1529MB
1538MB
BH1
BH3

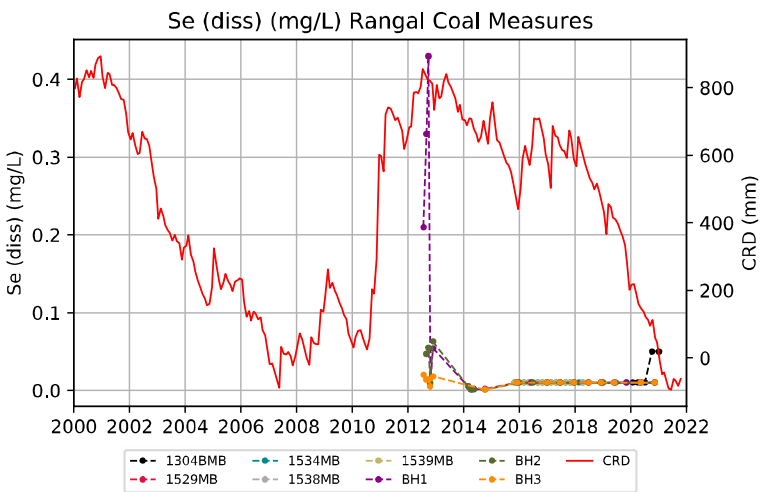

Mg (diss) (mg/L) Rangal Coal Measures
Mg (diss) (mg/L)
CRD (mm)
1304BMB
1534MB
1539MB
BH2
CRD
1529MB
1538MB
BH1
BH3

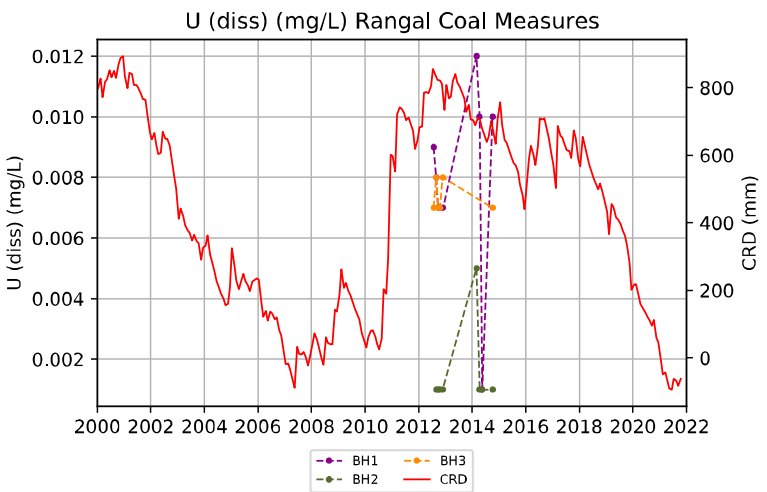

Mn (diss) (mg/L) Rangal Coal Measures
Mn (diss) (mg/L)
CRD (mm)
BH1
BH3
BH2
CRD

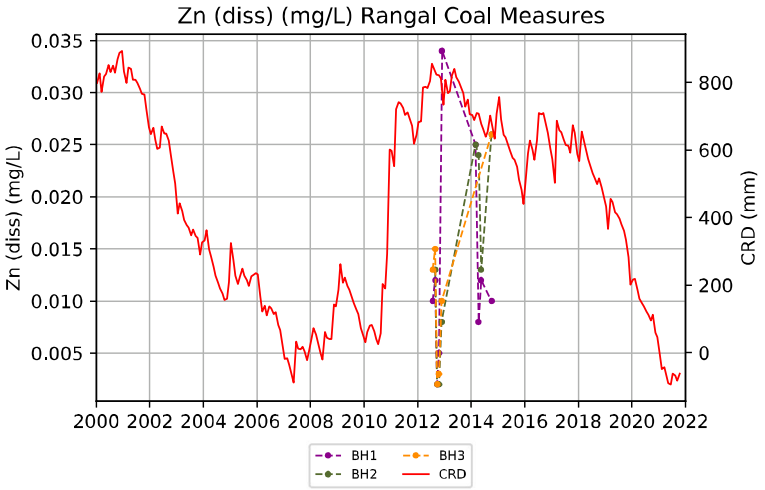

K (diss) (mg/L) Rangal Coal Measures
K (diss) (mg/L)
CRD (mm)
1304BMB
1534MB
1539MB
BH2
CRD
1529MB
1538MB
BH1
BH3

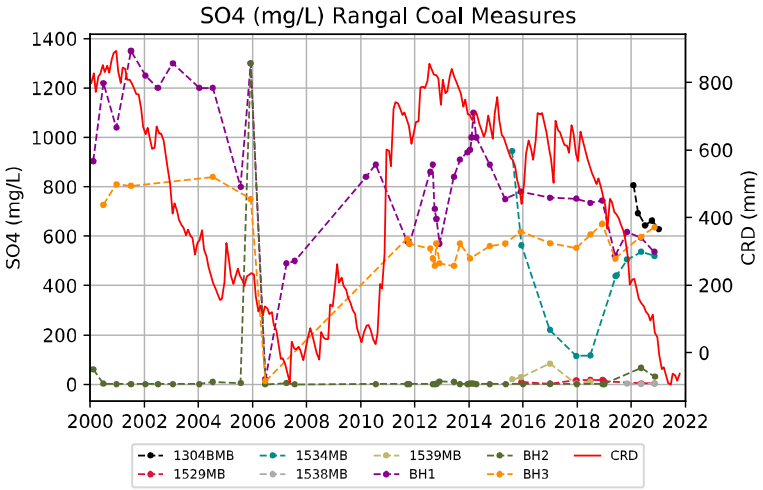

Na (mg/L) Rangal Coal Measures
Na (mg/L)
CRD (mm)
1304BMB
1534MB
1539MB
BH2
CRD
1529MB
1538MB
BH1
BH3

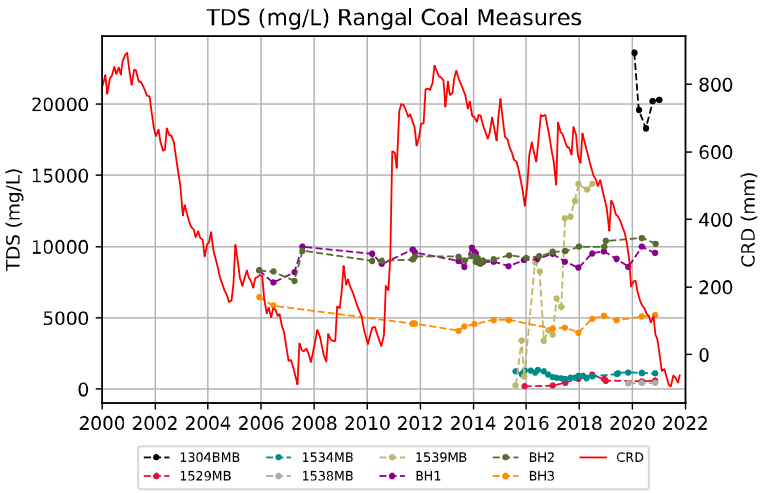

Ni (diss) (mg/L) Rangal Coal Measures
Ni (diss) (mg/L)
CRD (mm)
BH1
BH3
BH2
CRD

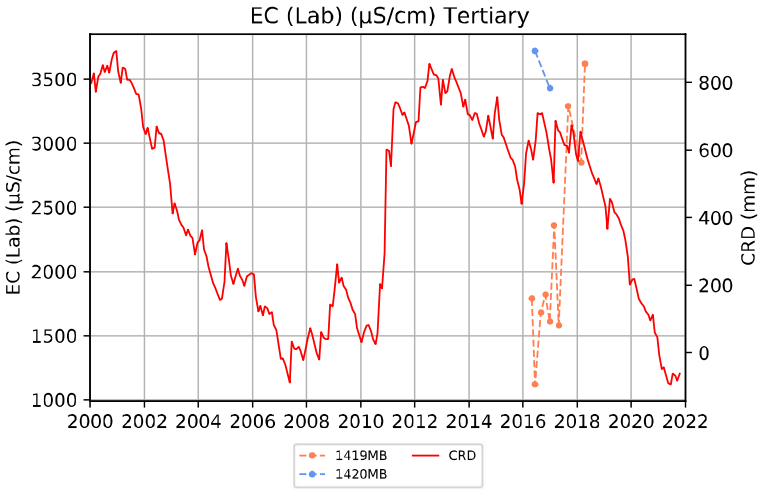

Se (diss) (mg/L) Rangal Coal Measures
Se (diss) (mg/L)
CRD (mm)
1304BMB
1534MB
1539MB
BH2
CRD
1529MB
1538MB
BH1
BH3

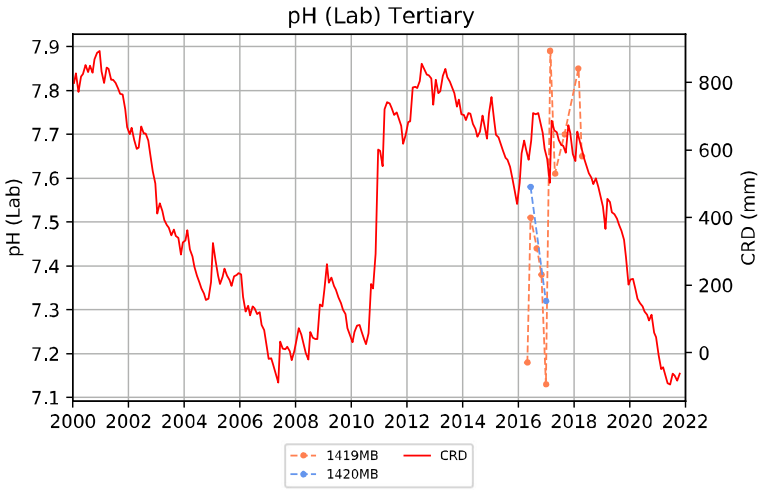

U (diss) (mg/L) Rangal Coal Measures
U (diss) (mg/L)
CRD (mm)
BH1
BH3
BH2
CRD

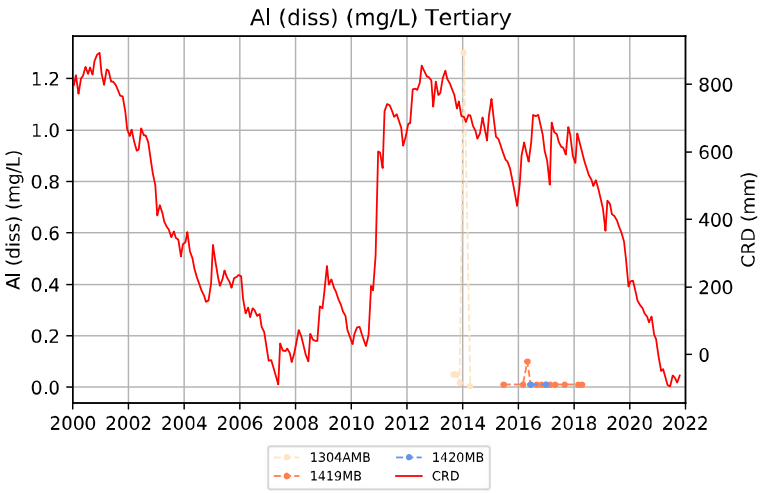

Zn (diss) (mg/L) Rangal Coal Measures
Zn (diss) (mg/L)
CRD (mm)
BH1
BH2
BH3
CRD

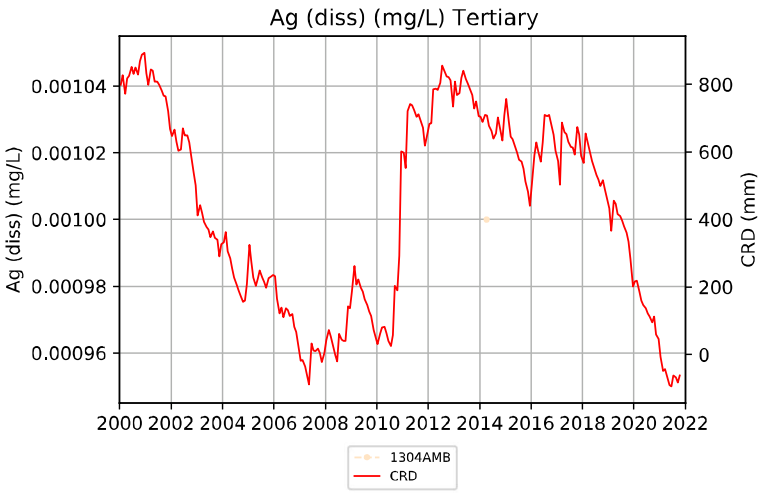

SO4 (mg/L) Rangal Coal Measures
SO4 (mg/L)
CRD (mm)
1304BMB
1529MB
1534MB
1538MB
1539MB
BH1
BH2
BH3
CRD

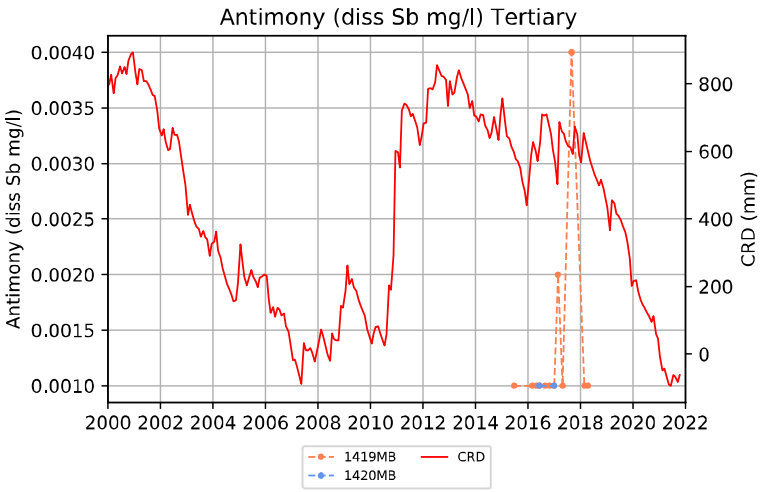

TDS (mg/L) Rangal Coal Measures
TDS (mg/L)
CRD (mm)
1304BMB
1529MB
1534MB
1538MB
1539MB
BH1
BH2
BH3
CRD

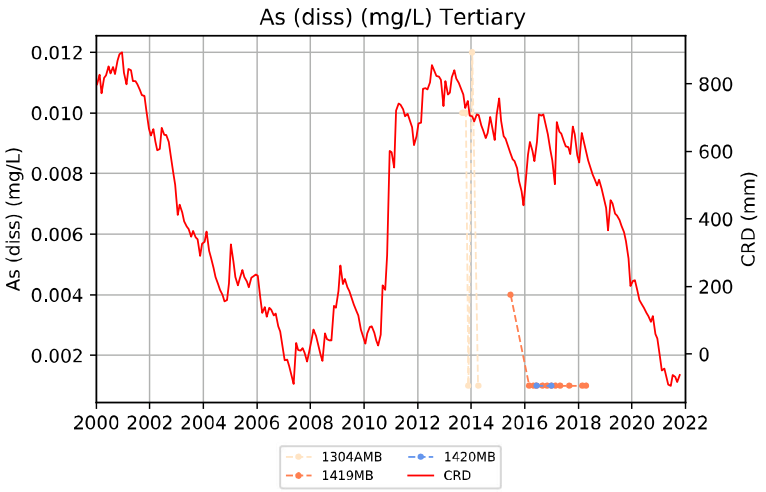

EC (Lab) (µS/cm) Tertiary
EC (Lab) (µS/cm)
CRD (mm)
1419MB
1420MB
CRD

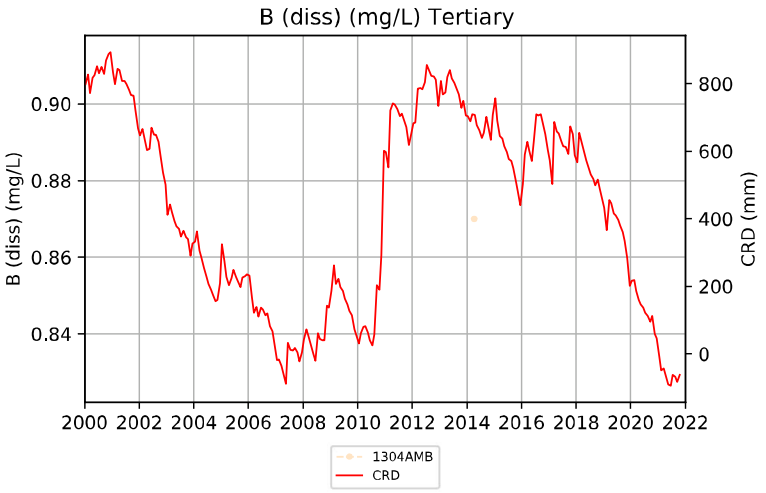

pH (Lab) Tertiary
pH (Lab)
CRD (mm)
1419MB
1420MB
CRD

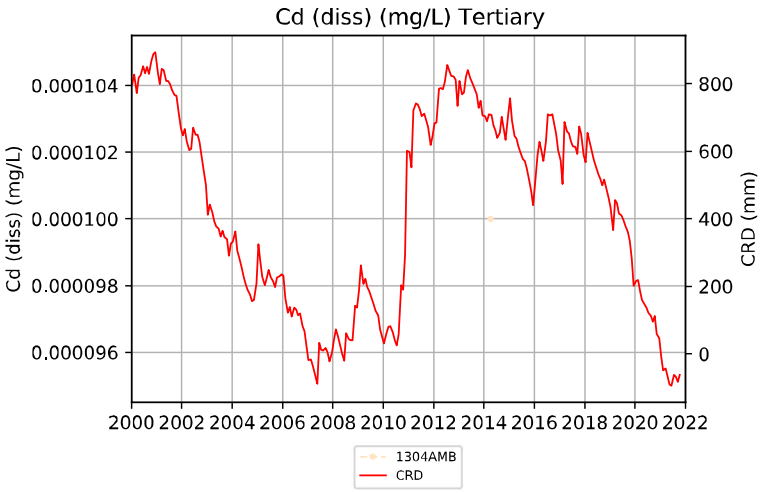

Al (diss) (mg/L) Tertiary
Al (diss) (mg/L)
CRD (mm)
1304AMB
1420MB
1419MB
CRD

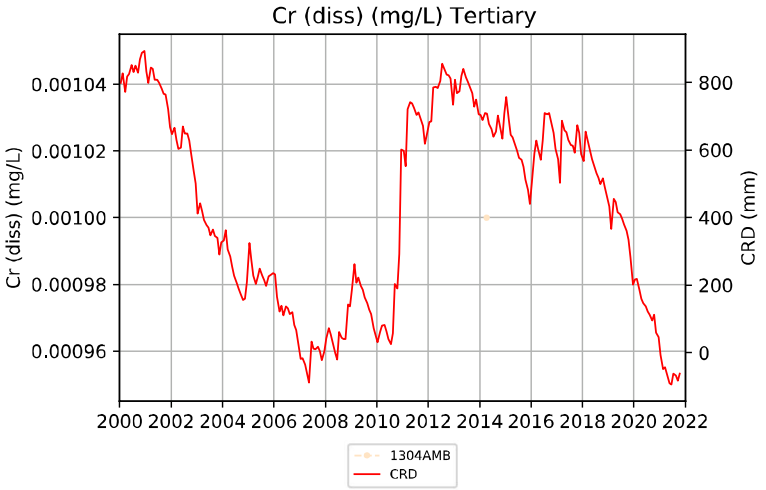

Ag (diss) (mg/L) Tertiary
Ag (diss) (mg/L)
CRD (mm)
1304AMB
CRD

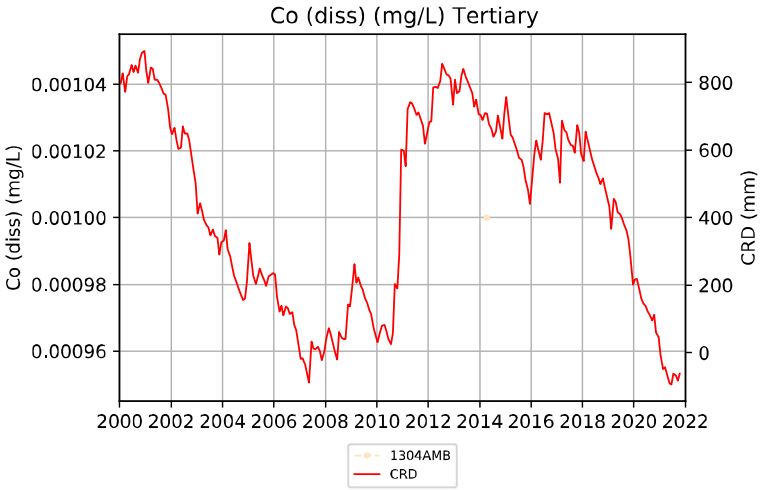

Antimony (diss Sb mg/l) Tertiary
Antimony (diss Sb mg/l)
CRD (mm)
1419MB
1420MB
CRD

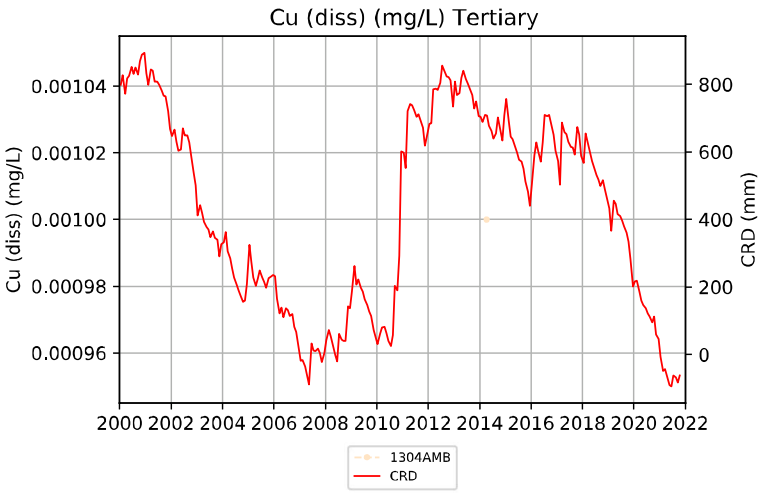

As (diss) (mg/L) Tertiary
As (diss) (mg/L)
CRD (mm)
1304AMB
1420MB
1419MB
CRD

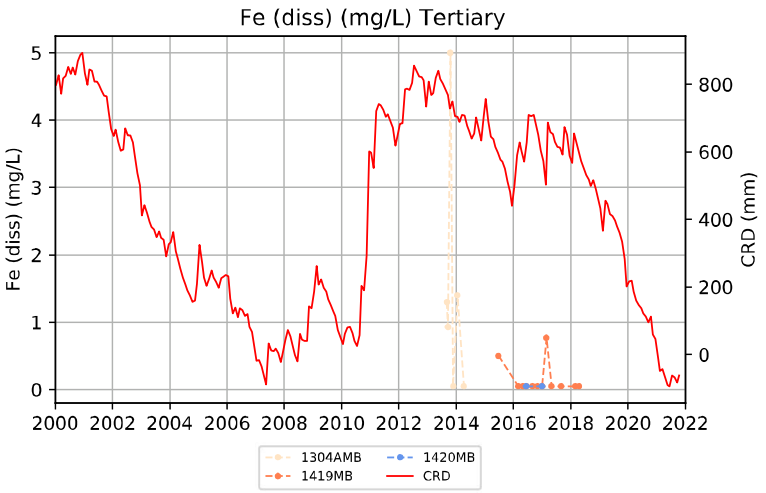

B (diss) (mg/L) Tertiary
B (diss) (mg/L)
CRD (mm)
1304AMB
CRD

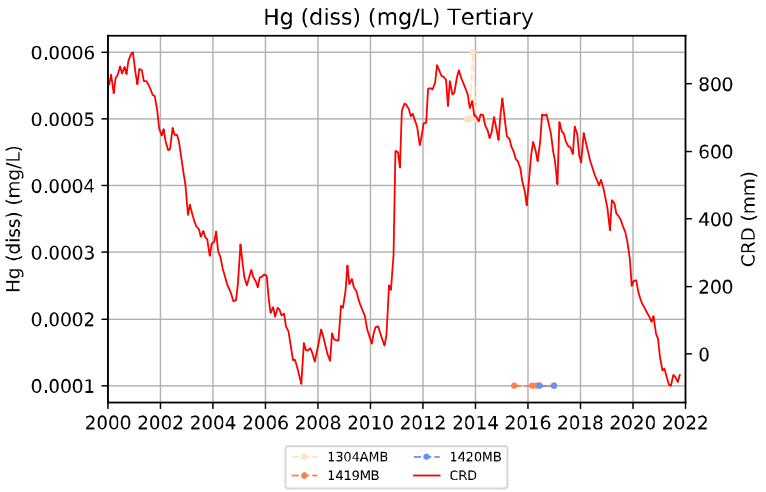

Cd (diss) (mg/L) Tertiary
Cd (diss) (mg/L)
CRD (mm)
1304AMB
CRD

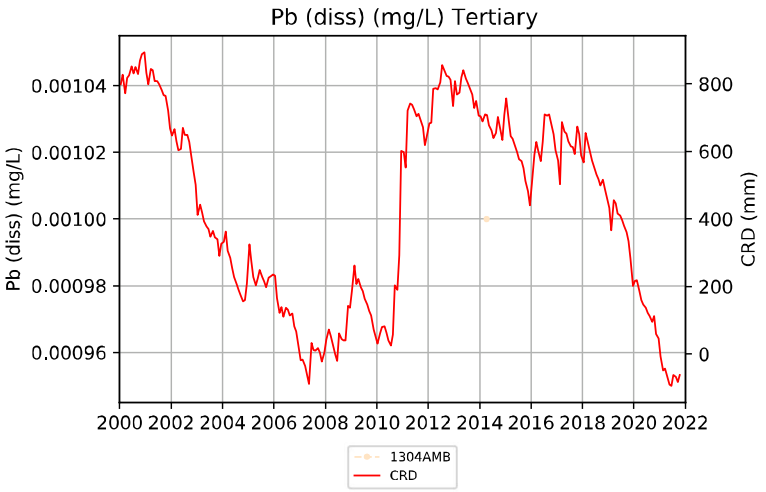

Cr (diss) (mg/L) Tertiary
Cr (diss) (mg/L)
CRD (mm)
1304AMB
CRD

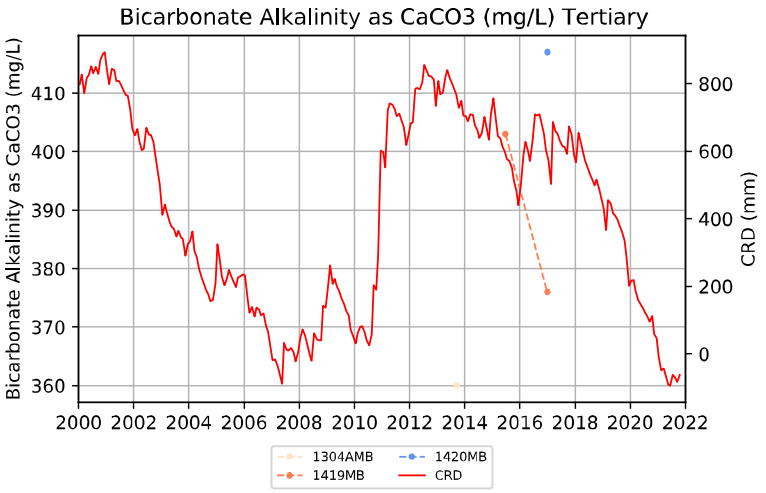

Co (diss) (mg/L) Tertiary
Co (diss) (mg/L)
CRD (mm)
1304AMB
CRD

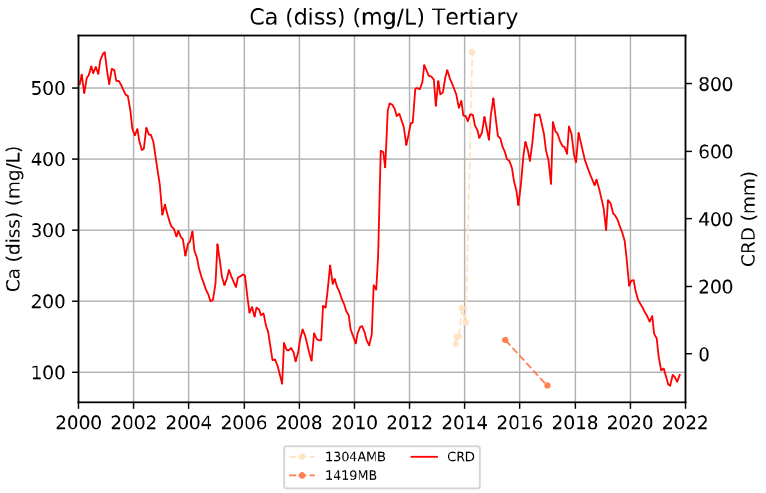

Cu (diss) (mg/L) Tertiary
Cu (diss) (mg/L)
CRD (mm)
1304AMB
CRD

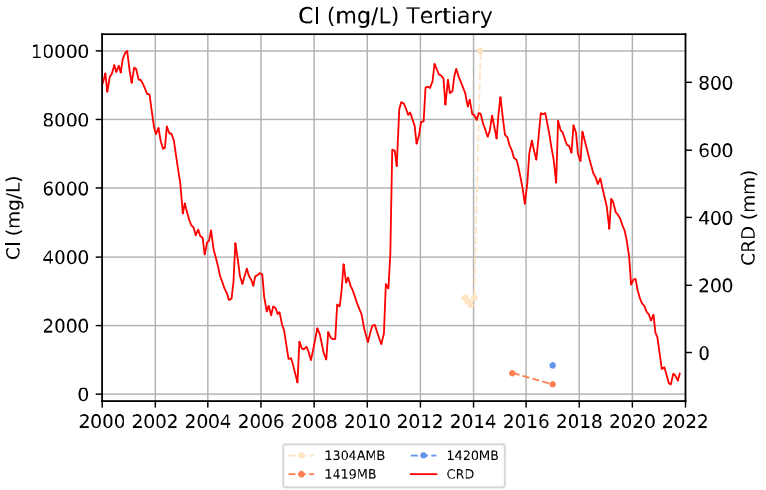

Fe (diss) (mg/L) Tertiary
Fe (diss) (mg/L)
CRD (mm)
1304AMB
1420MB
1419MB
CRD

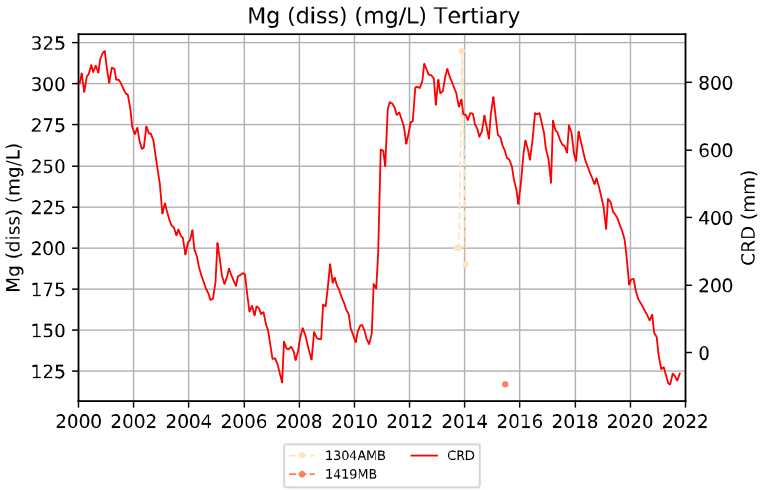

Hg (diss) (mg/L) Tertiary
Hg (diss) (mg/L)
CRD (mm)
1304AMB
1420MB
1419MB
CRD

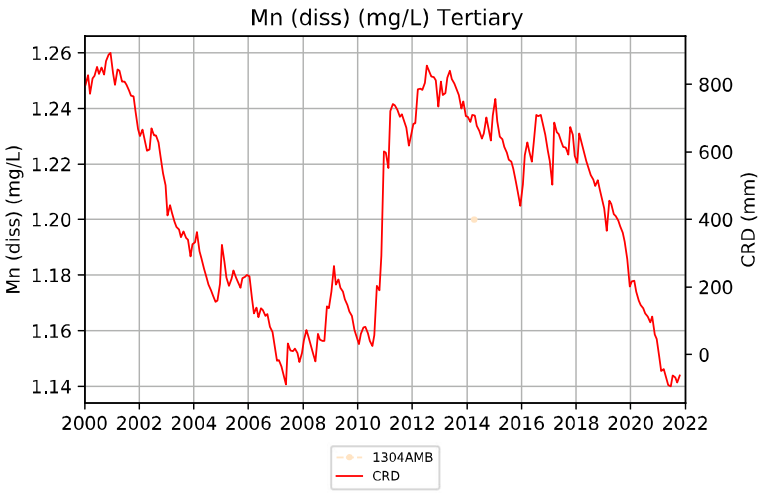

Pb (diss) (mg/L) Tertiary
Pb (diss) (mg/L)
CRD (mm)
1304AMB
CRD

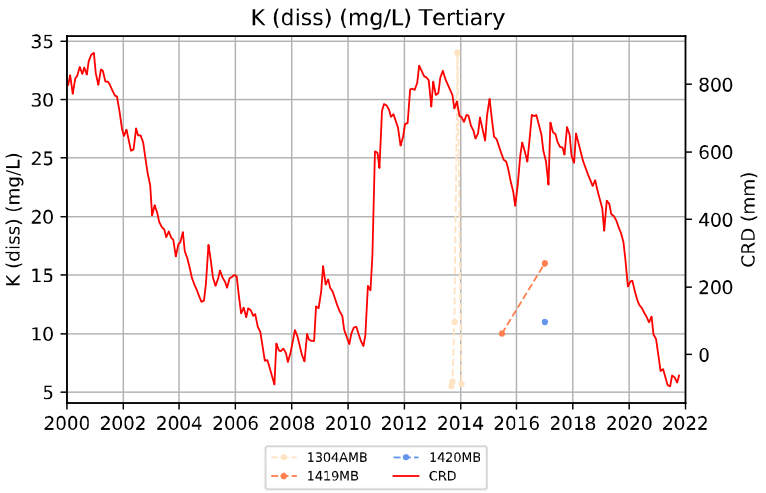

Bicarbonate Alkalinity as CaCO3 (mg/L) Tertiary
Bicarbonate Alkalinity as CaCO3 (mg/L)
CRD (mm)
1304AMB
1420MB
1419MB
CRD

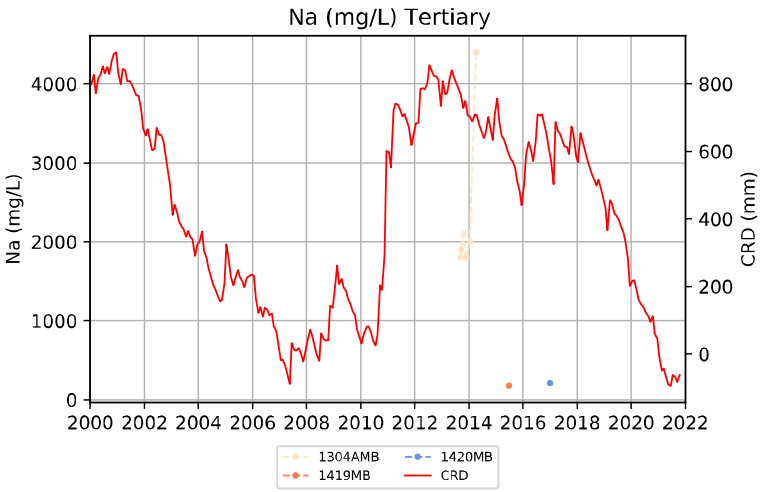

Ca (diss) (mg/L) Tertiary
Ca (diss) (mg/L)
CRD (mm)
1304AMB
CRD
1419MB

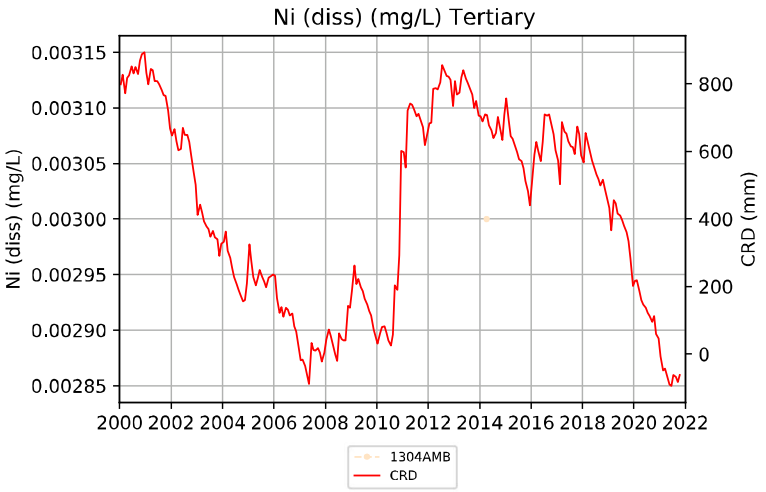

Cl (mg/L) Tertiary
Cl (mg/L)
CRD (mm)
1304AMB
1420MB
1419MB
CRD

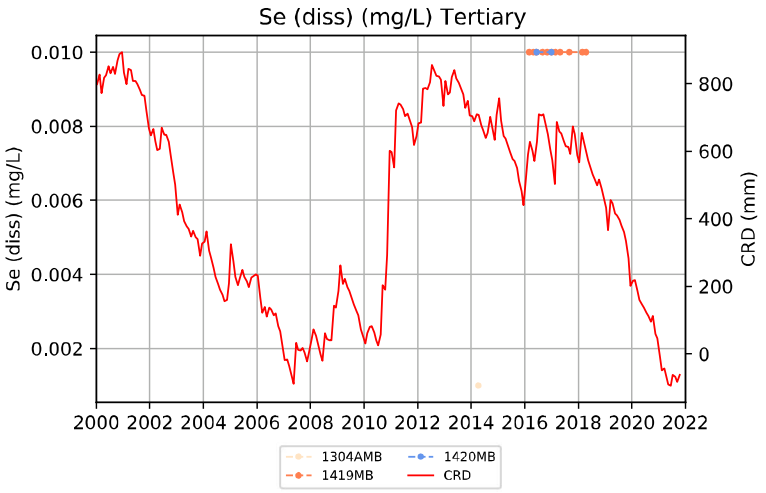

Mg (diss) (mg/L) Tertiary
Mg (diss) (mg/L)
CRD (mm)
1304AMB
CRD
1419MB

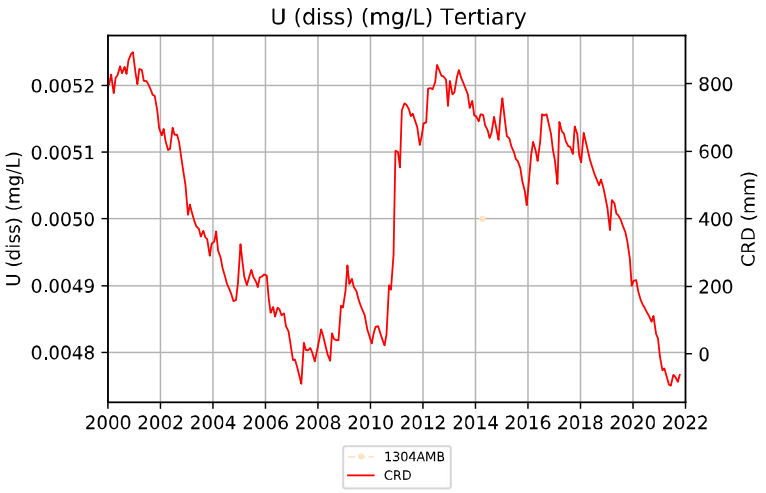

Mn (diss) (mg/L) Tertiary
Mn (diss) (mg/L)
CRD (mm)
1304AMB
CRD

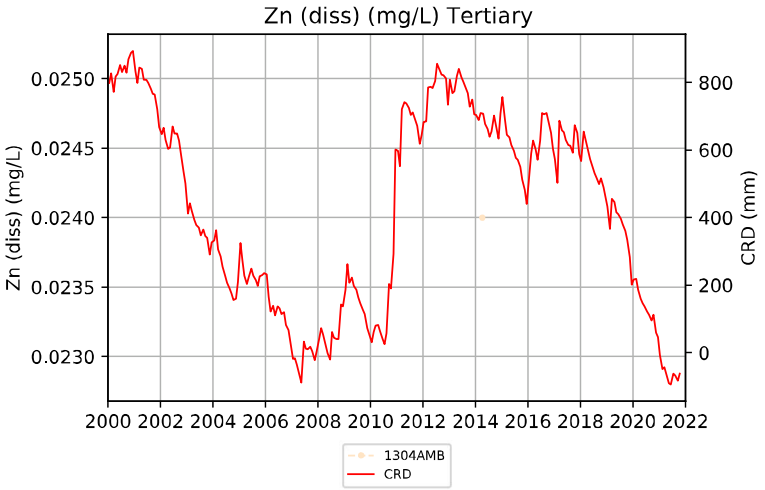

K (diss) (mg/L) Tertiary
K (diss) (mg/L)
CRD (mm)
1304AMB
1420MB
1419MB
CRD

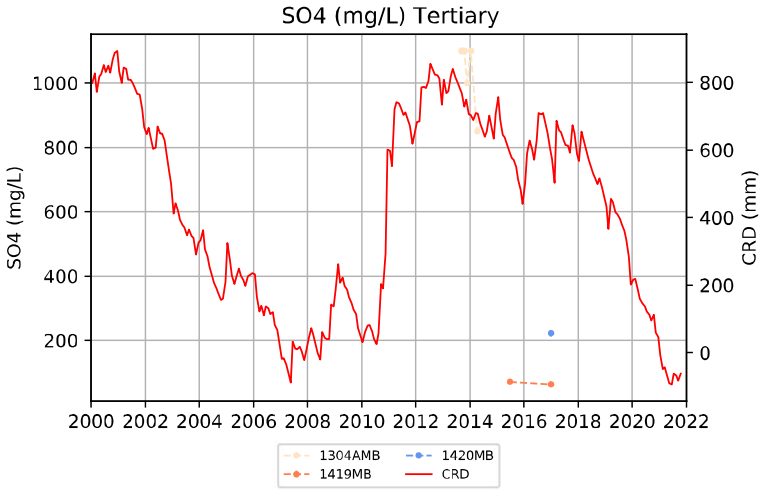

Na (mg/L) Tertiary
Na (mg/L)
CRD (mm)
1304AMB
1420MB
1419MB
CRD

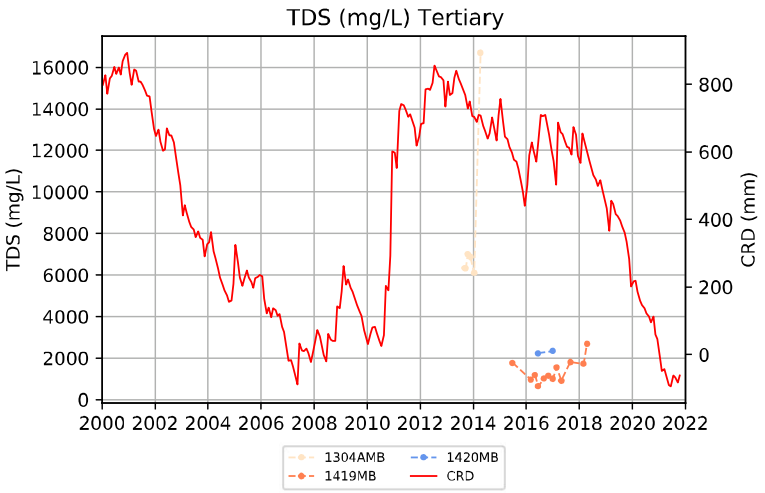

Ni (diss) (mg/L) Tertiary
Ni (diss) (mg/L)
CRD (mm)
1304AMB
CRD

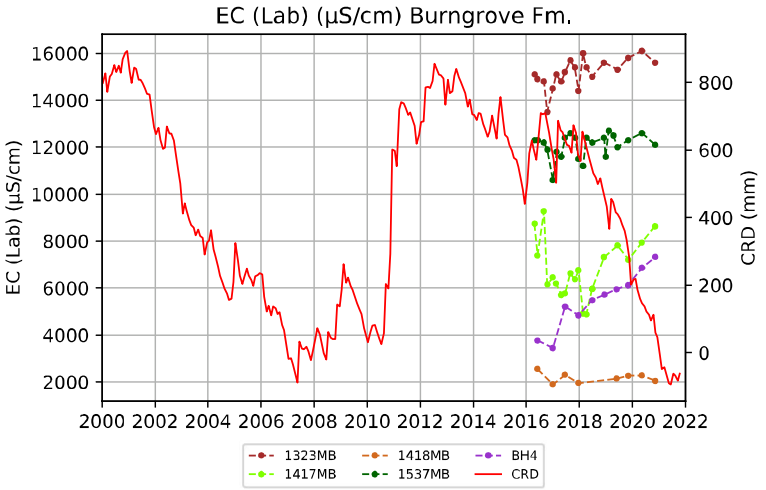

Se (diss) (mg/L) Tertiary
Se (diss) (mg/L)
CRD (mm)
1304AMB
1420MB
1419MB
CRD

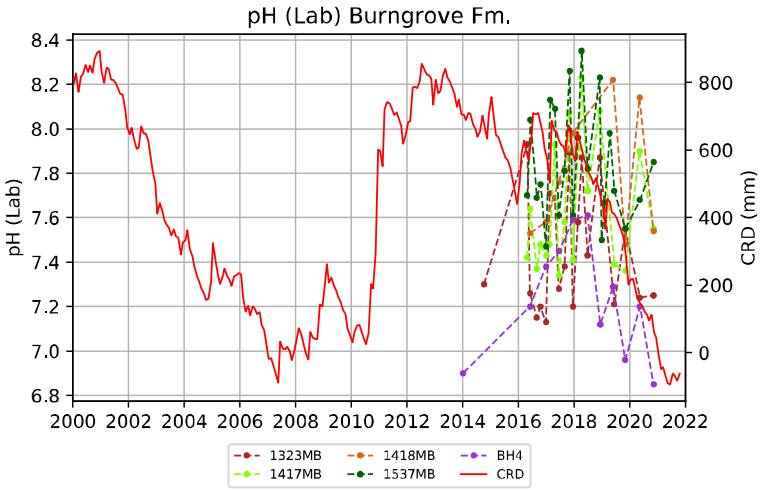

U (diss) (mg/L) Tertiary
U (diss) (mg/L)
CRD (mm)
1304AMB
CRD

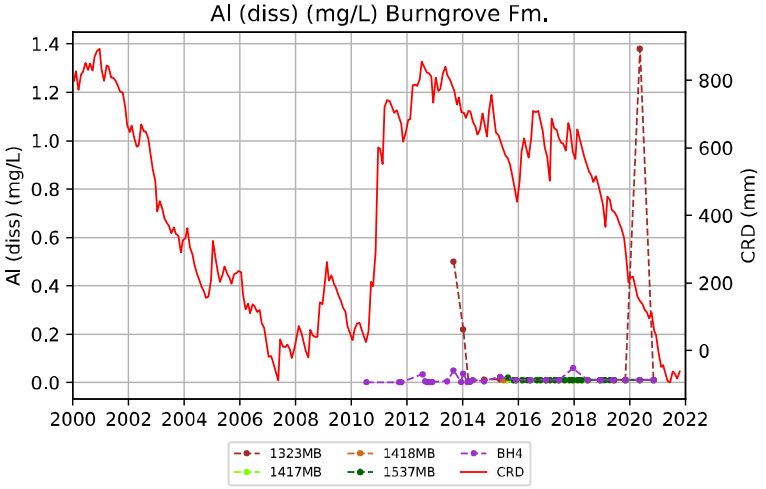

Zn (diss) (mg/L) Tertiary
Zn (diss) (mg/L)
CRD (mm)
0.0250
0.0245
0.0240
0.0235
0.0230
800
600
400
200
0
2000 2002 2004 2006 2008 2010 2012 2014 2016 2018 2020 2022
1304AMB
CRD

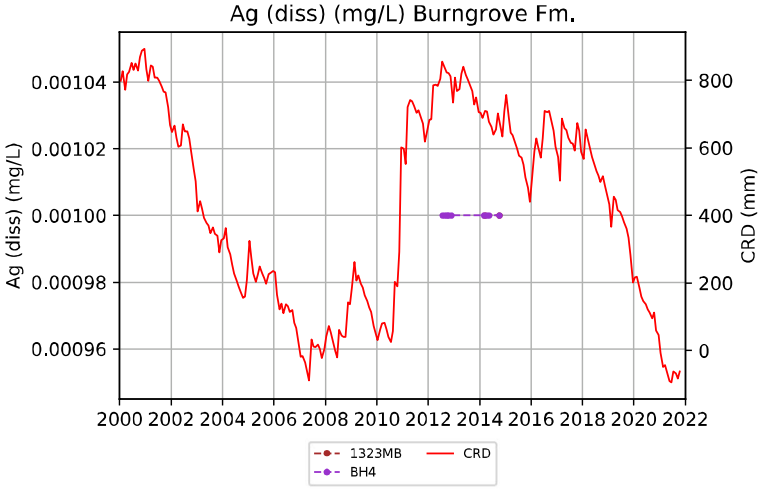

SO4 (mg/L) Tertiary
SO4 (mg/L)
CRD (mm)
1000
800
600
400
200
800
600
400
200
0
2000 2002 2004 2006 2008 2010 2012 2014 2016 2018 2020 2022
1304AMB
1420MB
1419MB
CRD

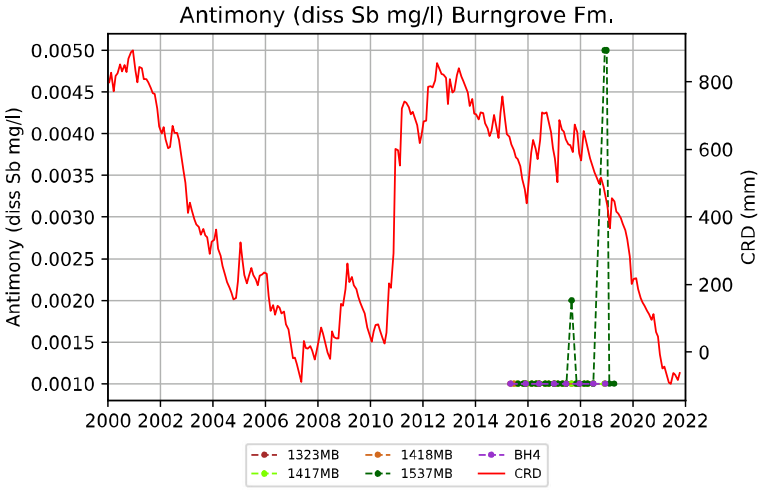

TDS (mg/L) Tertiary
TDS (mg/L)
CRD (mm)
16000
14000
12000
10000
8000
6000
4000
2000
0
800
600
400
200
0
2000 2002 2004 2006 2008 2010 2012 2014 2016 2018 2020 2022
1304AMB
1420MB
1419MB
CRD

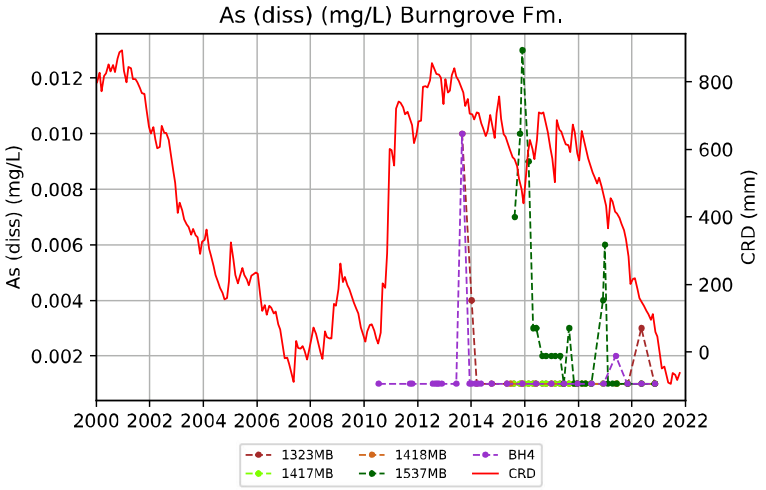

EC (Lab) (µS/cm) Burngrove Fm.
EC (Lab) (µS/cm)
CRD (mm)
1323MB
1418MB
BH4
1417MB
1537MB
CRD

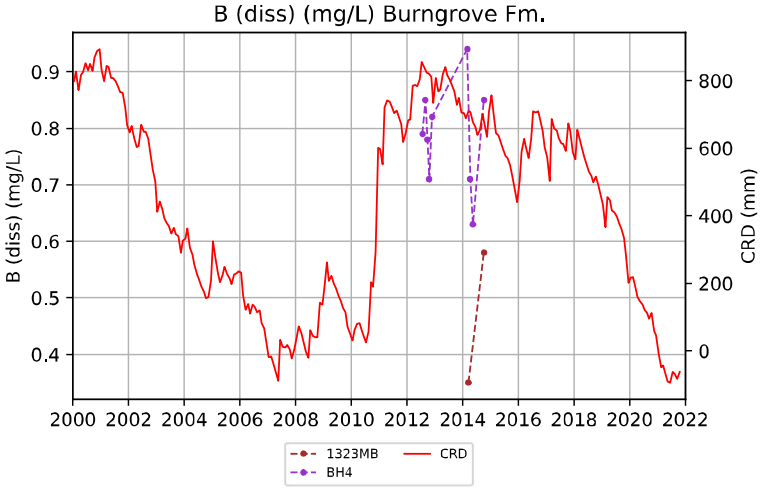

pH (Lab) Burngrove Fm.
pH (Lab)
CRD (mm)
1323MB
1418MB
BH4
1417MB
1537MB
CRD

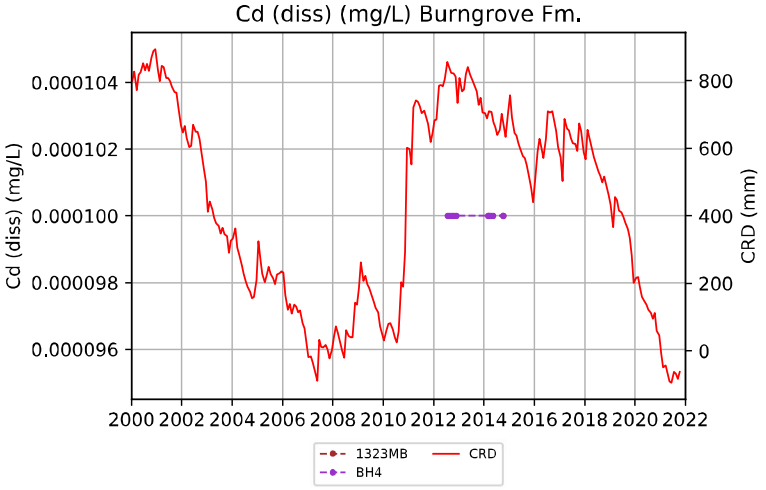

Al (diss) (mg/L) Burngrove Fm.
Al (diss) (mg/L)
CRD (mm)
1323MB
1418MB
BH4
1417MB
1537MB
CRD

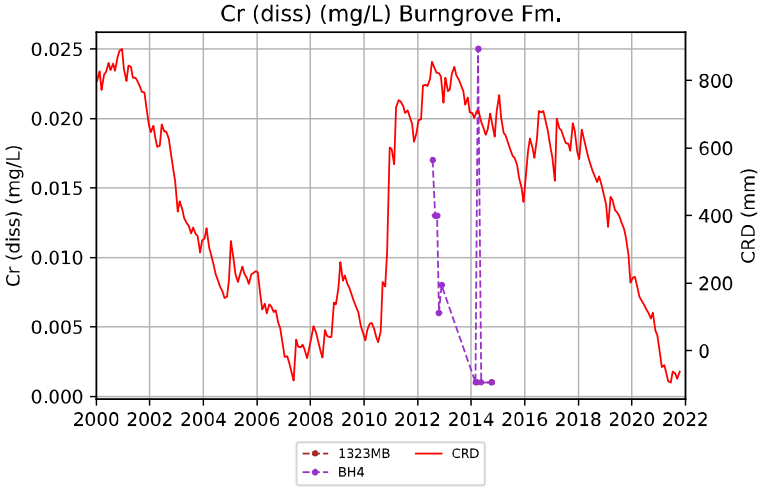

Ag (diss) (mg/L) Burngrove Fm.
Ag (diss) (mg/L)
CRD (mm)
1323MB
CRD
BH4

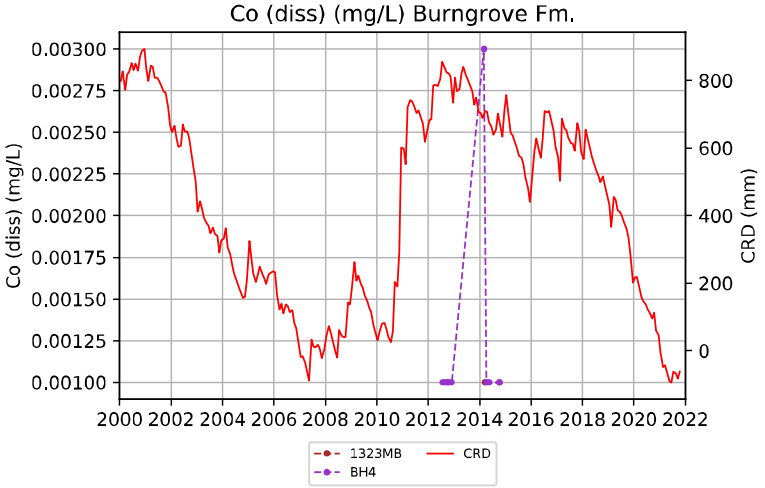

Antimony (diss Sb mg/l) Burngrove Fm.
Antimony (diss Sb mg/l)
CRD (mm)
1323MB
1418MB
BH4
1417MB
1537MB
CRD

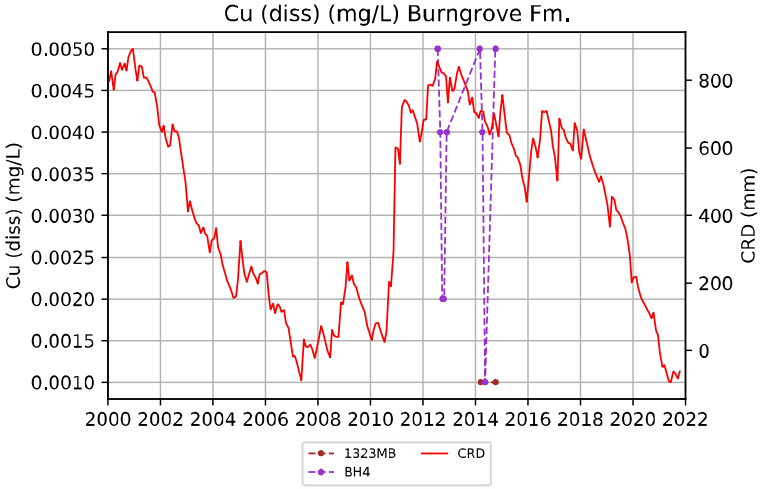

As (diss) (mg/L) Burngrove Fm.
As (diss) (mg/L)
CRD (mm)
1323MB
1418MB
BH4
1417MB
1537MB
CRD

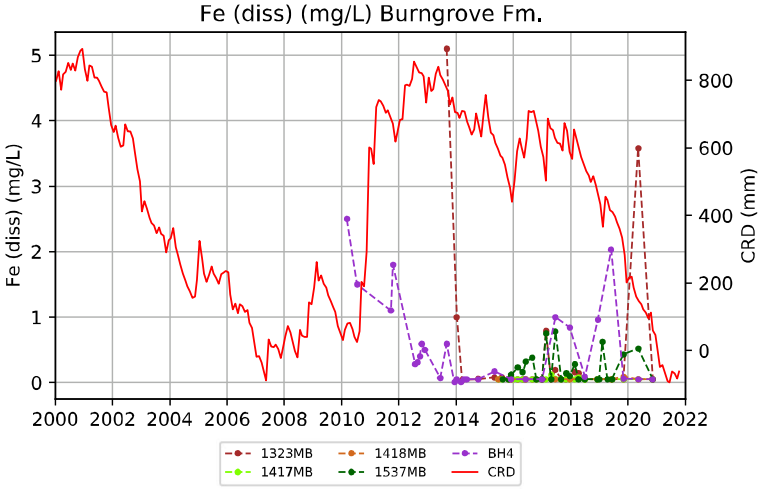

B (diss) (mg/L) Burngrove Fm.
B (diss) (mg/L)
CRD (mm)
1323MB
CRD
BH4

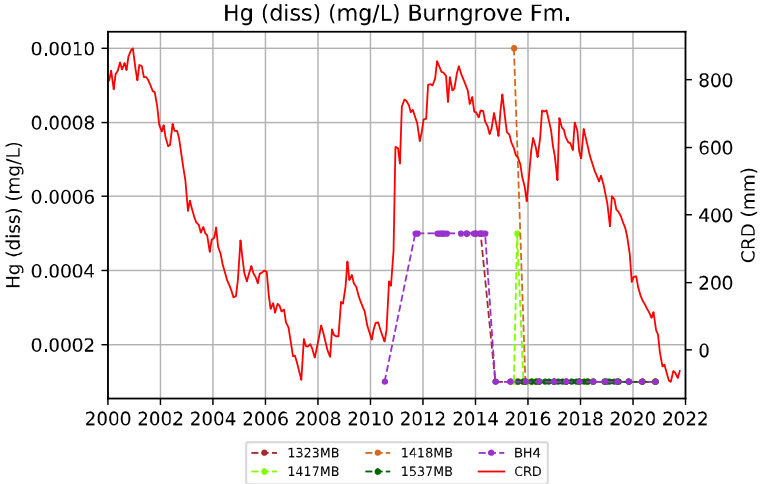

Cd (diss) (mg/L) Burngrove Fm.
Cd (diss) (mg/L)
CRD (mm)
1323MB
CRD
BH4

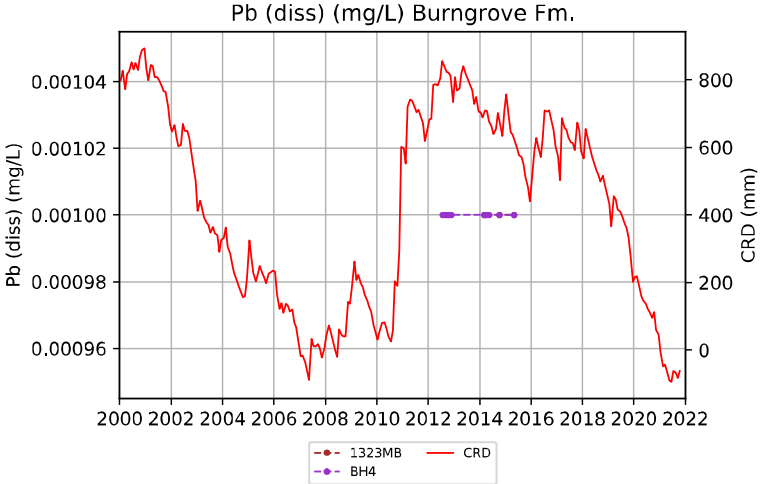

Cr (diss) (mg/L) Burngrove Fm.
Cr (diss) (mg/L)
CRD (mm)
1323MB
BH4
CRD

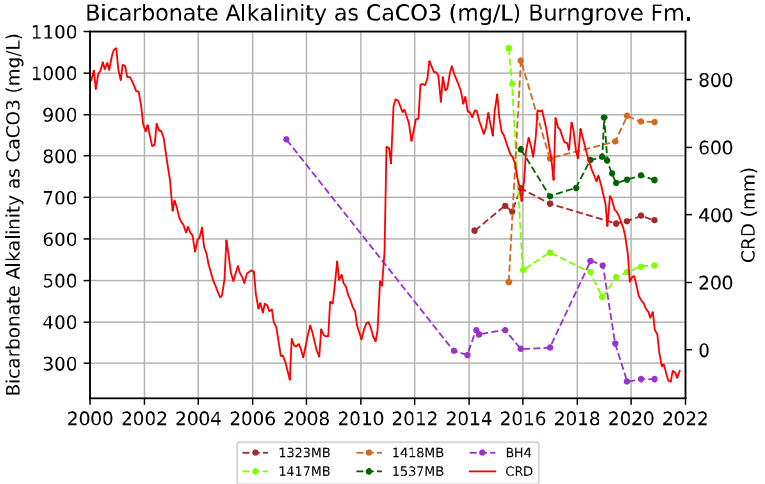

Co (diss) (mg/L) Burngrove Fm.
Co (diss) (mg/L)
CRD (mm)
1323MB
BH4
CRD

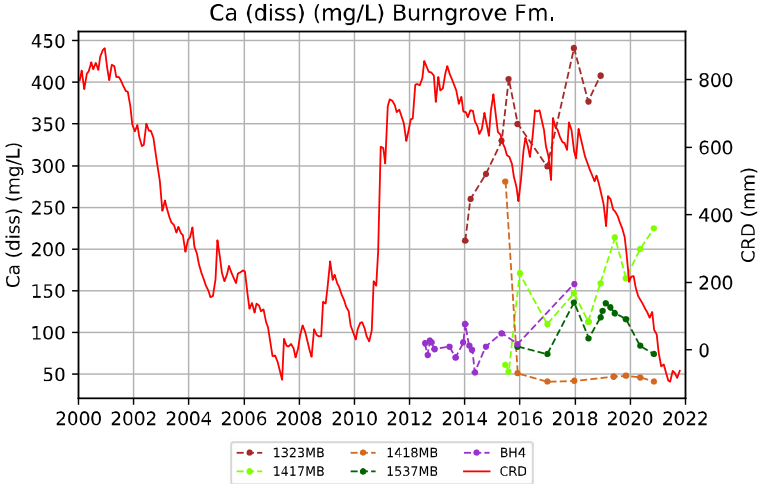

Cu (diss) (mg/L) Burngrove Fm.
Cu (diss) (mg/L)
CRD (mm)
1323MB
BH4
CRD

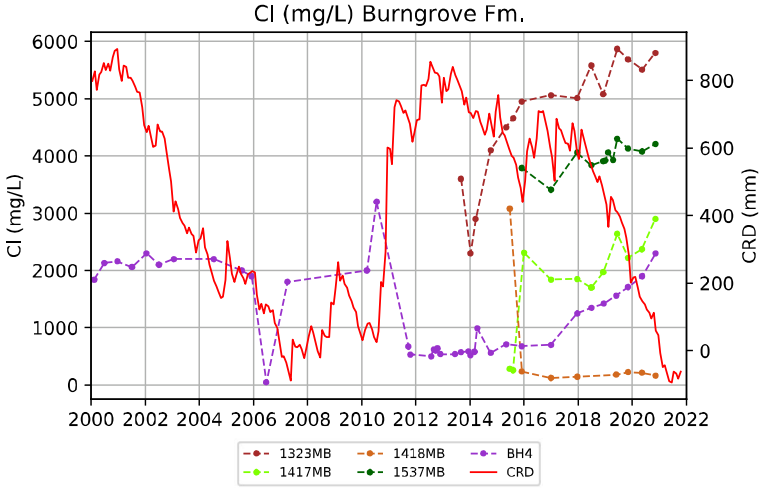

Fe (diss) (mg/L) Burngrove Fm.
Fe (diss) (mg/L)
CRD (mm)
1323MB
1418MB
BH4
1417MB
1537MB
CRD

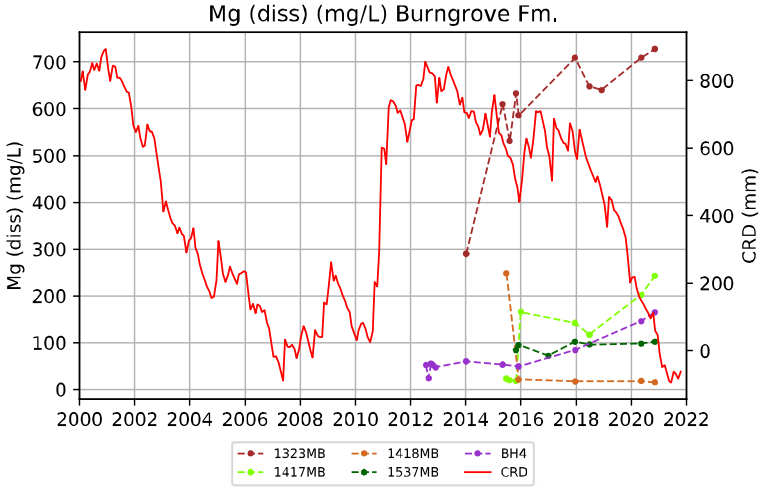

Hg (diss) (mg/L) Burngrove Fm.
Hg (diss) (mg/L)
CRD (mm)
1323MB
1418MB
BH4
1417MB
1537MB
CRD

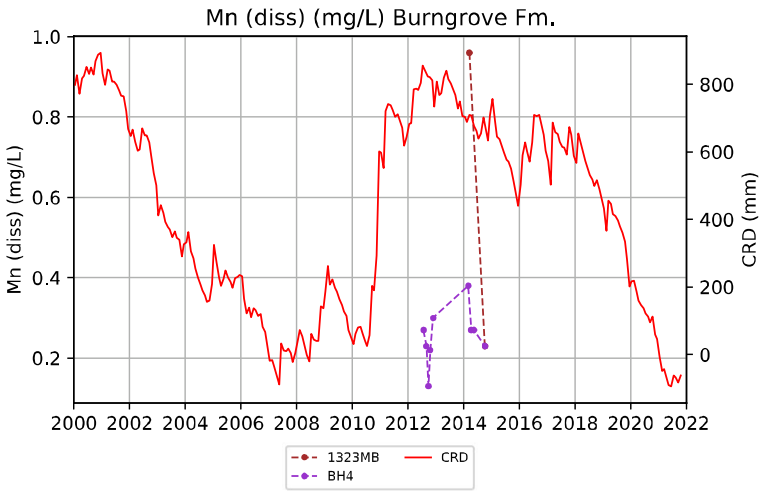

Pb (diss) (mg/L) Burngrove Fm.
Pb (diss) (mg/L)
CRD (mm)
1323MB
BH4
CRD

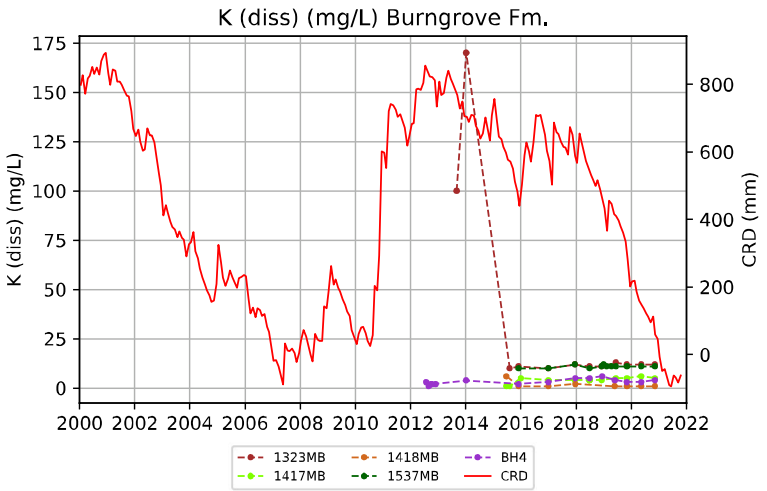

Bicarbonate Alkalinity as CaCO3 (mg/L) Burngrove Fm.
Bicarbonate Alkalinity as CaCO3 (mg/L)
CRD (mm)
1323MB
1418MB
BH4
1417MB
1537MB
CRD

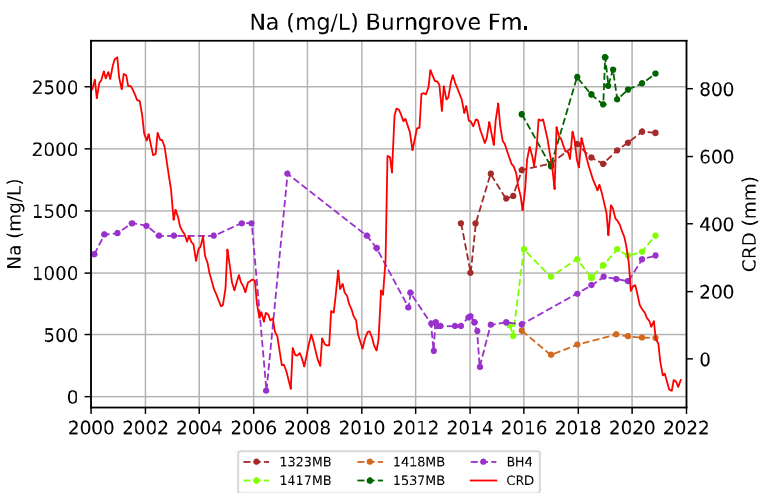

Ca (diss) (mg/L) Burngrove Fm.
Ca (diss) (mg/L)
CRD (mm)
1323MB
1418MB
BH4
1417MB
1537MB
CRD

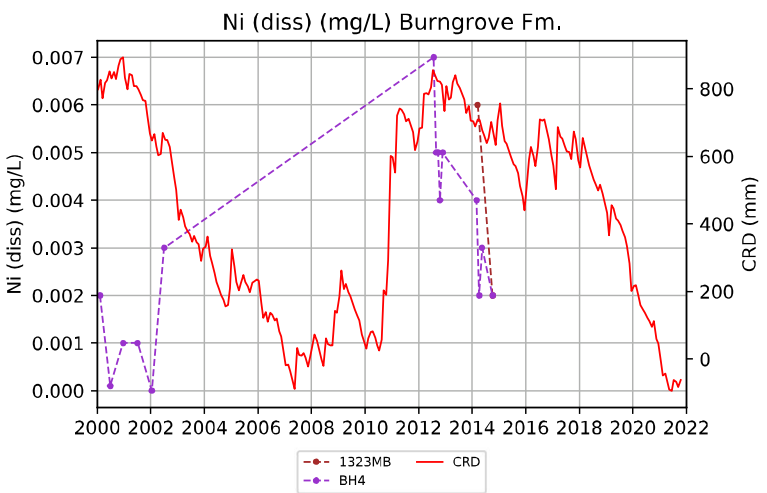

Cl (mg/L) Burngrove Fm.
Cl (mg/L)
CRD (mm)
1323MB
1418MB
BH4
1417MB
1537MB
CRD

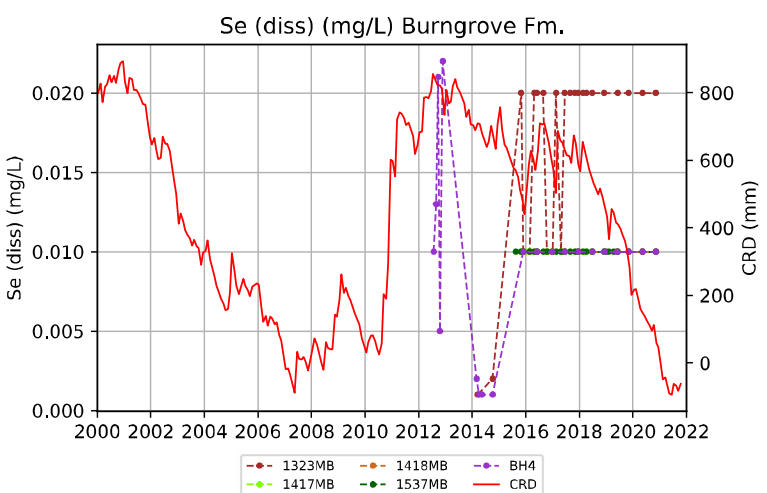

Mg (diss) (mg/L) Burngrove Fm.
Mg (diss) (mg/L)
CRD (mm)
1323MB
1418MB
BH4
1417MB
1537MB
CRD

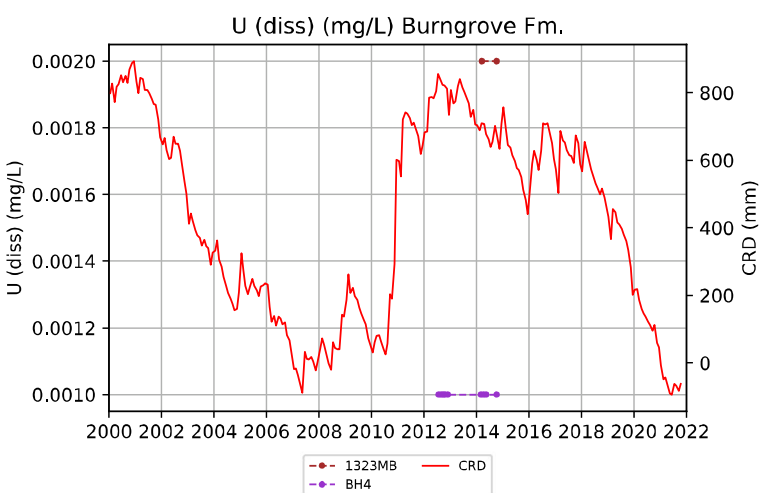

Mn (diss) (mg/L) Burngrove Fm.
Mn (diss) (mg/L)
CRD (mm)
1323MB
CRD
BH4

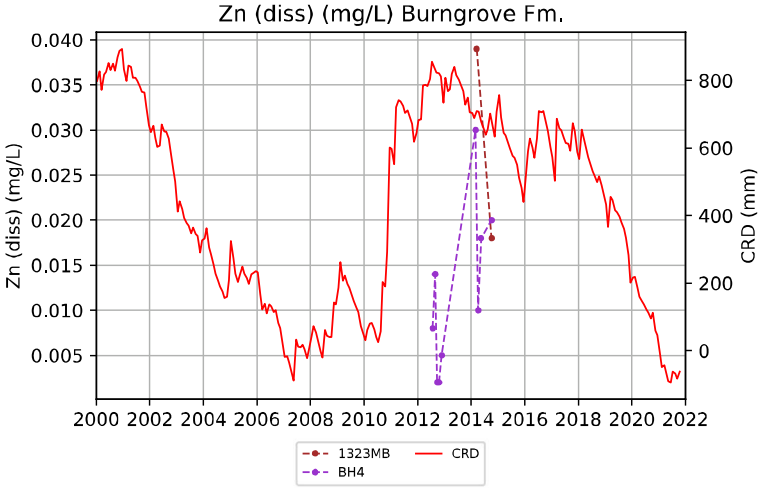

K (diss) (mg/L) Burngrove Fm.
K (diss) (mg/L)
CRD (mm)
1323MB
1418MB
BH4
1417MB
1537MB
CRD

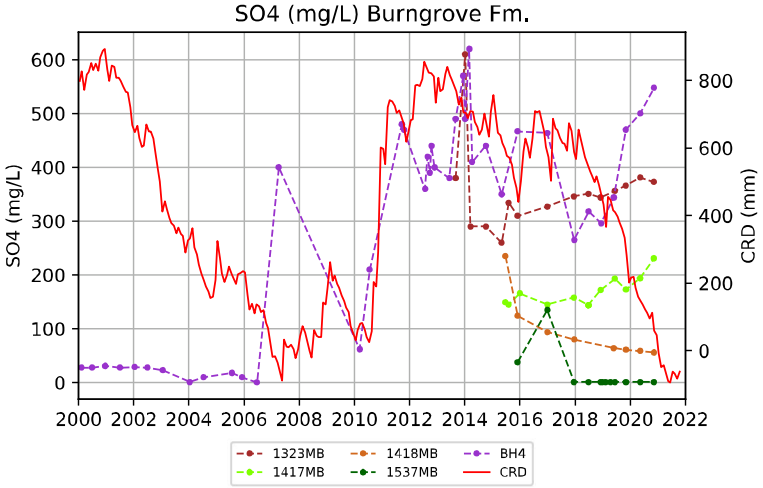

Na (mg/L) Burngrove Fm.
Na (mg/L)
CRD (mm)
1323MB
1418MB
BH4
1417MB
1537MB
CRD

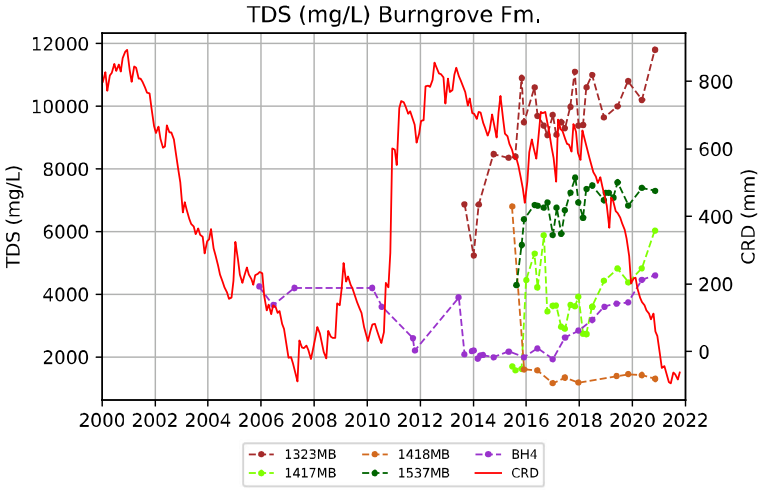

Ni (diss) (mg/L) Burngrove Fm.
Ni (diss) (mg/L)
CRD (mm)
1323MB
CRD
BH4


Se (diss) (mg/L) Burngrove Fm.
Se (diss) (mg/L)
CRD (mm)
1323MB
1418MB
BH4
1417MB
1537MB
CRD


U (diss) (mg/L) Burngrove Fm.
U (diss) (mg/L)
CRD (mm)
1323MB
CRD
BH4


Zn (diss) (mg/L) Burngrove Fm.
Zn (diss) (mg/L)
CRD (mm)
1323MB
CRD
BH4


SO4 (mg/L) Burngrove Fm.
SO4 (mg/L)
CRD (mm)
1323MB
1418MB
BH4
1417MB
1537MB
CRD


TDS (mg/L) Burngrove Fm.
TDS (mg/L)
CRD (mm)
1323MB
1418MB
BH4
1417MB
1537MB
CRD

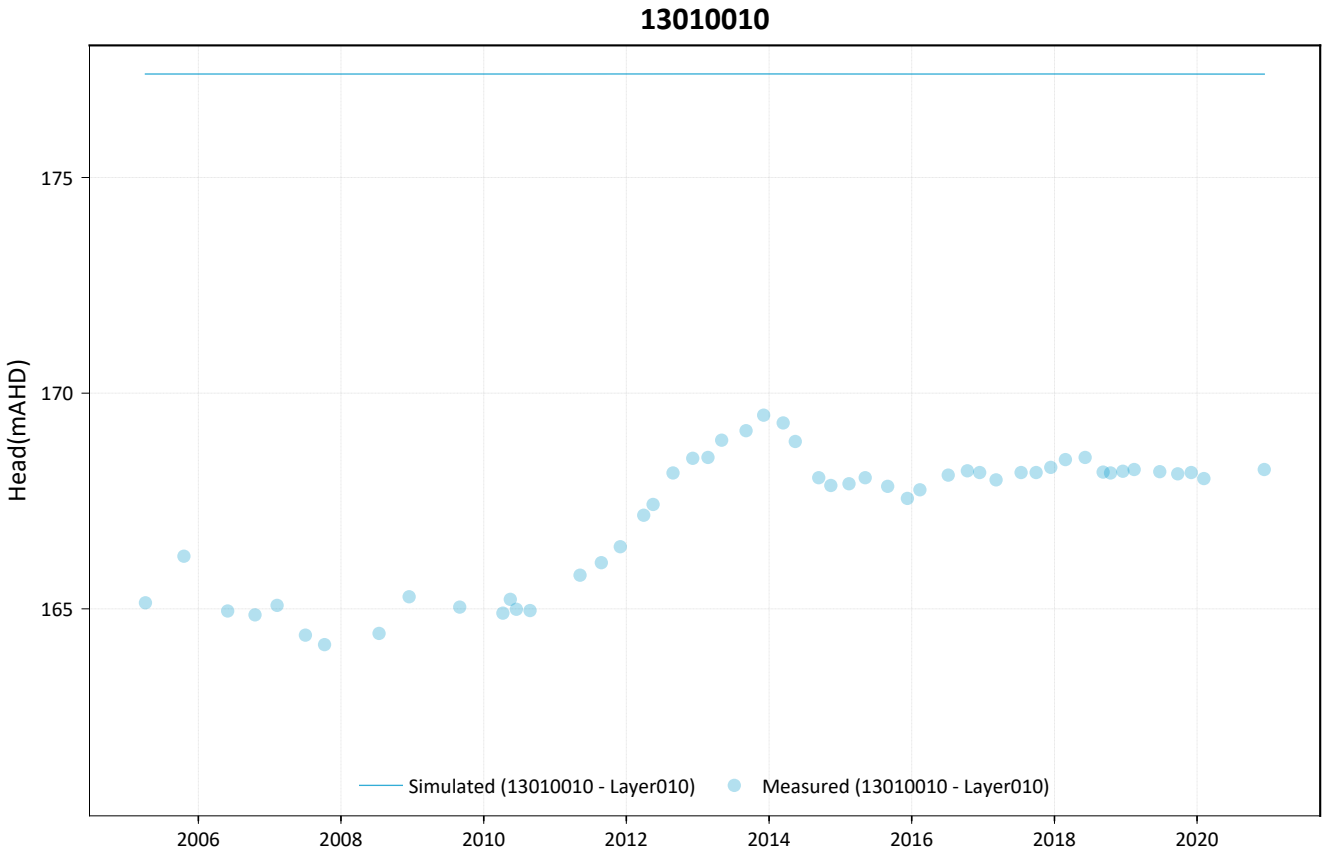
APPENDIX B
Calibration Average Residuals

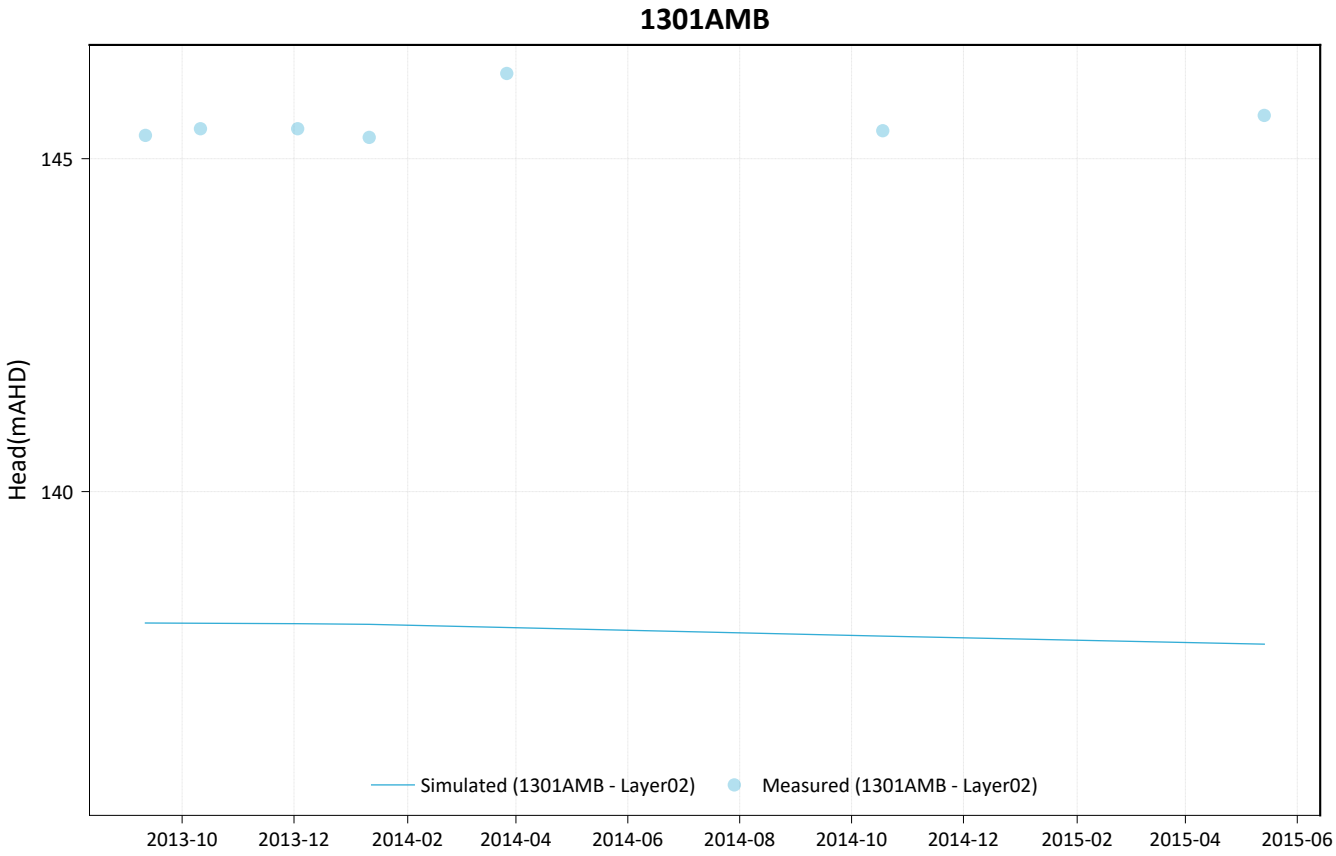
Bore ID	Model Layer	Easting (GDA94 Z55)	Northing (GDA94 Z55)	Average Residual	Min	Max
158166	1	697110	7429801	-11.83	-11.83	-11.83
158167	1	697216	7428270	-6.75	-6.75	-6.75
158168	1	694575	7426440	-0.10	-0.10	-0.10
158169	1	696360	7427541	-4.67	-4.67	-4.67
158171	1	697111	7429825	-16.39	-16.39	-16.39
158178	1	696548	7425796	-2.82	-2.82	-2.82
158200	1	695844	7426992	-11.81	-22.02	-1.60
158201	1	695844	7426991	-7.57	-13.22	-1.92
158202	1	695173	7427519	-0.44	-0.44	-0.44
158203	1	695553	7428644	-5.08	-5.08	-5.08
158204	2	695553	7428644	-13.67	-22.73	-4.60
158207	2	694898	7429684	-20.44	-24.50	-16.38
158208	1	695619	7430189	-21.91	-26.21	-17.61
158209	1	695619	7430189	-13.23	-13.23	-13.23
158210	2	694883	7431081	-20.56	-20.56	-20.56
158211	1	694883	7431081	-9.93	-9.93	-9.93
165446	19	695184	7427524	3.56	3.56	3.56
13010010	10	680703	7390562	-11.05	-13.97	-8.84
1301aMB	2	691308	7398335	6.26	5.69	7.03
1301bMB	2	691308	7398335	6.33	5.61	7.14
1302MB	2	691118	7397611	9.27	8.89	9.55
1303MB	2	691086	7396966	4.49	4.23	4.74
1304aMB	2	691481	7398090	4.69	4.20	5.10
1304bMB	2	691481	7398084	3.71	2.42	5.25
1307MB	1	692378	7403433	2.74	1.91	4.07
1308MB	1	692387	7403452	2.64	1.62	4.92
1309MB	1	689082	7423302	-2.76	-4.86	-0.86
1312MB	1	689148	7423118	-1.51	-2.68	-0.05
1321MB	1	687647	7401486	4.38	4.38	4.38
1322MB	1	688976	7402204	5.26	3.10	6.27
1323MB	2	687417	7403078	-1.66	-2.47	-1.23
1324MB	1	687673	7405113	-10.08	-10.08	-10.08
1410MB	1	688842	7423144	-1.87	-3.06	-0.85
1411MB	1	688974	7423011	-1.14	-2.94	-0.17
1417MB	1	688376	7400592	2.86	1.34	5.12

Bore ID	Model Layer	Easting (GDA94 Z55)	Northing (GDA94 Z55)	Average Residual	Min	Max
1418MB	1	688428	7400647	4.28	2.83	5.74
1419MB	1	693083	7418830	11.59	9.22	12.44
1420MB	1	693004	7418881	3.15	-5.14	11.44
1425MB	1	691229	7417747	10.87	10.65	11.16
1426MB	1	691085	7419864	0.59	-0.95	1.88
1428MB	1	691266	7418518	-3.81	-3.81	-3.81
1529MB	10	691161	7417212	-4.86	-5.64	-4.24
1531MB	1	691987	7426518	-0.10	-1.51	0.48
1533MB	1	689529	7421689	-5.11	-5.12	-5.11
1534MB	10	689540	7421687	-1.18	-2.93	1.03
1536MB	6	690116	7404141	9.81	8.03	14.50
1537MB	10	687589	7404885	-9.19	-10.77	-6.05
1538MB	10	690217	7405768	-0.96	-1.62	-0.01
1539MB	10	690523	7405931	2.12	1.52	3.14
1642MB	1	688631	7400213	2.76	2.45	3.68
1743MB	1	692314	7399333	-3.49	-21.35	7.70
1847MB	6	691246	7419276	2.41	1.22	3.95
1848MB	6	691184	7419553	-2.60	-3.54	-1.59
190160_A	15	699601	7416892	-20.80	-20.80	-20.80
190161_A	19	697507	7420034	-11.97	-11.97	-11.97
2060MB	1	691488	7420977	0.69	0.33	1.05
2061MB	1	692800	7419144	0.84	0.61	1.08
2062MB	1	692922	7425213	15.14	13.68	18.06
BH1	8	689979	7399250	7.84	5.74	11.39
BH3	8	688847	7404539	0.47	-0.01	1.46
BH4	10	688261	7401147	6.24	2.87	8.65
BH5	10	688269	7399885	-12.18	-19.66	-9.05
BH6	3	692902	7403743	1.67	1.20	2.43
BH8	3	692678	7403357	2.45	-0.04	4.26
BH8A	1	692678	7403356	2.24	1.05	3.74

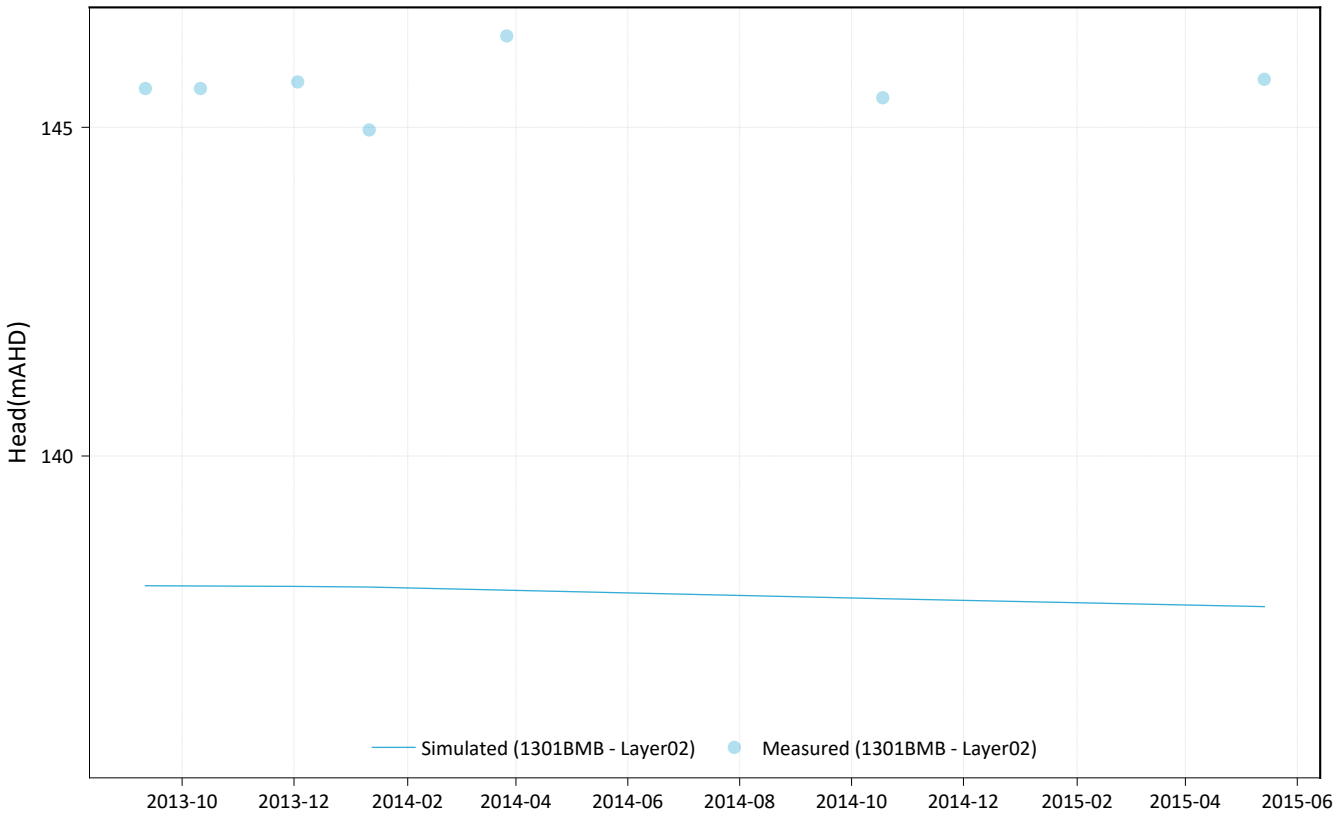
APPENDIX C

Calibration Hydrographs

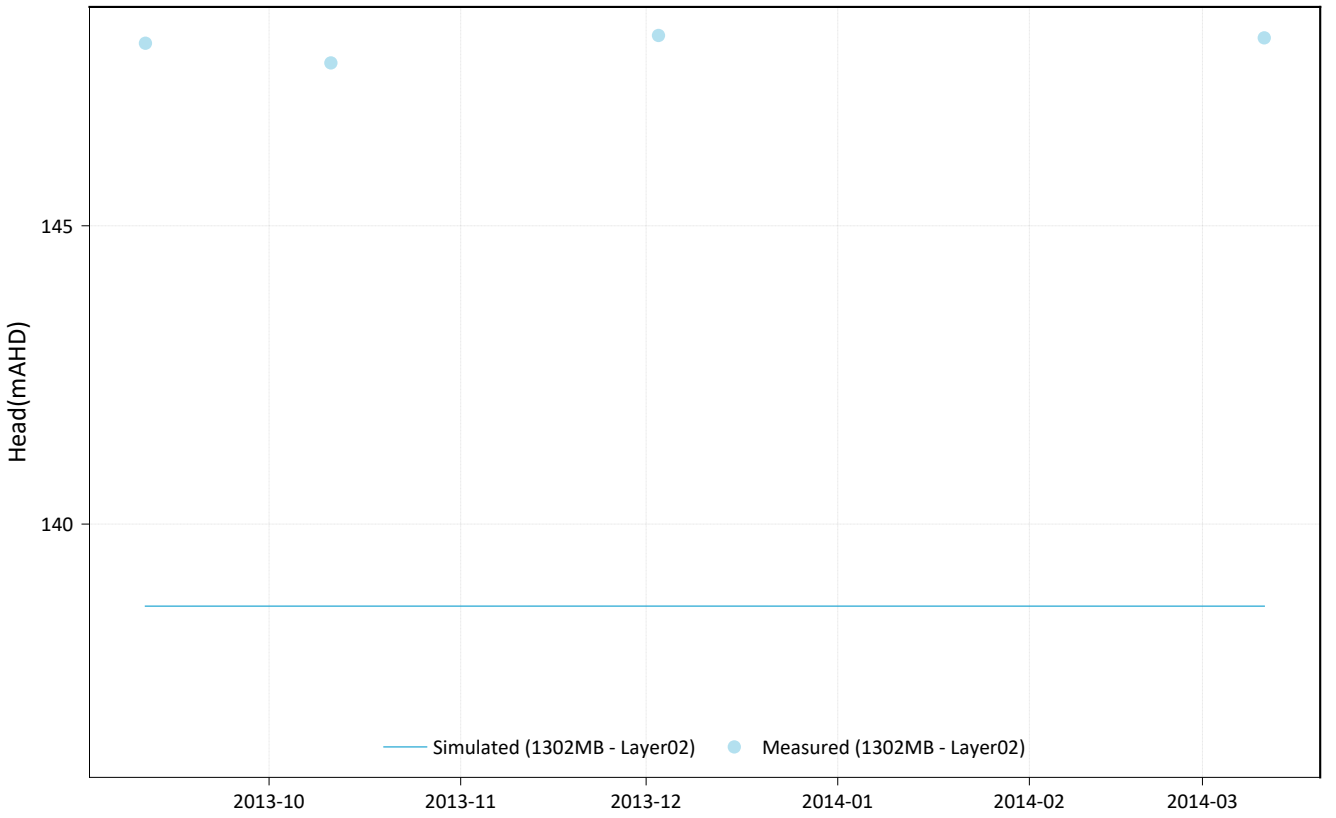

13010010
Head(mAHD)
175
170
165
2006
2008
2010
2012
2014
2016
2018
2020
Simulated (13010010 - Layer010)
Measured (13010010 - Layer010)


1301AMB
Head(mAHD)
145
140
2013-10
2013-12
2014-02
2014-04
2014-06
2014-08
2014-10
2014-12
2015-02
2015-04
2015-06
Simulated (1301AMB - Layer02)
Measured (1301AMB - Layer02)

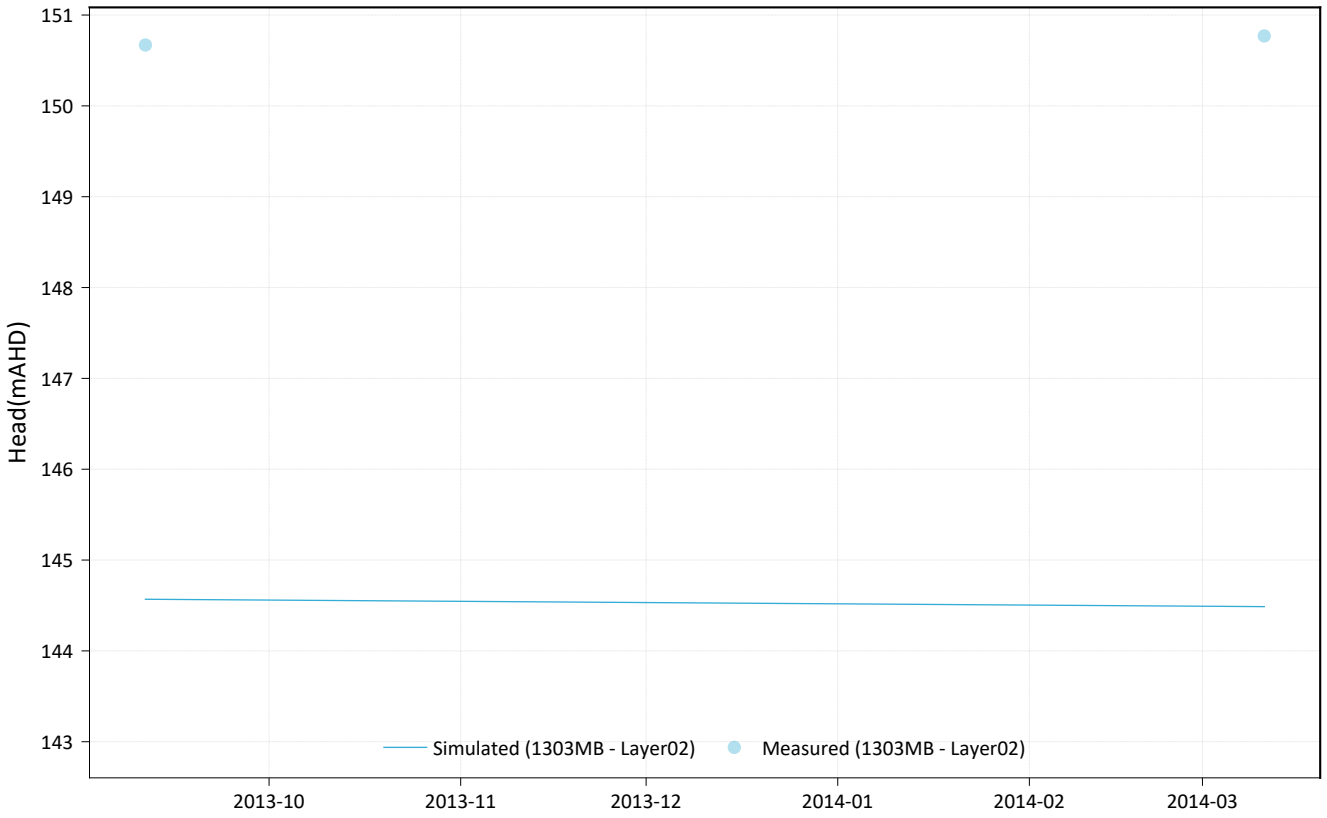
1301BMB



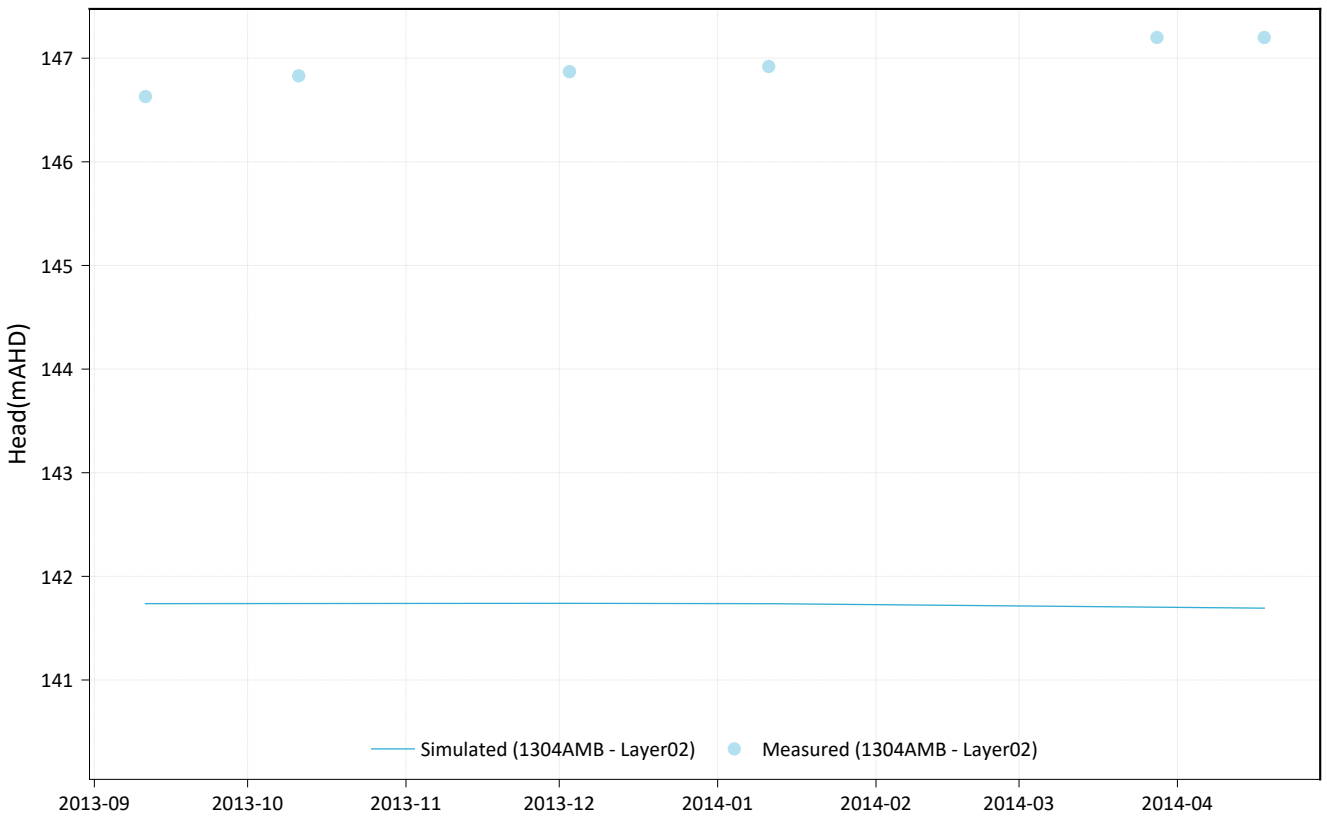
1302MB

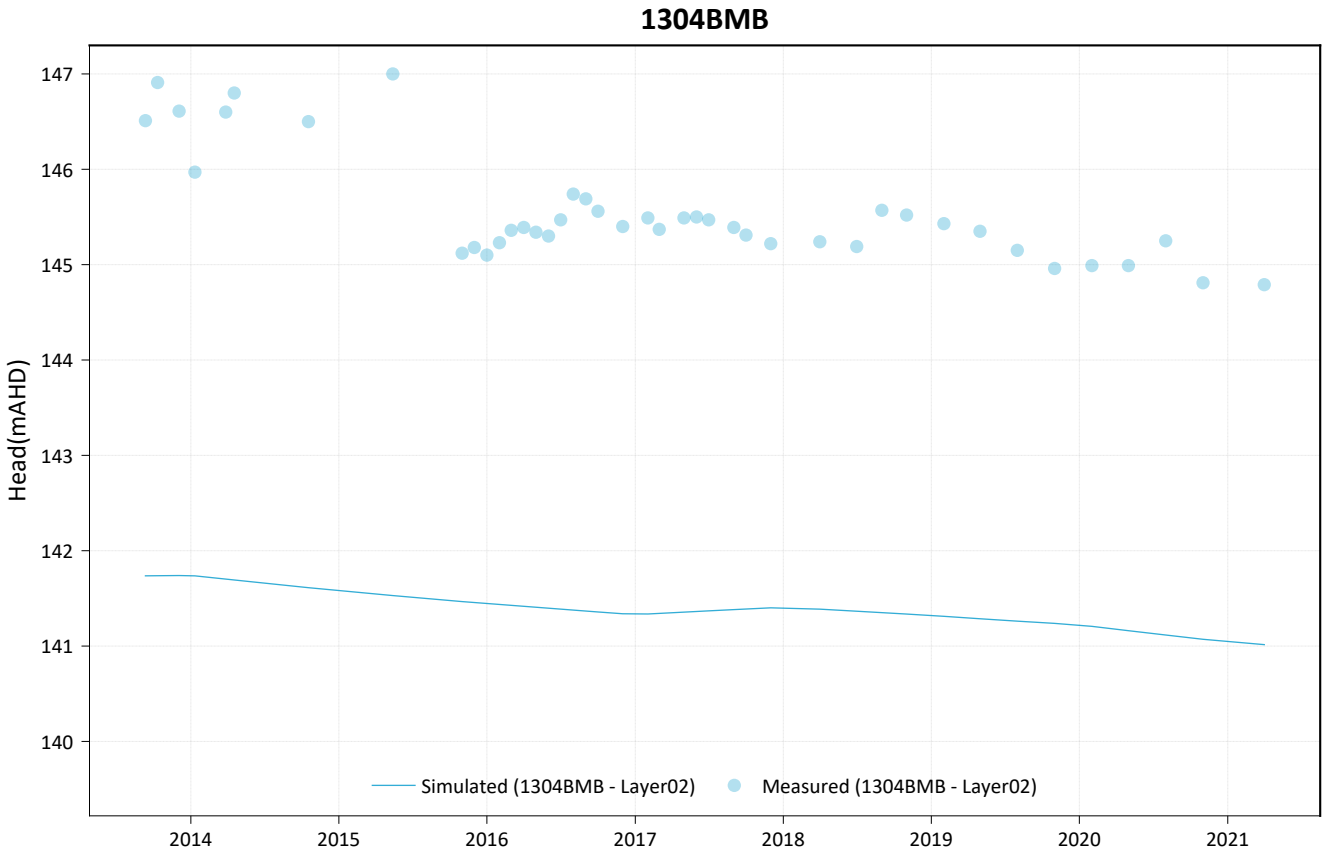


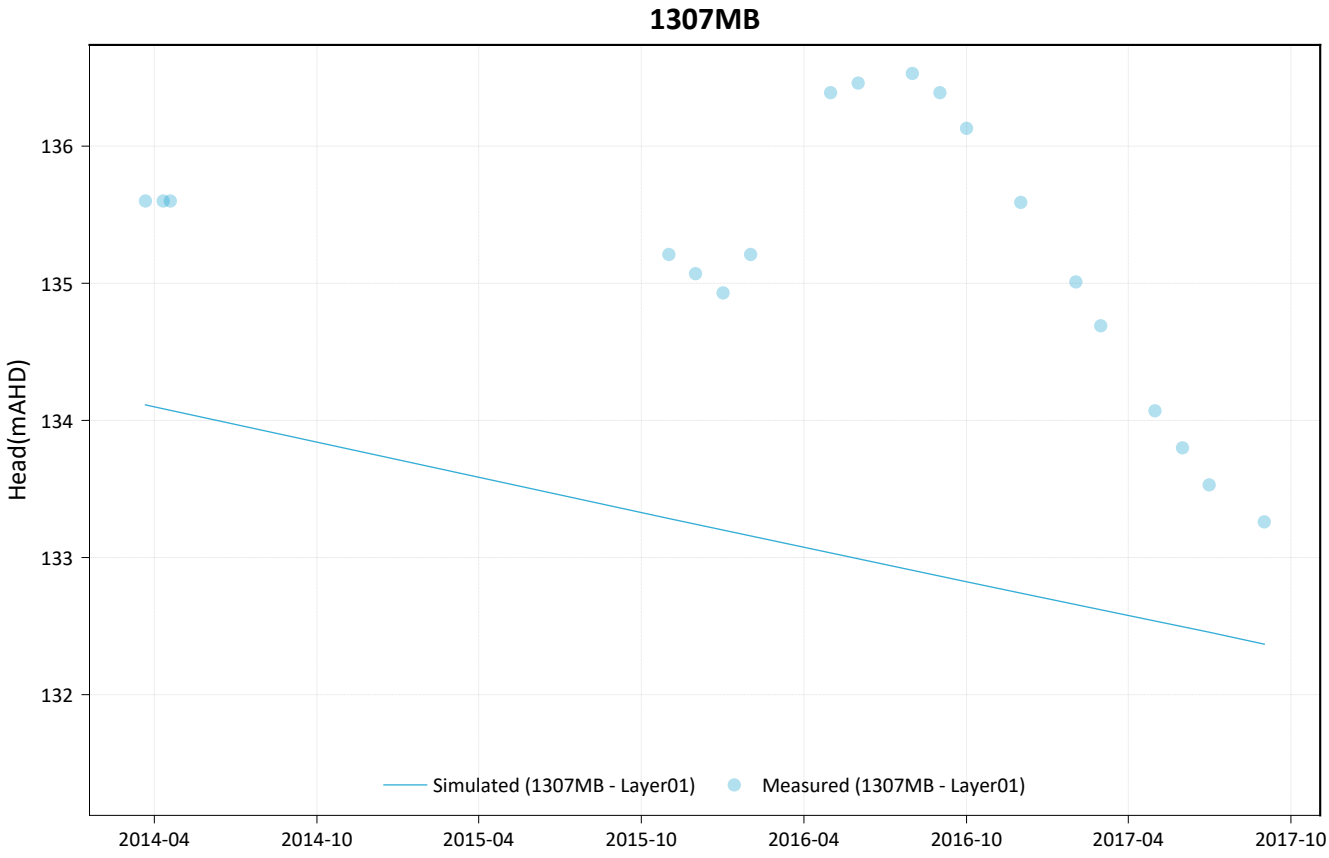
1303MB



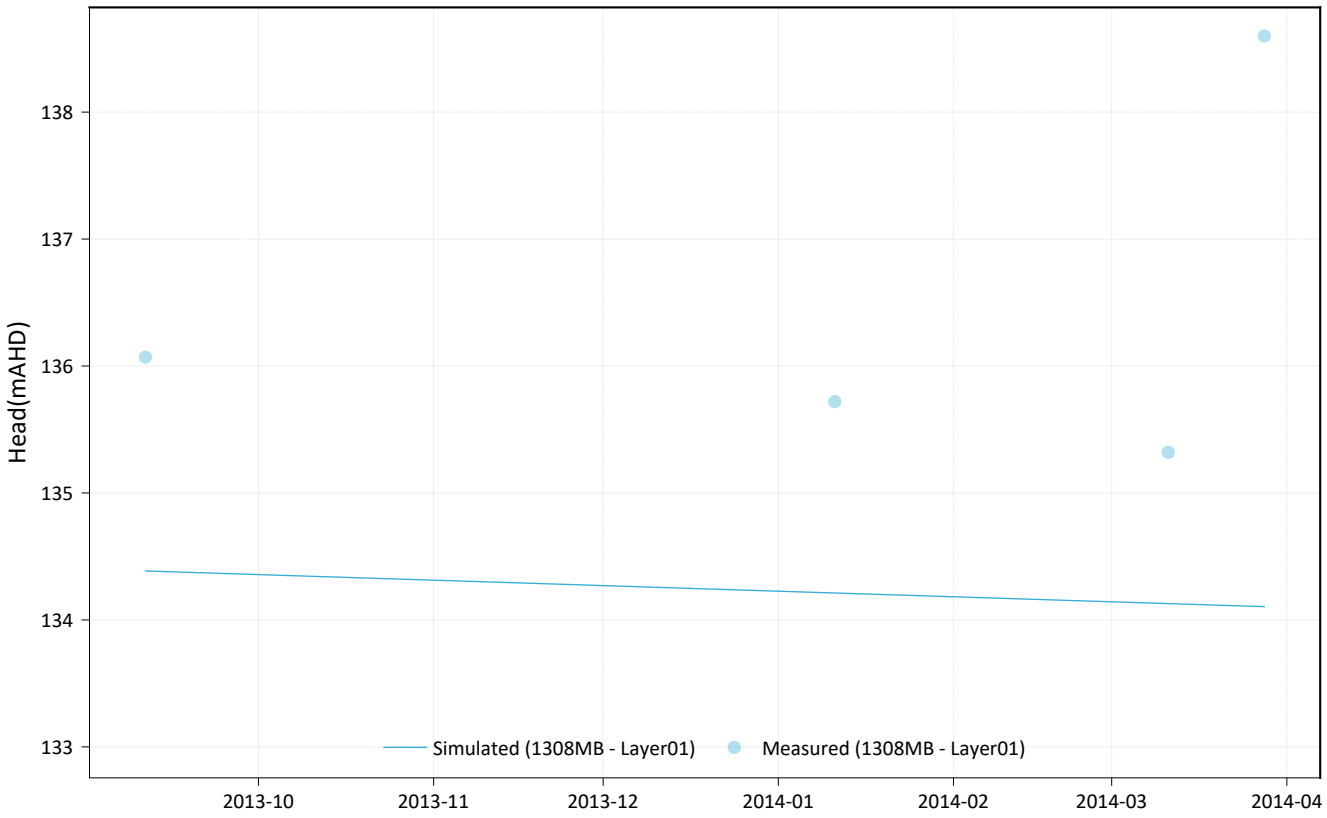
1304AMB



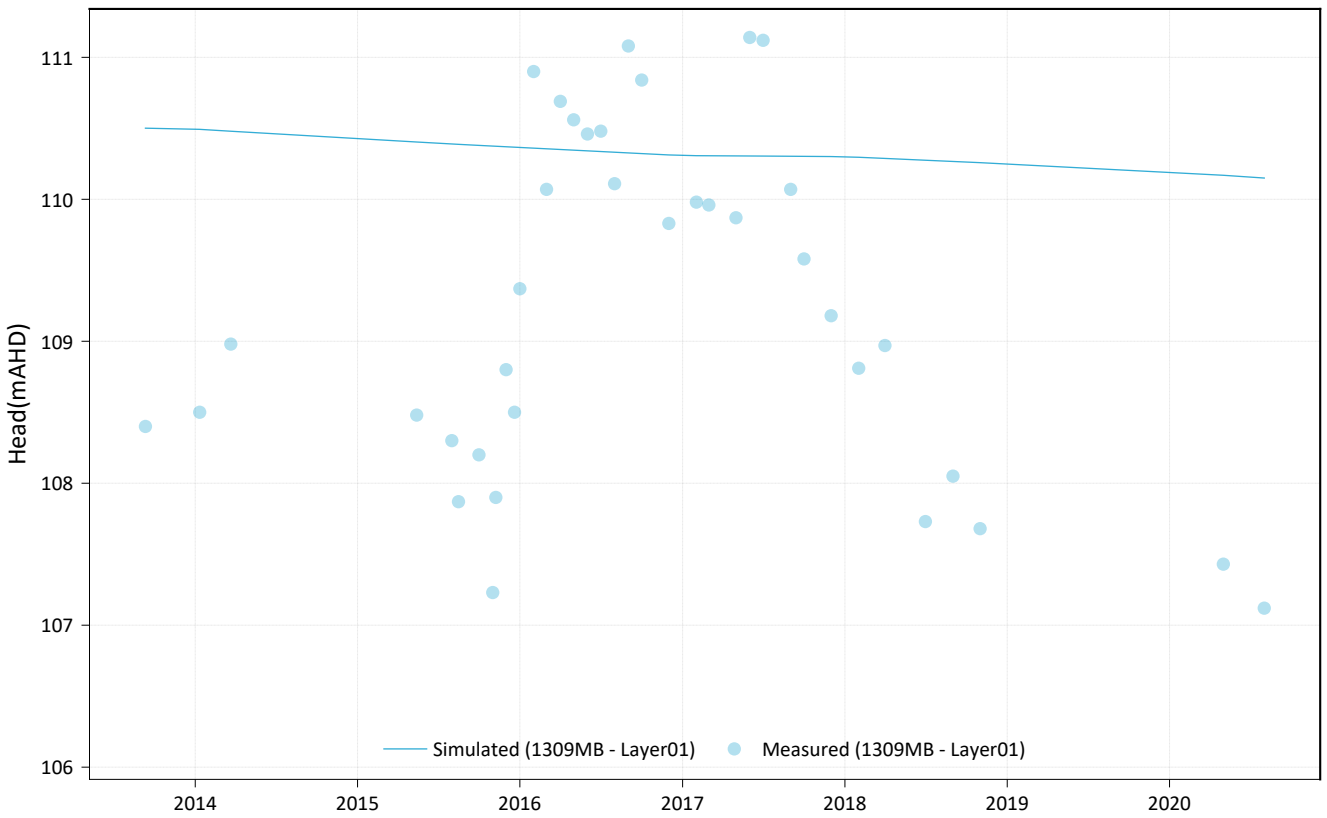

1304BMB
Head(mAHD)
147
146
145
144
143
142
141
140
2014
2015
2016
2017
2018
2019
2020
2021
Simulated (1304BMB - Layer02)
Measured (1304BMB - Layer02)


1307MB
Head(mAHD)
136
135
134
133
132
2014-04
2014-10
2015-04
2015-10
2016-04
2016-10
2017-04
2017-10
Simulated (1307MB - Layer01)
Measured (1307MB - Layer01)

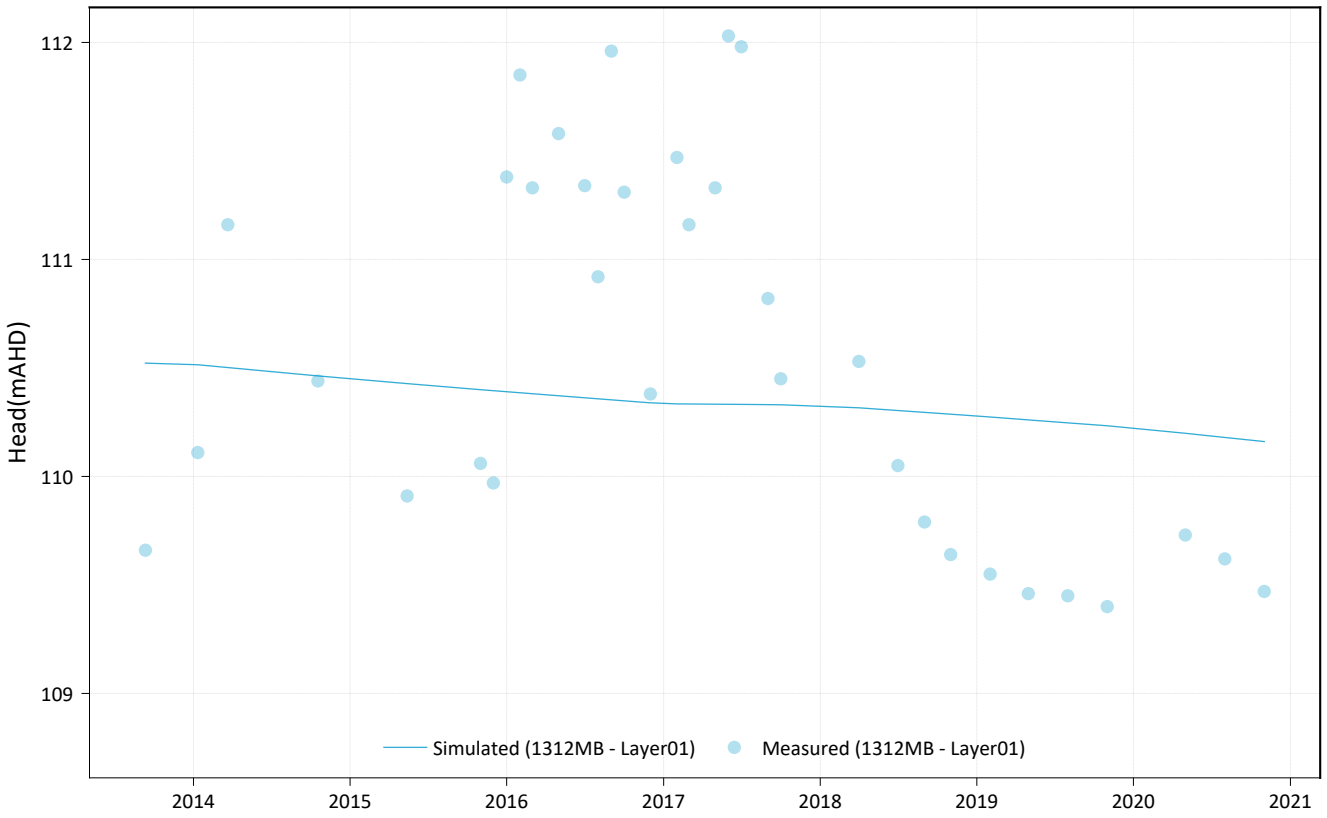
1308MB



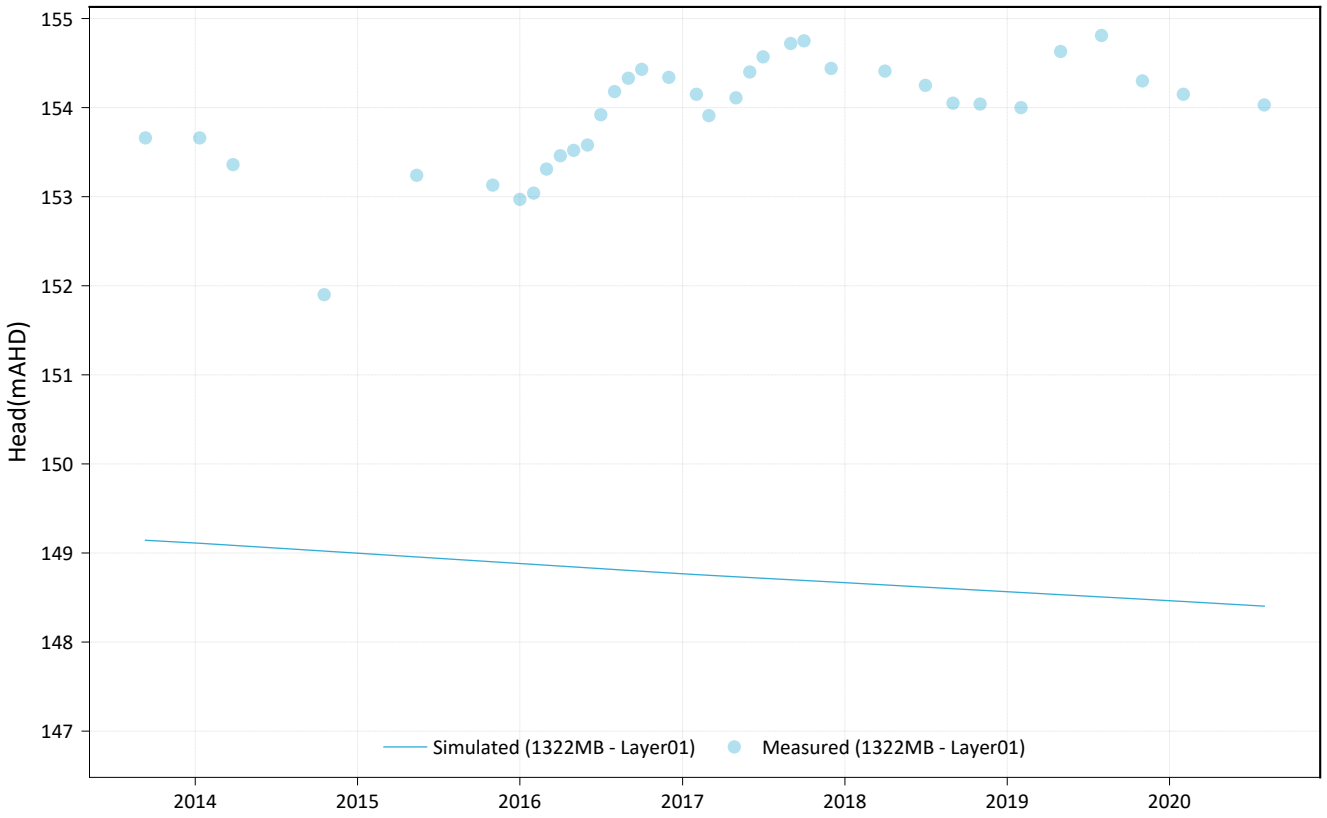
1309MB

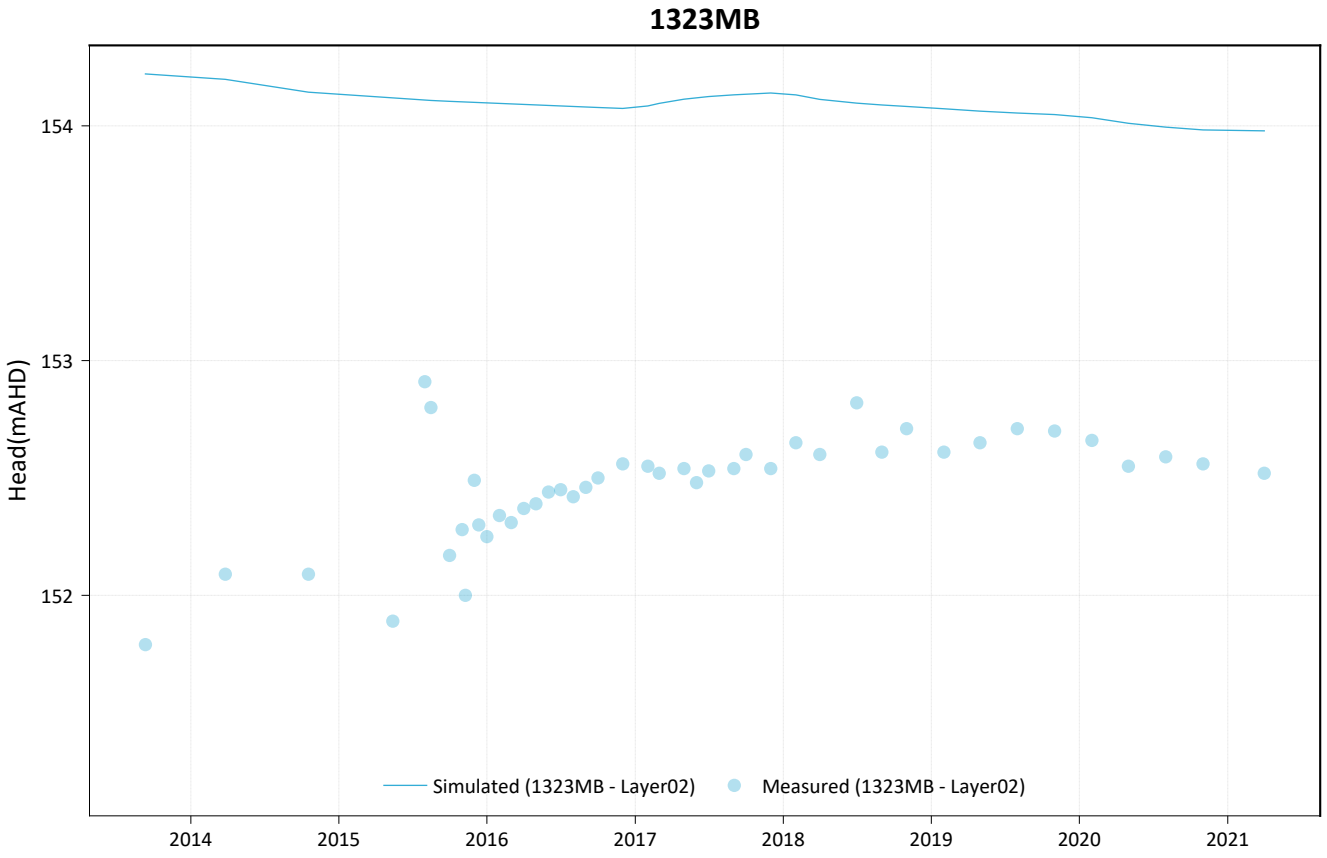


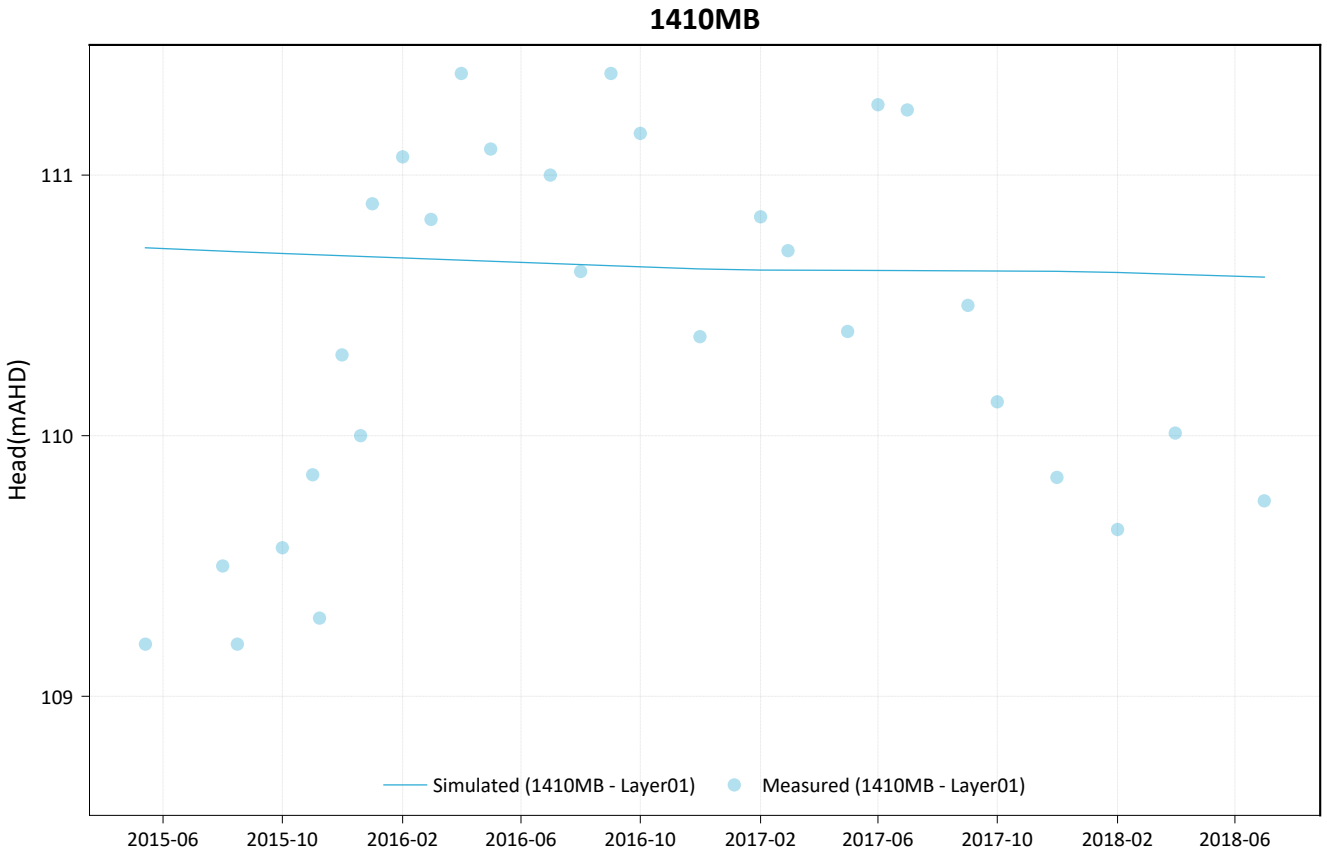
1312MB

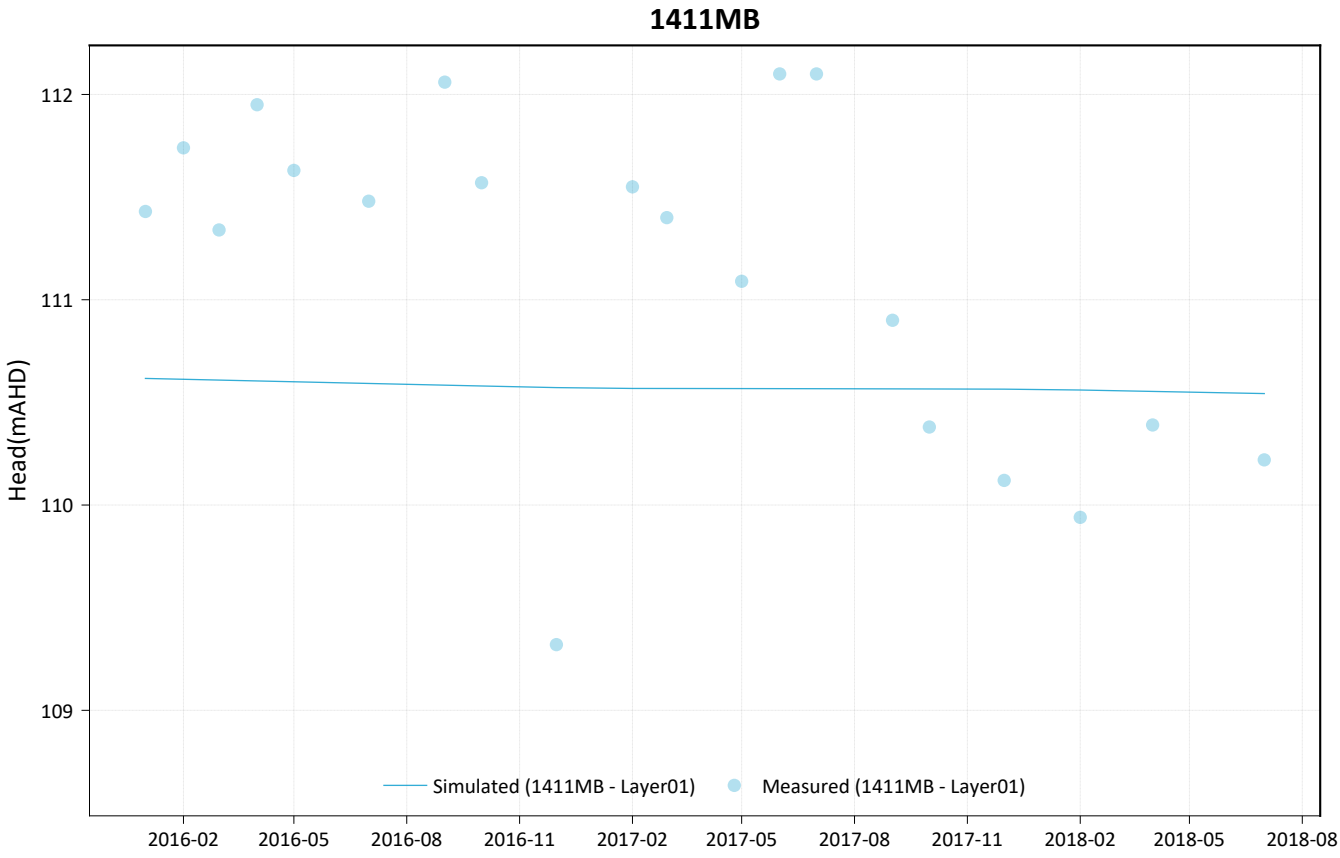


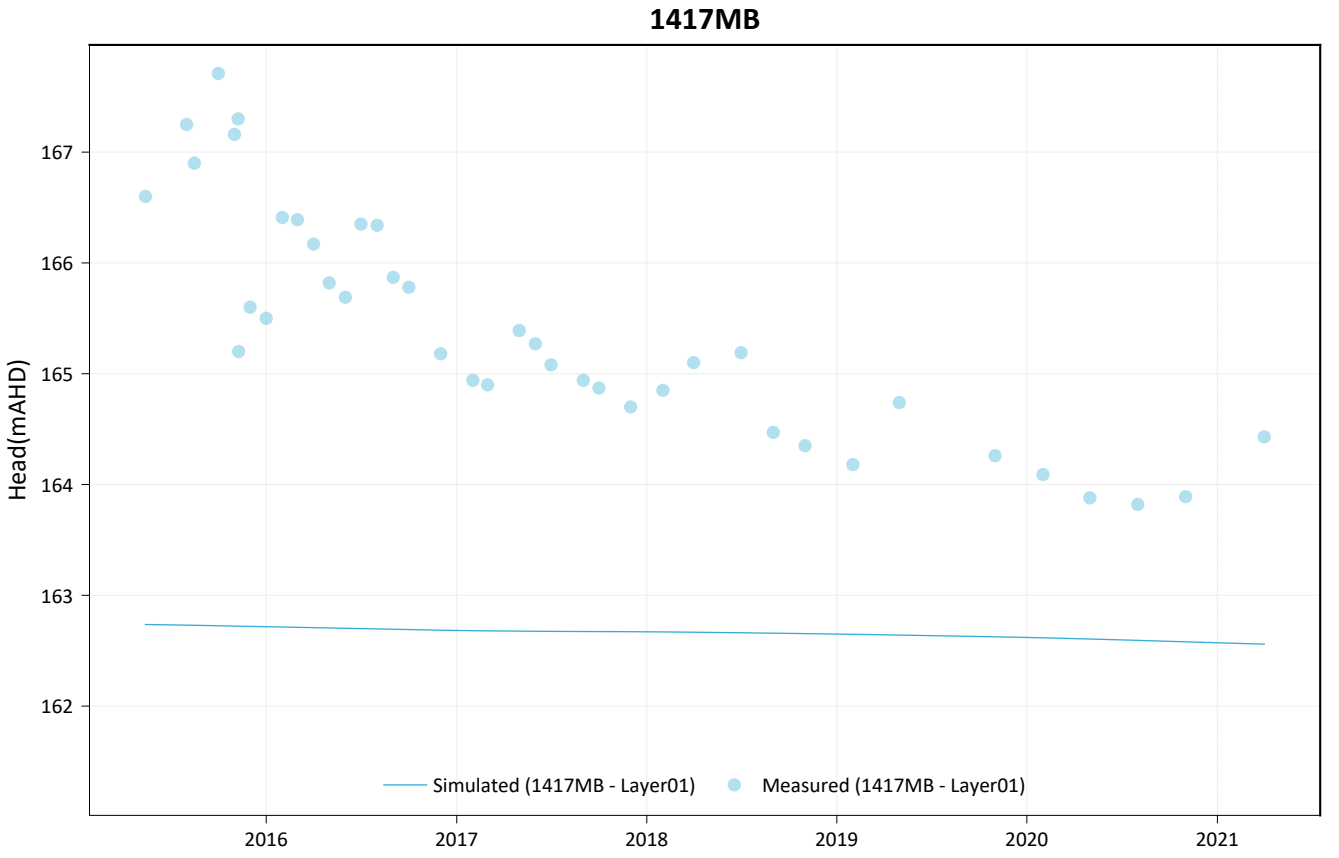
1322MB

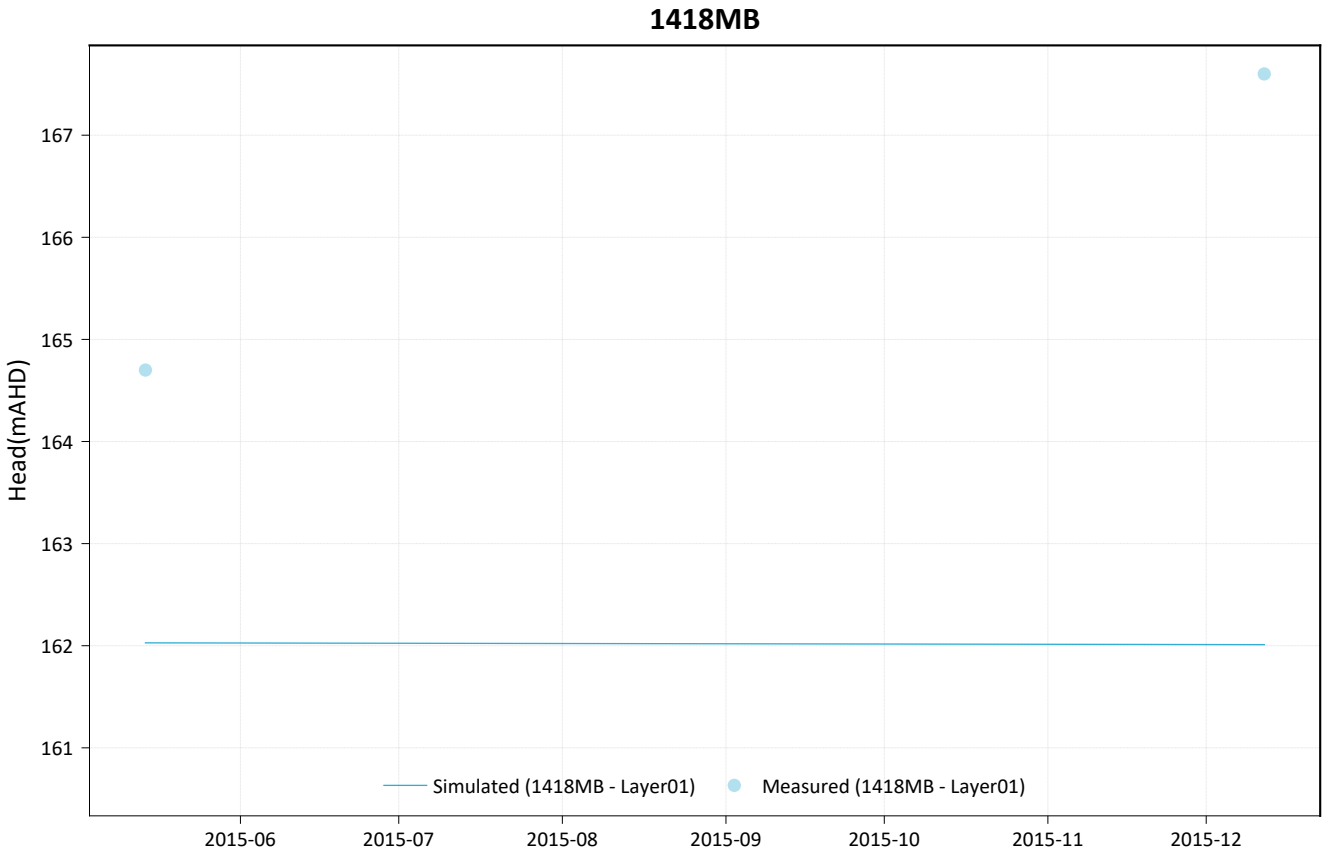


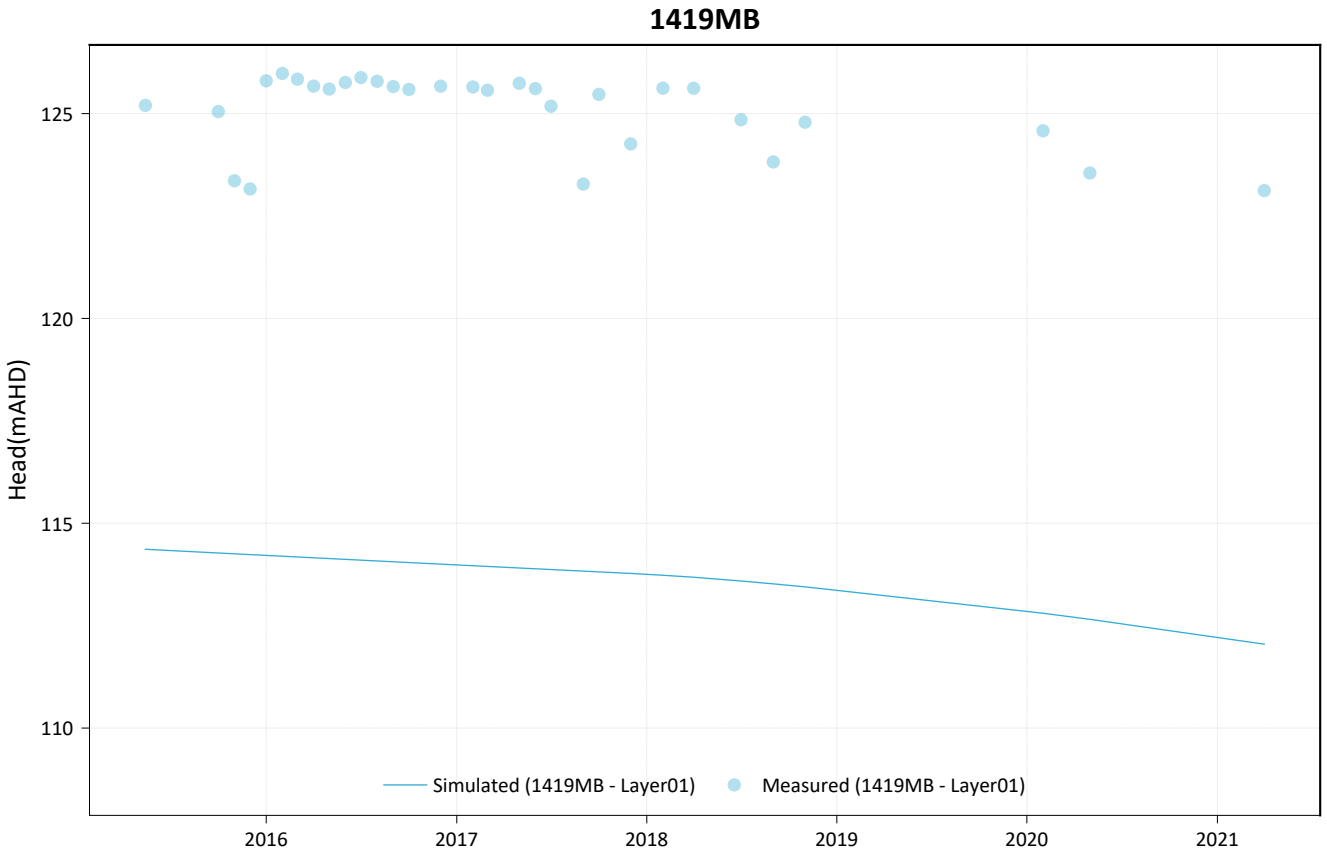

1323MB
Head(mAHD)
154
153
152
2014
2015
2016
2017
2018
2019
2020
2021
Simulated (1323MB - Layer02)
Measured (1323MB - Layer02)

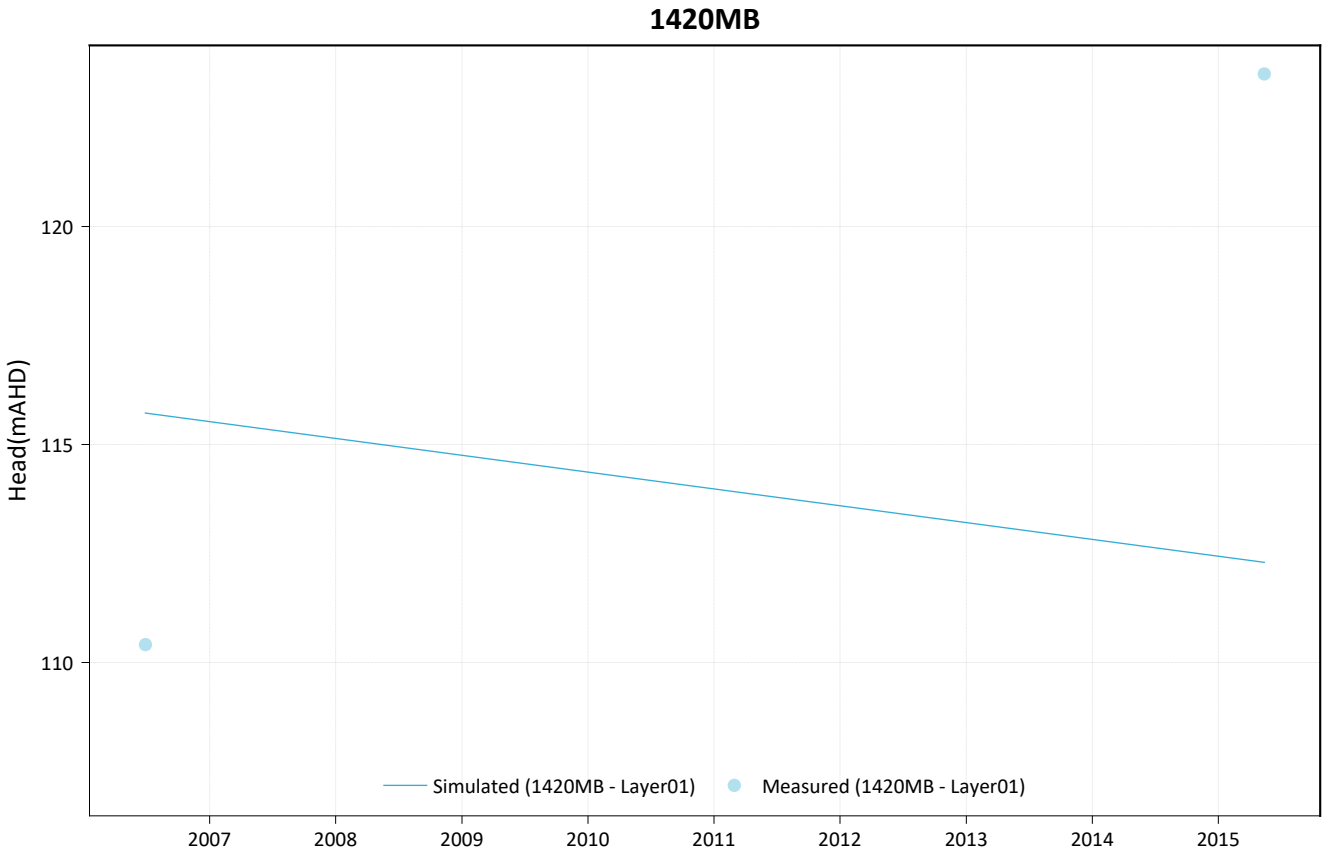

1410MB
Head(mAHD)
111
110
109
2015-06
2015-10
2016-02
2016-06
2016-10
2017-02
2017-06
2017-10
2018-02
2018-06
Simulated (1410MB - Layer01)
Measured (1410MB - Layer01)

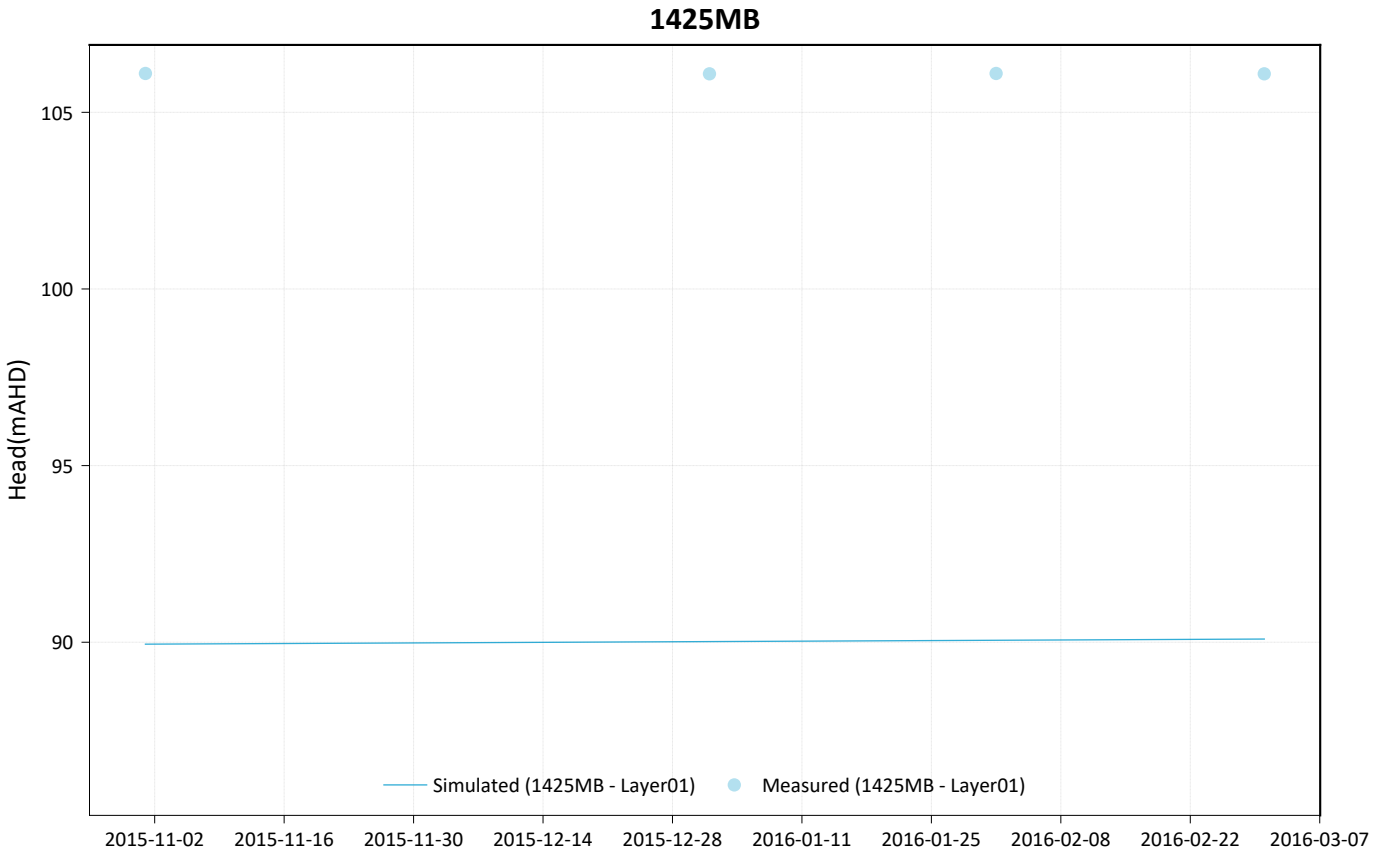

1411MB
Head(mAHD)
112
111
110
109
Simulated (1411MB - Layer01)
Measured (1411MB - Layer01)
2016-02
2016-05
2016-08
2016-11
2017-02
2017-05
2017-08
2017-11
2018-02
2018-05
2018-08


1417MB
Head(mAHD)
167
166
165
164
163
162
Simulated (1417MB - Layer01)
Measured (1417MB - Layer01)
2016
2017
2018
2019
2020
2021

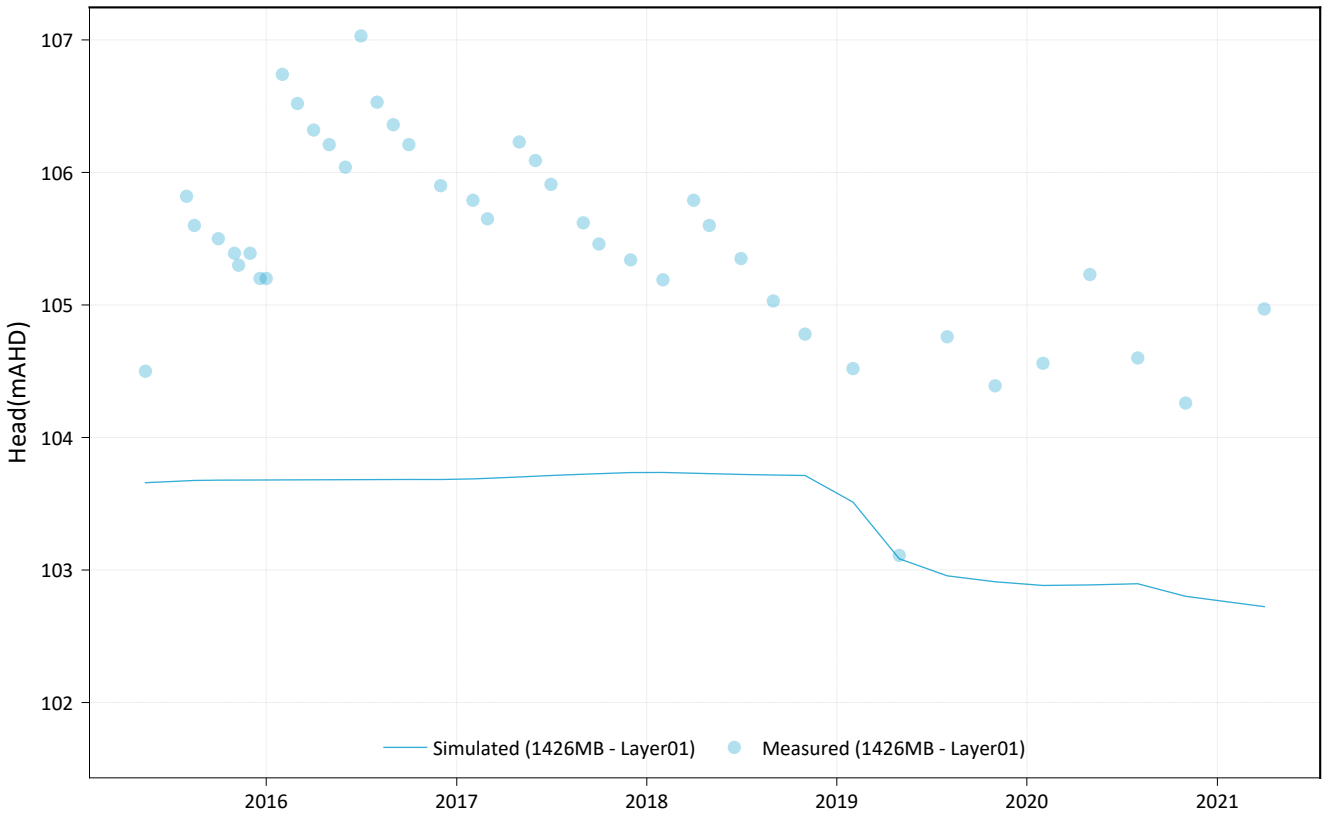

1418MB
Head(mAHD)
167
166
165
164
163
162
161
Simulated (1418MB - Layer01)
Measured (1418MB - Layer01)
2015-06
2015-07
2015-08
2015-09
2015-10
2015-11
2015-12


1419MB
Head(mAHD)
125
120
115
110
Simulated (1419MB - Layer01)
Measured (1419MB - Layer01)
2016
2017
2018
2019
2020
2021

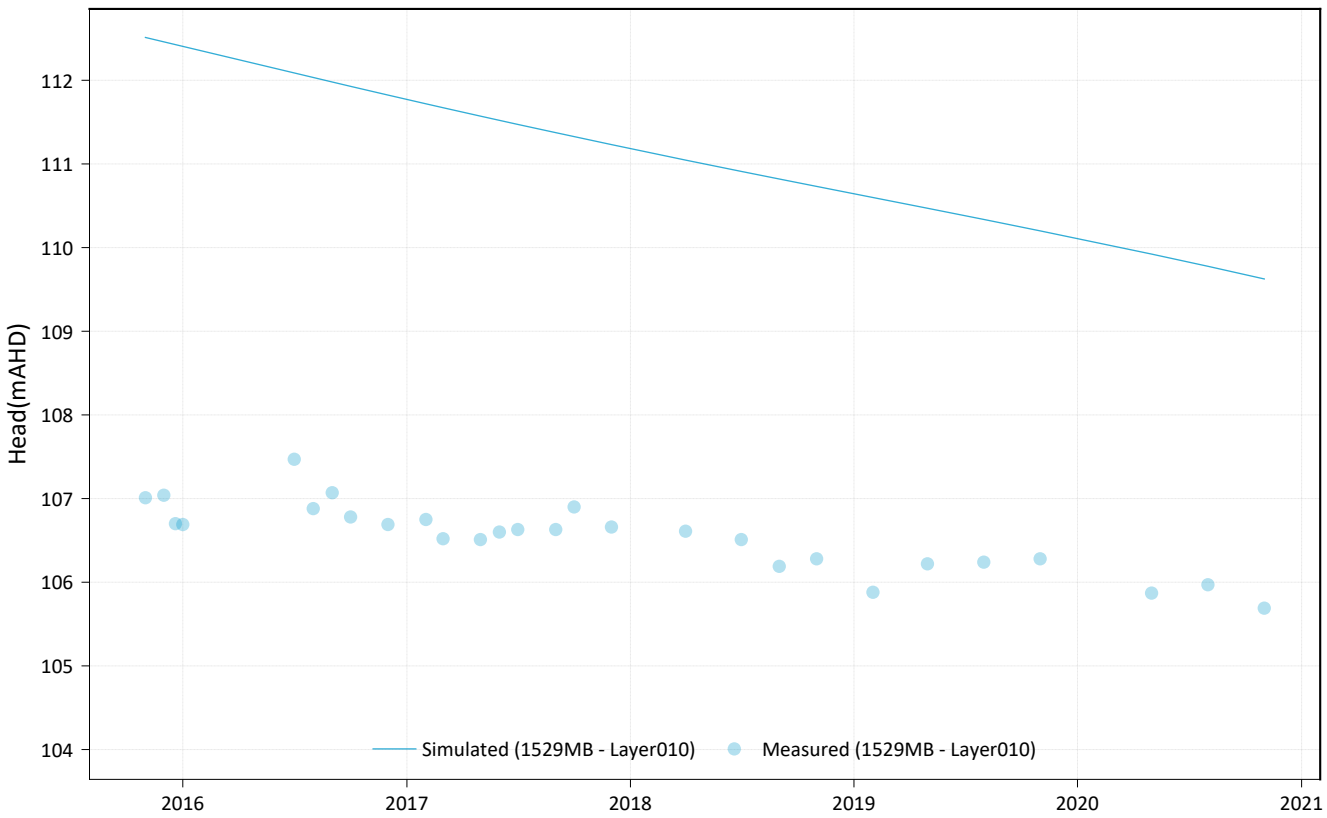

1420MB
Head(mAHD)
120
115
110
2007
2008
2009
2010
2011
2012
2013
2014
2015
Simulated (1420MB - Layer01)
Measured (1420MB - Layer01)


1425MB
Head(mAHD)
105
100
95
90
2015-11-02
2015-11-16
2015-11-30
2015-12-14
2015-12-28
2016-01-11
2016-01-25
2016-02-08
2016-02-22
2016-03-07
Simulated (1425MB - Layer01)
Measured (1425MB - Layer01)

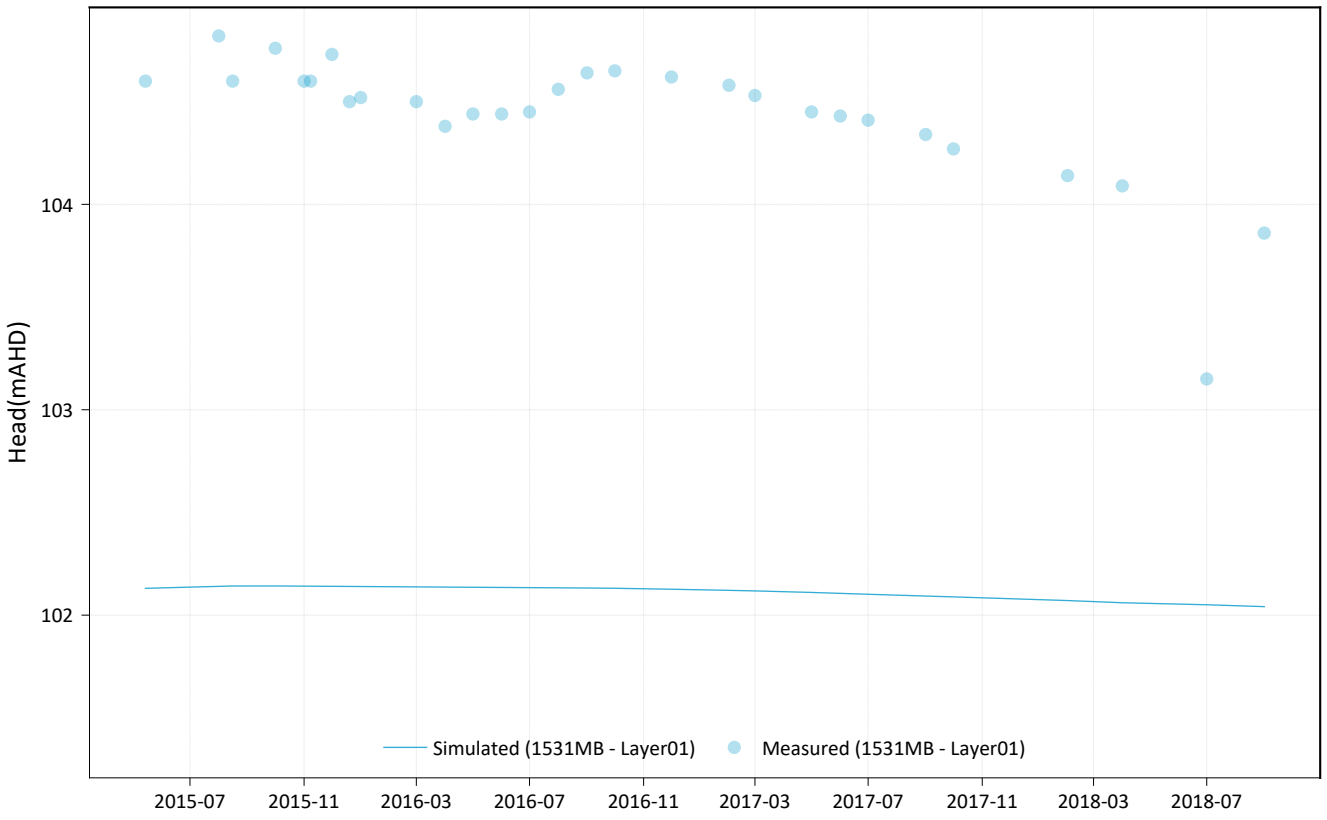
1426MB



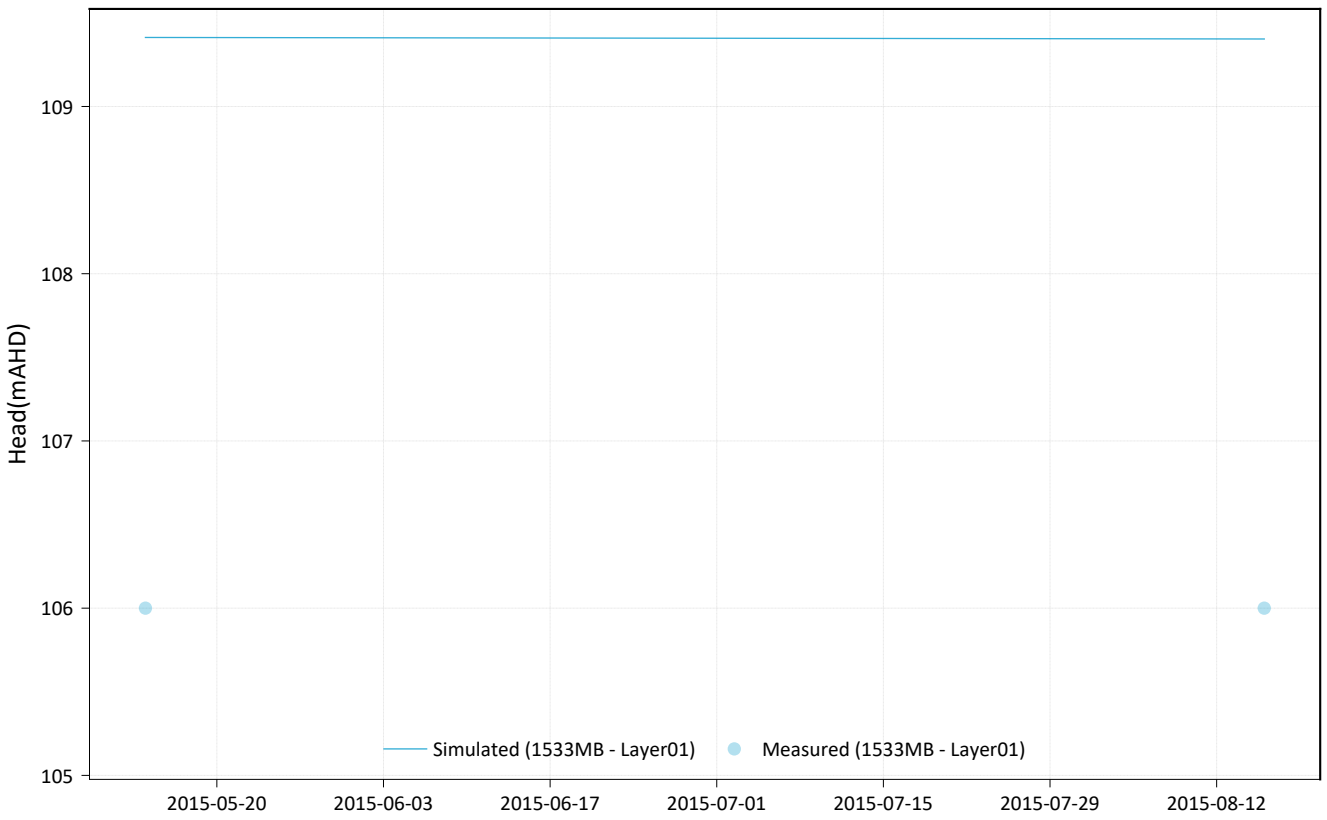
1529MB

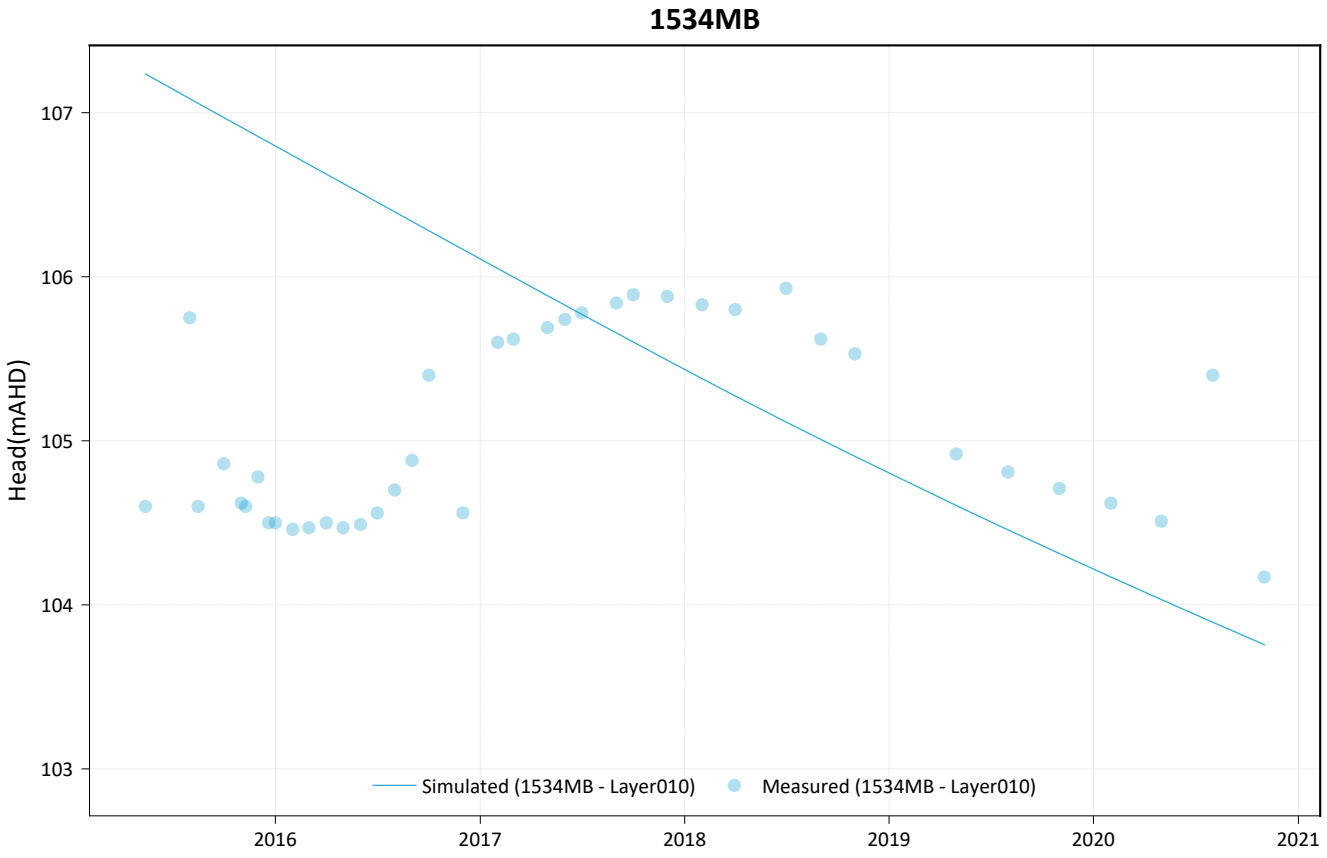


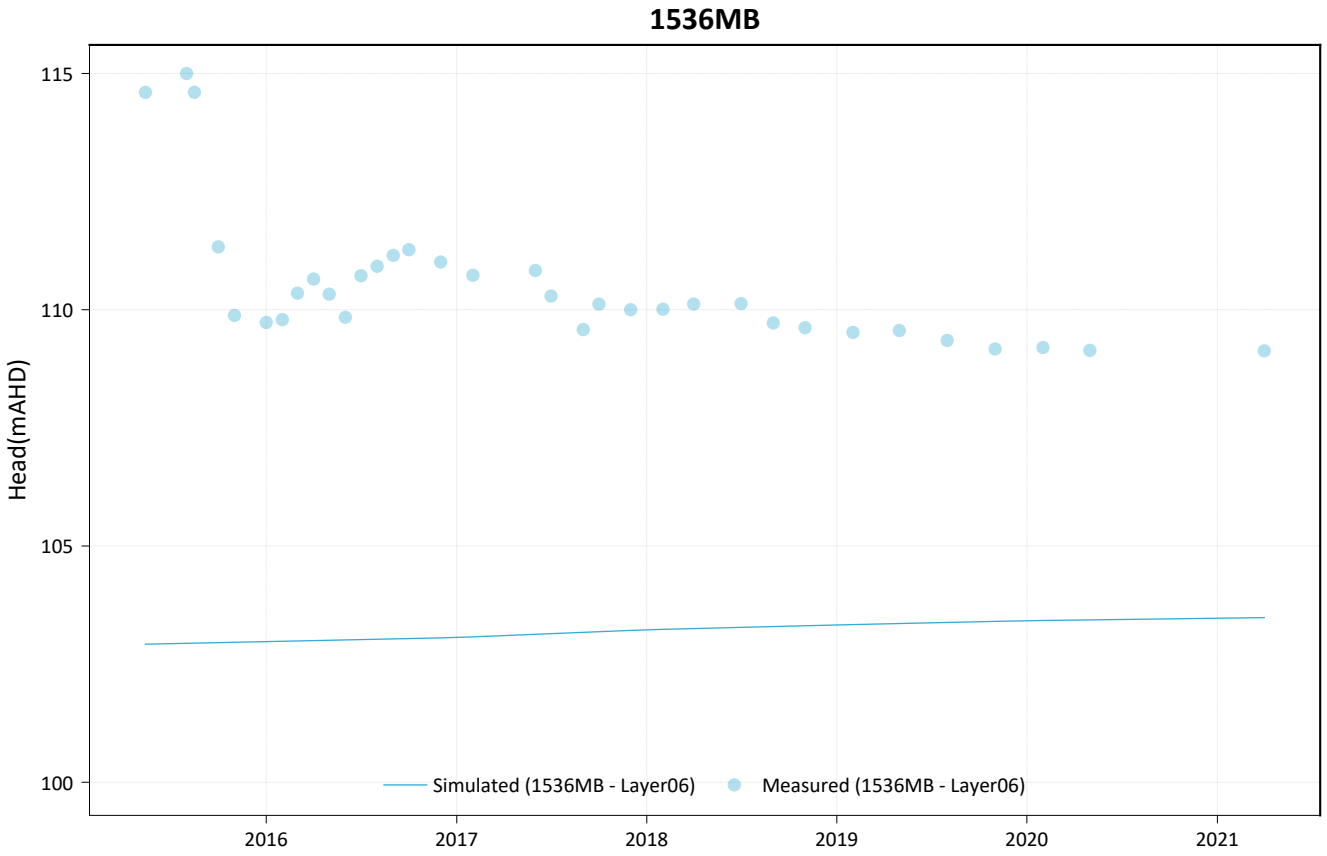
1531MB

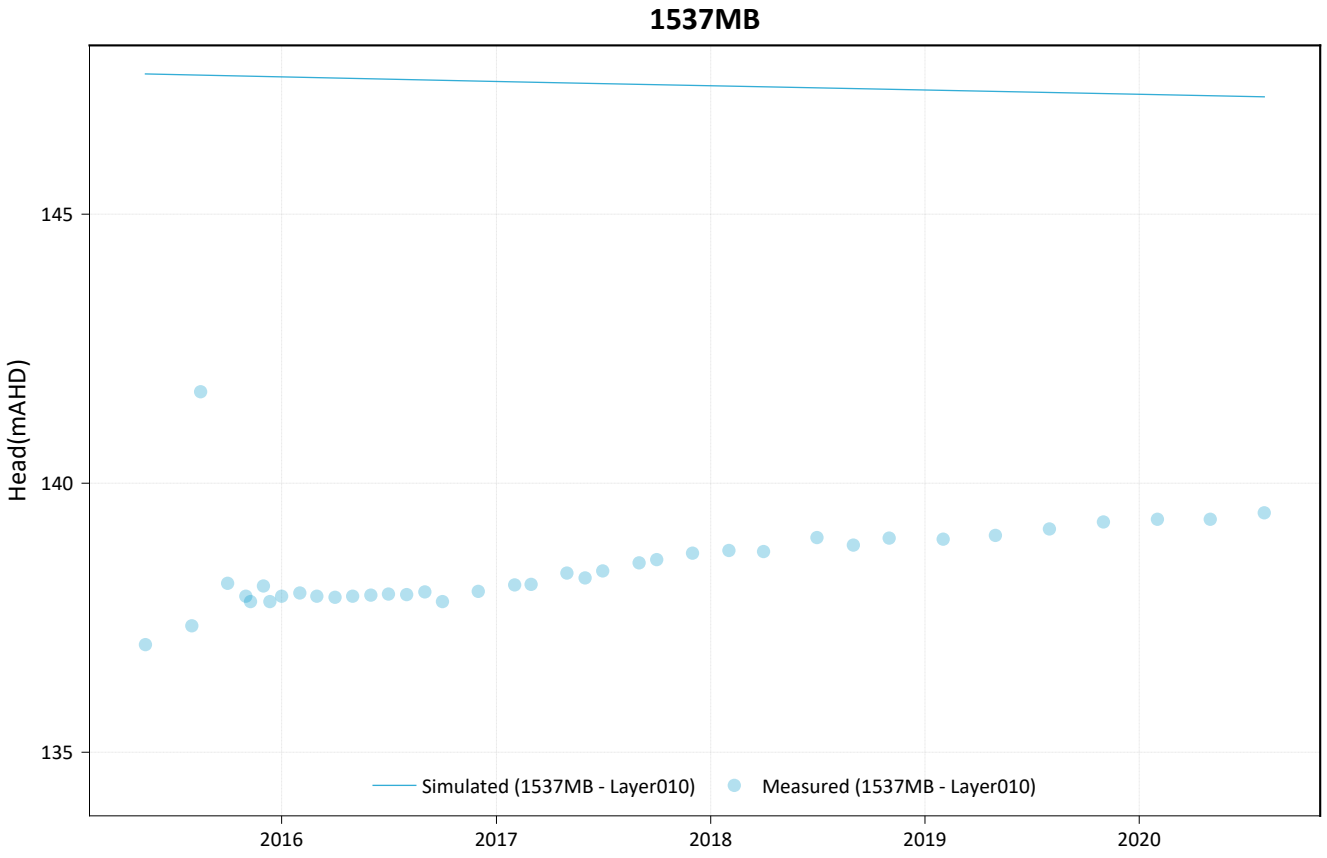


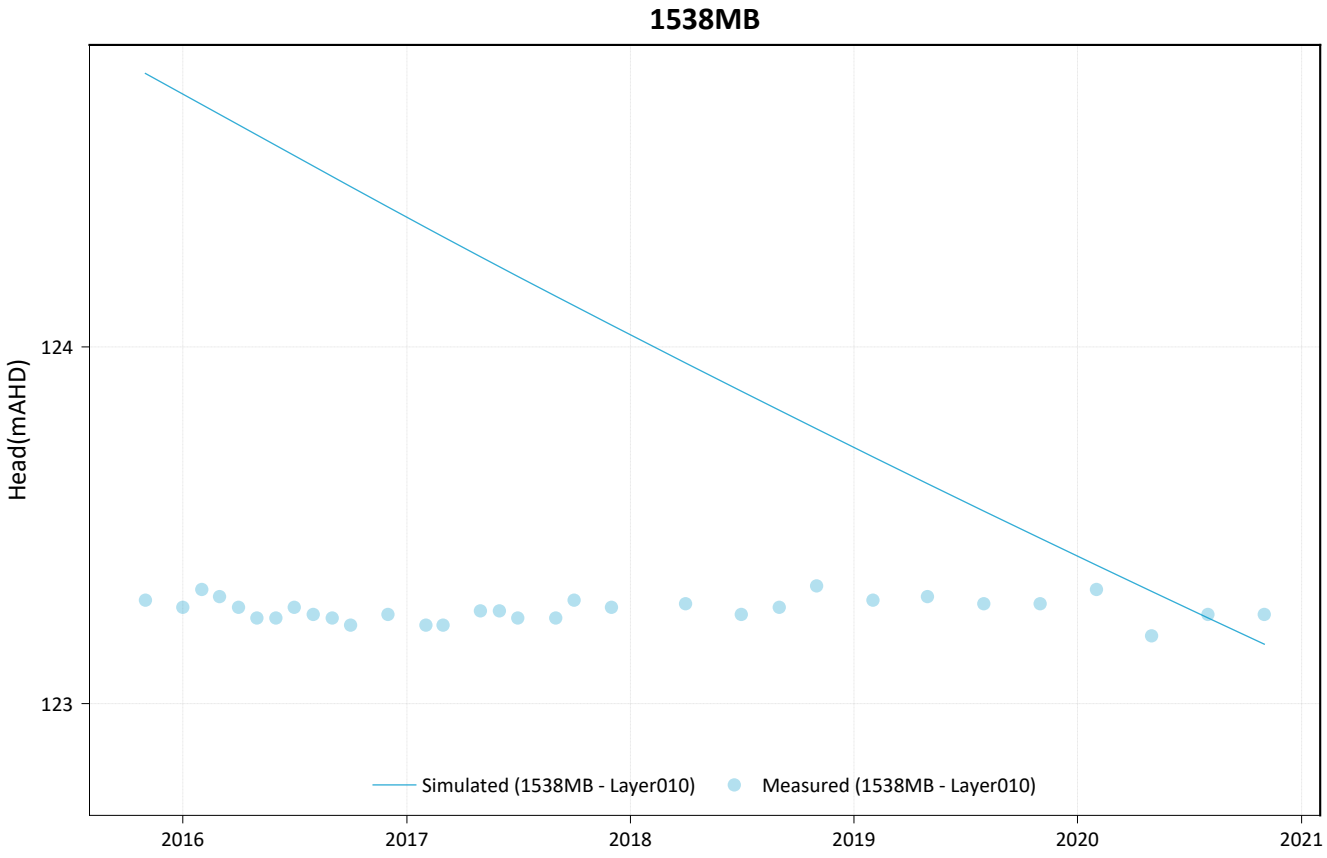
1533MB

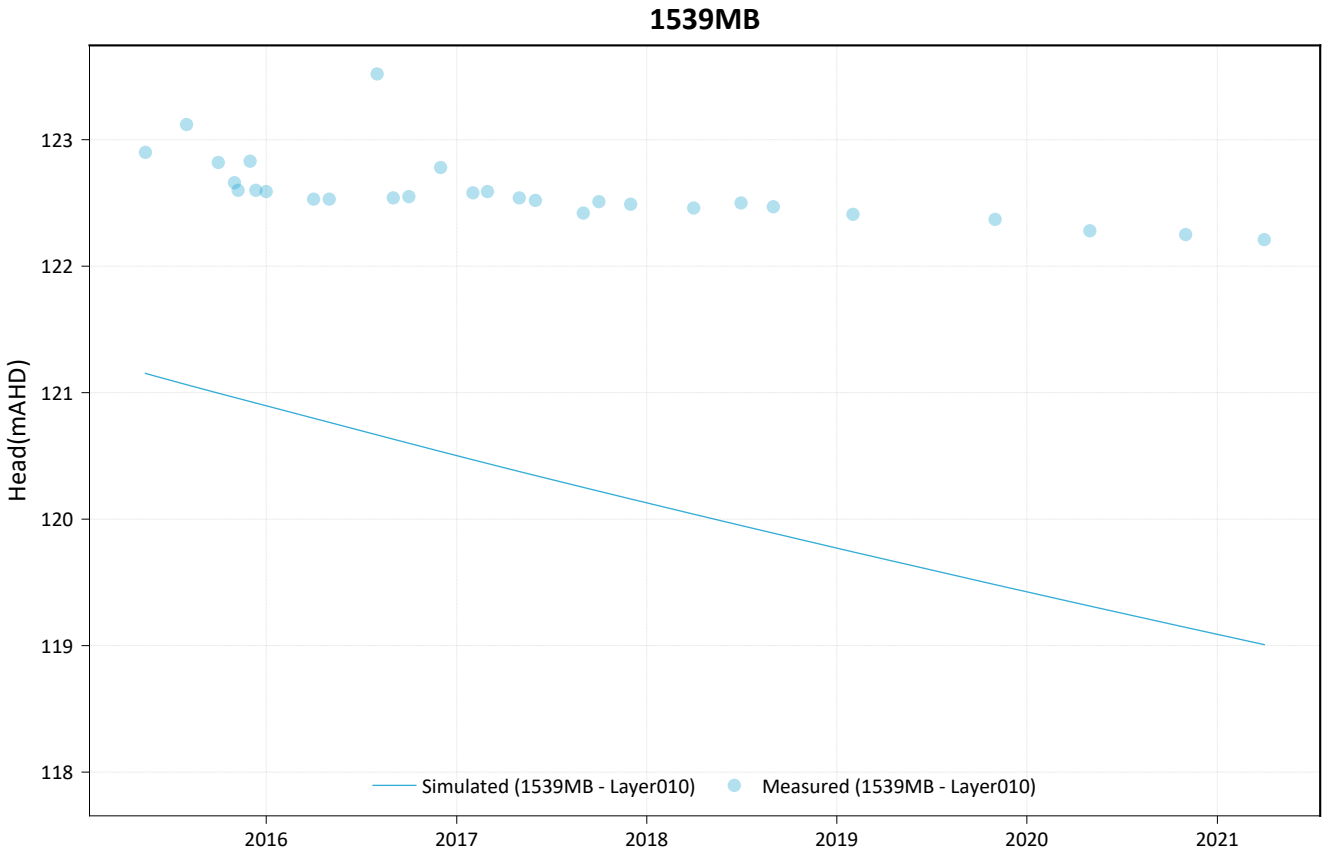


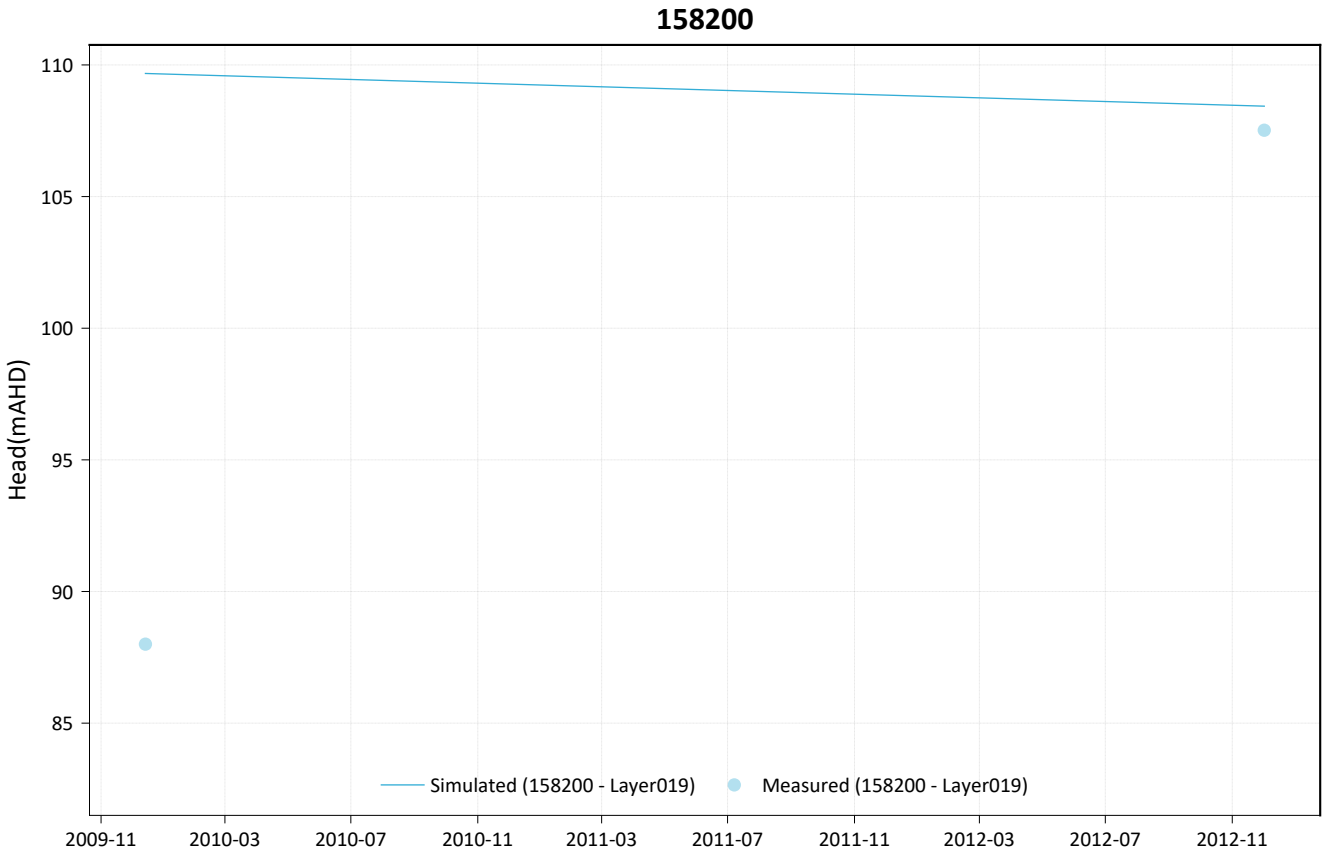

1534MB
Head(mAHD)
107
106
105
104
103
2016
2017
2018
2019
2020
2021
Simulated (1534MB - Layer010)
Measured (1534MB - Layer010)


1536MB
Head(mAHD)
115
110
105
100
2016
2017
2018
2019
2020
2021
Simulated (1536MB - Layer06)
Measured (1536MB - Layer06)

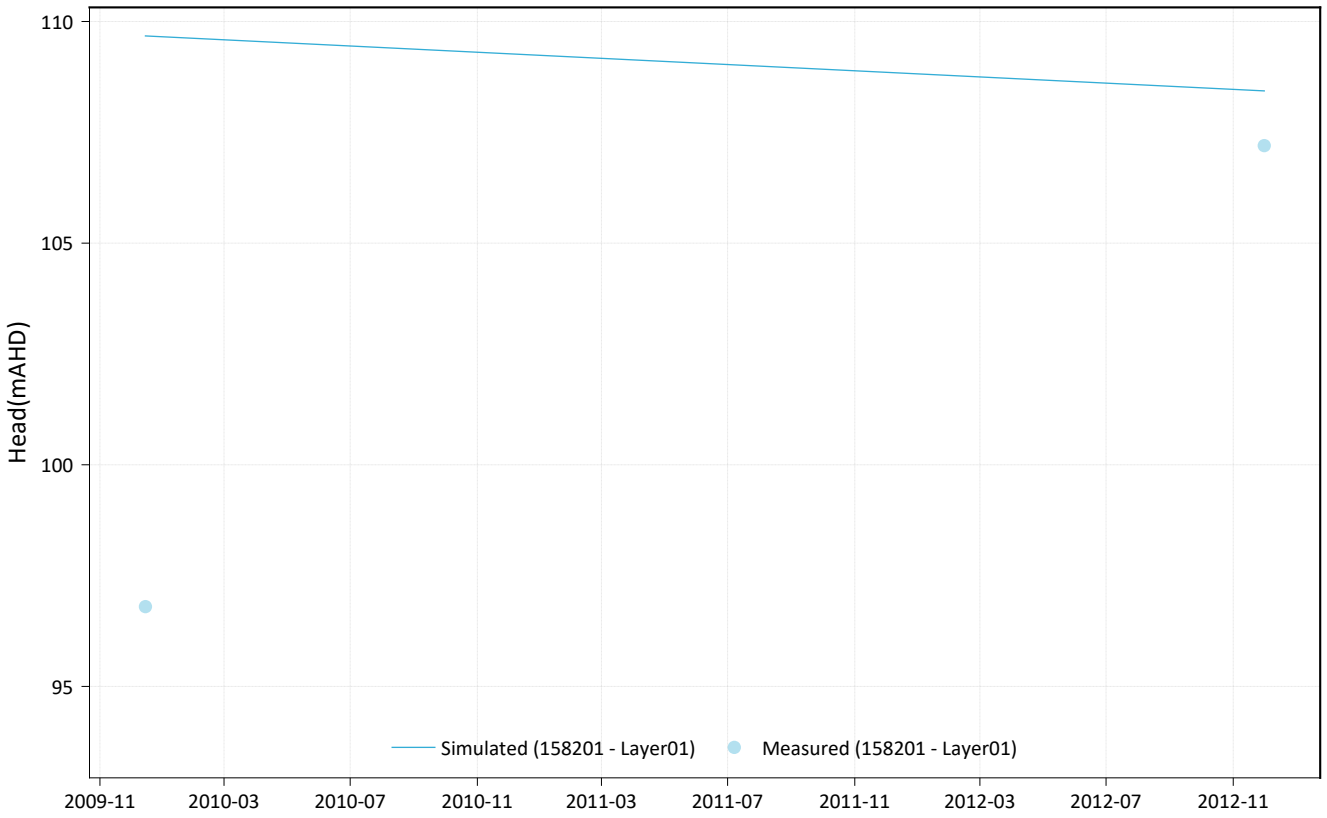

1537MB
Head(mAHD)
145
140
135
Simulated (1537MB - Layer010)
Measured (1537MB - Layer010)
2016
2017
2018
2019
2020


1538MB
Head(mAHD)
124
123
Simulated (1538MB - Layer010)
Measured (1538MB - Layer010)
2016
2017
2018
2019
2020
2021

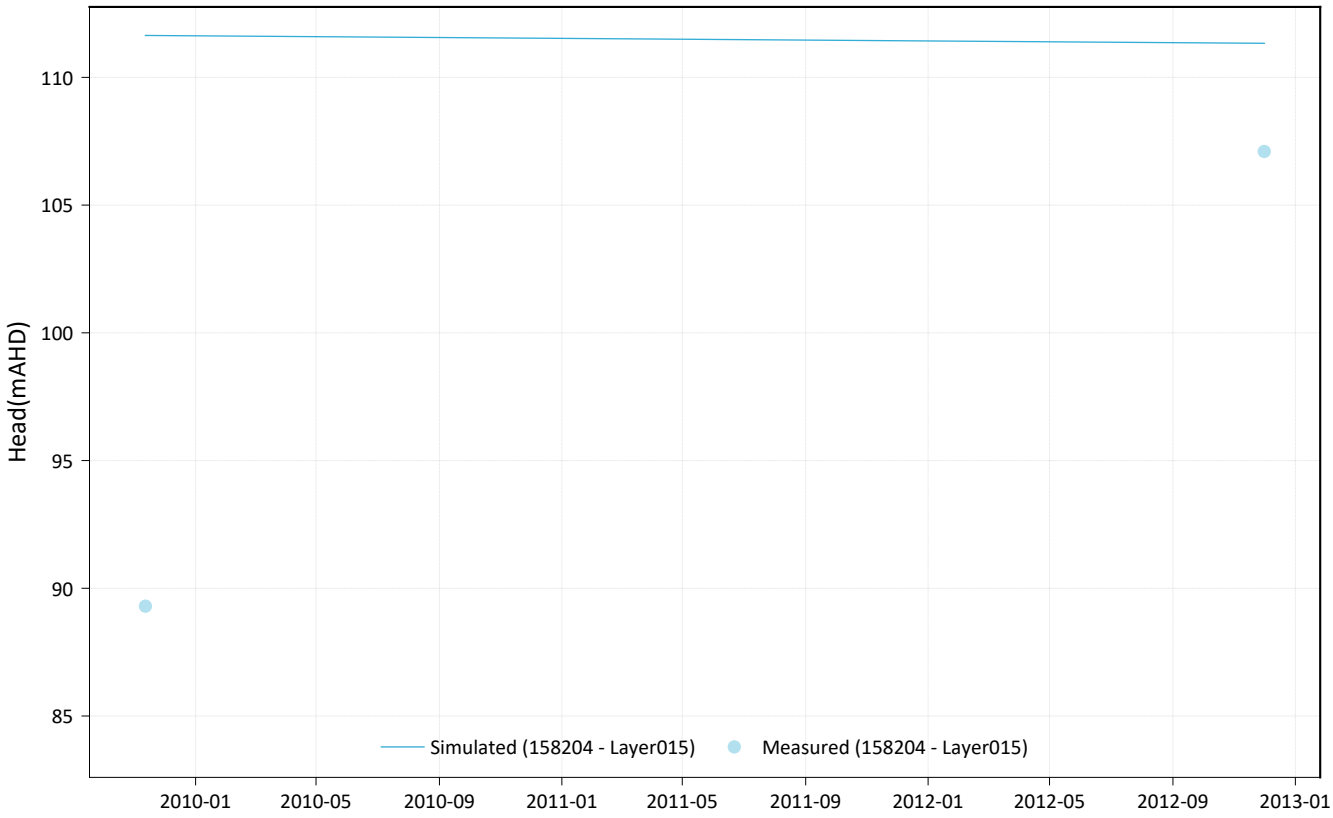

1539MB
Head(mAHD)
123
122
121
120
119
118
2016
2017
2018
2019
2020
2021
Simulated (1539MB - Layer010)
Measured (1539MB - Layer010)

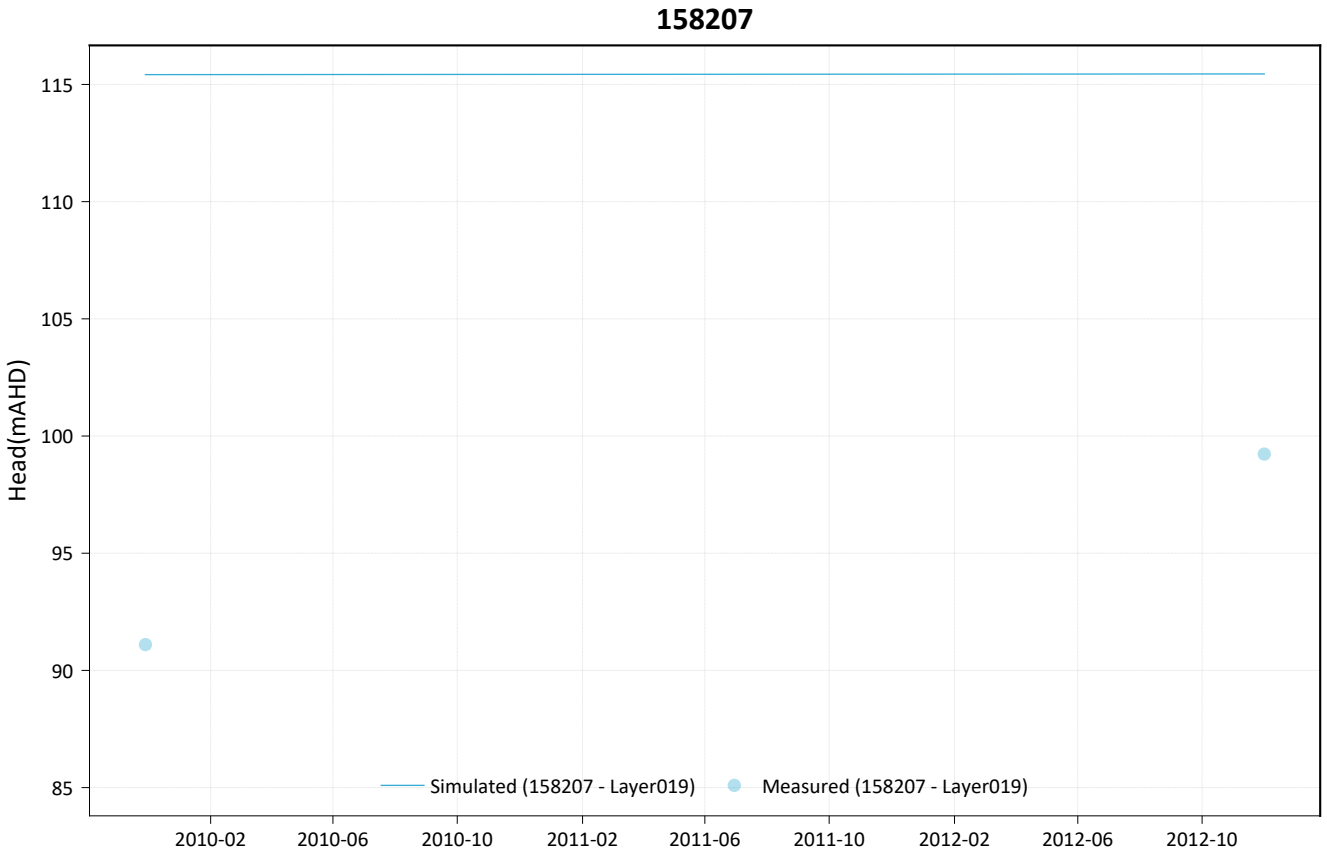

158200
Head(mAHD)
110
105
100
95
90
85
2009-11
2010-03
2010-07
2010-11
2011-03
2011-07
2011-11
2012-03
2012-07
2012-11
Simulated (158200 - Layer019)
Measured (158200 - Layer019)

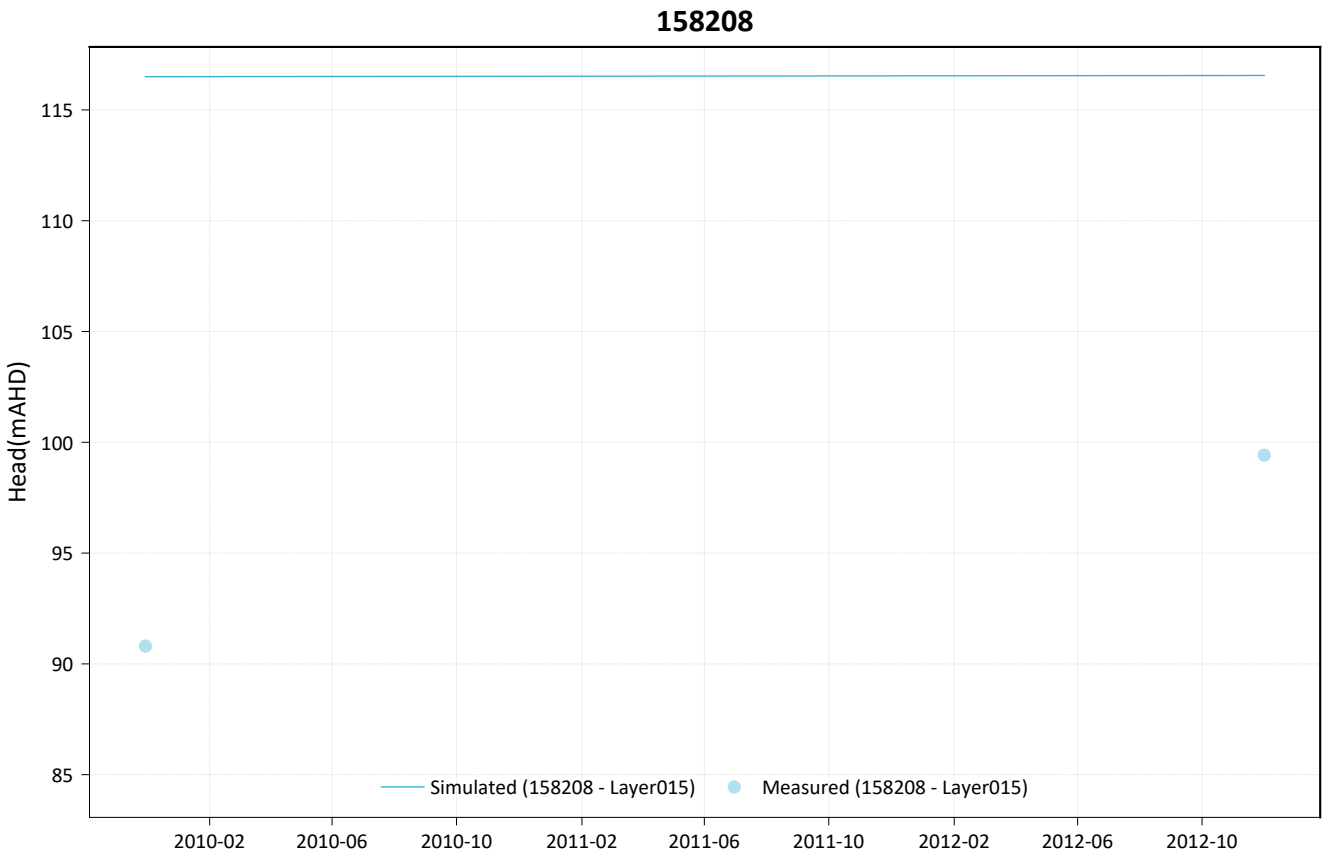
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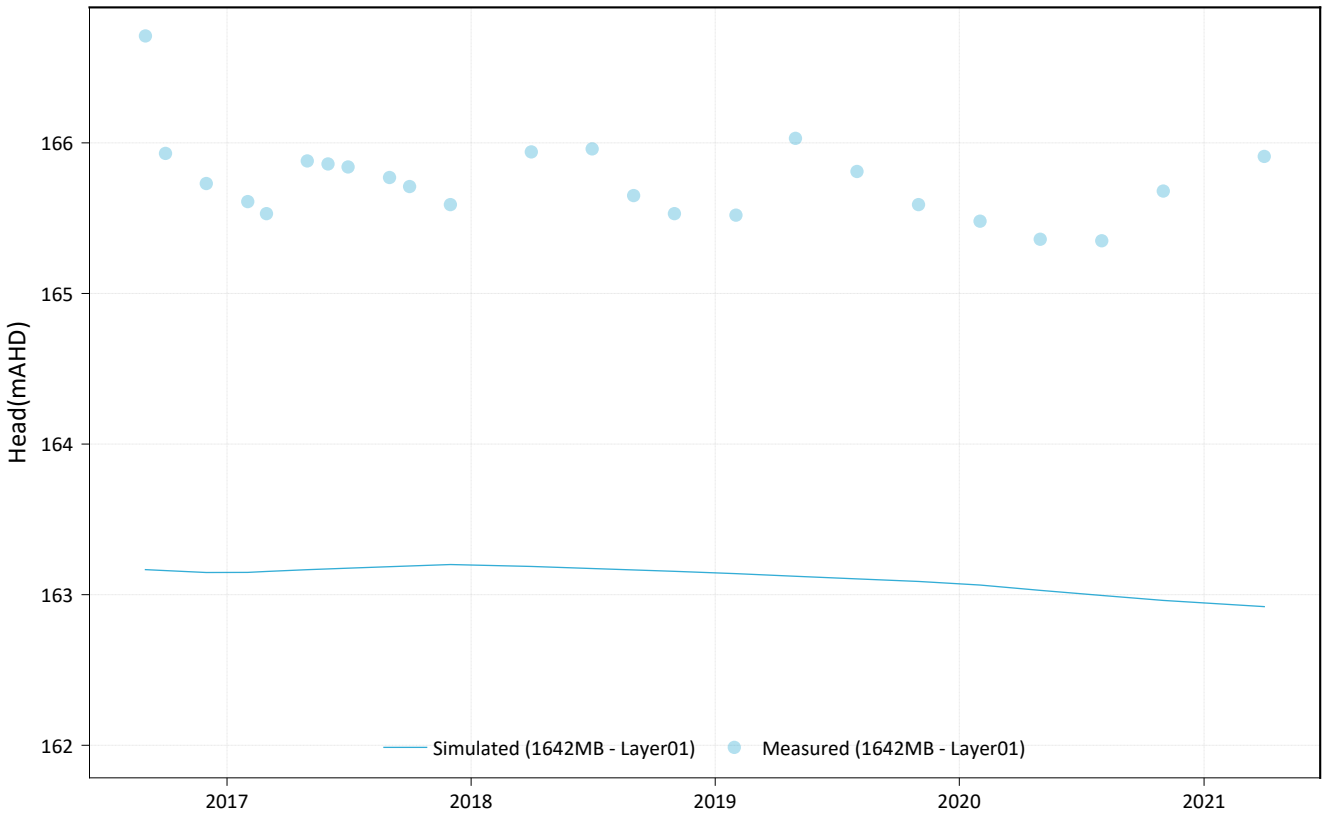
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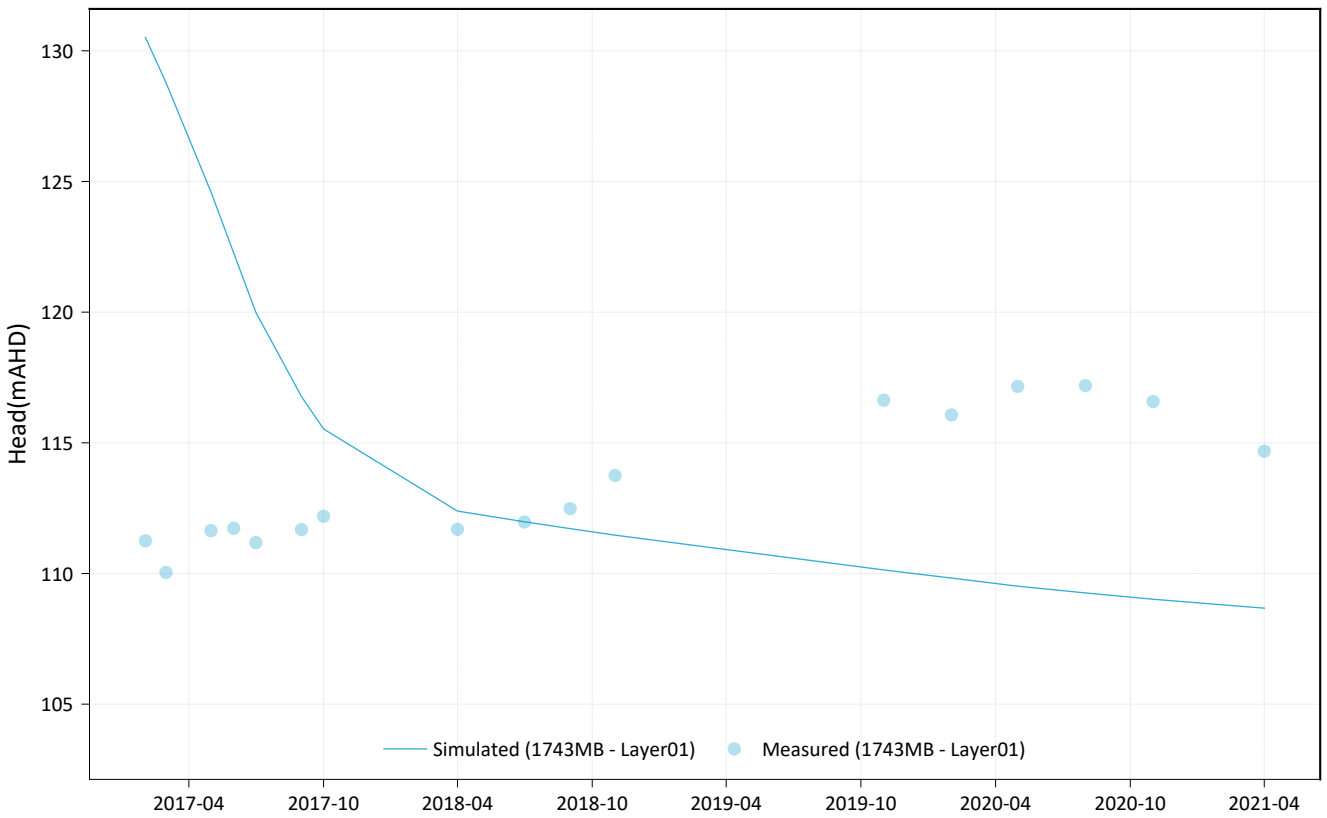

158207
Head(mAHD)
115
110
105
100
95
90
85
2010-02
2010-06
2010-10
2011-02
2011-06
2011-10
2012-02
2012-06
2012-10
Simulated (158207 - Layer019)
Measured (158207 - Layer019)


158208
Head(mAHD)
115
110
105
100
95
90
85
2010-02
2010-06
2010-10
2011-02
2011-06
2011-10
2012-02
2012-06
2012-10
Simulated (158208 - Layer015)
Measured (158208 - Layer015)

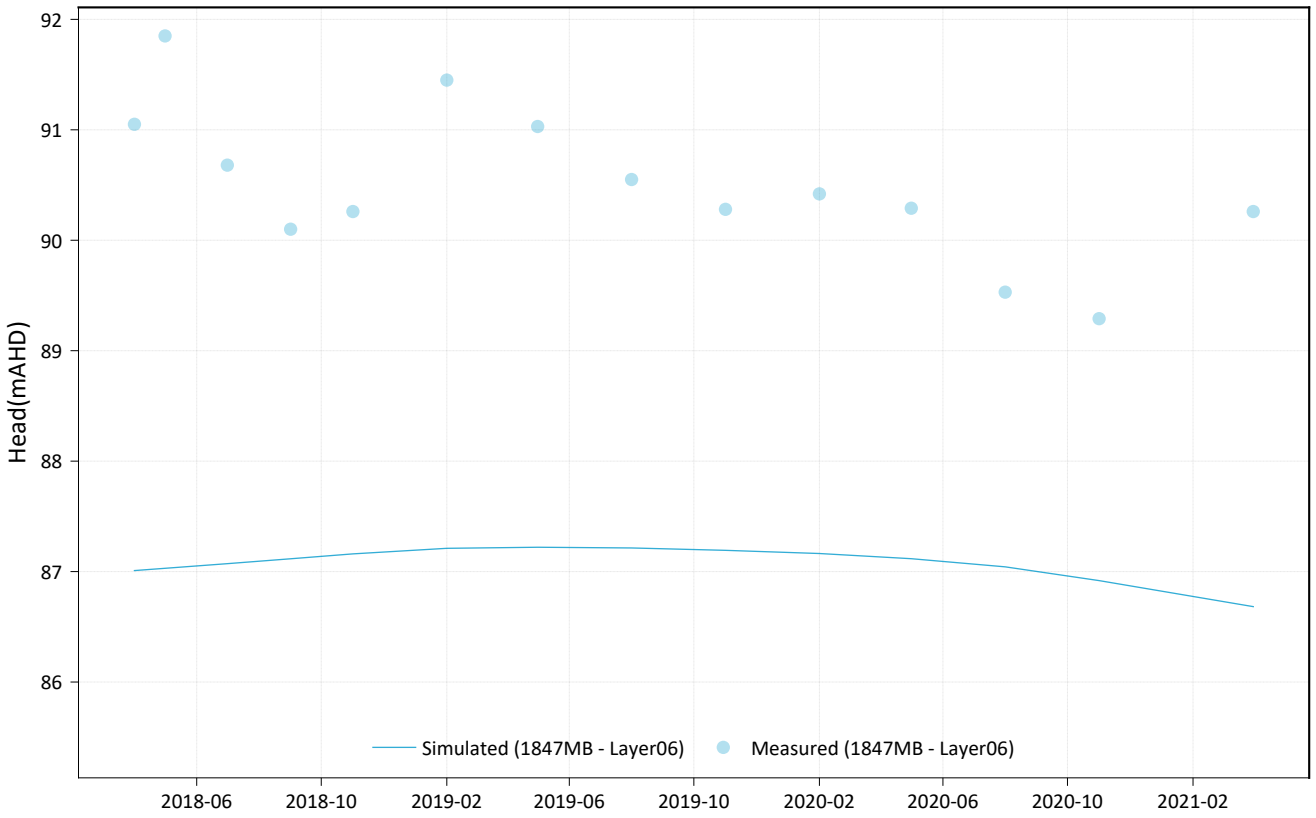
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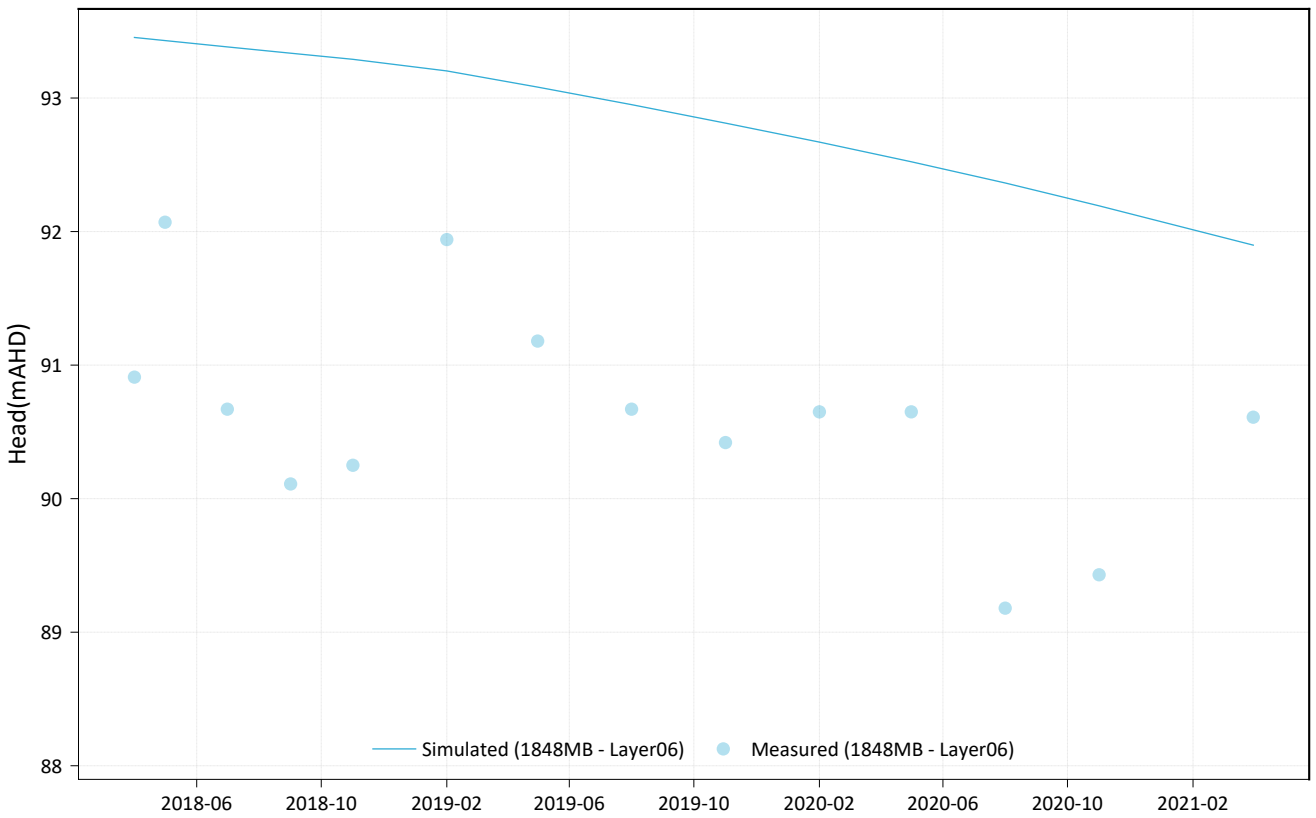
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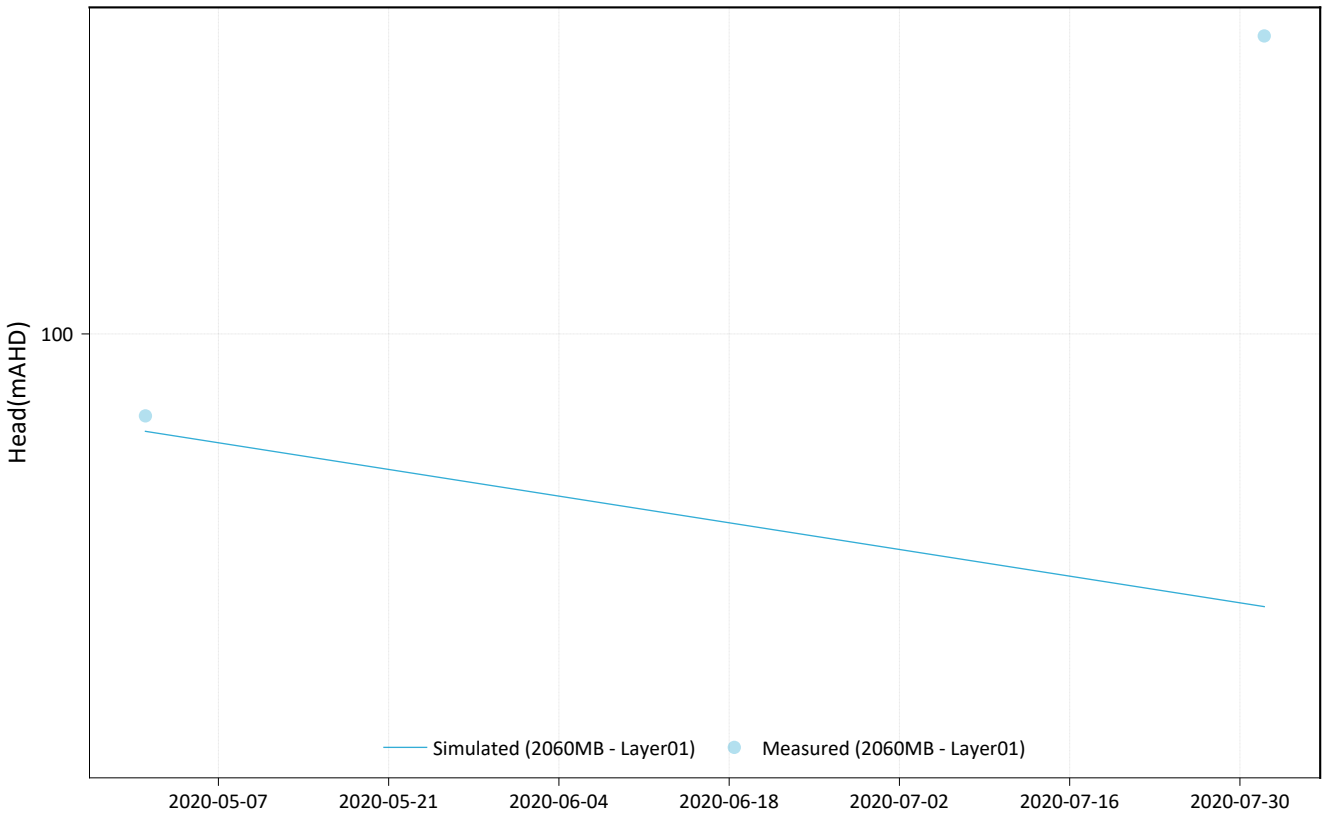
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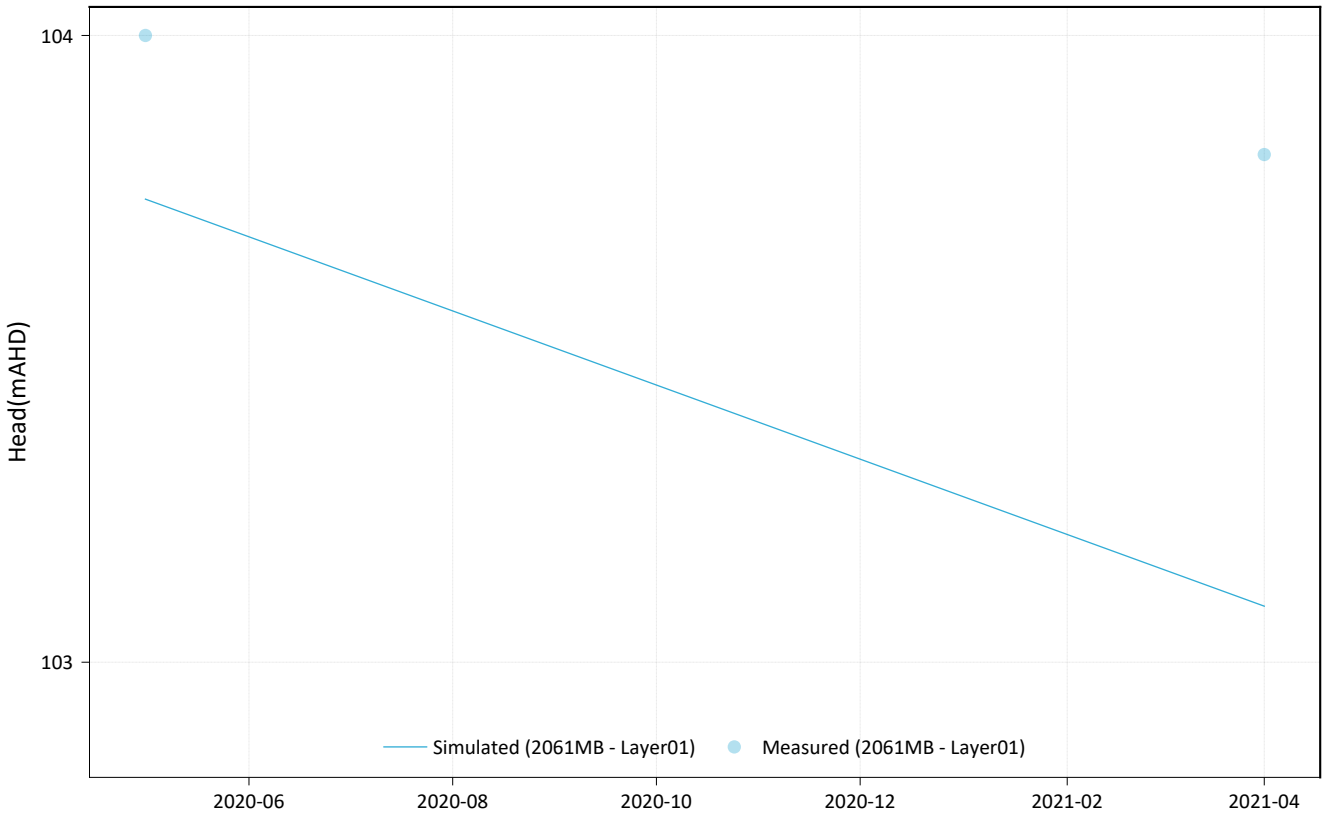
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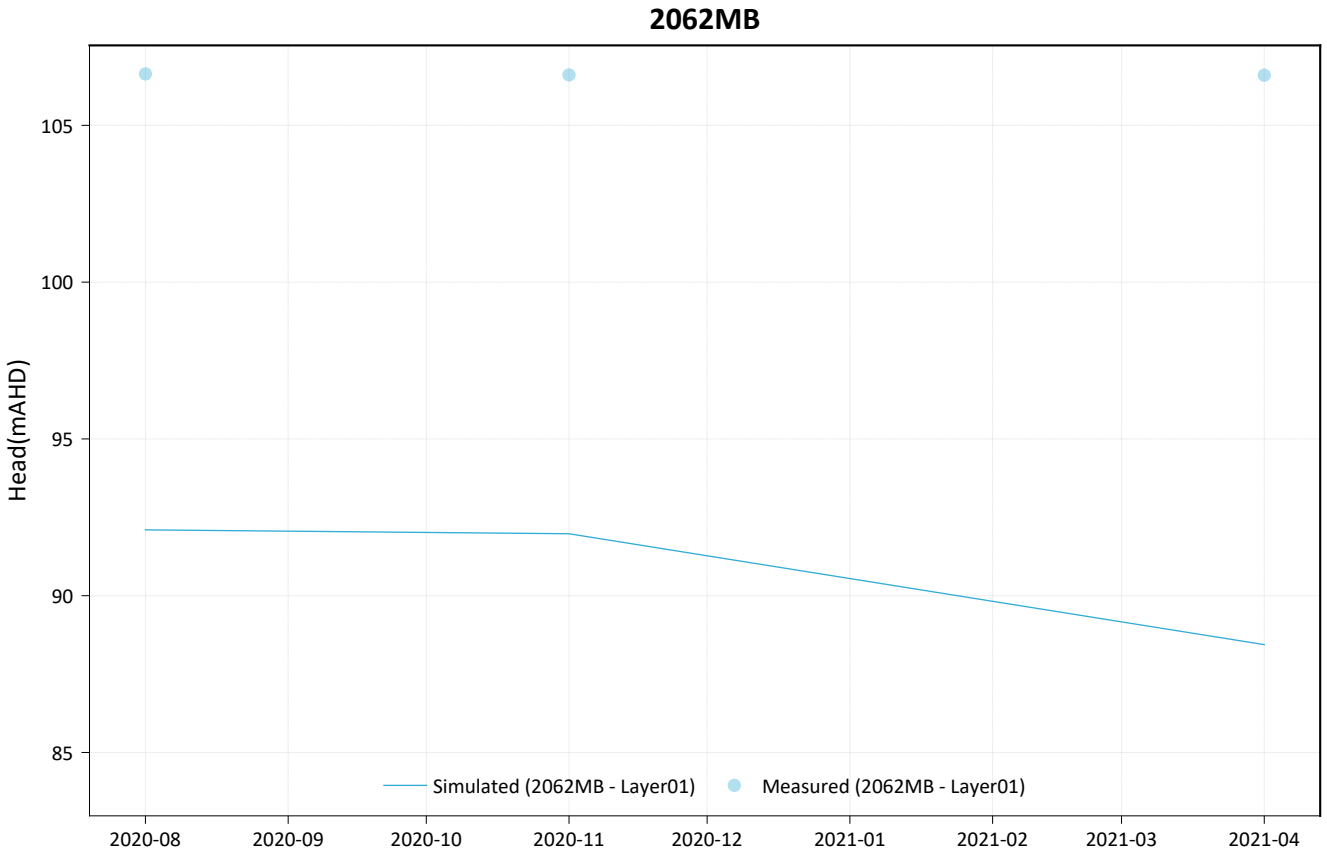


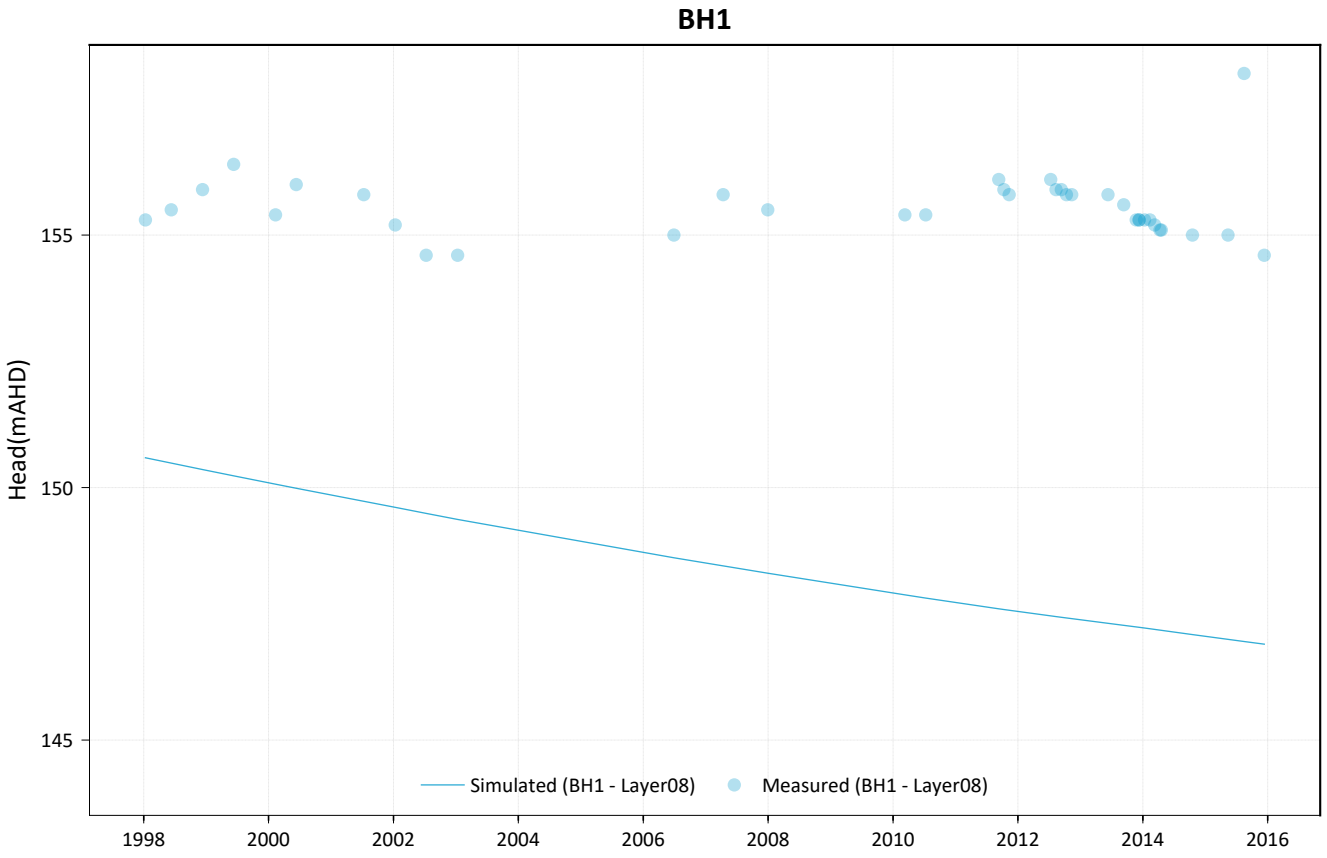
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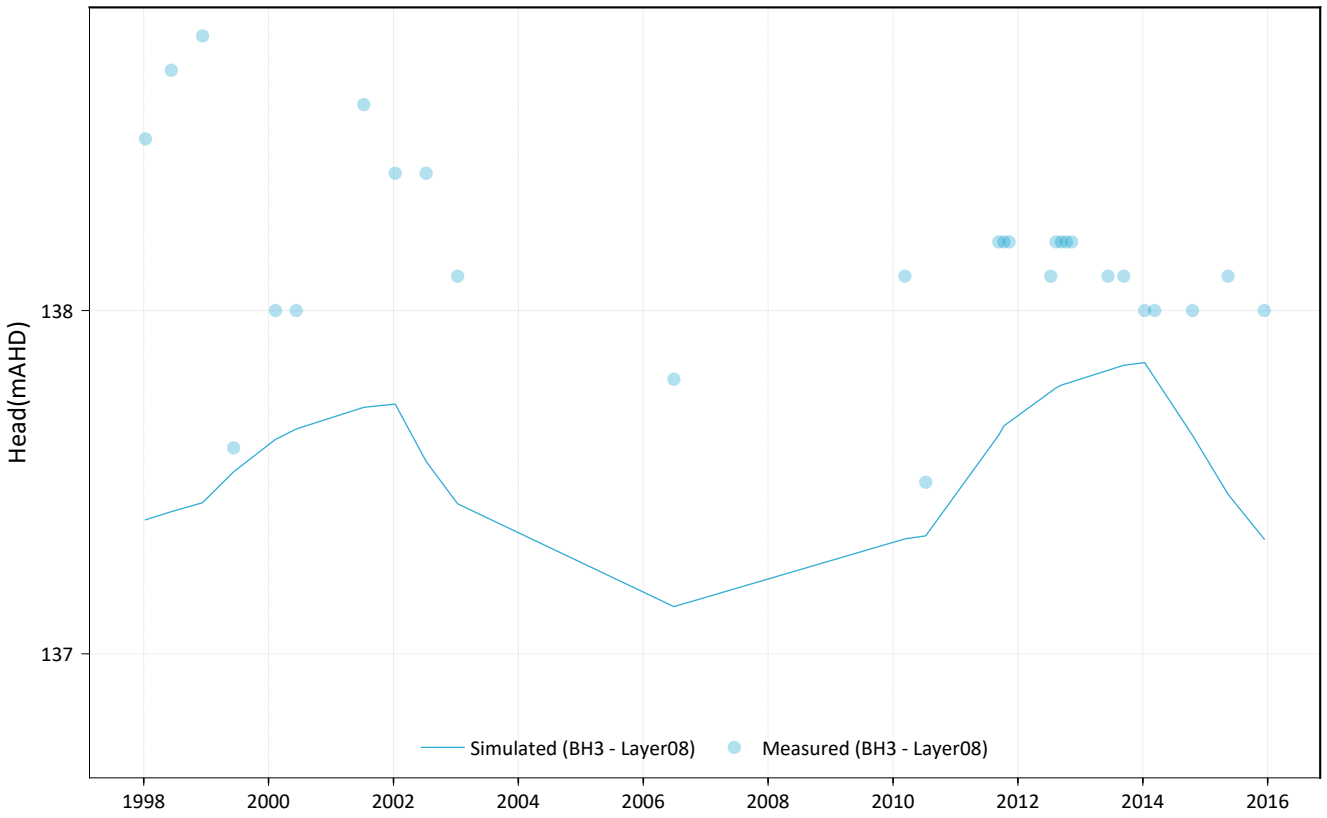
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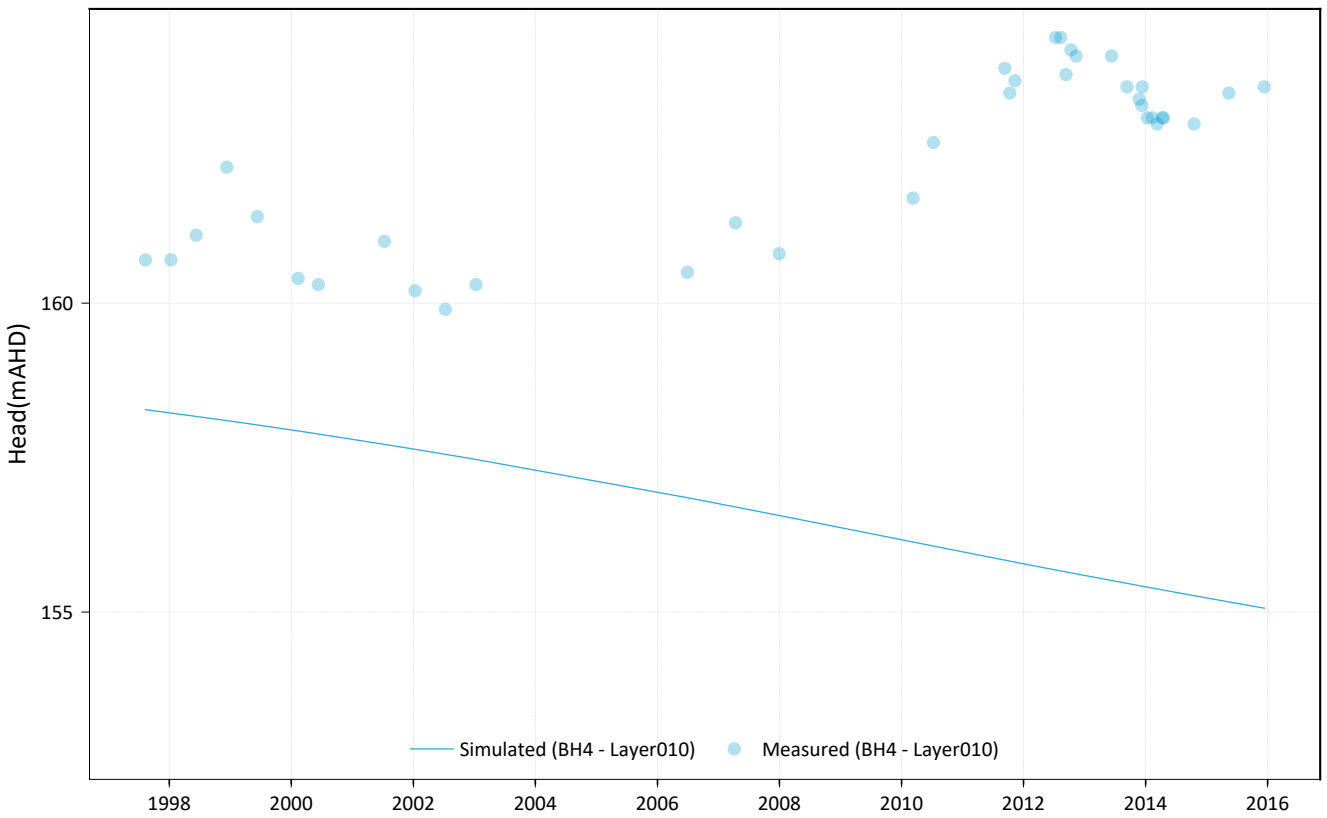

2062MB
Head(mAHD)
105
100
95
90
85
Simulated (2062MB - Layer01)
Measured (2062MB - Layer01)
2020-08
2020-09
2020-10
2020-11
2020-12
2021-01
2021-02
2021-03
2021-04


BH1
Head(mAHD)
155
150
145
Simulated (BH1 - Layer08)
Measured (BH1 - Layer08)
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016

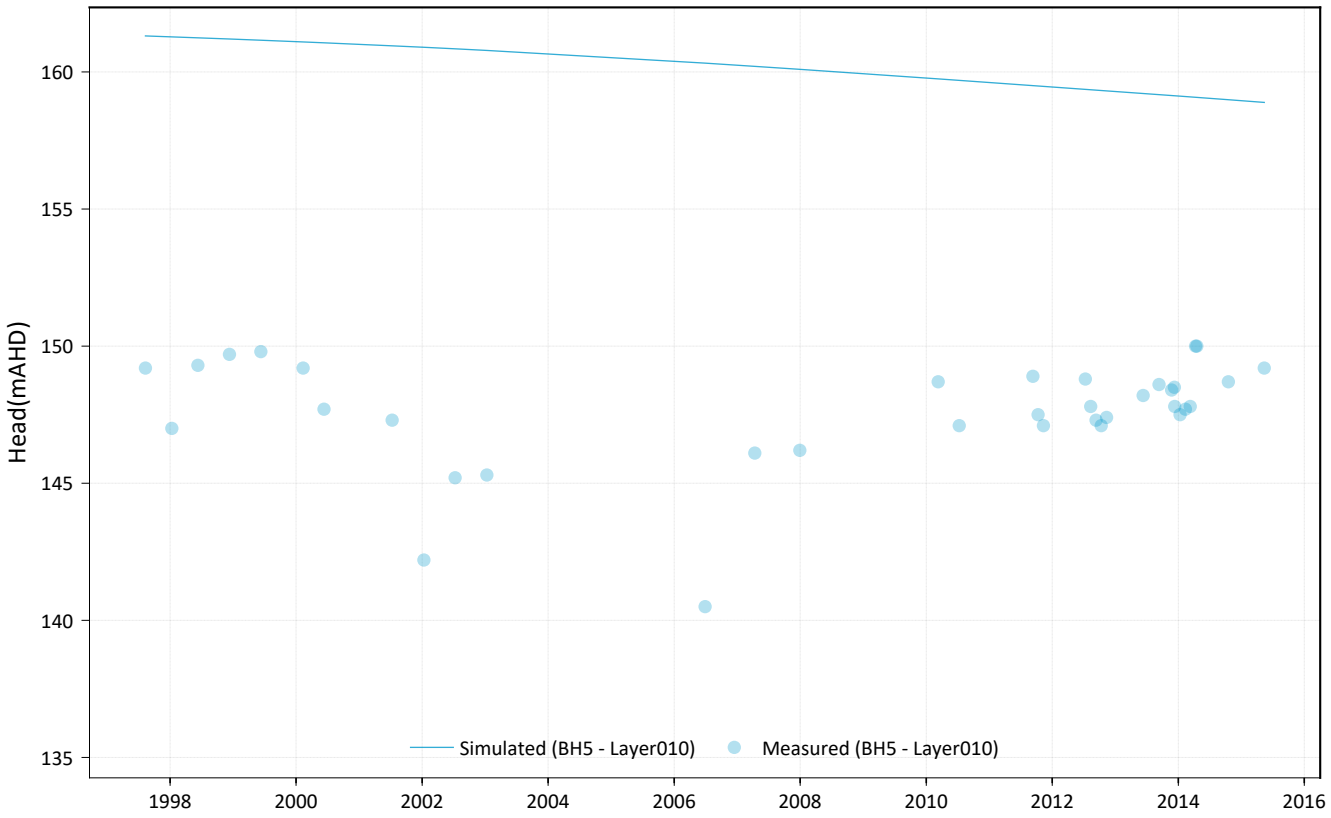
BH3


Head(mAHD)
138
137
Simulated (BH3 - Layer08)
Measured (BH3 - Layer08)
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016

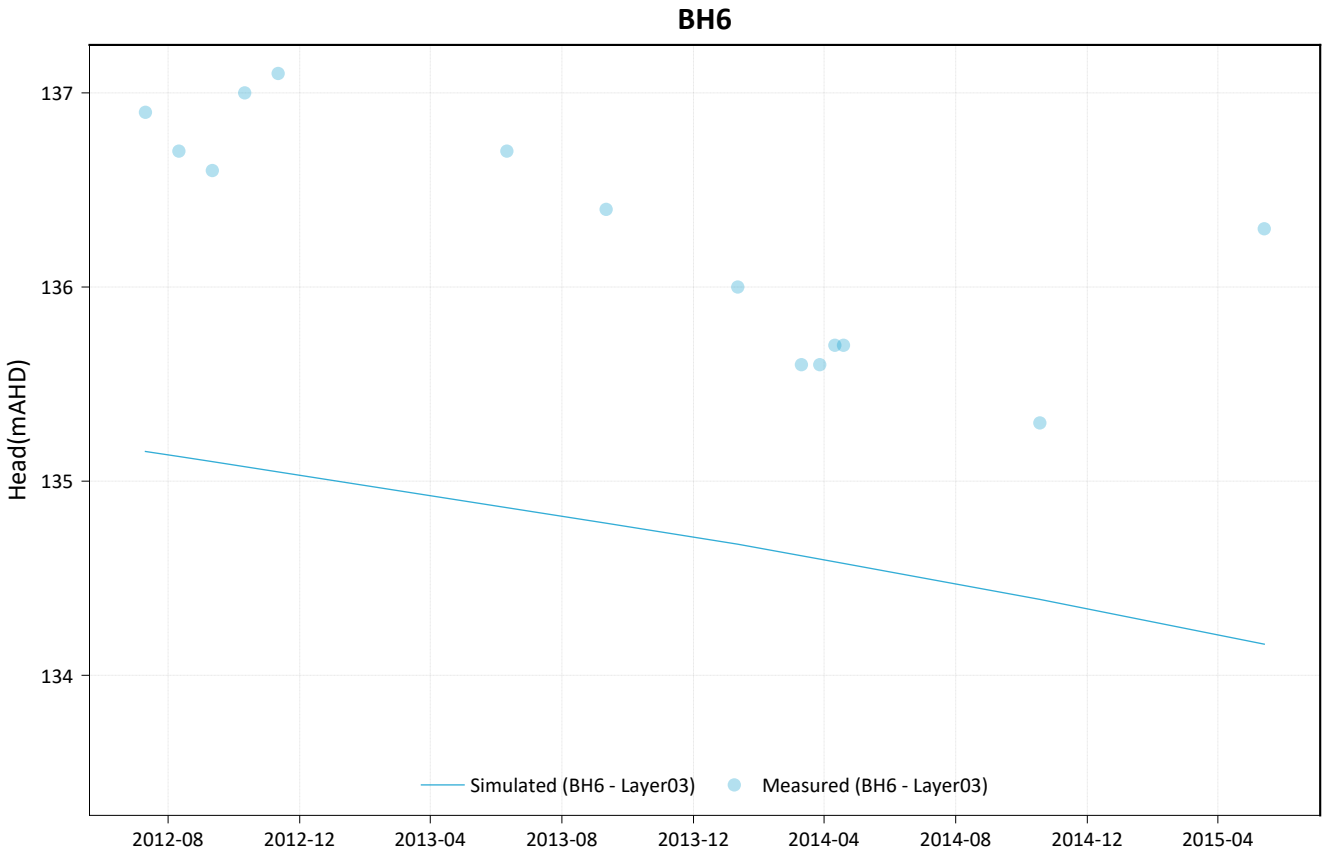
BH4


Head(mAHD)
160
155
Simulated (BH4 - Layer010)
Measured (BH4 - Layer010)
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016

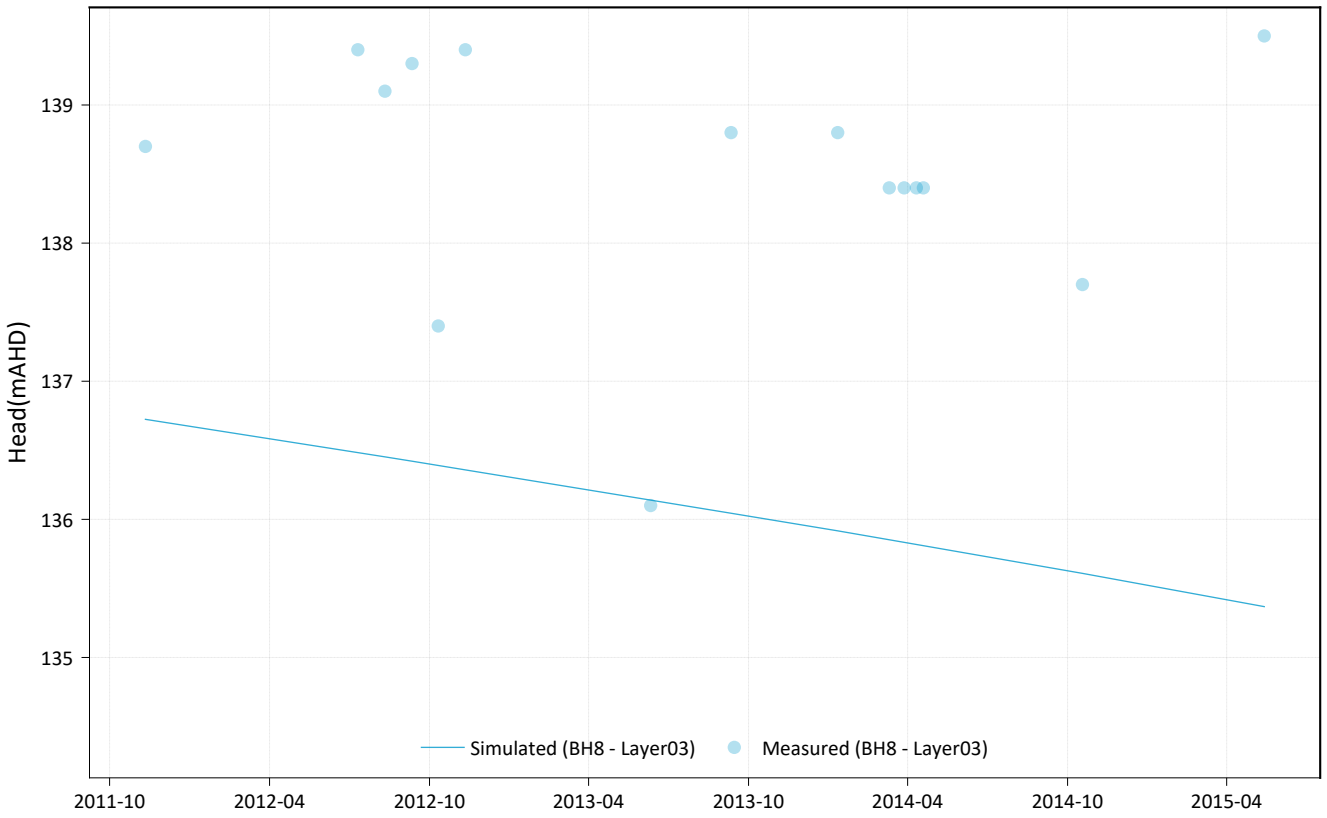
BH5


Head(mAHD)
160
155
150
145
140
135
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Simulated (BH5 - Layer010)
Measured (BH5 - Layer010)

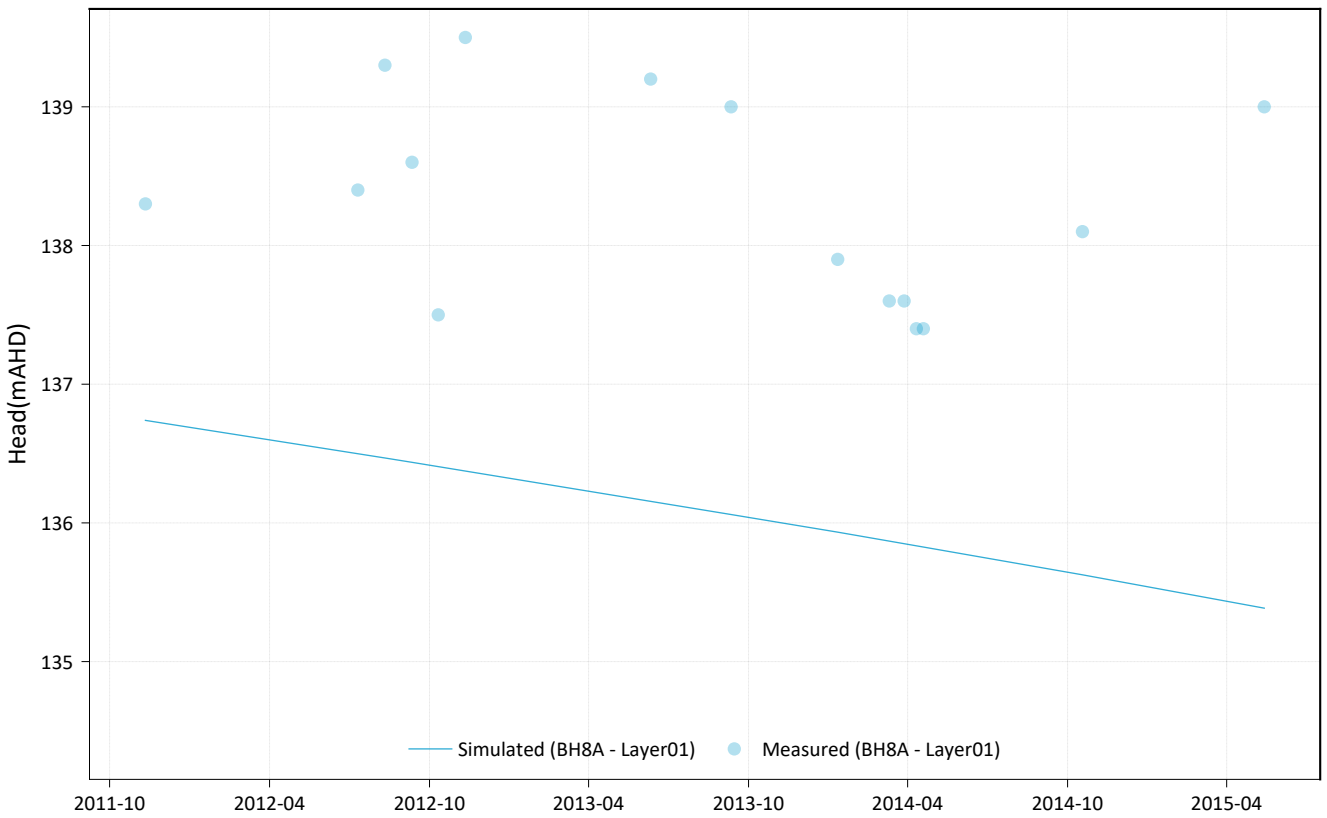
BH6


Head(mAHD)
137
136
135
134
2012-08
2012-12
2013-04
2013-08
2013-12
2014-04
2014-08
2014-12
2015-04
Simulated (BH6 - Layer03)
Measured (BH6 - Layer03)

BH8

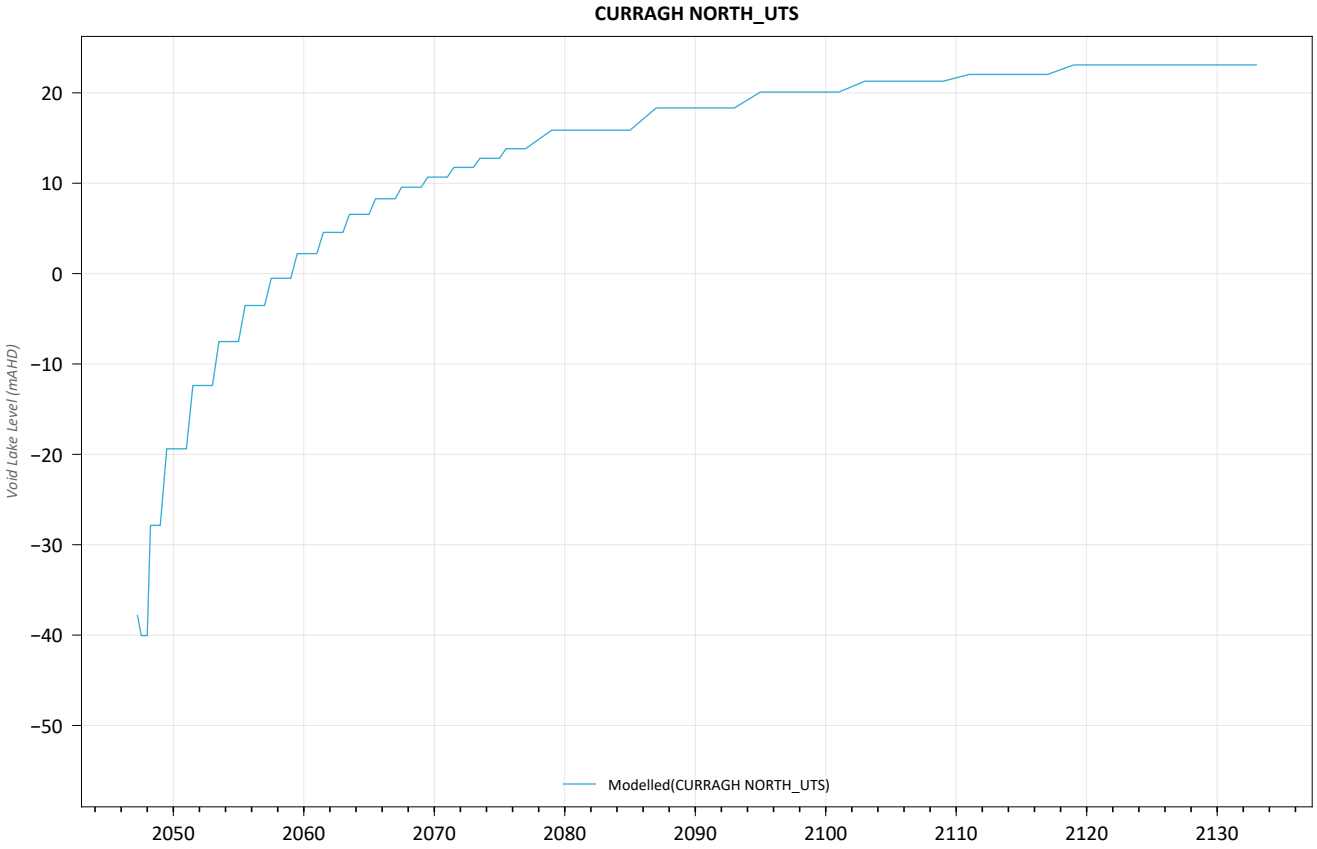

Head(mAHD)
139
138
137
136
135
Simulated (BH8 - Layer03)
Measured (BH8 - Layer03)
2011-10
2012-04
2012-10
2013-04
2013-10
2014-04
2014-10
2015-04

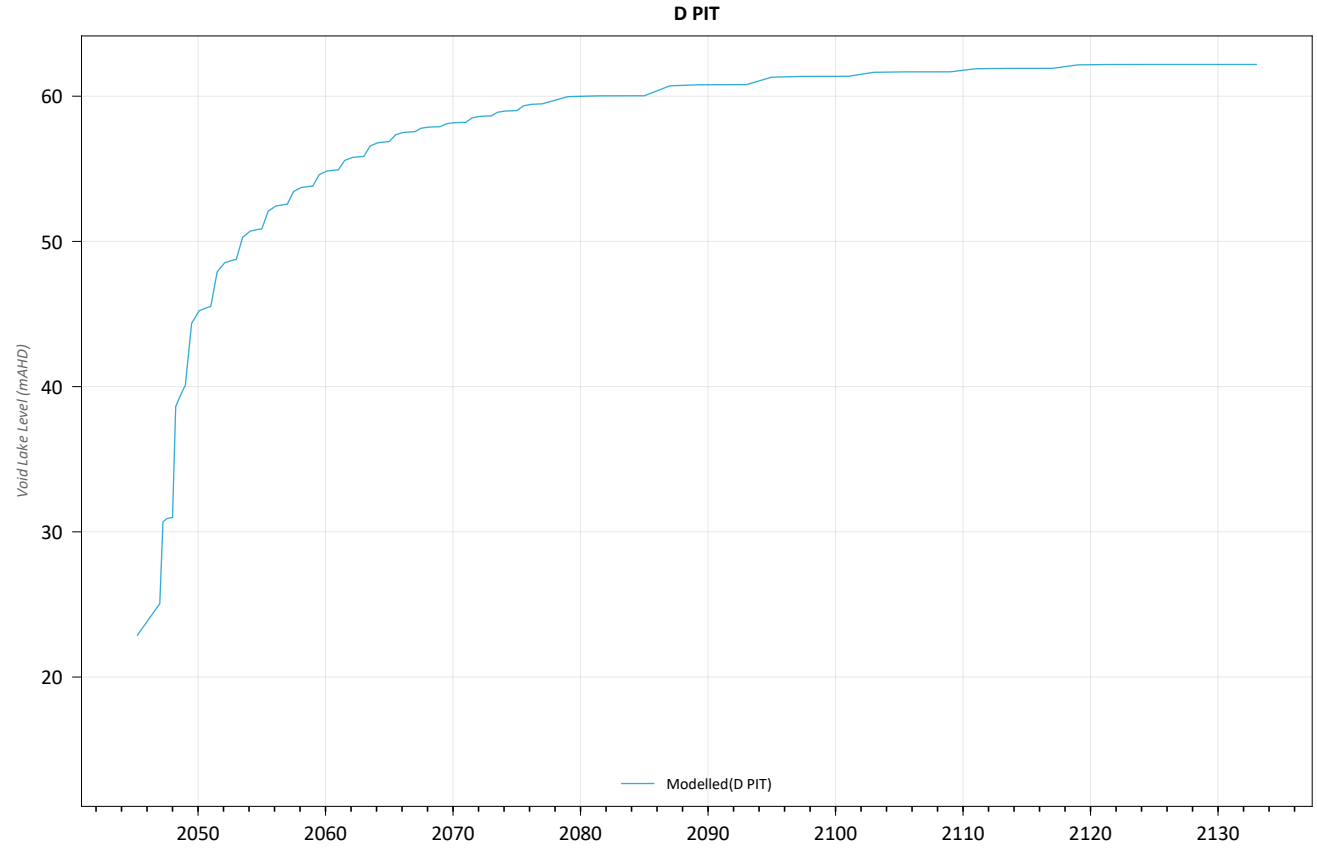
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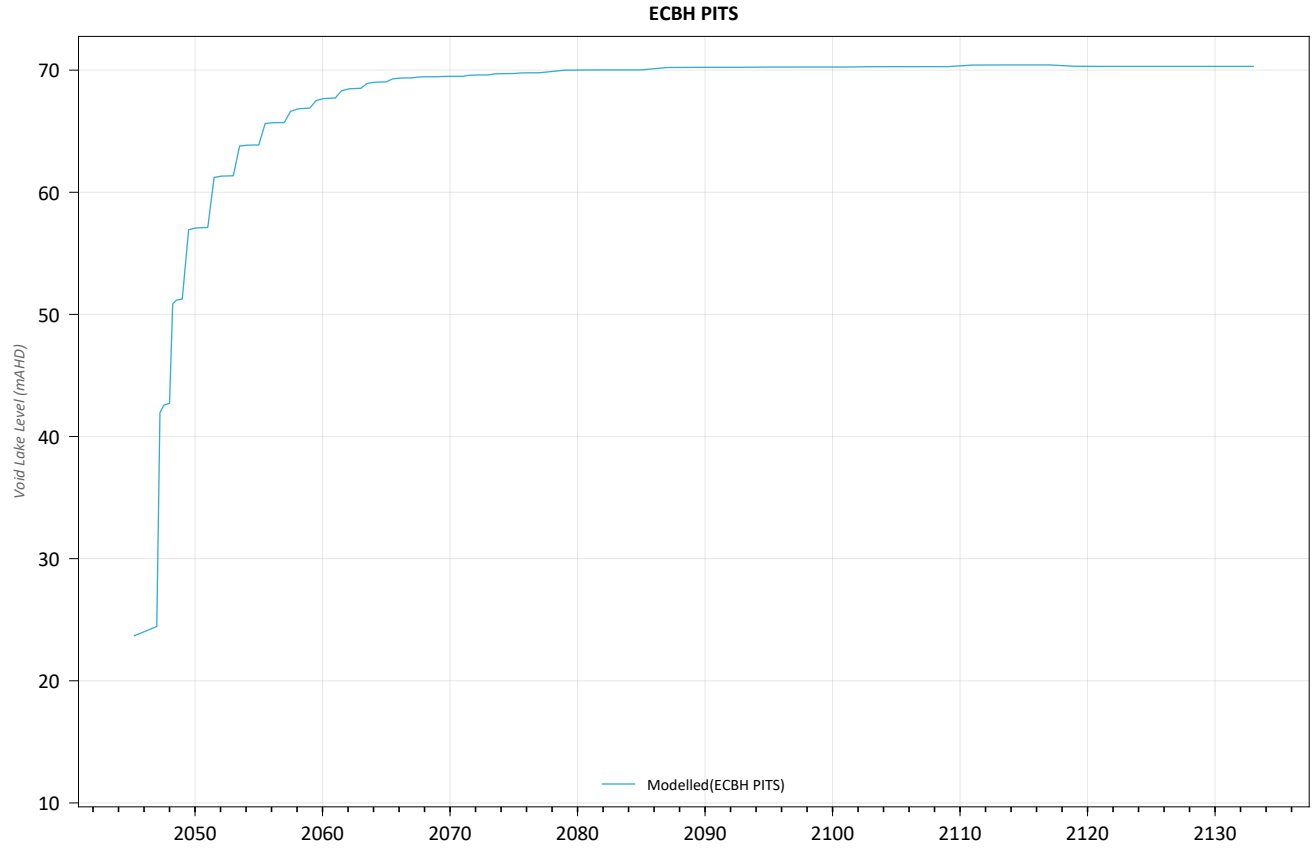

Head(mAHD)
139
138
137
136
135
Simulated (BH8A - Layer01)
Measured (BH8A - Layer01)
2011-10
2012-04
2012-10
2013-04
2013-10
2014-04
2014-10
2015-04

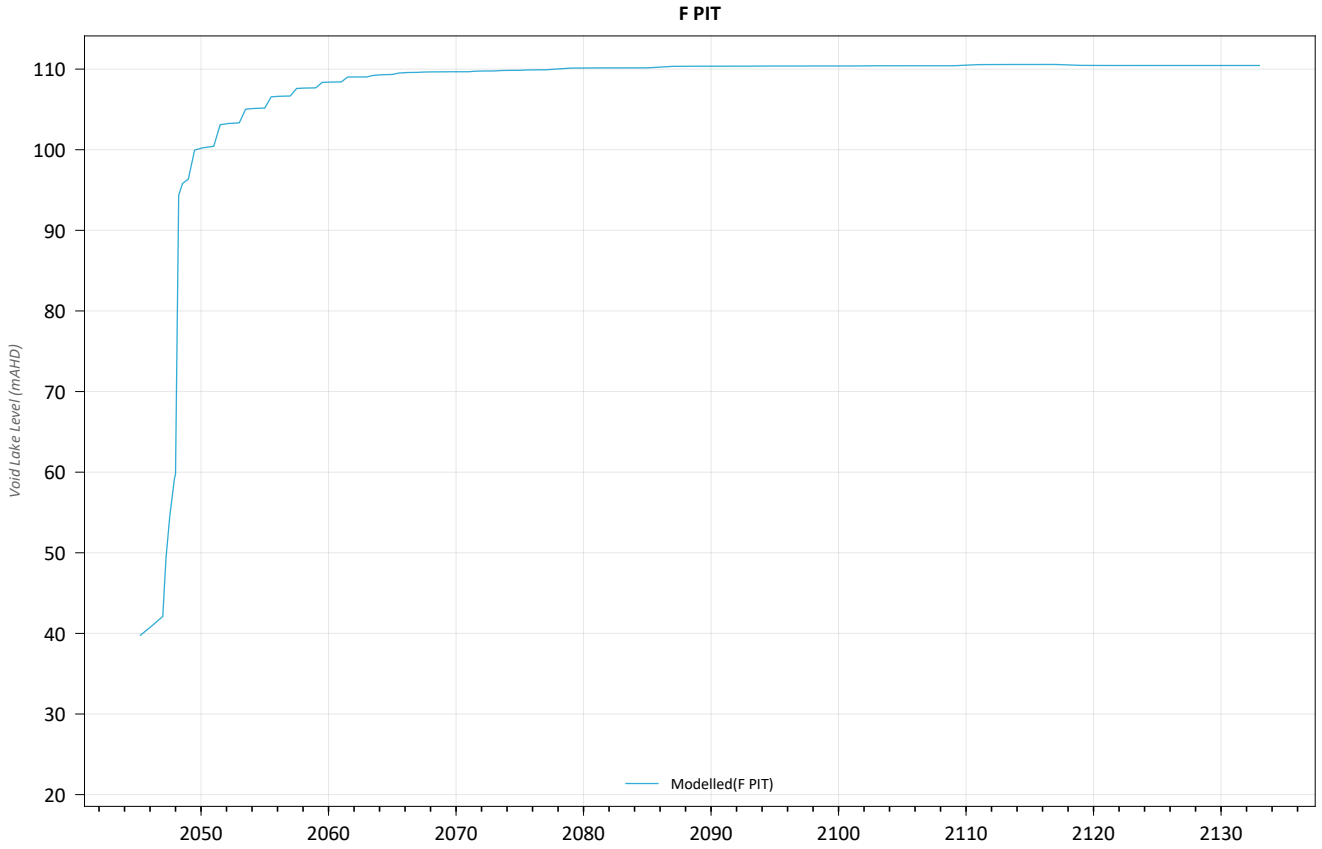
APPENDIX D

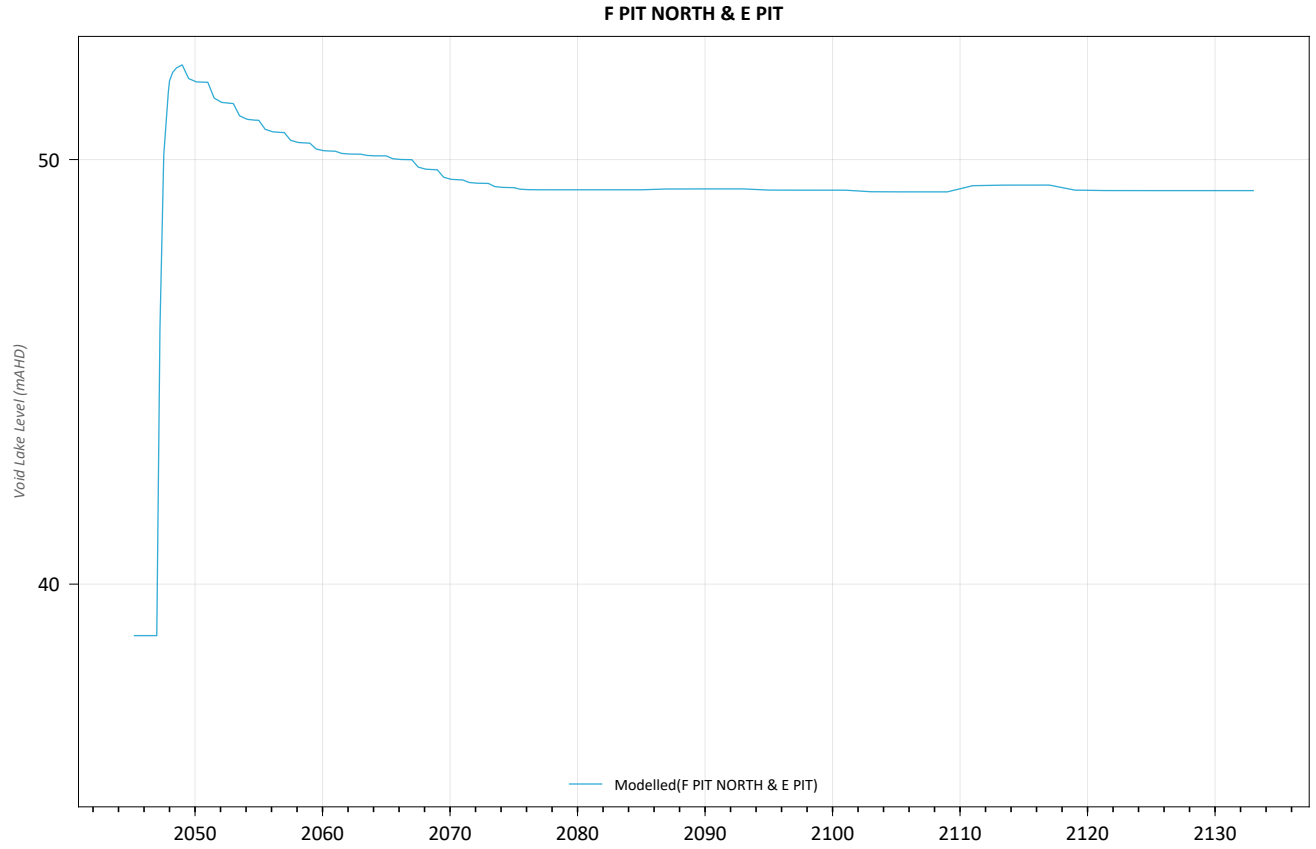
Post Mining Recovery Hydrographs

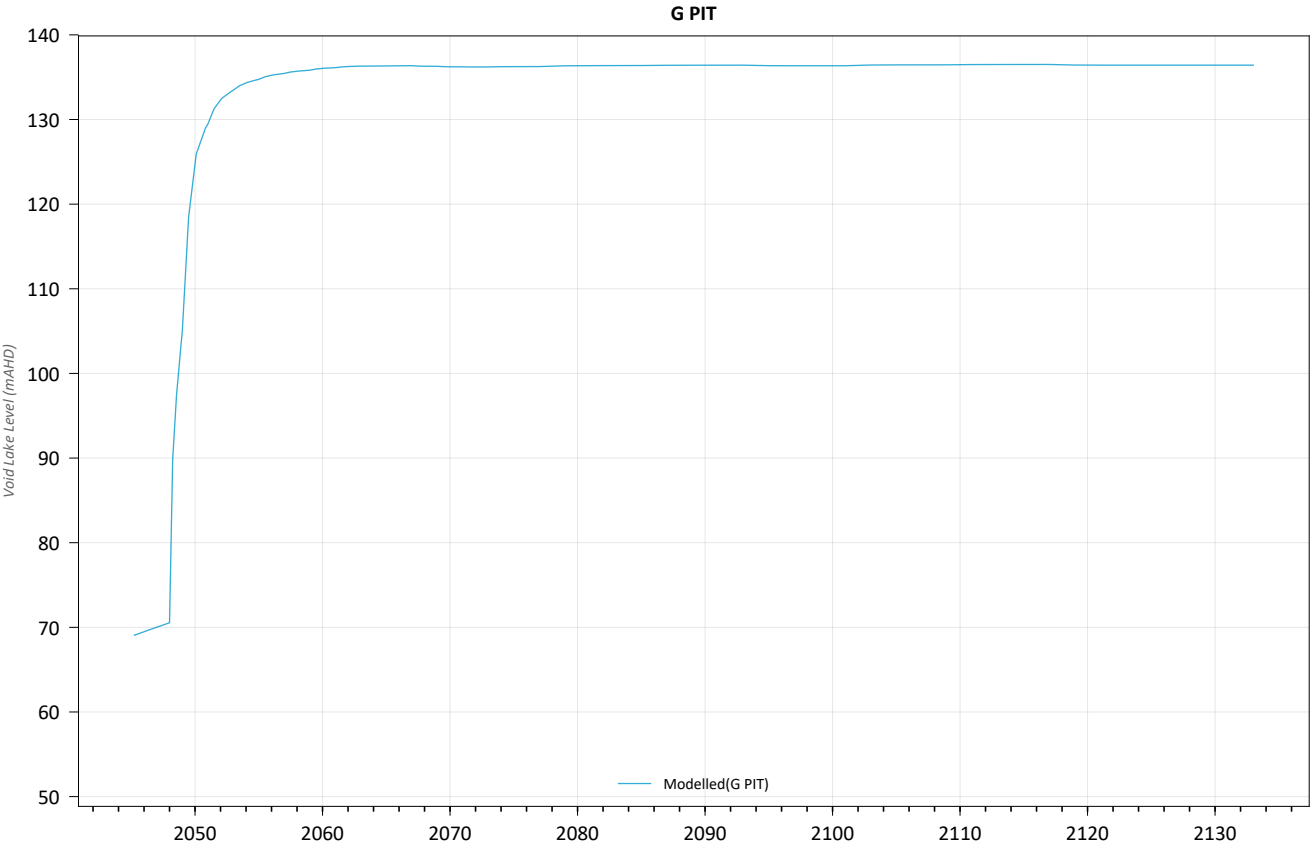

CURRAGH NORTH_UTS
Void Lake Level (mAHD)
20
10
0
−10
−20
−30
−40
−50
2050
2060
2070
2080
2090
2100
2110
2120
2130
Modelled(CURRAGH NORTH_UTS)

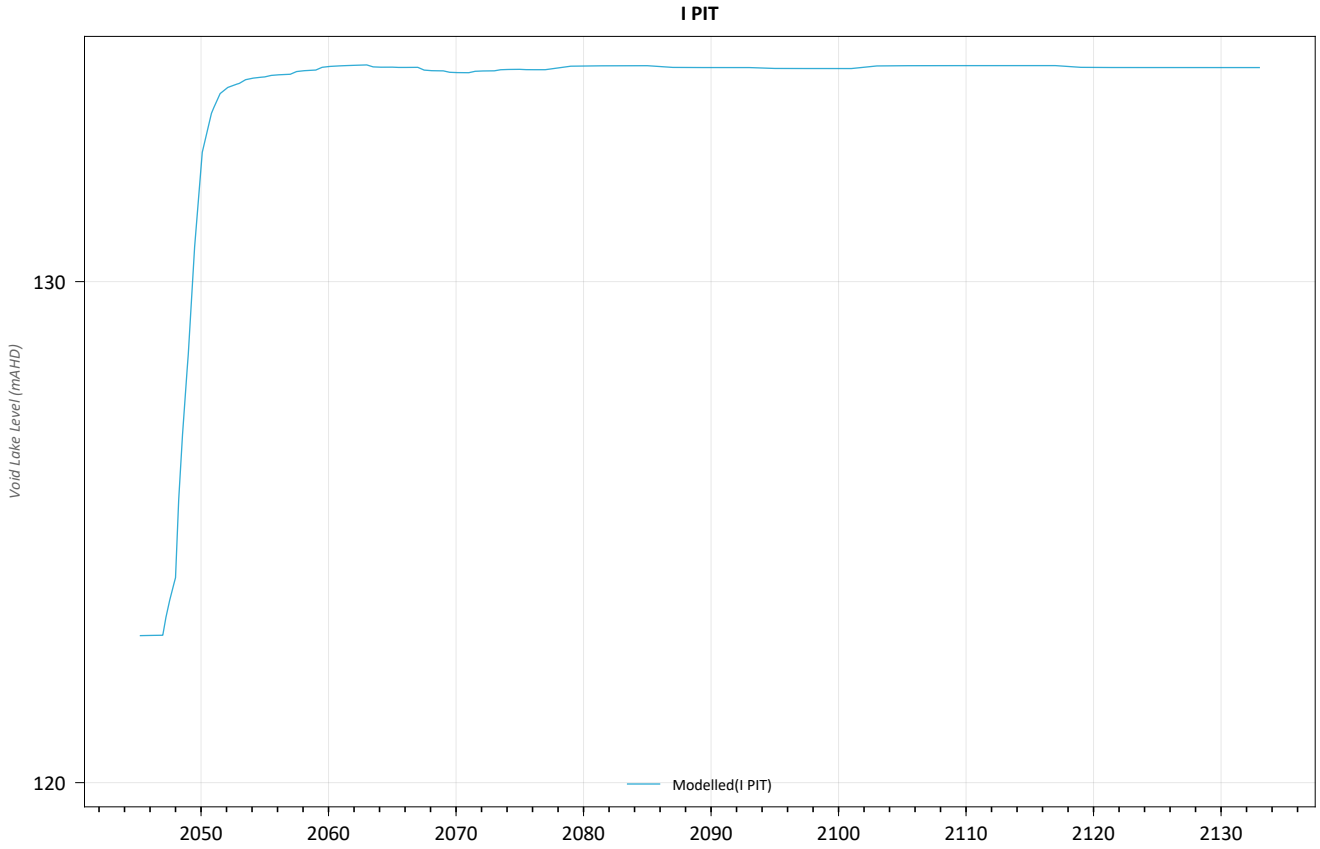

D PIT
Void Lake Level (mAHD)
60
50
40
30
20
2050
2060
2070
2080
2090
2100
2110
2120
2130
Modelled(D PIT)

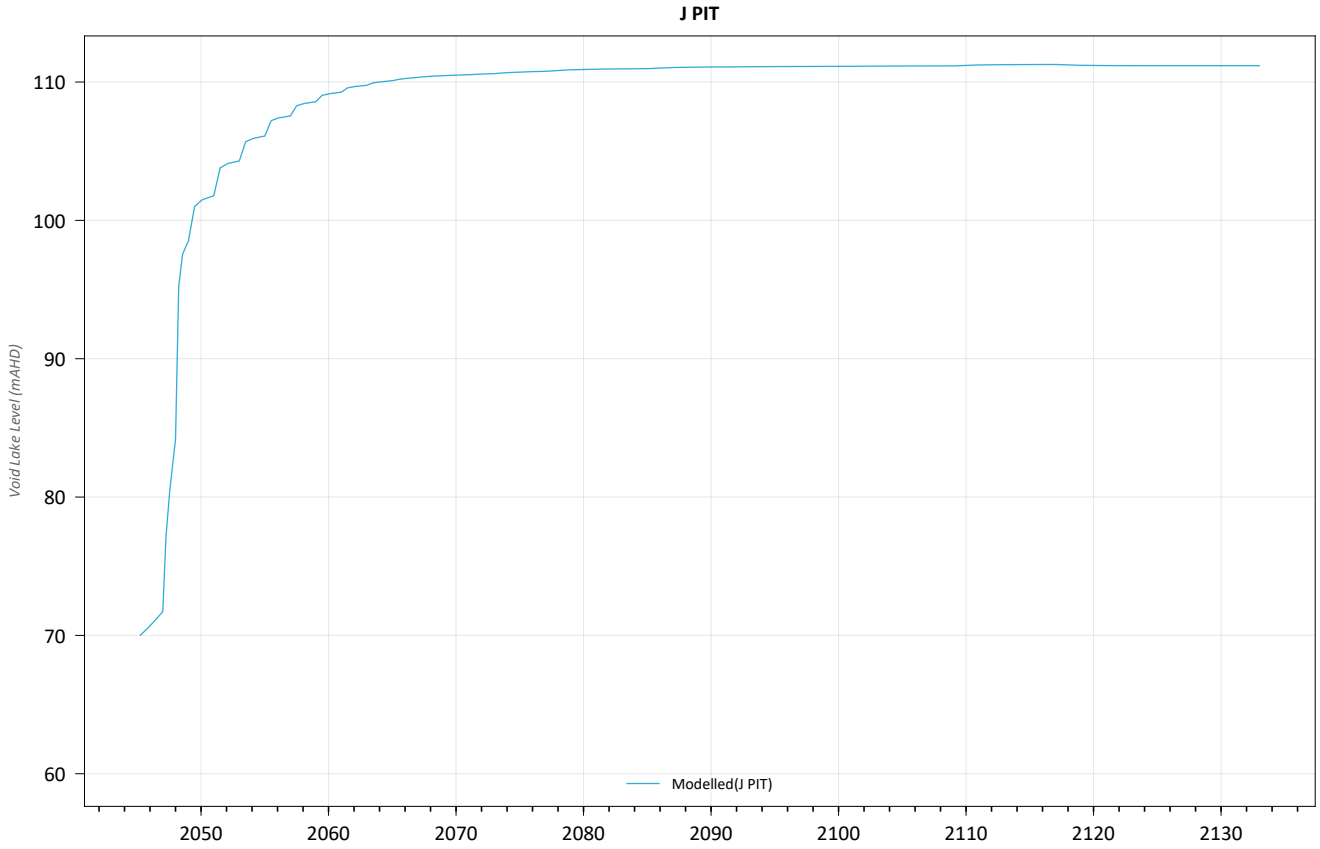

ECBH PITS
Void Lake Level (mAHD)
70
60
50
40
30
20
10
2050
2060
2070
2080
2090
2100
2110
2120
2130
Modelled(ECBH PITS)

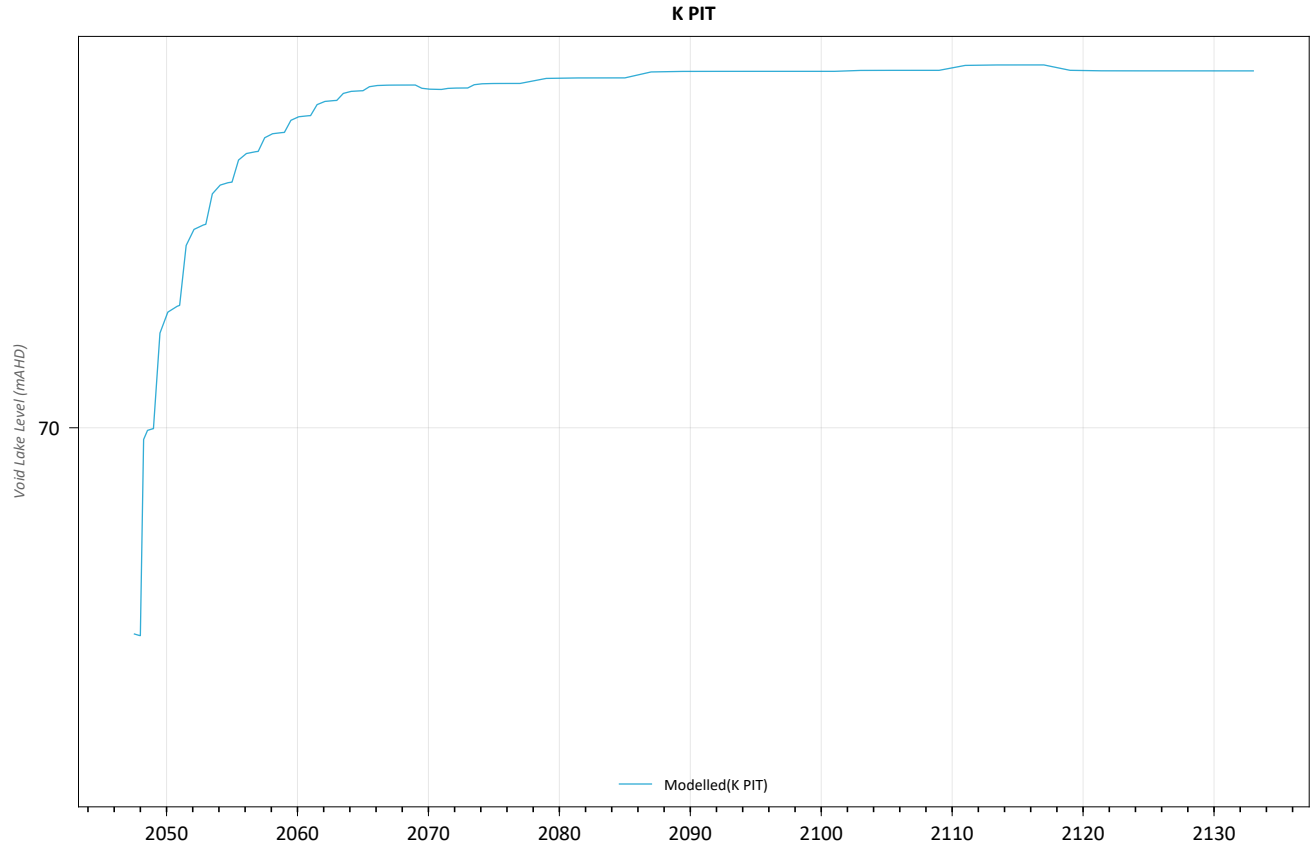

F PIT
Void Lake Level (mAHD)
110
100
90
80
70
60
50
40
30
20
2050
2060
2070
2080
2090
2100
2110
2120
2130
Modelled(F PIT)

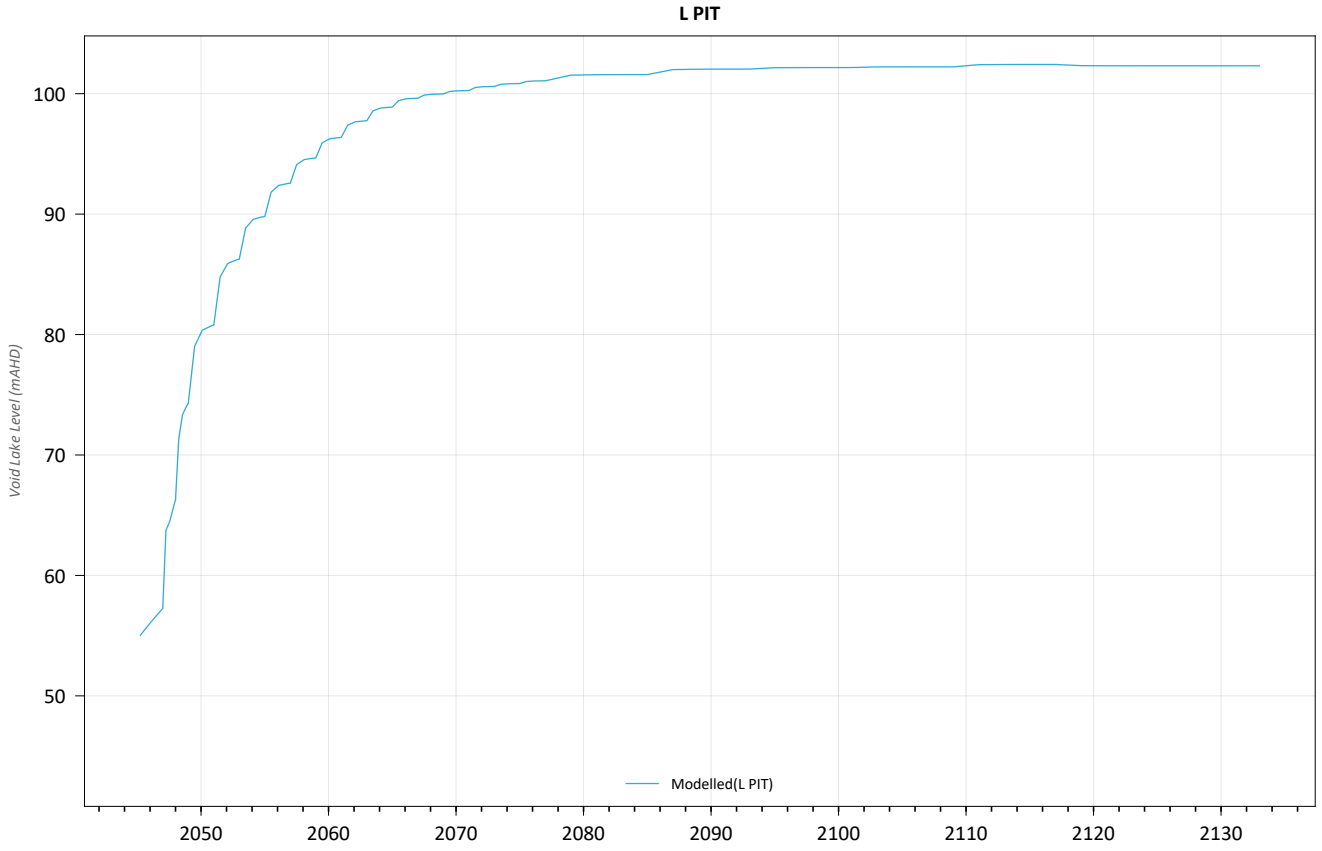

F PIT NORTH & E PIT
Void Lake Level (mAHD)
50
40
Modelled(F PIT NORTH & E PIT)
2050
2060
2070
2080
2090
2100
2110
2120
2130

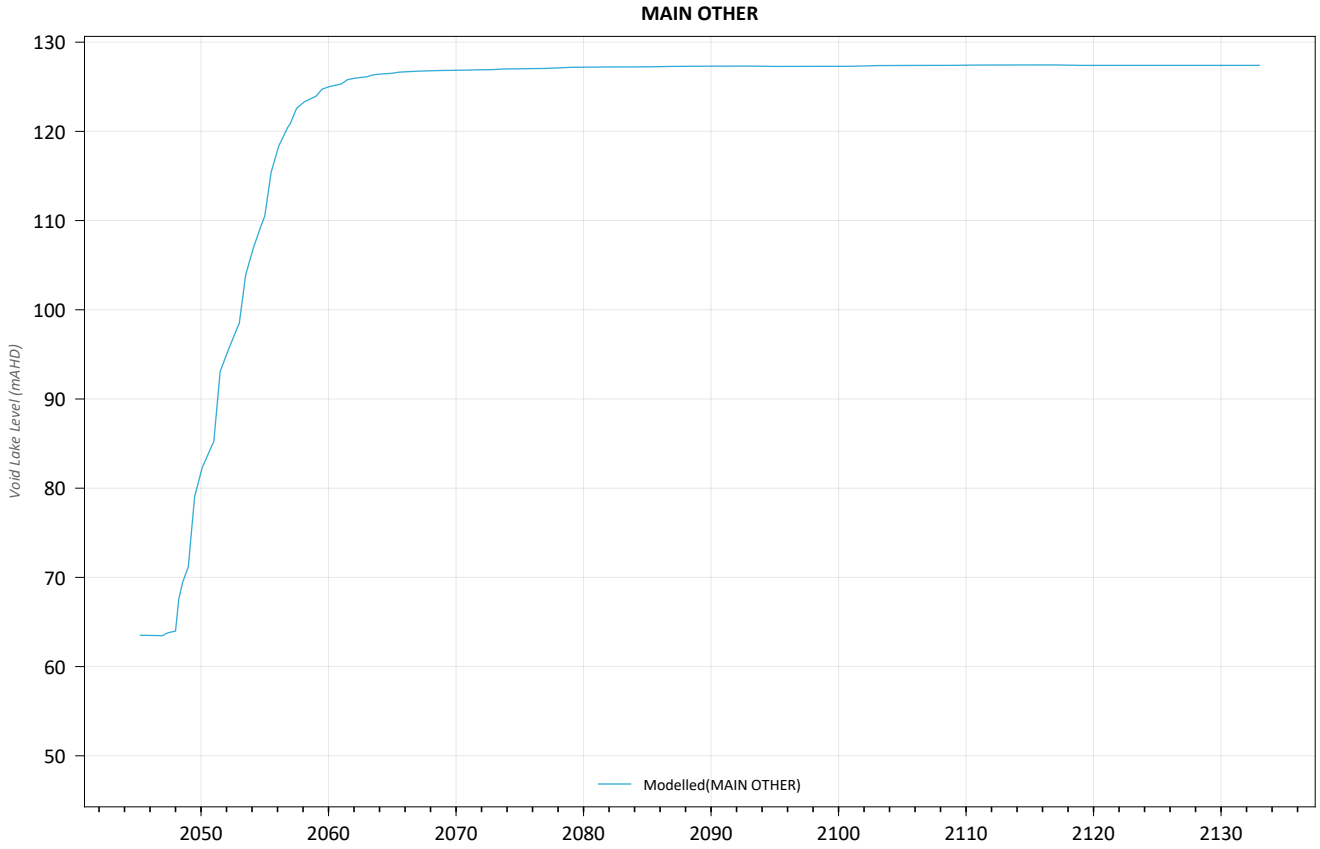

G PIT
Void Lake Level (mAHD)
140
130
120
110
100
90
80
70
60
50
Modelled(G PIT)
2050
2060
2070
2080
2090
2100
2110
2120
2130

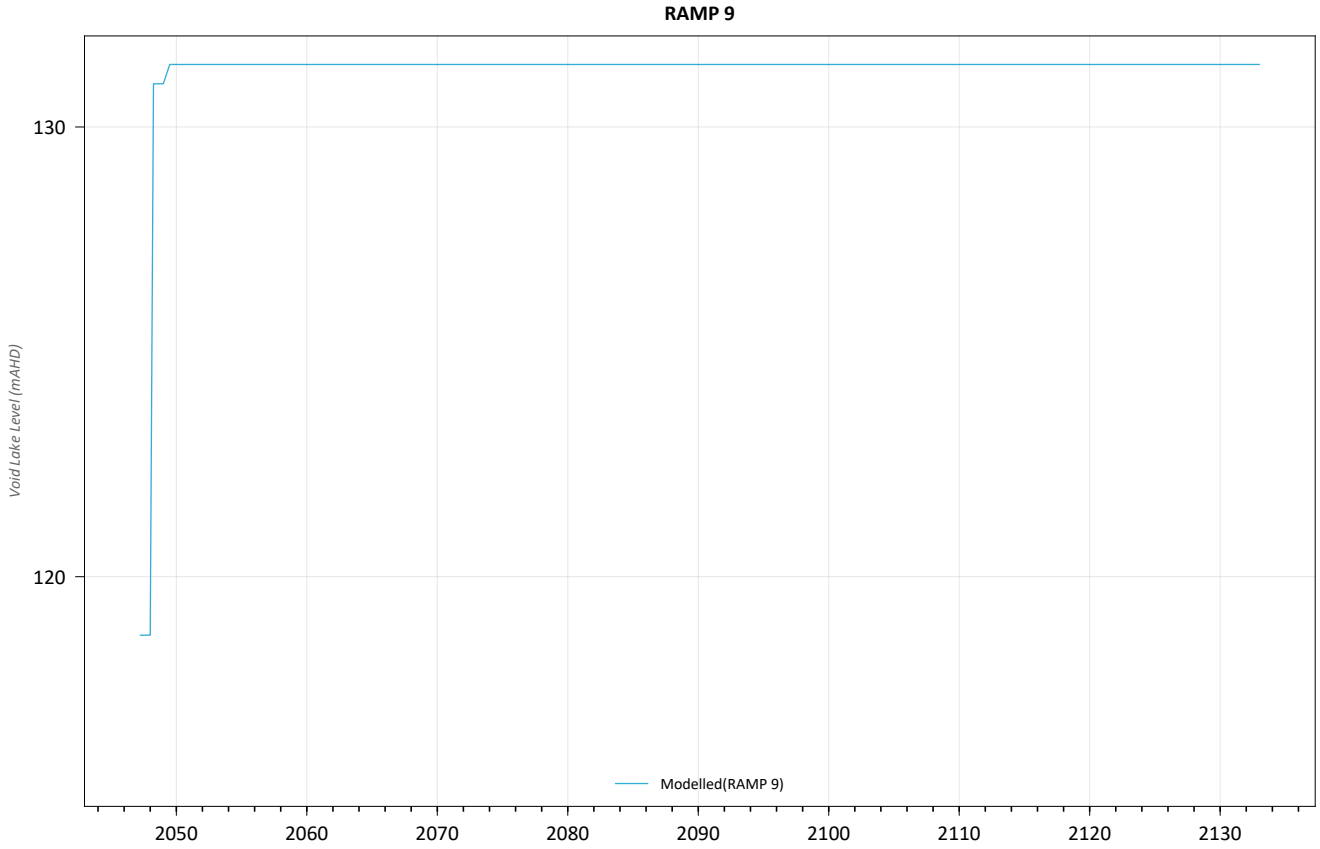

I PIT
Void Lake Level (mAHD)
130
120
Modelled(I PIT)
2050
2060
2070
2080
2090
2100
2110
2120
2130

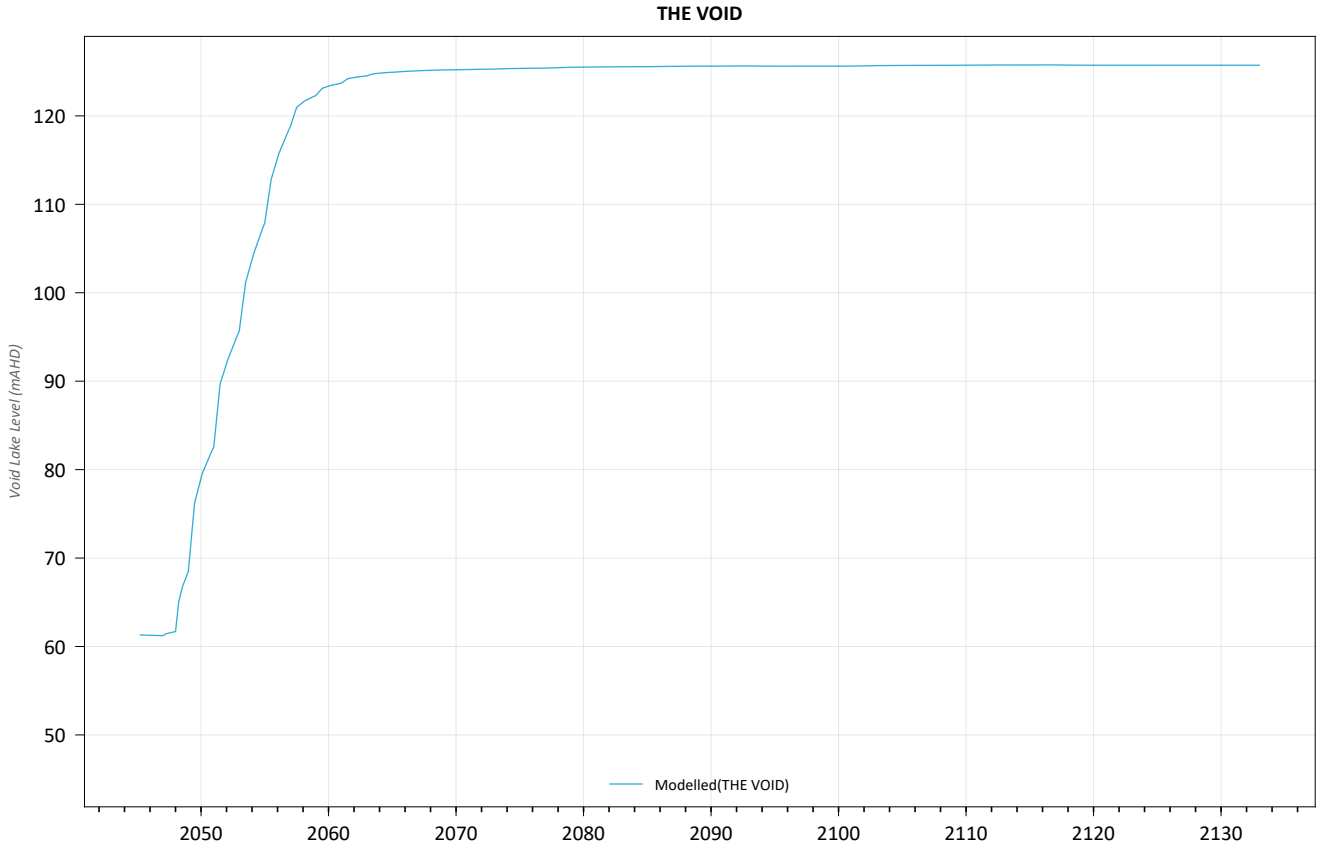

J PIT
Void Lake Level (mAHD)
110
100
90
80
70
60
Modelled(J PIT)
2050
2060
2070
2080
2090
2100
2110
2120
2130

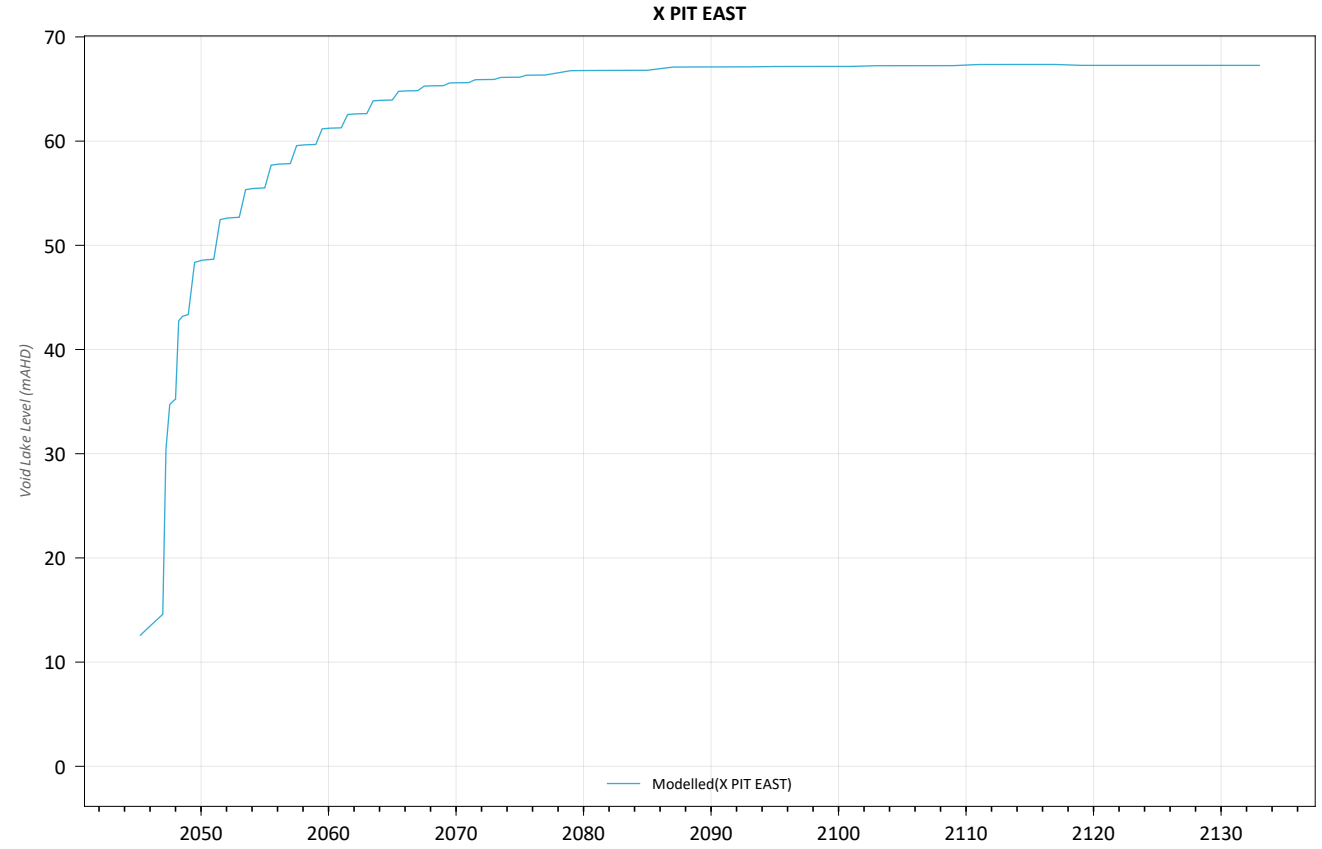

K PIT
Void Lake Level (mAHD)
70
Modelled(K PIT)
2050
2060
2070
2080
2090
2100
2110
2120
2130

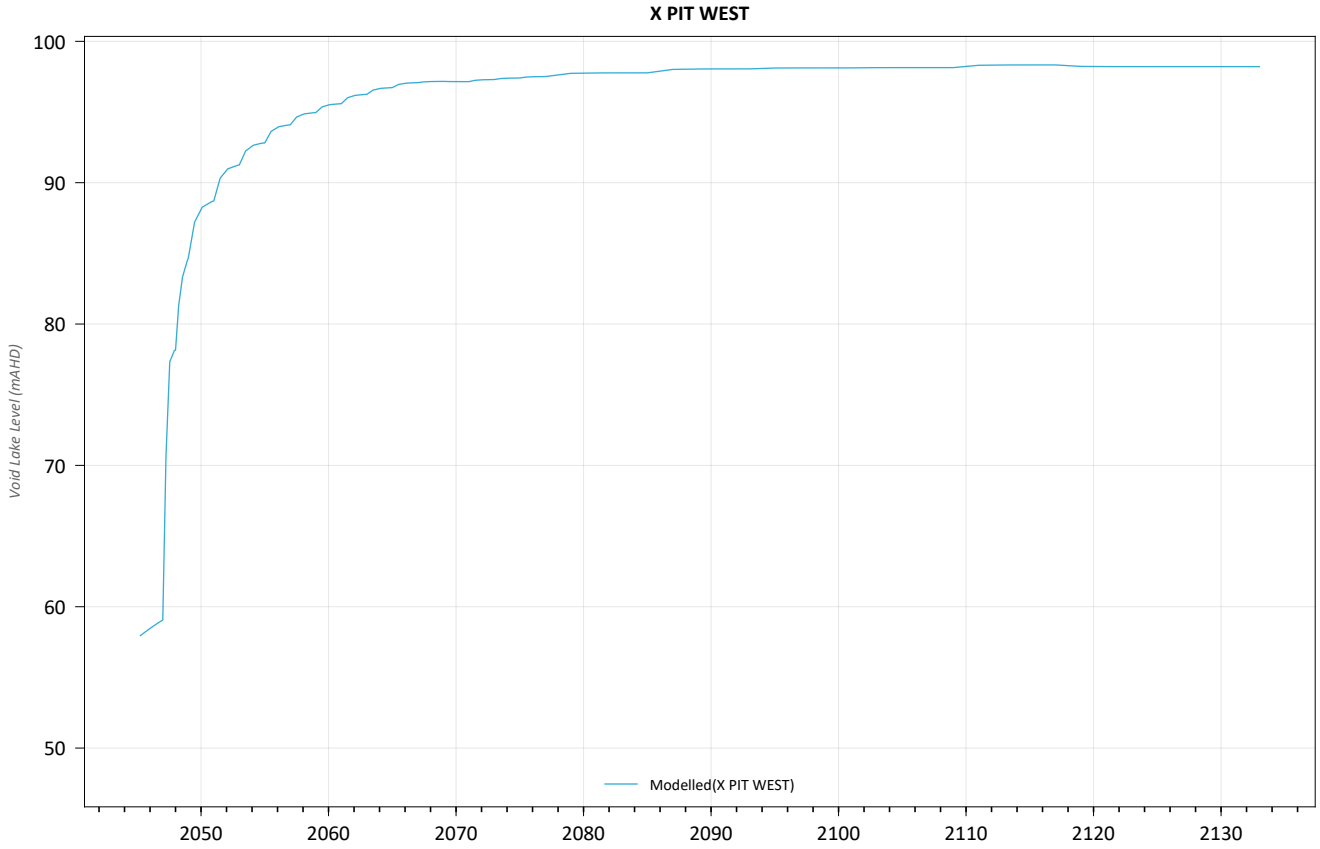

L PIT
Void Lake Level (mAHD)
100
90
80
70
60
50
Modelled(L PIT)
2050
2060
2070
2080
2090
2100
2110
2120
2130

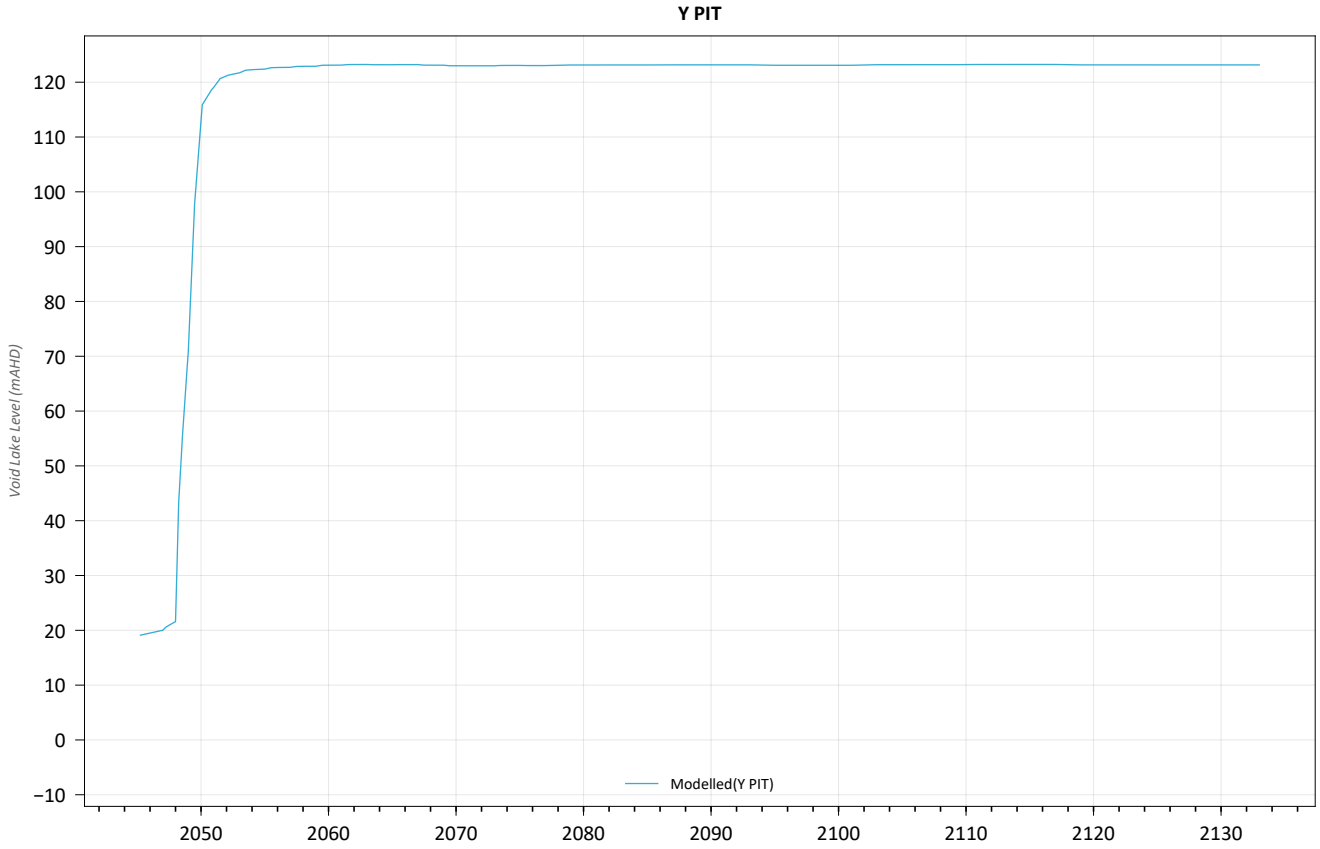

MAIN OTHER
Void Lake Level (mAHD)
130
120
110
100
90
80
70
60
50
2050
2060
2070
2080
2090
2100
2110
2120
2130
Modelled(MAIN OTHER)

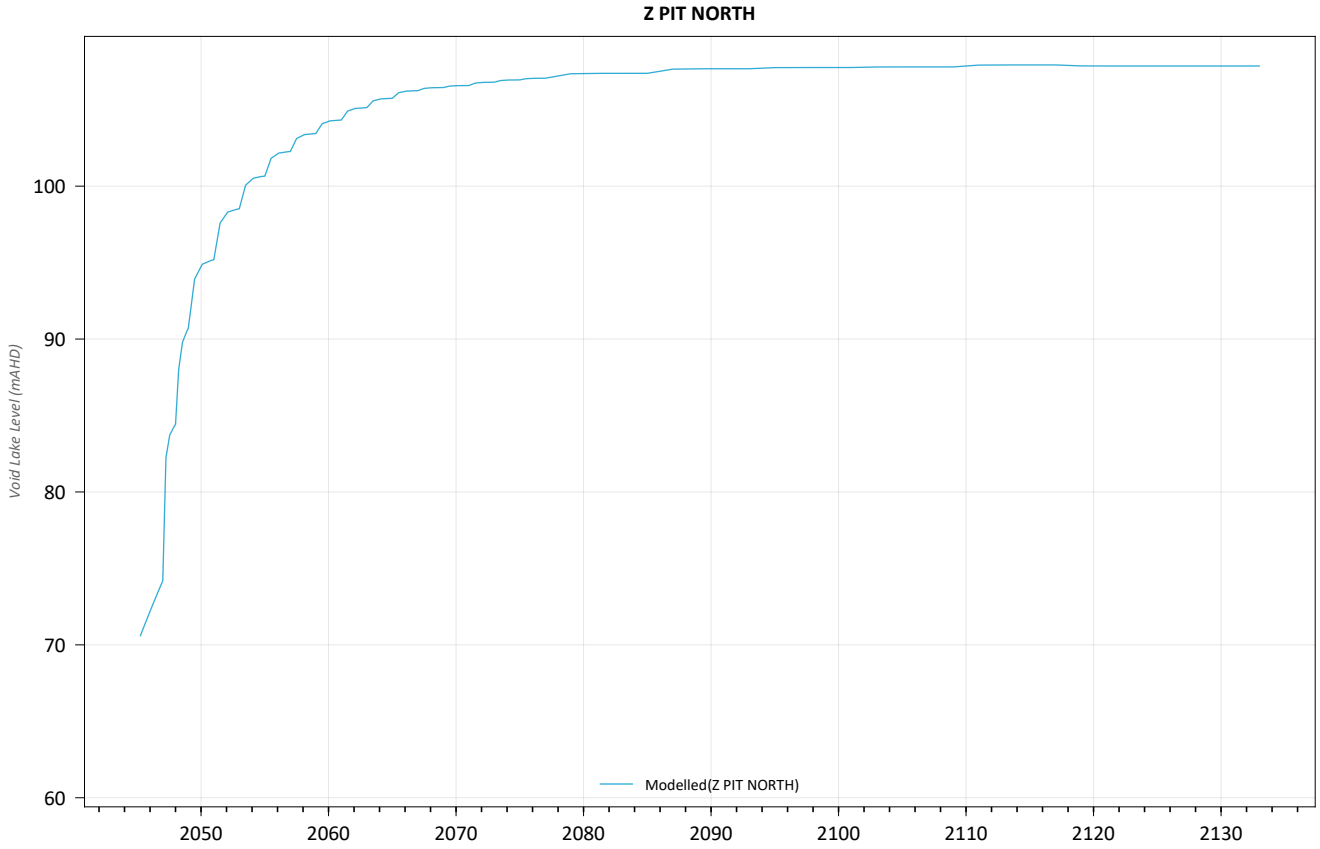

RAMP 9
Void Lake Level (mAHD)
130
120
2050
2060
2070
2080
2090
2100
2110
2120
2130
Modelled(RAMP 9)

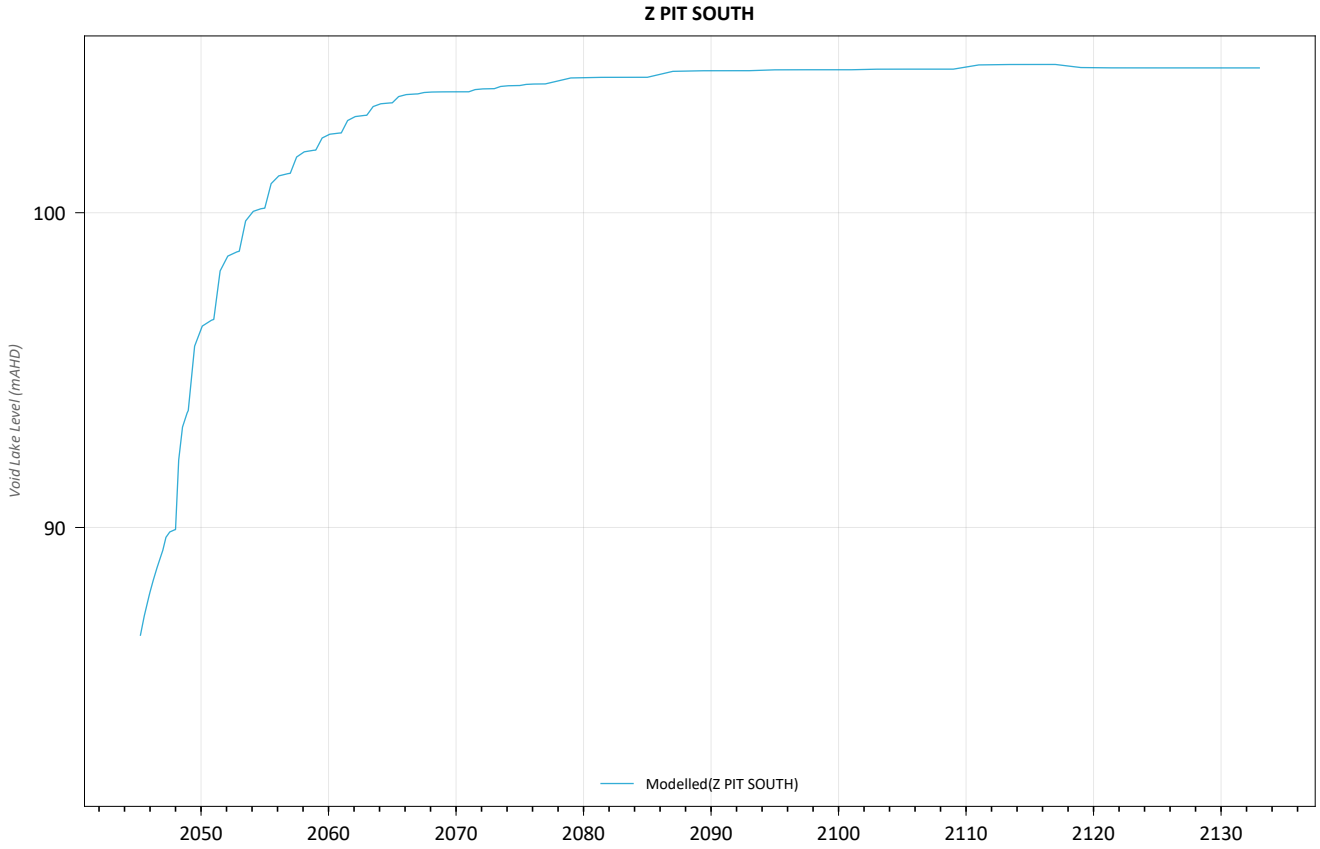

THE VOID
Void Lake Level (mAHD)
120
110
100
90
80
70
60
50
Modelled(THE VOID)
2050
2060
2070
2080
2090
2100
2110
2120
2130


X PIT EAST
Void Lake Level (mAHD)
70
60
50
40
30
20
10
0
Modelled(X PIT EAST)
2050
2060
2070
2080
2090
2100
2110
2120
2130


X PIT WEST
Void Lake Level (mAHD)
100
90
80
70
60
50
2050
2060
2070
2080
2090
2100
2110
2120
2130
Modelled(X PIT WEST)


Y PIT
Void Lake Level (mAHD)
120
110
100
90
80
70
60
50
40
30
20
10
0
−10
2050
2060
2070
2080
2090
2100
2110
2120
2130
Modelled(Y PIT)


Z PIT NORTH
Void Lake Level (mAHD)
100
90
80
70
60
2050
2060
2070
2080
2090
2100
2110
2120
2130
Modelled(Z PIT NORTH)


Z PIT SOUTH
Void Lake Level (mAHD)
100
90
2050
2060
2070
2080
2090
2100
2110
2120
2130
Modelled(Z PIT SOUTH)

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APPENDIX H

Topsoil Quality Assessment Report



Topsoil Quality Assessment Report

Coronado Curragh Pty Ltd

20 July 2022

Version Control

Please update this version control with updates when applicable:

Version Number	Date	Name	Update Details
1	25/Aug/2020	C Merlow	
2	20/Jul/2022	M Bourke	Update to reflect 2022 stockpile location and volume data

Review Status	
☐	Review by Click here to enter a date.
■	Review not required

Prepared	
■	By Curragh
☐	For Curragh Under PO/Contract Number:

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Curragh 18

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Appendix B – Laboratory Results 25

1.0 Introduction

This soil assessment report details information including spatial distribution, volumes and quality of topsoil stockpiles within the Curragh Mine. Coronado Curragh Pty Ltd (Curragh) has conducted this assessment study to determine topsoil availability and quality to assist in the management of topsoil in progressive rehabilitation activities.

2.0 Objective

The objective of this report is to assess the suitability of the currently stockpiled topsoil at Curragh Mine for rehabilitation purposes, and to determine what portion of the stockpiled topsoil, if any, may require amelioration for planned rehabilitation. There have been several baseline land suitability and soil type assessments conducted on Curragh mining leases since its inception. These reports have focused on in situ topsoil classification and land suitability of both pre and post mining activities. Excerpts from these reports are provided in Appendix A and indicate up to six soil types across the mining leases, with varying soil chemistry (GT Environmental, AARC, LRS EHSS).

In 2019 Curragh commissioned GT Environmental to engage with the Environmental Team and provide in depth, onsite practical training on topsoil assessment techniques and interpretation of field and laboratory results. During this training the *Coronado/GT Environment Topsoil Training, Assessment and Sampling Guideline* was developed, along with *EMS Work Instruction (WI) 20 Topsoil Stockpiles Quality Assessment* and *EMS FORM 1.14 Topsoil Quality Assessment*. *EMS PROC 1.3 Topsoil Management Procedure* was updated later as a result of the training.

Topsoil is currently stripped in advance of mining activities and stockpiled for utilisation in planned rehabilitation activities as per Environmental Authority (EA) conditions and in accordance with *EMS PLAN 1.0 Land Management Plan* and *EMS PROC 1.3 Topsoil Management Procedure*. As each new topsoil stockpile is created it is included into the topsoil inventory in its specific zone and allocated the next numerical number available. Therefore, the lower the stockpile ID number the older the topsoil stockpile is. However, as mining progresses some of the old topsoil stockpiles are required to be relocated. As this occurs comments are made in the topsoil inventory to indicate that a topsoil stockpile has been relocated to a new location, and whether it has kept its original number or had a new number allocated.

Topsoil stockpile zones are allocated as a new active mining pit or overburden dump location are created. Topsoil stockpiles are surveyed by the Curragh Survey Team for topsoil volume as they are generated, or at the end of each month with the aerial LIDAR process. Topsoil stockpile volume and location reconciliations are conducted by the Curragh Survey and Environmental Teams regularly and are saved in both a mapping layer for visual representation and an inventory list for volumetric analysis.

Topsoil stockpile locations and topsoil zones for Curragh Main and Curragh North are shown in Figure 1 and Figure 2 respectively, with current stockpiled topsoil volumes, by topsoil zone, provided in Table 1.



Figure 1 - Curragh Main Topsoil Stockpile Locations by Zone

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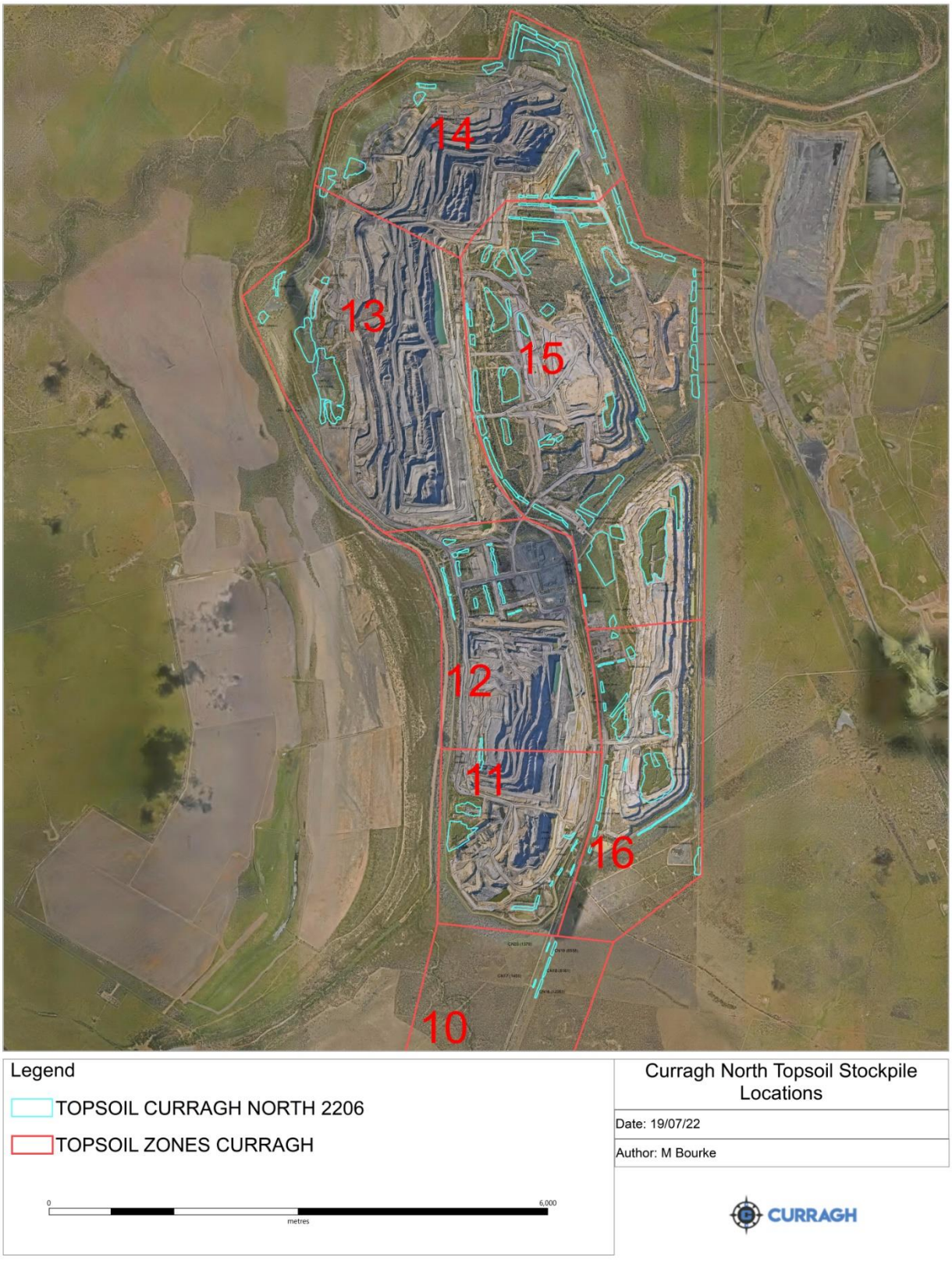


Figure 2 - Curragh North Topsoil Stockpile Locations by Zone

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Table 1 - Topsoil Inventory June 2022

Location Description		Volume m^3	Total m^3
Curragh	Zone 1	893,942	
	Zone 2	70,284	
	Zone 3	533,081	
	Zone 4	255,829	
	Zone 5	626,809	
	Zone 6	433,939	
	Zone 7	955,893	
	Zone 8	785,359	
	Zone 9	1,065,168	**5,620,304**
Curragh North	Zone 10	56,461	
	Zone 11	119,893	
	Zone 12	134,156	
	Zone 13	856,792	
	Zone 14	849,045	
	Zone 15	4,180,573	
	Zone 16	1,097,372	**7,294,292**
TOTAL			**12,914,596**

3.0 Methodology

3.1 Sampling Strategy

To undertake the assessment of all stockpiled topsoil on site, a sampling strategy was adopted. The Topsoil zones had previously been developed by the Curragh Survey Team to assist the process of mapping and accounting for stockpiled topsoil. Sampling was conducted in 2020 and a minimum of one stockpile from each zone was included in the sampling program*.

Zones with a collective volume of greater than 650,000m^3 of topsoil, were required to have two stockpiles from each zone sampled. Zones with a collective volume of less than 650,000m^3 were required to have only one stockpile from each zone sampled. Stockpile locations within each zone were chosen after a spatial assessment of all stockpile locations, taking into consideration adjacent zones.

Two composite samples, consisting of four grab samples each, were taken within every assessed stockpile. Each composite sample was collected in a north / south or east / west cross section dependent on the form and location of the stockpile.

The sampling strategy resulted in 23 stockpiles being sampled and a total of 45 individual samples being collected. The samples were taken by the Curragh environment personnel and sent to an Australian Laboratory Services (ALS) Laboratory for analysis of physical and chemical properties.

* - Zone 10 was omitted from the assessment as it is the area between Curragh and Curragh North. All topsoil in this location was stripped to form the access road between Curagh and Curragh Main and forms the smallest zone by volume

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3.2 Field Observations

A range of field observations were captured using *EMS FORM 1.14 Topsoil Quality Assessment* during sampling. Parameters assessed in the field observations included, but were not limited to, vegetation cover, soil surface, erosion impacts present, soil colour and inclusion of waste or foreign objects.

Additional dispersion behaviour and slaking assessments were conducted in accordance with *EMS WI 20 Topsoil Stockpile Quality Assessment*. Using the techniques and skills obtained during the 2019 detailed onsite training provided by GT Environmental, such methods as the field texture bolus, including ribboning was utilised to determine the field texture attributes and clay percentage as referenced in *Gunn, R.H, et. al (1988), Australian Soil and Land Survey: Guidelines for conducting surveys*. Slaking and dispersion behaviour of peds placed in deionised water over a ten minute period were observed and recorded. This information was used to provide a complete assessment of the topsoil quality. A summary of results from the field observations can be found in Section 4.0 of this report.

3.3 Laboratory Analysis

All samples were sent to an ALS Laboratory for analysis of the below parameters:

- ADMC at 40ºC
- pH plus EC 1:5
- Total N, Nitrate, Nitrite, Ammonia
- Bicarbonate Ext P (Oslen - Alkaline Soils)
- Organic Matter Content
- Exchangeable Cations (Ca, Mg, K, Na), CEC, Ca/Mg ratio, ESP
- Metals (Mn, Cu, Fe, Zn, B, Al)
- Sulphur (Total as S)
- Chloride

4.0 Results

4.1 Field Results

Vegetation cover was measured during the sample collection process by capturing the type of vegetation cover (Grass, weeds, native and non-native trees and shrubs), the percent of vegetation cover and the condition of the vegetation present (established, immature, green, dry, dead) on the topsoil. The type, condition and percentage of vegetation cover can indicate good soil and can also indicate the age of the stockpile. Percent and type of vegetation coverage was also noticed to be dependent on the stockpile shape and surface conditions. In paddock dumped topsoil stockpiles much of the grass cover was in the depressions and the shrubs were growing on the crests. In scraper produced stockpiles a more uniform coverage of vegetation was observed across the whole stockpile.

Some vegetation types can also provide other indications of soil type, for instance the presence of sandalwood or black tea-tree can indicate sodic or saline conditions. A full suite of general vegetation type was captured on EMS FORM 1.14 and are recorded in the field data entry spreadsheet on G Drive.

It was also observed that as the paddock dumped topsoil stockpiles aged the spread of the vegetation coverage increased over the slopes and crests. The age of the topsoil stockpile is identified by the topsoil stockpile ID number. The smaller the ID number the older the stockpile. Of the remaining topsoil stockpiles on site, that have not been consumed in the progressive rehabilitation to date, topsoil age can range from one month old to up to twenty-five years old.

Of the stockpiles sampled during the study, 89% were identified to have established vegetation, with the remaining 11% showing immature vegetation.

Erosion impacts were observed at 12 sample locations. Two locations (17%) at Curragh and ten locations (83%) at Curragh North. Rill erosion was evident at all locations where percent vegetation cover was less than 85%. At two sample locations where the percent vegetation cover was 95%, gully erosion was evident on the extremities of a paddock dump stockpile.

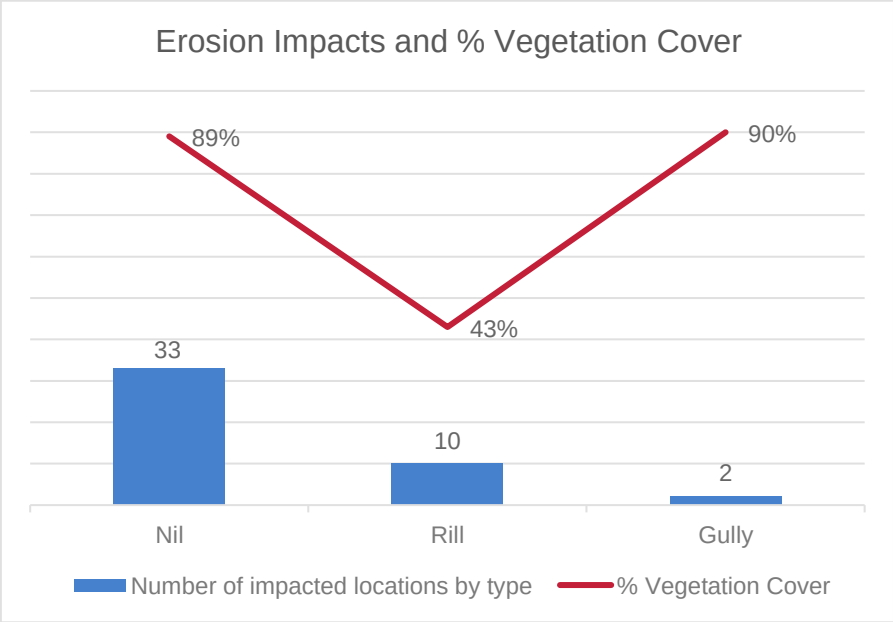


Figure 3 Erosion Impacts and Percent Vegetation Cover

During the topsoil stockpile assessment study ***Soil texture, Colour, Dispersion and Slaking behaviour*** were assessed in the field by the Curragh Environmental team. Soil texture and clay content as well as the dispersive nature of topsoil is vital to understand prior to use in rehabilitation activities, to ensure success.

Soils with distinctive 'bright' colours are usually of better quality than those soils with pale 'washed out' colours. Soils with pale colours are often an indication of 'base depletion', or soils that have been subject to many cycles of erosion and redeposition which has stripped and removed most of the referred cations and replaced them with sodium and chloride. These chemical constituents generally indicate poor fertility and other physical problems (McCann, R, 2019). A full suite of soil colours were captured on EMS FORM 1.14 and also recorded in the field data entry spreadsheet on G Drive.

The physical aspects of the soil such as field dispersion, slaking and dispersive behaviours provide indications as to the ability for use of the topsoil in rehabilitation applications. Most textures from sand to heavy clay can be used in rehabilitation when factors such as slope and location are planned for accordingly. Soils with approximately equal proportions of sand, silt and clay may form physical bonds and set hard, resulting in poor structure and infiltration potential. This is typical in brigalow and eucalypt subsoils (McCann, R, 2019).

The below tables from *EMS WI 20 Topsoil Stockpile Quality Assessment* were used as the basis for the infield assessment of all soil samples.

Table 2 - Field dispersion analysis

Score	Field analysis
0	Very stable soil
1	Stable soil, will resist dispersion after tillage
2 / 3	Soil is prone to compaction and hard setting
4 /5	Soil will disperse if cultivated wet
6	Soil disperses strongly if cultivated wet
7 / 8	May benefit from stubble retention. If complete dispersion is observed within both initial wetting and remoulded aggregate tests, it is likely that dispersive attributes of the soil may require soil amelioration and provide a poor environmental for plant growth. Laboratory analysis will assist with further analysis.

Table 3 - Field Slaking Scores

Score	Slaking Behaviour	Field analysis
0	If the aggregate remains intact	This soil is stable to wetting. This is typical of pasture soils. No action is needed
1	if the aggregate collapses around the edges but remains mainly intact	
2	If the aggregate collapses into angular pieces	This is typical of self-mulching clays. If the soil does not disperse no action is necessary.
3	If the aggregate collapses into small (less than 2 mm diameter) rounded pieces, forming a cone	Surface may form a crust. However, this is only a problem in non-swelling
4	If the aggregate collapses into single grains (you can see sand grains).	This soil is very likely to crust and hard-set (sands and loams). Reduced cultivation, stubble retention and more frequent irrigations may be necessary on these soils.

Table 4 - Dispersive behaviour

Score	Dispersive Behaviour
0	Nil dispersion
1	Slight dispersion, recognised by slight milkiness of water adjacent to the aggregate
2	Moderate dispersion with obvious milkiness
3	Strong dispersion with considerable milkiness and about half of the original volume of the aggregate dispersed outwards
4	Complete dispersion, leaving only sand grains in a cloud of clay

The results of the infield assessments are presented in Table 5 and indicate that of the 45 samples taken across 23 stockpiles on site, 32 samples or 71% place within the suitable range for field dispersion, 32 or 71% place within the suitable range for slaking behaviour and 45 or 100% of the samples place within the suitable range for dispersive behaviour.

Table 6 - Curragh North Field Dispersion and Slaking Behaviour

Topsoil Stockpile #	Zone #	Volume (m^3)	Dominant Texture	Field Dispersion Score	Field Slaking Score	Dispersive Behaviour
CN364_1	11	305,894	Clay, loam sandy	2 - 3	3	0
CN364_2	11	305,894	Clayey sand	2 - 3	1	0
CN385_1	11	26,135	Clayey sand	4 - 5	1	1
CN385_2	11	26,135	Clayey sand	4 - 5	3	2
CN387_1	11	51,624	Clayey sand	4 - 5	3	2
CN387_2	11	51,624	Sandy loam	4 - 5	3	0
CN212_1	12	22,240	Clay loam	1	2	0
CN212_2	12	22,240	Clay loam	1	2	0
CN413_1	13	420,158	Sandy clay loam	1	1	1
CN413_2	13	420,158	Sandy clay loam	4 - 5	3	0
CN55_1	13	38,570	Clay loam	1	1	1
CN55_2	13	38,570	Clay loam	1	1	2
CN326_1	14	46,764	Light medium clay	1	1	1
CN326_2	14	46,764	Light clay	2 - 3	1	0
CN400_1	14	66,387	Clay loam	1	4	0
CN400_2	14	66,387	Clay loam	1	4	0
CN93_1	15	328,172		2 - 3	1	0
CN93_2	15	328,172	Medium Clay	2 - 3	1	2
CN225_1	16	17,600	Medium heavy clay	4 - 5	3	0

CN225_2	16	17,600	Medium clay	4 - 5	1	0
CN414_1	16	28,087	Sand	4 - 5	0	1
CN414_2	16	28,087	Sand	4 - 5	4	1

General topsoil stockpile categorisation values can be assigned to each stockpile based on the overall presence of vegetation and percentage of uncontaminated material observed as per the categories defined in Table 7.

Table 7 - Stockpile Quality Category

Topsoil Stockpile Category	Value Description
A	High value. Low levels of contaminated material. Uncontaminated soil content at least 70% of the stockpile. Quality topsoil.
B	Moderate value. Soil purity 50-70%. Higher levels of contamination and variable quality. Useable topsoil value but preferable in lower sloping areas or as 'subsoil' material or capping.
C	Marginal. Significant levels of contamination present (>50%). Quality better than most spoil present but only useful a capping / subsoil material in rehabilitation.
D	Unsuitable. No better that spoil material present.

In total 23 Stockpiles were sampled during the study and the categories assigned to the stockpiles show a 50:50 split of Category A and Category B stockpiles, with 48% and 52% respectively. At Curragh Main the results split was 58%:42% for Category A and Category B stockpile qualities. With Curragh North stockpiles almost identically opposite with 41% assigned a stockpile quality Category A and 59% assigned a Category B.

4.2 Laboratory Results

Soil **pH** is important as it affects the ability of nutrients in soil. Ensuring the pH of the soil is as close as possible to the neutral range as indicated below in Table 8 will ensure satisfactory results when the topsoil is used for planned rehabilitation activities.

Table 8 - pH Rating

Rating	pH
Acidic	5.6–6.5
Neutral	6.6–7.5
Mild Alkalinity	7.6–8.5
Alkaline	>8.5

The laboratory results of all pH (1:5 soil/water) samples show soil pH within the 7.3 – 9.2 range. Topsoil at Curragh Main ranges from 7.6 – 8.4 with the average value of 8.13. Topsoil at Curragh North ranges from 8.4 – 9.2 with the average of 8.71. Overall pH of the topsoil

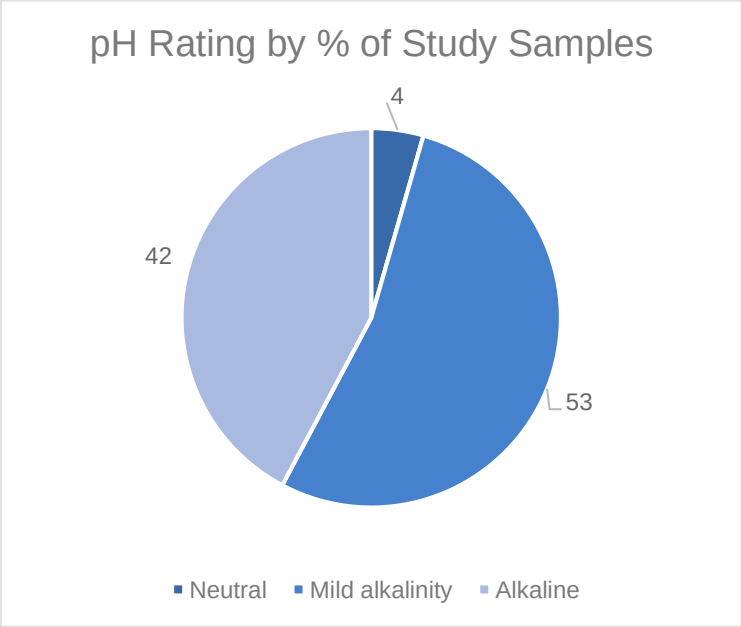


Figure 4 pH Rating by % of Study Samples

Cation Exchange Capacity (CEC) is the measurement used to assess the overall fertility status in surface soil. The stockpiled topsoil is surface soil stripped and placed into stockpiles. The samples taken and sent for laboratory analysis were all taken from within a depth of 300mm of the stockpile surfaces, the laboratory results indicated the overall fertility status of the samples collected and provide guidance to the fertility status of topsoil in general across site in accordance with Table 9.

Table 9 - Cation Exchange Capacity Rating and Results

Rating	CEC/ECEC (meq/100 g of soil)	# of samples	% of study area
very low	<5	3	7
low	5–15	11	24
moderate	15–25	25	56
high	25–40	6	13
very high	>40	0	0

The results of all CEC samples indicate a moderate rate of overall fertility within the sample suite, with 13% of samples in the high fertility range and 31% within the low or very low range. Curragh Main CEC results indicate more fertile soil overall than that of the Curragh North samples. Average CEC score for Curragh Main is 20.26meg/100g soil and Curragh North is 13.96meg/100g soil.

Exchangeable sodium percentage (ESP) is used to assess the relative abundance of exchangeable sodium. Where high levels of exchangeable sodium are present relative to other cations the soil material

physical property is deemed to be of a sodic nature. Table 10 provides the rating table used for analysis of the sample results. Soils with a low exchangeable sodium percentage disperse readily.

Table 10 – Exchangeable Sodium Percentage Rating

Rating	Exchangeable Sodium Percentage (%)
non-sodic (low)	<6
sodic (moderate)	6–15
strongly sodic (high)	15–20
extremely sodic (very high)	>20

Calcium Magnesium ratio provides a guide to the relative abundance of the two major cations (Calcium and Magnesium) and is useful when used in conjunction with Exchangeable Sodium Percentage to predict soil physical behaviour. Soils with a high Calcium dominance, as described by the rating in Table 11, will counteract the dispersive nature of the ESP.

Table 11 - Calcium Magnesium Ratio Rating

Rating	Ca/Mg ratio	Comments
very low	<0.10	Mg is >10 times more dominant than Ca
low	0.10–0.50	Mg is 5–10 times more dominant than Ca
moderate	0.51–1.0	Ca and Mg becoming co-dominant
high	1.1–2	Ca more dominant than Mg
very high	>2	Ca >2 times more dominant than Mg

The laboratory results of both the ESP and calcium/magnesium ratio indicate majority of soils across site (80%) rated as non-sodic with 18% being sodic and 2% (one sampled stockpile) with a strongly sodic rating. The strongly sodic stockpile is located at Curragh North. Correspondingly, of the soils sampled across site, 88% and 12% identify as having a very high and high dominance of calcium resulting in majority (80-100%) of soils across site physical property being non dispersive.

Bicarbonate Extractable Phosphorus is the current measurement for the assessment of relative differences in soil fertility.

Table 12 – Bicarbonate Extractable Phosphorus Rating

Rating	Bicarb. extr. P (ppm)
very low	<5
low	6-9
moderate	10-15
high	16-40
very high	>40

Using the rating table adapted from Ahern provided in McCann, R (2019), 46.7% of the samples taken during the assessment returned a moderate or higher soil fertility rating.
37.8% returned a low fertility rating and 15.6% returned a very low soil fertility rating. On average Curragh North samples indicated almost two times greater soil fertility than Curragh Main with the reading being 15.8ppm and 8.31ppm respectively. Curragh North samples ranged from 1ppm to 48.2ppm, whilst Curragh Main samples ranged for 1ppm to 26.7ppm.

Total Organic Carbon is generally used to assess surface soil fertility. All topsoil stockpiles on the mine site are surface topsoil stripped and placed in stockpiles. Therefore the assessment of total organic carbon is relevant to each stockpile in its entirety.

Table 13 - Organic Carbon Rating

Rating	Organic Carbon (%)[1]
Very Low	<0.5
Low	0.5-1.5
Moderate	1.6-2.5
High	2.6-5.0
Very High	>5.0

1 – Categories from Bruce and Rayment (1982)

Using the rating table from Bruce and Rayment (1982) the Laboratory results for ***Total Organic Carbon*** indicate that 44% of the samples taken during the assessment returned a moderate or higher soil fertility. 53% returned a low fertility rating and 2% a very low rating. Curragh Main samples were on average higher than Curragh North samples, with average values of 1.9% and 1.1% respectively. Curragh Main results ranged from 1% to 4.2%, whilst Curragh North results ranged from 0.5% to 2.4%.

The full suite of laboratory results is provided in Appendix B.

5.0 Conclusion and Recommendations

This topsoil quality assessment study conducted in 2020 has shown most of the stockpiled topsoil at both Curragh Main and Curragh North is of acceptable physical and chemical quality and will not require amelioration during planned rehabilitation activities. With selective placement of topsoil depending on its quality and proposed location, any potential negative effects from poorer soil quality can be further mitigated.

The overall stockpiled topsoil quality is rated as an A or B, based of field observations, indicating high purity and relatively uncontaminated high value topsoil.

The results from the topsoil quality assessment indicate a similar quality to that which has historically been found within Brigalow and Eucalypt Scrub plains at Curragh and Curragh Main (McCann, R, 2019).

It is recommended that all EMS Documents capturing the management of topsoil be updated to incorporate a routine sampling regime that may include aspects such as; sampling of topsoil once stripped and stockpiled, sampling of stockpiles during storage, as well as sampling the topsoil stockpiles identified for use in planned rehabilitation activities prior to the rehabilitation campaign commencement.

The site could also benefit from undertaking seeding of stockpiles to ensure the percent cover is greater than 85% to prevent erosion impacts and dilution of nutrients during the period of stockpiling until vegetation establishes naturally.

Amelioration could be considered if rehabilitation of an area is required to be established prior to an upcoming unfavourable weather event such as drought or a severe wet season. Inclusion of amelioration would improve the speed in which the vegetative cover establishes and provide protection from environmental impacts. Similarly, the use of a hydromulch or other materials could be considered in such circumstances.

6.0 References

AustralAsian Resource Consultants Pty Ltd (2004) Supplementary Topsoil Survey for the Curragh North Mining Lease. AARC

Bruce, R.C. and Rayment, G.F. (1982) Analytical Methods and interpretations used by the Agricultural Chemical Branch, QDPI, for soil and land use surveys. QDPI Bulletin QB82004.
Brisbane

EMS PLAN 1.0 Land Management Plan

EMS PLAN 1.1 Topsoil Management Plan

EMS PROC 1.3 Topsoil Management Procedure

EMS FORM 1.14 Topsoil Quality Assessment

Gunn, R.H, et. al (1988), Australian Soil and Land Survey: Guidelines for conducting surveys

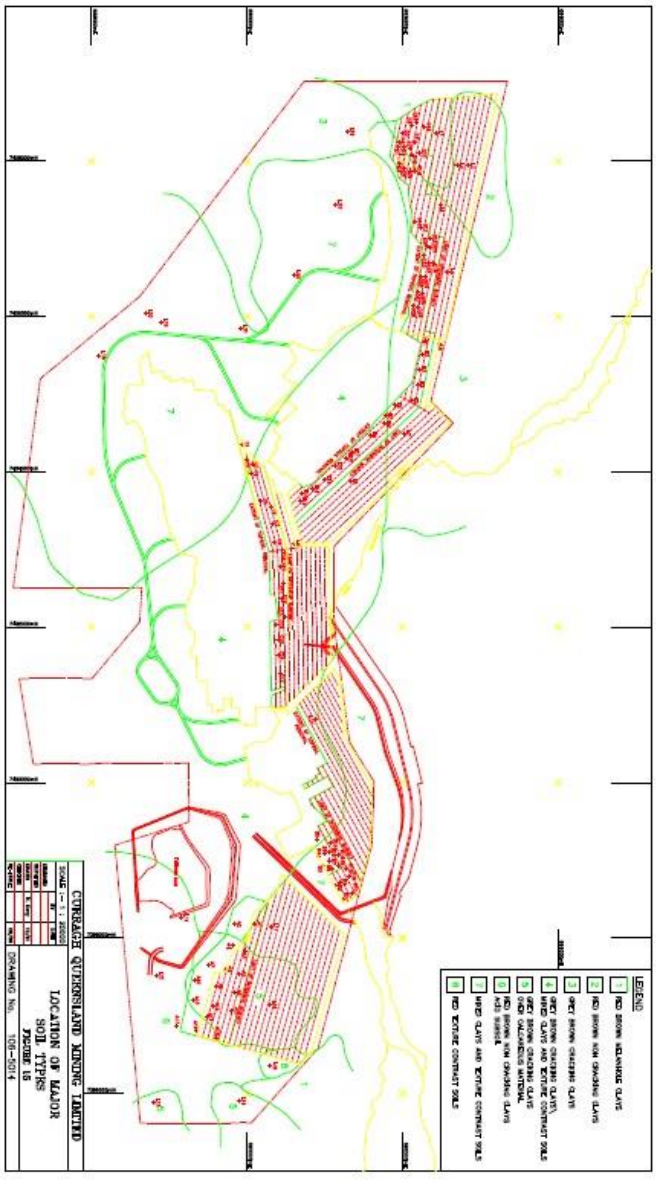
McCann, R (2019) Topsoil Training, Assessment and Sampling Coronado Global Resources Inc. v2. GT Environmental Pty Ltd.

7.0 Appendixes

Appendix A – Historical Soil Assessments

Curragh

During an insitu topsoil study, Land Reclamation Services (LRS) identified 7 soil mapping units in the Curragh mine area in 1990. The summary of soil types is shown in the below mapping with detailed summary provided in the table below.



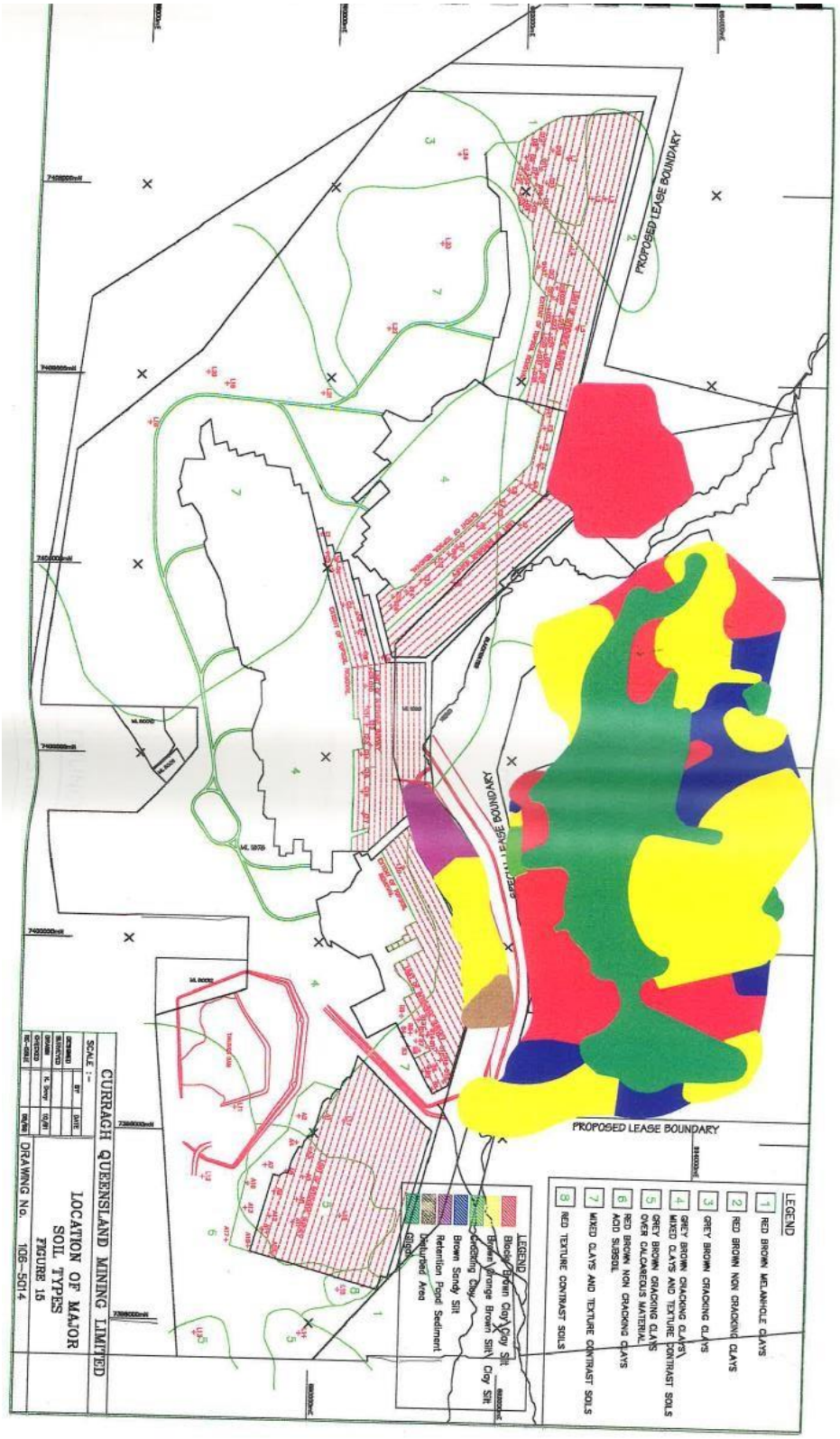
14 LRS 1990 Insitu soil study summary

Soil Description	Suitability for Rehabilitation
Red brown melonhole clays	• Top 10 cm chemically suitable for rehabilitation. • Lower horizons are dispersive and have high chloride concentration. • Melon hole relief makes striping top layer without contamination from lower horizons impossible. • Therefore this soil is not suitable for rehabilitation.
Red brown non-cracking clays	• Top 20cm are suitable for rehabilitation. • Lower horizons are dispersive and have moderate chloride concentrations. • Topsoil should be carefully stripped to 20 cm.
Grey brown cracking clays	• High chloride concentrations throughout the profile. • All horizons are potentially dispersive. • Recommended that this soil is not used in rehabilitation.
Grey brown cracking clays over calcareous material	• Well-structured cracking clay with low chlorides and dispersivity to at least 60 cm. • Soil should be stripped to 60 cm depth. • 0–30 cm should be stockpiled separately to 30-60 cm.
Red brown cracking clays – acid subsoil	• Only the top 20 cm is chemically suitable for rehabilitation. • Subsoils are not recommended for rehabilitation.
Mixed clays and texture contrast soils	• Only the top 15 cm is suitable for rehabilitation. • Lower horizons consist of impervious clays which are dispersive.
Red texture contrast soils	• Only the A horizon should be used for rehabilitation as the lower clays are impervious and dispersive. • Therefore only the top 15 cm should be stripped and stockpiled for rehabilitation.

Curragh East

In 1998, Environment Health and Safety Systems (EHSS) conducted soil samples from 17 sites and soils were described in detail to classify additional mapping area at Curragh East. The report indicates that:

- Analyses shows that some soils are poorly to moderately fertile;
- Soils are potassium and nitrogen deficient;
- Soils are calcium and magnesium moderately deficient; and
- Sodicity of soils is low although deeper layers may prove more problematic.


PROPOSED LEASE BOUNDARY
PROPOSED LEASE BOUNDARY
LEGEND
1 RED BROWN MELANHOLE CLAYS
2 RED BROWN NON CRACKING CLAYS
3 GREY BROWN CRACKING CLAYS
4 GREY BROWN CRACKING CLAYS\ MIXED CLAYS AND TEXTURE CONTRAST SOILS
5 GREY BROWN CRACKING CLAYS OVER CALCAREOUS MATERIAL
6 RED BROWN NON CRACKING CLAYS ACID SUBSOIL
7 MIXED CLAYS AND TEXTURE CONTRAST SOILS
8 RED TEXTURE CONTRAST SOILS
LEGEND
Bleached Brown Clay Clay Silt
Brown Orange Brown Silty Clay Silt
Cracking Clay
Brown Sandy Silt
Retention Pond Sediment
Disturbed Area
Slope
CURRAGH QUEENSLAND MINING LIMITED
LOCATION OF MAJOR SOIL TYPES
FIGURE 15
DRAWING No. 105-5014

15 Curragh East Soils and Additional Mapping

Soil Description	Description of Soils
Variable Texture Contrast Soils	• Occur on the eastern and north-eastern part of the Curragh East area and are characterised by coarse textured sandy clay loams to sandy clay over-lying coarsely structured alkaline clay subsoil. • The soils are associated with the ridge running north/south over the Curragh East area and support a range of vegetation from tall Poplar Box forest to short mixed forest.
Cracking Clays over Alluvial Parent Material	• This mapping unit is associated with the undisturbed section of the Blackwater Creek streambed. This cracking heavy clay forms a deep layer over an alluvial parent material, the dark brown to grey soil has a coarse blocky structure and ranges from acid to neutral in the upper 0.5 metres to strongly alkaline below this depth.

Curragh North

In 2003, a soil survey of the Curragh North Project (ML80110 and ML 80123) site was conducted by Australasian Resource Consultants Pty Ltd as part of a study of the existing environment for the Curragh North project. The results of this survey included the results of soil sampling undertaken in 1996, 1998 and 2003. In total, 61 samples were collected in these previous sampling episodes.

Based on field and laboratory assessment, the 6 soil types identified at Curragh North have been mapped into 4 different mapping units and described in the Map and Table below

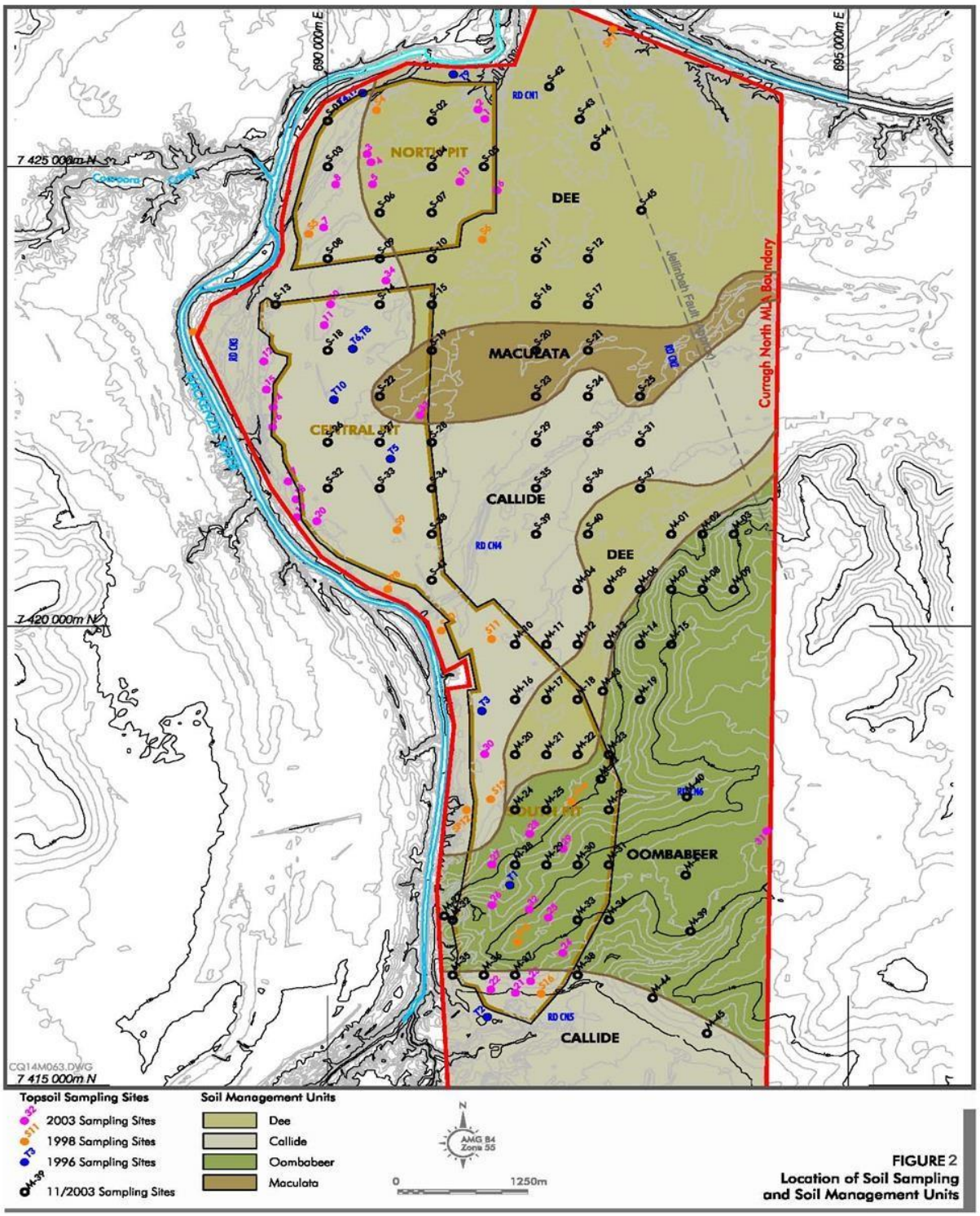


FIGURE 2
Location of Soil Sampling and Soil Management Units

Soil Type	Description
Soil Type 1	• Grey to reddish brown self-mulching clays with a moderate to strong pedal structure with some calcareous inclusions. • The majority of this area has been cleared for low intensity grazing on improved pastures. The topography is of low relief with slopes tending to be less than 2%. This soil type constitutes the Dee soil management unit. • Structure changes with depth to become massive typically at a depth of approximately 30cm. The soil is alkaline to strongly alkaline, nonsaline, of low sodicity and a high cation exchange capacity. Calcareous inclusions occur at depths below approximately 30cm.
Soil Type 2	• Light clay to clay loam A horizon (grey to dark reddish brown) graduating to medium to heavy clay subsoil. Moderately pedal structure is typical throughout the profile. • The area has previously been cleared for low intensity grazing. The topography is generally of low relief with slopes tending to be less than 2%. • The area is characterised by grey to dark reddish brown clay loam to light clay with occasional cracking. The surface is firm and is typically moderately pedal. Peds are less than 20 mm in size. The A horizon is approximately 30 cm in depth, below which a sharp texture and colour change of the lower horizon can be found. Colour becomes darker and texture increases to medium to heavy clays. • The soil is typically slightly acid to neutral with pH increasing with depth. The soils are non-sodic and are of moderate to high cation exchange capacity. This soil constitutes the Callide soil management unit.
Soil Type 3	• Loamy sand to clay loam A horizon (dark reddish grey to black) underlain by sandy loam to silty clay loam horizons. Structure is typically moderate to strongly pedal and polyhedral in nature. • Native vegetation has been cleared from this soil type for low intensity cattle grazing. The topography is of low relief with slopes of less than 2% common. • This soil is typified by loamy sand to clay loam a horizon of approximately 20 cm in depth. The A horizon is dark reddish grey to black in colour. Underlying the A horizon is a sandy loam to silty clay loam horizon which is darker in colour than the A horizon. The boundary between horizons is clear in nature. A polyhedral structure of moderate to strong pedality occurs throughout the profile. • pH of the A horizon is neutral to slightly alkaline, with the pH becoming more alkaline with depth. These soils are non-saline in nature and are of moderate fertility (CEC). This soil constitutes the Maculata soil management unit.

Soil Type	Description
Soil Type 4	• Light yellowish brown to reddish black loamy sand to sandy loam A horizon of weak to moderate pedality overlying loamy sand to silty loam horizons. • Soil type 4 has been cleared of native vegetation for low intensity cattle grazing. Occurring on the upper ridges and steeper slopes of the proposed mining lease area, this soil type is found on gently to moderately inclined relief. • A loamy sand to sandy loam A horizon typifies this soil type. This horizon is generally light yellowish brown to reddish black in colour. The A horizon is of weak to moderate pedality. Underlying the A horizon is a horizon of slightly higher clay content (loamy sand to silty loam). The underlying horizon is also darker in colour and is only weakly pedal or a pedal (granular) in structure. The boundary between these horizons is abrupt. • These soils are slightly acid to slightly alkaline in the A horizon, with alkalinity increasing with depth. These soils are slightly to moderately sodic in the surface horizon with exchangeable sodium percent generally increasing with depth. Excessive salinity does not occur in these soils. This soil is one of the three soil types which constitute the Oombabeer soil management unit.
Soil Type 5	• Brown/dark brown A horizon of light clay with strong polyhedral pedality overlying a pale yellow massive B horizon. • This soil type occurs in a portion of the mining lease adjacent to the Mackenzie River on which native woodland is established. Cattle frequently graze this area. This soil type occurs on slopes with a slope of less than 2%. • The A horizon of this soil consists of a brown/dark brown light clay with strong polyhedral (< 20mm) pedality. A pale yellow massive B horizon underlies the A horizon. The boundary between horizons is gradual. • These soils are moderately alkaline in the A horizon, with alkalinity increasing with depth. This soil type is also non-sodic in nature and is of moderate fertility. Salinity is not a limitation to plant growth on this soil. This soil is one of the three soil types which constitutes the Oombabeer soil management unit.

Soil Type	Description
Soil Type 6	• Weak red to dark reddish grey A horizon of loamy sand to clayey sand texture overlying a weak red to pinkish grey B horizon with a single grain apedal structure. Each of these soil types is described below. • This soil type has been cleared for low intensity cattle grazing. Improved pastures are found on this soil type. This soil type occurs on low relief with slopes tending to less than 2%. • A weak red to dark reddish grey loamy sand to clayey sand constitutes the A horizon of this soil. This horizon is characterised by a weak pedal structure with peds less than 10 mm. The underlying horizon is a weak red to pinkish grey loamy sand with granular apedal structure. A gradual boundary separates the horizons. • This soil is neutral to moderately alkaline with pH increasing with depth. The soil is also non-sodic, non-saline and of low cation exchange capacity (fertility). This soil is one of the three soil types which constitute the Oombabeer soil management unit.

Curragh West

Existing soils data for Curragh West (ML 80171) is limited to broad-scale mapping based on aerial photo interpretation and limited regional scale fieldwork. A soil investigation was conducted to determine soil types and a summary included in the 2011 Environmental Management Plan prepared by Parsons Brinckerhoff. Selected soil samples were tested to assess their acidity, salinity, dispersion potential, and nutrient content. The results were used to aid classification of individual soil types and to assess reuse potential of soils for future rehabilitation purposes.

Based on the investigation, three soil units were identified within Curragh West. The distribution of soil units is closely related to the topography and geomorphology of Curragh West. Abrupt boundaries between soil types generally do not occur. The three soils types are Grey duplex soils, Grey-brown uniform clays, and Red-brown uniform clays.

Appendix B – Laboratory Results

ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order	: **EB2020245**	Page	: 1 of 20
Client	: **CORONADO CURRAGH PTY LTD**	Laboratory	: Environmental Division Brisbane
Contact	: KIM TUART	Contact	: Anna Riddell
Address	: CURRAGH MINE BLACKWATER QLD, AUSTRALIA 4717	Address	: 2 Byth Street Stafford QLD Australia 4053
Telephone	: 07 4986 9338	Telephone	: +61 7 4952 5795
Project	: General Soil	Date Samples Received	: 31-Jul-2020 12:20
Order number	: ----	Date Analysis Commenced	: 04-Aug-2020
C-O-C number	: ----	Issue Date	: 19-Aug-2020 12:41
Sampler	: CRYSTAL MERLOW, KELLY SMITH		
Site	: ----		
Quote number	: TV/028/19 v5		
No. of samples received	: 45		
No. of samples analysed	: 45		

Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Ben Felgendrejeris	Senior Acid Sulfate Soil Chemist	Brisbane Acid Sulphate Soils, Stafford, QLD
Ben Felgendrejeris	Senior Acid Sulfate Soil Chemist	Brisbane Inorganics, Stafford, QLD
Dave Gitsham	Metals Instrument Chemist	Brisbane Inorganics, Stafford, QLD
Kim McCabe	Senior Inorganic Chemist	Brisbane Acid Sulphate Soils, Stafford, QLD
Kim McCabe	Senior Inorganic Chemist	Brisbane Inorganics, Stafford, QLD
Mark Hallas	Senior Inorganic Chemist	Brisbane Acid Sulphate Soils, Stafford, QLD
Mark Hallas	Senior Inorganic Chemist	Brisbane Inorganics, Stafford, QLD
Santusha Pandra	Senior Chemist	Brisbane Inorganics, Stafford, QLD

General Comments

The analytical procedures used by ALS have been developed from established internationally recognised procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are fully validated and are often at the client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting
ø = ALS is not NATA accredited for these tests.
~ = Indicates an estimated value.

- EG020-T (Total Metals by ICP-MS): Sample C125_2 (EB2020245-001) shows poor duplicate results due to sample heterogeneity. Confirmed by visual inspection.
- ED006(Exchangeable Cations on Alkaline Soils): Unable to calculate Calcium/Magnesium Ratio for some samples as the required results for Calcium/Magnesium are below limit of reporting.
- ED006(Exchangeable Cations on Alkaline Soils): Unable to calculate Magnesium/Potassium Ratio for CN387_1 (EB2020245-037) as the required results for Magnesium/Potassium are below limit of reporting.
- ALS is not NATA accredited for the analysis of Exchangeable Aluminium and Exchange Acidity in soils when performed under ALS Method ED005.
- ALS is not NATA accredited for the analysis of Exchangeable Cations on Alkaline Soils when performed under ALS Method ED006.
- EK061G (Total Kjeldahl Nitrogen as N) / EK067G (Total Phosphorus as P): Sample EB2020245_002 (C125_1) shows poor matrix spike recovery due to sample heterogeneity. Confirmed by visual inspection.
- EG020-T (Total Metals): Manganese Method Blank is above the limit of reporting but are not considered significant compared to analyte levels in the samples.
- EG020-T (Total Metals by ICP-MS): Sample C142_1 (EB2020245-031) shows poor duplicate results due to sample heterogeneity. Confirmed by visual inspection.
- EG005T (Total Metals by ICP-AES): Sample CN413_1 (EB2020245-011) shows poor duplicate results due to sample heterogeneity. Confirmed by visual inspection.
- EK061G (Total Kjeldahl Nitrogen as N) / EK067G (Total Phosphorus as P): Sample EB2020245_042 (C07_1) shows poor matrix spike recovery due to sample heterogeneity. Confirmed by visual inspection.
- ED007 and ED008: When Exchangeable Al is reported from these methods, it should be noted that Rayment & Lyons (2011) suggests Exchange Acidity by 1M KCl - Method 15G1 (ED005) is a more suitable method for the determination of exchange acidity (H+ + Al3+).
- Test comment

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	C125_2	C125_1	C122_1	C81_1	C81_2
			Client sampling date / time	02-Jul-2020 13:10	02-Jul-2020 12:15	21-Jul-2020 16:00	21-Jul-2020 14:00	21-Jul-2020 14:30
Compound	CAS Number	LOR	Unit	EB2020245-001	EB2020245-002	EB2020245-003	EB2020245-004	EB2020245-005
				Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	8.9	8.9	8.4	8.3	7.9
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	220	335	986	180	176
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	5.5	5.9	4.1	12.7	15.0
ED006: Exchangeable Cations on Alkaline Soils								
ø Exchangeable Calcium	----	0.2	meq/100g	12.2	8.4	10.6	10.7	13.7
ø Exchangeable Magnesium	----	0.2	meq/100g	4.0	2.8	4.9	4.2	5.8
ø Exchangeable Potassium	----	0.2	meq/100g	0.3	0.2	0.5	1.8	2.6
ø Exchangeable Sodium	----	0.2	meq/100g	1.8	1.5	2.2	<0.2	<0.2
ø Cation Exchange Capacity	----	0.2	meq/100g	18.3	13.0	18.2	16.8	22.1
ø Exchangeable Sodium Percent	----	0.2	%	9.8	11.7	12.0	<0.2	<0.2
ø Calcium/Magnesium Ratio	----	0.2	-	3.1	3.0	2.2	2.5	2.3
ø Magnesium/Potassium Ratio	----	0.2	-	11.8	10.8	9.2	2.3	2.2
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.02	0.02	0.04	0.03	0.03
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	10	mg/kg	80	230	1100	70	30
EG005(ED093)T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	8450	9690	9880	12300	14100
Boron	7440-42-8	50	mg/kg	<50	<50	<50	<50	<50
Iron	7439-89-6	50	mg/kg	24100	27500	20600	26300	27900
EG020T: Total Metals by ICP-MS								
Copper	7440-50-8	0.1	mg/kg	18.3	20.2	19.6	25.1	26.4
Manganese	7439-96-5	0.1	mg/kg	1300	739	800	955	1360
Zinc	7440-66-6	0.5	mg/kg	18.0	22.3	32.8	29.7	32.6
EK055: Ammonia as N								
Ammonia as N	7664-41-7	20	mg/kg	<20	<20	<20	<20	<20
EK057G: Nitrite as N by Discrete Analyser								
Nitrite as N (Sol.)	14797-65-0	0.1	mg/kg	0.3	0.4	0.6	0.7	0.9
EK058G: Nitrate as N by Discrete Analyser								
Nitrate as N (Sol.)	14797-55-8	0.1	mg/kg	17.5	23.5	18.8	28.7	55.6
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)				Client sample ID	C125_2	C125_1	C122_1	C81_1	C81_2
				Client sampling date / time	02-Jul-2020 13:10	02-Jul-2020 12:15	21-Jul-2020 16:00	21-Jul-2020 14:00	21-Jul-2020 14:30
Compound	CAS Number	LOR	Unit		EB2020245-001	EB2020245-002	EB2020245-003	EB2020245-004	EB2020245-005
					Result	Result	Result	Result	Result
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser - Continued									
Nitrite + Nitrate as N (Sol.)	----	0.1	mg/kg		17.8	23.9	19.4	29.4	56.5
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser									
Total Kjeldahl Nitrogen as N	----	20	mg/kg		800	990	640	1420	2230
EK062: Total Nitrogen as N (TKN + NOx)									
^ Total Nitrogen as N	----	20	mg/kg		820	1010	660	1450	2290
EK067G: Total Phosphorus as P by Discrete Analyser									
Total Phosphorus as P	----	2	mg/kg		215	252	319	408	443
EK081: Bicarbonate Extractable Phosphorus (Olsen)									
Bicarbonate Extractable P (Olsen)	----	1.0	mg/kg		1.7	1.5	10.7	8.3	14.1
EP004: Organic Matter									
Organic Matter	----	0.5	%		2.2	2.4	1.5	3.5	5.3
Total Organic Carbon	----	0.5	%		1.2	1.4	0.9	2.0	3.1

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	C31_1	C71_1	C71_2	C122_2	CN413_2
			Client sampling date / time	09-Jul-2020 15:30	21-Jul-2020 13:00	21-Jul-2020 13:30	21-Jul-2020 16:35	23-Jul-2020 16:00
Compound	CAS Number	LOR	Unit	EB2020245-006	EB2020245-007	EB2020245-008	EB2020245-009	EB2020245-010
				Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	7.4	8.3	8.2	8.2	9.0
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	137	142	158	294	290
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	2.0	9.7	10.3	4.1	9.5
ED006: Exchangeable Cations on Alkaline Soils								
ø Exchangeable Calcium	----	0.2	meq/100g	2.4	16.9	19.9	14.7	9.1
ø Exchangeable Magnesium	----	0.2	meq/100g	1.1	4.7	6.8	4.4	4.9
ø Exchangeable Potassium	----	0.2	meq/100g	0.8	1.4	2.7	0.7	0.6
ø Exchangeable Sodium	----	0.2	meq/100g	<0.2	<0.2	<0.2	1.1	1.8
ø Cation Exchange Capacity	----	0.2	meq/100g	4.2	23.0	29.5	21.0	16.5
ø Exchangeable Sodium Percent	----	0.2	%	<0.2	<0.2	<0.2	5.3	11.2
ø Calcium/Magnesium Ratio	----	0.2	-	2.2	3.6	2.9	3.3	1.8
ø Magnesium/Potassium Ratio	----	0.2	-	1.4	3.4	2.5	5.9	8.6
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.01	0.03	0.03	0.01	0.02
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	10	mg/kg	20	30	30	220	170
EG005(ED093)T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	2640	11700	13000	8640	6840
Boron	7440-42-8	50	mg/kg	<50	<50	<50	<50	<50
Iron	7439-89-6	50	mg/kg	7790	22800	26600	18600	13900
EG020T: Total Metals by ICP-MS								
Copper	7440-50-8	0.1	mg/kg	6.0	22.0	22.6	17.4	10.6
Manganese	7439-96-5	0.1	mg/kg	431	827	827	663	400
Zinc	7440-66-6	0.5	mg/kg	6.8	31.7	31.1	29.8	22.9
EK055: Ammonia as N								
Ammonia as N	7664-41-7	20	mg/kg	<20	<20	<20	<20	<20
EK057G: Nitrite as N by Discrete Analyser								
Nitrite as N (Sol.)	14797-65-0	0.1	mg/kg	0.5	0.9	0.9	0.4	0.2
EK058G: Nitrate as N by Discrete Analyser								
Nitrate as N (Sol.)	14797-55-8	0.1	mg/kg	23.2	11.0	21.6	44.7	26.4
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)				Client sample ID	C31_1	C71_1	C71_2	C122_2	CN413_2
				Client sampling date / time	09-Jul-2020 15:30	21-Jul-2020 13:00	21-Jul-2020 13:30	21-Jul-2020 16:35	23-Jul-2020 16:00
Compound	CAS Number	LOR	Unit		EB2020245-006	EB2020245-007	EB2020245-008	EB2020245-009	EB2020245-010
					Result	Result	Result	Result	Result
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser - Continued									
Nitrite + Nitrate as N (Sol.)	----	0.1	mg/kg		23.7	11.9	22.5	45.1	26.6
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser									
Total Kjeldahl Nitrogen as N	----	20	mg/kg		920	2450	2080	640	450
EK062: Total Nitrogen as N (TKN + NOx)									
^ Total Nitrogen as N	----	20	mg/kg		940	2460	2100	680	480
EK067G: Total Phosphorus as P by Discrete Analyser									
Total Phosphorus as P	----	2	mg/kg		190	371	360	305	351
EK081: Bicarbonate Extractable Phosphorus (Olsen)									
Bicarbonate Extractable P (Olsen)	----	1.0	mg/kg		8.8	3.3	4.0	16.4	16.2
EP004: Organic Matter									
Organic Matter	----	0.5	%		2.6	3.7	4.8	1.8	1.6
Total Organic Carbon	----	0.5	%		1.5	2.1	2.8	1.0	0.9

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	CN413_1	C17_1	C17_2	C46_1	C46_2
			Client sampling date / time	23-Jul-2020 16:00	22-Jul-2020 11:00	22-Jul-2020 11:00	22-Jul-2020 12:30	22-Jul-2020 12:30
Compound	CAS Number	LOR	Unit	EB2020245-011	EB2020245-012	EB2020245-013	EB2020245-014	EB2020245-015
				Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	8.7	8.5	8.5	8.2	7.6
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	311	121	106	189	73
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	6.8	7.3	10.0	4.4	3.5
ED006: Exchangeable Cations on Alkaline Soils								
ø Exchangeable Calcium	----	0.2	meq/100g	7.9	13.5	14.0	6.4	13.4
ø Exchangeable Magnesium	----	0.2	meq/100g	2.9	4.5	3.7	2.6	3.8
ø Exchangeable Potassium	----	0.2	meq/100g	0.5	0.9	0.8	0.7	1.1
ø Exchangeable Sodium	----	0.2	meq/100g	0.8	<0.2	<0.2	0.4	<0.2
ø Cation Exchange Capacity	----	0.2	meq/100g	12.1	19.0	18.5	10.1	18.3
ø Exchangeable Sodium Percent	----	0.2	%	7.0	<0.2	<0.2	3.8	<0.2
ø Calcium/Magnesium Ratio	----	0.2	-	2.8	3.0	3.7	2.5	3.6
ø Magnesium/Potassium Ratio	----	0.2	-	5.9	4.8	4.9	3.6	3.4
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.01	0.04	0.01	0.01	0.01
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	10	mg/kg	170	20	20	60	<10
EG005(ED093)T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	7660	12200	14100	5370	3680
Boron	7440-42-8	50	mg/kg	<50	<50	<50	<50	<50
Iron	7439-89-6	50	mg/kg	11000	27600	31200	11800	9480
EG020T: Total Metals by ICP-MS								
Copper	7440-50-8	0.1	mg/kg	11.8	26.2	29.0	11.6	9.4
Manganese	7439-96-5	0.1	mg/kg	599	1080	922	1290	796
Zinc	7440-66-6	0.5	mg/kg	18.6	36.7	35.6	12.3	10.9
EK055: Ammonia as N								
Ammonia as N	7664-41-7	20	mg/kg	<20	<20	<20	<20	<20
EK057G: Nitrite as N by Discrete Analyser								
Nitrite as N (Sol.)	14797-65-0	0.1	mg/kg	0.3	0.7	0.4	0.3	0.2
EK058G: Nitrate as N by Discrete Analyser								
Nitrate as N (Sol.)	14797-55-8	0.1	mg/kg	41.2	10.2	6.7	34.4	11.5
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)				Client sample ID	CN413_1	C17_1	C17_2	C46_1	C46_2
				Client sampling date / time	23-Jul-2020 16:00	22-Jul-2020 11:00	22-Jul-2020 11:00	22-Jul-2020 12:30	22-Jul-2020 12:30
Compound	CAS Number	LOR	Unit		EB2020245-011	EB2020245-012	EB2020245-013	EB2020245-014	EB2020245-015
					Result	Result	Result	Result	Result
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser - Continued									
Nitrite + Nitrate as N (Sol.)	----	0.1	mg/kg		41.5	10.9	7.1	34.7	11.7
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser									
Total Kjeldahl Nitrogen as N	----	20	mg/kg		700	1460	1520	970	840
EK062: Total Nitrogen as N (TKN + NOx)									
^ Total Nitrogen as N	----	20	mg/kg		740	1470	1530	1000	850
EK067G: Total Phosphorus as P by Discrete Analyser									
Total Phosphorus as P	----	2	mg/kg		254	386	354	231	222
EK081: Bicarbonate Extractable Phosphorus (Olsen)									
Bicarbonate Extractable P (Olsen)	----	1.0	mg/kg		17.7	5.8	1.3	11.4	21.9
EP004: Organic Matter									
Organic Matter	----	0.5	%		2.7	4.8	4.1	2.6	2.1
Total Organic Carbon	----	0.5	%		1.6	2.8	2.4	1.5	1.2

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	C60_2	CN364_1	CN364_2	CN326_1	CN326_2
			Client sampling date / time	24-Jul-2020 11:15	27-Jul-2020 14:30	27-Jul-2020 14:30	28-Jul-2020 09:45	28-Jul-2020 09:45
Compound	CAS Number	LOR	Unit	EB2020245-016	EB2020245-017	EB2020245-018	EB2020245-019	EB2020245-020
				Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	8.5	9.1	8.8	8.6	9.0
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	160	118	87	84	94
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	11.4	6.6	3.6	16.5	13.6
ED006: Exchangeable Cations on Alkaline Soils								
ø Exchangeable Calcium	----	0.2	meq/100g	3.5	5.0	3.4	13.5	13.9
ø Exchangeable Magnesium	----	0.2	meq/100g	1.5	2.6	1.4	8.2	8.4
ø Exchangeable Potassium	----	0.2	meq/100g	1.1	0.4	0.5	0.7	0.5
ø Exchangeable Sodium	----	0.2	meq/100g	<0.2	0.7	<0.2	0.8	1.1
ø Cation Exchange Capacity	----	0.2	meq/100g	6.1	8.8	5.3	23.2	23.9
ø Exchangeable Sodium Percent	----	0.2	%	<0.2	8.5	<0.2	3.6	4.8
ø Calcium/Magnesium Ratio	----	0.2	-	2.4	1.9	2.3	1.6	1.6
ø Magnesium/Potassium Ratio	----	0.2	-	1.4	5.9	3.1	12.3	15.9
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.02	<0.01	<0.01	<0.01	0.01
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	10	mg/kg	20	30	20	10	<10
EG005(ED093)T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	11000	5350	3050	9400	12200
Boron	7440-42-8	50	mg/kg	<50	<50	<50	<50	<50
Iron	7439-89-6	50	mg/kg	30900	10500	6290	17300	23000
EG020T: Total Metals by ICP-MS								
Copper	7440-50-8	0.1	mg/kg	24.5	8.3	5.9	14.2	18.4
Manganese	7439-96-5	0.1	mg/kg	1020	282	184	472	908
Zinc	7440-66-6	0.5	mg/kg	36.4	11.5	6.4	28.0	35.9
EK055: Ammonia as N								
Ammonia as N	7664-41-7	20	mg/kg	<20	<20	<20	<20	<20
EK057G: Nitrite as N by Discrete Analyser								
Nitrite as N (Sol.)	14797-65-0	0.1	mg/kg	0.2	<0.1	<0.1	<0.1	<0.1
EK058G: Nitrate as N by Discrete Analyser								
Nitrate as N (Sol.)	14797-55-8	0.1	mg/kg	32.9	4.7	9.5	1.9	1.4
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)				Client sample ID	C60_2	CN364_1	CN364_2	CN326_1	CN326_2
				Client sampling date / time	24-Jul-2020 11:15	27-Jul-2020 14:30	27-Jul-2020 14:30	28-Jul-2020 09:45	28-Jul-2020 09:45
Compound	CAS Number	LOR	Unit		EB2020245-016	EB2020245-017	EB2020245-018	EB2020245-019	EB2020245-020
					Result	Result	Result	Result	Result
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser - Continued									
Nitrite + Nitrate as N (Sol.)	----	0.1	mg/kg		33.1	4.7	9.5	1.9	1.4
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser									
Total Kjeldahl Nitrogen as N	----	20	mg/kg		1400	390	310	620	560
EK062: Total Nitrogen as N (TKN + NOx)									
^ Total Nitrogen as N	----	20	mg/kg		1430	390	320	620	560
EK067G: Total Phosphorus as P by Discrete Analyser									
Total Phosphorus as P	----	2	mg/kg		508	161	132	538	498
EK081: Bicarbonate Extractable Phosphorus (Olsen)									
Bicarbonate Extractable P (Olsen)	----	1.0	mg/kg		12.7	4.6	6.5	15.5	10.0
EP004: Organic Matter									
Organic Matter	----	0.5	%		3.3	1.3	1.2	1.8	1.6
Total Organic Carbon	----	0.5	%		1.9	0.8	0.7	1.0	0.9

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	CN93_1	CN93_2	C51_1	C51_2	CN212_1
			Client sampling date / time	28-Jul-2020 12:45	28-Jul-2020 12:45	28-Jul-2020 16:30	28-Jul-2020 16:30	27-Jul-2020 12:15
Compound	CAS Number	LOR	Unit	EB2020245-021	EB2020245-022	EB2020245-023	EB2020245-024	EB2020245-025
				Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	8.0	7.8	8.5	8.0	8.5
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	137	98	136	248	113
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	13.7	18.2	12.0	16.4	12.0
ED006: Exchangeable Cations on Alkaline Soils								
ø Exchangeable Calcium	----	0.2	meq/100g	11.0	14.2	17.4	15.7	11.5
ø Exchangeable Magnesium	----	0.2	meq/100g	4.4	6.2	5.8	3.9	4.9
ø Exchangeable Potassium	----	0.2	meq/100g	1.0	1.7	1.6	1.6	1.2
ø Exchangeable Sodium	----	0.2	meq/100g	<0.2	<0.2	0.3	<0.2	<0.2
ø Cation Exchange Capacity	----	0.2	meq/100g	16.4	22.2	25.1	21.2	17.6
ø Exchangeable Sodium Percent	----	0.2	%	<0.2	<0.2	1.1	<0.2	<0.2
ø Calcium/Magnesium Ratio	----	0.2	-	2.5	2.3	3.0	4.0	2.3
ø Magnesium/Potassium Ratio	----	0.2	-	4.3	3.6	3.5	2.4	4.0
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.02	0.02	0.02	0.04	<0.01
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	10	mg/kg	30	20	30	30	30
EG005(ED093)T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	12900	13600	12400	10400	10000
Boron	7440-42-8	50	mg/kg	<50	<50	<50	<50	<50
Iron	7439-89-6	50	mg/kg	19700	19900	26500	28000	16700
EG020T: Total Metals by ICP-MS								
Copper	7440-50-8	0.1	mg/kg	18.3	17.8	26.9	23.0	13.3
Manganese	7439-96-5	0.1	mg/kg	854	665	913	874	438
Zinc	7440-66-6	0.5	mg/kg	30.4	31.5	34.5	31.0	24.0
EK055: Ammonia as N								
Ammonia as N	7664-41-7	20	mg/kg	<20	<20	<20	<20	<20
EK057G: Nitrite as N by Discrete Analyser								
Nitrite as N (Sol.)	14797-65-0	0.1	mg/kg	0.2	<0.1	0.2	0.2	0.1
EK058G: Nitrate as N by Discrete Analyser								
Nitrate as N (Sol.)	14797-55-8	0.1	mg/kg	24.5	13.9	21.2	78.4	5.3
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)				Client sample ID	CN93_1	CN93_2	C51_1	C51_2	CN212_1
				Client sampling date / time	28-Jul-2020 12:45	28-Jul-2020 12:45	28-Jul-2020 16:30	28-Jul-2020 16:30	27-Jul-2020 12:15
Compound	CAS Number	LOR	Unit		EB2020245-021	EB2020245-022	EB2020245-023	EB2020245-024	EB2020245-025
					Result	Result	Result	Result	Result
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser - Continued									
Nitrite + Nitrate as N (Sol.)	----	0.1	mg/kg		24.7	13.9	21.4	78.6	5.4
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser									
Total Kjeldahl Nitrogen as N	----	20	mg/kg		1040	1340	1460	2710	900
EK062: Total Nitrogen as N (TKN + NOx)									
^ Total Nitrogen as N	----	20	mg/kg		1060	1350	1480	2790	900
EK067G: Total Phosphorus as P by Discrete Analyser									
Total Phosphorus as P	----	2	mg/kg		369	530	336	347	377
EK081: Bicarbonate Extractable Phosphorus (Olsen)									
Bicarbonate Extractable P (Olsen)	----	1.0	mg/kg		24.0	23.2	4.0	4.2	26.1
EP004: Organic Matter									
Organic Matter	----	0.5	%		3.7	3.3	3.3	7.2	2.9
Total Organic Carbon	----	0.5	%		2.2	1.9	1.9	4.2	1.7

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	CN212_2	CN400_1	CN400_2	CN225_1	CN225_2
			Client sampling date / time	27-Jul-2020 12:15	27-Jul-2020 13:30	27-Jul-2020 13:30	23-Jul-2020 12:00	23-Jul-2020 12:00
Compound	CAS Number	LOR	Unit	EB2020245-026	EB2020245-027	EB2020245-028	EB2020245-029	EB2020245-030
				Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	7.8	8.0	8.0	8.6	8.8
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	74	205	92	905	664
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	11.9	8.6	8.6	11.1	18.8
ED006: Exchangeable Cations on Alkaline Soils								
ø Exchangeable Calcium	----	0.2	meq/100g	8.6	11.0	12.0	15.6	12.0
ø Exchangeable Magnesium	----	0.2	meq/100g	2.5	4.8	4.8	6.3	5.7
ø Exchangeable Potassium	----	0.2	meq/100g	1.3	0.6	1.2	0.5	0.4
ø Exchangeable Sodium	----	0.2	meq/100g	<0.2	0.8	0.6	3.3	3.3
ø Cation Exchange Capacity	----	0.2	meq/100g	12.4	17.2	18.7	25.6	21.5
ø Exchangeable Sodium Percent	----	0.2	%	<0.2	4.6	3.5	12.8	15.4
ø Calcium/Magnesium Ratio	----	0.2	-	3.4	2.3	2.5	2.5	2.1
ø Magnesium/Potassium Ratio	----	0.2	-	1.9	8.6	4.0	12.8	13.0
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.01	0.01	0.01	0.03	0.04
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	10	mg/kg	20	140	50	710	310
EG005(ED093)T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	6850	8510	8830	11100	10400
Boron	7440-42-8	50	mg/kg	<50	<50	<50	<50	<50
Iron	7439-89-6	50	mg/kg	12500	14400	13900	15100	13600
EG020T: Total Metals by ICP-MS								
Copper	7440-50-8	0.1	mg/kg	10.2	12.5	12.4	15.2	13.9
Manganese	7439-96-5	0.1	mg/kg	333	522	420	880	1480
Zinc	7440-66-6	0.5	mg/kg	20.8	24.6	24.0	23.9	20.6
EK055: Ammonia as N								
Ammonia as N	7664-41-7	20	mg/kg	<20	<20	<20	<20	<20
EK057G: Nitrite as N by Discrete Analyser								
Nitrite as N (Sol.)	14797-65-0	0.1	mg/kg	<0.1	0.2	0.1	0.9	<0.1
EK058G: Nitrate as N by Discrete Analyser								
Nitrate as N (Sol.)	14797-55-8	0.1	mg/kg	14.8	36.5	9.6	47.9	43.3
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)				Client sample ID	CN212_2	CN400_1	CN400_2	CN225_1	CN225_2
				Client sampling date / time	27-Jul-2020 12:15	27-Jul-2020 13:30	27-Jul-2020 13:30	23-Jul-2020 12:00	23-Jul-2020 12:00
Compound	CAS Number	LOR	Unit		EB2020245-026	EB2020245-027	EB2020245-028	EB2020245-029	EB2020245-030
					Result	Result	Result	Result	Result
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser - Continued									
Nitrite + Nitrate as N (Sol.)	----	0.1	mg/kg		14.8	36.7	9.7	48.8	43.3
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser									
Total Kjeldahl Nitrogen as N	----	20	mg/kg		930	650	830	650	680
EK062: Total Nitrogen as N (TKN + NOx)									
^ Total Nitrogen as N	----	20	mg/kg		940	690	840	700	720
EK067G: Total Phosphorus as P by Discrete Analyser									
Total Phosphorus as P	----	2	mg/kg		432	376	399	164	153
EK081: Bicarbonate Extractable Phosphorus (Olsen)									
Bicarbonate Extractable P (Olsen)	----	1.0	mg/kg		35.8	18.0	30.2	4.4	4.6
EP004: Organic Matter									
Organic Matter	----	0.5	%		2.9	1.9	2.1	1.6	1.8
Total Organic Carbon	----	0.5	%		1.7	1.1	1.2	1.0	1.1

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	C142_1	C142_2	CN385_1	CN385_2	CN414_1
			Client sampling date / time	23-Jul-2020 10:30	23-Jul-2020 10:30	23-Jul-2020 11:30	23-Jul-2020 11:30	23-Jul-2020 12:45
Compound	CAS Number	LOR	Unit	EB2020245-031	EB2020245-032	EB2020245-033	EB2020245-034	EB2020245-035
				Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	8.5	8.4	8.7	8.2	7.8
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	77	70	73	48	63
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	15.2	17.3	9.3	10.4	6.0
ED006: Exchangeable Cations on Alkaline Soils								
ø Exchangeable Calcium	----	0.2	meq/100g	15.3	20.9	4.0	3.8	2.2
ø Exchangeable Magnesium	----	0.2	meq/100g	3.0	5.3	1.7	2.0	<0.2
ø Exchangeable Potassium	----	0.2	meq/100g	0.5	0.5	0.3	0.7	0.3
ø Exchangeable Sodium	----	0.2	meq/100g	<0.2	0.2	<0.2	<0.2	<0.2
ø Cation Exchange Capacity	----	0.2	meq/100g	18.9	27.0	6.0	6.5	2.5
ø Exchangeable Sodium Percent	----	0.2	%	<0.2	0.9	<0.2	<0.2	<0.2
ø Calcium/Magnesium Ratio	----	0.2	-	5.1	3.9	2.3	1.9	----
ø Magnesium/Potassium Ratio	----	0.2	-	6.1	10.5	4.9	2.8	<0.2
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	<0.01	0.02	<0.01	<0.01	<0.01
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	10	mg/kg	10	10	20	20	<10
EG005(ED093)T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	15400	14100	4160	3460	1260
Boron	7440-42-8	50	mg/kg	<50	<50	<50	<50	<50
Iron	7439-89-6	50	mg/kg	29800	26700	9240	9450	3360
EG020T: Total Metals by ICP-MS								
Copper	7440-50-8	0.1	mg/kg	25.9	23.1	4.7	4.6	2.8
Manganese	7439-96-5	0.1	mg/kg	940	2490	112	102	242
Zinc	7440-66-6	0.5	mg/kg	40.5	23.9	4.1	5.0	3.3
EK055: Ammonia as N								
Ammonia as N	7664-41-7	20	mg/kg	<20	<20	<20	<20	<20
EK057G: Nitrite as N by Discrete Analyser								
Nitrite as N (Sol.)	14797-65-0	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
EK058G: Nitrate as N by Discrete Analyser								
Nitrate as N (Sol.)	14797-55-8	0.1	mg/kg	5.7	3.3	2.1	5.4	21.4
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)				Client sample ID	C142_1	C142_2	CN385_1	CN385_2	CN414_1
				Client sampling date / time	23-Jul-2020 10:30	23-Jul-2020 10:30	23-Jul-2020 11:30	23-Jul-2020 11:30	23-Jul-2020 12:45
Compound	CAS Number	LOR	Unit		EB2020245-031	EB2020245-032	EB2020245-033	EB2020245-034	EB2020245-035
					Result	Result	Result	Result	Result
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser - Continued									
Nitrite + Nitrate as N (Sol.)	----	0.1	mg/kg		5.7	3.3	2.1	5.4	21.4
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser									
Total Kjeldahl Nitrogen as N	----	20	mg/kg		1000	1550	290	350	340
EK062: Total Nitrogen as N (TKN + NOx)									
^ Total Nitrogen as N	----	20	mg/kg		1000	1550	290	360	360
EK067G: Total Phosphorus as P by Discrete Analyser									
Total Phosphorus as P	----	2	mg/kg		478	309	98	88	107
EK081: Bicarbonate Extractable Phosphorus (Olsen)									
Bicarbonate Extractable P (Olsen)	----	1.0	mg/kg		2.4	<1.0	<1.0	2.9	6.4
EP004: Organic Matter									
Organic Matter	----	0.5	%		1.8	3.5	1.0	1.1	1.3
Total Organic Carbon	----	0.5	%		1.0	2.0	0.6	0.6	0.8

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	CN414_2	CN387_1	CN387_2	CN55_1	CN55_2
			Client sampling date / time	23-Jul-2020 12:45	23-Jul-2020 13:30	23-Jul-2020 13:30	23-Jul-2020 14:45	23-Jul-2020 14:45
Compound	CAS Number	LOR	Unit	EB2020245-036	EB2020245-037	EB2020245-038	EB2020245-039	EB2020245-040
				Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	8.3	9.2	8.4	7.3	8.3
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	34	126	50	61	94
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	5.8	9.6	6.8	15.6	14.2
ED006: Exchangeable Cations on Alkaline Soils								
ø Exchangeable Calcium	----	0.2	meq/100g	2.1	3.1	5.6	----	10.3
ø Exchangeable Magnesium	----	0.2	meq/100g	<0.2	1.2	1.2	----	3.1
ø Exchangeable Potassium	----	0.2	meq/100g	0.3	<0.2	0.5	----	1.3
ø Exchangeable Sodium	----	0.2	meq/100g	<0.2	0.6	<0.2	----	0.2
ø Cation Exchange Capacity	----	0.2	meq/100g	2.4	5.0	7.4	----	15.0
ø Exchangeable Sodium Percent	----	0.2	%	<0.2	11.4	<0.2	----	1.6
ø Calcium/Magnesium Ratio	----	0.2	-	----	2.5	4.7	----	3.4
ø Magnesium/Potassium Ratio	----	0.2	-	<0.2	----	2.2	----	2.3
ED007: Exchangeable Cations								
Exchangeable Calcium	----	0.1	meq/100g	----	----	----	14.0	----
Exchangeable Magnesium	----	0.1	meq/100g	----	----	----	4.9	----
Exchangeable Potassium	----	0.1	meq/100g	----	----	----	2.0	----
Exchangeable Sodium	----	0.1	meq/100g	----	----	----	<0.1	----
Cation Exchange Capacity	----	0.1	meq/100g	----	----	----	21.0	----
Exchangeable Sodium Percent	----	0.1	%	----	----	----	0.4	----
Calcium/Magnesium Ratio	----	0.1	-	----	----	----	2.8	----
Magnesium/Potassium Ratio	----	0.1	-	----	----	----	2.5	----
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	<0.01	<0.01	<0.01	0.02	<0.01
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	10	mg/kg	<10	<10	<10	<10	10
EG005(ED093)T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	1360	2740	3280	7850	8600
Boron	7440-42-8	50	mg/kg	<50	<50	<50	<50	<50
Iron	7439-89-6	50	mg/kg	3390	8180	5420	14000	15100
EG020T: Total Metals by ICP-MS								
Copper	7440-50-8	0.1	mg/kg	3.3	2.4	5.3	12.2	13.2
Manganese	7439-96-5	0.1	mg/kg	266	168	206	497	626

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)				Client sample ID	CN414_2	CN387_1	CN387_2	CN55_1	CN55_2
				Client sampling date / time	23-Jul-2020 12:45	23-Jul-2020 13:30	23-Jul-2020 13:30	23-Jul-2020 14:45	23-Jul-2020 14:45
Compound	CAS Number	LOR	Unit		EB2020245-036	EB2020245-037	EB2020245-038	EB2020245-039	EB2020245-040
					Result	Result	Result	Result	Result
EG020T: Total Metals by ICP-MS - Continued									
Zinc	7440-66-6	0.5	mg/kg		3.5	3.2	4.4	25.6	27.0
EK055: Ammonia as N									
Ammonia as N	7664-41-7	20	mg/kg		<20	<20	<20	<20	<20
EK057G: Nitrite as N by Discrete Analyser									
Nitrite as N (Sol.)	14797-65-0	0.1	mg/kg		<0.1	<0.1	<0.1	<0.1	<0.1
EK058G: Nitrate as N by Discrete Analyser									
Nitrate as N (Sol.)	14797-55-8	0.1	mg/kg		3.6	6.5	6.6	11.6	19.4
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser									
Nitrite + Nitrate as N (Sol.)	----	0.1	mg/kg		3.6	6.5	6.6	11.6	19.4
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser									
Total Kjeldahl Nitrogen as N	----	20	mg/kg		360	200	510	1410	990
EK062: Total Nitrogen as N (TKN + NOx)									
^ Total Nitrogen as N	----	20	mg/kg		360	210	520	1420	1010
EK067G: Total Phosphorus as P by Discrete Analyser									
Total Phosphorus as P	----	2	mg/kg		111	136	134	488	455
EK081: Bicarbonate Extractable Phosphorus (Olsen)									
Bicarbonate Extractable P (Olsen)	----	1.0	mg/kg		5.4	1.8	6.4	48.2	38.7
EP004: Organic Matter									
Organic Matter	----	0.5	%		1.4	0.7	1.4	4.2	3.2
Total Organic Carbon	----	0.5	%		0.8	<0.5	0.8	2.4	1.8

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	C07_2	C07_1	C149_1	C149_2	C60_1
			Client sampling date / time	24-Jul-2020 09:00	24-Jul-2020 09:00	24-Jul-2020 10:15	24-Jul-2020 10:15	24-Jul-2020 11:15
Compound	CAS Number	LOR	Unit	EB2020245-041	EB2020245-042	EB2020245-043	EB2020245-044	EB2020245-045
				Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	8.4	8.4	8.5	8.4	8.2
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	105	108	147	178	140
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	16.0	13.4	12.2	10.4	16.4
ED006: Exchangeable Cations on Alkaline Soils								
ø Exchangeable Calcium	----	0.2	meq/100g	15.4	25.9	14.6	13.6	23.6
ø Exchangeable Magnesium	----	0.2	meq/100g	5.7	8.5	5.7	5.6	7.2
ø Exchangeable Potassium	----	0.2	meq/100g	1.7	1.3	1.6	1.6	2.5
ø Exchangeable Sodium	----	0.2	meq/100g	0.3	0.4	0.3	<0.2	<0.2
ø Cation Exchange Capacity	----	0.2	meq/100g	23.2	36.1	22.2	20.9	33.3
ø Exchangeable Sodium Percent	----	0.2	%	1.5	1.0	1.3	<0.2	<0.2
ø Calcium/Magnesium Ratio	----	0.2	-	2.7	3.0	2.6	2.4	3.3
ø Magnesium/Potassium Ratio	----	0.2	-	3.3	6.4	3.6	3.4	2.8
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.02	<0.01	0.01	0.01	0.02
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	10	mg/kg	20	20	40	20	20
EG005(ED093)T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	15000	14600	6940	6060	15500
Boron	7440-42-8	50	mg/kg	<50	<50	<50	<50	<50
Iron	7439-89-6	50	mg/kg	30800	31100	9540	13000	32400
EG020T: Total Metals by ICP-MS								
Copper	7440-50-8	0.1	mg/kg	28.8	28.2	13.9	11.9	26.6
Manganese	7439-96-5	0.1	mg/kg	1100	2400	1040	909	1820
Zinc	7440-66-6	0.5	mg/kg	32.0	32.6	14.3	14.3	38.5
EK055: Ammonia as N								
Ammonia as N	7664-41-7	20	mg/kg	<20	<20	<20	<20	<20
EK057G: Nitrite as N by Discrete Analyser								
Nitrite as N (Sol.)	14797-65-0	0.1	mg/kg	0.1	0.2	0.1	0.2	<0.1
EK058G: Nitrate as N by Discrete Analyser								
Nitrate as N (Sol.)	14797-55-8	0.1	mg/kg	11.9	8.6	16.7	42.2	29.7
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)				Client sample ID	C07_2	C07_1	C149_1	C149_2	C60_1
				Client sampling date / time	24-Jul-2020 09:00	24-Jul-2020 09:00	24-Jul-2020 10:15	24-Jul-2020 10:15	24-Jul-2020 11:15
Compound	CAS Number	LOR	Unit		EB2020245-041	EB2020245-042	EB2020245-043	EB2020245-044	EB2020245-045
					Result	Result	Result	Result	Result
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser - Continued									
Nitrite + Nitrate as N (Sol.)	----	0.1	mg/kg		12.0	8.8	16.8	42.4	29.7
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser									
Total Kjeldahl Nitrogen as N	----	20	mg/kg		1020	1330	960	970	1470
EK062: Total Nitrogen as N (TKN + NOx)									
^ Total Nitrogen as N	----	20	mg/kg		1030	1340	980	1010	1500
EK067G: Total Phosphorus as P by Discrete Analyser									
Total Phosphorus as P	----	2	mg/kg		182	228	185	366	538
EK081: Bicarbonate Extractable Phosphorus (Olsen)									
Bicarbonate Extractable P (Olsen)	----	1.0	mg/kg		2.6	1.7	14.8	11.8	26.7
EP004: Organic Matter									
Organic Matter	----	0.5	%		3.2	2.9	2.3	2.5	3.7
Total Organic Carbon	----	0.5	%		1.9	1.7	1.3	1.4	2.1

ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order	: **EB2020245**	Page	: 1 of 20
Amendment	: **1**		
Client	: **CORONADO CURRAGH PTY LTD**	Laboratory	: Environmental Division Brisbane
Contact	: KIM TUART	Contact	: Anna Riddell
Address	: CURRAGH MINE BLACKWATER QLD, AUSTRALIA 4717	Address	: 2 Byth Street Stafford QLD Australia 4053
Telephone	: 07 4986 9338	Telephone	: +61 7 4952 5795
Project	: General Soil	Date Samples Received	: 31-Jul-2020 12:20
Order number	: ----	Date Analysis Commenced	: 04-Aug-2020
C-O-C number	: ----	Issue Date	: 26-Aug-2020 16:46
Sampler	: CRYSTAL MERLOW, KELLY SMITH		
Site	: ----		
Quote number	: TV/028/19 v5		
No. of samples received	: 45		
No. of samples analysed	: 45		

Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Ben Felgendrejeris	Senior Acid Sulfate Soil Chemist	Brisbane Acid Sulphate Soils, Stafford, QLD
Ben Felgendrejeris	Senior Acid Sulfate Soil Chemist	Brisbane Inorganics, Stafford, QLD
Dave Gitsham	Metals Instrument Chemist	Brisbane Inorganics, Stafford, QLD
Kim McCabe	Senior Inorganic Chemist	Brisbane Acid Sulphate Soils, Stafford, QLD
Kim McCabe	Senior Inorganic Chemist	Brisbane Inorganics, Stafford, QLD
Mark Hallas	Senior Inorganic Chemist	Brisbane Acid Sulphate Soils, Stafford, QLD
Mark Hallas	Senior Inorganic Chemist	Brisbane Inorganics, Stafford, QLD
Santusha Pandra	Senior Chemist	Brisbane Inorganics, Stafford, QLD

General Comments

The analytical procedures used by ALS have been developed from established internationally recognised procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are fully validated and are often at the client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting
ø = ALS is not NATA accredited for these tests.
~ = Indicates an estimated value.

- EG020-T (Total Metals by ICP-MS): Sample C125_2 (EB2020245-001) shows poor duplicate results due to sample heterogeneity. Confirmed by visual inspection.
- ED006(Exchangeable Cations on Alkaline Soils): Unable to calculate Calcium/Magnesium Ratio for some samples as the required results for Calcium/Magnesium are below limit of reporting.
- ED006(Exchangeable Cations on Alkaline Soils): Unable to calculate Magnesium/Potassium Ratio for CN387_1 (EB2020245-037) as the required results for Magnesium/Potassium are below limit of reporting.
- ALS is not NATA accredited for the analysis of Exchangeable Aluminium and Exchange Acidity in soils when performed under ALS Method ED005.
- ALS is not NATA accredited for the analysis of Exchangeable Cations on Alkaline Soils when performed under ALS Method ED006.
- Amendment (26/08/2020): This report has been amended to allow the distribution to additional recipients. All analysis results are as per the previous report.
- EK061G (Total Kjeldahl Nitrogen as N) / EK067G (Total Phosphorus as P): Sample EB2020245_002 (C125_1) shows poor matrix spike recovery due to sample heterogeneity. Confirmed by visual inspection.
- EG020-T (Total Metals): Manganese Method Blank is above the limit of reporting but are not considered significant compared to analyte levels in the samples.
- EG020-T (Total Metals by ICP-MS): Sample C142_1 (EB2020245-031) shows poor duplicate results due to sample heterogeneity. Confirmed by visual inspection.
- EG005T (Total Metals by ICP-AES): Sample CN413_1 (EB2020245-011) shows poor duplicate results due to sample heterogeneity. Confirmed by visual inspection.
- EK061G (Total Kjeldahl Nitrogen as N) / EK067G (Total Phosphorus as P): Sample EB2020245_042 (C07_1) shows poor matrix spike recovery due to sample heterogeneity. Confirmed by visual inspection.
- ED007 and ED008: When Exchangeable Al is reported from these methods, it should be noted that Rayment & Lyons (2011) suggests Exchange Acidity by 1M KCl - Method 15G1 (ED005) is a more suitable method for the determination of exchange acidity (H+ + Al3+).
- Test comment

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	C125_2	C125_1	C122_1	C81_1	C81_2
			Client sampling date / time	02-Jul-2020 13:10	02-Jul-2020 12:15	21-Jul-2020 16:00	21-Jul-2020 14:00	21-Jul-2020 14:30
Compound	CAS Number	LOR	Unit	EB2020245-001	EB2020245-002	EB2020245-003	EB2020245-004	EB2020245-005
				Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	8.9	8.9	8.4	8.3	7.9
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	220	335	986	180	176
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	5.5	5.9	4.1	12.7	15.0
ED006: Exchangeable Cations on Alkaline Soils								
ø Exchangeable Calcium	----	0.2	meq/100g	12.2	8.4	10.6	10.7	13.7
ø Exchangeable Magnesium	----	0.2	meq/100g	4.0	2.8	4.9	4.2	5.8
ø Exchangeable Potassium	----	0.2	meq/100g	0.3	0.2	0.5	1.8	2.6
ø Exchangeable Sodium	----	0.2	meq/100g	1.8	1.5	2.2	<0.2	<0.2
ø Cation Exchange Capacity	----	0.2	meq/100g	18.3	13.0	18.2	16.8	22.1
ø Exchangeable Sodium Percent	----	0.2	%	9.8	11.7	12.0	<0.2	<0.2
ø Calcium/Magnesium Ratio	----	0.2	-	3.1	3.0	2.2	2.5	2.3
ø Magnesium/Potassium Ratio	----	0.2	-	11.8	10.8	9.2	2.3	2.2
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.02	0.02	0.04	0.03	0.03
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	10	mg/kg	80	230	1100	70	30
EG005(ED093)T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	8450	9690	9880	12300	14100
Boron	7440-42-8	50	mg/kg	<50	<50	<50	<50	<50
Iron	7439-89-6	50	mg/kg	24100	27500	20600	26300	27900
EG020T: Total Metals by ICP-MS								
Copper	7440-50-8	0.1	mg/kg	18.3	20.2	19.6	25.1	26.4
Manganese	7439-96-5	0.1	mg/kg	1300	739	800	955	1360
Zinc	7440-66-6	0.5	mg/kg	18.0	22.3	32.8	29.7	32.6
EK055: Ammonia as N								
Ammonia as N	7664-41-7	20	mg/kg	<20	<20	<20	<20	<20
EK057G: Nitrite as N by Discrete Analyser								
Nitrite as N (Sol.)	14797-65-0	0.1	mg/kg	0.3	0.4	0.6	0.7	0.9
EK058G: Nitrate as N by Discrete Analyser								
Nitrate as N (Sol.)	14797-55-8	0.1	mg/kg	17.5	23.5	18.8	28.7	55.6
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)				Client sample ID	C125_2	C125_1	C122_1	C81_1	C81_2
				Client sampling date / time	02-Jul-2020 13:10	02-Jul-2020 12:15	21-Jul-2020 16:00	21-Jul-2020 14:00	21-Jul-2020 14:30
Compound	CAS Number	LOR	Unit		EB2020245-001	EB2020245-002	EB2020245-003	EB2020245-004	EB2020245-005
					Result	Result	Result	Result	Result
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser - Continued									
Nitrite + Nitrate as N (Sol.)	----	0.1	mg/kg		17.8	23.9	19.4	29.4	56.5
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser									
Total Kjeldahl Nitrogen as N	----	20	mg/kg		800	990	640	1420	2230
EK062: Total Nitrogen as N (TKN + NOx)									
^ Total Nitrogen as N	----	20	mg/kg		820	1010	660	1450	2290
EK067G: Total Phosphorus as P by Discrete Analyser									
Total Phosphorus as P	----	2	mg/kg		215	252	319	408	443
EK081: Bicarbonate Extractable Phosphorus (Olsen)									
Bicarbonate Extractable P (Olsen)	----	1.0	mg/kg		1.7	1.5	10.7	8.3	14.1
EP004: Organic Matter									
Organic Matter	----	0.5	%		2.2	2.4	1.5	3.5	5.3
Total Organic Carbon	----	0.5	%		1.2	1.4	0.9	2.0	3.1

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	C31_1	C71_1	C71_2	C122_2	CN413_2
			Client sampling date / time	09-Jul-2020 15:30	21-Jul-2020 13:00	21-Jul-2020 13:30	21-Jul-2020 16:35	23-Jul-2020 16:00
Compound	CAS Number	LOR	Unit	EB2020245-006	EB2020245-007	EB2020245-008	EB2020245-009	EB2020245-010
				Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	7.4	8.3	8.2	8.2	9.0
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	137	142	158	294	290
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	2.0	9.7	10.3	4.1	9.5
ED006: Exchangeable Cations on Alkaline Soils								
ø Exchangeable Calcium	----	0.2	meq/100g	2.4	16.9	19.9	14.7	9.1
ø Exchangeable Magnesium	----	0.2	meq/100g	1.1	4.7	6.8	4.4	4.9
ø Exchangeable Potassium	----	0.2	meq/100g	0.8	1.4	2.7	0.7	0.6
ø Exchangeable Sodium	----	0.2	meq/100g	<0.2	<0.2	<0.2	1.1	1.8
ø Cation Exchange Capacity	----	0.2	meq/100g	4.2	23.0	29.5	21.0	16.5
ø Exchangeable Sodium Percent	----	0.2	%	<0.2	<0.2	<0.2	5.3	11.2
ø Calcium/Magnesium Ratio	----	0.2	-	2.2	3.6	2.9	3.3	1.8
ø Magnesium/Potassium Ratio	----	0.2	-	1.4	3.4	2.5	5.9	8.6
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.01	0.03	0.03	0.01	0.02
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	10	mg/kg	20	30	30	220	170
EG005(ED093)T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	2640	11700	13000	8640	6840
Boron	7440-42-8	50	mg/kg	<50	<50	<50	<50	<50
Iron	7439-89-6	50	mg/kg	7790	22800	26600	18600	13900
EG020T: Total Metals by ICP-MS								
Copper	7440-50-8	0.1	mg/kg	6.0	22.0	22.6	17.4	10.6
Manganese	7439-96-5	0.1	mg/kg	431	827	827	663	400
Zinc	7440-66-6	0.5	mg/kg	6.8	31.7	31.1	29.8	22.9
EK055: Ammonia as N								
Ammonia as N	7664-41-7	20	mg/kg	<20	<20	<20	<20	<20
EK057G: Nitrite as N by Discrete Analyser								
Nitrite as N (Sol.)	14797-65-0	0.1	mg/kg	0.5	0.9	0.9	0.4	0.2
EK058G: Nitrate as N by Discrete Analyser								
Nitrate as N (Sol.)	14797-55-8	0.1	mg/kg	23.2	11.0	21.6	44.7	26.4
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)				Client sample ID	C31_1	C71_1	C71_2	C122_2	CN413_2
				Client sampling date / time	09-Jul-2020 15:30	21-Jul-2020 13:00	21-Jul-2020 13:30	21-Jul-2020 16:35	23-Jul-2020 16:00
Compound	CAS Number	LOR	Unit		EB2020245-006	EB2020245-007	EB2020245-008	EB2020245-009	EB2020245-010
					Result	Result	Result	Result	Result
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser - Continued									
Nitrite + Nitrate as N (Sol.)	----	0.1	mg/kg		23.7	11.9	22.5	45.1	26.6
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser									
Total Kjeldahl Nitrogen as N	----	20	mg/kg		920	2450	2080	640	450
EK062: Total Nitrogen as N (TKN + NOx)									
^ Total Nitrogen as N	----	20	mg/kg		940	2460	2100	680	480
EK067G: Total Phosphorus as P by Discrete Analyser									
Total Phosphorus as P	----	2	mg/kg		190	371	360	305	351
EK081: Bicarbonate Extractable Phosphorus (Olsen)									
Bicarbonate Extractable P (Olsen)	----	1.0	mg/kg		8.8	3.3	4.0	16.4	16.2
EP004: Organic Matter									
Organic Matter	----	0.5	%		2.6	3.7	4.8	1.8	1.6
Total Organic Carbon	----	0.5	%		1.5	2.1	2.8	1.0	0.9

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	CN413_1	C17_1	C17_2	C46_1	C46_2
			Client sampling date / time	23-Jul-2020 16:00	22-Jul-2020 11:00	22-Jul-2020 11:00	22-Jul-2020 12:30	22-Jul-2020 12:30
Compound	CAS Number	LOR	Unit	EB2020245-011	EB2020245-012	EB2020245-013	EB2020245-014	EB2020245-015
				Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	8.7	8.5	8.5	8.2	7.6
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	311	121	106	189	73
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	6.8	7.3	10.0	4.4	3.5
ED006: Exchangeable Cations on Alkaline Soils								
ø Exchangeable Calcium	----	0.2	meq/100g	7.9	13.5	14.0	6.4	13.4
ø Exchangeable Magnesium	----	0.2	meq/100g	2.9	4.5	3.7	2.6	3.8
ø Exchangeable Potassium	----	0.2	meq/100g	0.5	0.9	0.8	0.7	1.1
ø Exchangeable Sodium	----	0.2	meq/100g	0.8	<0.2	<0.2	0.4	<0.2
ø Cation Exchange Capacity	----	0.2	meq/100g	12.1	19.0	18.5	10.1	18.3
ø Exchangeable Sodium Percent	----	0.2	%	7.0	<0.2	<0.2	3.8	<0.2
ø Calcium/Magnesium Ratio	----	0.2	-	2.8	3.0	3.7	2.5	3.6
ø Magnesium/Potassium Ratio	----	0.2	-	5.9	4.8	4.9	3.6	3.4
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.01	0.04	0.01	0.01	0.01
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	10	mg/kg	170	20	20	60	<10
EG005(ED093)T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	7660	12200	14100	5370	3680
Boron	7440-42-8	50	mg/kg	<50	<50	<50	<50	<50
Iron	7439-89-6	50	mg/kg	11000	27600	31200	11800	9480
EG020T: Total Metals by ICP-MS								
Copper	7440-50-8	0.1	mg/kg	11.8	26.2	29.0	11.6	9.4
Manganese	7439-96-5	0.1	mg/kg	599	1080	922	1290	796
Zinc	7440-66-6	0.5	mg/kg	18.6	36.7	35.6	12.3	10.9
EK055: Ammonia as N								
Ammonia as N	7664-41-7	20	mg/kg	<20	<20	<20	<20	<20
EK057G: Nitrite as N by Discrete Analyser								
Nitrite as N (Sol.)	14797-65-0	0.1	mg/kg	0.3	0.7	0.4	0.3	0.2
EK058G: Nitrate as N by Discrete Analyser								
Nitrate as N (Sol.)	14797-55-8	0.1	mg/kg	41.2	10.2	6.7	34.4	11.5
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)				Client sample ID	CN413_1	C17_1	C17_2	C46_1	C46_2
				Client sampling date / time	23-Jul-2020 16:00	22-Jul-2020 11:00	22-Jul-2020 11:00	22-Jul-2020 12:30	22-Jul-2020 12:30
Compound	CAS Number	LOR	Unit		EB2020245-011	EB2020245-012	EB2020245-013	EB2020245-014	EB2020245-015
					Result	Result	Result	Result	Result
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser - Continued									
Nitrite + Nitrate as N (Sol.)	----	0.1	mg/kg		41.5	10.9	7.1	34.7	11.7
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser									
Total Kjeldahl Nitrogen as N	----	20	mg/kg		700	1460	1520	970	840
EK062: Total Nitrogen as N (TKN + NOx)									
^ Total Nitrogen as N	----	20	mg/kg		740	1470	1530	1000	850
EK067G: Total Phosphorus as P by Discrete Analyser									
Total Phosphorus as P	----	2	mg/kg		254	386	354	231	222
EK081: Bicarbonate Extractable Phosphorus (Olsen)									
Bicarbonate Extractable P (Olsen)	----	1.0	mg/kg		17.7	5.8	1.3	11.4	21.9
EP004: Organic Matter									
Organic Matter	----	0.5	%		2.7	4.8	4.1	2.6	2.1
Total Organic Carbon	----	0.5	%		1.6	2.8	2.4	1.5	1.2

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	C60_2	CN364_1	CN364_2	CN326_1	CN326_2
			Client sampling date / time	24-Jul-2020 11:15	27-Jul-2020 14:30	27-Jul-2020 14:30	28-Jul-2020 09:45	28-Jul-2020 09:45
Compound	CAS Number	LOR	Unit	EB2020245-016	EB2020245-017	EB2020245-018	EB2020245-019	EB2020245-020
				Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	8.5	9.1	8.8	8.6	9.0
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	160	118	87	84	94
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	11.4	6.6	3.6	16.5	13.6
ED006: Exchangeable Cations on Alkaline Soils								
ø Exchangeable Calcium	----	0.2	meq/100g	3.5	5.0	3.4	13.5	13.9
ø Exchangeable Magnesium	----	0.2	meq/100g	1.5	2.6	1.4	8.2	8.4
ø Exchangeable Potassium	----	0.2	meq/100g	1.1	0.4	0.5	0.7	0.5
ø Exchangeable Sodium	----	0.2	meq/100g	<0.2	0.7	<0.2	0.8	1.1
ø Cation Exchange Capacity	----	0.2	meq/100g	6.1	8.8	5.3	23.2	23.9
ø Exchangeable Sodium Percent	----	0.2	%	<0.2	8.5	<0.2	3.6	4.8
ø Calcium/Magnesium Ratio	----	0.2	-	2.4	1.9	2.3	1.6	1.6
ø Magnesium/Potassium Ratio	----	0.2	-	1.4	5.9	3.1	12.3	15.9
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.02	<0.01	<0.01	<0.01	0.01
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	10	mg/kg	20	30	20	10	<10
EG005(ED093)T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	11000	5350	3050	9400	12200
Boron	7440-42-8	50	mg/kg	<50	<50	<50	<50	<50
Iron	7439-89-6	50	mg/kg	30900	10500	6290	17300	23000
EG020T: Total Metals by ICP-MS								
Copper	7440-50-8	0.1	mg/kg	24.5	8.3	5.9	14.2	18.4
Manganese	7439-96-5	0.1	mg/kg	1020	282	184	472	908
Zinc	7440-66-6	0.5	mg/kg	36.4	11.5	6.4	28.0	35.9
EK055: Ammonia as N								
Ammonia as N	7664-41-7	20	mg/kg	<20	<20	<20	<20	<20
EK057G: Nitrite as N by Discrete Analyser								
Nitrite as N (Sol.)	14797-65-0	0.1	mg/kg	0.2	<0.1	<0.1	<0.1	<0.1
EK058G: Nitrate as N by Discrete Analyser								
Nitrate as N (Sol.)	14797-55-8	0.1	mg/kg	32.9	4.7	9.5	1.9	1.4
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)				Client sample ID	C60_2	CN364_1	CN364_2	CN326_1	CN326_2
				Client sampling date / time	24-Jul-2020 11:15	27-Jul-2020 14:30	27-Jul-2020 14:30	28-Jul-2020 09:45	28-Jul-2020 09:45
Compound	CAS Number	LOR	Unit		EB2020245-016	EB2020245-017	EB2020245-018	EB2020245-019	EB2020245-020
					Result	Result	Result	Result	Result
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser - Continued									
Nitrite + Nitrate as N (Sol.)	----	0.1	mg/kg		33.1	4.7	9.5	1.9	1.4
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser									
Total Kjeldahl Nitrogen as N	----	20	mg/kg		1400	390	310	620	560
EK062: Total Nitrogen as N (TKN + NOx)									
^ Total Nitrogen as N	----	20	mg/kg		1430	390	320	620	560
EK067G: Total Phosphorus as P by Discrete Analyser									
Total Phosphorus as P	----	2	mg/kg		508	161	132	538	498
EK081: Bicarbonate Extractable Phosphorus (Olsen)									
Bicarbonate Extractable P (Olsen)	----	1.0	mg/kg		12.7	4.6	6.5	15.5	10.0
EP004: Organic Matter									
Organic Matter	----	0.5	%		3.3	1.3	1.2	1.8	1.6
Total Organic Carbon	----	0.5	%		1.9	0.8	0.7	1.0	0.9

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	CN93_1	CN93_2	C51_1	C51_2	CN212_1
			Client sampling date / time	28-Jul-2020 12:45	28-Jul-2020 12:45	28-Jul-2020 16:30	28-Jul-2020 16:30	27-Jul-2020 12:15
Compound	CAS Number	LOR	Unit	EB2020245-021	EB2020245-022	EB2020245-023	EB2020245-024	EB2020245-025
				Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	8.0	7.8	8.5	8.0	8.5
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	137	98	136	248	113
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	13.7	18.2	12.0	16.4	12.0
ED006: Exchangeable Cations on Alkaline Soils								
ø Exchangeable Calcium	----	0.2	meq/100g	11.0	14.2	17.4	15.7	11.5
ø Exchangeable Magnesium	----	0.2	meq/100g	4.4	6.2	5.8	3.9	4.9
ø Exchangeable Potassium	----	0.2	meq/100g	1.0	1.7	1.6	1.6	1.2
ø Exchangeable Sodium	----	0.2	meq/100g	<0.2	<0.2	0.3	<0.2	<0.2
ø Cation Exchange Capacity	----	0.2	meq/100g	16.4	22.2	25.1	21.2	17.6
ø Exchangeable Sodium Percent	----	0.2	%	<0.2	<0.2	1.1	<0.2	<0.2
ø Calcium/Magnesium Ratio	----	0.2	-	2.5	2.3	3.0	4.0	2.3
ø Magnesium/Potassium Ratio	----	0.2	-	4.3	3.6	3.5	2.4	4.0
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.02	0.02	0.02	0.04	<0.01
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	10	mg/kg	30	20	30	30	30
EG005(ED093)T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	12900	13600	12400	10400	10000
Boron	7440-42-8	50	mg/kg	<50	<50	<50	<50	<50
Iron	7439-89-6	50	mg/kg	19700	19900	26500	28000	16700
EG020T: Total Metals by ICP-MS								
Copper	7440-50-8	0.1	mg/kg	18.3	17.8	26.9	23.0	13.3
Manganese	7439-96-5	0.1	mg/kg	854	665	913	874	438
Zinc	7440-66-6	0.5	mg/kg	30.4	31.5	34.5	31.0	24.0
EK055: Ammonia as N								
Ammonia as N	7664-41-7	20	mg/kg	<20	<20	<20	<20	<20
EK057G: Nitrite as N by Discrete Analyser								
Nitrite as N (Sol.)	14797-65-0	0.1	mg/kg	0.2	<0.1	0.2	0.2	0.1
EK058G: Nitrate as N by Discrete Analyser								
Nitrate as N (Sol.)	14797-55-8	0.1	mg/kg	24.5	13.9	21.2	78.4	5.3
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)				Client sample ID	CN93_1	CN93_2	C51_1	C51_2	CN212_1
				Client sampling date / time	28-Jul-2020 12:45	28-Jul-2020 12:45	28-Jul-2020 16:30	28-Jul-2020 16:30	27-Jul-2020 12:15
Compound	CAS Number	LOR	Unit		EB2020245-021	EB2020245-022	EB2020245-023	EB2020245-024	EB2020245-025
					Result	Result	Result	Result	Result
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser - Continued									
Nitrite + Nitrate as N (Sol.)	----	0.1	mg/kg		24.7	13.9	21.4	78.6	5.4
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser									
Total Kjeldahl Nitrogen as N	----	20	mg/kg		1040	1340	1460	2710	900
EK062: Total Nitrogen as N (TKN + NOx)									
^ Total Nitrogen as N	----	20	mg/kg		1060	1350	1480	2790	900
EK067G: Total Phosphorus as P by Discrete Analyser									
Total Phosphorus as P	----	2	mg/kg		369	530	336	347	377
EK081: Bicarbonate Extractable Phosphorus (Olsen)									
Bicarbonate Extractable P (Olsen)	----	1.0	mg/kg		24.0	23.2	4.0	4.2	26.1
EP004: Organic Matter									
Organic Matter	----	0.5	%		3.7	3.3	3.3	7.2	2.9
Total Organic Carbon	----	0.5	%		2.2	1.9	1.9	4.2	1.7

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	CN212_2	CN400_1	CN400_2	CN225_1	CN225_2
			Client sampling date / time	27-Jul-2020 12:15	27-Jul-2020 13:30	27-Jul-2020 13:30	23-Jul-2020 12:00	23-Jul-2020 12:00
Compound	CAS Number	LOR	Unit	EB2020245-026	EB2020245-027	EB2020245-028	EB2020245-029	EB2020245-030
				Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	7.8	8.0	8.0	8.6	8.8
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	74	205	92	905	664
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	11.9	8.6	8.6	11.1	18.8
ED006: Exchangeable Cations on Alkaline Soils								
ø Exchangeable Calcium	----	0.2	meq/100g	8.6	11.0	12.0	15.6	12.0
ø Exchangeable Magnesium	----	0.2	meq/100g	2.5	4.8	4.8	6.3	5.7
ø Exchangeable Potassium	----	0.2	meq/100g	1.3	0.6	1.2	0.5	0.4
ø Exchangeable Sodium	----	0.2	meq/100g	<0.2	0.8	0.6	3.3	3.3
ø Cation Exchange Capacity	----	0.2	meq/100g	12.4	17.2	18.7	25.6	21.5
ø Exchangeable Sodium Percent	----	0.2	%	<0.2	4.6	3.5	12.8	15.4
ø Calcium/Magnesium Ratio	----	0.2	-	3.4	2.3	2.5	2.5	2.1
ø Magnesium/Potassium Ratio	----	0.2	-	1.9	8.6	4.0	12.8	13.0
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.01	0.01	0.01	0.03	0.04
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	10	mg/kg	20	140	50	710	310
EG005(ED093)T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	6850	8510	8830	11100	10400
Boron	7440-42-8	50	mg/kg	<50	<50	<50	<50	<50
Iron	7439-89-6	50	mg/kg	12500	14400	13900	15100	13600
EG020T: Total Metals by ICP-MS								
Copper	7440-50-8	0.1	mg/kg	10.2	12.5	12.4	15.2	13.9
Manganese	7439-96-5	0.1	mg/kg	333	522	420	880	1480
Zinc	7440-66-6	0.5	mg/kg	20.8	24.6	24.0	23.9	20.6
EK055: Ammonia as N								
Ammonia as N	7664-41-7	20	mg/kg	<20	<20	<20	<20	<20
EK057G: Nitrite as N by Discrete Analyser								
Nitrite as N (Sol.)	14797-65-0	0.1	mg/kg	<0.1	0.2	0.1	0.9	<0.1
EK058G: Nitrate as N by Discrete Analyser								
Nitrate as N (Sol.)	14797-55-8	0.1	mg/kg	14.8	36.5	9.6	47.9	43.3
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)				Client sample ID	CN212_2	CN400_1	CN400_2	CN225_1	CN225_2
				Client sampling date / time	27-Jul-2020 12:15	27-Jul-2020 13:30	27-Jul-2020 13:30	23-Jul-2020 12:00	23-Jul-2020 12:00
Compound	CAS Number	LOR	Unit		EB2020245-026	EB2020245-027	EB2020245-028	EB2020245-029	EB2020245-030
					Result	Result	Result	Result	Result
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser - Continued									
Nitrite + Nitrate as N (Sol.)	----	0.1	mg/kg		14.8	36.7	9.7	48.8	43.3
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser									
Total Kjeldahl Nitrogen as N	----	20	mg/kg		930	650	830	650	680
EK062: Total Nitrogen as N (TKN + NOx)									
^ Total Nitrogen as N	----	20	mg/kg		940	690	840	700	720
EK067G: Total Phosphorus as P by Discrete Analyser									
Total Phosphorus as P	----	2	mg/kg		432	376	399	164	153
EK081: Bicarbonate Extractable Phosphorus (Olsen)									
Bicarbonate Extractable P (Olsen)	----	1.0	mg/kg		35.8	18.0	30.2	4.4	4.6
EP004: Organic Matter									
Organic Matter	----	0.5	%		2.9	1.9	2.1	1.6	1.8
Total Organic Carbon	----	0.5	%		1.7	1.1	1.2	1.0	1.1

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	C142_1	C142_2	CN385_1	CN385_2	CN414_1
			Client sampling date / time	23-Jul-2020 10:30	23-Jul-2020 10:30	23-Jul-2020 11:30	23-Jul-2020 11:30	23-Jul-2020 12:45
Compound	CAS Number	LOR	Unit	EB2020245-031	EB2020245-032	EB2020245-033	EB2020245-034	EB2020245-035
				Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	8.5	8.4	8.7	8.2	7.8
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	77	70	73	48	63
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	15.2	17.3	9.3	10.4	6.0
ED006: Exchangeable Cations on Alkaline Soils								
ø Exchangeable Calcium	----	0.2	meq/100g	15.3	20.9	4.0	3.8	2.2
ø Exchangeable Magnesium	----	0.2	meq/100g	3.0	5.3	1.7	2.0	<0.2
ø Exchangeable Potassium	----	0.2	meq/100g	0.5	0.5	0.3	0.7	0.3
ø Exchangeable Sodium	----	0.2	meq/100g	<0.2	0.2	<0.2	<0.2	<0.2
ø Cation Exchange Capacity	----	0.2	meq/100g	18.9	27.0	6.0	6.5	2.5
ø Exchangeable Sodium Percent	----	0.2	%	<0.2	0.9	<0.2	<0.2	<0.2
ø Calcium/Magnesium Ratio	----	0.2	-	5.1	3.9	2.3	1.9	----
ø Magnesium/Potassium Ratio	----	0.2	-	6.1	10.5	4.9	2.8	<0.2
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	<0.01	0.02	<0.01	<0.01	<0.01
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	10	mg/kg	10	10	20	20	<10
EG005(ED093)T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	15400	14100	4160	3460	1260
Boron	7440-42-8	50	mg/kg	<50	<50	<50	<50	<50
Iron	7439-89-6	50	mg/kg	29800	26700	9240	9450	3360
EG020T: Total Metals by ICP-MS								
Copper	7440-50-8	0.1	mg/kg	25.9	23.1	4.7	4.6	2.8
Manganese	7439-96-5	0.1	mg/kg	940	2490	112	102	242
Zinc	7440-66-6	0.5	mg/kg	40.5	23.9	4.1	5.0	3.3
EK055: Ammonia as N								
Ammonia as N	7664-41-7	20	mg/kg	<20	<20	<20	<20	<20
EK057G: Nitrite as N by Discrete Analyser								
Nitrite as N (Sol.)	14797-65-0	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
EK058G: Nitrate as N by Discrete Analyser								
Nitrate as N (Sol.)	14797-55-8	0.1	mg/kg	5.7	3.3	2.1	5.4	21.4
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)				Client sample ID	C142_1	C142_2	CN385_1	CN385_2	CN414_1
				Client sampling date / time	23-Jul-2020 10:30	23-Jul-2020 10:30	23-Jul-2020 11:30	23-Jul-2020 11:30	23-Jul-2020 12:45
Compound	CAS Number	LOR	Unit		EB2020245-031	EB2020245-032	EB2020245-033	EB2020245-034	EB2020245-035
					Result	Result	Result	Result	Result
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser - Continued									
Nitrite + Nitrate as N (Sol.)	----	0.1	mg/kg		5.7	3.3	2.1	5.4	21.4
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser									
Total Kjeldahl Nitrogen as N	----	20	mg/kg		1000	1550	290	350	340
EK062: Total Nitrogen as N (TKN + NOx)									
^ Total Nitrogen as N	----	20	mg/kg		1000	1550	290	360	360
EK067G: Total Phosphorus as P by Discrete Analyser									
Total Phosphorus as P	----	2	mg/kg		478	309	98	88	107
EK081: Bicarbonate Extractable Phosphorus (Olsen)									
Bicarbonate Extractable P (Olsen)	----	1.0	mg/kg		2.4	<1.0	<1.0	2.9	6.4
EP004: Organic Matter									
Organic Matter	----	0.5	%		1.8	3.5	1.0	1.1	1.3
Total Organic Carbon	----	0.5	%		1.0	2.0	0.6	0.6	0.8

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	CN414_2	CN387_1	CN387_2	CN55_1	CN55_2
			Client sampling date / time	23-Jul-2020 12:45	23-Jul-2020 13:30	23-Jul-2020 13:30	23-Jul-2020 14:45	23-Jul-2020 14:45
Compound	CAS Number	LOR	Unit	EB2020245-036	EB2020245-037	EB2020245-038	EB2020245-039	EB2020245-040
				Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	8.3	9.2	8.4	7.3	8.3
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	34	126	50	61	94
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	5.8	9.6	6.8	15.6	14.2
ED006: Exchangeable Cations on Alkaline Soils								
ø Exchangeable Calcium	----	0.2	meq/100g	2.1	3.1	5.6	----	10.3
ø Exchangeable Magnesium	----	0.2	meq/100g	<0.2	1.2	1.2	----	3.1
ø Exchangeable Potassium	----	0.2	meq/100g	0.3	<0.2	0.5	----	1.3
ø Exchangeable Sodium	----	0.2	meq/100g	<0.2	0.6	<0.2	----	0.2
ø Cation Exchange Capacity	----	0.2	meq/100g	2.4	5.0	7.4	----	15.0
ø Exchangeable Sodium Percent	----	0.2	%	<0.2	11.4	<0.2	----	1.6
ø Calcium/Magnesium Ratio	----	0.2	-	----	2.5	4.7	----	3.4
ø Magnesium/Potassium Ratio	----	0.2	-	<0.2	----	2.2	----	2.3
ED007: Exchangeable Cations								
Exchangeable Calcium	----	0.1	meq/100g	----	----	----	14.0	----
Exchangeable Magnesium	----	0.1	meq/100g	----	----	----	4.9	----
Exchangeable Potassium	----	0.1	meq/100g	----	----	----	2.0	----
Exchangeable Sodium	----	0.1	meq/100g	----	----	----	<0.1	----
Cation Exchange Capacity	----	0.1	meq/100g	----	----	----	21.0	----
Exchangeable Sodium Percent	----	0.1	%	----	----	----	0.4	----
Calcium/Magnesium Ratio	----	0.1	-	----	----	----	2.8	----
Magnesium/Potassium Ratio	----	0.1	-	----	----	----	2.5	----
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	<0.01	<0.01	<0.01	0.02	<0.01
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	10	mg/kg	<10	<10	<10	<10	10
EG005(ED093)T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	1360	2740	3280	7850	8600
Boron	7440-42-8	50	mg/kg	<50	<50	<50	<50	<50
Iron	7439-89-6	50	mg/kg	3390	8180	5420	14000	15100
EG020T: Total Metals by ICP-MS								
Copper	7440-50-8	0.1	mg/kg	3.3	2.4	5.3	12.2	13.2
Manganese	7439-96-5	0.1	mg/kg	266	168	206	497	626

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)				Client sample ID	CN414_2	CN387_1	CN387_2	CN55_1	CN55_2
				Client sampling date / time	23-Jul-2020 12:45	23-Jul-2020 13:30	23-Jul-2020 13:30	23-Jul-2020 14:45	23-Jul-2020 14:45
Compound	CAS Number	LOR	Unit		EB2020245-036	EB2020245-037	EB2020245-038	EB2020245-039	EB2020245-040
					Result	Result	Result	Result	Result
EG020T: Total Metals by ICP-MS - Continued									
Zinc	7440-66-6	0.5	mg/kg		3.5	3.2	4.4	25.6	27.0
EK055: Ammonia as N									
Ammonia as N	7664-41-7	20	mg/kg		<20	<20	<20	<20	<20
EK057G: Nitrite as N by Discrete Analyser									
Nitrite as N (Sol.)	14797-65-0	0.1	mg/kg		<0.1	<0.1	<0.1	<0.1	<0.1
EK058G: Nitrate as N by Discrete Analyser									
Nitrate as N (Sol.)	14797-55-8	0.1	mg/kg		3.6	6.5	6.6	11.6	19.4
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser									
Nitrite + Nitrate as N (Sol.)	----	0.1	mg/kg		3.6	6.5	6.6	11.6	19.4
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser									
Total Kjeldahl Nitrogen as N	----	20	mg/kg		360	200	510	1410	990
EK062: Total Nitrogen as N (TKN + NOx)									
^ Total Nitrogen as N	----	20	mg/kg		360	210	520	1420	1010
EK067G: Total Phosphorus as P by Discrete Analyser									
Total Phosphorus as P	----	2	mg/kg		111	136	134	488	455
EK081: Bicarbonate Extractable Phosphorus (Olsen)									
Bicarbonate Extractable P (Olsen)	----	1.0	mg/kg		5.4	1.8	6.4	48.2	38.7
EP004: Organic Matter									
Organic Matter	----	0.5	%		1.4	0.7	1.4	4.2	3.2
Total Organic Carbon	----	0.5	%		0.8	<0.5	0.8	2.4	1.8

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	C07_2	C07_1	C149_1	C149_2	C60_1
			Client sampling date / time	24-Jul-2020 09:00	24-Jul-2020 09:00	24-Jul-2020 10:15	24-Jul-2020 10:15	24-Jul-2020 11:15
Compound	CAS Number	LOR	Unit	EB2020245-041	EB2020245-042	EB2020245-043	EB2020245-044	EB2020245-045
				Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	8.4	8.4	8.5	8.4	8.2
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	105	108	147	178	140
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	16.0	13.4	12.2	10.4	16.4
ED006: Exchangeable Cations on Alkaline Soils								
ø Exchangeable Calcium	----	0.2	meq/100g	15.4	25.9	14.6	13.6	23.6
ø Exchangeable Magnesium	----	0.2	meq/100g	5.7	8.5	5.7	5.6	7.2
ø Exchangeable Potassium	----	0.2	meq/100g	1.7	1.3	1.6	1.6	2.5
ø Exchangeable Sodium	----	0.2	meq/100g	0.3	0.4	0.3	<0.2	<0.2
ø Cation Exchange Capacity	----	0.2	meq/100g	23.2	36.1	22.2	20.9	33.3
ø Exchangeable Sodium Percent	----	0.2	%	1.5	1.0	1.3	<0.2	<0.2
ø Calcium/Magnesium Ratio	----	0.2	-	2.7	3.0	2.6	2.4	3.3
ø Magnesium/Potassium Ratio	----	0.2	-	3.3	6.4	3.6	3.4	2.8
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.02	<0.01	0.01	0.01	0.02
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	10	mg/kg	20	20	40	20	20
EG005(ED093)T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	15000	14600	6940	6060	15500
Boron	7440-42-8	50	mg/kg	<50	<50	<50	<50	<50
Iron	7439-89-6	50	mg/kg	30800	31100	9540	13000	32400
EG020T: Total Metals by ICP-MS								
Copper	7440-50-8	0.1	mg/kg	28.8	28.2	13.9	11.9	26.6
Manganese	7439-96-5	0.1	mg/kg	1100	2400	1040	909	1820
Zinc	7440-66-6	0.5	mg/kg	32.0	32.6	14.3	14.3	38.5
EK055: Ammonia as N								
Ammonia as N	7664-41-7	20	mg/kg	<20	<20	<20	<20	<20
EK057G: Nitrite as N by Discrete Analyser								
Nitrite as N (Sol.)	14797-65-0	0.1	mg/kg	0.1	0.2	0.1	0.2	<0.1
EK058G: Nitrate as N by Discrete Analyser								
Nitrate as N (Sol.)	14797-55-8	0.1	mg/kg	11.9	8.6	16.7	42.2	29.7
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)				Client sample ID	C07_2	C07_1	C149_1	C149_2	C60_1
				Client sampling date / time	24-Jul-2020 09:00	24-Jul-2020 09:00	24-Jul-2020 10:15	24-Jul-2020 10:15	24-Jul-2020 11:15
Compound	CAS Number	LOR	Unit		EB2020245-041	EB2020245-042	EB2020245-043	EB2020245-044	EB2020245-045
					Result	Result	Result	Result	Result
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser - Continued									
Nitrite + Nitrate as N (Sol.)	----	0.1	mg/kg		12.0	8.8	16.8	42.4	29.7
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser									
Total Kjeldahl Nitrogen as N	----	20	mg/kg		1020	1330	960	970	1470
EK062: Total Nitrogen as N (TKN + NOx)									
^ Total Nitrogen as N	----	20	mg/kg		1030	1340	980	1010	1500
EK067G: Total Phosphorus as P by Discrete Analyser									
Total Phosphorus as P	----	2	mg/kg		182	228	185	366	538
EK081: Bicarbonate Extractable Phosphorus (Olsen)									
Bicarbonate Extractable P (Olsen)	----	1.0	mg/kg		2.6	1.7	14.8	11.8	26.7
EP004: Organic Matter									
Organic Matter	----	0.5	%		3.2	2.9	2.3	2.5	3.7
Total Organic Carbon	----	0.5	%		1.9	1.7	1.3	1.4	2.1

APPENDIX I

Waste Characterisation Memorandum

Memorandum

To:	Margaret Stewart	**At:**	Coronado Curragh Pty Ltd
From:	Luke Rettke	**At:**	SLR Consulting Australia Pty Ltd
Date:	12 October 2022	**Ref:**	620.30075.0000-M01-v0.1-20221012.docx
Subject:	Waste Rock Characterisation Report		

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1 Waste Rock Characterisation

1.1 Sampling Frequency

A total of 20 waste rock samples were collected from the Curragh WRD. Based on the minor volumes of waste rock to be generated by the Curragh Mine the waste rock characterisation frequency is believed to comply with the frequency suggested in MEND (2009) (**Table 1**).

Table 1 Sampling frequency based on waste rock tonnage (MEND 2009)

Tonnage of Unit (metric tonnes)	Minimum Number of Samples
<10,000	3
<100,000	8
<1,000,000	26
<10,000,000	80

1.2 Acid Producing Potential

The characterisation of 20 waste rock samples from the Curragh WRD (**Figure 1** and **Table 2**) suggests that 17 of 20 samples are non-acid forming (NAF). Two sample are classified as Uncertain and one sample was classified as potentially acid generating (PAF). The net acid producing potential (NAPP) of all 20 samples ranges from positive 6.7 to negative 88.8 kg/H_2SO_4/tonne. Combined with the mostly alkaline NAG pH (16 of 20 samples) the overwhelming negative NAPP indicates a strong and available alkaline buffering capacity. Given this strong and available buffering capacity, the bulk waste rock is very unlikely to develop acid generating characteristics.

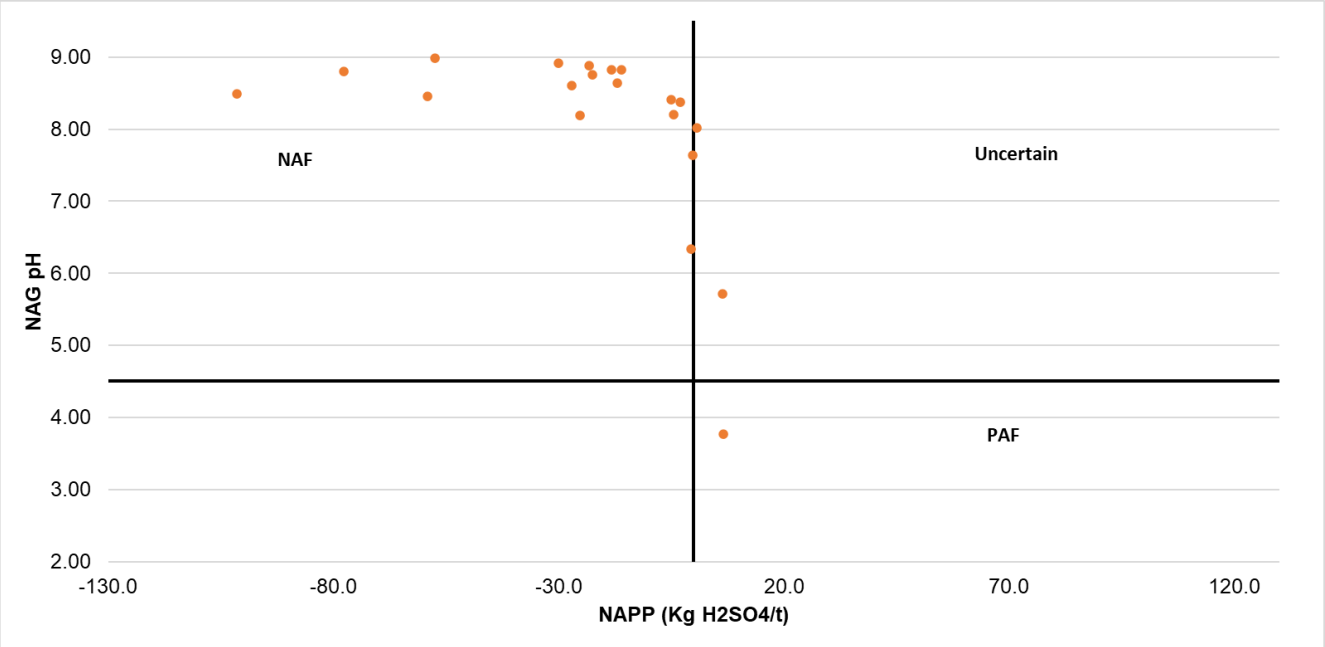


Figure 1 AMD characteristics of total 20 samples collected

Table 2 Summary of test results for 20 Curragh waste rock samples collected

Sample	NAG pH	MPA kg H_2SO_4/t based on total S	ANC kg H_2SO_4/t	NAPP kg H_2SO_4/t based on total S
SP-CN-C418	8.64	1.348	18.3	-23.8
SP-CN-C16	7.64	0.980	1.1	-0.1
SP-CM-C07	8.91	0.980	31.0	-30.1
SP-CM-C10	8.49	0.858	102.4	-88.8
SP-CM-C126	8.02	3.461	2.9	-6.5
SP-CM-C042	8.98	1.041	58.4	-61.1
SP-CM-C152	8.82	1.776	17.9	-30.7
SP-CM-C100	8.41	1.807	6.8	-10.7
SP-CM-C38/38	8.75	2.266	24.7	-54.8
SP-CM-C077	8.82	1.960	20.3	-38.6
SP-CN-C369/370	5.72	7.656	1.2	-1.8
SP-CN-CN93	8.20	1.378	5.9	-6.9
SP-CN-CN320	6.34	1.011	1.7	-0.7
SP-CN-CN342	3.77	6.584	0.0	6.7
SP-CN-CN413	8.19	1.439	26.7	-37.7

Sample	NAG pH	MPA kg H_2SO_4/t based on total S	ANC kg H_2SO_4/t	NAPP kg H_2SO_4/t based on total S
SP-CN-CN334	8.37	5.114	8.0	-36.8
SP-CN-CN364	8.88	1.807	25.0	-44.4
SP-CM-C051	8.60	1.348	28.5	-37.9
SP-CN-CN223	8.46	1.256	60.4	-76.3
SP-CM-C142	8.80	0.858	78.5	-67.9

1.1 Geochemical Abundance Index (GAI)

The geochemical abundance index (GAI) can be used to estimate the enrichment of metals in the samples relative to median crustal concentration. The GAI is expressed on a log 2 scale. The GAI was developed by Förstner et al., (1993) and is defined as follows:

$$GAI = log_2 \left({}^{C}/_{(1.5 * B)} \right)$$

$$C = measured\ concentration\ in\ sample$$
$$B = average\ crustal\ abundance$$

The enrichment ranges of a metal based on the GAI values are interpreted as follow:

- GAI=0 indicates <3 times median crustal abundance
- GAI=1 indicates 3 to 6 times median crustal abundance
- GAI=2 indicates 6 to 12 times median crustal abundance
- GAI=3 indicates 12 to 24 times median crustal abundance
- GAI=4 indicates 24 to 48 times median crustal abundance
- GAI=5 indicates 48 to 96 times median crustal abundance
- GAI=6 indicates more than 96 times median crustal abundance

GAI value of 3 is taken as the threshold for predicting potential metalliferous drainage from samples. The median crustal abundances used to compare results against in the GAI are provided in **Table 3**.

Table 3 Median crustal abundance for trace metals (Berkman and Ryall, 1976; Bowen, 1979)

Name	Symbol	Median Crustal Abundance (mg/kg)
Aluminium	Al	71000
Arsenic	As	6
Beryllium	Be	6
Boron	B	8.6
Cadmium	Cd	0.35
Cobalt	Co	8
Chromium	Cr	70
Copper	Cu	30

Name	Symbol	Median Crustal Abundance (mg/kg)
Iron	Fe	40000
Manganese	Mn	1000
Molybdenum	Mo	2
Nickel	Ni	50
Lead	Pb	35
Zinc	Zn	90
Selenium	Se	0.4
Vanadium	V	90

The GAI assessment of the 20 waste rock samples (**Table 4**) shows that the waste rock is depleted with regards to most metals. A slight enrichment only exists in four samples with regards to arsenic and cobalt.

Table 4 GAI summary of 20 drill core waste rock samples the Curragh WRD

Sample	Al	As	Be	B	Cd	Co	Cr	Cu	Fe	Pb	Mn	Mo	Ni	Zn	V
SP-CN-C418	-2	-1	-3	-2	-3	0	-2	0	0	-1	0	-4	0	0	-1
SP-CN-C16	-4	-2	-4	-1	-8	-1	-2	-2	-2	-4	-4	-4	-3	-4	-2
SP-CM-C07	-2	0	-2	0	-2	0	-1	0	0	-1	0	-2	-1	0	0
SP-CM-C10	-3	0	-3	0	-2	0	-3	0	-1	-1	-1	-2	-1	0	-2
SP-CM-C126	-3	0	-3	-1	-1	0	-3	0	-1	-1	-3	-1	-1	0	-2
SP-CM-C042	-3	0	-3	-1	-2	0	-3	0	-1	-2	0	-1	-1	0	-2
SP-CM-C152	-3	0	-3	0	-3	0	-2	0	0	-2	-1	-3	-1	-1	-1
SP-CM-C100	-3	0	-4	-1	-4	0	-2	-1	-1	-2	-1	-5	-1	-1	-2
SP-CM-C38/38	-3	0	-3	-1	-2	0	-3	0	0	-2	0	-1	-1	0	-2
SP-CM-C077	-3	1	-2	0	-1	0	-3	0	0	-1	0	-1	-1	0	-1
SP-CN-C369/370	-3	1	-3	-2	-2	0	-3	0	0	-1	0	0	-1	0	-2
SP-CN-CN93	-3	-1	-3	-1	-4	0	-1	-1	-1	-3	-1	-3	-1	-1	-1
SP-CN-CN320	-5	-3	-5	-3	-8	-1	-3	-3	-3	-4	-3	0	-3	-3	-3
SP-CN-CN342	-4	0	-4	-2	-4	0	-2	-1	-1	-3	-3	-3	-1	-1	-2
SP-CN-CN413	-3	0	-3	-2	-2	0	-2	0	-1	-1	-1	-3	-1	0	-1
SP-CN-CN334	-4	0	-3	-2	-2	0	-3	0	0	-1	0	-1	-1	-1	-2
SP-CN-CN364	-3	0	-3	-2	-2	0	-2	0	-1	-2	-1	-1	-1	0	-2
SP-CM-C051	-3	1	-3	-1	-2	0	-3	0	0	-1	0	-1	-1	0	-2
SP-CN-CN223	-3	0	-3	-2	-3	0	-2	0	-1	-2	-1	-1	-1	-1	-2
SP-CM-C142	-1	0	-2	-2	-2	1	0	0	0	-2	0	-2	0	0	0

1.2 Waste Rock Leachate Characteristics

The Australian Standard Leaching procedure (ASLP) subjects the waste rock samples to a 1:5 deionised (DI) water leach. The leachate is then tested for dissolved metal concentrations. ASLP results for the 20 samples from the Curragh WRD are shown in **Table 5** and exceeding water quality parameters with regards to the toxicant default guideline values for water quality in aquatic ecosystems (95% protection level) of the Australian & New Zealand Guidelines for Fresh & Marine Water Quality (Australian Government, 2022) are discussed below.

Limit exceedances in the 1:5 DI leachate occurred mainly for dissolved aluminium, copper, chromium, zinc and vanadium, with less exceedances for manganese, cadmium, cobalt and nickel . At the pH values measured (pH 8.4 – 9.8) most of these metals should not be mobile. Hence, the exceedances of these metal are likely due to the presence of natural clays (Brookins; 1988, Meunier; 1994), which will disperse and potentially pass through the standard (0.45 µm) filtration as particles. The NATA accredited laboratory assisting with the analysis noted that all samples were filtered at 0.45µm prior to analysis, however while “some samples were quite clear, others still had fine particulate suspended in the solution which was biasing the results high” (Matt Pocock, pers com 2022).

Table 5 ASLP results of the 20 core waste rock samples compared to the ANZECC95% protection Level (Australian Government 2022)

	pH	EC	Al	As	Cd	Cu	Pb	Mo	Zn	B	Cr	Co	Mn	Ni	V
		mS/cm	mg/L >pH6.5	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
ANZECC 95%			**0.055**	**0.024**	**0.0002**	**0.0014**	**0.0034**	**0.034**	**0.008**	**0.94**	**0.0033**	**0.0014**	**1.9**	**0.011**	**0.006**
SP-CN-C418	9.52	140	**0.41**	0.002	0.000	0.000	0.001	0.004	0.003	0.028	0.000	0.000	0.002	0.000	0.002
SP-CN-C16	8.92	180	**22.9**	0.001	0.000	0.001	0.001	0.002	**0.010**	0.099	**0.019**	0.001	0.005	0.005	**0.007**
SP-CM-C07	8.67	1980	0.02	0.000	0.000	0.000	0.000	0.002	0.000	0.181	0.001	0.000	0.000	0.000	0.001
SP-CM-C10	9.46	500	**0.90**	0.002	0.000	**0.003**	0.001	0.004	0.005	0.132	0.001	0.000	0.011	0.001	0.01
SP-CM-C126	8.27	2670	0.00	0.004	0.000	0.001	0.000	0.023	0.001	0.086	0.000	0.000	0.005	0.000	0.001
SP-CM-C042	9.82	220	**0.11**	0.003	0.000	0.001	0.000	0.012	0.003	0.059	0.000	0.000	0.002	0.000	0.002
SP-CM-C152	8.83	3220	0.00	0.000	0.000	0.000	0.000	0.002	0.000	0.157	0.000	0.000	0.001	0.000	0.001
SP-CM-C100	9.43	120	**7.36**	0.002	0.000	**0.003**	0.002	0.002	**0.009**	0.075	**0.006**	0.001	0.038	0.003	**0.014**
SP-CM-C38/38	10.02	420	**0.15**	0.001	0.000	0.000	0.000	0.004	0.003	0.047	0.000	0.000	0.000	0.000	0.00
SP-CM-C077	9.18	740	**0.18**	0.002	0.000	**0.003**	0.001	0.005	0.004	0.089	0.000	0.000	0.006	0.001	0.002
SP-CN-C369/370	5.70	120	0.01	0.000	0.000	0.000	0.000	0.000	0.007	0.014	0.000	**0.002**	0.620	0.009	0.000
SP-CN-CN93	9.15	180	**5.15**	0.006	0.000	**0.004**	0.002	0.004	**0.013**	0.056	**0.008**	0.001	0.103	0.007	**0.044**
SP-CN-CN320	9.23	40	**3.23**	0.002	0.000	0.001	0.001	0.001	0.007	0.005	**0.008**	0.001	0.012	0.003	**0.011**
SP-CN-CN342	3.39	1340	**3.17**	0.001	**0.002**	**0.021**	0.001	0.000	**0.734**	0.006	**0.002**	**0.891**	**8.26**	**1.14**	0.000
SP-CN-CN413	9.33	120	**0.09**	0.001	0.000	**0.002**	0.000	0.001	**0.094**	0.011	0.000	**0.145**	1.53	**0.173**	0.001
SP-CN-CN334	9.54	270	0.03	0.007	0.000	0.000	0.000	0.024	0.006	0.020	0.000	0.001	0.016	0.002	0.001
SP-CN-CN364	9.69	430	**0.11**	0.005	0.000	0.001	0.000	0.010	0.005	0.039	0.000	0.000	0.003	0.000	0.00
SP-CM-C051	9.12	700	**0.06**	0.001	0.000	0.001	0.000	0.005	0.000	0.080	0.000	0.000	0.004	0.000	0.002

	pH	EC	Al	As	Cd	Cu	Pb	Mo	Zn	B	Cr	Co	Mn	Ni	V
SP-CN-CN223	9.47	190	**0.24**	0.008	0.000	0.001	0.000	0.015	0.006	0.037	0.000	0.000	0.004	0.000	0.003
SP-CM-C142	9.05	110	0.01	0.000	0.000	0.000	0.000	0.001	0.000	0.011	**0.002**	0.000	0.001	0.000	0.004
SP-CN-C418	9.52	140	**0.41**	0.002	0.000	0.000	0.001	0.004	0.003	0.028	0.000	0.000	0.002	0.000	0.002
SP-CN-C16	8.92	180	**22.9**	0.001	0.000	0.001	0.001	0.002	**0.010**	0.099	**0.019**	0.001	0.005	0.005	**0.007**

2 Conclusion

The geochemical assessment of 20 additional wasterock samples from Curragh confirmed the results of previous waste rock assessments by URS in 2005 and 2015. The waste rock collected is in its entirety non-acid generating and has significant buffering capacity. Metal concentrations of the waste rock, represented through the GAI, are very low. Showing that the sedimentary sequences forming the waste rock are depleted with regards to most metals. As a result of the high buffering capacity and relatively low metal concentrations of the solid waste rock future metal leaching from the waste rock will be low. Compared to available guideline values for freshwater, several ASLP metal concentrations, particularly aluminium and vanadium, are in exceedance. Such exceedances are unlikely at the reported leachate pH and are thought to be the result of colloid transport through the 0.45µm filter membrane.

3 References

Australian Government, (2022). Toxicant default guideline values for water quality in aquatic ecosystems. https://www.waterquality.gov.au/anz-uidelines/guideline-values/default/water-quality-toxicants/search#tox-289. Accessed 07.02.2022.

Brookins D. G. (1988). Eh-pH Diagrams for Geochemistry. Springer-Verlag, Berlin.

Förstner, U., Ahlf, W., & Calmano, W., 1993, "Sediment Quality Objectives and Criteria Development in Germany", Water Science & Technology, 28:307-316.

MEND (2009). Prediction Manual for Drainage Chemistry from sulphidic Geologic Materials. MEND Report 1.20.1.

Matt Pocock (2022). Technical Team Leader (Waters and ICP), Environmental Analysis Laboratory. Southern Cross University.

Meunier, J.D. (1994). The Composition and Origin of Vanadium-Rich Clay Minerals in Colorado Plateau Jurassic Sandstones. Clays and Clay Minerals, Volume 42, pages391–401.

URS (2005). Geochemical Characterisation and Assessment of Overburden and Potential Coal Reject material at the Ensham Central Project. Prepared for Hansen Consulting. 24 October, 2005. 42625576/R001-Final.DOC.

URS (2015). Geochemical Characterisation of Overburden and Potential Rejects. Prepared for Ensham Resources Pty. Ltd., 19 March 2015. 42627460/R001/A

Checked/
Authorised by: MT

APPENDIX J

Flood Modelling Report

CURRAGH MINE

Progressive Rehabilitation and Closure Plan
Flood Assessment

Prepared for:

Coronado Curragh Pty Ltd
Blackwater, QLD, 4717

SLR Ref: 626.30075-R02
Version No: -v0.2
September 2022

PREPARED BY

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BASIS OF REPORT

This report has been prepared by SLR Consulting Australia Pty Ltd (SLR) with all reasonable skill, care and diligence, and taking account of the timescale and resources allocated to it by agreement with Coronado Curragh Pty Ltd (the Client). Information reported herein is based on the interpretation of data collected, which has been accepted in good faith as being accurate and valid.

This report is for the exclusive use of the Client. No warranties or guarantees are expressed or should be inferred by any third parties. This report may not be relied upon by other parties without written consent from SLR.

SLR disclaims any responsibility to the Client and others in respect of any matters outside the agreed scope of the work.

DOCUMENT CONTROL

Reference	Date	Prepared	Checked	Authorised
626.30075-R02-v0.2	8 September 2022	TS	HD	EW
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1 Introduction

1.1 Scope of Work

SLR was engaged by Coronado Curragh Pty Ltd (CCPL) to undertaken hydrologic and hydraulic modelling for the floodplain surrounding the Curragh Complex, as part of the Progressive Rehabilitation and Closure Plan. The modelling was undertaken to refine the previous hydraulic modelling undertaken in the *Conceptual Residual Void Assessment Preliminary Flood Impact Report* (SLR, 2021). The key tasks undertaken include:

- Development of a hydrologic model in WBNM of the Mackenzie River and Blackwater Creek catchments and calibration to two historical events;
- Refinement of previously conducted stream gauge Flood Frequency Analysis (FFA);
- Estimation of 0.1% AEP and PMF events in accordance with Australian Rainfall and Runoff (2019);
- Revision of the hydraulic model with updated LiDAR;
- Reporting of methods used and findings of the above assessments, including all relevant mapping of flood level and depths.

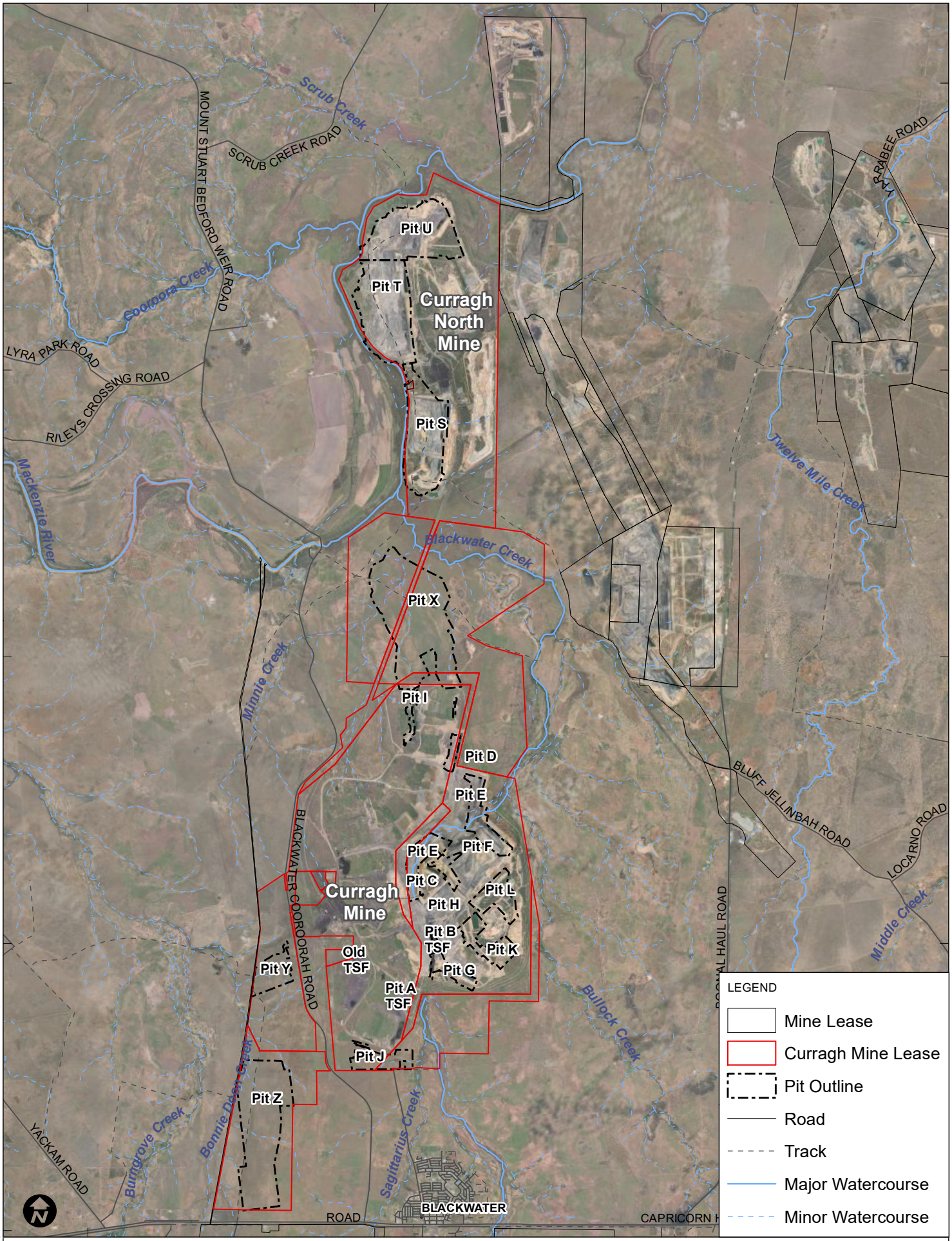
1.2 Project Information

The Curragh mine is an open cut coal mine located in the Bowen Basin, approximately 6 km north of the town of Blackwater and approximately 200 km west of Rockhampton in Central Queensland. The Curragh Complex has been operating since 1983 and covers an area of approximately 19,650 ha. Mackenzie River and Blackwater Creek run adjacent to the mine. Blackwater Creek flows from the south, flows through a diversion and joins Mackenzie River north of Pit X. The project location is shown in **Figure 1**.

1.3 Relevant Documentation

This assessment was undertaken referring to the following guidelines and documentation:

- *Environmental Protection Act 1994;*
- *Environmental Protection Regulation 2019;*
- *'Guideline – Progressive Rehabilitation and Closure Plans'*, Department of Environment and Science, March 2021 (PRCP Guideline);
- *'Information Sheet – Environmental Protection Act 1994 – Voids in Flood Plains'*, Department of Environment and Science, March 2020 (Voids in Flood Plains Information Sheet); and
- *'Australian Rainfall and Runoff: A guide to Flood estimation'*, Geoscience Australia, 2019 (AR&R).



SLR

DISCLAIMER: All information within this document may be based on external sources. SLR Consulting Pty Ltd makes no warranty regarding the data's accuracy or reliability for any purpose.

0 2 4 km

Coordinate System:	AGD 1984 AMG Zone 55
Scale:	1:170,000 at A4
Project Number:	626.30075
Date:	24-Nov-2021
Drawn by:	ML
Reviewed by:	ML

Data Source:

CURRAGH PRCP

Current Mine Layout

FIGURE 1

H:\Projects-SLR\626-MKY\626.30075.00000 Curragh Mine PRCP 2021\06 SLR Data\01 CAD\GIS\GIS\626.630075 F01 Base Map.mxd

1.4 Assumptions and Limitations

This flood assessment has relied upon information which was received from the client and other sources. SLR has assumed that information provided is accurate and, except where noted, SLR has not verified the accuracy of the information provided.

This report has been prepared for the purposes of assessing the impacts of a PMF and 0.1% AEP flood event for the relevant watercourse which impacts on the Curragh Complex.

- The hydrological model has been developed using the *Jellinbah Mackenzie North Pit Flood Study* (WRM, 2018) (referred herein as the Jellinbah flood study) as a guide. A model in WBNM has been developed, using larger sub-catchments. Although there are differences between the model set up and parameters used, two calibration events have been run through the current WBNM model to verify that the model can achieve a similar level of calibration using reasonable model parameters.
- The FFA undertaken in the *Conceptual Residual Void Assessment Preliminary Flood Impact Report* (SLR, 2021) and the Jellinbah flood study report show large differences in magnitude. It was noted in the *Conceptual Residual Void Assessment Preliminary Flood Impact Report* that the various gauges assessed lacked any convergence, with the 0.1% AEP peak flow estimates differing by an order of magnitude. Potential reasons for this include the inability of this assessment to account for large floodplain storage, the presence of artificial features such as dams and weirs, the presence of mine pits which absorbed flow on at least one occasion, short gauge records and lack of accuracy of rating curves.
- Coincident flooding assessment between the Mackenzie River and the other tributaries within the hydraulic model has not been undertaken. The hydrological model output with the highest peak in the main Mackenzie River and Blackwater Creek inflows have been chosen as the critical event for assessment.
- The hydraulic modelling is based on 1m LiDAR information (dated Dec 2021). A terrain surface was developed combining the residual void landform and 1m LiDAR.
- No bathymetric data for Mackenzie River was available and hence assumptions were made regarding the bathymetry in the vicinity of the weirs.
- All roughness values adopted were as established in the *Conceptual Residual Void Assessment Preliminary Flood Impact Report* (SLR, 2021). These were determined by review of aerial photography with no site visits carried out.
- The proposed Mackenzie North Levee, Pit V levee, and Jellinbah levee are not included in this assessment as there was no information available. As data becomes available, re-running of the hydraulic model is recommended.

This report should be read in full, and no excerpts are to be taken as representative of the findings. This report has been prepared on behalf of CCPL and we accept no liability or responsibility whatsoever for, or in respect of, any use of, or reliance upon, this report by any third party.

1.5 Definitions and Terminology

Table 1 Report Definitions

Term	Definition
Annual Exceedance Probability (AEP)	The chance of a flood of a given size (or larger) occurring in any one year, usually expressed as a percentage. For example, if a flood level of 3.5 mAHD has an AEP of 1% or 1 in 100 (or 1:100), it means that there is a 1% chance (i.e., a 1 in 100 chance) of a flood level of 3.5 mAHD (or larger) occurring in any one year (See also average recurrence interval).
Australian Height Datum (AHD)	National survey datum corresponding approximately to mean sea level.
Average Recurrence Interval (ARI)	The long-term average number of years between the occurrence of a flood as big as (or larger than) the selected event. ARI is another way of expressing the likelihood of occurrence of a flood event (see also annual exceedance probability).
Average Variability Method (AVM)	Technique for estimating design temporal pattern of average variability to ensure AEP neutrality in transition from PMP to PMPDF
Catchment	The catchment at a particular point is the area of land that drains to that point.
Design flood	A hypothetical flood representing a specific likelihood of occurrence (for example the 1% AEP probability flood).
Discharge	The rate of flow of water measured in terms of volume over time (i.e., the amount of water moving past a point). Discharge and flow are interchangeable.
DEM	Digital Elevation Model – a three-dimensional model of the ground surface.
Flood	Relatively high river or creek flows, which overtop the natural or artificial banks, and inundate floodplains and/or coastal inundation resulting from super elevated sea levels and/or waves overtopping coastline defences.
Flood Frequency Analysis	An analysis of historical flood records to determine estimates of design flood flows.
Floodplain	Land adjacent to a river or creek that is periodically inundated due to floods. The floodplain includes all land that is susceptible to inundation by the probable maximum flood (PMF) event.
Flood Storage	Floodplain areas that are important for the temporary storage of floodwaters during a flood
Floodway	A flow path (sometimes artificial) that carries significant volumes of floodwaters during a flood.
Historical Flood	A flood which has occurred in the past.
Hydrograph	A graph showing how a river or creek's discharge or water level changes with time.

Term	Definition
Hydrology	The term given to the study of the rainfall-runoff process in catchments.
Levee	Operational mine protection device.
Long-term stable embankment	Landform feature which may protect residual voids from flood ingress, is not a regulated structure.
Peak flood level, flow, or velocity	The maximum flood level, flow or velocity occurring during a flood event at a particular location.
Pit	Operational open cut mine pit/void
Probable Maximum Flood (PMF)	The flood that results from the transformation of the PMP using conservatively high (but reasonable) values for design inputs such as losses, temporal pattern, etc. (BoM, 2005)
Probable Maximum Precipitation (PMP)	'The greatest depth of precipitation for a given duration meteorologically possible over a given size storm area at a particular location at a particular time of the year, with no allowance made for long-term climatic trends" (World Meteorological Organization, 1986)
Probability	A statistical measure of the likely frequency or occurrence of flooding
Residual void	Post closure landform design term.
Runoff	The amount of rainfall from a catchment that actually ends up as flowing water in the river or creek.
Velocity	The speed at which floodwater are moving.
Water level	Same as flood level.

Table 2 Report Abbreviations

Abbreviation	Term
1D/2D	One dimensional / two dimensional
AEP	Annual Exceedance Probability
AHD	Australian Height Datum
ARI	Average Recurrence Interval
ARR2019	Australian Rainfall and Runoff 2019
BoM	Bureau of Meteorology
CCPL	Coronado Curragh Pty Ltd
CRVA	Concept Residual Void Assessment
Curragh Complex	Curragh Mine Complex "the mine"
DEM	Digital Elevation Model
km	Kilometres
m^3/s	Cubic Metres per second

Abbreviation	Term
mAHD	Elevation in metres relative to the Australian Height Datum
RFFE	Regional Flood Frequency Estimation

2 Legislation and Guidelines

2.1 Relevant Legislation and Guidelines

The relevant documentation for this assessment is detailed in **Section 1.3**. Key details in the context of the assessment are provided below.

The Environmental Protection Act 1994 states:

'In accordance with Section 126D(3) of the EP Act, if land the subject of the proposed PRCP schedule will contain a void situated wholly or partly in a flood plain, the schedule must provide for the rehabilitation of the land to a stable condition.'

The Environmental Protection Regulation 2019 section 41C(3) also states:

'The administering authority must treat the land as a flood plain to the extent the results of the flood plain modelling show that, when all relevant activities carried out on the land have ended, the land is the same height as, or lower than, the level modelled as the peak water level 0.1% AEP for a relevant watercourse under the ARR'

Further guidance is provided in the PRCP Guideline and the Voids in Flood Plains Information Sheet.

Sections 3.4 and 3.6.1 of the PRCP Guideline both require a floodplain assessment to be carried out. Specifically, Section 3.4 requires a Void in Floodplain assessment for all unapproved Non-Use Management Area (NUMA) voids (i.e. floodplain assessment of the pre-mining landform), whilst Section 3.6.1 requires a post-mining landform assessment irrespective whether a post-mining land use (PMLU) or NUMA is proposed. This assessment was undertaken only to address the requirements of Section 3.6.1.

The hydrologic and hydraulic analyses were undertaken in accordance with AR&R (2019).

2.2 Applicability to the Project

Based on the review of the EP Act, EP Regulation, PRCP Guideline and the Voids in Floodplains information sheets, it is considered that the legislative requirements set out **Table 3** are applicable to the project.

Table 3 Applicable Legislative Requirements

Requirement	Application to the Project	Source
For transitional sites, a floodplain assessment is required where: - A void has been identified as a NUMA in a land outcome document, but the location has not been specified; or - Where there are no land outcomes in the land outcome document.	A Voids in Floodplain was previously undertaken by SLR as detailed in *Conceptual Residual Void Assessment Preliminary Flood Impact Report* (SLR, 2021) (ref 626.30075-R01-v0.1)	PRCP Guideline Section 3.4

Requirement	Application to the Project	Source
The requirement for a flood assessment under Section 3.6.1 of the Guideline applies to the post mining landform across the whole site irrespective of whether a PMLU or a NUMA are proposed. Furthermore, Section 3.6.1 is not only required to indicate flood risk but also to demonstrate the final landform (including waste rock dumps and diversions) will remain in a stable condition in a range of flood flow conditions.	The final voids are all considered to be NUMAs and therefore will be retained in the post-mining landform where it can be shown the voids are in a stable condition. Therefore, a flood assessment is required to show the proposed final voids will remain in a stable condition following closure of Curragh.	PRCP Guideline Section 3.6.1

3 Data Review and Gap Analysis

3.1 Available Data

The following data was provided or obtained for the assessment:

- Residual void landform (supplied as 0.5m contours);
- 1m LiDAR provided as x,y,z points;
- Shuttle Radar Topography Mission (SRTM) terrain data – sourced from Geoscience Australia for the hydraulic model extent where LiDAR wasn't available;
- Aerial photography sourced from Queensland Globe, used to determine roughness of land uses within the floodplain extent;
- Rainfall intensity-frequency-duration (IFD) data for the area (Bureau of Meteorology (BoM));
- Catchment specific hydrologic data (ARR Data Hub);
- Pluviograph rainfall data for various gauges in the catchment (Bureau of Meteorology (BoM));
- Stream gauge station records for creeks within the catchment (Department of Regional Development, Manufacturing and Water (RDMW));
- *'Bowen Basin River Diversions – Design and Rehabilitation Criteria'* (Australian Coal Association Research Program (ACARP), 2002); and
- *Jellinbah Mackenzie North Pit Flood Study* (WRM, 2018).

3.2 Watercourses

A review of the existing watercourses in the vicinity of Curragh Mine was undertaken to identify the watercourses that may affect flooding conditions at CVM. The following watercourses were included in the assessment in the hydraulic model (refer to **Figure 1** for location):

- Mackenzie River;
- Blackwater Creek;
- Sagittarius Creek;
- Bullock Creek;
- Burngrove Creek;
- Cooroora Creek; and
- Scrub Creek.

3.3 Landform

A model landform was developed for the assessment based on the available data as detailed in **Section 3.1.** The 2021 LiDAR DEM was used as the underlying base topography. The provided post-mining DEM was overlayed on the base topography to form the post-mining model landform, as shown in **Figure 6** and discussed further in **Section 5.2.**

3.4 Previous Studies

The following assessment has been undertaken for the Mackenzie River:

- *Jellinbah Mackenzie North Pit Flood Study* (WRM, 2018).

The Jellinbah Mackenzie North Pit Flood Study involved developing a calibrated hydrologic model of the Mackenzie River catchment. The results of the hydrological model were used to for the detailed design of the proposed Mackenzie North Levee.

4 Hydrologic Modelling

4.1 Overview

WBNM software was adopted for the hydrologic modelling of the catchment. WBNM software is a general runoff and streamflow routing program used to calculate flood hydrographs from rainfall. WBNM was used with the software Storm Injector (Version 1.3.2) to streamline the required model runs by Australian Rainfall and Runoff 2019 (ARR2019) and to develop the local and total inflow hydrograph boundaries for input to the hydraulic model.

The hydrological model catchment for the Mackenzie River is in excess of 50,000 km^2 and combines the Nogoa River, Theresa Creek, and Comet River catchments which discharge into the Mackenzie River catchment.

4.2 Previous Modelling

Previous modelling of the Mackenzie River catchment in the vicinity of the Curragh site has been conducted by WRM using URBS (WRM, 2018). This model was calibrated and amended over a number of projects. The model itself was not available however the reporting associated with the modelling was contained in *the Jellinbah Mackenzie North Pit Flood Study* (WRM, 2018). The information available within this report, particularly the catchment boundaries, was used to develop the WBNM model. A smaller number of catchment subareas was adopted for the WBNM model as the level of detail adopted for the previous hydrological modelling was not considered necessary or beneficial.

The URBS parameters adopted in the Jellinbah flood study hydrological model are noted as below in **Table 4**.

Table 4 Adopted URBS model parameters (WRM, 2018)

Catchment	Alpha	Beta
Nogoa	0.33	2.5
Theresa	0.27	3.0
Mackenzie	0.35	3.0
Comet	0.45	3.5

According to the URBS manual (Carroll, 2016), the typical range of Alpha is 0.1 to 0.3 and for Beta is 1 to 9. While the values of Beta are in the typical range, some values of Alpha are outside the typical range. As Alpha and Beta are related to catchment routing, this suggests that the calibration required some parameters to be outside the typical range.

4.3 Model set up

4.3.1 Catchments

The total catchment area for the Mackenzie River is 50,714 km^2. This can be separated into the Nogoa River (16,189 km^2), Theresa Creek (8,484 km^2), Comet River (16,133 km^2) and Mackenzie River (9,908 km^2) catchments. Sub-catchments for the WBNM model were delineated using SRTM topographic data and watercourse data from QSpatial, with the Jellinbah flood study URBS model as a guide. The WBNM model layout is shown in **Figure 2**. Details for the sub-catchments are listed in **Table 5**.

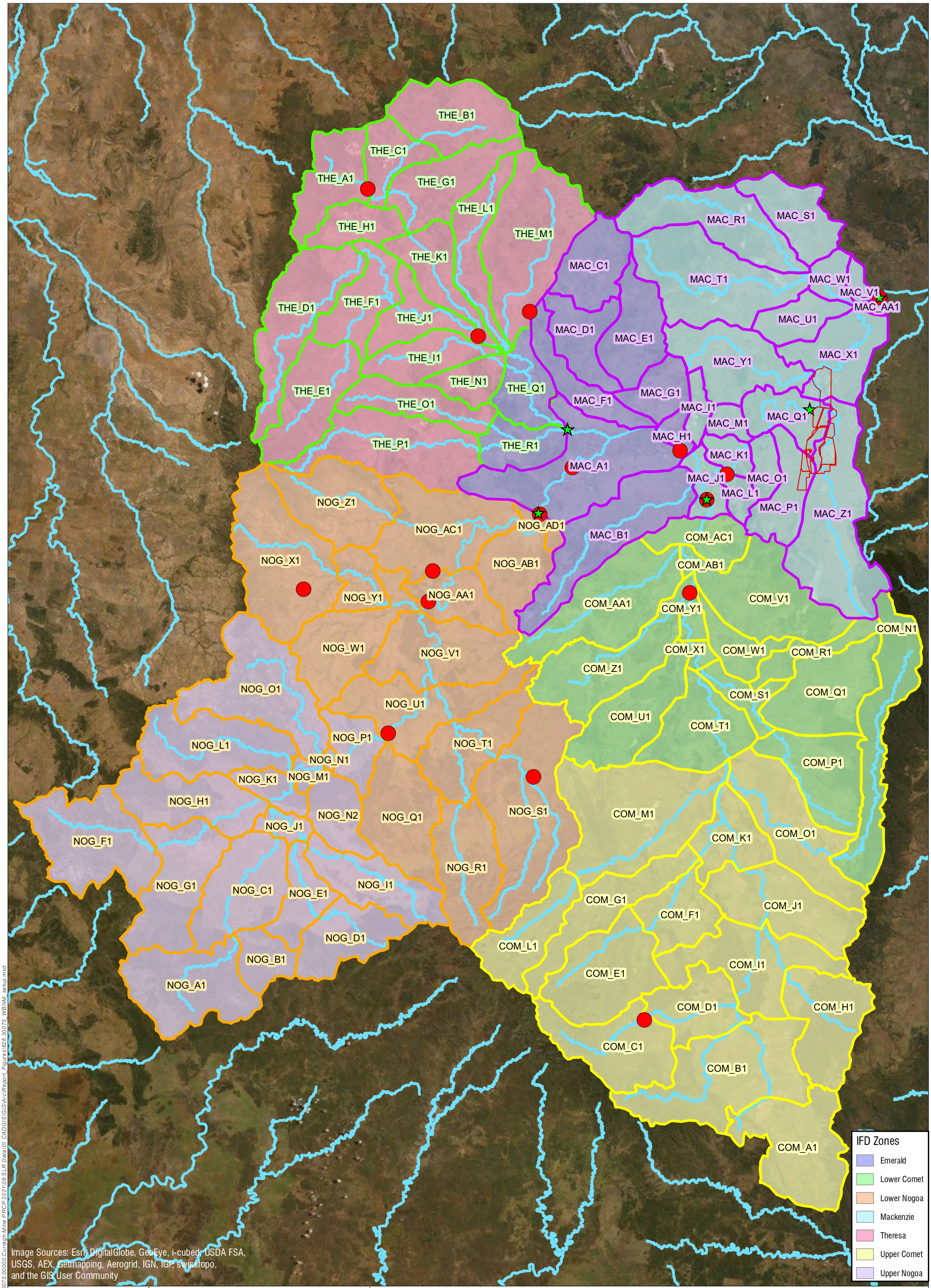
Table 5 WBNM Model Sub-catchment Details

Sub-catchment ID	Downstream Sub-catchment ID	Area (km^2)	Fraction Impervious
COM_A1	COM_B1	780.2	0.01
COM_B1	COM_D1	1067.9	0.03
COM_C1	COM_D1	646.6	0.00
COM_D1	COM_I1	434.5	0.03
COM_E1	COM_F1	738.3	0.00
COM_F1	COM_K1	378.6	0.03
COM_G1	COM_K1	524.8	0.00
COM_H1	COM_I1	619.6	0.00
COM_I1	COM_J1	740.1	0.00
COM_J1	COM_K1	703.8	0.01
COM_K1	COM_T1	385.0	0.02
COM_L1	COM_M1	459.8	0.00
COM_M1	COM_T1	1217.0	0.03
COM_N1	COM_O1	744.0	0.00
COM_O1	COM_T1	760.3	0.01
COM_P1	COM_S1	582.5	0.00
COM_Q1	COM_S1	650.1	0.00
COM_R1	COM_S1	213.5	0.03
COM_S1	COM_X1	194.5	0.01
COM_T1	COM_X1	577.3	0.00
COM_U1	COM_Y1	593.5	0.01
COM_V1	COM_AB1	773.6	0.02
COM_W1	COM_AB1	249.6	0.00
COM_X1	COM_Y1	62.1	0.03
COM_Y1	COM_AB1	143.2	0.01

Sub-catchment ID	Downstream Sub-catchment ID	Area (km²)	Fraction Impervious
COM_Z1	COM_Y1	663.0	0.01
COM_AA1	COM_AB1	875.6	0.01
COM_AB1	COM_AC1	51.2	0.06
COM_AC1	MAC_J1	303.3	0.01
MAC_A1	MAC_J1	1004.2	0.04
MAC_B1	MAC_J1	817.0	0.03
MAC_C1	MAC_D1	420.2	0.00
MAC_D1	MAC_G1	366.2	0.00
MAC_E1	MAC_G1	462.3	0.06
MAC_F1	MAC_H1	324.9	0.01
MAC_G1	MAC_H1	255.0	0.01
MAC_H1	MAC_J1	85.9	0.12
MAC_I1	MAC_J1	112.4	0.14
MAC_J1	MAC_K1	182.0	0.05
MAC_K1	MAC_O1	133.3	0.00
MAC_L1	MAC_K1	97.7	0.01
MAC_M1	MAC_Q1	101.6	0.00
MAC_O1	MAC_Q1	139.7	0.04
MAC_P1	MAC_Q1	353.3	0.07
MAC_Q1	MAC_X1	319.1	0.04
MAC_R1	MAC_W1	708.7	0.07
MAC_S1	MAC_W1	411.0	0.05
MAC_T1	MAC_W1	953.7	0.08
MAC_U1	MAC_AA1	259.4	0.00
MAC_V1	MAC_AA1	69.3	0.01
MAC_W1	MAC_AA1	143.3	0.00
MAC_X1	MAC_AA1	518.5	0.07
MAC_Y1	MAC_X1	619.5	0.00
MAC_Z1	MAC_X1	1024.8	0.10
MAC_AA1	SINK	25.1	0.01
NOG_A1	NOG_C1	745.7	0.00
NOG_B1	NOG_C1	236.5	0.00
NOG_C1	NOG_J1	658.0	0.00

Sub-catchment ID	Downstream Sub-catchment ID	Area (km²)	Fraction Impervious
NOG_D1	NOG_E1	456.1	0.00
NOG_E1	NOG_J1	303.0	0.00
NOG_F1	NOG_G1	816.8	0.00
NOG_G1	NOG_H1	680.9	0.00
NOG_H1	NOG_K1	589.6	0.00
NOG_I1	NOG_J1	517.5	0.00
NOG_J1	NOG_K1	118.9	0.01
NOG_K1	NOG_M1	185.4	0.00
NOG_L1	NOG_M1	722.0	0.00
NOG_M1	NOG_N1	69.2	0.00
NOG_N1	NOG_P1	21.1	0.00
NOG_N2	NOG_N1	314.2	0.00
NOG_O1	NOG_N1	874.9	0.00
NOG_P1	NOG_U1	270.8	0.00
NOG_Q1	NOG_U1	654.2	0.00
NOG_R1	NOG_T1	618.6	0.00
NOG_S1	NOG_T1	1231.8	0.00
NOG_T1	NOG_U1	565.5	0.00
NOG_U1	NOG_V1	678.2	0.00
NOG_V1	NOG_AA1	690.4	0.00
NOG_W1	NOG_AA1	632.0	0.00
NOG_X1	NOG_Y1	1000.5	0.00
NOG_Y1	NOG_W1	225.0	0.01
NOG_Z1	NOG_AC1	655.4	0.00
NOG_AA1	NOG_AC1	331.8	0.00
NOG_AB1	NOG_AD1	430.0	0.14
NOG_AC1	NOG_AD1	823.3	0.07
NOG_AD1	MAC_A1	71.9	0.36
THE_A1	THE_C1	446.4	0.03
THE_B1	THE_C1	590.9	0.01
THE_C1	THE_G1	295.8	0.06
THE_D1	THE_F1	744.0	0.01
THE_E1	THE_F1	589.9	0.00

Sub-catchment ID	Downstream Sub-catchment ID	Area (km²)	Fraction Impervious
THE_F1	THE_J1	425.5	0.00
THE_G1	THE_K1	515.8	0.01
THE_H1	THE_K1	273.8	0.00
THE_I1	THE_Q1	363.9	0.00
THE_J1	THE_K1	330.1	0.00
THE_K1	THE_Q1	405.2	0.00
THE_L1	THE_Q1	425.3	0.01
THE_M1	THE_Q1	1020.5	0.01
THE_N1	THE_Q1	202.8	0.00
THE_O1	THE_R1	387.4	0.00
THE_P1	THE_R1	823.6	0.02
THE_Q1	MAC_A1	342.1	0.00
THE_R1	MAC_A1	301.0	0.03


THE_B1
THE_C1
THE_A1
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COM_I1
COM_E1
COM_D1
COM_H1
COM_C1
COM_B1
COM_A1
IFD Zones
Emerald
Lower Comet
Lower Nogoa
Mackenzie
Theresa
Upper Comet
Upper Nogoa
Image Sources: Esri, DigitalGlobe, GeoEye, i-cubed, USDA FSA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community
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Legend
Mackenzie River Subcatchments
Comet Creek Subcatchments
Nogoa River Subcatchments
Theresa Creek Subcatchments
Curragh Mine Lease
Streamflow Gauges
Sub-daily Rainfall Gauges
Major Watercourses
Curragh Mine PRCP
Flood Assessment
WBNM Model Layout
Figure 2

4.4 Model Calibration

A number of flood events have occurred within the Mackenzie River catchment in the last 10 years. Gauge data was examined to determine appropriate events for use in the calibration of the modelling. The following events were considered to be of sufficient size to be adopted for further assessment:

- January 2008;
- January 2011; and
- May 2022

After detailed assessment of these events, the 2011 event and the 2022 event were chosen for hydrologic model calibration. Although the 2008 event was larger than the 2011 event, there were several BoM gauges where 2008 rainfall data was not available and therefore the 2011 was chosen over the 2008 event. The 2008 event also had the added complication of the flooding of the Ensham open cut pits, as outlined in Section A5.2 of the Jellinbah flood study (WRM, 2018) and was therefore not considered further.

The streamflow gauges used are listed in **Table 6**. These gauges are located at the most downstream end of the Theresa Creek, Nogoa River, and Comet River catchments, and two gauges in the Mackenzie River catchment. They are also shown in **Figure 2**.

Table 6 Streamflow Gauges

Stream Gauge No.	Station Name	Catchment	2011	2022
130206A	Gregory Highway	Theresa	✓	✓
130504B	Comet Weir	Comet	✓	✓
130216A	Fairbairn Dam	Nogoa	✓	x
130111A	Bedford Weir TW	Mackenzie	✓	x
130106A	Bingegang Weir HW	Mackenzie	x	✓

The sub-daily rainfall gauges used in calibration are listed in **Table 7**. Thiessen polygons were used to initially allocate which rainfall gauge was attributed to each subarea. The gauges are also shown in **Figure 2**.

Table 7 Sub-daily rainfall gauges

Gauge No.	Station Name	Catchment	2011	2022
35187	Valeria Alert	Theresa	✓	✓
35185	Capella (Rowe's Hill) Alert	Theresa	✓	✓
130207	Sandy Creek at Clermont	Theresa	✓	✓
535101	Fairbairn Dam Alert	Nogoa	✓	✓
535099	Raymond Alert	Nogoa	✓	✓
35251	Craigmore Alert	Nogoa	✓	✓

Gauge No.	Station Name	Catchment	2011	2022
35292	Ducabrook Alert	Nogoa	✓	✓
35293	Heathwood Alert	Nogoa	✓	✓
35294	Kulumur Range Alert	Nogoa	✓	✓
535076	Emerald Alert	Mackenzie	✓	✓
130504	Comet River at Comet Weir	Mackenzie	✓	✓
130219	Nogoa River at Duck Ponds	Mackenzie	✓	✓
130113	Riley's Crossing TM	Mackenzie	✓	✓
130106	Bingegang Weir HW Alert	Mackenzie	x	✓
130509	Carnarvon Creek at Rewan	Comet	✓	✓
35276	Springsure Creek Junction	Comet	✓	✓

The results were compared at Bedford Weir for the 2011 event and at Bingegang for the 2022 event, as the data for the 2011 event at Bingegang Weir was not available The calibration results are shown in **Figure 3** for the 2011 event and **Figure 4** for the 2022 event. The model parameters adopted are listed in **Table 8**.

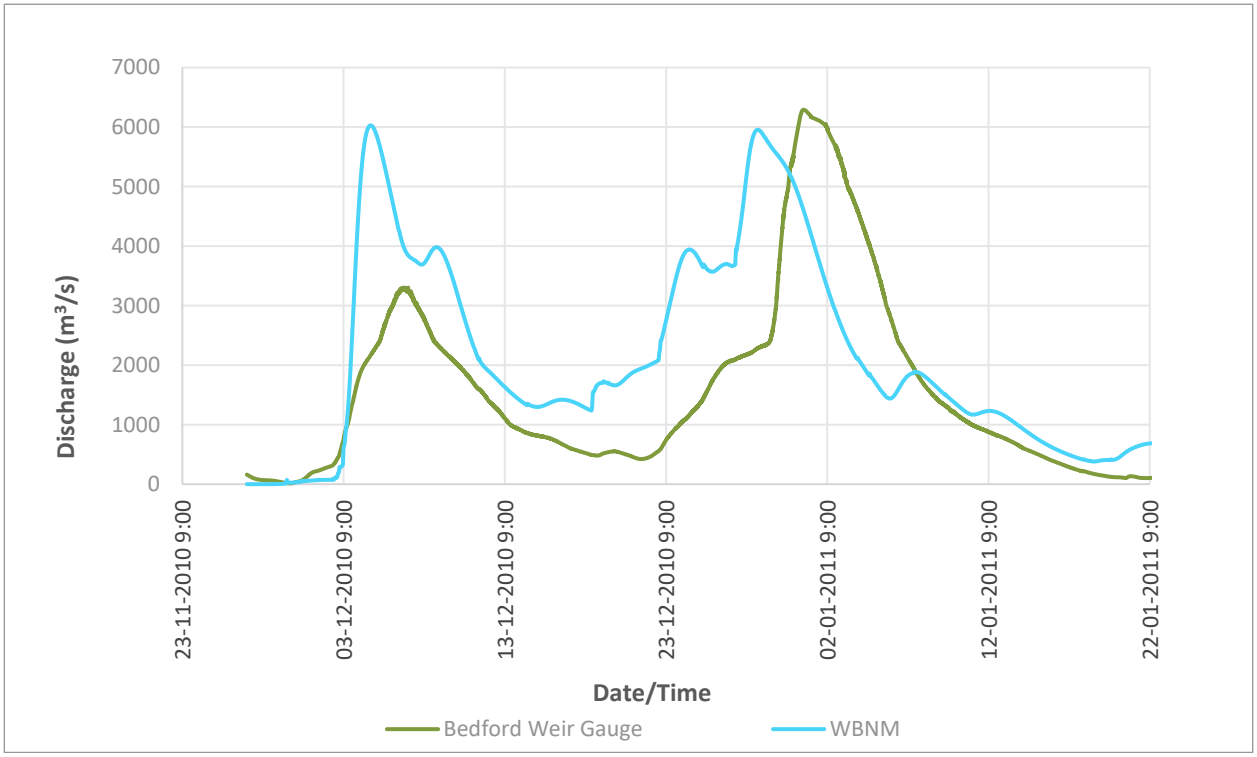


Figure 3 Comparison of Flows for 2011 event at Bedford Weir

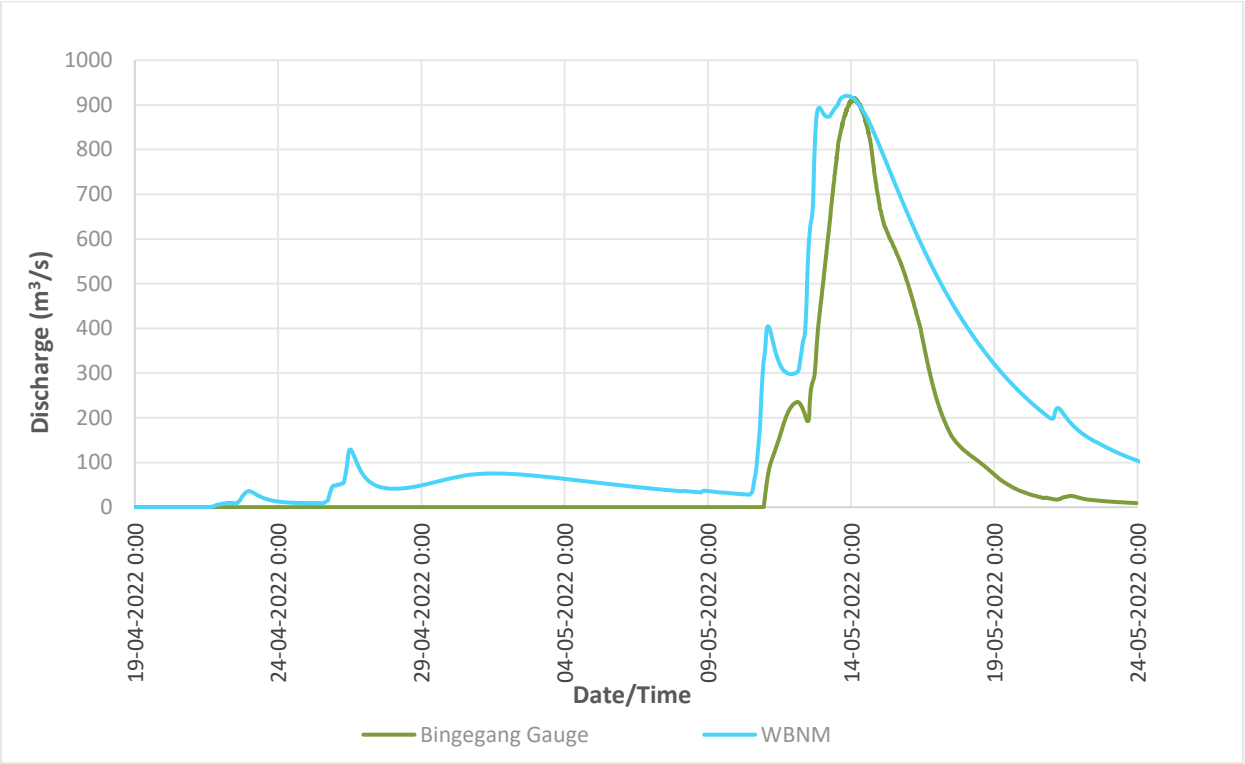


Figure 4 Comparison of Flows for 2022 event at Bingegang Weir

For the 2011 event, while the magnitude of the second peak is similar to the measured peak discharge at the gauge, the timing is different by approximately half a day. The first peak is over-predicted while the shape of the peak is similar to the recorded peak. As the catchment which contributes to the flow to the Bedford Weir is of a significant size and as there is large variability across the subareas, the number of sub-daily rainfall gauges may have been insufficient. The results show that there is more variability across the catchment than the WBNM model is predicting, which was also the case for the Jellinbah flood study URBS model, despite having used more gauge information.

For the 2022 event, the timing and magnitude of the peak of the modelled discharge was matched to the recorded gauge peak discharge. However, the volume of the WBNM hydrograph is much higher than the recorded data. It should be noted that, as the event was very recent, there is no quality rating for the rainfall gauge information.

Table 8 Adopted WBNM model parameters for calibration events

Catchment	Lag Parameter	2011		2022	
		IL (mm)	CL (mm/h)	IL (mm)	CL (mm/h)
Nogoa	2.6	20	3.0	20	4.0
Theresa	2.6	30	3.0	80	10.0
Mackenzie	2.6	60	1.5	80	5.0
Comet	2.6	60	2.0	40	4.0

The purpose of this calibration exercise was to verify that the WBNM model was able to replicate similar peak flows to historical gauge data. Calibration of a large catchment is very difficult, as demonstrated in the Jellinbah flood study (WRM, 2018), with the added complication of inaccurate rating curves to convert recorded levels to discharge. Rating curves were also investigated at Bingegang Weir and Bedford Weir using TUFLOW, and both rating curves used by Department of Regional Development, Manufacturing and Water (RDMW) were deemed to be sufficient for the purposes of this project.

4.5 Rating Curves

The Jellinbah flood study (WRM, 2018) discussed the inconsistencies of rating curves at length. Rating curves at three locations were checked to verify the recommended changes from the Jellinbah flood study at the following locations –Theresa Creek at Gregory Highway, Bedford Weir and Bingegang Weir. TUFLOW was used to create rating curves which modelled flows from 0 to 8000 m^3/s.

The gauge information at Theresa Creek showed good agreement with both the TUFLOW model rating curve and the latest rating curve information from RDMW. The Bedford Weir gauge data also showed good agreement with the TUFLOW model rating curve and rating curve from RDMW. The Bingegang Weir rating curve generated by TUFLOW differed from the RDMW rating curve and the recommended rating curve by the Jellinbah flood study, due to the TUFLOW model being based on SRTM data for model terrain. The rating curve generated by TUFLOW was more similar to the RDMW rating curve for higher flows, and therefore it was deemed appropriate for use in the FFA.

4.6 Flood Frequency Analysis

The size of the catchment necessitates a flood frequency analysis for the determination of peak flow rates for design events. A number of flood frequency analyses have been conducted for the gauges in this area, with varying results. In the Jellinbah flood study (WRM, 2018), two stream gauges were analysed for the FFA – Mackenzie River at Carnangarra (1974-1999), and Mackenzie River at Bingegang Weir HW (1974-2002). Mackenzie River at Carnangarra is approximately 37km upstream from Bedford Weir, and approximately 100km upstream from Bingegang Weir. The Carnangarra flows were taken as representative of flows at Bedford Weir in the Jellinbah flood study (WRM, 2018). These gauges were analysed for the period since the Fairbairn Dam was constructed.

In the Voids in Floodplain modelling report (SLR, 2021), the same gauge at Bingegang (1972-2021) was used for analysis. All analyses used a LP3 flood frequency distribution. The peak discharges predicted from these analyses are listed in **Table 9.**

Table 9 Comparison of previously analysed FFA results

Event (% AEP)	Peak Discharge (m^3/s)		
	Mackenzie River at Bedford (WRM, 2018)	**Mackenzie River at Bingegang** (WRM, 2018)	**Mackenzie River at Bingegang** (SLR, 2021)
1%	9,300	9,300	12,777
0.1%	17,200	-	54,393
PMF	49,900	-	-

As there was a significant difference between the flow rates, further analyses were undertaken using TUFLOW FLIKE and comparing different rating curves to convert the peak water level to peak discharge.

Analysis of the data sets used for each FFA shows that different rating curves were used for each. All gauges record the water level, which is later converted to a flow rate based on a rating curve for the gauge. Whilst many gauges include recorded information to assist in the development of the rating curve, these recordings are typically for small events, with the higher flow rates determined based on theoretical equations (e.g., the weir equation if the gauge is at a weir) or hydraulic models. Calibration of hydrologic models is dependent on flow hydrographs and therefore on the rating curve for the gauge. The Jellinbah flood study FFA (WRM, 2018) noted that the rating curve may not be reliable for larger events and adjusted the rating curve based on the results of the URBS model, surmising that the URBS model predicted the more frequent events well and therefore should also predict the larger events well. This resulted in the 1978 event flow rate at Bingegang (the largest recorded event) being adjusted from approximately 8000 m^3/s to 5500 m^3/s. This, in turn, resulted in a significant reduction in the flow rates determined using the FFA for the 1%, 0.1% and PMF events.

It should be noted that information from 2003 to 2013 is missing from the Bingegang gauge. It is known that two large flood events occurred in this time – in 2008 and 2011. The Bingegang FFA results are shown in **Figure 5**.

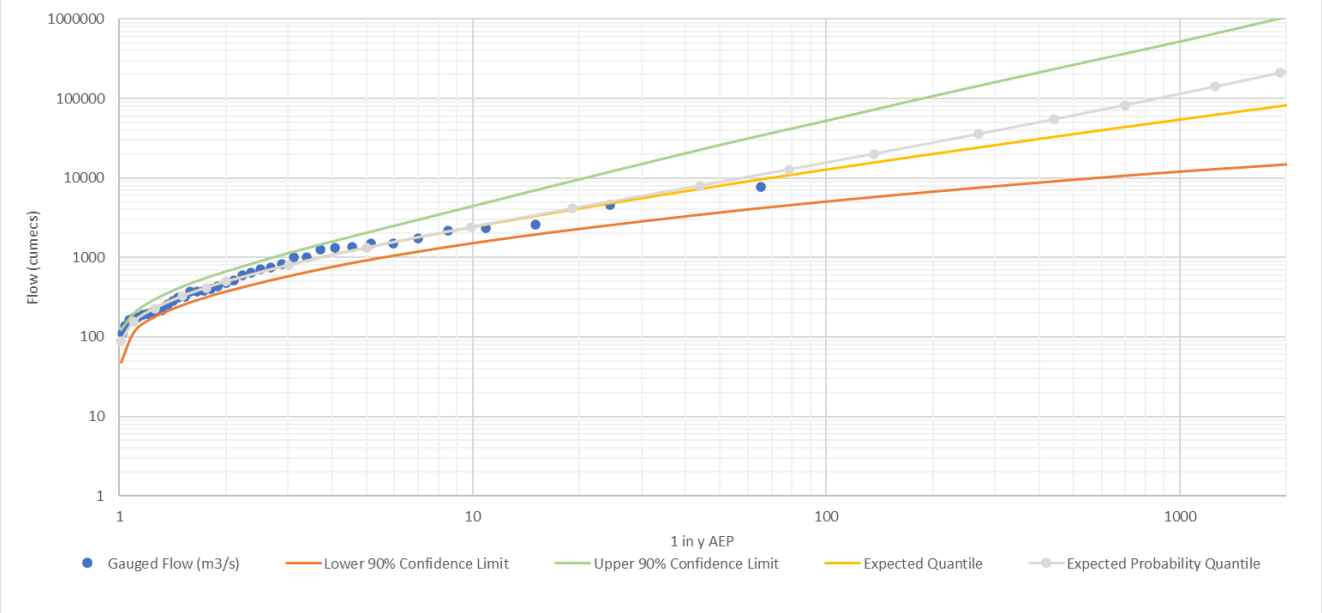


Figure 5 Flood Frequency Analysis at Bingegang Weir

Based on the results of this assessment, it was considered that there is insufficient recorded data available to determine the peak flow rate for rare events. As shown above, the error bands for the 0.1% AEP event are more than an order of magnitude. It was considered appropriate to adopt the 1% AEP peak flow rate based on the FFA. However, beyond this, it was considered that the WBNM model, which resulted in a 1% AEP peak flow rate within an acceptable range of the flow determined using the FFA, was the most appropriate method for determining the peak flow rates for rarer events.

4.7 Regional Flood Frequency Estimation

Regional Flood Frequency Estimation (RFFE) is not suitable for this catchment due to the significant catchment size. RFFE is recommended for catchments between 0.5km^2 and 1000km^2. Additionally, catchments with multiple dams and weirs are not suitable for RFEE. In the Mackenzie River catchment, there are multiple weirs and Fairbairn Dam is located downstream of the Nogoa River catchment.

4.8 Design Events

4.8.1 Intensity-Frequency-Duration Rainfall Data

Rainfall Intensity-Frequency-Duration (IFD) data for the model was obtained from the Bureau of Meteorology (BoM) for a range of AEP events. The catchment was split into 7 zones – Mackenzie, Upper Nogoa, Theresa, Lower Nogoa, Upper Comet, Lower Comet, and Emerald. The adopted design rainfalls for Mackenzie are listed as an example in **Table 10**. All IFD data are listed in **Appendix A**. Refer to **Figure 2** to show the split of the catchments to IFD zones.

Table 10 IFD Rainfall Data

Mackenzie Storm Duration	Rainfall depth (mm)	
	1%	0.1%
6 hour	144	220
9 hour	163	279
12 hour	178	305
18 hour	203	346
24 hour	223	380
30 hour	240	413
36 hour	255	439
48 hour	280	476
72 hour	315	521
96 hour	335	548
120 hour	347	565
144 hour	352	577

4.8.2 Losses

Initial and continuing losses were obtained from ARR Data Hub. The global initial loss adopted was 65mm and continuing loss was 1.1 mm/h. For the 0.1% AEP and PMP events, initial loss of 0mm was adopted. The initial loss for each storm duration is calculated by subtracting the median pre-burst rainfall depth from the global catchment initial loss, as outlined by ARR2019.

4.8.3 Lag Parameter

The WBNM manual recommends a lag parameter of between 1.3 and 1.8 for most catchments. As mentioned in **Section 4.2**, some of the adopted model parameters in URBS were outside the recommended values, which suggested that this model required atypical model parameters in order to produce realistic peak flows. This proved to be correct when the peak flows with default losses were producing significantly higher flows compared to the peak flows predicted from the Flood Frequency Analysis (FFA) (refer to **Section 4.5**) when using a lag parameter of 1.8. The lag parameter of 2.6 was chosen to produce a 1% AEP design peak flow that matched the peak flow from the FFA. The FFA is discussed in **Section 4.5.** Historical event calibration was also undertaken with the same lag parameter of 2.6, with acceptable results.

4.8.4 Areal Reduction Factor

Areal reduction factors (ARF) are required under ARR2019 as design rainfall IFDs are based on specific points in a catchment rather than the whole catchment, and these point rainfall intensities are not representative of the areal average rainfall intensity across the catchment. The ARFs represent the ratio between the areal average rainfall and point rainfall for the same AEP and storm duration. ARFs are calculated based on the catchment area, AEP, and storm duration. As there are two main inflows for the project site, Mackenzie River and Blackwater Creek, the ARFs needed to be calculated separately due to the difference in magnitude of the contributing catchments (i.e., the larger Mackenzie River catchment is less likely to have high intensity storms across the whole catchment than the smaller Blackwater Creek catchment).

According to ARR2019, for catchments larger than 30,000 km^2, the generalised equations for areal reduction factor (ARF) in ARR2019 do not apply. ARR2019 recommends that a flood frequency analysis for catchment rainfall data be undertaken.

The following approach was taken:

- The ARFs using 30,000km^2 was adopted for Mackenzie River inflow, checking that the values aligned with the FFA peak flows; and
- The ARFs using 1024km^2 were adopted for the MAC_Z1 subarea (which contains Blackwater, Bullock, and Sagittarius Creeks). The adopted ARFs are listed in **Table 11**.

Table 11 WBNM Areal Reduction Factor

Storm Duration	ARF 1% AEP		ARF 0.1% AEP	
	Mackenzie River	Blackwater Creek	Mackenzie River	Blackwater Creek
18 hour	0.597	0.877	0.558	0.876
24 hour	0.633	0.891	0.593	0.889
30 hour	0.652	0.898	0.612	0.897
36 hour	0.667	0.904	0.627	0.903
48 hour	0.689	0.912	0.648	0.911
72 hour	0.717	0.923	0.676	0.921
96 hour	0.735	0.929	0.693	0.928
120 hour	0.747	0.934	0.705	0.933
144 hour	0.757	0.938	0.714	0.936

4.8.5 Temporal Patterns

In accordance with ARR 2019, areal temporal patterns were used for the 1% AEP event, for the 40,000km^2 catchment area for the Mackenzie River inflow. It should be noted that 40,000km^2 catchment area is the largest available in ARR2019 for areal temporal patterns. For the events for the Blackwater Creek catchment, the areal temporal pattern for 1000km^2 was adopted. For the 0.1% AEP event, the GTSMR temporal patterns were applied; AVM60000 for Mackenzie River and AVM1000 for Blackwater Creek.

4.8.6 Storm Events

The WBNM model was run for the 1%, 0.1% AEP and PMP events. A range of storm durations between 6 and 144 hours were analysed for the 1% AEP and between 24 and 120 hours for the 0.1% AEP and PMP events.

4.8.7 Probable Maximum Flood Analysis

As the Mackenzie River catchment is larger than 1000km^2, short duration PMP estimates cannot be calculated. The Generalised Tropical Storm Method Revised (GTSMR) was used to estimate PMP depths for the 24 hour, 36 hour, 48 hour, 72 hour and 96 hour and 120 hour storm durations.

Analyses were done for both Mackenzie River and Blackwater Creek. They are located in the GTSMR Coastal Zone. The adopted parameters are provided in **Table 12** and the PMP rainfall depth estimates are listed in **Table 13.**

Table 12 GTSMR Parameters

Parameter	Mackenzie River	Blackwater Creek
Moisture Adjustment Factor (MAF)	0.727	0.735
Topographical Adjustment Factor (TAF)	1.03	1.0
Decay Amplitude Factor (DAF)	0.967	0.998
Standard Area (km^2)	60000	1000

Table 13 PMP Rainfall Estimates

Storm Duration (h)	PMP Rainfall Depth (mm)	
	Mackenzie River	Blackwater Creek
24	410	910
36	510	1080
48	620	1240
72	760	1510
96	840	1710
120	870	1800

4.9 Adopted Peak Flows

The adopted design flows for the 1% AEP, 0.1% AEP, and PMF events for Mackenzie River are listed in **Table 14**.

Table 14 Adopted Peak Design Flows

Event	Peak flow at MAC_AA1 (m^3/s) [Equivalent to Bingegang Weir location]	Peak flow into TUFLOW model (m^3/s) [MAC_Q1]
1% AEP	12,816	11,997
0.1% AEP	28,412	26,742
PMF	95,080	87,338

5 Hydraulic Assessment

5.1 Software

A hydraulic model was developed for the purpose of assessing the post-mining flood extent. The industry standard hydrodynamic modelling software TUFLOW (Build 2020-10-AD) was utilised for the 2D hydraulic modelling. The TUFLOW Heavily Parallelised Compute (HPC) solution scheme was adopted in this project to minimise the model simulation time. Details of the model setup, methodology and results are provided in the following sections.

5.2 Model Setup

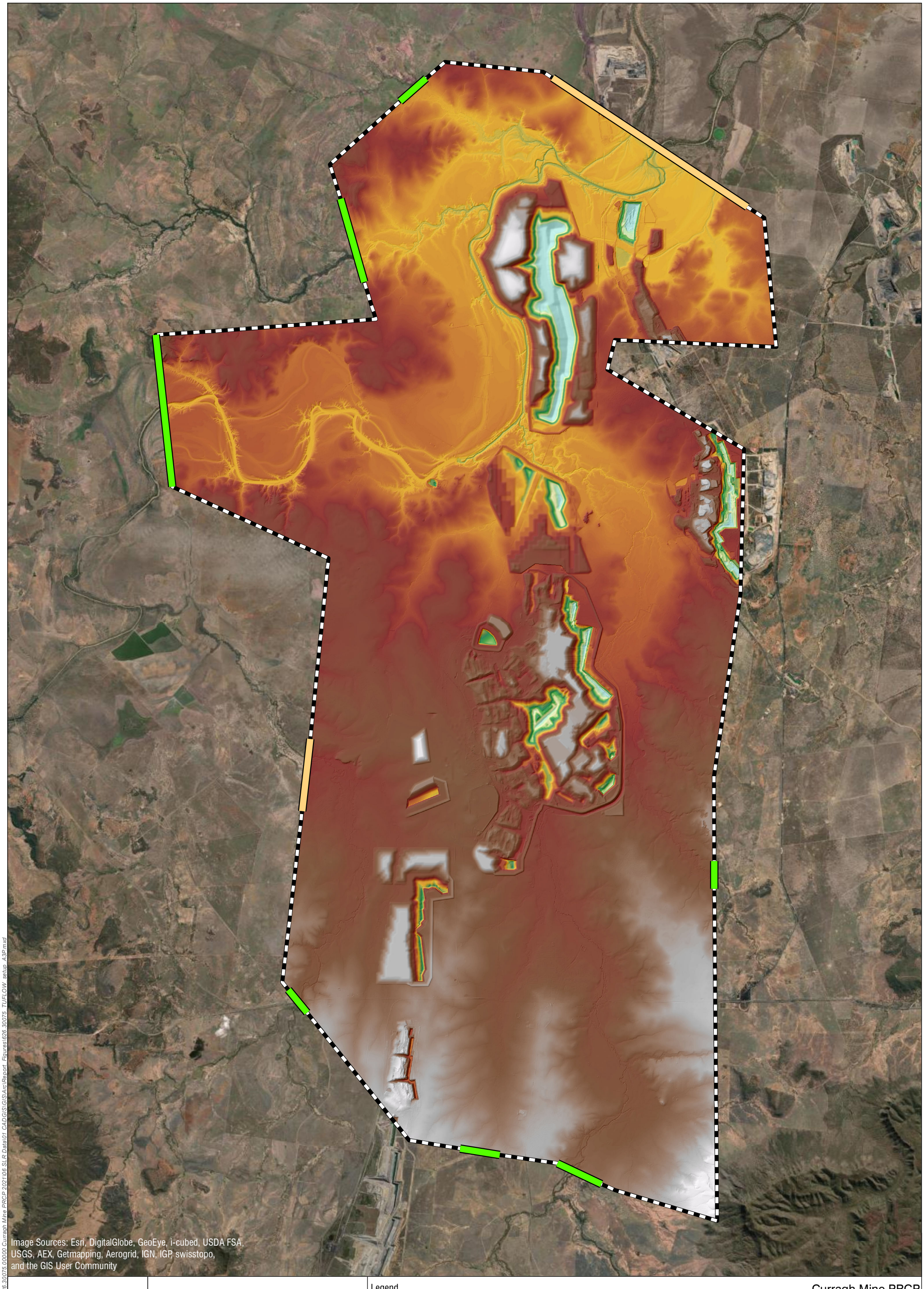
5.2.1 Topography

The residual void DEM (as supplied Nov 2021 and provided Sept 2022 for Curragh North and X Pit) was utilised as the topography for the hydraulic modelling. A grid cell size of 20 metres was adopted for the model. The model domain and DEM data are shown in **Figure 6**.

Post-mining contour data was processed into a 5-metre spaced Digital Elevation Model (DEM). To create the residual void landform used in the floodplain modelling, the processed residual void DEM (which incorporated available 1m LiDAR) was overlaid on 1m LiDAR from CCPL. A long-term stable embankment has been incorporated into the residual void landform to provide flood immunity to the residual voids up to the 0.1% AEP event.

5.2.2 Hydraulic Roughness

The hydraulic roughness for the model was adopted based on available Queensland Globe aerial imagery and the model landform. The adopted land use types are consistent with the current catchment characteristics. The Manning's roughness values adopted for the various land use types in the assessment are shown in **Table 15**. The model hydraulic roughness is shown in **Figure 7**.



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0 2,000 4,000 6,000 8,000 Metres

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Legend

- Downstream Boundaries
- Inflow Boundaries
- TUFLOW Model Extent

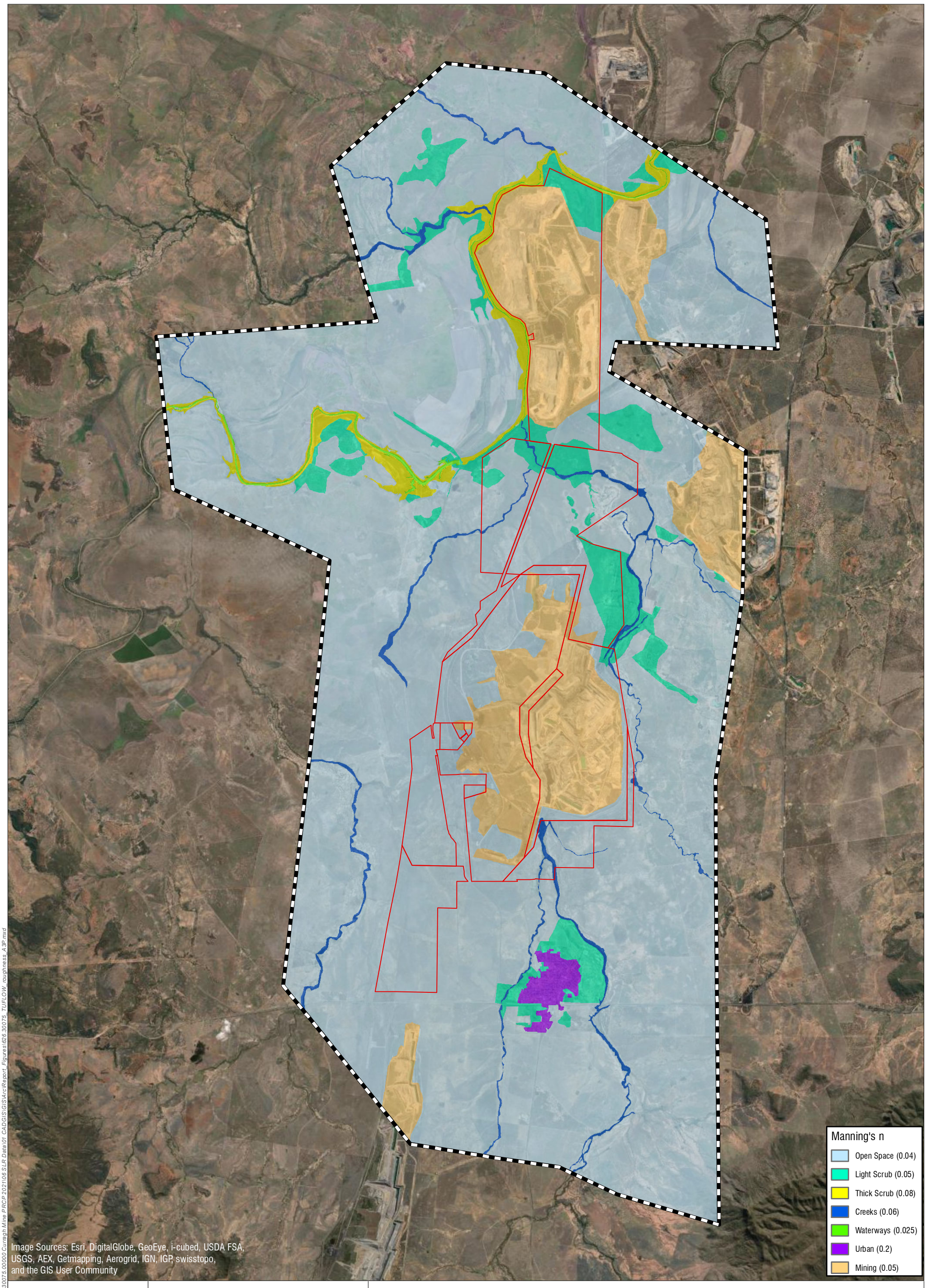
Topography (mAHD)
High : 230
Low : 40

Curragh Mine PRCP
Flood Assessment

TUFLOW Model Layout

Figure 6

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Sheet Size : A3 AGD 1966 AMG Zone 55

Legend

Curragh Mine Lease

TUFLOW Model Extent

Curragh Mine PRCP
Flood Assessment

TUFLOW Model Hydraulic Roughness

Figure 7

Table 15 TUFLOW Manning's n Values

Land use	Manning's n
Creek	0.06
Waterways	0.025
Grassland	0.04
Light Scrub	0.05
Thick Scrub	0.08
Mining and rehabilitated area	0.05
Urban	0.2

5.2.3 Inflows

Inflows were adopted from the WBNM model outputs. The hydrographs were applied as inflow boundaries as 2D boundary condition lines for the Mackenzie River, Blackwater Creek, Burngrove Creek, and Sagittarius Creek on the model domain as shown in **Figure 6**. The smaller inflows were split according to catchment area.

5.2.4 Downstream Boundaries

The downstream boundaries adopted for the Conceptual Residual Void Assessment TUFLOW model were maintained. The location was chosen to ensure that the boundary condition would not impact flood behaviour in the areas of interest. Boundaries were positioned on Burngrove Creek on the western side and Mackenzie River on the northern boundary of the site. A stage-discharge relationship was applied as the tailwater condition for the 2D model domain, with the water surface gradient equivalent to the ground surface slope in the vicinity of the boundaries. Based on the post-mining landform data, slopes of 0.004% and 0.2% were used for the boundary locations for Burngrove Creek and Mackenzie River respectively. Downstream boundaries are shown in **Figure 6**. A sensitivity test was also undertaken for the downstream slope for the Mackenzie River, testing 0.1% and 0.4% slope, and this showed no significant changes in water level for the areas of interest.

5.2.5 Critical Duration Assessment

As recommended by ARR2019, several design storm events per AEP event were simulated in the hydraulic models (one duration either side of the hydrological critical duration, where possible). The critical durations for Mackenzie River and Blackwater Creek are listed in **Table 16**.

Table 16 Critical Storm Durations

	AEP Events		
Watercourse	1%	0.1%	PMF
Mackenzie River	120h	48h	72h
Blackwater Creek	96h	24h	24h

6 Results

Peak water surface levels, depths, velocities, and bed shear stress for each AEP are mapped in **Appendix B**.

6.1 Flood Ingress to voids

The results show that all voids are not subject to inundation in the AEP events assessed for events up to and including the 0.1% AEP, as required by PRCP guidelines. Inundation of Curragh North, X Pit West, X Pit East, E Pit, C Pit, B Pit, H Pit, and J Pit occurs in the PMF. Refer to Figures B1-3, B2-3 for the peak flood level and depths respectively.

A summary of the modelled 0.1% AEP flood levels and velocities for each of the points is provided in **Table 17**. The location of the points is shown in **Figure 8.**

Table 17 Maximum Surface Water Elevations and Velocities

Void Name	0.1% AEP Indicative Water Level (mAHD)	PMF Indicative Water Level (mAHD)	0.1% AEP Average Velocity (m/s)
D Pit	140.34	142.06	0.5-1.8
F Pit	148.03	149.18	1.0-3.1
F Pit N/ E Pit N*	144.83	145.49	3.0-4.7
J Pit*	158.16	163.71	0.5-1.7
K Pit	153.39	158.22	2.2-5.6
L Pit*	149.98	152.54	2.0-3.3
S Pit (Curragh North)	134.93	140.68	0.5-0.9
U Pit (Curragh North)	127.78	131.69	0.5-1.6
X Pit East	134.93	140.68	0.5-3.3
X Pit West	134.93	140.68	0.5-2.0
X Pit SE*	134.93	140.68	0.5-1.0
Y Pit*	157.53	158.61	0.5-1.5
Z Pit North	164.37	165.64	0.5-1.7
Z Pit South	169.08	170.49	0.5-1.4

* Note that these points have been moved from their previous position in the Voids in Floodplain Modelling assessment (SLR, 2021) as they were no longer inundated in the current assessment

It should be noted that the proposed modifications to the floodplain due to progression of mining on adjacent mining leases is outside the control of CCPL and it may have impacts to the Curragh site. It is recommended that further assessment be undertaken as the information becomes available to determine whether any impacts are exacerbated.

Based on the results of the model, flooding in Mackenzie River and Blackwater Creek will not result in inundation of the final voids which could impact their structural integrity for events up to the 0.1% AEP.

6.2 Scour and Erosion Potential

The ACARP 2002 Guidelines provide indicative parameter thresholds for scour potential in diversions in the Bowen Basin. The criteria, which is provided in **Table 18**, is directed towards diversion design, which is not the purpose of this assessment, however also provides general indication of scour and erosion potential in all waterways in the Bowen Basin and was therefore utilised in the analysis of the hydraulic model results.

The stability of the proposed landform was assessed by considering the bed shear stress and velocities in the vicinity of the landforms. There is no guideline relating to bed shear stress for events larger than 2% AEP in the ACARP guidelines.

Table 18 Guideline values for average shear stress and velocity for streams within the Bowen Basin (ACARP C8030 – Maintenance of Geomorphic Processes in Bowen Basin River Diversions)

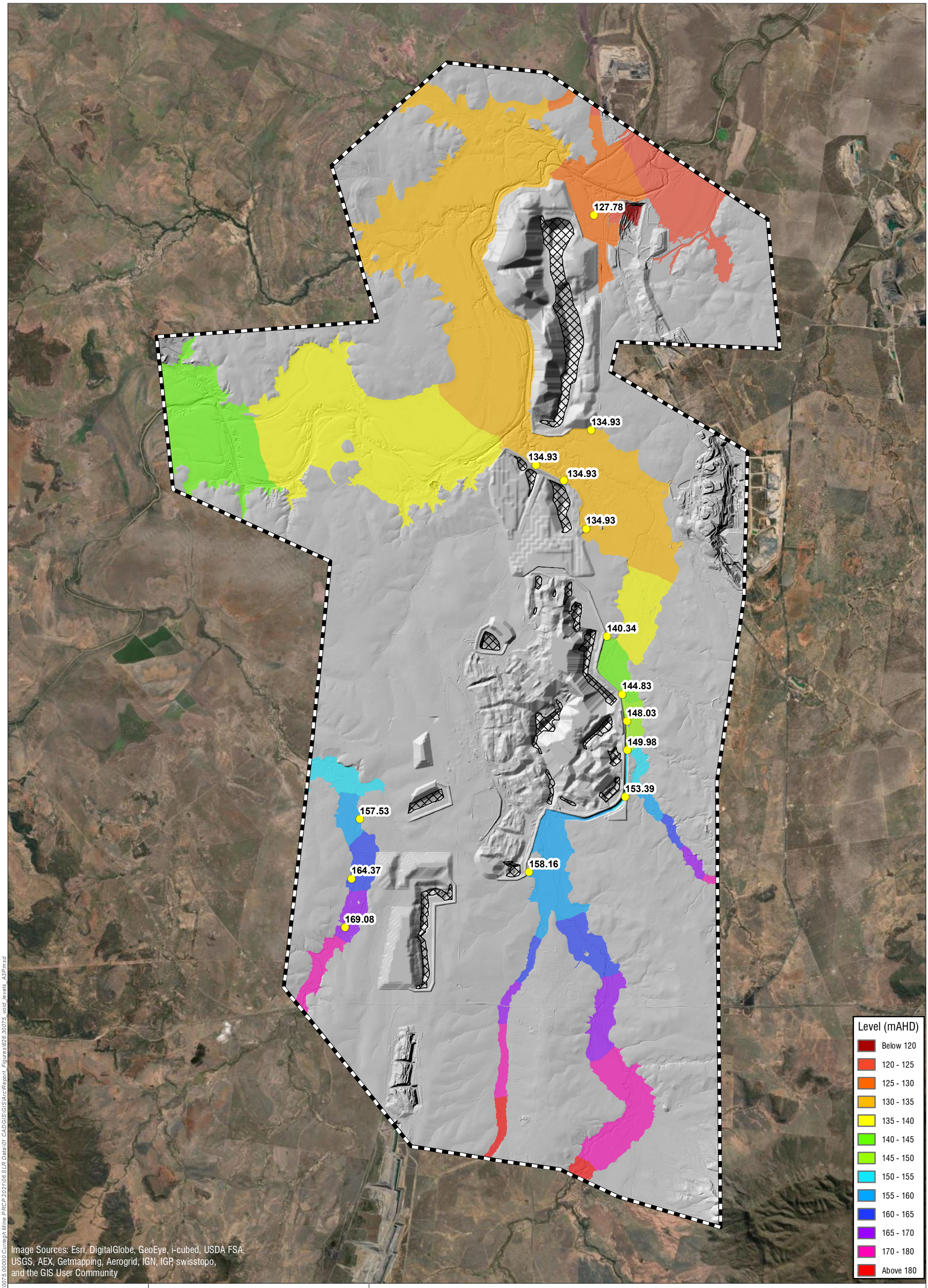
Parameter	2% AEP
Shear Stress (N/m^2)	< 80
Velocity (m/s)	< 2.5

The shear stresses predicted for the 1% AEP in this assessment are generally below the values in the ACARP guidelines. The high shear stress values are localised and located within the waterways. The same can be said for velocities in the 1% AEP event, where the velocities are generally lower than 2.5m/s apart from in the waterways. The shear stress and velocities are high in the Blackwater Creek diversion (velocities up to 2.8m/s and bed shear stress of up to 400 N/m^2), however the diversion is considered stable in its current form. Ongoing monitoring of the diversion may be required in accordance with legislative requirements.

For the larger events (0.1% AEP and PMF), more breakouts from the waterways are evident and higher velocities and bed shear stress are predicted, especially north of Curragh North, where the Blackwater Creek flow has joined Mackenzie River. However, high velocity values are not near the landforms in the 0.1% AEP in this area and therefore are unlikely to affect the erosion susceptibility of the landforms. Velocities of up to 3m/s are predicted for the Blackwater Creek diversion adjacent to landforms for the 0.1% AEP. It should be noted however that erosion potential of creek diversions is assessed based on 2% AEP and 50% AEP events, and there is no guideline relating to 0.1% AEP velocity values.

Based on the results of the flood modelling undertaken, the main outcomes are:

- All pits are not inundated in events up to and including the 0.1% AEP, as required by PRCP guidelines;
- Scour and erosion potential of landforms is low for the 1% AEP, as high shear stresses and velocities occur in localised areas within the watercourses;
- Inundation of Curragh North, X Pit West, X Pit East, E Pit, C Pit, B Pit, H Pit, and J Pit occurs in the PMF event (Note there are no requirements that pits be flood free in a PMF event);
- High velocities and bed shear stress are predicted within the Blackwater Creek diversion, which may require ongoing monitoring in accordance with legislative requirements;
- High velocities and bed shear stress are predicted in the 0.1% AEP and PMF events north of Curragh North.



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Legend

- Extraction Points
- Residual Void Extent
- TUFLOW Model Extent

Curragh Mine PRCP Flood Assessment

0.1% AEP Peak Flood Levels

Figure 8

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7 Conclusions

SLR was contracted by CCPL to support the preparation of the Curragh Mine Progressive Rehabilitation and Closure Plan (PRCP). The assessment detailed in this report was undertaken specifically to address Section 3.6.1 of the PRCP Guideline, which relates to the analysis of flooding as part of the PRCP.

A model landform was developed for the project, which was based on the post-mining surface provided by CCPL and included the proposed final voids.

A hydrological model was developed using SRTM topographical data for the Mackenzie River catchment. The model was calibrated using recorded stream flow data for Mackenzie River for two historical events. A range of hydrological analyses including FFA and rating curve generation utilising TUFLOW were undertaken to evaluate the peak flows for the Mackenzie River catchment.

A hydraulic model was updated from the modelling previously developed in the Voids in Floodplain Modelling assessment (SLR, 2021) with updated LiDAR dated 2021 provided by CCPL. The hydraulic model covers Mackenzie River and Blackwater Creek and was based on the model landform for the purpose of assessing the post-mining flooding conditions in accordance with Section 3.6.1 of the PRCP Guideline.

The results of the hydraulic modelling showed that inundation of the pits does not occur for the 0.1% AEP event as required by the PRCP Guideline. Inundation of Curragh North, X Pit West, X Pit East, E Pit, C Pit, B Pit, H Pit, and J Pit occurs for the PMF event, with the remainder of the pits not inundated for this event. The hydraulic results also suggest that the landforms are not likely to be prone to erosion for up to the 0.1% AEP event.

APPENDIX A IFD DATA

Mackenzie (Lat -23.260, Long 148.72)	Rainfall depth (mm)	
Storm Duration	1%	0.1%
6 hour	144	220
9 hour	163	279
12 hour	178	305
18 hour	203	346
24 hour	223	380
30 hour	240	413
36 hour	255	439
48 hour	280	476
72 hour	315	521
96 hour	335	548
120 hour	347	565
144 hour	352	577

Upper Nogoa (Lat -24.52, Long 147.22)	Rainfall depth (mm)	
Storm Duration	1%	0.1%
6 hour	140	201
9 hour	158	227
12 hour	173	248
18 hour	197	283
24 hour	216	311
30 hour	232	341
36 hour	246	365
48 hour	269	401
72 hour	301	445
96 hour	322	470
120 hour	335	486
144 hour	344	495

Lower Nogoa (Lat -24.06, Long 147.74)	Rainfall depth (mm)	
Storm Duration	1%	0.1%
6 hour	152	221
9 hour	171	247
12 hour	185	269
18 hour	209	304
24 hour	229	334
30 hour	246	368
36 hour	261	394
48 hour	285	432
72 hour	320	475
96 hour	343	500
120 hour	357	516
144 hour	364	528

Upper Comet (Lat -24.81, Long 148.55)	Rainfall depth (mm)	
Storm Duration	1%	0.1%
6 hour	164	236
9 hour	186	267
12 hour	203	292
18 hour	228	328
24 hour	247	356
30 hour	262	388
36 hour	274	410
48 hour	294	437
72 hour	322	464
96 hour	342	482
120 hour	357	498
144 hour	370	515

Lower Comet (Lat -24.06, Long 148.62)	Rainfall depth (mm)	
Storm Duration	1%	0.1%
6 hour	156	224
9 hour	175	251
12 hour	190	273
18 hour	214	307
24 hour	231	332
30 hour	246	355
36 hour	258	372
48 hour	277	398
72 hour	303	431
96 hour	321	453
120 hour	333	470
144 hour	342	484

Emerald (Lat -24.39, Long 148.22)	Rainfall depth (mm)	
Storm Duration	1%	0.1%
6 hour	154	222
9 hour	173	250
12 hour	188	271
18 hour	210	304
24 hour	228	329
30 hour	242	358
36 hour	254	378
48 hour	273	405
72 hour	301	436
96 hour	320	456
120 hour	335	473
144 hour	346	489

Theresa (Lat -23.06, Long 147.70)	Rainfall depth (mm)	
Storm Duration	1%	0.1%
6 hour	153	226
9 hour	174	256
12 hour	190	280
18 hour	217	320
24 hour	239	353
30 hour	257	384
36 hour	273	409
48 hour	300	449
72 hour	338	503
96 hour	363	537
120 hour	379	558
144 hour	389	572

APPENDIX B FLOOD MODELLING RESULTS

Image Sources: Esri, DigitalGlobe, GeoEye, i-cubed, USDA FSA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Level (m AHD)
- Below 120
- 120 - 125
- 125 - 130
- 130 - 135
- 135 - 140
- 140 - 145
- 145 - 150
- 150 - 155
- 155 - 160
- 160 - 165
- 165 - 170
- 170 - 180
- Above 180

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Legend
- Curragh Mine Lease
- TUFLOW Model Extent

Curragh Mine PRCP Flood Assessment

PRCP Conditions (E11) Peak Flood Levels - 1% AEP

APPENDIX B1-1

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Level (m AHD)
- Below 120
- 120 - 125
- 125 - 130
- 130 - 135
- 135 - 140
- 140 - 145
- 145 - 150
- 150 - 155
- 155 - 160
- 160 - 165
- 165 - 170
- 170 - 180
- Above 180

Image Sources: Esri, DigitalGlobe, GeoEye, i-cubed, USDA FSA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

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Legend
- Curragh Mine Lease
- TUFLOW Model Extent

Curragh Mine PRCP
Flood Assessment

PRCP Conditions (E12)
Peak Flood Levels - 0.1% AEP

APPENDIX B1-2

Level (m AHD)
- Below 120
- 120 - 125
- 125 - 130
- 130 - 135
- 135 - 140
- 140 - 145
- 145 - 150
- 150 - 155
- 155 - 160
- 160 - 165
- 165 - 170
- 170 - 180
- Above 180

Image Sources: Esri, DigitalGlobe, GeoEye, i-cubed, USDA FSA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

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Legend
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- TUFLOW Model Extent

Curragh Mine PRCP
Flood Assessment

PRCP Conditions (E12)
Peak Flood Levels - PMP

APPENDIX B1-3

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Depth (m)
- Below 0.5
- 0.5 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- 4 - 5
- 5 - 6
- 6 - 8
- 8 - 10
- Above 10

Image Sources: Esri, DigitalGlobe, GeoEye, i-cubed, USDA FSA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

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Legend
- Curragh Mine Lease
- TUFLOW Model Extent

Curragh Mine PRCP
Flood Assessment

PRCP Conditions (E11)
Peak Flood Depths - 1% AEP

APPENDIX B2-1

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Depth (m)
- Below 0.5
- 0.5 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- 4 - 5
- 5 - 6
- 6 - 8
- 8 - 10
- Above 10

Image Sources: Esri, DigitalGlobe, GeoEye, i-cubed, USDA FSA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

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Legend
- Curragh Mine Lease
- TUFLOW Model Extent

Curragh Mine PRCP
Flood Assessment

PRCP Conditions (E12)
Peak Flood Depths - 0.1% AEP

APPENDIX B2-2

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Depth (m)
- Below 0.5
- 0.5 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- 4 - 5
- 5 - 6
- 6 - 8
- 8 - 10
- Above 10

Image Sources: Esri, DigitalGlobe, GeoEye, i-cubed, USDA FSA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

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Legend
- Curragh Mine Lease
- TUFLOW Model Extent

Curragh Mine PRCP
Flood Assessment

PRCP Conditions (E12)
Peak Flood Depths - PMP

APPENDIX B2-3

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Image Sources: Esri, DigitalGlobe, GeoEye, i-cubed, USDA FSA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Velocity (m/s)
- Below 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- Above 3.5

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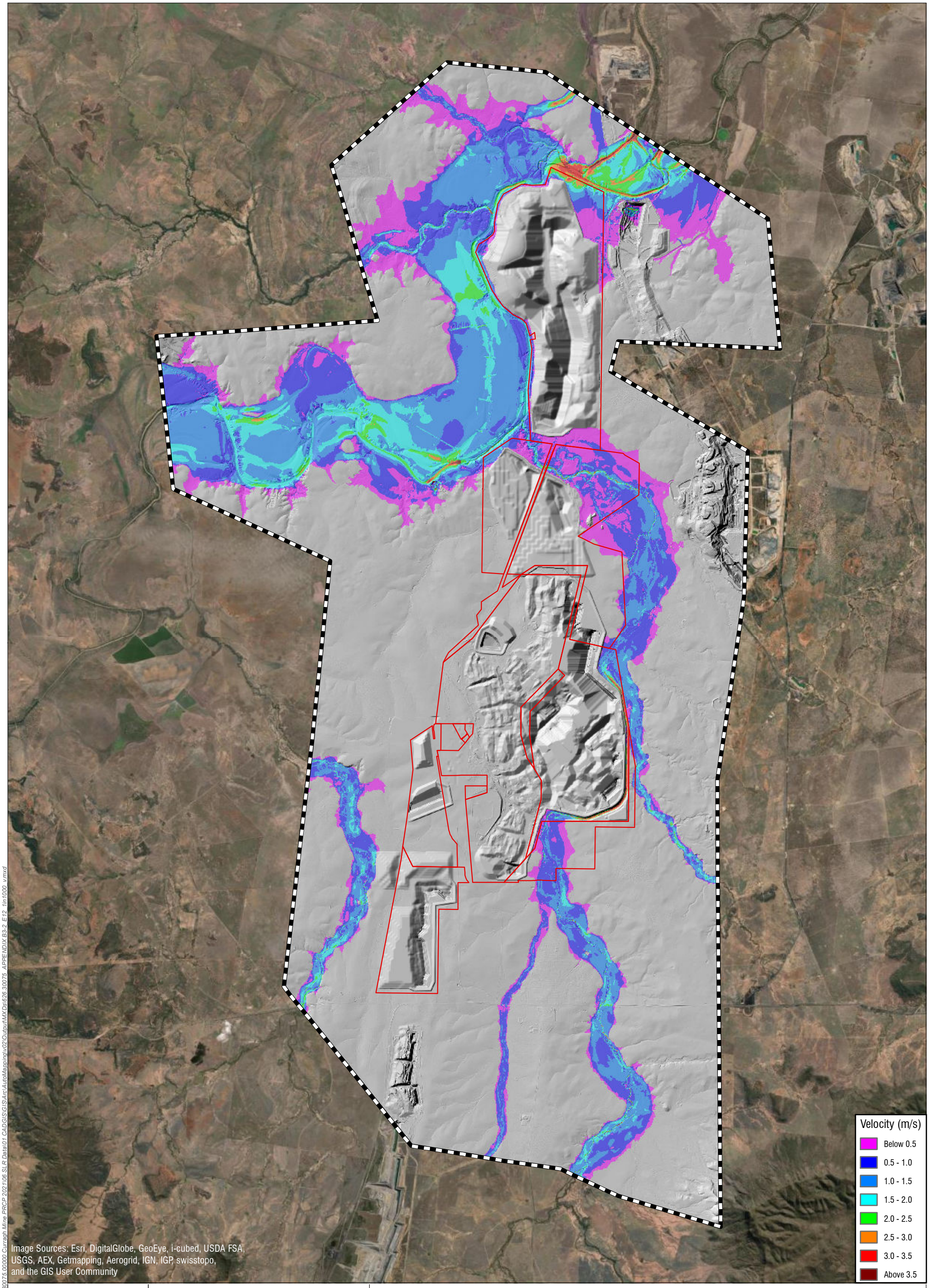
Legend
- Curragh Mine Lease
- TUFLOW Model Extent

Curragh Mine PRCP
Flood Assessment

PRCP Conditions (E11)
Peak Flood Velocities - 1% AEP

APPENDIX B3-1

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Legend

- Curragh Mine Lease
- TUFLOW Model Extent

Curragh Mine PRCP
Flood Assessment

PRCP Conditions (E12)
Peak Flood Velocities - 0.1% AEP

APPENDIX B3-2

Image Sources: Esri, DigitalGlobe, GeoEye, i-cubed, USDA FSA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Velocity (m/s)
- Below 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- Above 3.5

Legend
- Curragh Mine Lease
- TUFLOW Model Extent

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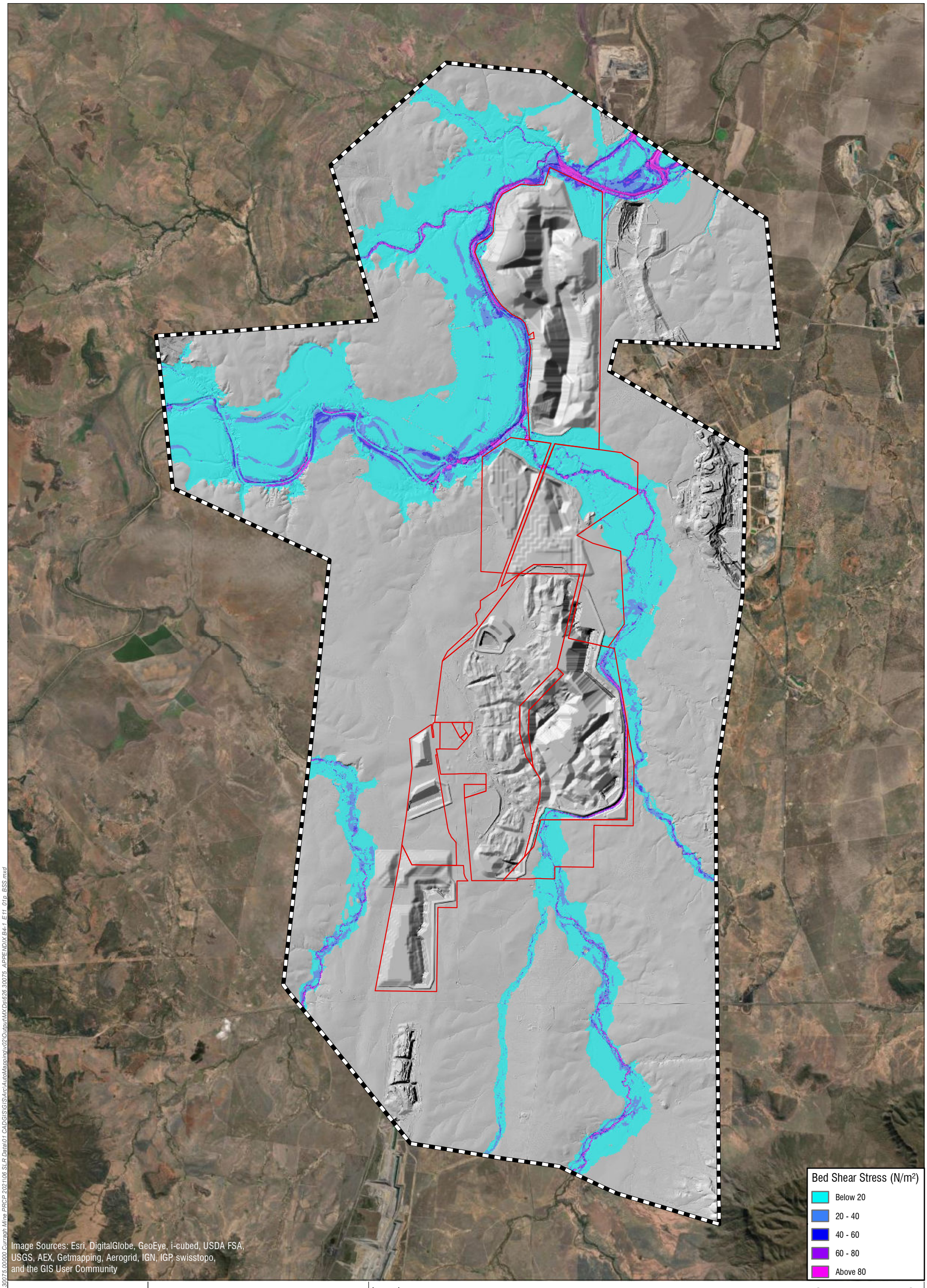
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Curragh Mine PRCP
Flood Assessment

PRCP Conditions (E12)
Peak Flood Velocities - PMP

APPENDIX B3-3

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Legend

- Curragh Mine Lease
- TUFLOW Model Extent

Curragh Mine PRCP
Flood Assessment

PRCP Conditions (E11)
Peak Flood Bed Shear Stress - 1% AEP

APPENDIX B4-1

Image Sources: Esri, DigitalGlobe, GeoEye, i-cubed, USDA FSA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Bed Shear Stress (N/m²)
- Below 20
- 20 - 40
- 40 - 60
- 60 - 80
- Above 80

Legend
- Curragh Mine Lease
- TUFLOW Model Extent

0 2,000 4,000 6,000 8,000 Metres

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Curragh Mine PRCP
Flood Assessment

PRCP Conditions (E12)
Peak Flood Bed Shear Stress - 0.1% AEP

APPENDIX B4-2

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Image Sources: Esri, DigitalGlobe, GeoEye, i-cubed, USDA FSA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Bed Shear Stress (N/m²)
- Below 20
- 20 - 40
- 40 - 60
- 60 - 80
- Above 80

Legend
- Curragh Mine Lease
- TUFLOW Model Extent

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Curragh Mine PRCP
Flood Assessment

PRCP Conditions (E12)
Peak Flood Bed Shear Stress - PMP

APPENDIX B4-3

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APPENDIX K

Residual Void Modelling

CURRAGH MINE COMPLEX

Residual Void Modelling

Prepared for:

Coronado Curragh Pty Ltd
Blackwater,
QLD, 4717



SLR Ref: 626.30075-R01
Version No: -v3.0
September 2022

PREPARED BY

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BASIS OF REPORT

This report has been prepared by SLR Consulting Australia Pty Ltd (SLR) with all reasonable skill, care and diligence, and taking account of the timescale and resources allocated to it by agreement with Coronado Curragh Pty Ltd (the Client). Information reported herein is based on the interpretation of data collected, which has been accepted in good faith as being accurate and valid.

This report is for the exclusive use of the Client. No warranties or guarantees are expressed or should be inferred by any third parties. This report may not be relied upon by other parties without written consent from SLR.

SLR disclaims any responsibility to the Client and others in respect of any matters outside the agreed scope of the work.

DOCUMENT CONTROL

Reference	Date	Prepared	Checked	Authorised
626.30075-R01-v3.0	9 September 2022	Emily Curtis	Fiona Stark	Fiona Stark
626.30075-R01-v2.0	29 November 2021	Emily Curtis	Nicole Bichel	Nicole Bichel
626.30075-R01-v1.0	26 November 2021	Emily Curtis	Nicole Bichel	Nicole Bichel

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Appendix C Residual Void Water Quality

1 Introduction

SLR was engaged by Coronado Curragh Pty Ltd (CCPL) to provide a Concept Residual Void Assessment (CRVA) for the Curragh Mine Complex (the mine). In support of the CRVA a Residual Void Water Balance Model (WBM) for the mine and has been developed to determine the final water level and quality of the residual voids.

1.1 Scope of works

The scope of work includes the development of a surface water final void model which accounts for the modelled groundwater inflows derived from the recovery groundwater model.

An iterative modelling process is required between the groundwater numerical model and the WBM to develop a groundwater inflow relationship for the final void. The final void model then provides long-term estimate of water level and salt concentration for the void stored water while the groundwater recovery model allows estimating post-closure (equilibrium) groundwater levels, potential areas of seepage and discharge to creeks.

This report covers the WBM development. For further information regarding the groundwater numerical model can be found in the Curragh Mine Complex Progressive Rehabilitation and Closure Plan Groundwater Technical Appendix (SLR, 2022).

1.2 Residual Voids

Following closure of the mine, 19 residual void areas are expected to remain. The arrangement of these voids for the purpose of the WBM are listed below with multiple pits grouped where hydrologically linked.

- Curragh North;
- Curragh Main: Pit I; Main Other; The Void; D Pit; F Pit North and Pit E North; E, C and H Pit; B Pit; F Pit; L Pit; K Pit; G Pit; J Pit; and
- Expansion Areas: Ramp 9; X Pit (East and West); Y Pit; Z Pit (North and South).

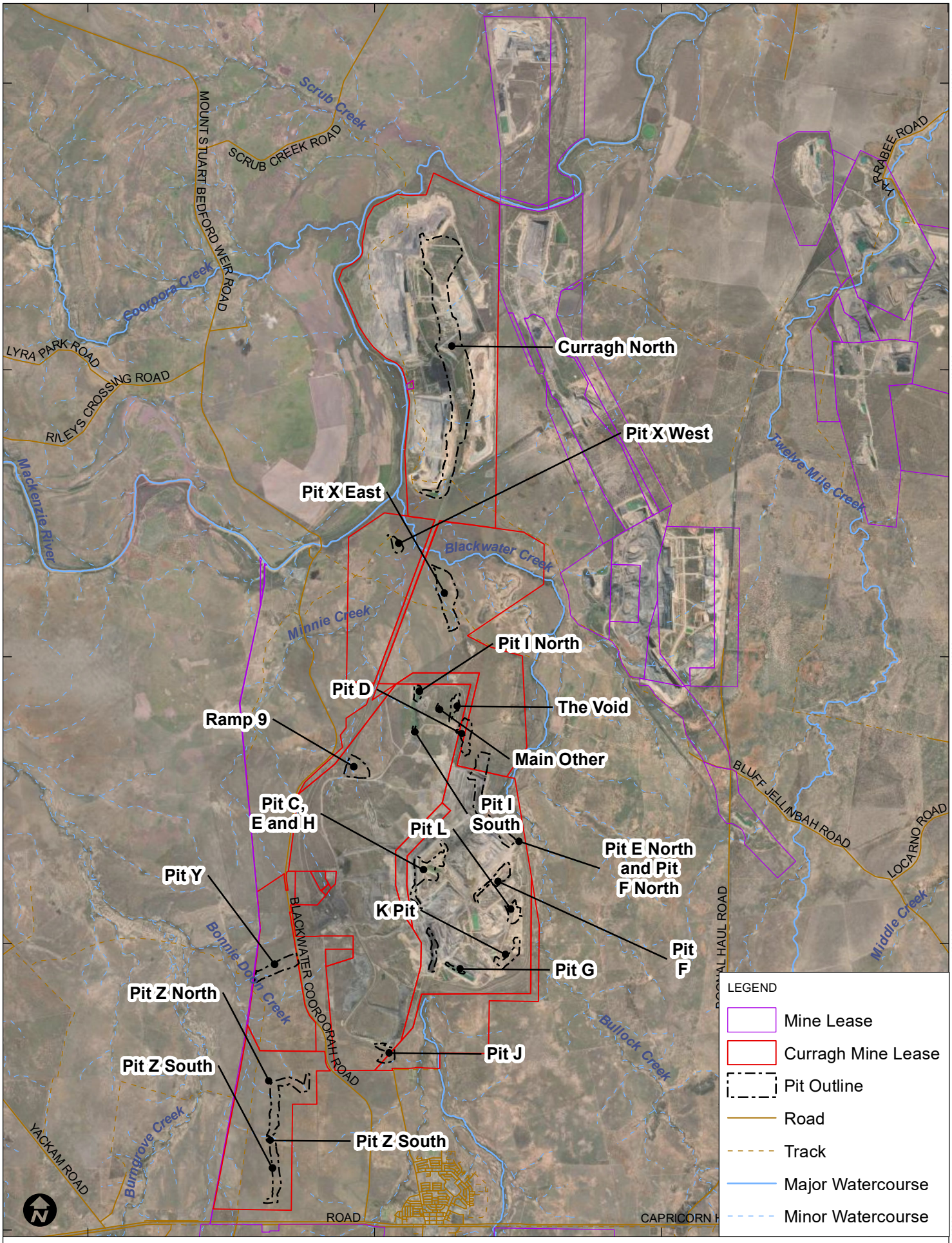
The assessed voids are shown in **Figure 1-1**.

1.3 Supplied Data

The following data was provided by CCPL to SLR to complete the assessment

- A final landform as separate designs for Curragh main, Curragh North, and Pits X, Y and Z. The final void designs were provided in dxf format as 0.5 m contours.
- 1 m Lidar data for the existing site (dated 2021).

Anticipated groundwater inflow volumes and associated water quality was derived from the numerical groundwater report.



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SLR

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0 2 4 km

Coordinate System:	AGD 1984 AMG Zone 55
Scale:	1:170,000 at A4
Project Number:	626.30075
Date:	16-Sep-2022
Drawn by:	SM
Reviewed by:	FS

Data Source:

CURRAGH PRCP

Proposed Void Locations

FIGURE 1-1

2 Water Balance Modelling

A Water Balance Model (WBM) was developed using Goldsim software package to assess the long-term water level and water quality was of the residual voids following closure of CCPL.

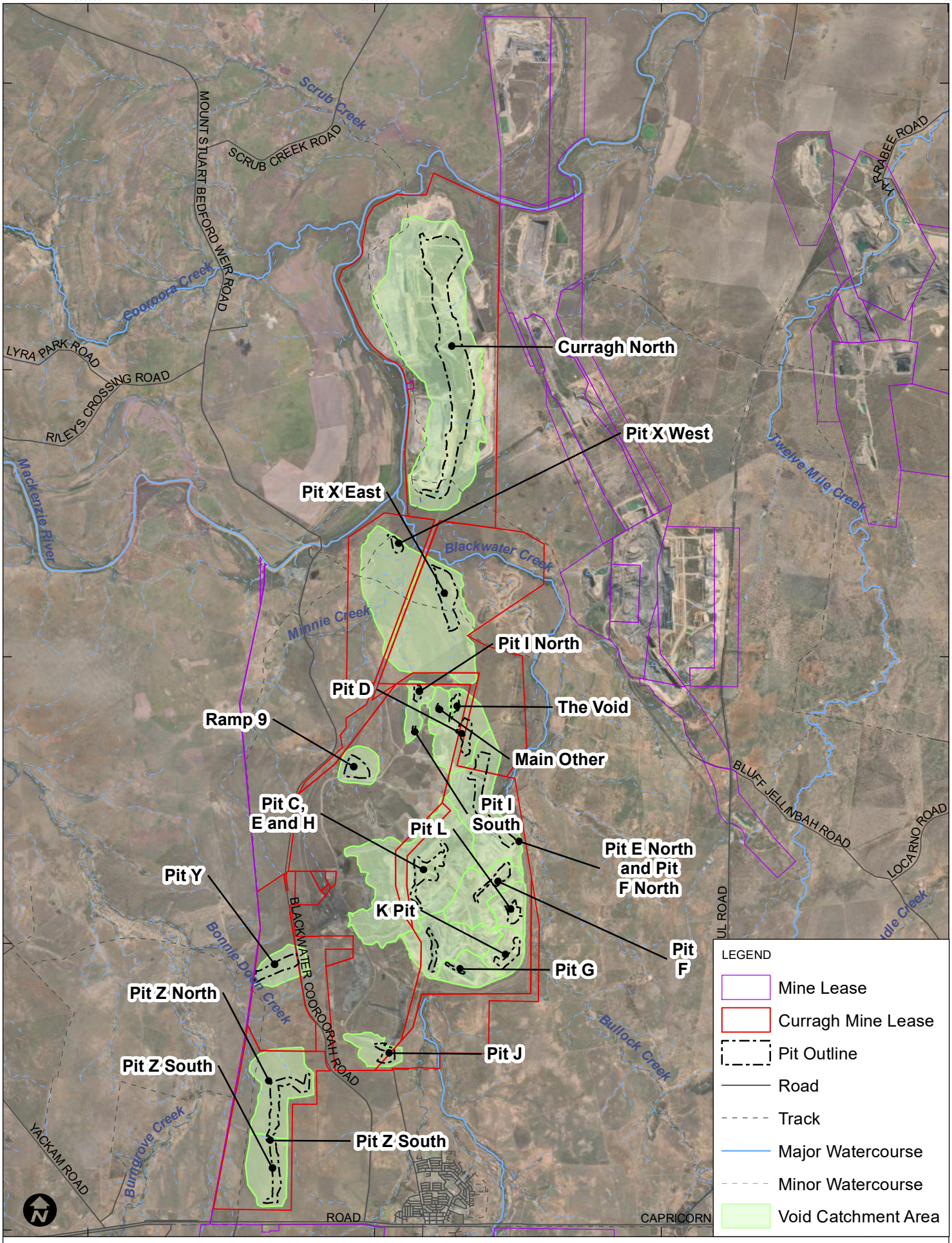
The model simulates daily changes in the volumes of stored water in response to inflows (rainfall, groundwater) and outflows (evaporation and controlled releases/overflows). The WBM was run for daily time step over 200-year simulation period, represented by 500 climate sequences, allowing the model to assess long term water levels, quality and risk of overflow for each void.

2.1 Catchment Areas

The catchment configurations for the residual voids at the mine were determined based on the final landform contours provided by CCPL. The residual void catchments consist primarily of rehabilitated spoil dumps, with an elevated stable landform constructed around the perimeter prevent external catchment and flood ingress into the voids. A summary of the catchment breakdown is provided in **Table 1.** The catchments are shown in **Figure 2-1**.

Table 1 Catchment Summary

Curragh Area	Residual Void	Residual Void Footprint (ha)	Catchment Area (ha)
Curragh North	Curragh North	637.3	2404.3
Curragh Main	I Pit	31.8	122.0
	Main Other	2.1	77.4
	The Void	7.1	26.6
	D Pit	28.4	342.8
	F Pit North and Pit E North	127.3	625.7
	E, C and H Pit	170.1	1257.5
	B Pit	41.0	406.6
	F Pit	39.4	350.3
	L Pit	18.6	164.6
	K Pit	13.0	163.5
	G Pit	14.6	179.8
	J Pit	27.9	146.2
Ramp 9	Ramp 9	40.3	149.8
X Pit	X Pit East	100.0	905.9
	X Pit West	26.4	542.0
Y Pit	Y Pit	47.8	181.9
Z Pit	Z Pit North	92.6	469.9
	Z Pit South	35.7	315.6



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Data Source:

CURRAGH PRCP

Catchment Plan

FIGURE 2-1

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2.2 Stage Storage Relationship

The stage storage surface area curves were derived from the final landform contours, provided by CCPL. Void depths range from 13 m to 180 m with inverts from -48 mAHD to 133 mAHD. Residual void stage storage surface area relationship for each residual void is provided in **Appendix A**.

2.3 Climate

Long term historical climate data has been collected by the Bureau of Meteorology (BoM) for the New Caledonia station (035132) at -23.429, 148.927 for 1900 to 2020 and was sourced from the Scientific Information for Land Owners (SILO) data drill as a Patch Point Data set. The Patch Point Data provides infilling of any missing data from nearby gauges based on relationships developed between the overlapping records of each gauge.

A summary of the annual average climate data is given in **Figure 2-2**.

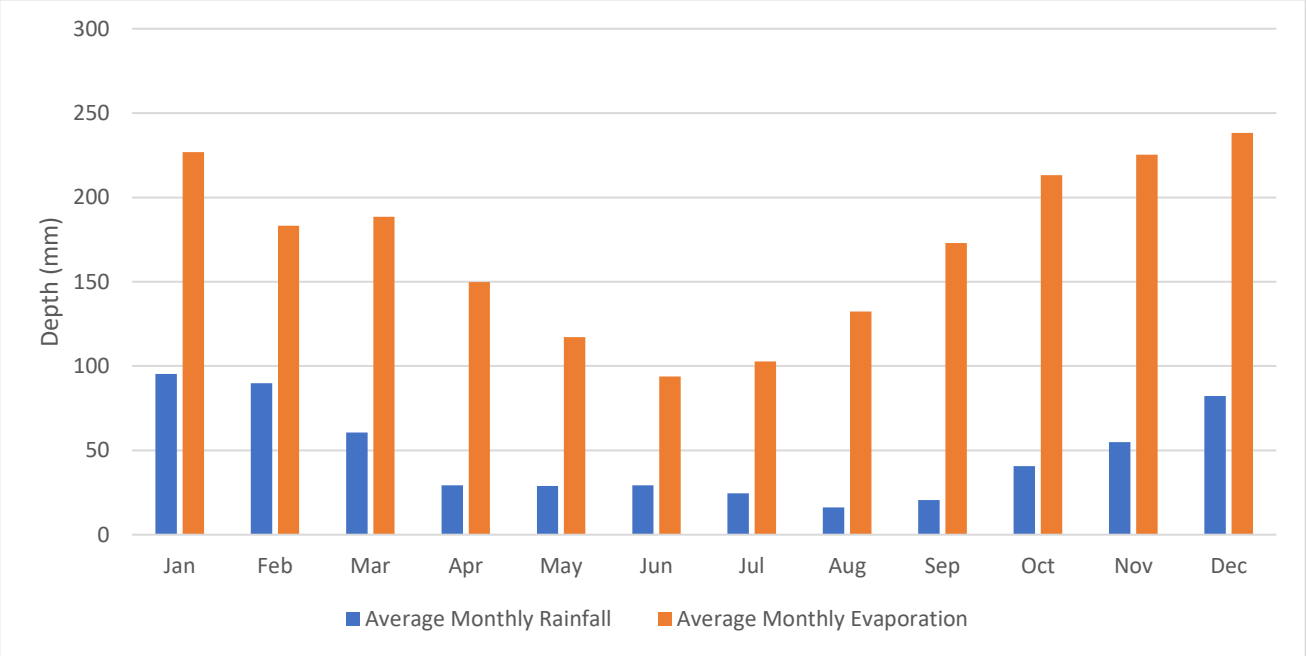


Figure 2-2 Long Term Average Rainfall and Evaporation

The average annual rainfall in the region (BoM Station 035132) is approximately 572mm, with the distribution of monthly rainfall shown in **Figure 2-2**. Rainfall is greatest during the summer months December to February, with 47% of annual rainfall occurring over these months. The highest monthly average rainfall total is 95mm in January, and the driest month is August with an average rainfall of 16mm.

The site experiences large water loss year-round, with an average annual evaporation for the site of 2,044mm. On a monthly basis, maximum evaporation occurs later in the year (October to December). During the dryer months evaporation is significantly lower, with the lowest total typically occurring in June. **Figure 2-2** summaries the average evaporation for all moths of the year for the site.

2.3.1 Probabilistic Rainfall

Probabilistic rainfall was generated for the WBM. The purpose of the probabilistic rainfall generation is to develop a wide range of climate sequences based on the recorded rainfall data of the area. These sequences have the same statistical characteristics of the historical data set for a range of parameters including mean, variance, skew, and the number of wet days or dry days. The 500 sequences of probabilistic data are summarised as exceedance probabilities. Some sequences may be wetter or dryer than others in order to account for the variability of the climate which may occur following establishment of the residual voids. The probabilistic rainfall data replicated the seasonality of the rainfall data.

The probabilistic rainfall data was generated from the historical data using the eWater CRC Stochastic Climate Library (SCL). Data was generated from 500 replicates of 120 years (from 1900 to 2020 as consistent with the available historical data record) of daily rainfall data for in accordance with the SCL Manual. Probabilistic rainfall at 200 years length were generated. The generated data was found to be representative of the historical record within acceptable tolerances for key statistics.

Comparison of the probabilistic data and the historical rainfall record for the annual rainfall totals is shown in **Figure 2-3**. Review of **Figure 2-3** shows the model simulates a range greater than that of the recorded historical rainfall data but the median (50th percentile) of the results are aligned.

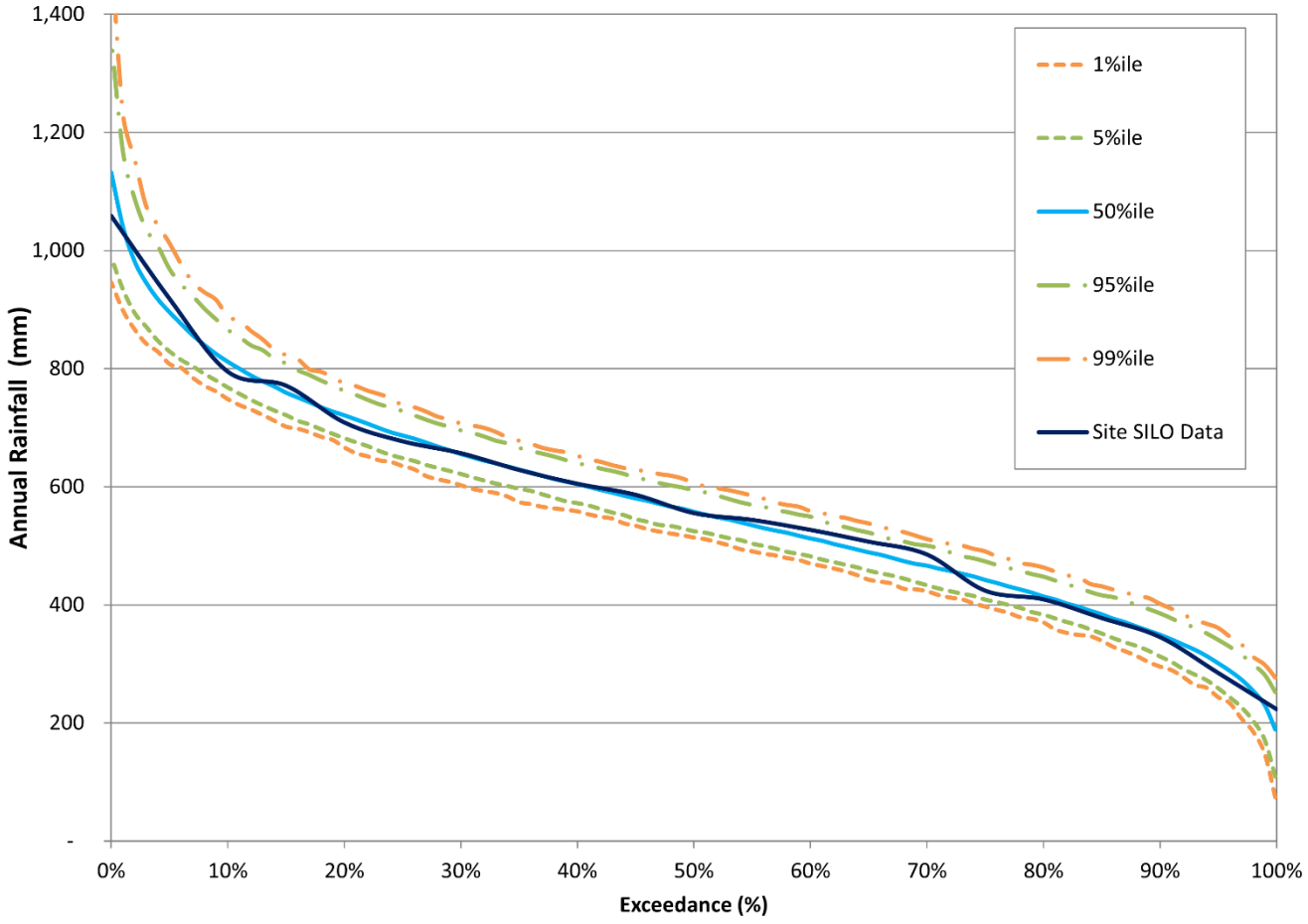


Figure 2-3 Comparison of Historical and Probabilistic Data

2.3.2 Evaporation

The evaporation values in the model were sourced from SILO, which provides Class A rates. For the WBM, monthly averages were used as the evaporation data for the area is limited. The extended evaporation records available in SILO consisted of infilled data from monthly averages (rather than daily records from other gauges) for the period prior to gauge readings. This is most likely due to the limited available data for infilling. **Table 2** outlines the adopted lake evaporation rates and pan factor. Pan factors have been determined using the Morton Lake Evaporation.

Table 2 Adopted Monthly Evaporation Rates

Month	Evaporation (mm/d)	Pan Factor
January	7.3	0.90
February	6.5	0.93
March	6.1	0.90
April	5.0	0.89
May	3.8	0.86
June	3.1	0.84
July	3.3	0.87
August	4.3	0.88
September	5.8	0.87
October	6.9	0.88
November	7.5	0.89
December	7.7	0.89

Note: Class A Pan Evaporation and the above Pan Factors were applied to the model, resulting in evaporation rates similar to Morton evaporation over shallow lakes.

2.4 Runoff Modelling

The WBM utilises the Australian Water Balance Model (AWBM) rainfall runoff module to calculate the rainfall and runoff inflows in each catchment. There are two AWBM modules in the WBM representing the runoff response for the following land use types:

- Void; and
- Rehabilitation.

The rainfall is converted to runoff using the Australian Water Balance Model (AWBM), illustrated in **Figure 2-4**. This runoff can be split into two forms:

1. Surface runoff which travels overland to the destination; or
2. Sub-surface which travels through the ground to reach the destination.

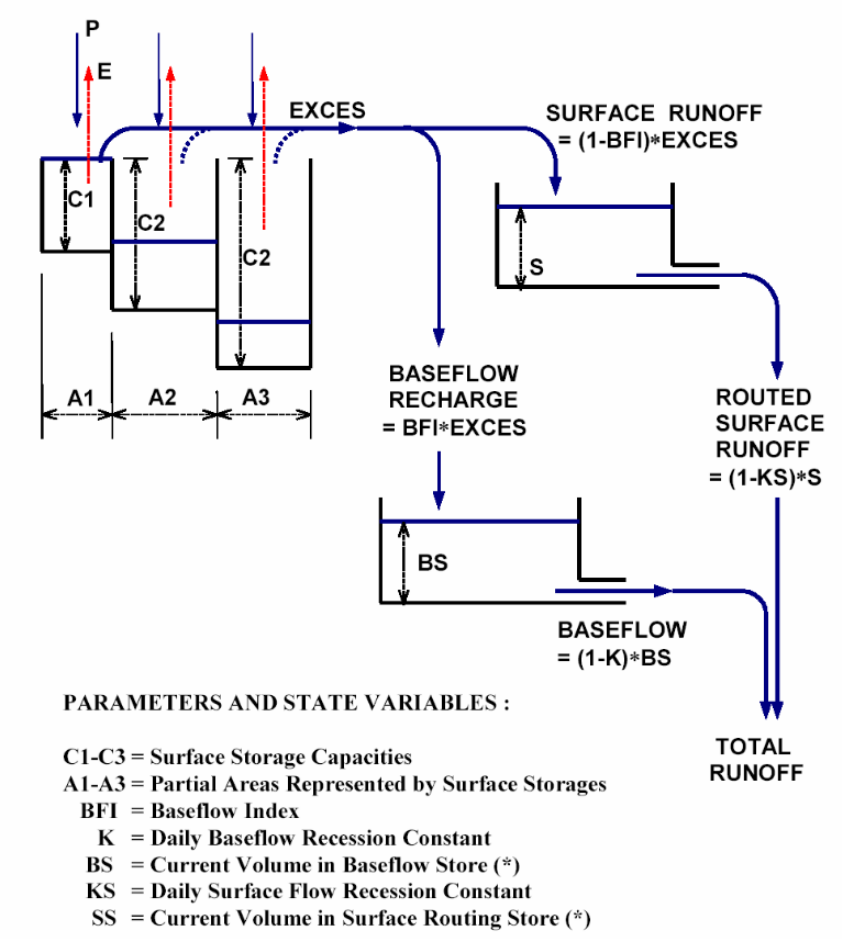


Figure 2-4 AWBM Rainfall Runoff Model

AWBM parameters were adopted based on values derived in the area for similar projects and are considered suitable for use in this assessment. A summary of the AWBM parameters used for different catchment types are presented in **Table 3**.

Table 3 Adopted AWBM Parameters

Parameter	Abb	Landuse	
		Void	Rehabilitation
Small storage capacity (mm)	C1	10	11
Medium storage capacity (mm)	C2	25	60
Large storage capacity (mm)	C3	50	130
Small partial area portion	A1	0.134	0.134
Medium partial area portion	A2	0.433	0.433
Large partial area portion	A3	0.433	0.433
Baseflow Index	BFI	0.1	0.35
Baseflow recession	K	0.6	0.6
Daily streamflow recession	KS	0.1	0.1

2.5 Groundwater Interaction

Groundwater interactions with the WBM were derived from the groundwater model developed for the PRCP and provided as a relationship between water level and inflow (SLR, 2022). The relationships adopted in the WBM were calculated at a daily timestep based on this relationship using the water level in the voids as predicted by the WBM.

Further information relating to derived groundwater inflows can be found in Section 4 of the Curragh Mine Complex Progressive Rehabilitation and Closure Plan Groundwater Technical Appendix (SLR, 2022).

2.6 Water Quality

The water balance model was developed to include a high-level salt balance to track both the quantity and quality of water on-site. The salt balance tracks the water quality in all of the inflows into the voids and subsequent effects from evaporation and releases on the storage water quality. The water quality values are presented in . These adopted values are consistent with those adopted for other Queensland mine sites.

Based on groundwater monitoring data at the mine, an EC of 12,500 µS/cm was adopted as the average salinity concentration of groundwater inflows. Salinity parameters for surface runoff were determined based on prior experience in the area.

Adopted water quality parameters are summarised in **Table 4**.

Table 4 Adopted Salinity Generation Parameters

Inflow	Salinity (EC) (µS/cm)
Void	3,000
Rehabilitation	250
Groundwater Inflow	12,500

The above salinity values are converted to a concentration in milligrams per litre using an average multiplication factor of 0.67 (Measuring Salinity DERM, June 2007) to quantify the mass of salt transferred in the model.

3 Results

The WBM was run for a range of rainfall conditions to allow for the calculation of percentiles of the final void levels. These percentiles represent the results range due to variability in climate. The results of the WBM focus on the 5th, 50th and 99th percentile. This represents the dry, median and very wet climatic condition. The 99th percentile result is used to assess the risk of overflow of the voids.

3.1 Residual Void Water Levels

The WBM was predicted to stabilise after approximately 100 years to the approximate levels for the median condition shown in **Table 5**. It is noted that some individual voids within the WBM reached equilibrium level in less than 20 years. Graphical representations of the results for each residual void are provided in **Appendix B.**

Table 5 Residual Void Water Level Summary

Void	Residual Void Level (50%ile) (mAHD)	Depth (m)	Surface Area (ha)
Curragh North	23	71	197
I Pit	135	1	5
Main Other	135	15	2
The Void	100	7	1
D Pit	62	33	12
F Pit North and Pit E North	49	23	24
E, C and H Pit	70	30	45
B Pit	112	4	13
F Pit	111	19	12
L Pit	103	38	6
K Pit	77	14	8
G Pit	137	7	6
Ramp 9	132	54	39
J Pit	111	18	8
X Pit East	67	33	39
X Pit West	98	20	19
Y Pit	123	8	8
Z Pit North	108	30	27
Z Pit South	105	17	13

The relative size of external catchment to the void footprint results in water levels that stabilise well below the indicative spill level with evaporative losses balancing inflows into the voids. A similar trend in water level is seen across all the residual voids. Water depths range from 1 m to 71 m within the voids for median conditions (50th percentile). During dry climatic conditions (5th percentile) water levels are approximately 0.1 m to 6 m lower. During very wet (99th percentile) climatic conditions the water level increases by 0.4 m to 9 m depending on the void and generally causes greater fluctuation in the equilibrium water level. Median final water levels range from 11 m to 109 m below the indicative spill levels and are not expected to overtop.

The surface area of the final void water level ranges in size from 1 ha to ~200 ha. There is one main final void at Curragh North with all other voids having a footprint less than 50 ha. Of the 19 voids 73 % have a footprint less than 24 ha and 42% less than 10 ha.

3.2 Water Quality

Water within the residual voids becomes highly saline throughout the simulation. This was not unexpected due to the high salinity of groundwater in the region and the assumption that the only loss from the system is evaporation (through which no salt is lost). Within the WBM salinity is capped at a maximum EC of 532,836 µS/cm which is equivalent to the point where the concentration of salt becomes high enough that the solution is saturated and any additional salt will precipitate out of solution. All voids are expected to exceed hypersaline EC levels (>50,000 µS/cm) within approximately 120 years of closure, with some exceeding this value within 30 years.

The average salinity of the voids throughout the simulation period are provided in **Table 6**. Graphical representations of the results for each residual void are provided in **Appendix C.**

Table 6 Average Stage Salinity (EC µS/cm)

Void	Year 10	Year 30	Year 200
Curragh North	13,900	20,100	>50,000
I Pit	>50,000	>50,000	>50,000
Main Other	11,700	25,700	>50,000
The Void	10,200	15,600	>50,000
D Pit	16,500	28,800	>50,000
F Pit North and Pit E North	27,500	>50,000	>50,000
E, C and H Pit	15,700	33,700	>50,000
B Pit	>50,000	>50,000	>50,000
F Pit	18,200	38,600	>50,000
L Pit	13,800	24,200	>50,000
K Pit	28,400	>50,000	>50,000
G Pit	40,700	>50,000	>50,000
Ramp 9	17,300	25,600	>50,000
J Pit	23,300	49,300	>50,000
X Pit East	15,600	27,500	>50,000
X Pit West	19,200	39,600	>50,000

Void	Year 10	Year 30	Year 200
Y Pit	40,600	>50,000	>50,000
Z Pit North	19,800	37,600	>50,000
Z Pit South	23,400	48,500	>50,000

4 Conclusions

At Curragh Complex the median residual void water levels are expected to range from 23 mAHD to 137 mAHD with water depths of 1 m to 71 m . The results indicate that the mine is not a net accumulator of water after approximately 100 years when the equilibrium water levels are reached. The final water levels remain below the spill level and the voids are unlikely to overtop in the 99th percentile climate scenario.

A significantly high concentration of salt is expected to accumulate within the residual voids. The elevated salinity of the groundwater inflows input a high level of salt into the voids which is not lost from the system via evaporation. The salinity of the voids is expected to exceed that of the groundwater and form highly concentrated solution. Although poor quality, water within the voids is not expected to interact with surrounding surface water given the final water levels.

APPENDIX A

Stage Storage Curves

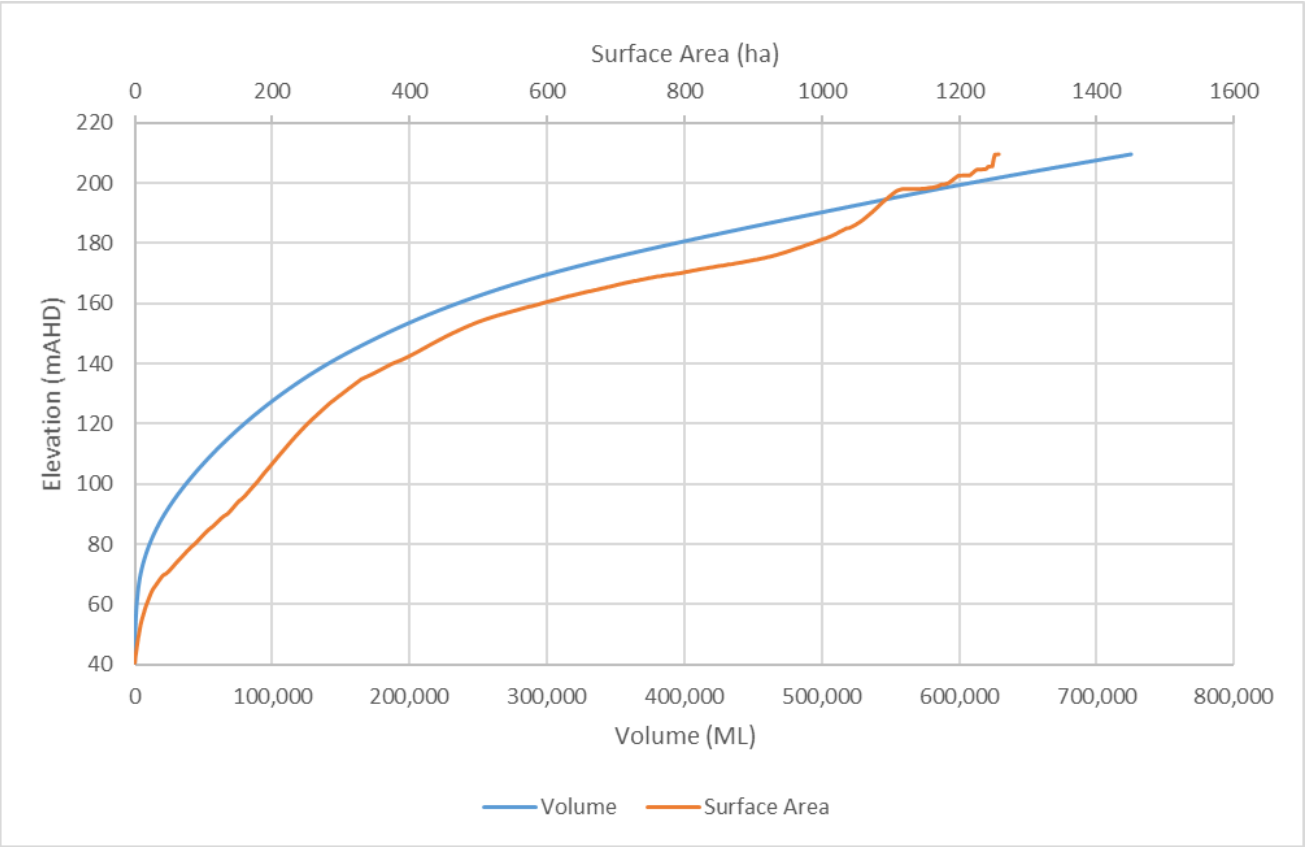


Figure 1A – E, C and H Pit Stage Storage

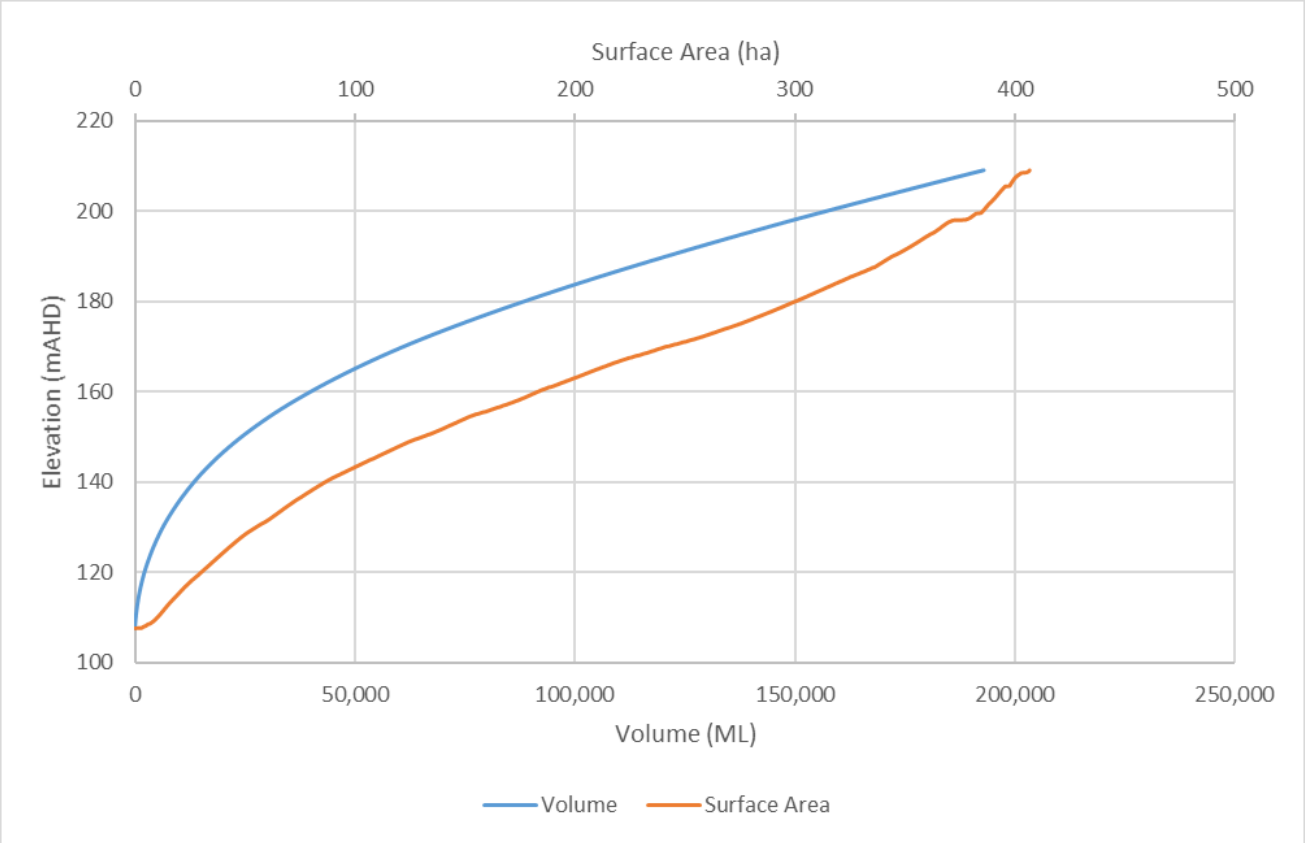


Figure 2A – B Pit Stage Storage

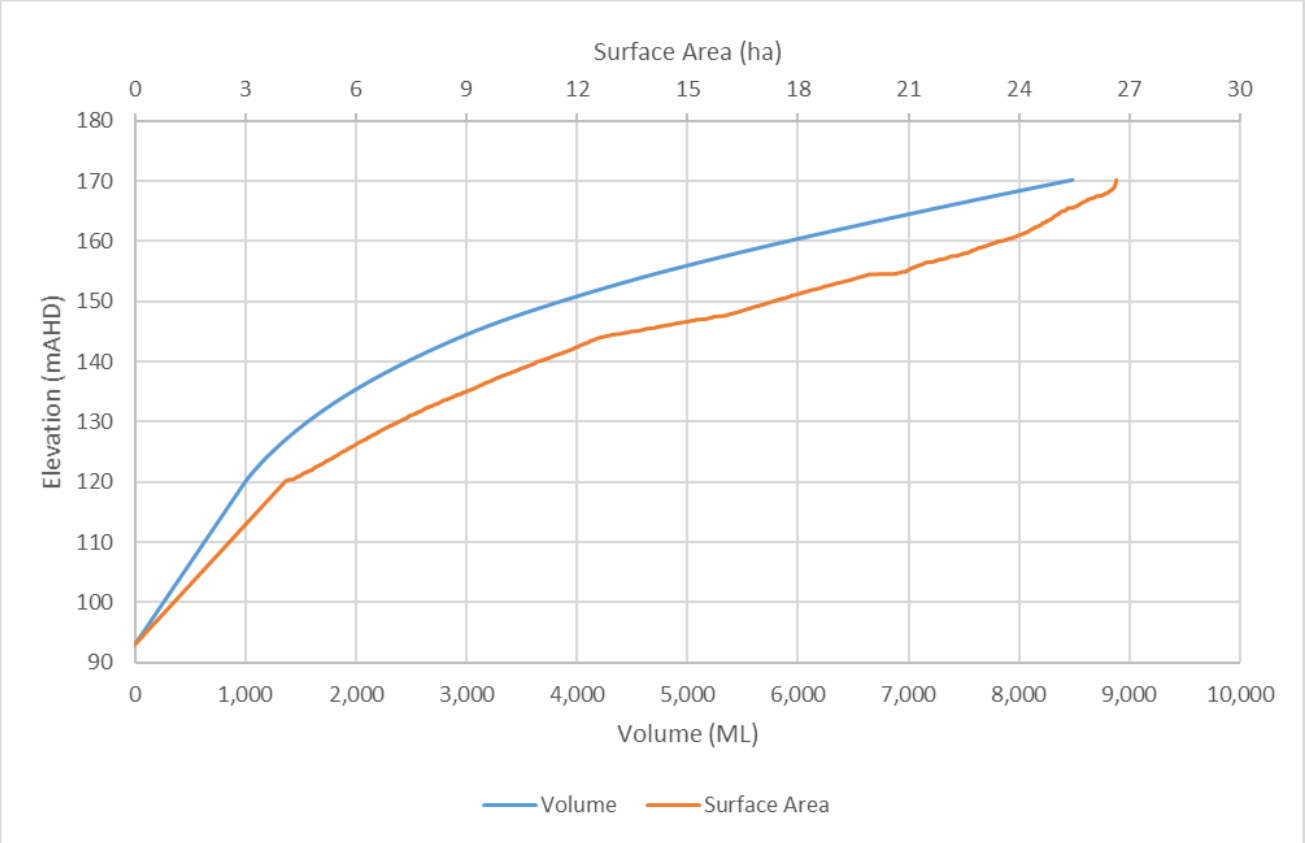


Figure 3A – The Void Stage Storage

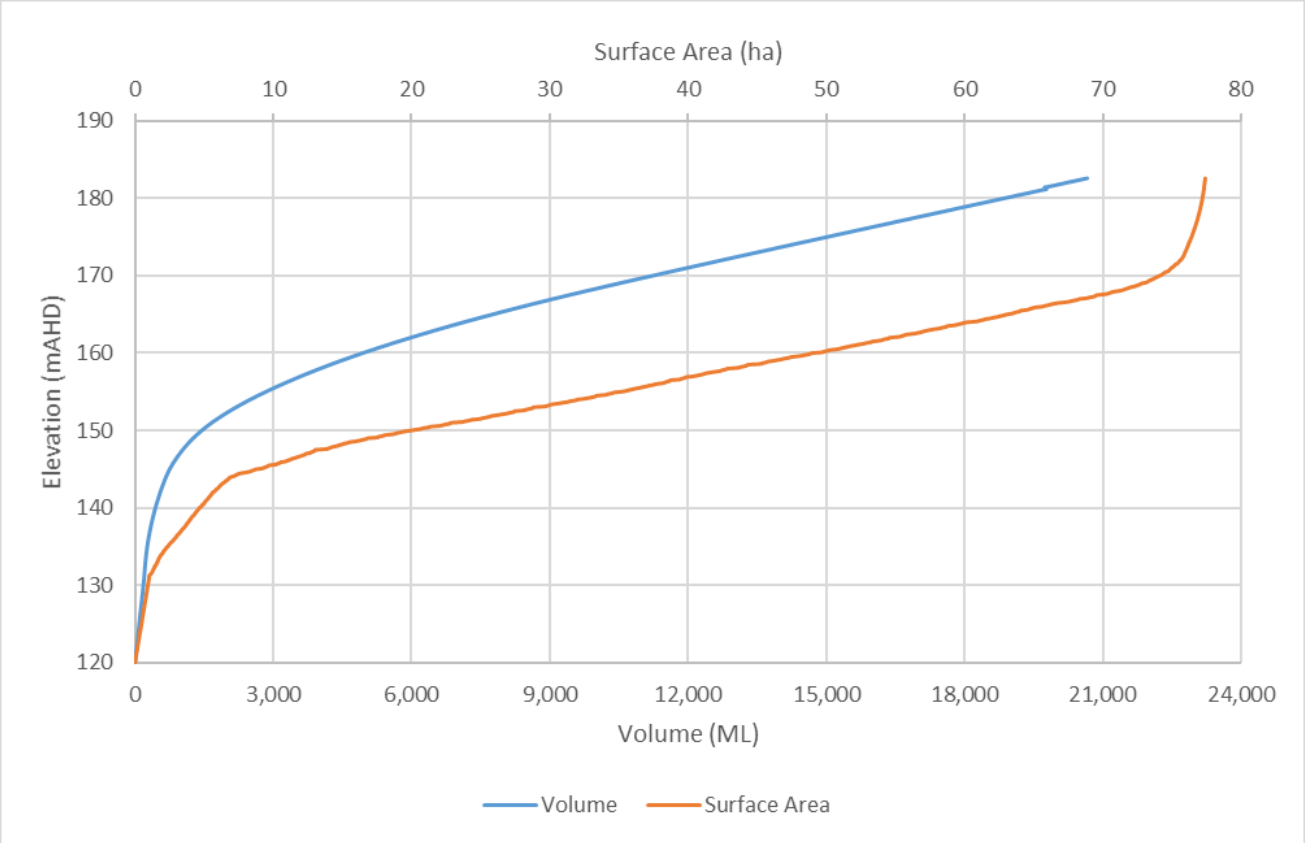


Figure 4A – Main Other Stage Storage

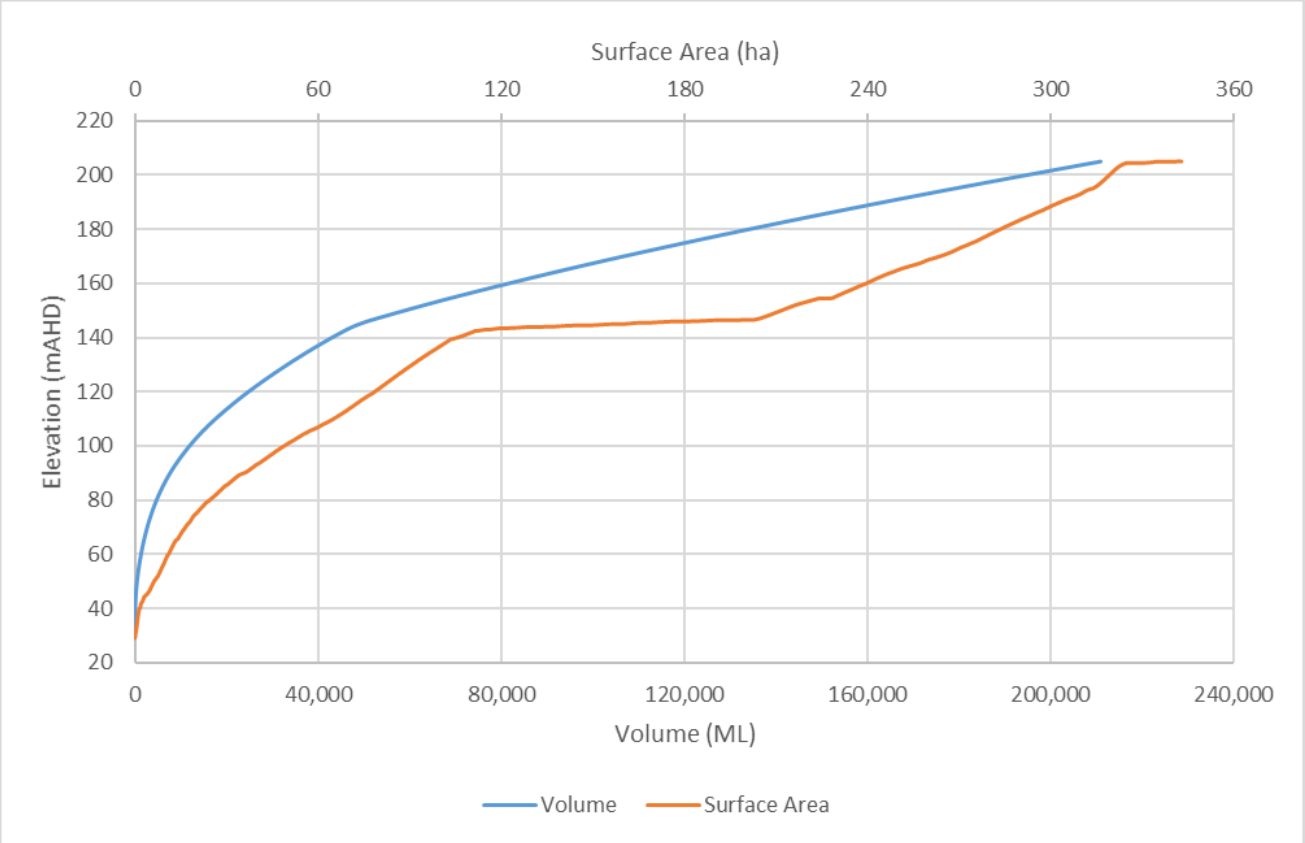


Figure 5A – D Pit Stage Storage

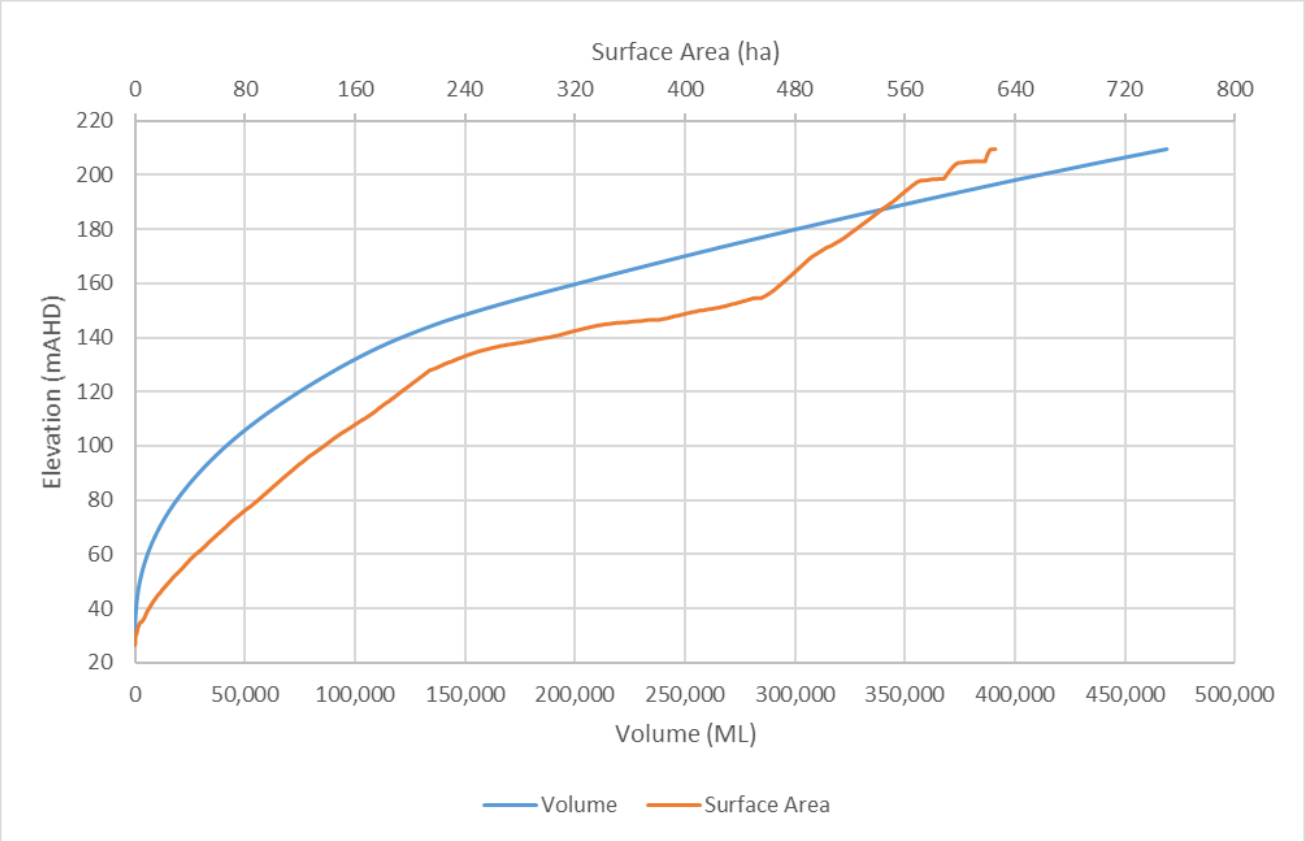


Figure 6A – F Pit North and Pit E North Stage Storage

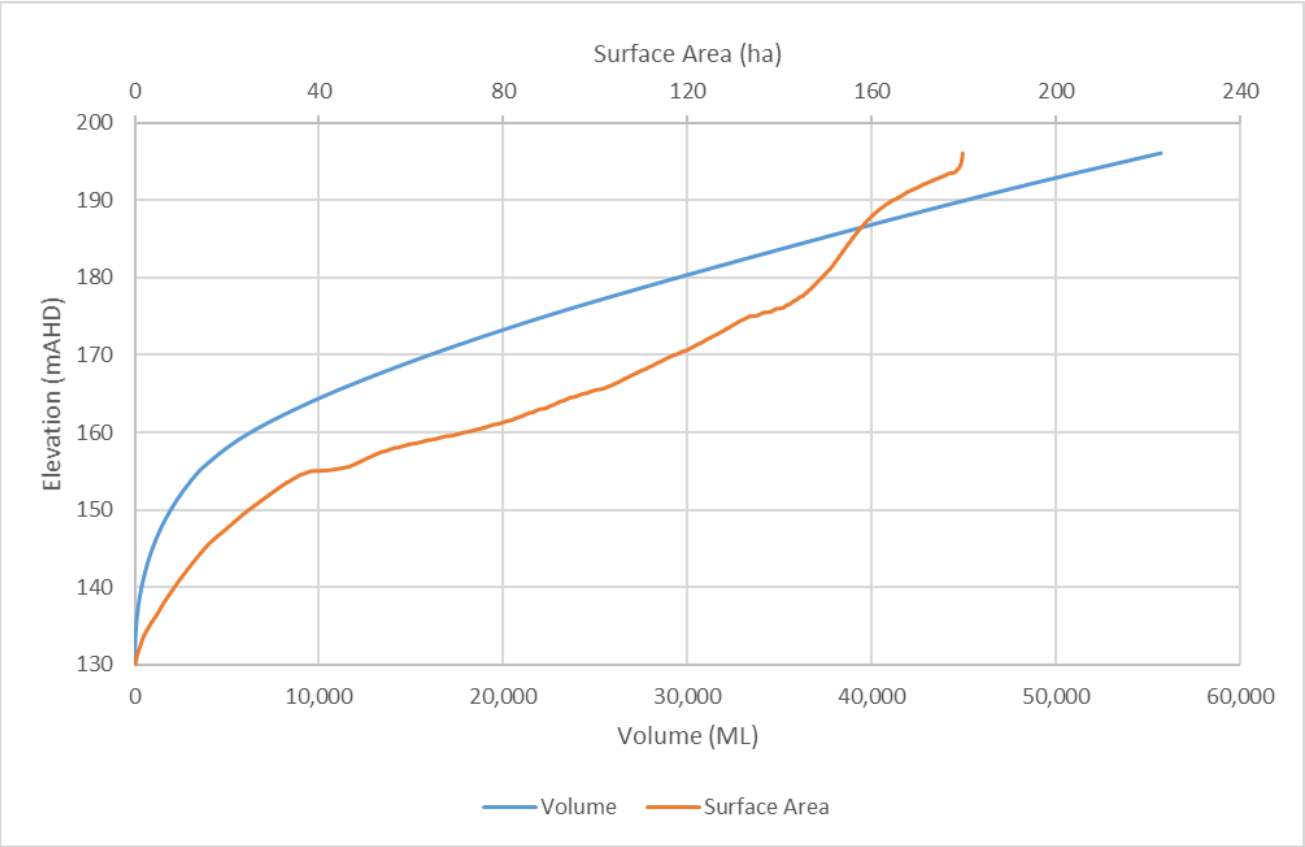


Figure 7A – G Pit Stage Storage

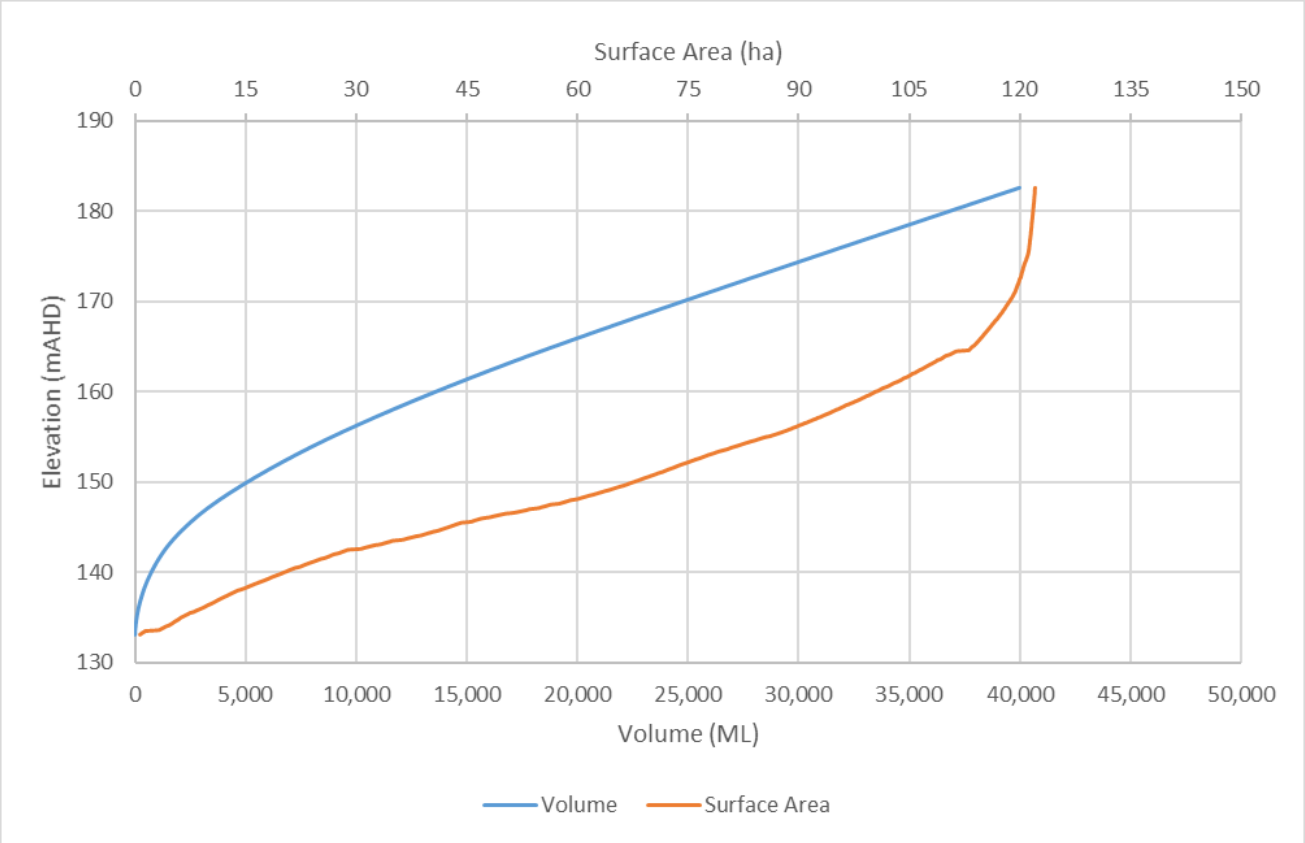


Figure 8A – I Pit Stage Storage

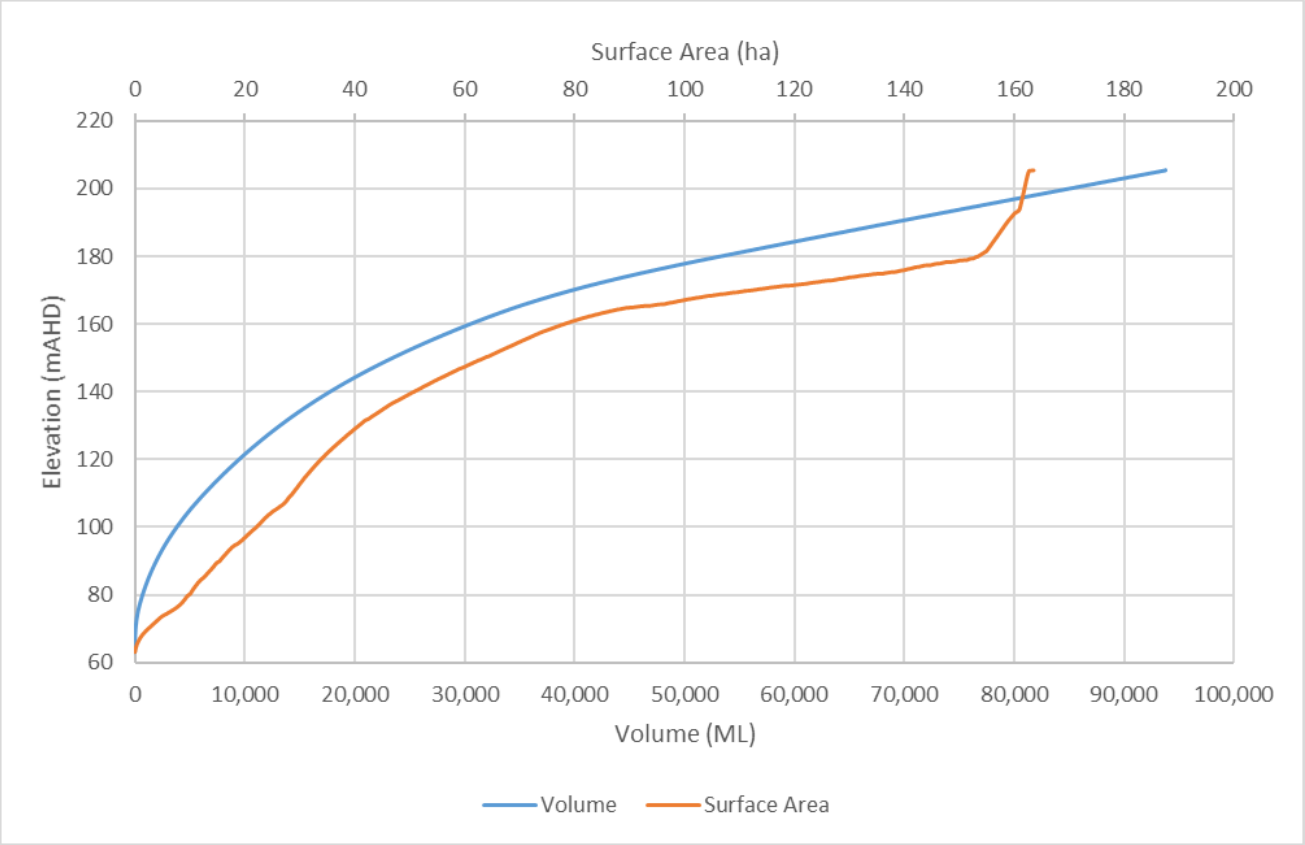


Figure 9A – K Pit Stage Storage

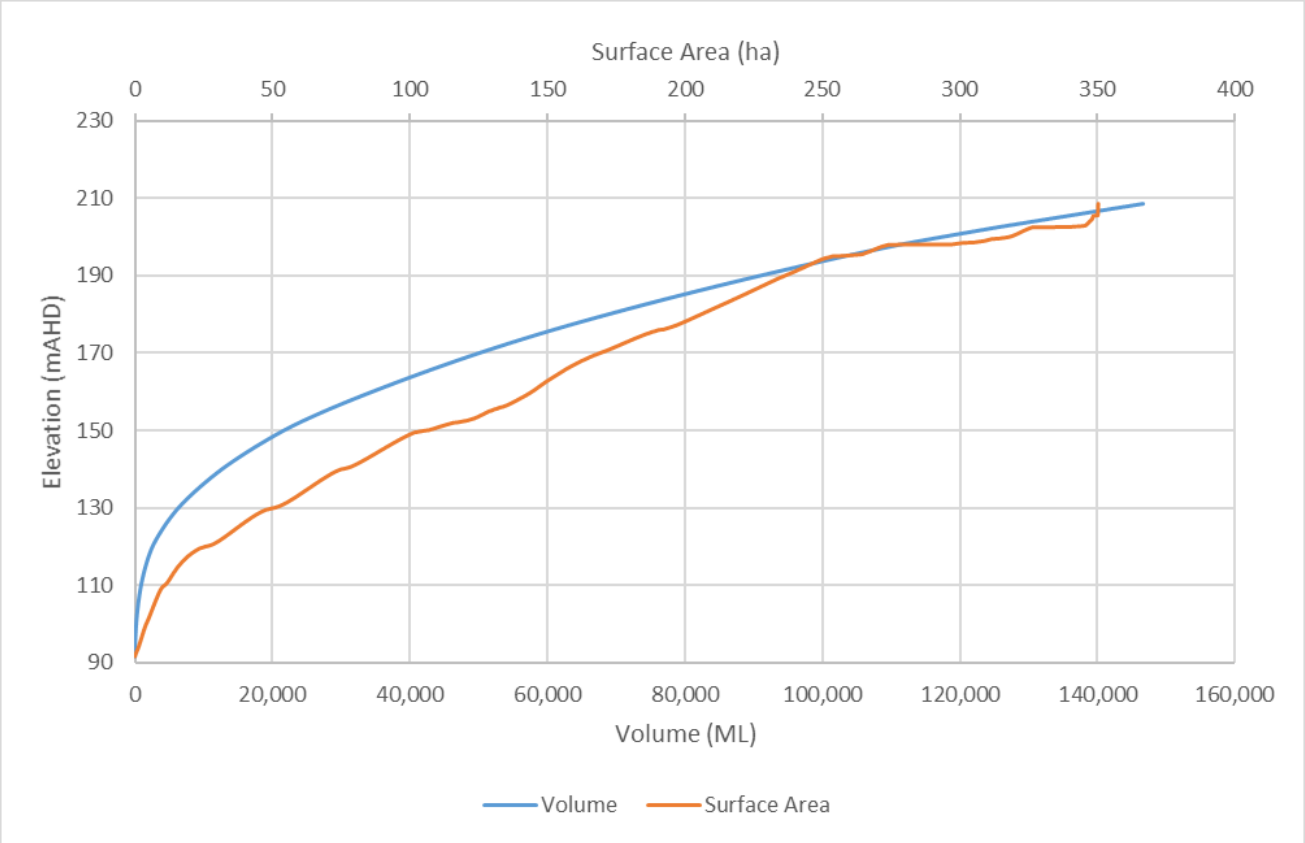


Figure 10A – F Pit Stage Storage

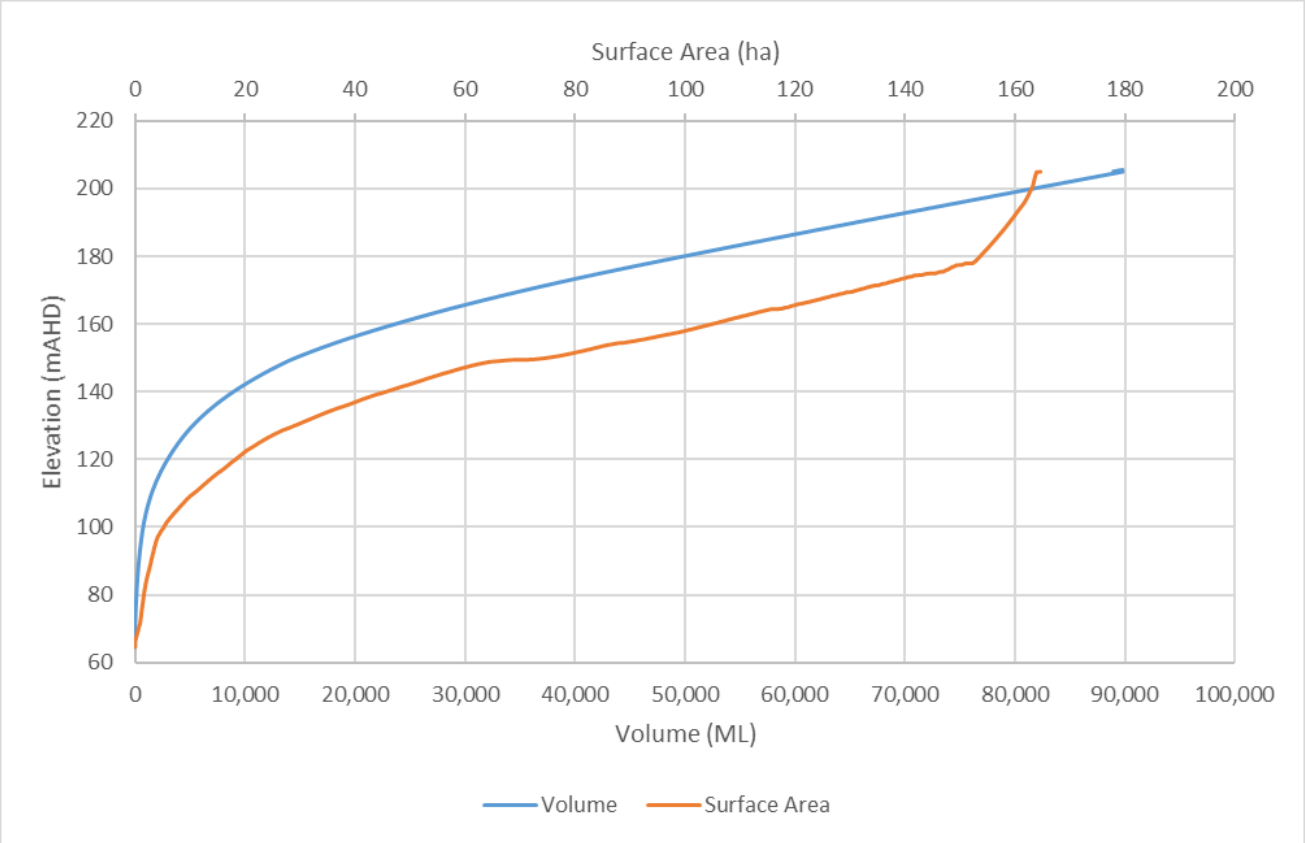


Figure 11A – L Pit Stage Storage

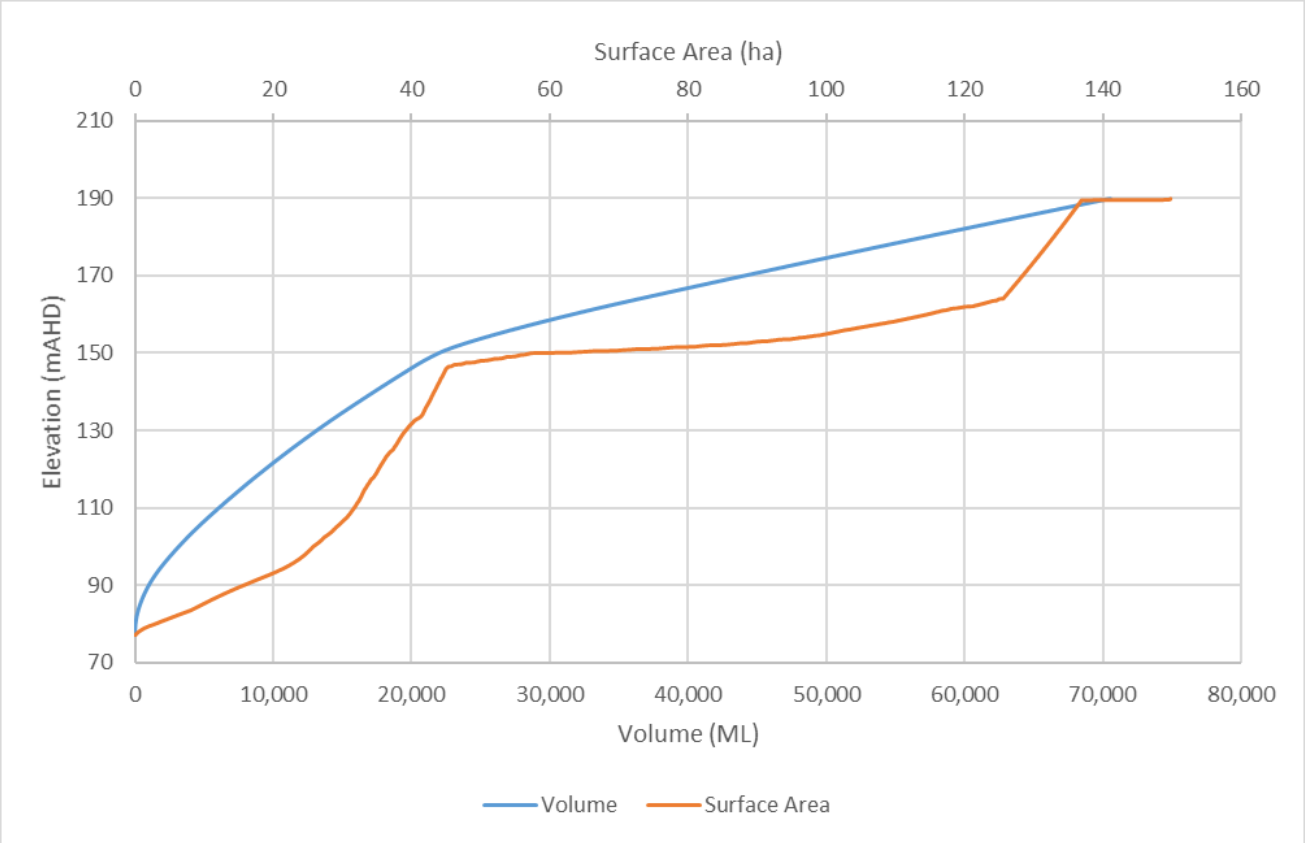


Figure 12A – Ramp 9 Stage Storage

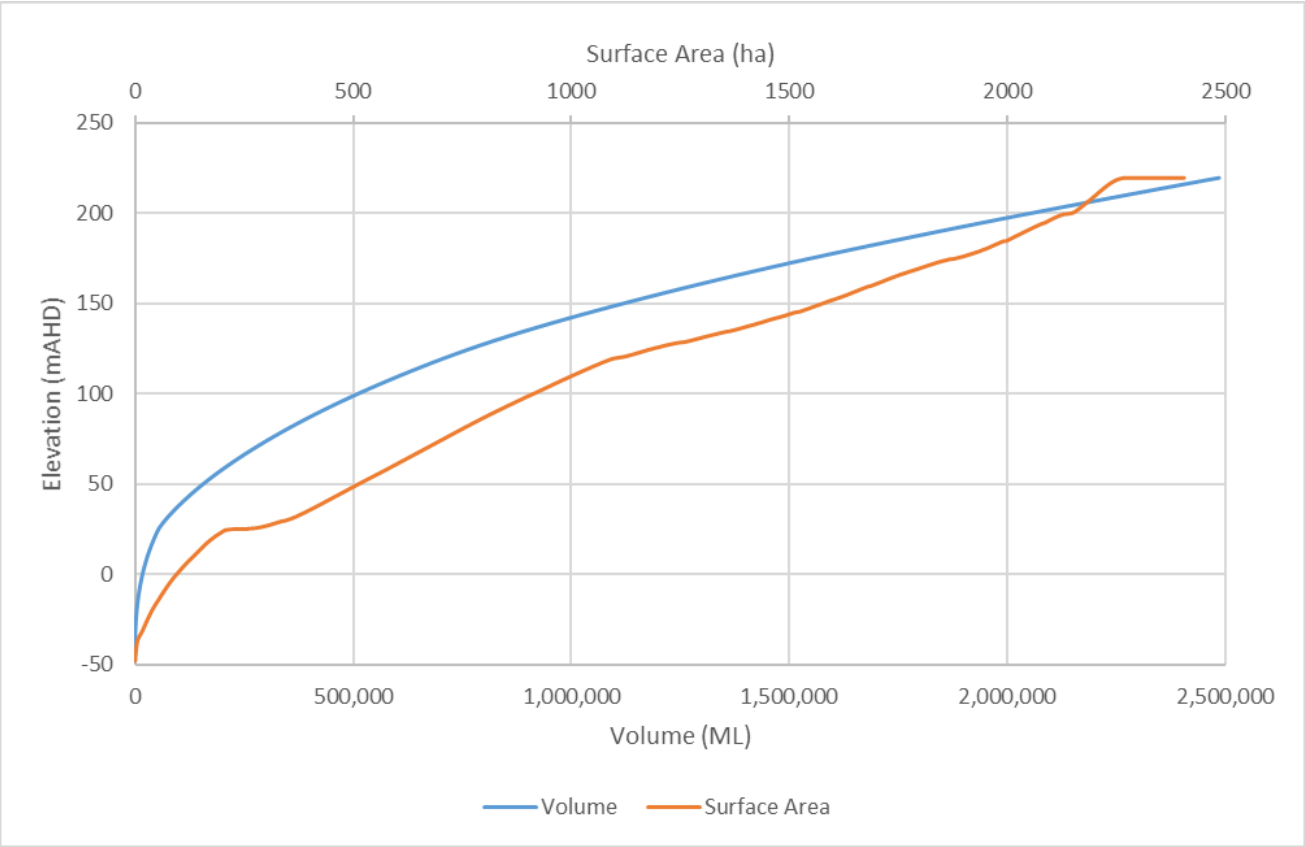


Figure 13A – Curragh North Stage Storage

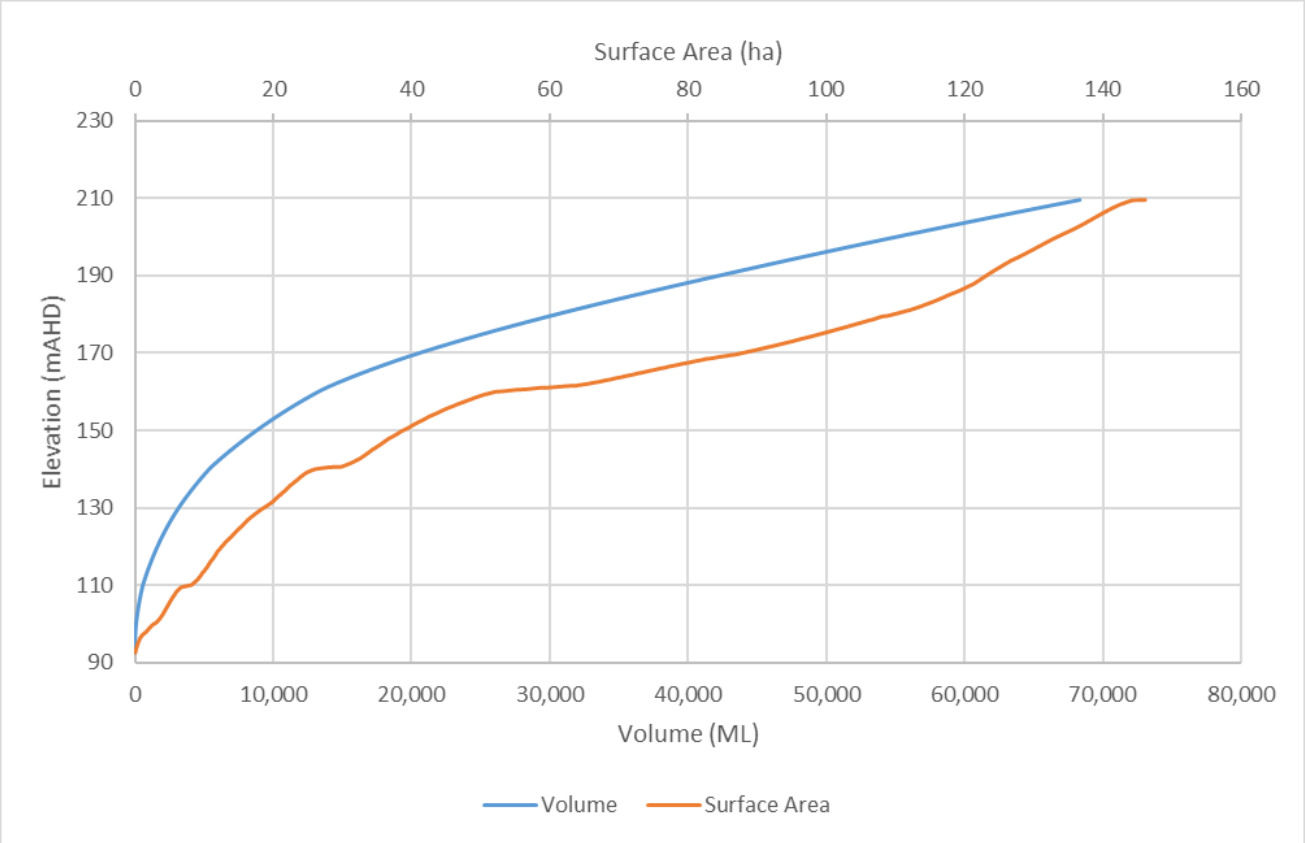


Figure 14A – J Pit Stage Storage

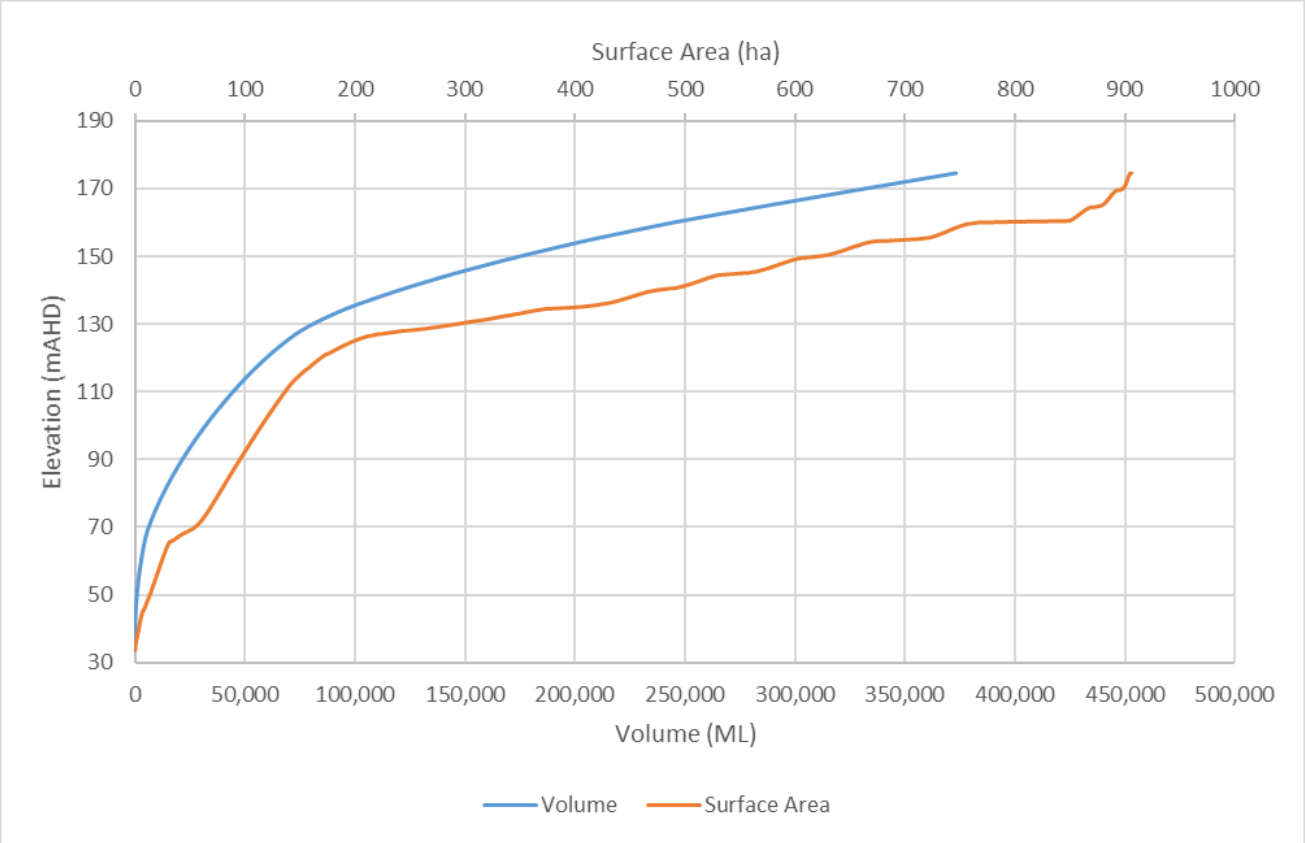


Figure 15A – X Pit East Stage Storage

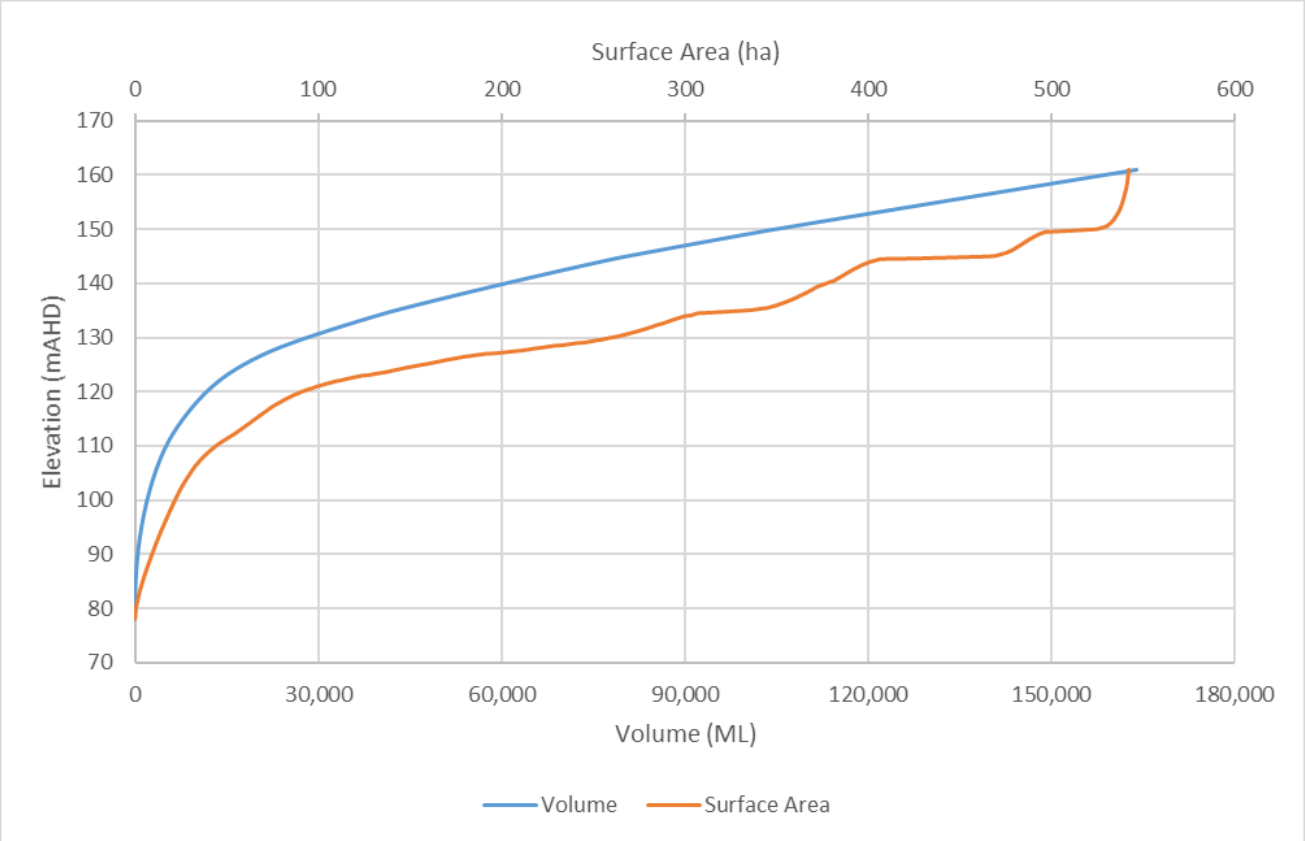


Figure 16A – X Pit West Stage Storage

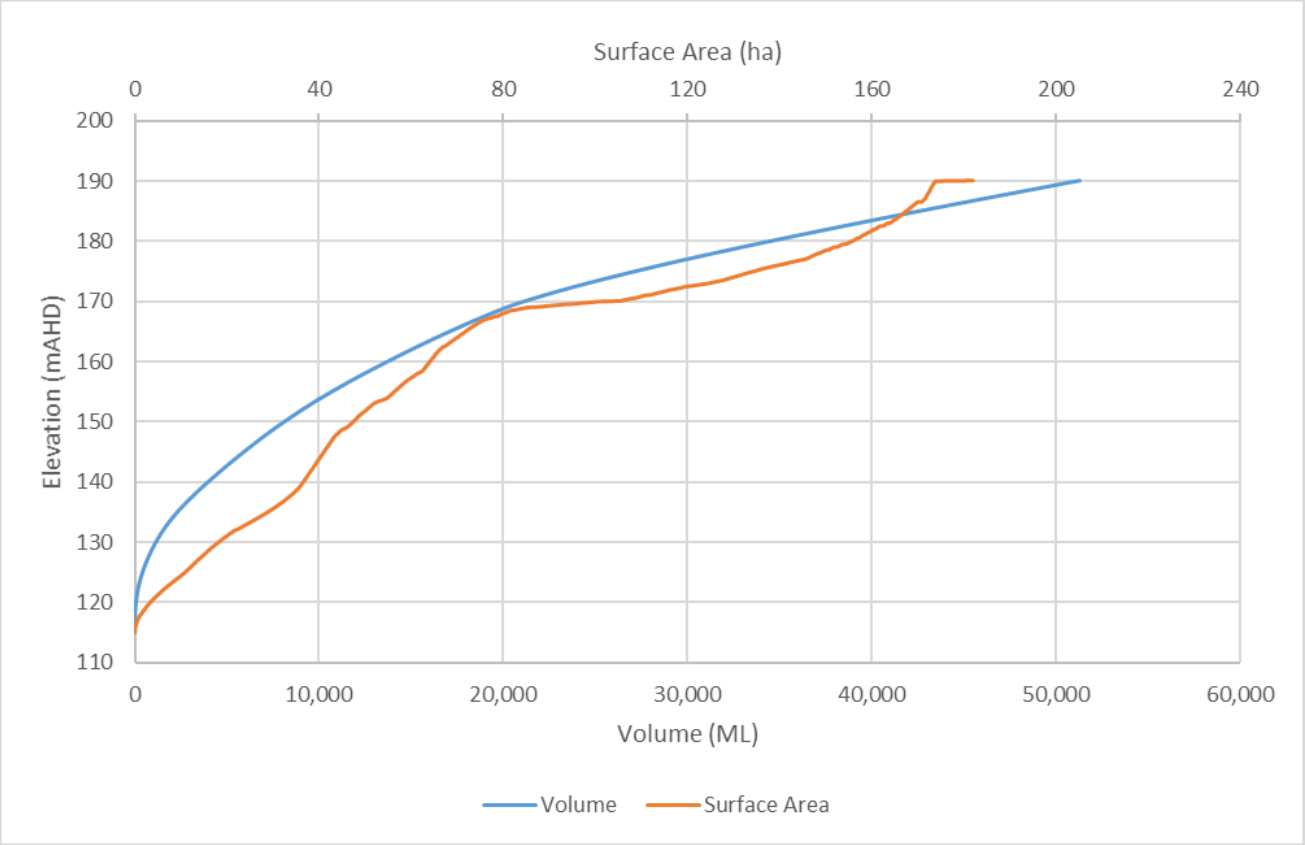


Figure 17A – Y Pit Stage Storage

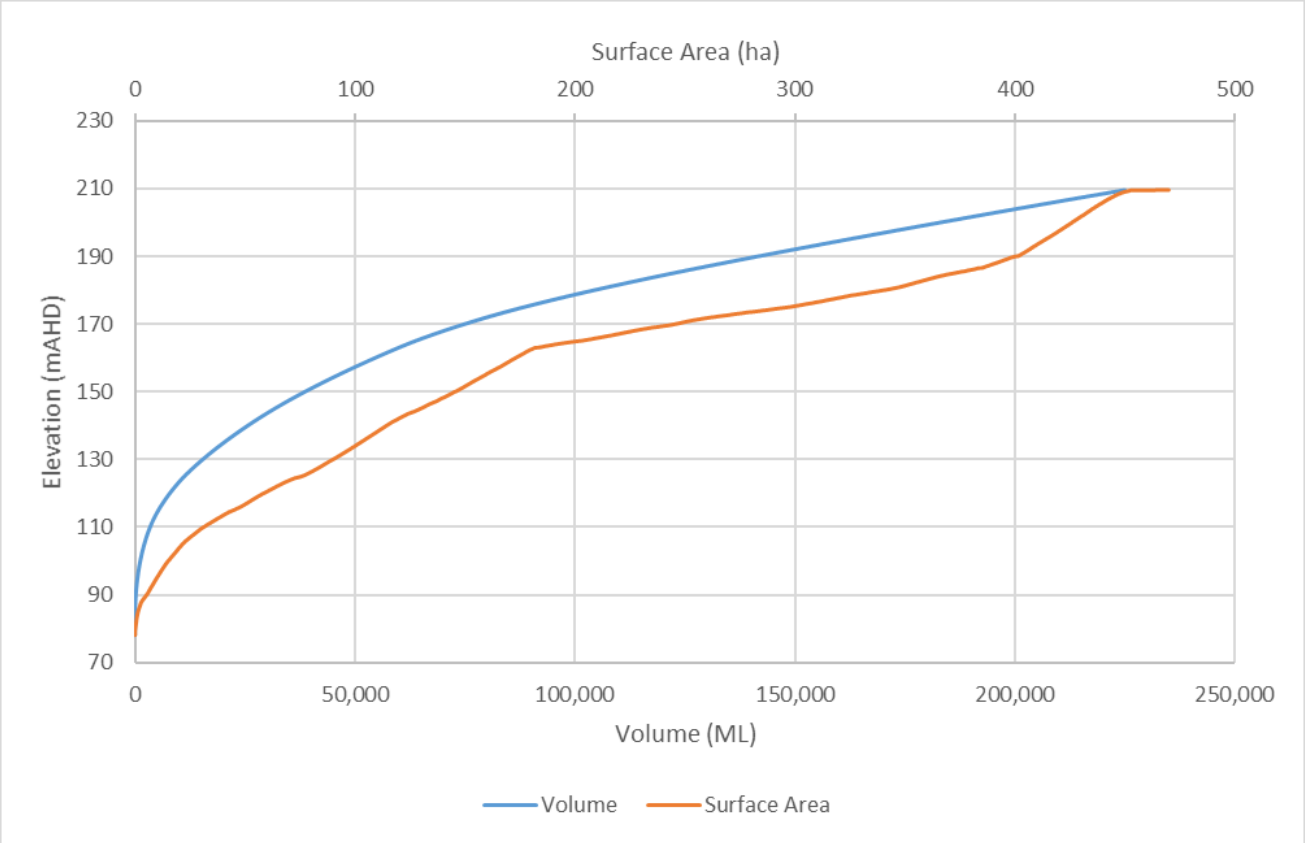


Figure 18A – Z Pit North Stage Storage

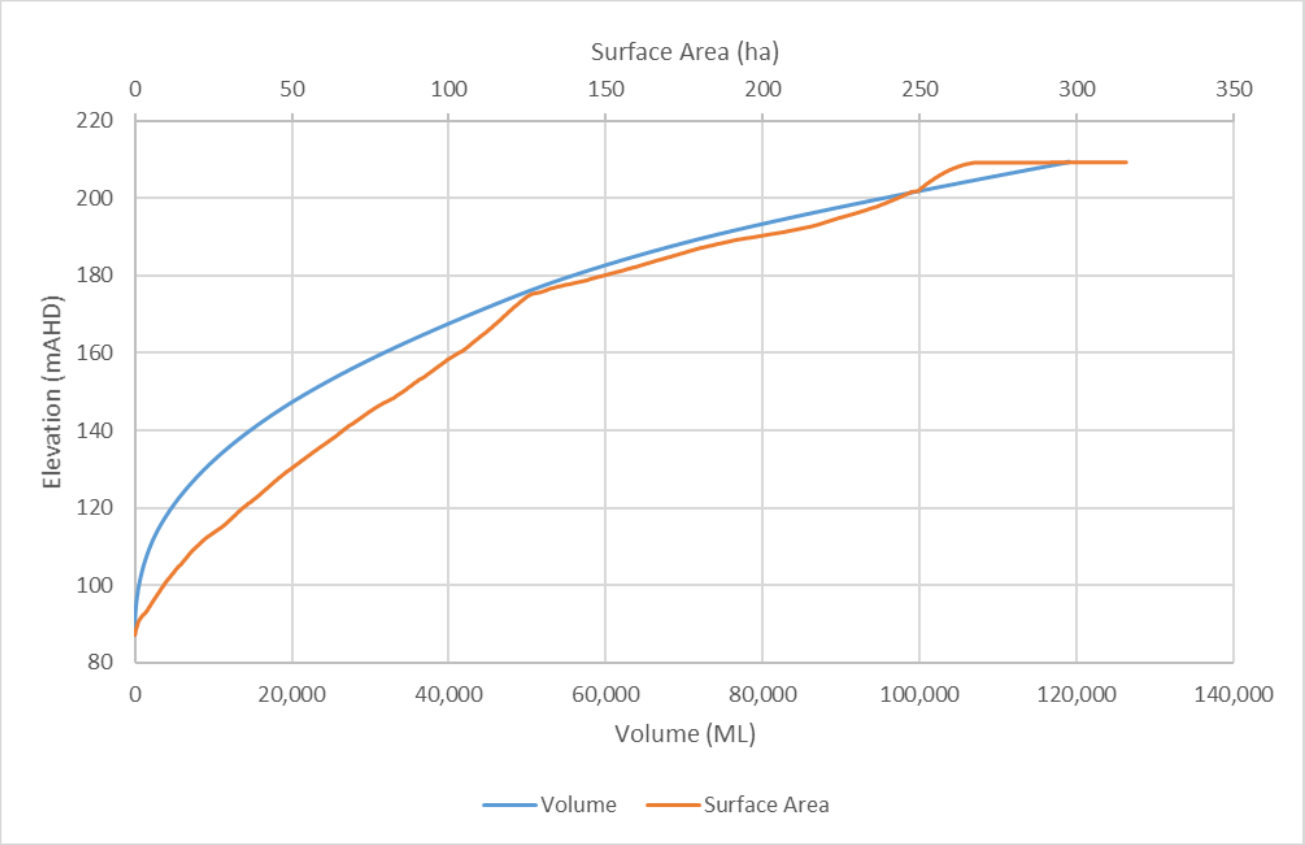


Figure 19A – Z Pit South Stage Storage

APPENDIX B

Residual Void Water Levels

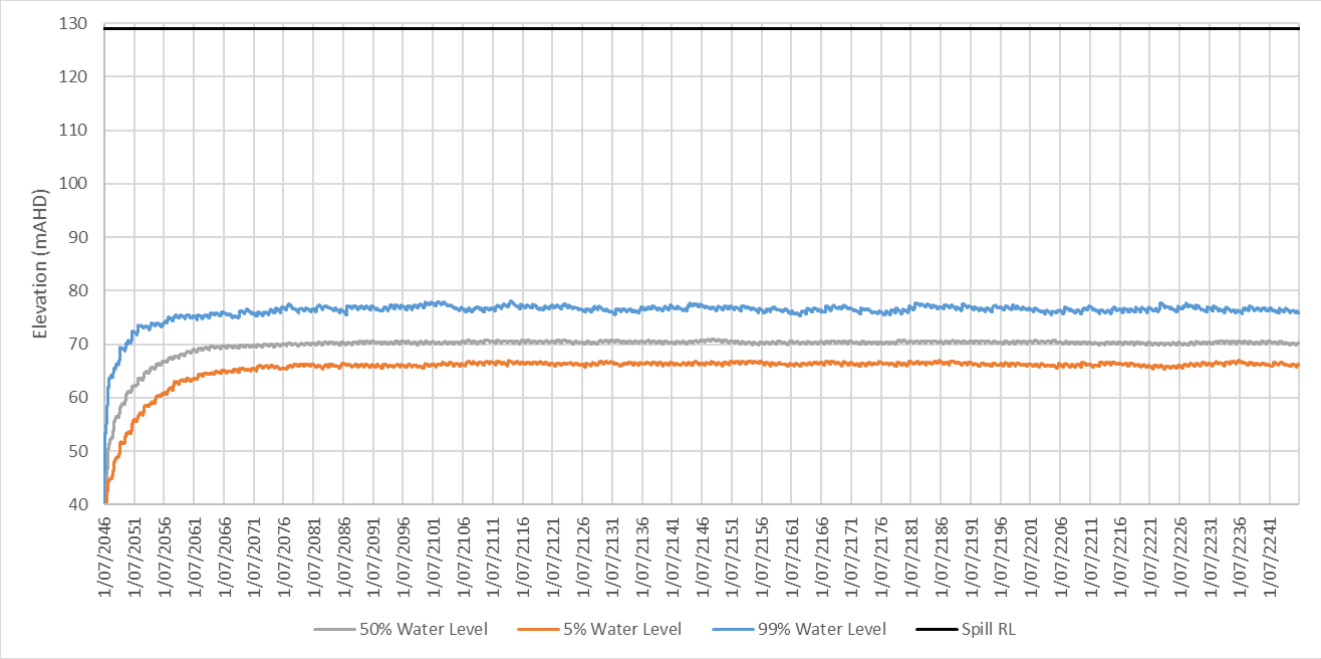


Figure 1B – E, C and H Pit Final Water Level

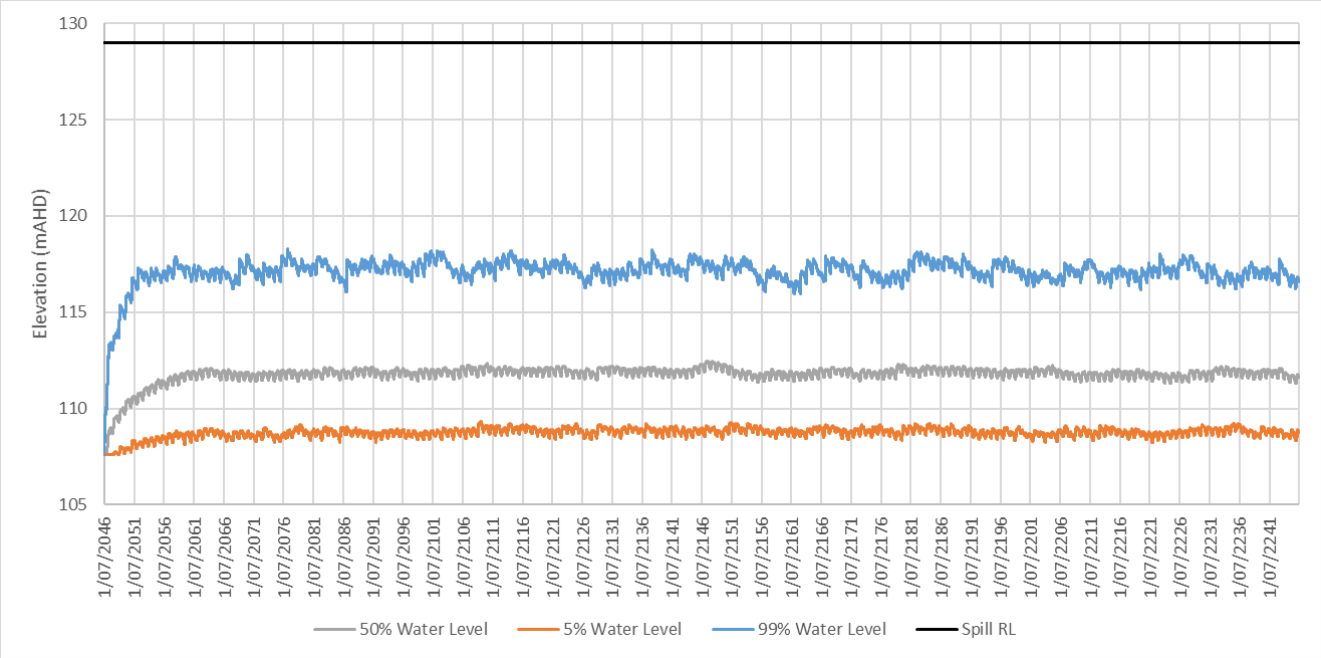


Figure 2B – B Pit Final Water Level

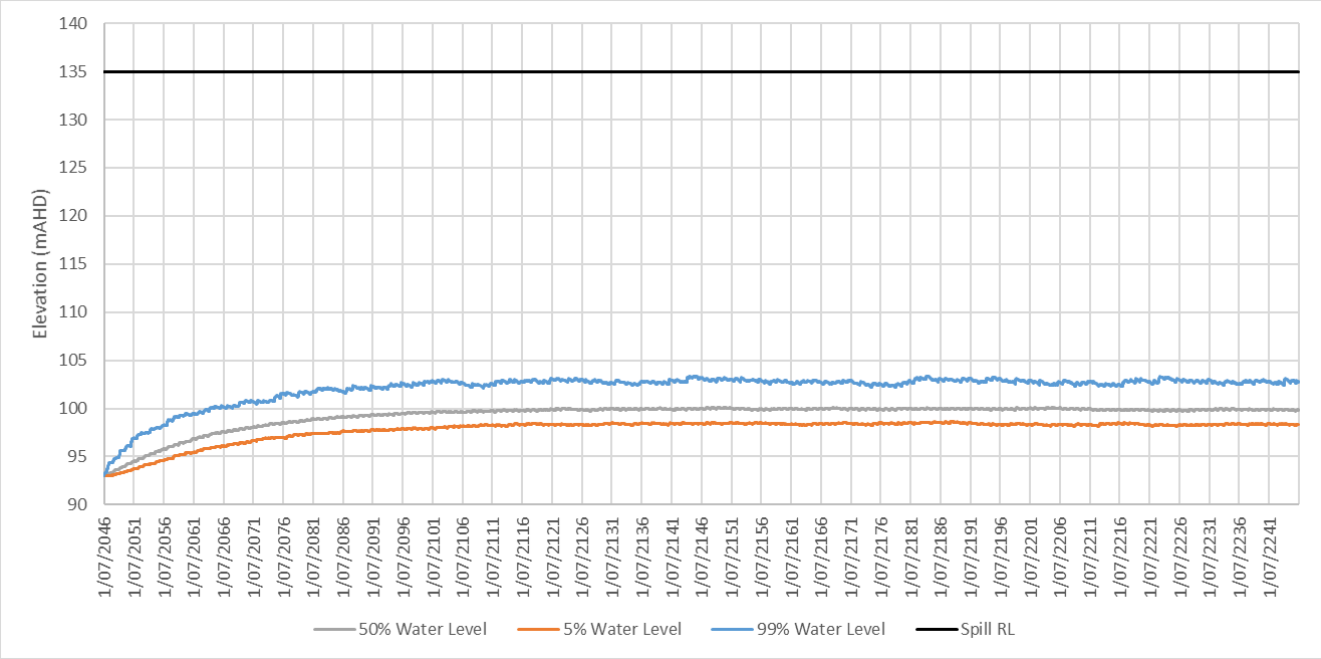


Figure 3B – The Void Final Water Level

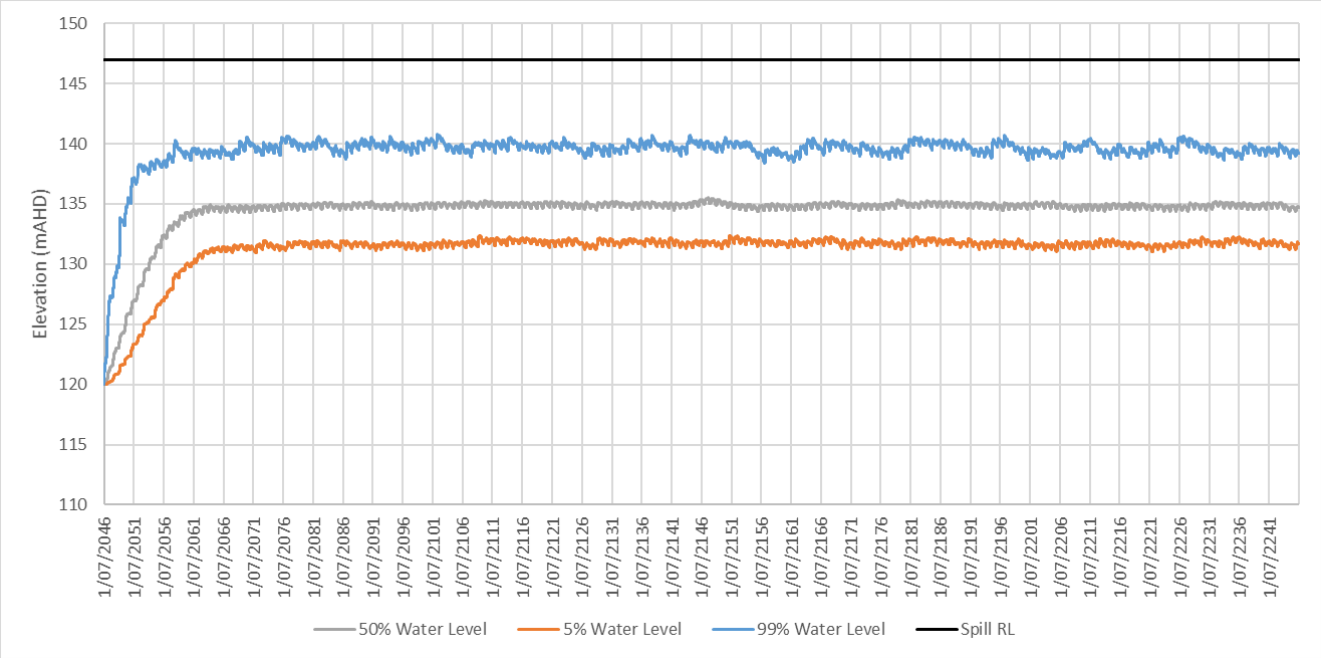


Figure 4B – Main Other Final Water Level

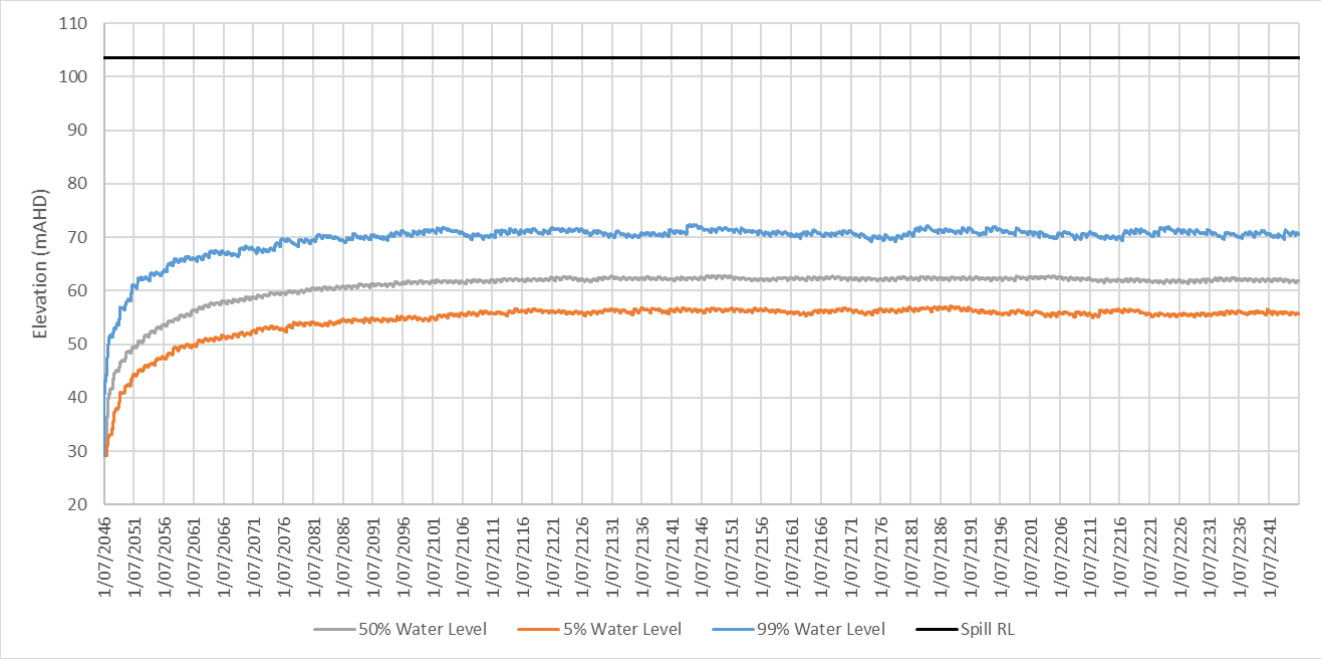


Figure 5B – D Pit Final Water Level

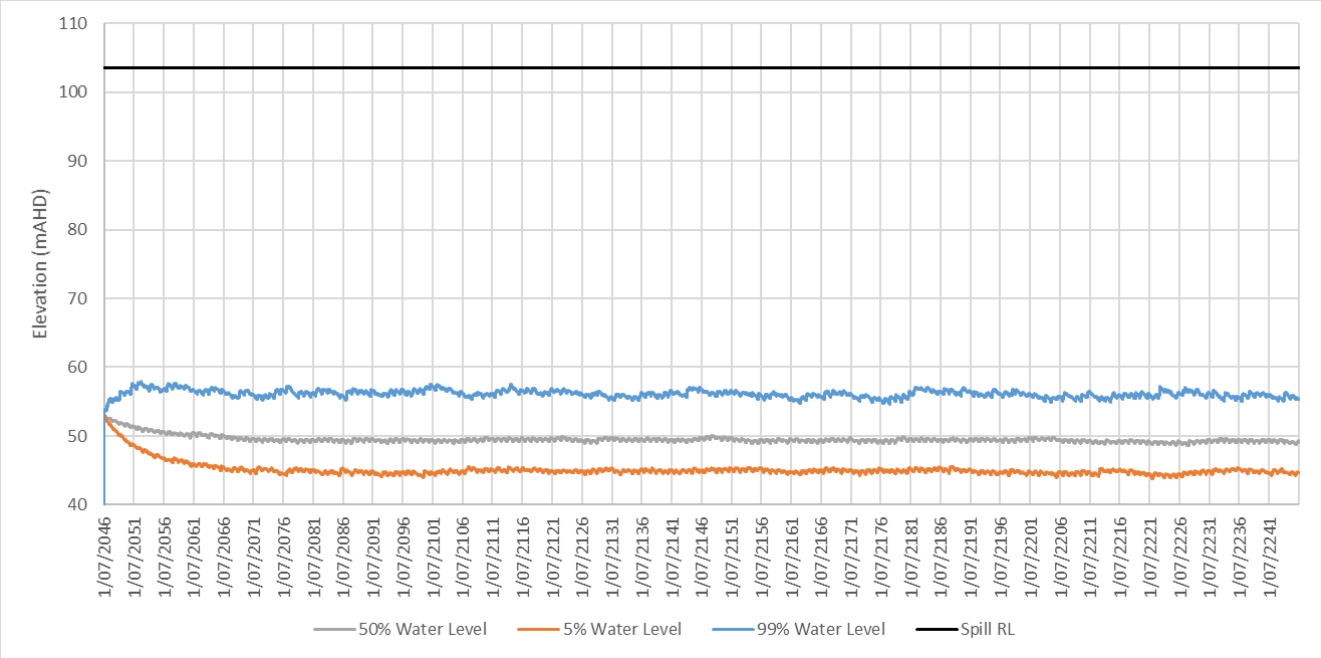


Figure 6B – F Pit North and Pit E North Final Water Level

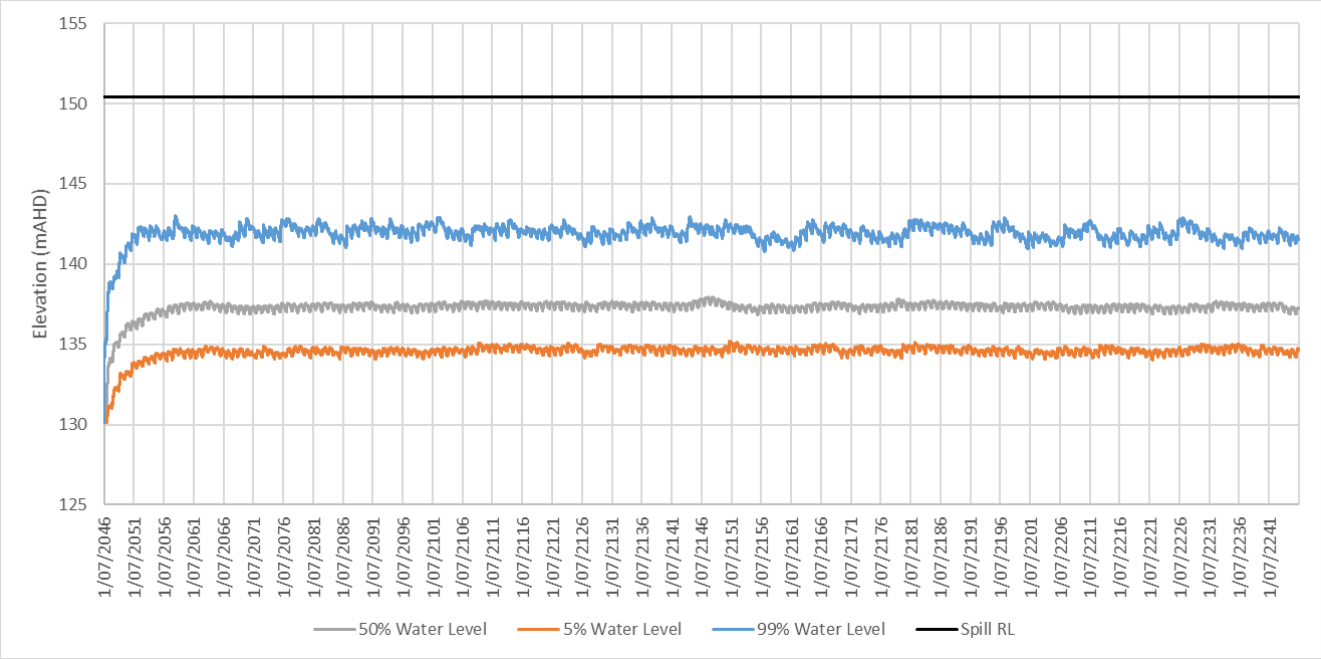


Figure 7B – G Pit Final Water Level

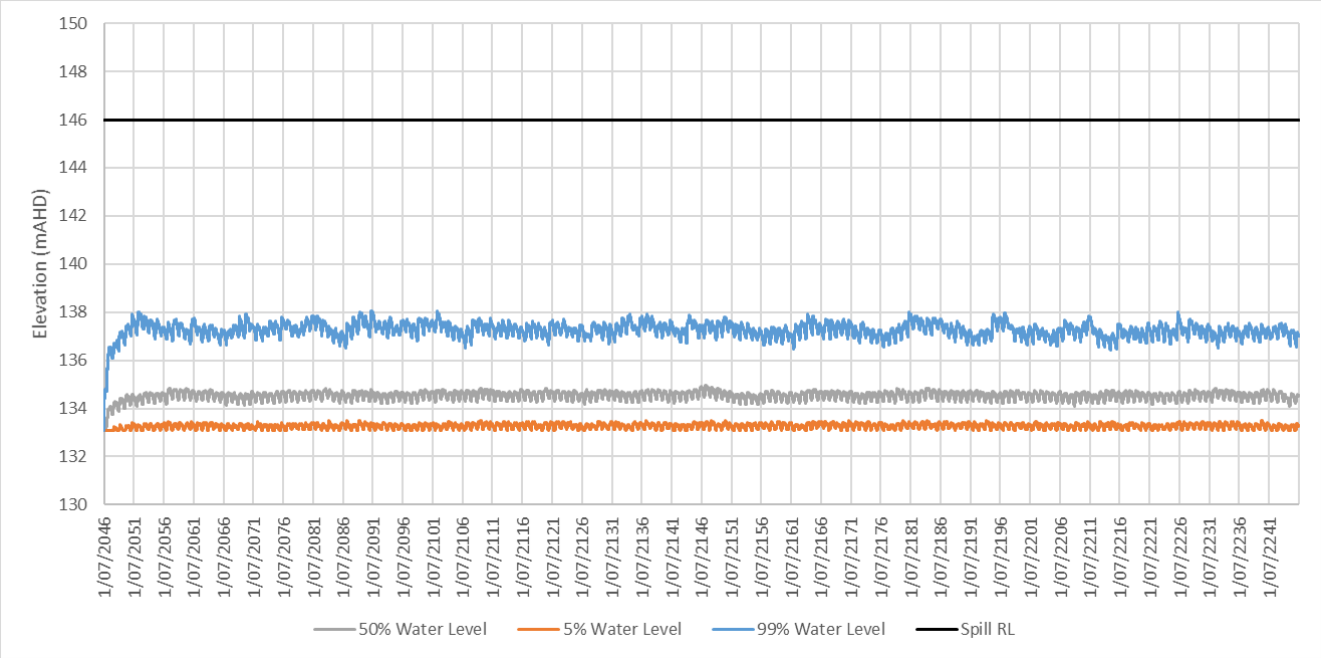


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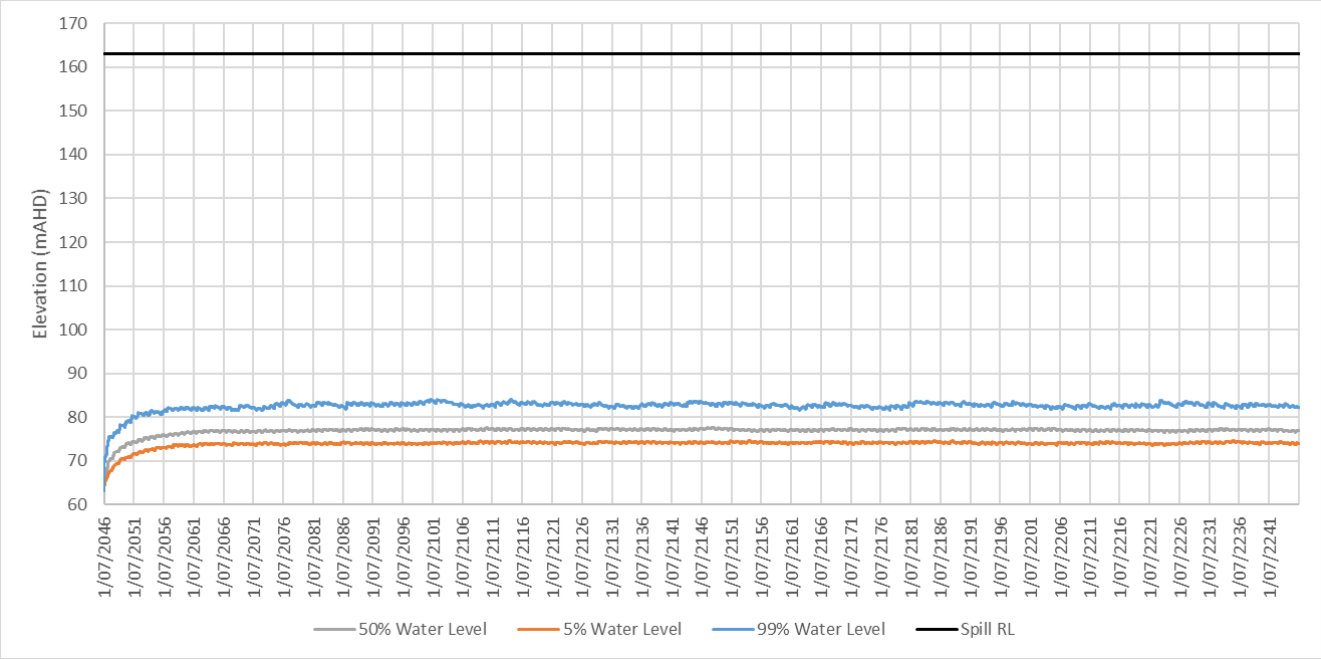


Figure 9B – K Pit Final Water Level

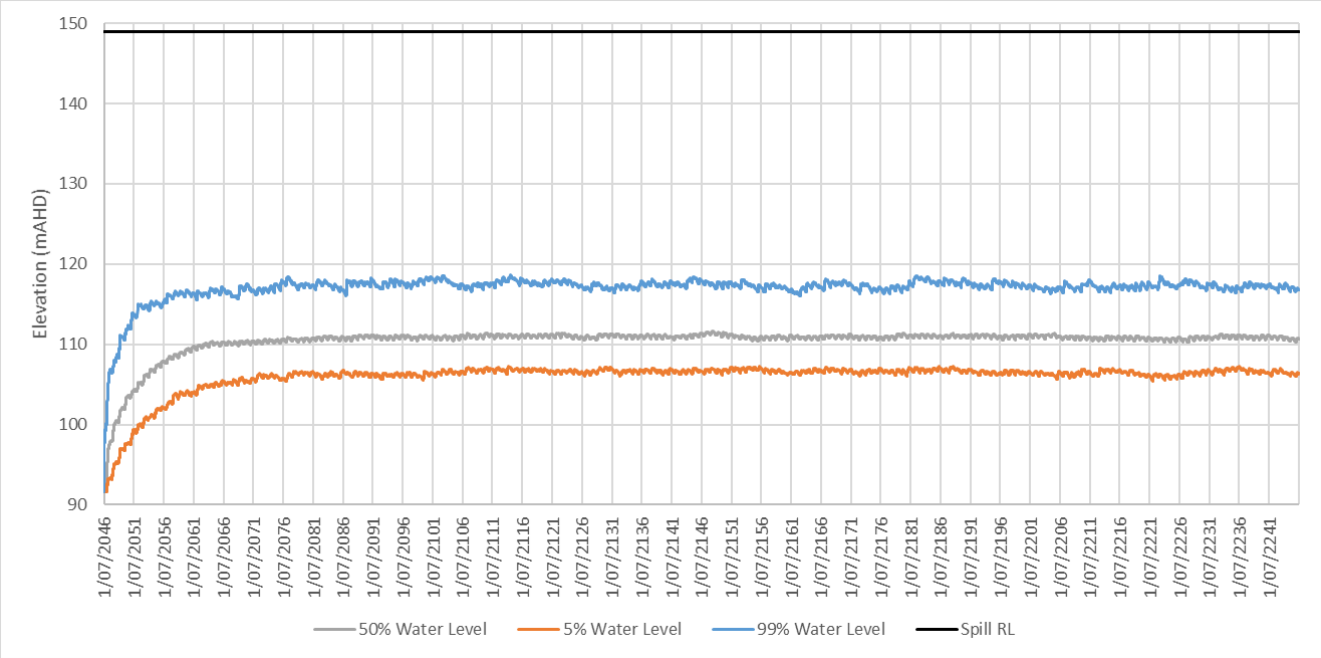


Figure 10B – F Pit Final Water Level

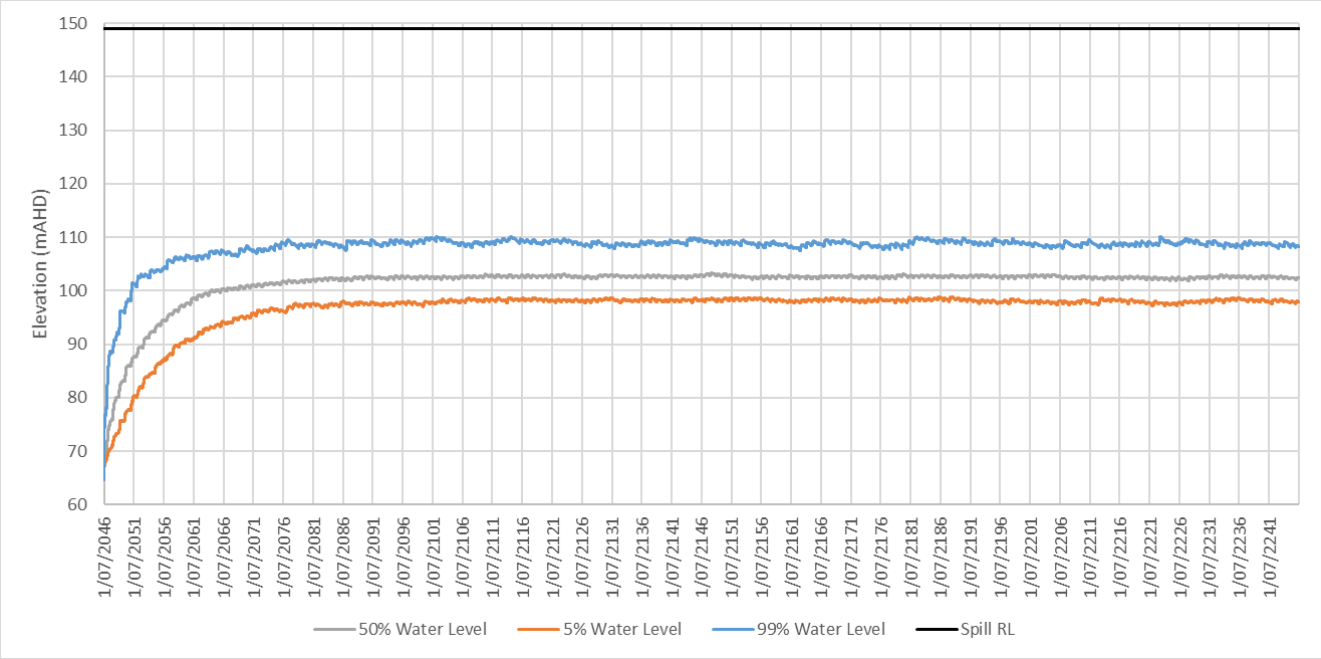


Figure 11B – L Pit Final Water Level

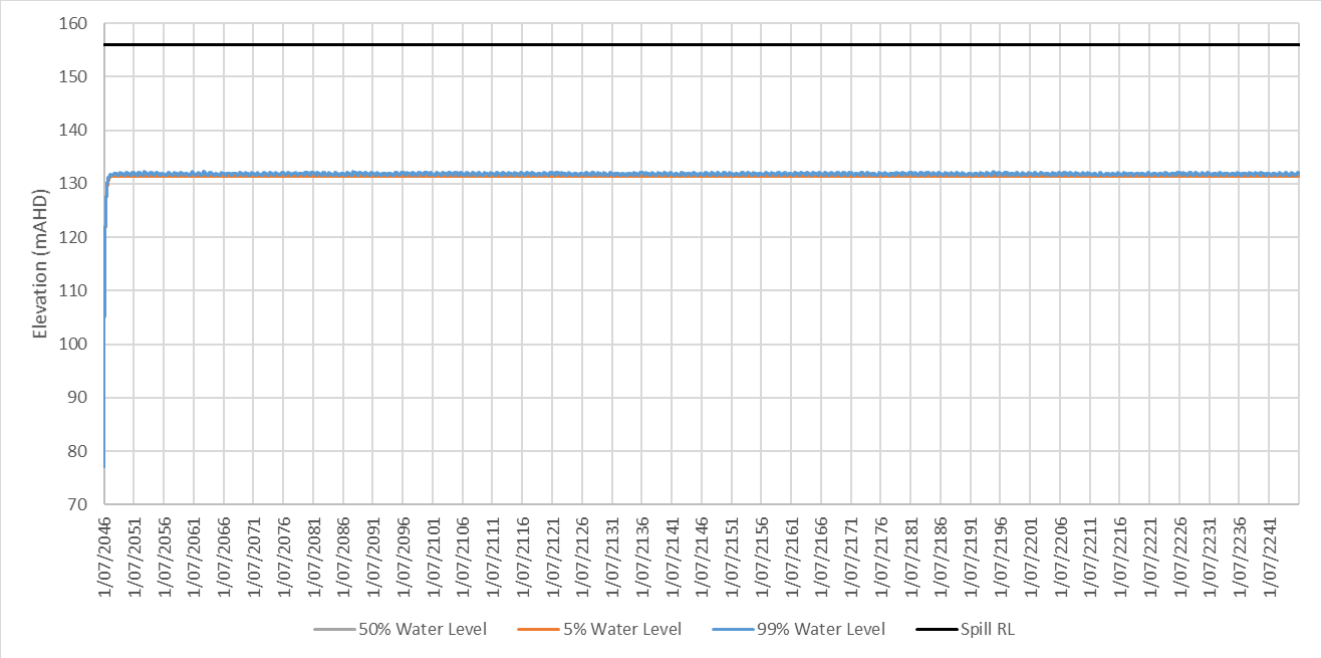


Figure 12B – Ramp 9 Final Water Level

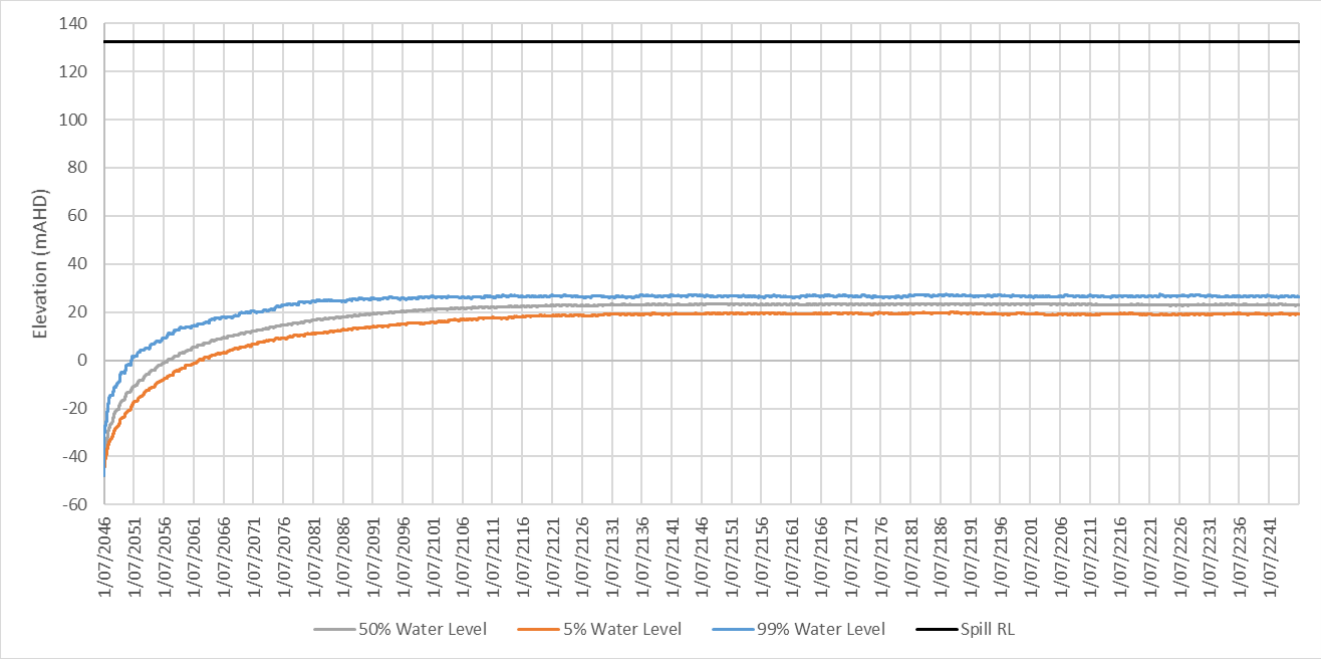


Figure 13B – Curragh North Final Water Level

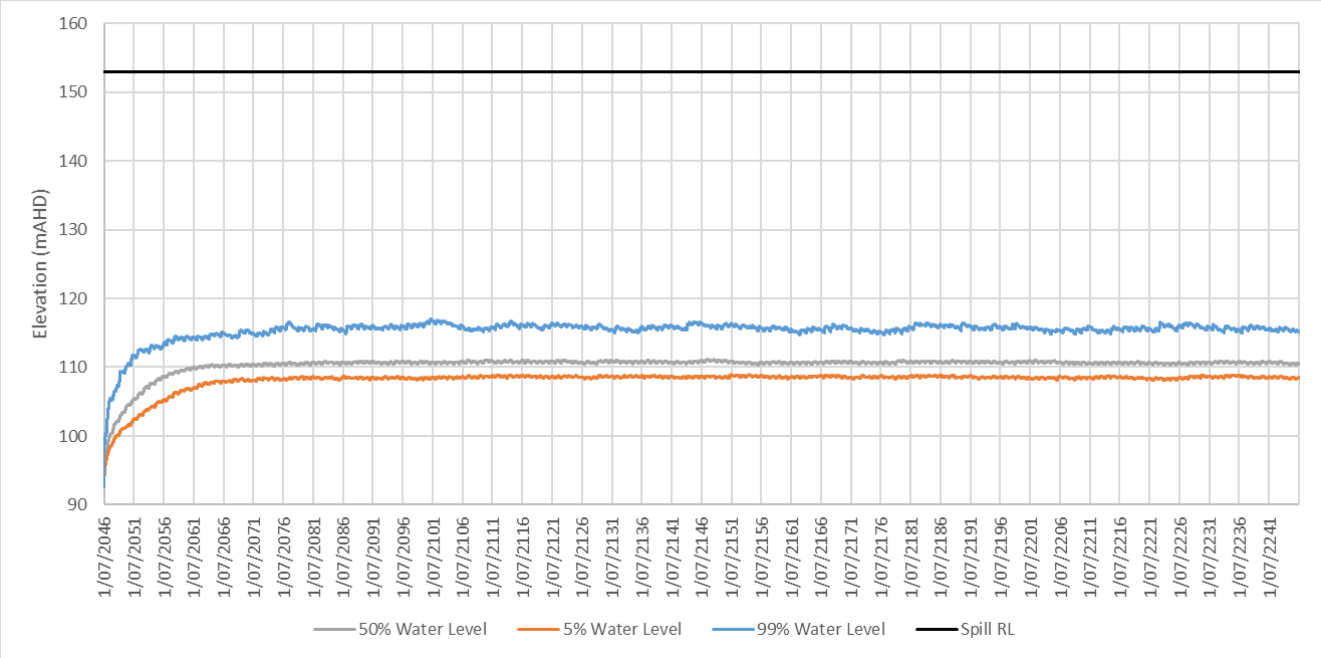


Figure 14B – J Pit Final Water Level

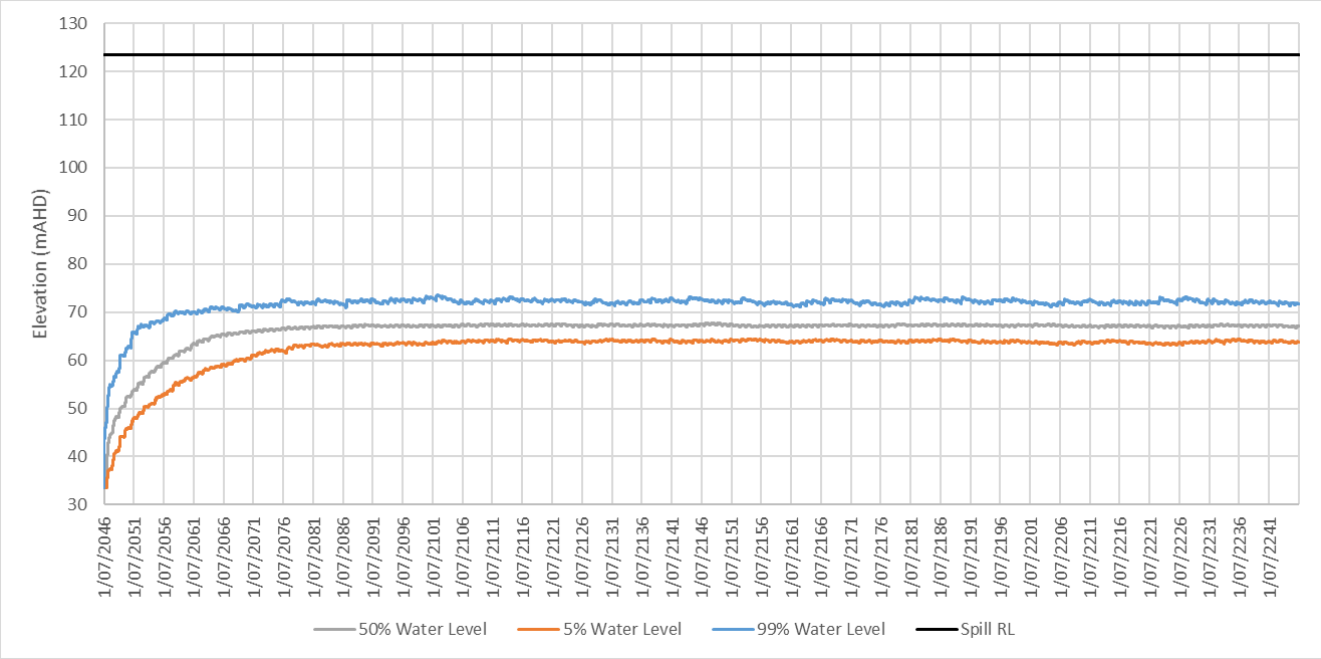


Figure 15B – X Pit East Final Water Level

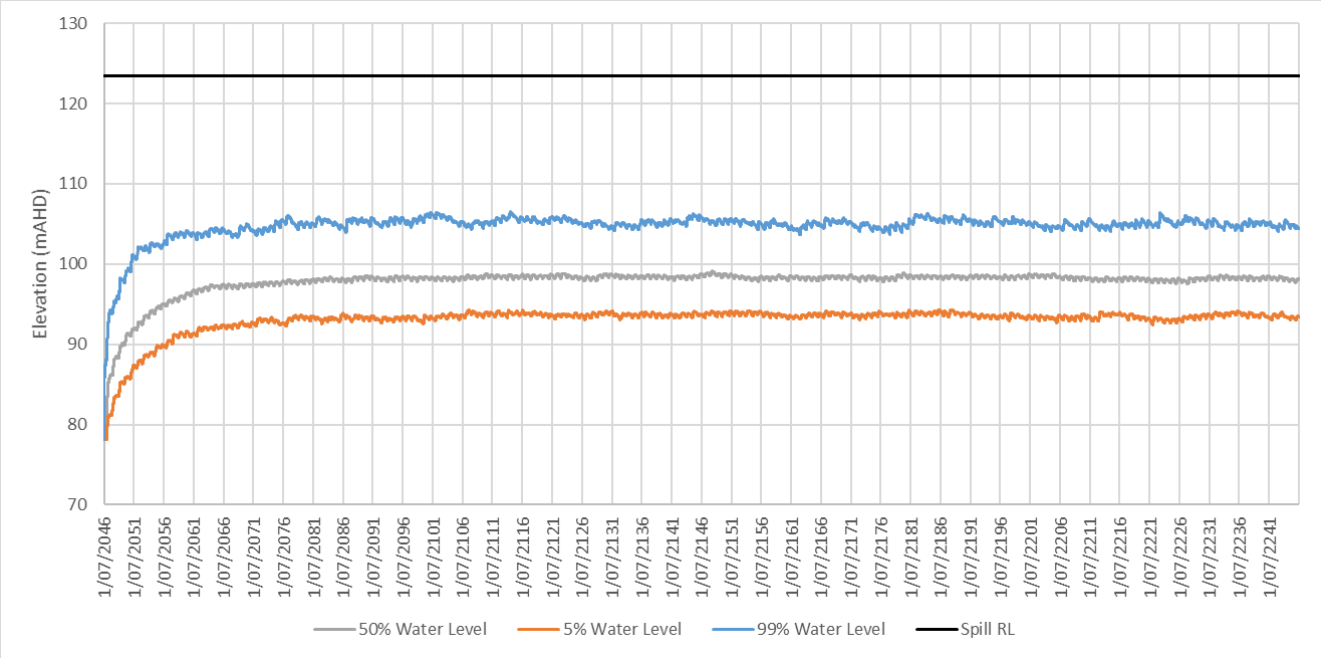


Figure 16B – X Pit West Final Water Level

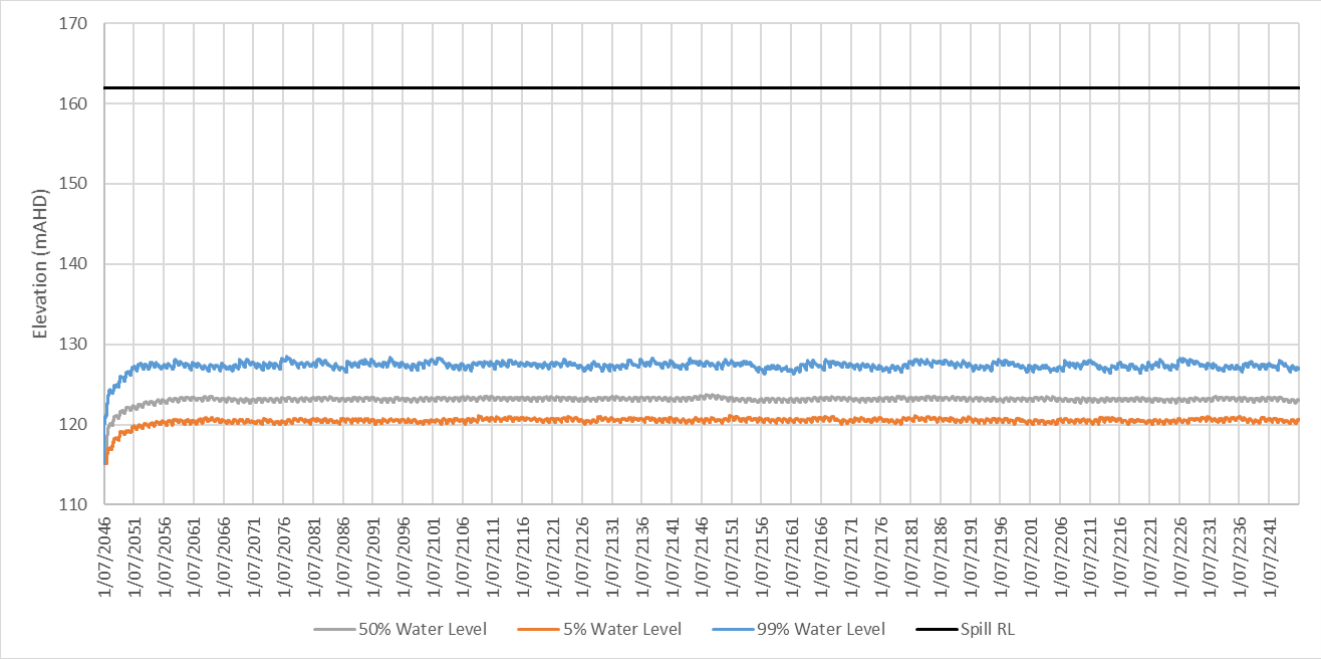


Figure 17B – Y Pit Final Water Level

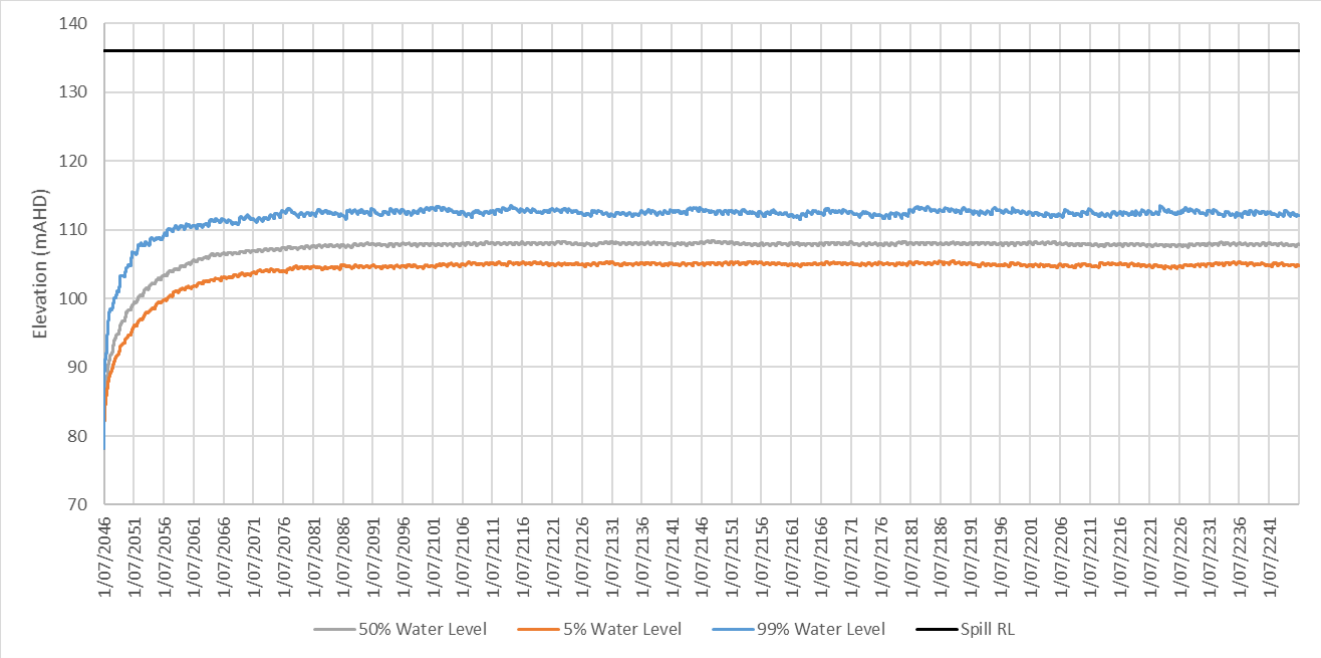


Figure 18B – Z Pit North Final Water Level

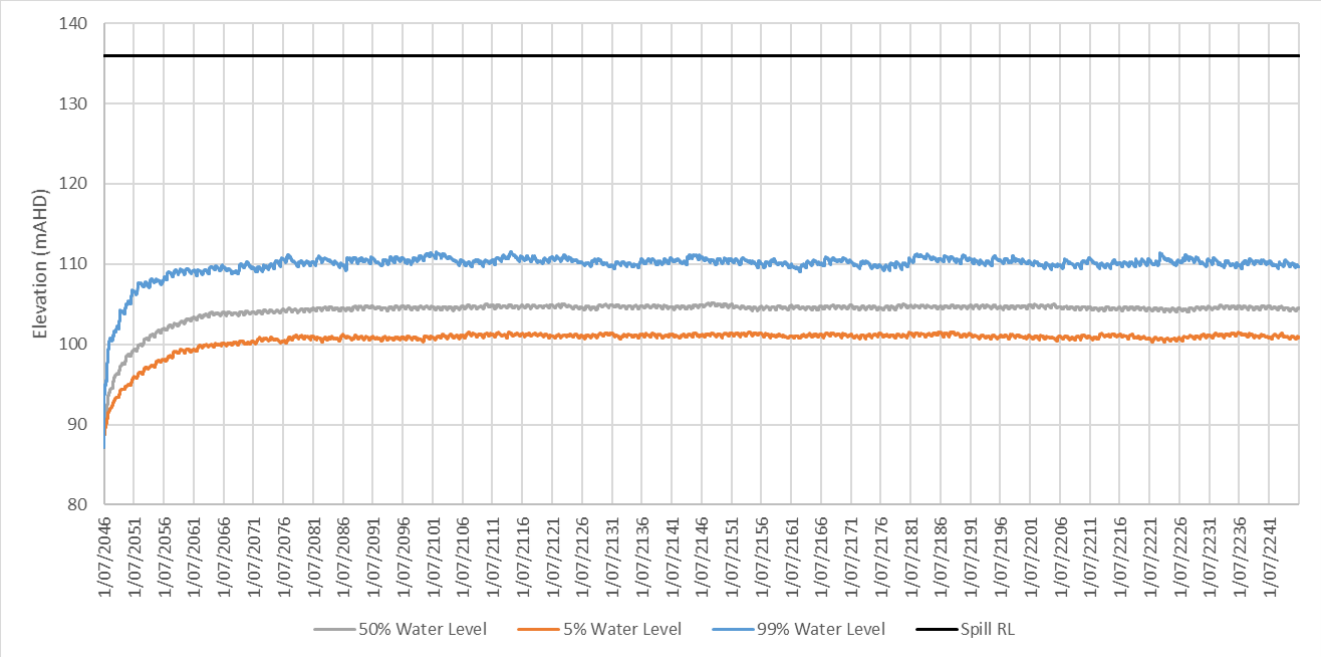


Figure 19B – Z Pit South Final Water Level

APPENDIX C

Residual Void Water Quality

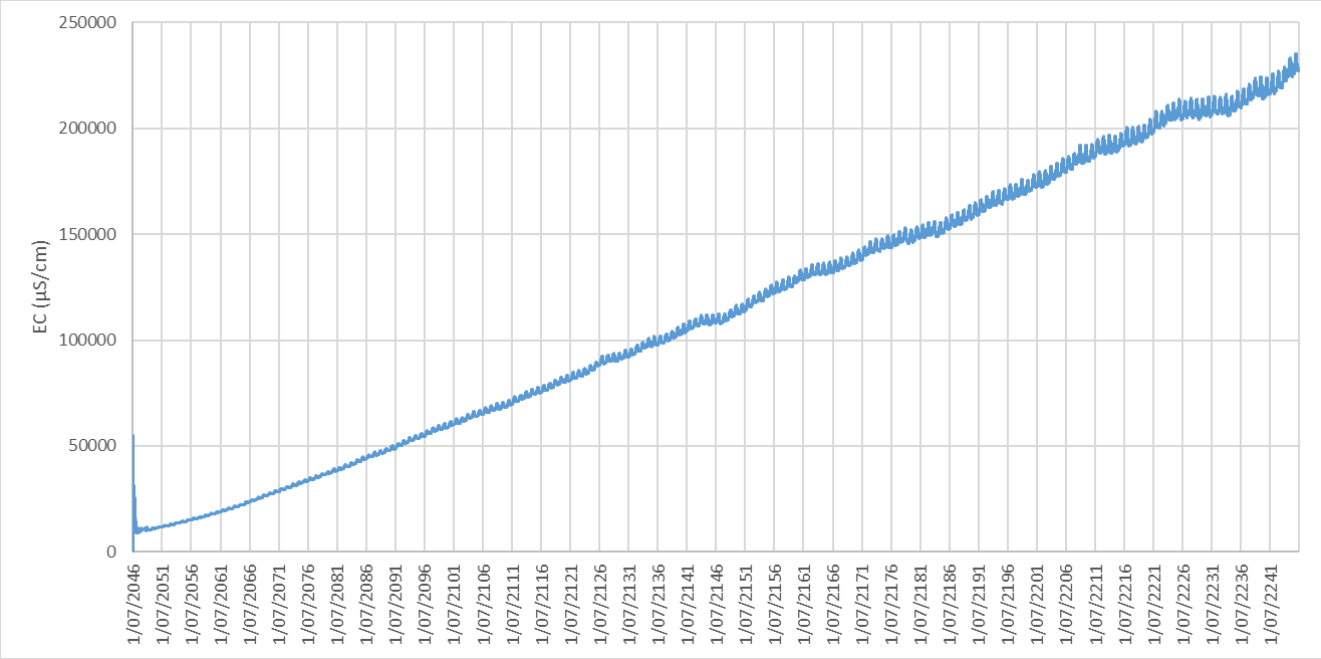


Figure 1C – E, C and H Pit Water Quality

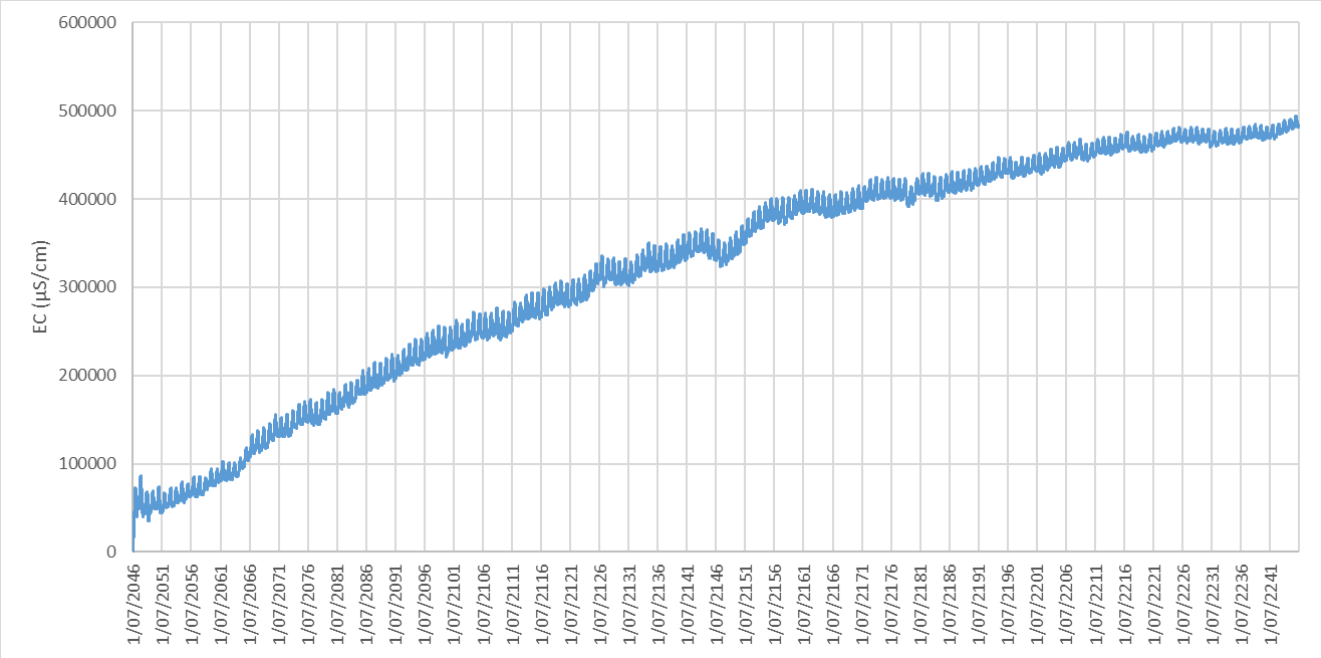


Figure 2C – B Pit Water Quality

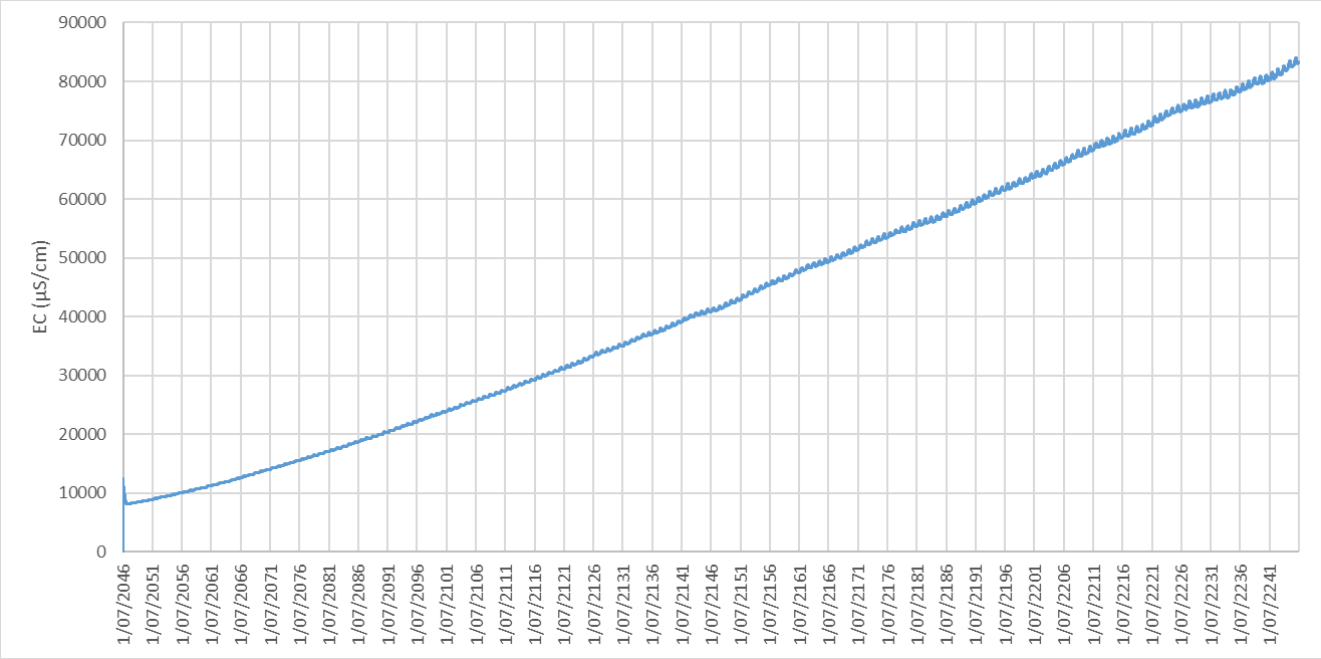


Figure 3C – The Void Water Quality

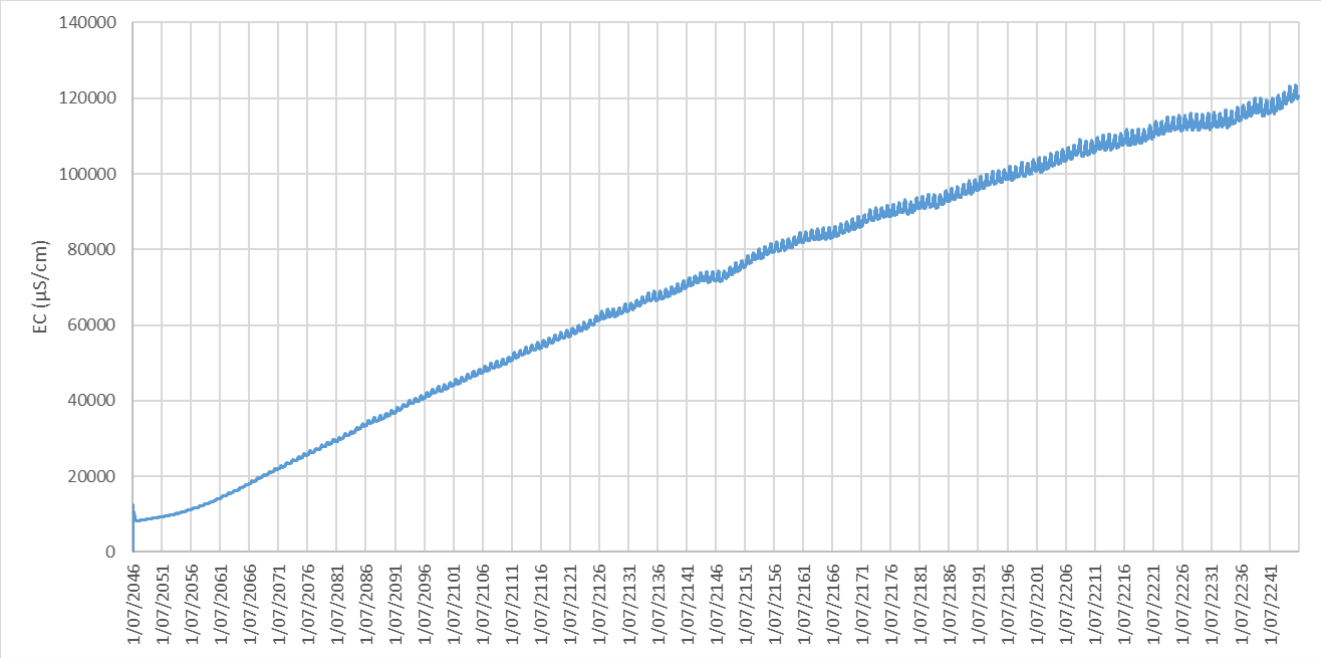


Figure 4C – Main Other Water Quality

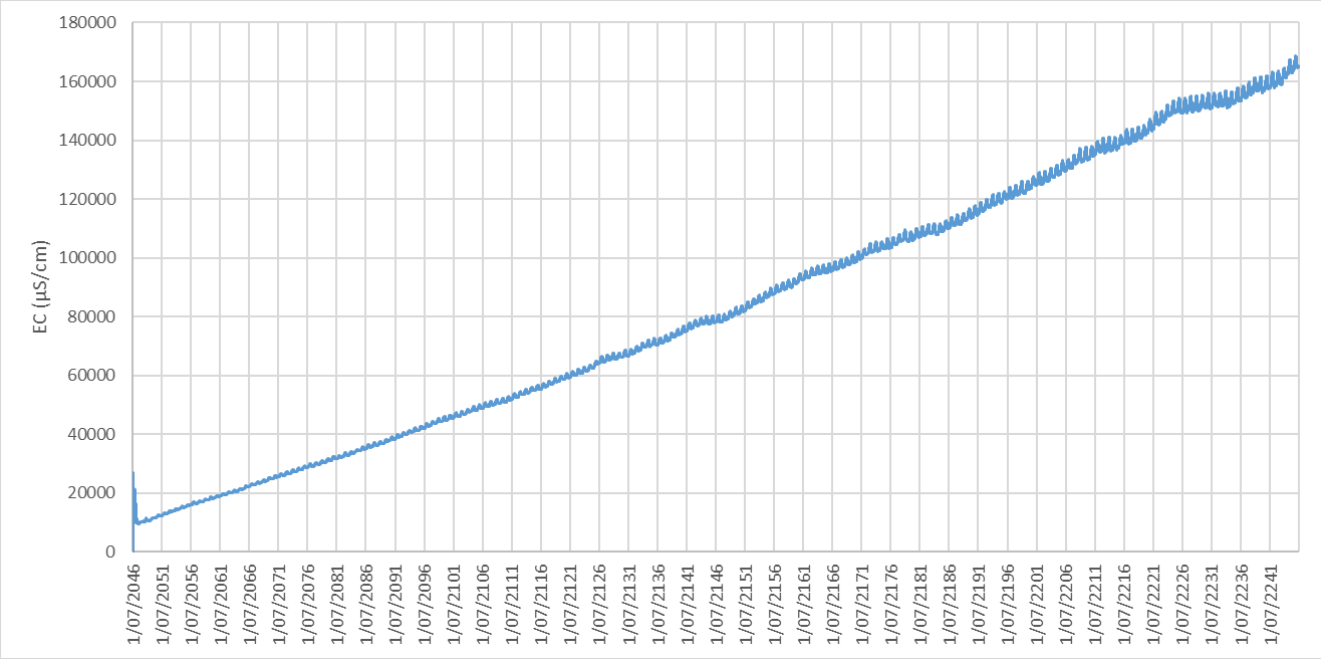


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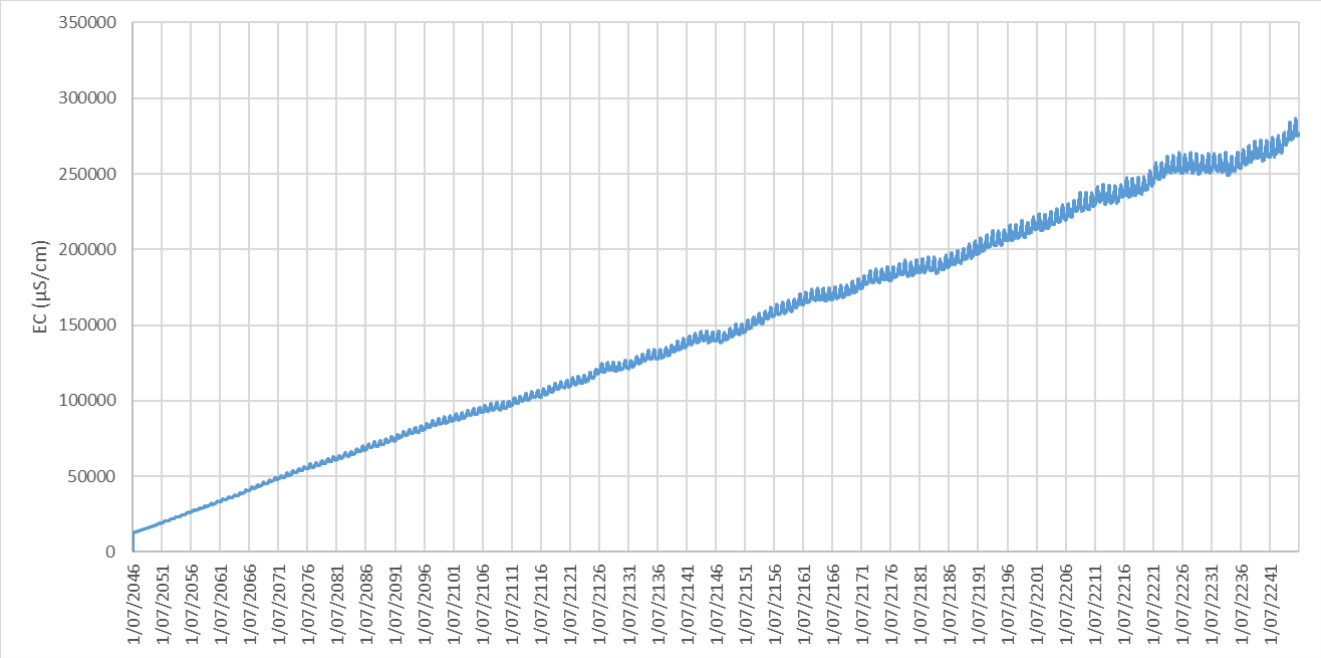


Figure 6C – F Pit North and Pit E North Water Quality

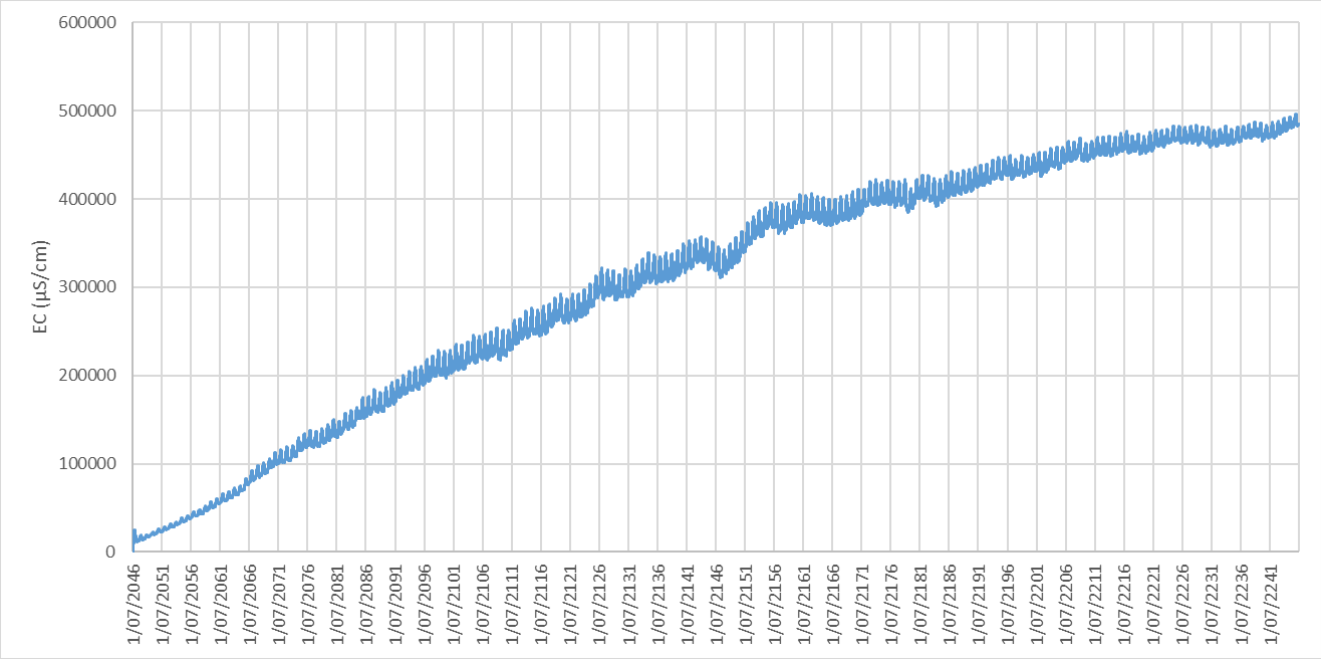


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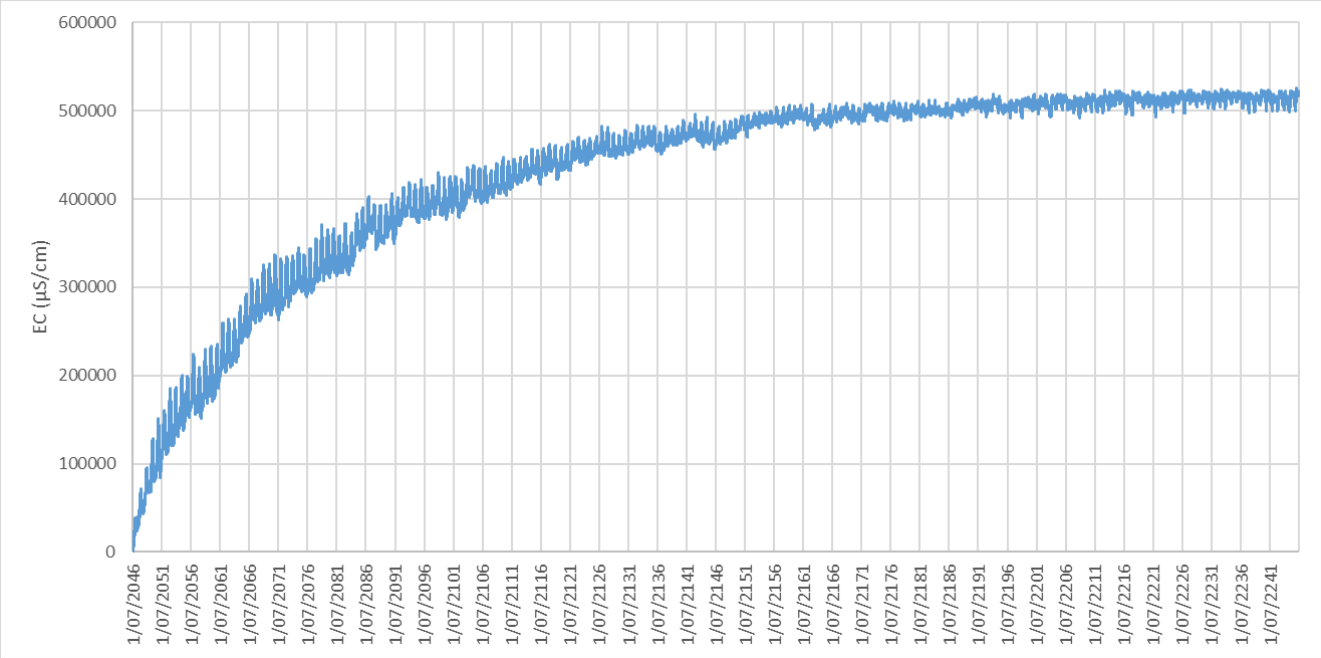


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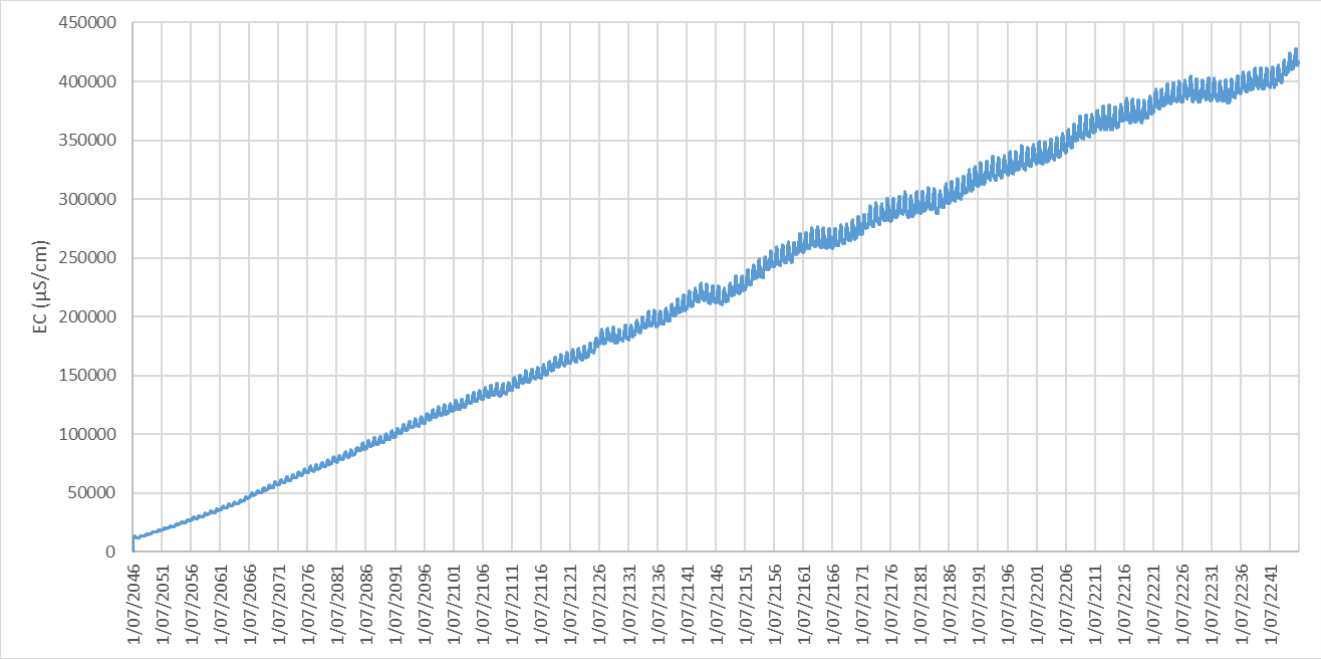


Figure 9C – K Pit Water Quality

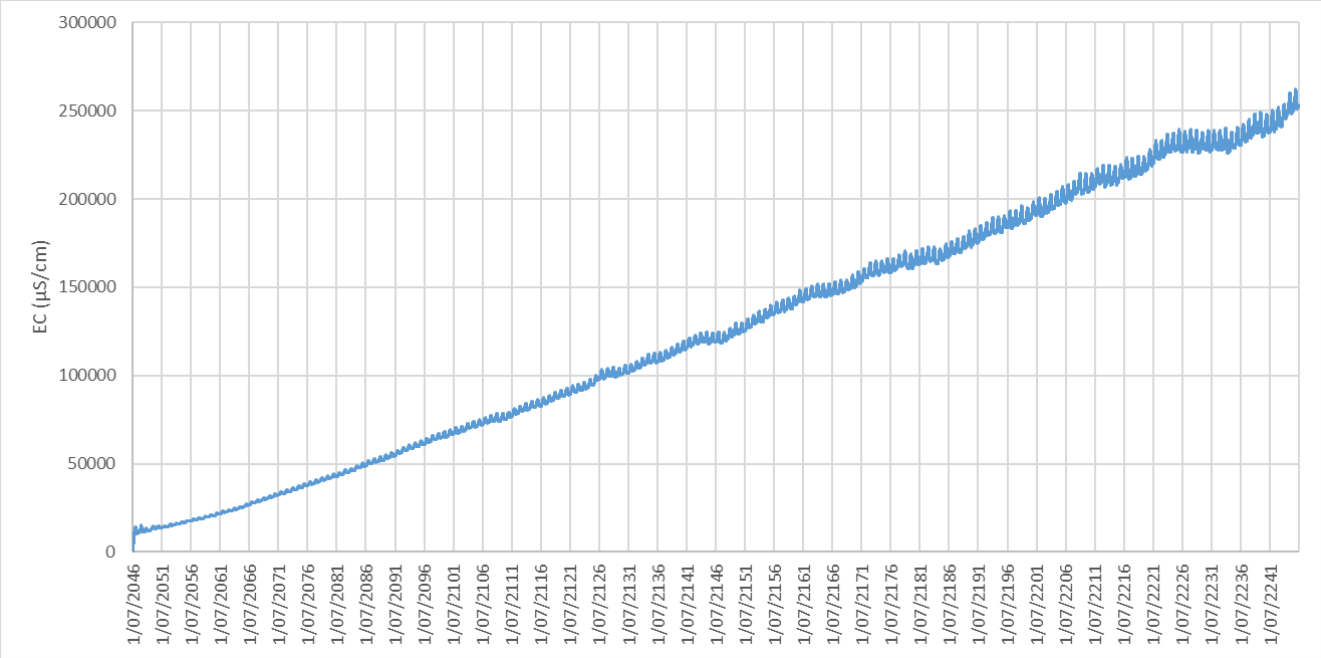


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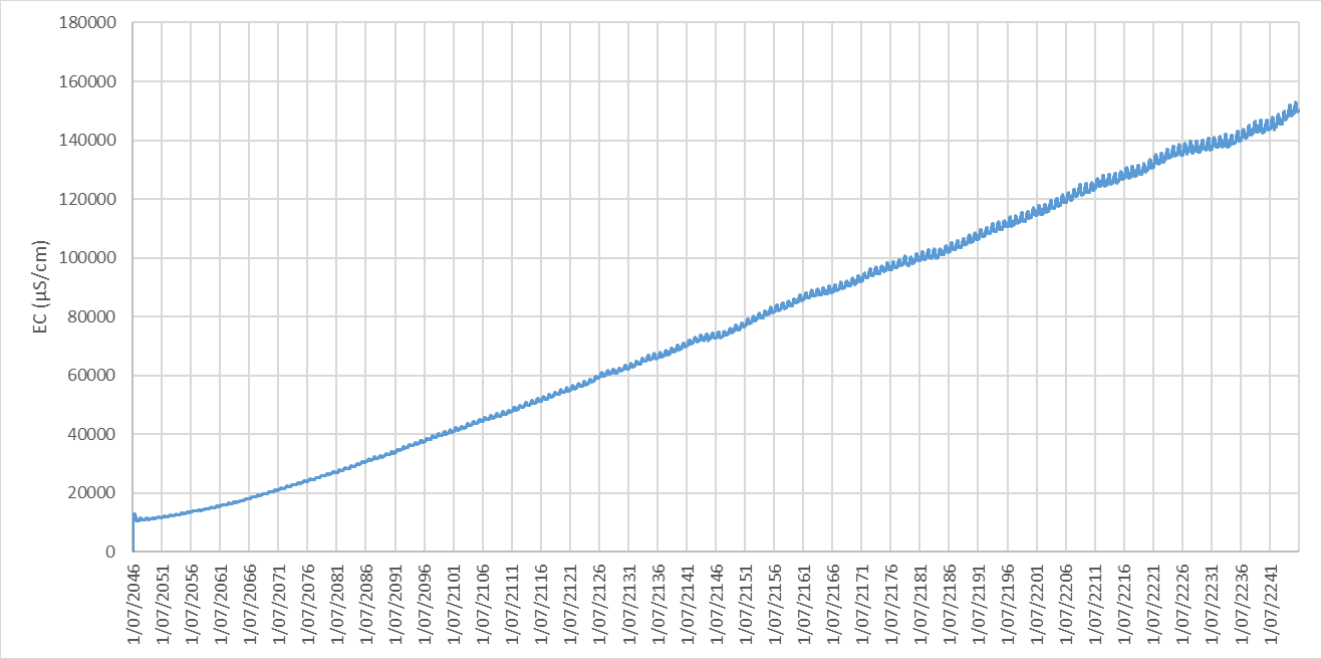


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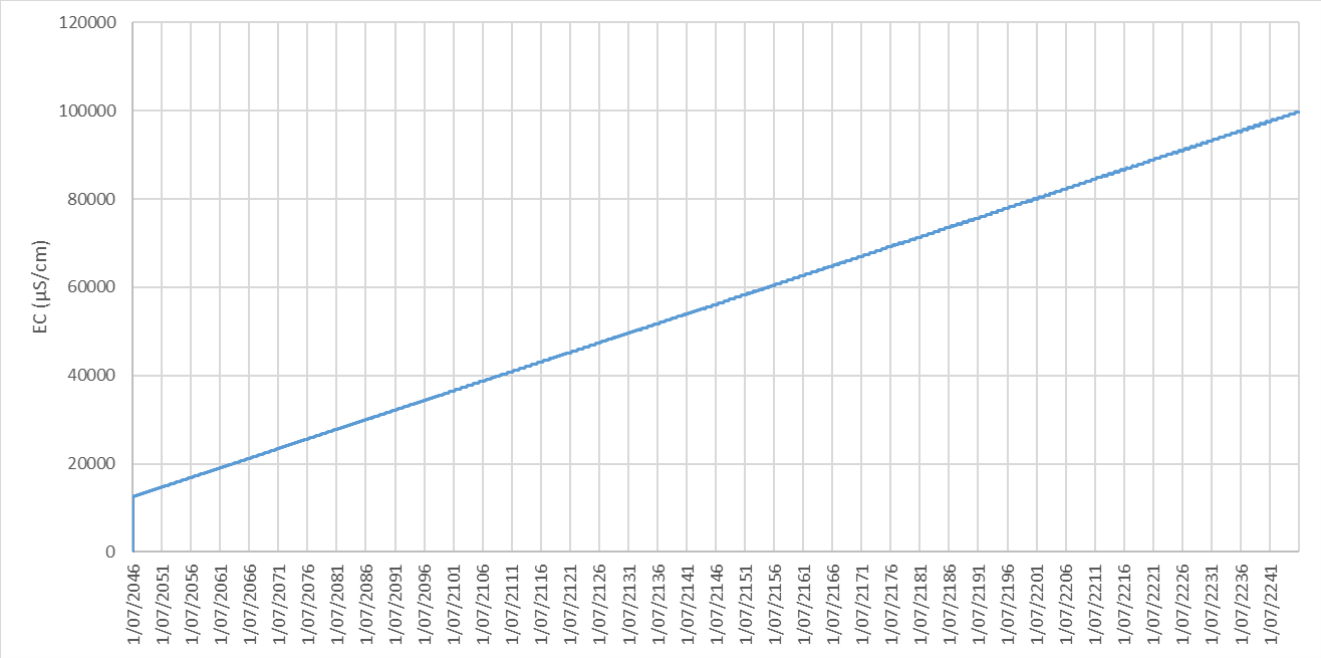


Figure 12C – Ramp 9 Water Quality

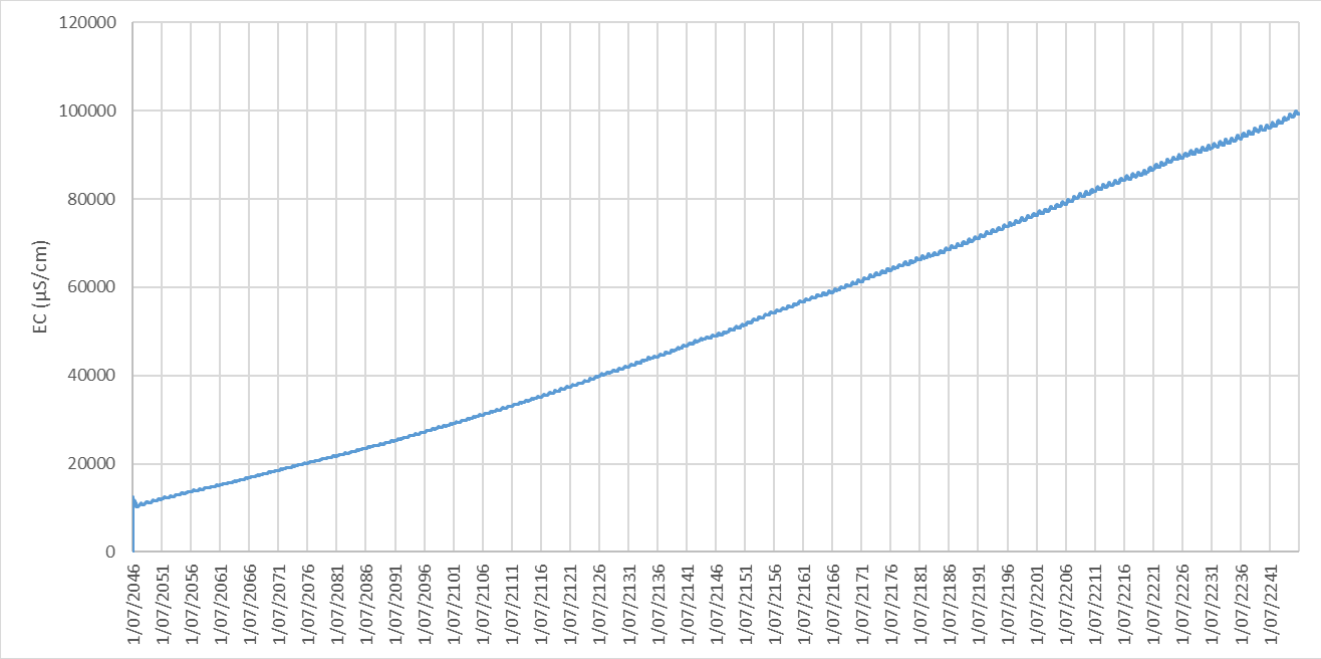


Figure 13C – Curragh North Water Quality

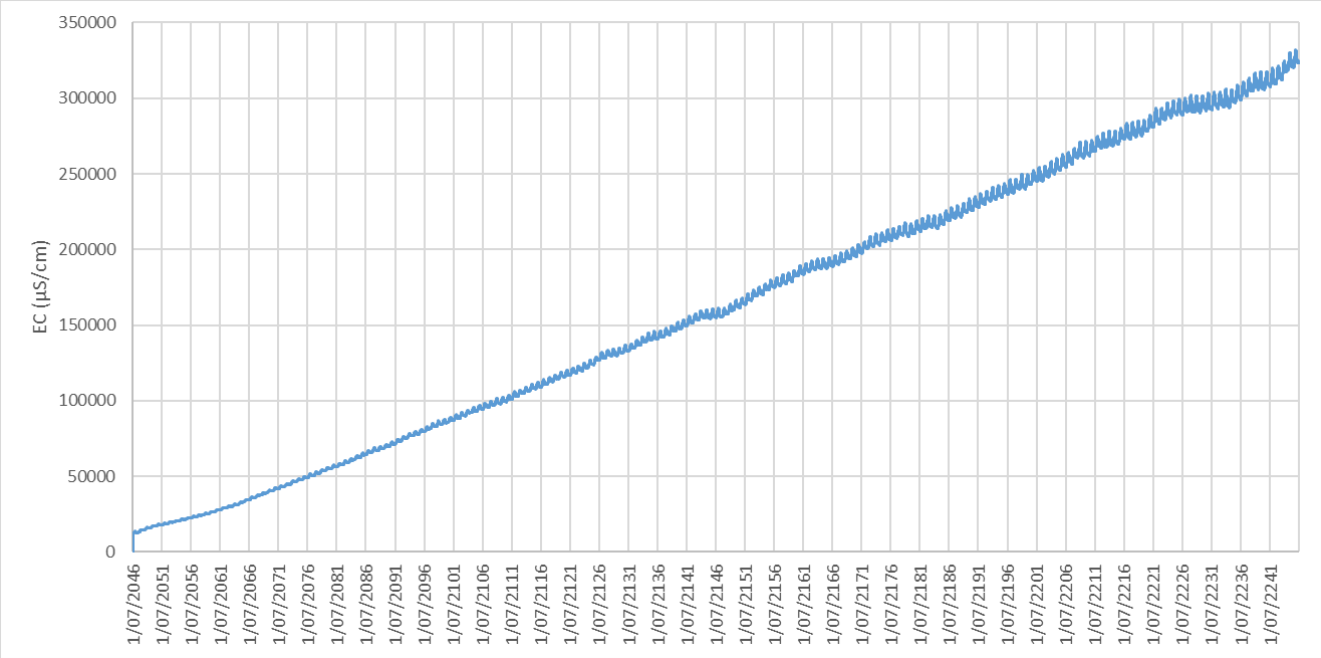


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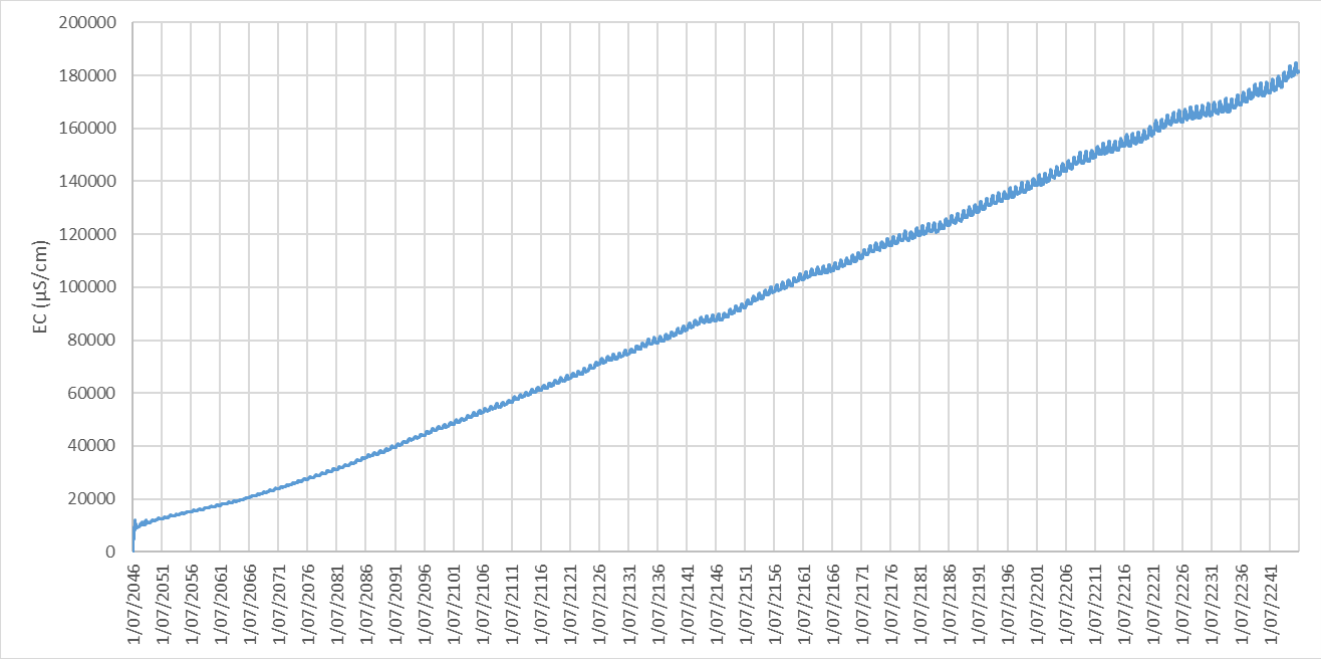


Figure 15C – X Pit East Water Quality

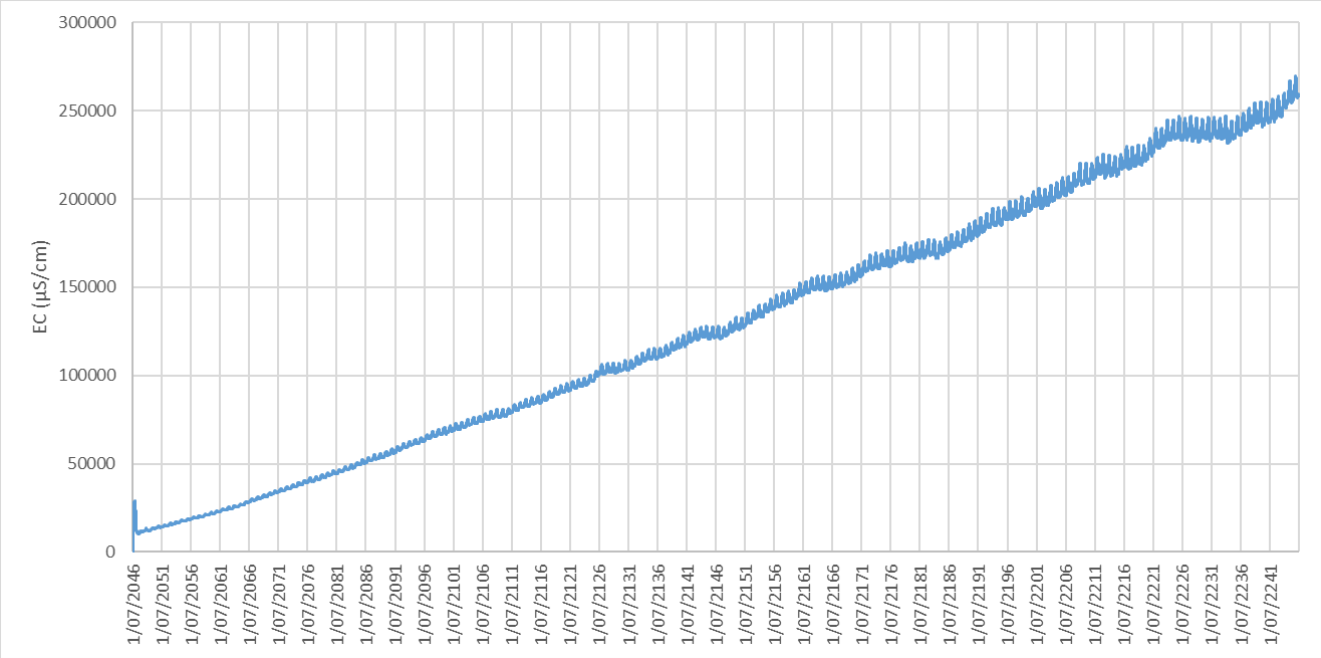


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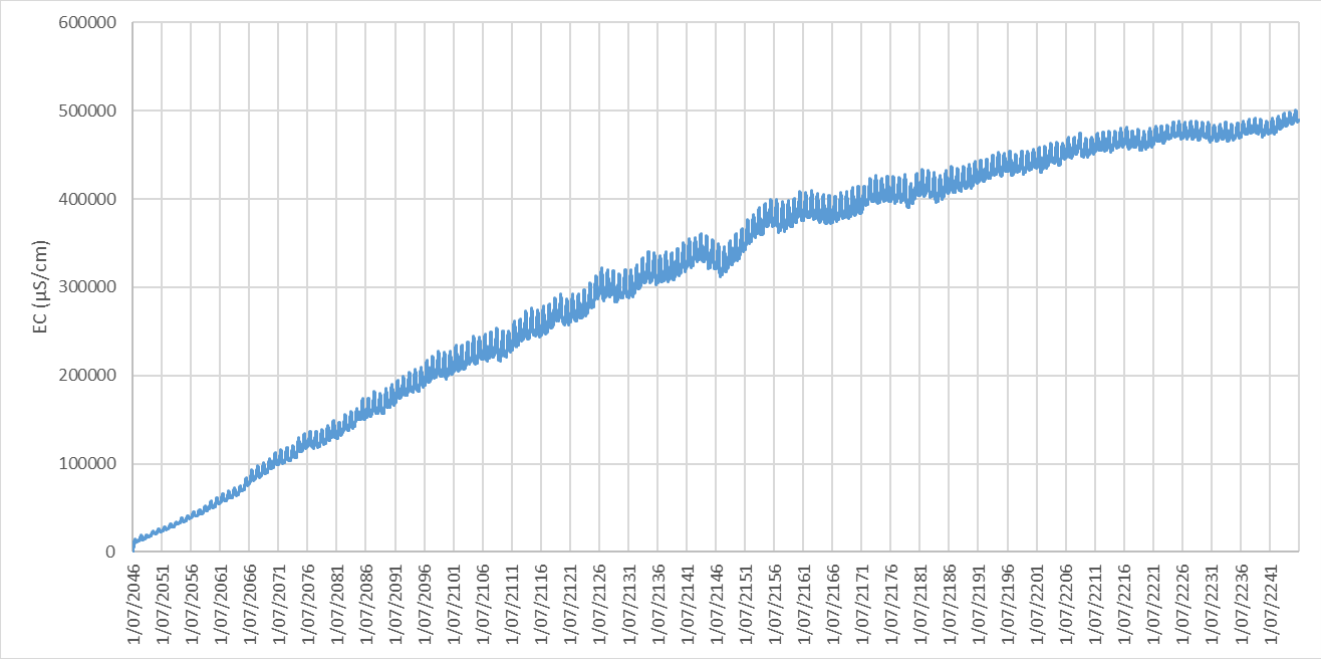


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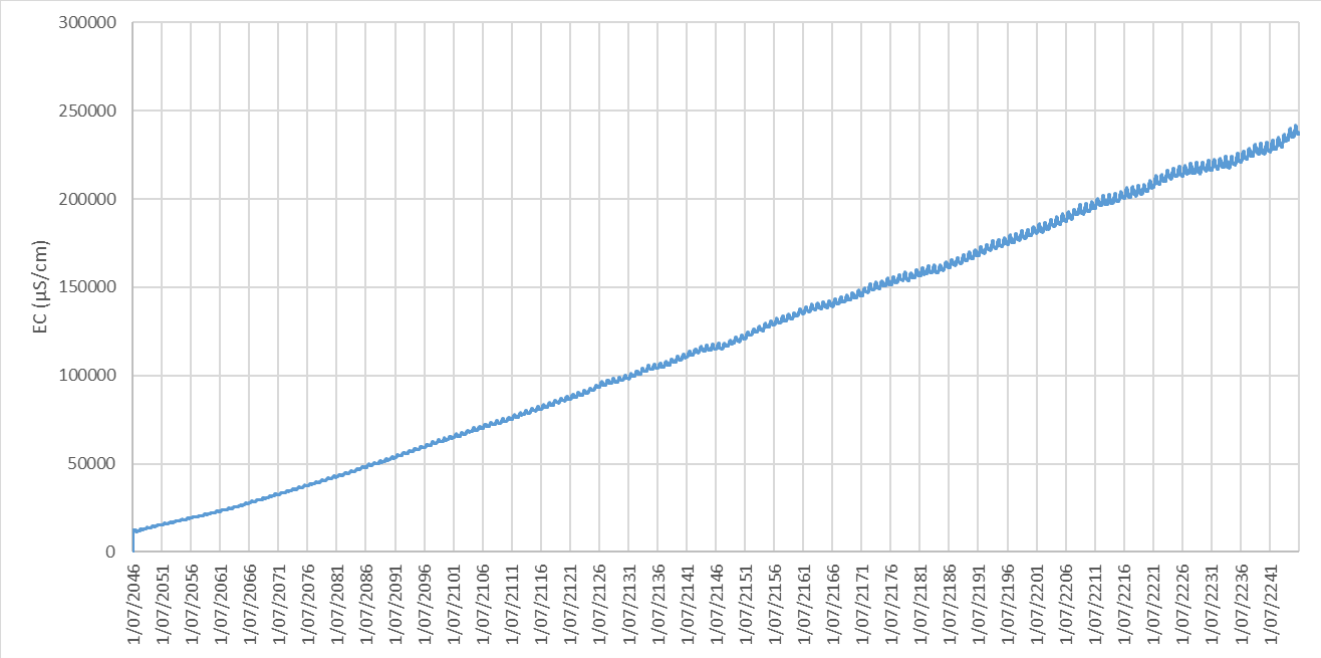


Figure 18C – Z Pit North Water Quality

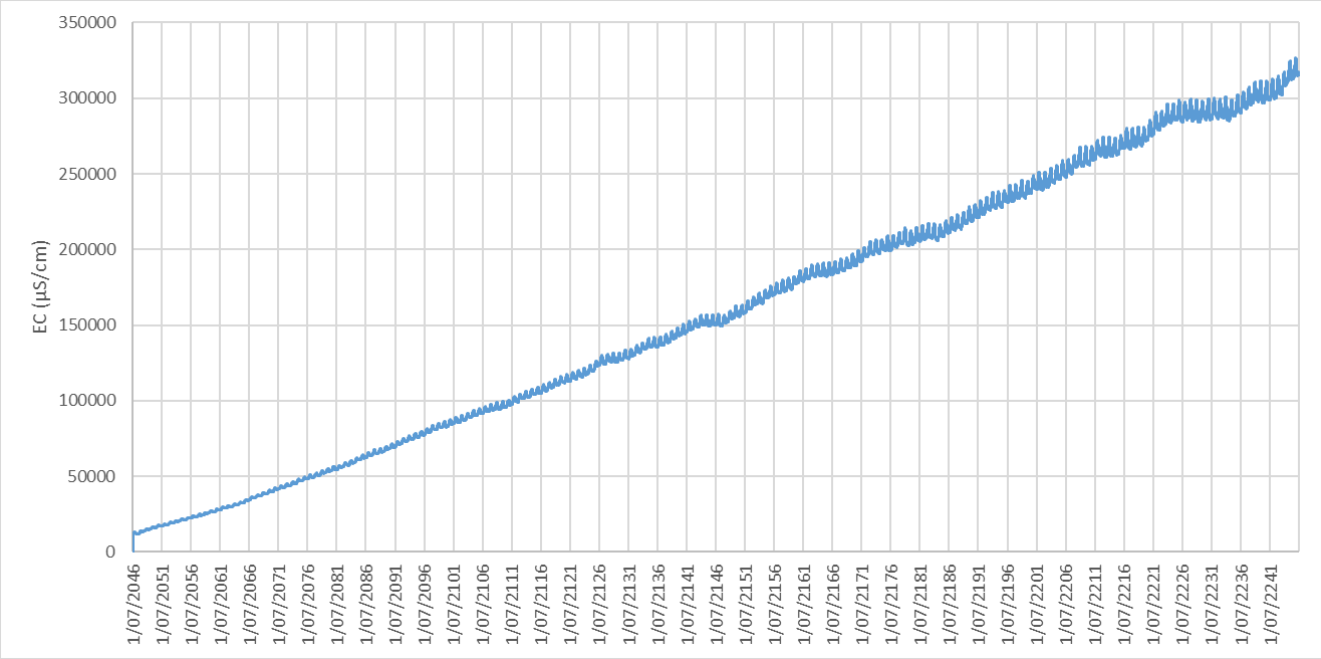


Figure 19C – Z Pit South Water Quality

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APPENDIX L

Geotechnical Investigation and Assessment of Capping

Wesfarmers Curragh

Old Tailings Dam Rehabilitation

Geotechnical Investigation and Assessment for Capping

5 May 2016



PARSONS BRINCKERHOFF

Document information
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1. Introduction

Deposition of tailings in the Curragh Mine Tailings Dam, referred to as Old Tailings Dam, has ceased and regulatory requirements (Condition H11) dictate that rehabilitation commences. Curragh are currently in the planning process of decommissioning Old Tailings Dam such that a stable and relatively maintenance free final landform is achieved to satisfy regulatory requirements.

The Old Tailings Dam has a surface area of around 195ha, approximately 114ha of which has been covered with tailings. For the most part, the Old Tailings Dam does not hold water, however, the southern area of the dam (near the spillway) had approximately 1 m of water (at time of preparation of the scope of works). Any capping strategy is to incorporate dewatering of this area as well as consideration for placing material over these wet tailings.

Tailings are retained by an earth embankment constructed from mine spoil. A mine haul road is located at the downstream toe of the embankment to the east, with an explosive magazine and hard stand located to the north and power lines to the west.

The final landform of the rehabilitated tailings dam is to support self-sustaining vegetation and graded so that all surface waters flows are redirected to the spillway at the south of the dam. Permian spoil from the adjacent mining operations has been proposed to be utilised in the capping layers.

This report presents the results of the site investigation and stability analysis for the initial placement of a capping layer over the tailings and provides comments and recommendations to allow a construction process to be developed while working over tailings. Separate documentation is to be provided which will address the requirements of a self-sustaining vegetation cover.

1.1 Background

Principal characteristics of the Stage 3 embankment are summarised in Table 1. Key dates on the dams operation to provide background and support to the condition of the tailings are below:

- Stage 1 of the tailings dam was designed by Longworth and Mackenzie in 1987/1988 and licenced in 1989
- The decant structure in the northern cell was buried in 1998 (PB inspection report 2005)
- Deposition in the northern cell ceased in 1999 (PPK report 2001)
- Placement of the tailings in the southern cell was from two discharge points
- Seepage through the embankment (PPK report 2001)
- Following an inspection of the tailings dam completed by Golder Associates in October 2013, GHD completed a stability review of the north east corner of the embankment (GHD, 2014). GHD completed a number of stability analyses and recommended that the embankment batter face be trimmed to a slope of 2.5H in 1V or construction of a 6 m wide buttress at the base of the embankment.

Table 1 Dam details

Total length	3350 m
Crest height	RL 176 m RL 177m (top of safety berm)
Crest width	13 m
Maximum height	24 m
Batter slopes	2 horizontal (H) in 1 vertical (V) – upstream = 2.5 H in 1 V - downstream
Spillway crest level	RL 174.6 m

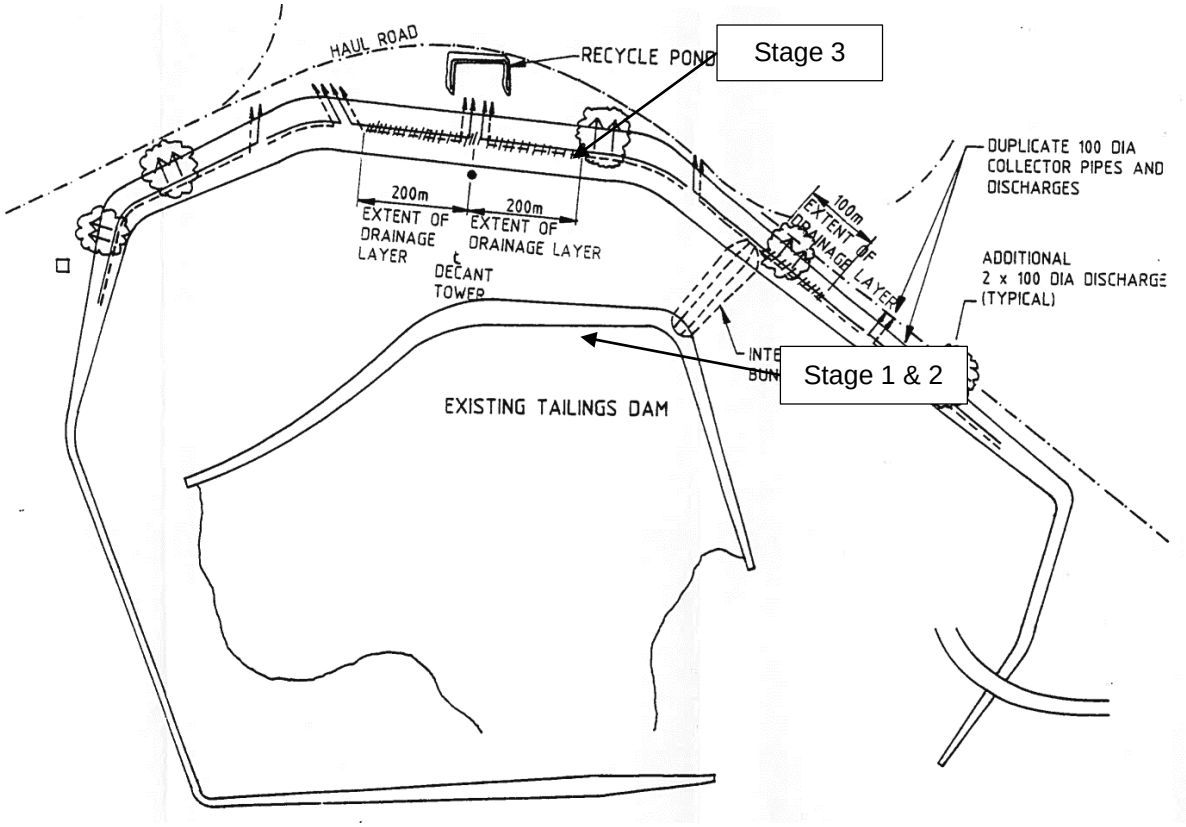


Figure 1-1: Old Tailings Dam layout

2. Method of investigation

The objective of the investigation was to characterise the near surface strength profile of the tailings material to assess whether the tailings surface could support a capping layer. This was achieved through a field investigation comprising in-situ testing, sub-surface sampling and a laboratory testing regime

Fieldwork for the investigation was carried out on the 3rd and 4th of December 2015 and comprised:

- 10 x test pits excavated with a long reach excavator
- 5 x dynamic cone penetrometer (DCP) tests
- 3 x vane shear tests

Test locations were recorded on site using a hand held GPS, which has an accuracy of ± 5 m, and are shown on Figure 1, attached in Appendix B. Pocket penetrometer (PP) tests were also completed on material excavated from the test pits as noted on the logs.

Fieldwork was carried out by a senior engineering geologist from Parson Brinckerhoff who was responsible for recording subsurface conditions encountered, preparing engineering logs and nominating sampling and testing locations. Test pit logs and explanatory notes that describe the terms and symbols used are included in Appendix C.

Disturbed samples of the tailings were collected from the test pits which were sent to a NATA accredited laboratory for the following testing:

- Moisture content
- Atterberg limits
- Particles size distribution with hydrometer.

3. Results of investigation

3.1 Site description

At the time of the investigation and site inspection, the surface of the Old Tailings Dam was in a relatively dry state. The tailings surface was concave, indicating either settlement of the tailings or beaching as a result of the deposition. Alligator cracking (which occurs as the tailings shrinks) was not readily evident on the surface, however previous inspections of the tailings has noted cracking (PPK E&I, 2001). Some grass and trees have established in the tailings deposit.



Figure 3-1: Tailings surface from northern cell

3.2 Subsurface conditions

Based on the results of the site investigation, the tailings appears to be in a relatively dry state. Previous annual inspections noted that there was seepage (readily) observed through the Stage 3 embankment which is likely to have helped promote drainage and consolidation of the tailings. The moisture content profile of the tailings measured from the samples collected during the investigation, is shown in Figure 3.1. Moisture contents are generally less than the liquid limits.

The undrained shear strength was directly (vane shear) and indirectly (DCP and PP) measured in situ, as shown in Figure 3.2. Results from the vane shear test show that the undrained shear strength is generally

greater 30 kPa. Remoulded undrained shear strengths are generally above 20 kPa (with the exception of one point in SH3). DCP blow counts are generally between 1 and 3 to depths of 1.5 m, followed by a gradual increase. PP results (excluding TP08 and TP07, either side of the ponded water) suggest values greater than 100 kPa to a depth around 1.5 m.

The observations from the test pit investigation also indicate that the vertical faces of the excavation remained stable to the depths investigated (max 5.0m).

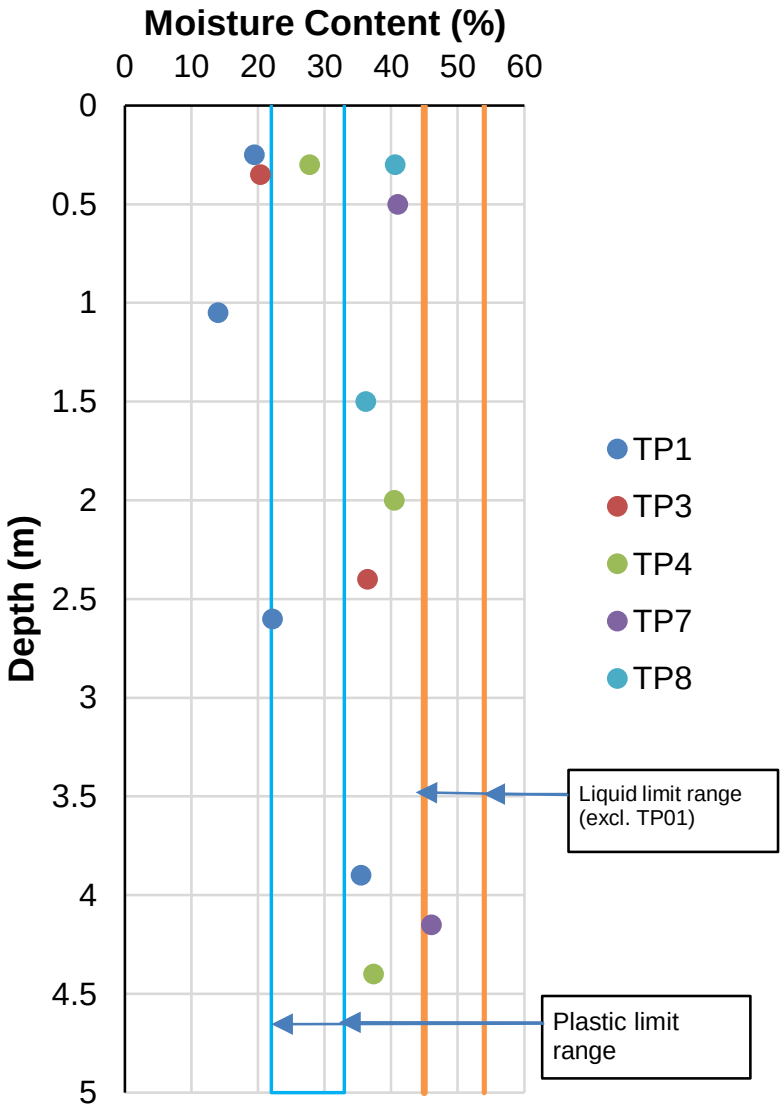


Figure 3-2: Moisture content profile with depth

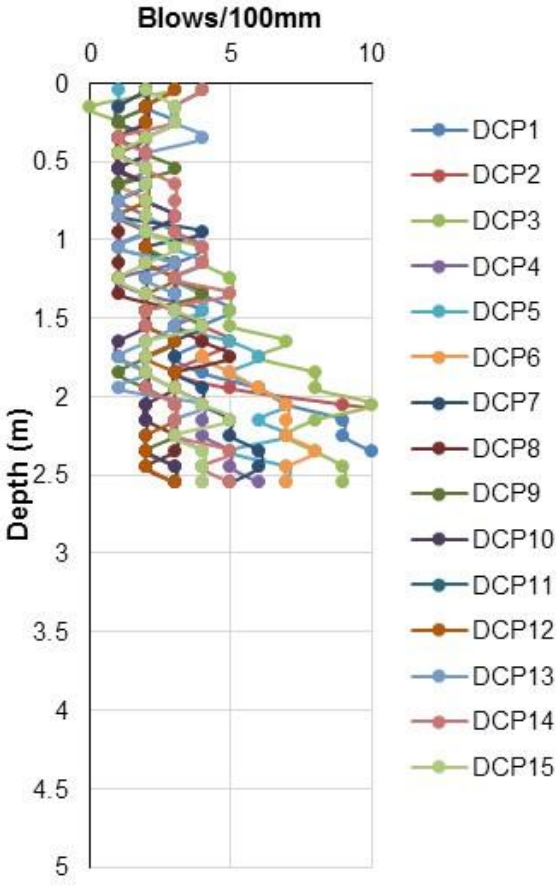


Figure 3-3: In situ testing results- Dynamic Cone Penetrometer Results

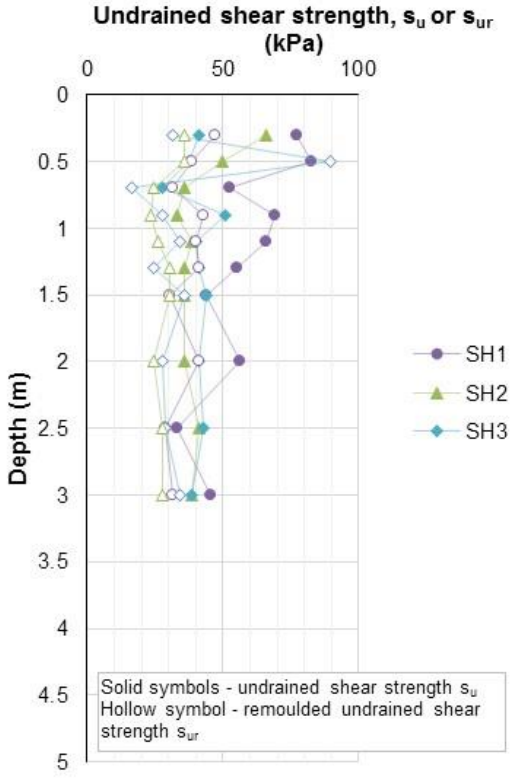


Figure 3-4: In situ testing results - Undrained shear strength

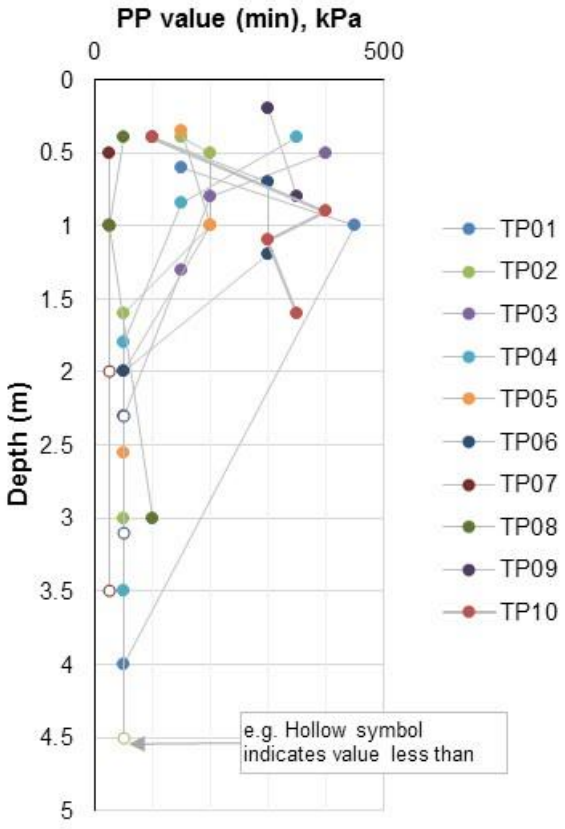


Figure 3-5: In situ testing results - Pocket Penetrometer results

3.3 Laboratory results

Laboratory test certificates are included in Appendix D and summarised below in Table 3-1.

Laboratory results indicate that the tailings is of medium to high plasticity and is predominantly silt sized. Moisture contents generally increase with depth.

Table 3-1 Atterberg limits, moisture content and particle size distribution test results

Location	Depth (m)	Moisture content (%)	LL[(1)] (%)	PL[(2)] (%)	PI[(3)] (%)	LS[(4)] (%)	Sand (%)	Silt (%)	Clay (%)
TP01	0.10-0.40	19.5	-	-	-	-	-	-	-
TP01	1.00-1.10	14.0	35	22	13	3.5	42	46	12
TP01	2.50-2.70	22.2	-	-	-	-	-	-	-
TP01	3.80-4.00	35.5	-	-	-	-	-	-	-
TP03	0.20-0.50	20.4	-	-	-	-	-	-	-
TP03	2.30-2.50	36.5	45	29	16	5.0	15	62	23
TP04	0.20-0.40	27.8	-	-	-	-	-	-	-
TP04	1.90-2.10	40.5	47	31	16	5.0	7	72	21
TP07	0.40-0.60	41.0	54	33	21	6.0	1	66	33
TP07	4.00-4.30	46.1	-	-	-	-	-	-	-
TP08	0.20-0.40	40.6	53	33	20	5.5	6	69	25
TP08	1.40-1.60	36.2	-	-	-	-	-	-	-

(1) Liquid limit
(2) Plastic limit
(3) Plasticity index
(4) Linear shrinkage

4. Capping design

4.1 Capping and rehabilitation criteria

A number of performance criteria were initially set out in the design brief which are summarised below:

1. Produce a “stable” final landform. From a geotechnical perspective this suggests that the final landform should maintain a suitable factor of safety (generally > 1.5 for long term) against bearing capacity failure for normal land use practices. A stable landform is also taken to include the stability of the capping during construction.
2. Develop a final landform that is free draining to the spillway at the south of the dam. This serviceability requirement will necessitate consideration of the settlement of the tailings as a result of the placement of the capping layers.
3. Provide a finished surface with self-sustaining vegetation cover that requires minimum (if any) maintenance in the long term.

Based on the current conditions of the tailings, it is considered that controlled capping of Old Tailings Dam is feasible.

4.2 Capping design approaches

The conventional approach for capping coal tailings dams is to allow sufficient time following the cessation of tailings placement for desiccation (drying) of near surface tailings to form a crust of sufficient strength and depth to support the placement of the first layer of capping fill. The desiccation can be assisted by promoting surface drainage during and following last tailings deposition. The desiccation process can typically take 3 to 8 years to achieve the required strength profile.

As the Old Tailings Dam is currently no longer in use, it is possible that development of the crust is well underway. The scope of works proposed by Parsons Brinckerhoff is based on this assumption.

4.3 Methodology

To assess the global stability and bearing capacity of tailings under the proposed capping, the computer programme GEOSTUDIO Slope/W was used. Slope/W is based on limit equilibrium analysis for assessing the stability of earth structures using the Morgenstern-Price method.

A number of stability models were run to assess what mine spoil layer lift thickness could be recommended; i.e. the maximum layer thickness that could be placed without triggering an unacceptable factor of safety against failure. The Slope/W analysis output data is presented in Appendix E.

4.4 Geotechnical model

Based on the results of the investigation, the material properties shown in Table 4.1 have been adopted in analysis of the capping thickness.

Table 4.1 Material properties adopted for the analysis

Material	Unit weight (kN/m^3)	Undrained shear strength (kPa)	Effective cohesion, c' (kPa)	Effective friction angle, ϕ' (°)
Capping	17	-	1	30
Tailings	15	30	-	-

4.5 Failure mechanisms

The failure mechanisms which are modelled to assess the capping thickness comprise:

1. Punching shear failure due to the load of the construction equipment and the capping
2. Bearing capacity failure at the leading edge of the capping cover due to capping thickness
3. Squeezing failure where tailings are forced into a 'bow wave' due to the weight of the advancing capping

The failure mechanisms and the corresponding factors of safety (FoS) considered for each model are summarised in Table 4-2.

Table 4-2 Failure mechanisms

Failure mechanism	Adopted FoS	Reference
Punching shear failure to assess the minimum thickness of capping material required over very soft tailings to support a dozer	2.0	Bowles, 1996
Bearing capacity/stability failure to assess the stability of the capping layer over tailings with a dozer	1.5	Kingsland and Burton, 2009
Squeezing (bow wave) failure where the very low strength tailings extrude from under the edge of the stiff capping material	1.3	Bowles, 1996

4.6 Plant selection

Reject material is proposed to be delivered to the dam using CAT 785 mining trucks. Spreading of the capping is anticipated to be completed with either a D6 or D9 dozer. The static ground pressures estimated for each design vehicle are shown in Table 4.3.

These design ground pressures do not allow for dynamic loads (e.g. during tipping material from the CAT785 or pushing with the dozer). In particular, use of the CAT 785 trucks during initial placement of the first capping layer is not recommended.

Table 4.3 Design vehicles

Material	CAT 785	D9T	D6N XL
Gross machine weight (kg)	249,433 Distribution loaded - Front 33% - Rear 67%	47,900	21,783
Ground pressure (kPa)	410	110	52

4.7 Analysis

The bearing capacity and stability of the tailings was analysed with varying capping thickness.

The allowable bearing capacity (q_{all}) of the tailings can first be assessed based on the following equation

$$q_{all} = \frac{5.14 s_u}{FoS} \qquad \text{Eq. 1}$$

where *FoS* is the factor of safety, taken as 1.5. By assuming a density for the capping layer (loosely placed coarse reject γ=17 kN/m^3), an initial thickness of the cap can be trialled.

Adopting a uniform tailings profile with an undrained shear strength of 30 kPa, up to 6 m of coarse rejects could be placed. This thickness of capping is considered excessive and thinner layers are proposed as outlined below.

Given the uniform undrained shear strength profile, squeezing of soft tailings is considered unlikely.

Punching shear, assuming a 0.81m wide x 3.28m long area (representative of D9 dozer tracks), has been assessed and was found to achieve a suitable FoS (i.e. >2.0).

Global stability of the capping was analysed using Geostudio Slope/W, with a similar tailings profile as above. An initial 1 m thick layer of capping has been adopted along with a 110 kPa surcharge loading (4m wide) and 52 kPa to simulate construction equipment (D9 and D6, respectively). An offset of 1 m from the leading edge has been adopted and should be applied during construction.

The loading applied by the construction equipment is short-term, and a minimum FoS of 1.3 is considered appropriate for this case. As shown in **Error! Reference source not found.**, an unacceptable FoS is obtained for the D9, while an acceptable value is obtained for the D6 dozer in **Error! Reference source not found.**.

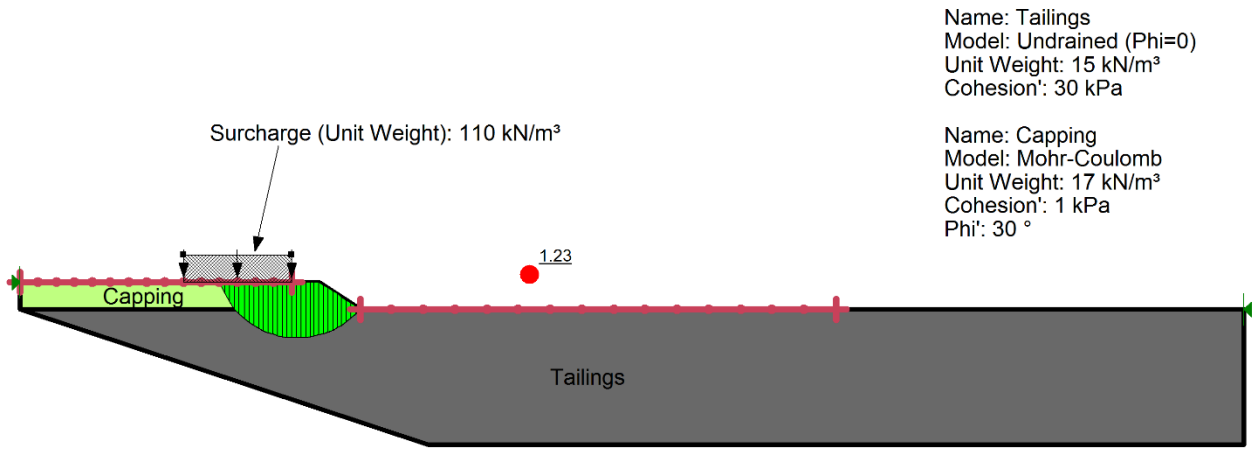


Figure 4-1: Slip circle analysis of tailing capping – D9 dozer

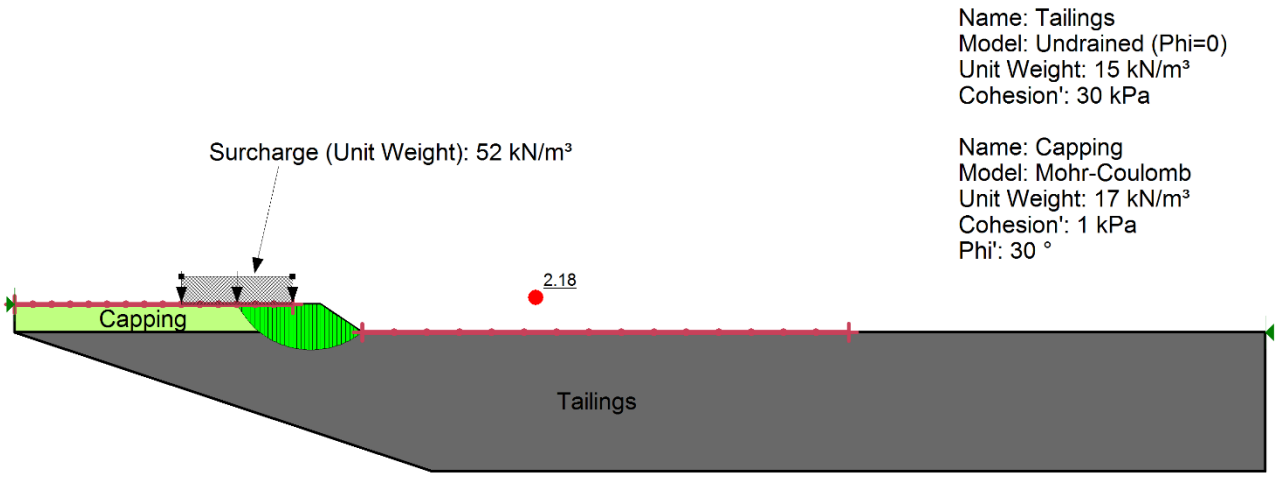


Figure 4-2: Slip circle analysis of tailing capping – D6 dozer

It is envisaged that the CAT 785s could be used to block tip from the embankment and spreading of the capping layer be completed with a dozer push. During this operation it is suggested that the stockpile height be limited to a maximum of 2m (above the 1m capping thickness).

A proximity limit of 5 m is recommended for vehicle movements where there the minimum capping thickness to support vehicles is achieved.

5. Capping strategy

5.1 Capping material and layer thickness

Capping material is to comprise coarse reject material or inert well-graded granular mine spoil with boulders greater than 500 mm removed to reduce the likelihood of a punching failure. The capping material will need to have a low moisture content (i.e. not saturated) prior to placement and will need to be placed in accordance with approval requirements regarding minimum cover.

Capping material should be dumped short of the leading edge of the advancing cap and pushed into position by a dozer. Dumping of the capping material directly onto the tailings surface should be avoided until additional geotechnical testing is carried out across the tailings surface.

5.2 Rate of construction

The geotechnical analysis indicates that the tailings profile tested was of sufficient shear strength to support a capping thickness up to 1.0 m and dozer. Some additional strength gain might also be expected with time following capping placement. Block tipping may be possible over the capping layer as it progresses, but will require a minimum offset to be maintained from the leading edge. Larger vehicles and increased block tipping limits may be possible after some measured strength gain within the tailings.

5.3 Water management

The existing tailings surface should be kept free of water until such time as the entire tailings surface is capped.

The placed capping layer should generally be graded in a south direction towards the spillway.

5.4 Testing

As construction of the capping layer progresses, testing of the tailings should be carried out in front of the advancing layer. Geotechnical investigation including test pitting by mini excavator and shear vane testing at to assess the tailings profile within capped areas to verify the shear strength for access by larger dump trucks

5.5 Capping construction

Given the size of Old Tailings Dam works area may be defined for placement of capping material in a single shift which will allow working on multiple fronts. Placement of capping in these areas would then be on a round-robin basis.

Equipment sizes should be kept to a minimum. In the above analysis, a ground pressure applied by the equipment has been limited to 100 kPa. Where dump trucks are used for the placement of material over tailings consideration should be given to offset distances (e.g. 50/30m rules). These should be maintained while working on the capping to limit the interaction of dynamic loads.

Further investigation of the underlying tailings shear strength is required following the placement of the initial cap prior to placement of subsequent layers or accessing by larger construction vehicles than analysed.

5.6 Construction control measures

Visual inspection of the capping and tailings surface should be undertaken at the commencement of capping placement each day. Additionally, an experienced tailings dam/geotechnical engineer should undertake routine visual inspection at weekly intervals. All personnel working on the dam should be trained to recognise warning signs of dam failure.

The best indication of the stability of the capping layer will come from detailed observation and recording of the performance of the capping as material is placed and shortly thereafter. Items to particularly take note of are outlined below and shown in Figure 5-1:

- Cracks forming within the capping layer – cracks may take a period of time after placement to be observed on the surface. Mapping the extent and time after material placement will provide information which can be used to update the capping strategy as the works progress.
- Deformation of the tailings surface at the toe of the capping. Settlement monitoring markers (0.5m x 0.5m base plate and 2m long vertical bar) are recommended to be installed at a number of locations to allow survey monitoring of the settlement of the tailings with time and provide a rough visual guide for capping layer thickness during placement. The measured settlements can be used to provide an indication of the likely long-term settlement of the tailings and any requirements for over placement of the capping layer to allow for a final free draining landform.
- Pore pressure generation (and dissipation with time). Placement of the capping layer generates an excess pore-water pressure in the tailings which will dissipate over time (a function of material state and permeability). The rate with which this excess pore-water pressure dissipates will govern the time intervals required between placement of the capping and subsequent loading.

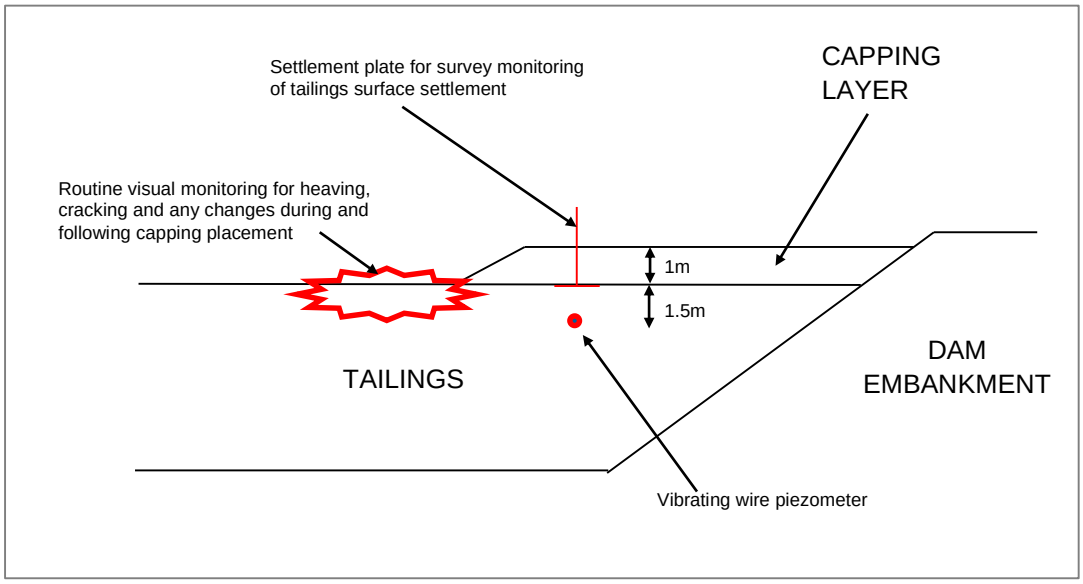


Figure 5-1: Typical monitoring arrangement

Should any of the following warning signs be observed at any time, work should be suspended and inspected by an experienced tailings dam/geotechnical engineer prior to recommencement of capping:

- Significant settlement of capping material (i.e. >300 mm in 24 hours) where there has been no trafficking
- Formation of wheel ruts greater than 200 mm deep. This could be avoided by vehicles not driving in the same path
- Settlement of a machine (punching failure) greater than 200 mm
- cracking of capping layer with cracks 200 mm deep

- cracking of tailings crust greater than 50 mm
- bulging of tailings
- formation of scarps (steps in surface where one side moves vertically relative to another)
- generation of a ‘bow wave’ during dozer push greater than 300 mm high at the leading edge.

Due to the dynamic nature of the capping construction, survey monitoring and trigger action response plans (TARPs) should be developed. The survey monitoring and TARPs should be referenced for the monitoring of settlement of the capping and safe work practices that are to be adhered to for the duration of the capping construction.

6. Final landform earthworks

As part of mine rehabilitation, additional earthworks are required to tie the capping layers in to the surrounding landform.

Future capping layers should be placed from the north of the storage towards the south to promote the drainage of surface water runoff and prevent areas of ponding. The final capped surface should tie in with the surrounding landform in accordance with mine approvals.

Further geotechnical advice is required prior to the placement of subsequent capping layers to confirm the strength of the underlying tailings to support the additional capping material and advise on allowable construction load limits for future rehabilitation.

7. References

GHD (2014). Tailings Dam Stability Analysis. Job No. 41/21979. Dated 14 February 2014.

PPK Environment & Infrastructure (2000). Tailings dam annual report October 2000. Report No: 86M064A-PR0001Abpw. Dated October 2000.

PPK Environment & Infrastructure (2001). Tailings dam annual report November 2001. Report No: 86P194A-PR0001Abpw. Dated November 2001.

Rust PPK (1996) Tailings dam annual report. Report No: 82H116A-PR001Bbw. Dated December 1996.

Appendix A

Limitations



Limitations of Geotechnical Site Investigation

Scope of services

This geotechnical site assessment report (the report) has been prepared in accordance with the scope of services set out in the contract, or as otherwise agreed, between the client and PB (scope of services). In some circumstances the scope of services may have been limited by a range of factors such as time, budget, access and/or site disturbance constraints.

Reliance on data

In preparing the report, PB has relied upon data, surveys, analyses, designs, plans and other information provided by the client and other individuals and organisations, most of which are referred to in the report (the data). Except as otherwise stated in the report, PB has not verified the accuracy or completeness of the data. To the extent that the statements, opinions, facts, information, conclusions and/or recommendations in the report (conclusions) are based in whole or part on the data, those conclusions are contingent upon the accuracy and completeness of the data. PB will not be liable in relation to incorrect conclusions should any data, information or condition be incorrect or have been concealed, withheld, misrepresented or otherwise not fully disclosed to PB.

Geotechnical investigation

Geotechnical engineering is based extensively on judgment and opinion. It is far less exact than other engineering disciplines. Geotechnical engineering reports are prepared to meet the specific needs of individuals. A report prepared for a consulting civil engineer may not be adequate for a construction contractor or even some other consulting civil engineer. This report was prepared expressly for the client and expressly for purposes indicated by the client or his representative. Use by any other persons for any purpose, or by the client for a different purpose, might result in problems. The client should not use this report for other than its intended purpose without seeking additional geotechnical advice.

This geotechnical report is based on project-specific factors

This geotechnical engineering report is based on a subsurface investigation which was designed for project-specification factors, including the nature of any development, its size and configuration, the location of any development on the site and its orientation, and the location of access roads and parking areas. Unless further geotechnical advice is obtained this geotechnical engineering report cannot be used:

- when the nature of any proposed development is changed
- when the size, configuration location or orientation of any proposed development is modified.

This geotechnical engineering report cannot be applied to an adjacent site.

Limitations of Geotechnical Site Investigation

The limitations of site investigation

In making an assessment of a site from a limited number of boreholes or test pits there is the possibility that variations may occur between test locations. Site exploration identifies specific subsurface conditions only at those points from which samples have been taken. The risk that variations will not be detected can be reduced by increasing the frequency of test locations; however this often does not result in any overall cost savings for the project. The investigation program undertaken is a professional estimate of the scope of investigation required to provide a general profile of the subsurface conditions. The data derived from the site investigation program and subsequent laboratory testing are extrapolated across the site to form an inferred geological model and an engineering opinion is rendered about overall subsurface conditions and their likely behaviour with regard to the proposed development. Despite investigation the actual conditions at the site might differ from those inferred to exist, since no subsurface exploration program, no matter how comprehensive, can reveal all subsurface details and anomalies.

The borehole logs are the subjective interpretation of subsurface conditions at a particular location, made by trained personnel. The interpretation may be limited by the method of investigation, and can not always be definitive. For example, inspection of an excavation or test pit allows a greater area of the subsurface profile to be inspected than borehole investigation, however, such methods are limited by depth and site disturbance restrictions. In borehole investigation, the actual interface between materials may be more gradual or abrupt than a report indicates.

Subsurface conditions are time dependent

Subsurface conditions may be modified by changing natural forces or man-made influences. A geotechnical engineering report is based on conditions which existed at the time of subsurface exploration.

Construction operations at or adjacent to the site, and natural events such as floods, or groundwater fluctuations, may also affect subsurface conditions, and thus the continuing adequacy of a geotechnical report. The geotechnical engineer should be kept appraised of any such events, and should be consulted to determine if additional tests are necessary.

Avoid misinterpretation

A geotechnical engineer should be retained to work with other appropriate design professionals explaining relevant geotechnical findings and in reviewing the adequacy of their plans and specifications relative to geotechnical issues.

Bore/profile logs should not be separated from the engineering report

Final bore/profile logs are developed by geotechnical engineers based upon their interpretation of field logs and laboratory evaluation of field samples. Customarily, only the final bore/profile logs are included in geotechnical engineering reports. These logs should not under any circumstances be redrawn for inclusion in architectural or other design drawings. To minimise the likelihood of bore/profile log misinterpretation, contractors should be given access to the complete geotechnical engineering report prepared or authorised for their use. Providing the best available information to contractors helps prevent costly construction problems. For further information on this matter reference should be made to ‘Guidelines for the Provision of Geotechnical Information in Construction Contracts’ published by the Institution of Engineers Australia, National Headquarters, Canberra 1987.

Geotechnical involvement during construction

During construction, excavation is frequently undertaken which exposes the actual subsurface conditions. For this reason geotechnical consultants should be retained through the construction stage, to identify variations if they are exposed and to conduct additional tests which may be required and to deal quickly with geotechnical problems if they arise.

Limitations of Geotechnical Site Investigation

Report for benefit of client

The report has been prepared for the benefit of the client and no other party. PB assumes no responsibility and will not be liable to any other person or organisation for or in relation to any matter dealt with or conclusions expressed in the report, or for any loss or damage suffered by any other person or organisation arising from matters dealt with or conclusions expressed in the report (including without limitation matters arising from any negligent act or omission of PB or for any loss or damage suffered by any other party relying upon the matters dealt with or conclusions expressed in the report). Other parties should not rely upon the report or the accuracy or completeness of any conclusions and should make their own enquiries and obtain independent advice in relation to such matters.

Other limitations

PB will not be liable to update or revise the report to take into account any events or emergent circumstances or facts occurring or becoming apparent after the date of the report.

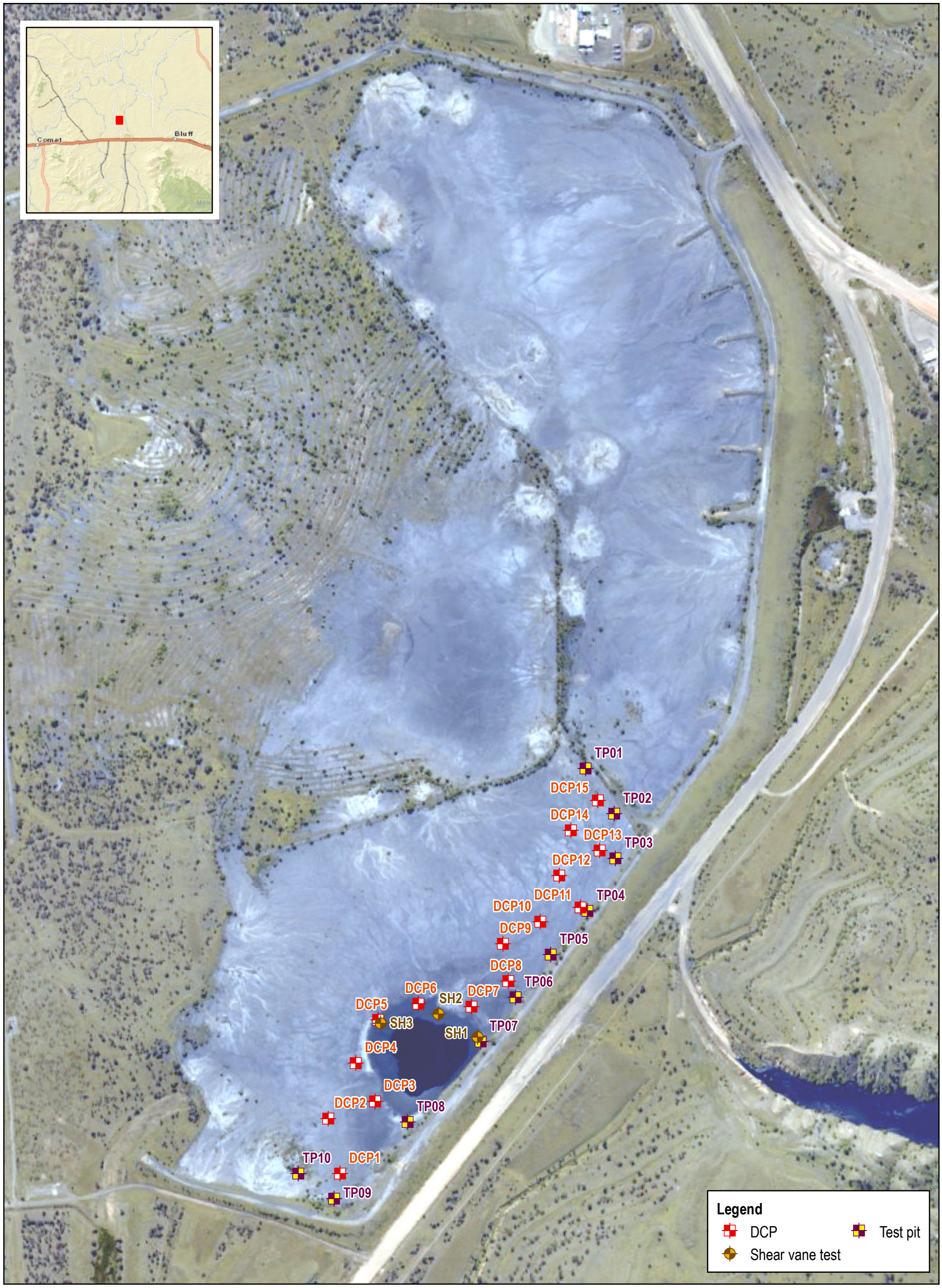
Amendment details

Revision	Details	Date	By
A	Original	18/07/08	M Jenkins

Appendix B

Site plan





Data source:

Aerial provided by Wesfarmers Curragh (9/12/2015)

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Map no: 2172961A_GIS_F001_A1

Author: - SuansriR

Last edited by: - SuansriR

Last edited date: 11/12/2015

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Scale ratio correct when printed at A3

Coord sys: GCS GDA 1994

Old Tailings Dam Rehabilitation

Figure X

Test locations

Wesfarmers Curragh

Appendix C

Engineering logs



PARSONS BRINCKERHOFF

Explanatory Notes — Soil Description

In engineering terms soil includes every type of uncemented or partially cemented inorganic material found in the ground. In practice, if the material can be remoulded by hand in its field condition or in water it is described as a soil. The dominant soil constituent is given in capital letters, with secondary textures in lower case. The dominant feature is assessed from the Unified Soil Classification system and a soil symbol is used to define a soil layer as follows:

SUPPORT

C Casing
M Drill mud
Nil No support

FIELD TEST

DM Dilatometer test
HB Hammer bounce
OT Other test (eg. plate load test)
PE Permeability test
PM Pressuremeter test
PP Pocket penetrometer
SPT Standard penetration test
SV Shear vane test

SAMPLE

B Bulk disturbed sample
D Disturbed sample
PT Push tube
SPT SPT sample
U50 Undisturbed sample in 50mm diameter tube
U75 Undisturbed sample in 75mm diameter tube

UNIFIED SOIL CLASSIFICATION

The appropriate symbols are selected on the result of visual examination, field tests and available laboratory tests, such as, sieve analysis, liquid limit and plasticity index.

USC Symbol	Description
GW	Well graded gravel
GP	Poorly graded gravel
GM	Silty gravel
GC	Clayey gravel
SW	Well graded sand
SP	Poorly graded sand
SM	Silty sand
SC	Clayey sand
ML	Silt of low plasticity
CL	Clay of low plasticity
OL	Organic soil of low plasticity
MH	Silt of high plasticity
CH	Clay of high plasticity
OH	Organic soil of high plasticity
Pt	Peaty Soil

MOISTURE CONDITION

Dry - Cohesive soils are friable or powdery
Cohesionless soil grains are free-running

Moist - Soil feels cool, darkened in colour
Cohesive soils can be moulded
Cohesionless soil grains tend to adhere

Wet - Cohesive soils usually weakened
Free water forms on hands when handling

For cohesive soils the following codes may also be used:

MC>PL Moisture Content greater than the Plastic Limit.
MC~PL Moisture Content near the Plastic Limit.
MC<PL Moisture Content less than the Plastic Limit.

WATER SYMBOLS AND DEFINITIONS

Partial water loss **Water inflow**

Complete water loss

Water level at date shown

COHESIVE SOILS - CONSISTENCY

The consistency of a cohesive soil is defined by descriptive terminology such as very soft, soft, firm, stiff, very stiff and hard. These terms are assessed by the shear strength of the soil as observed visually, by the pocket penetrometer values and by resistance to deformation to hand moulding.

A Pocket Penetrometer may be used in the field or the laboratory to provide approximate assessment of unconfined compressive strength of cohesive soils. The values are recorded in kPa, as follows:

Strength	Symbol	Pocket Penetrometer Reading (kPa)
Very Soft	VS	< 25
Soft	S	25 to 50
Firm	F	50 to 100
Stiff	St	100 to 200
Very Stiff	VSt	200 to 400
Hard	H	> 400

COHESIONLESS SOILS - RELATIVE DENSITY

Relative density terms such as very loose, loose, medium, dense and very dense are used to describe silty and sandy material, and these are usually based on resistance to drilling penetration or the Standard Penetration Test (SPT) 'N' values. Other condition terms, such as friable, powdery or crumbly may also be used.

The Standard Penetration Test (SPT) is carried out in accordance with AS 1289, 6.3.1. For completed tests the number of blows required to drive the split spoon sampler 300 mm is recorded as the N value. For incomplete tests the number of blows and the penetration beyond the seating depth of 150 mm are recorded. If the 150 mm seating penetration is not achieved the number of blows to achieve the measured penetration is recorded. SPT correlations may be subject to corrections for overburden pressure and equipment type.

Term	Symbol	Density Index	N Value (blows /0.3 m)	DCP (blows /100m
Very Loose	VL	0 to 15	0 to 4	0 to 1
Loose	L	15 to 35	4 to 10	1 to 2
Medium Dense	MD	35 to 65	10 to 30	2 to 5
Dense	D	65 to 85	30 to 50	5 to 10
Very Dense	VD	>85	>50	>10

COHESIONLESS SOILS - PARTICLE SIZE TERMS

Name	Subdivision	Size
Boulders		>200mm
Cobbles		63mm to 200mm
Gravel	coarse	20mm to 63mm
	medium	6mm to 20mm
	fine	2.36mm to 6mm
Sand	coarse	0.6mm to 2.36mm
	medium	0.2mm to 0.6mm
	fine	0.075mm to 0.2mm

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Explanatory Notes — Rock Description

The rock is described with strength and weathering symbols as shown below. Other features such as bedding and dip angle are given.

NFGWO **No Free Groundwater Observed**

The observation of groundwater, whether present or not, was not possible due to drilling water, surface seepage or cave in of the borehole/test pit.

NFGWE **No Free Groundwater Encountered**

The borehole/test pit was dry soon after excavation. Inflow may have been observed had the borehole/test pit been left open for a longer period.

DRILLING/EXCAVATION METHODS

Symbol	Term
AS	Auger Screwing
HA	Hand Auger
NMLC	Diamond Core –triple tube
NQ/HQ/PQ	Diamond Core – wireline
PCB	Poly Carbonised Diamond Bit
PC	Percussion
PT	Push Tube
RAB	Rotary Air Blast
RC	Reverse Circulation
S	Sonic drill
VB	Vibrocoring
WB	Washbore with blade
WR	Washbore with roller (tricone)

ROCK MATERIAL WEATHERING

Rock weathering is described mainly using the following abbreviations and definitions used in AS1726.

Term	Symbol	Definition
Residual soil	RS	Soil developed on extremely weathered rock, the mass structure & substance fabric are no longer evident; there is a large change in volume but the soil has not been significantly transported.
Extremely weathered	XW	Rock is weathered to such an extent that it has 'soil' properties, ie: it either disintegrates or can be remoulded in water, but the texture of original rock is evident.
Highly weathered	HW	Rock substance affected by weathering to the extent that limonite staining or bleaching affects the whole of the rock substance and other signs of chemical or physical decomposition are evident. Porosity and strength may be increased or decreased compared to fresh rock usually as a result of iron leaching or deposition. The colour and strength of the original rock substance
Distinctly weathered	DW	Rock strength usually changed by weathering. The rock may be highly discoloured, usually iron staining. Porosity may be increased by leaching, or may be decreased due to deposition of weathering products in pores.
Moderately weathered	MW	Rock substance affected by weathering to the extent that staining extends throughout the whole of the rock substance and the original colour of the fresh rock is no longer recognisable
Slightly weathered	SW	Rock is slightly discoloured but shows little or no change of strength from fresh rock.
Fresh	FR	Rock shows no sign of decomposition or staining.

If differentiation between highly and moderately weathered rock cannot be determined, then distinctly weathered is used which complies to terms described in Australian Standard AS1726.

ROCK QUALITY

The fracture spacing is shown where applicable and the Rock Quality Designation (RQD) where:

$$RQD\ (\%) = \frac{\text{Sum of Axial lengths of core > 100mm long}}{\text{length of core run}}$$

ROCK STRENGTH

Rock strength is described using AS1726 & ISRM - Commission on Standardisation of Laboratory & Field Tests, "Suggested method of determining the Uniaxial Compressive Strength of Rock materials & the Point Load Index", as follows:

Term	Symbol	Point Load Index $Is_{(50)}$ (MPa)
Extremely Low	EL	<0.03
Very Low	VL	0.03 to 0.1
Low	L	0.1 to 0.3
Medium	M	0.3 to 1
High	H	1 to 3
Very High	VH	3 to 10
Extremely High	EH	>10

● Diametral Point Load Index test

■ Axial Point Load Index test

DEFECT SPACING/BEDDING THICKNESS

Measured at right angles to defects of same set or bedding.

The method of measurement shall be reported.

Term	Defect Spacing	Bedding
Extremely closely spaced	<6 mm 6 to 20 mm	Thinly Laminated Laminated
Very closely spaced	20 to 60 mm	Very Thin
Closely spaced	0.06 to 0.2 m	Thin
Moderately widely spaced	0.2 to 0.6 m	Medium
Widely spaced	0.6 to 2 m	Thick
Very widely spaced	>2 m	Very Thick

DEFECT DESCRIPTION

Symbol	Term	Symbol	Term
Bg	Bedding	DB	Drill Break
Pt	Parting	Se	Seam
Cn	Contact	SZ	Sheared Zone
Bd	Boundary	CZ	Crushed Zone
Jt	Joint	F	Fault
Fo	Foliation	Vn	Vein
C	Cleavage		

PLANARITY/ROUGHNESS

Planarity	Description	Planarity	Description
Pl	Planar	Cu	Curved
Un	Undulating	Vu	Vuggy
Ir	Irregular	Wv	Wavy
St	Stepped		

Roughness	Description	Roughness	Description
Sm	Smooth	Po	Polished
Ro	Rough	Sl	Slickensided

The inclination if defects are measured from the perpendicular to the core axis.

COATING OR INFILLING

Abbreviation	Description	Abbreviation	Description
Cl	Clay	Py	Pyrite
Qz	Quartz	Fl	Feldspar
Ca	Calcite	Co	Coal
Ch	Chlorite	Gp	Gypsum
Fe	Limonite/ironstone	Cr	Crushed rock
Mn	Manganese		

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TEST PIT ENGINEERING LOG

TEST PIT NO.

TP01

SHEET : 1 OF 1

Client:	**Wesfarmers Curragh**	Date Commenced:	**3/12/15**
Project:	**Geotechnical investigation for old tailings dam**	Date Completed:	**3/12/15**
Test Pit Location:	**Old Tailings Dam- Southern Cell**	Recorded By:	**AH**
Project Number:	**2172961A**	Log Checked By:	**JB**

Excavation Method:	**Long reach excavator**	Hole Angle:	**-90°**	Surface RL:	
Dimensions:	**4.00 m x 1.50 m**	Bearing:	**---**	Co-ords:	**E 689648 N 7398594 MGA94 55 K**

Test Pit Information							Field Material Description							
METHOD	SUPPORT	WATER	RL (m AHD)	DEPTH (m)	FIELD TEST	SAMPLE	GRAPHIC LOG	USCS SYMBOL	SOIL/ROCK MATERIAL FIELD DESCRIPTION	MOISTURE	RELATIVE DENSITY / CONSISTENCY (VS S F ST VST H / FB VL L MD D VD)	POCKET PENETROMETER (kPa)	STRUCTURE AND ADDITIONAL OBSERVATIONS
EX	Nil	NFGWO		0.00		D		ML	FILL: Clayey SILT, brown / black.	MC<PL		150 - 250	
				0.90				CI	FILL: Silty CLAY, black			450	
				1		D							
				2									
				2.50		D		CI	As above, but with fine grained sand.	MC=PL			
				3									
						D						50	
				4									
				4.30				CI	FILL: Gravelly Sandy CLAY, medium plasticity, fine to coarse gravel, fine grained sand.				FILL
									END OF TEST PIT AT 4.60 m Target depth				

This Test Pit log should be read in conjunction with Parsons Brinckerhoff's accompanying standard notes.

Parsons Brinckerhoff Australia Pty Ltd. V00 8.30.002 PB_LIB_7.4_GJB.GLB Log PB NON-CORED LOG CURRAGH 2172961A.GPJ <<DrawingFile>> 14/12/2015 09:42 Developed by Datgel Pty Ltd



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TITLE

Wesfarmers Curragh
Geotechnical investigation for old tailings dam
Photo - TP01

DRAWN	DATE 14/12/2015
CHECKED	DATE 14/12/2015
SCALE Not To Scale	A4
PROJECT No 2172961A	FIGURE No 1/1

PB_LIB_7.4_GJB.GLB GrfcTbl DG PHOTO TEST PIT PHOTO 1 PER PAGE CURRAGH 2172961A.GPJ <<DrawingFile>> 14/Dec/2015 09:42 8.30.002 Datgel CPT Tool gINT Add-In

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TEST PIT ENGINEERING LOG

TEST PIT NO.

TP02

SHEET : 1 OF 1

Client:	**Wesfarmers Curragh**	Date Commenced:	**3/12/15**
Project:	**Geotechnical investigation for old tailings dam**	Date Completed:	**3/12/15**
Test Pit Location:	**Old Tailings Dam- Southern Cell**	Recorded By:	**AH**
Project Number:	**2172961A**	Log Checked By:	**JB**

Excavation Method:	**Long reach excavator**	Hole Angle:	**-90°**	Surface RL:	
Dimensions:	**4.00 m x 1.50 m**	Bearing:	**---**	Co-ords:	**E 689693 N 7398514 MGA94 55 K**

Test Pit Information							Field Material Description						
METHOD	SUPPORT	WATER	RL (m AHD) / DEPTH (m)	FIELD TEST	SAMPLE	GRAPHIC LOG	USCS SYMBOL	SOIL/ROCK MATERIAL FIELD DESCRIPTION	MOISTURE	RELATIVE DENSITY / CONSISTENCY	POCKET PENETROMETER (kPa)	STRUCTURE AND ADDITIONAL OBSERVATIONS
EX	Nil	NFGWO	0.00		D		ML	FILL: Clayey SILT, black, low plasticity	MC<PL		150 - 200	
			0.50				ML-MH	As above, but brown / black, low to medium plasticity			200 - 300	
			1.00 1				CI	FILL: Silty CLAY, black, medium plasticity			200 - 250	
					D						50	
			2									
			3.00 3		D		CI-CH	As above, but medium to high plasticity	MC=PL		50 - 100	
			4								<50	
								END OF TEST PIT AT 4.80 m Target depth				

This Test Pit log should be read in conjunction with Parsons Brinckerhoff's accompanying standard notes.

Parsons Brinckerhoff Australia Pty Ltd. V00 8.30.002 PB_LIB_74_GJB.GLB Log PB NON-CORED LOG CURRAGH 2172961A.GPJ <<DrawingFile>> 14/12/2015 09:42 Developed by Datgel Pty Ltd



PARSONS BRINCKERHOFF

TITLE

Wesfarmers Curragh
Geotechnical investigation for old tailings dam
Photo - TP02

DRAWN	DATE 14/12/2015	
CHECKED	DATE 14/12/2015	
SCALE Not To Scale		A4
PROJECT No 2172961A	FIGURE No 1/1	

PB_LIB_7.4_GJB.GLB GrfcTbl DG PHOTO TEST PIT PHOTO 1 PER PAGE CURRAGH 2172961A.GPJ <<DrawingFile>> 14/Dec/2015 09:43 8.30.002 Datgel CPT Tool gINT Add-In

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TEST PIT ENGINEERING LOG

TEST PIT NO.

TP03

SHEET : 1 OF 1

Client:	**Wesfarmers Curragh**	Date Commenced:	**3/12/15**
Project:	**Geotechnical investigation for old tailings dam**	Date Completed:	**3/12/15**
Test Pit Location:	**Old Tailings Dam- Southern Cell**	Recorded By:	**AH**
Project Number:	**2172961A**	Log Checked By:	**JB**

Excavation Method:	**Long reach excavator**	Hole Angle:	**-90°**	Surface RL:	
Dimensions:	**4.00 m x 1.50 m**	Bearing:	**---**	Co-ords:	**E 689694 N 7398437 MGA94 55 K**

Test Pit Information							Field Material Description						
METHOD	SUPPORT	WATER	RL (m AHD) / DEPTH (m)	FIELD TEST	SAMPLE	GRAPHIC LOG	USCS SYMBOL	SOIL/ROCK MATERIAL FIELD DESCRIPTION	MOISTURE	RELATIVE DENSITY / CONSISTENCY (VS S F ST VST H / FB VL L MD D VD)	POCKET PENETROMETER (kPa)	STRUCTURE AND ADDITIONAL OBSERVATIONS
EX	Nil	NFGWO	0.00		D		ML	FILL: Clayey SILT, low plasticity, black, dark / grey	MC<PL		400 - 450	
			0.70				CL-CI	FILL: Silty CLAY, low to medium plasticity, black			200 - 250	
			1								150 - 200	
			2.00 2				CI	As above, but medium plasticity	MC=PL			
					D						50	
			3									
			4					END OF TEST PIT AT 4.60 m Target depth				

This Test Pit log should be read in conjunction with Parsons Brinckerhoff's accompanying standard notes.

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TITLE

Wesfarmers Curragh
Geotechnical investigation for old tailings dam
Photo - TP03

DRAWN	DATE 14/12/2015	
CHECKED	DATE 14/12/2015	
SCALE Not To Scale		A4
PROJECT No 2172961A	FIGURE No 1/1	

PB_LIB_7.4_GJB.GLB GrfcTbl DG PHOTO TEST PIT PHOTO 1 PER PAGE CURRAGH 2172961A.GPJ <<DrawingFile>> 14/Dec/2015 09:43 8.30.002 Datgel CPT Tool gINT Add-In

PARSONS BRINCKERHOFF

TEST PIT ENGINEERING LOG

TEST PIT NO.

TP04

SHEET : 1 OF 1

Client:	**Wesfarmers Curragh**	Date Commenced:	**3/12/15**
Project:	**Geotechnical investigation for old tailings dam**	Date Completed:	**3/12/15**
Test Pit Location:	**Old Tailings Dam- Southern Cell**	Recorded By:	**AH**
Project Number:	**2172961A**	Log Checked By:	**JB**

Excavation Method:	**Long reach excavator**	Hole Angle:	**-90°**	Surface RL:	
Dimensions:	**4.00 m x 1.50 m**	Bearing:	**---**	Co-ords:	**E 689648 N 7398346 MGA94 55 K**

Test Pit Information							Field Material Description						
METHOD	SUPPORT	WATER	RL (m AHD)	DEPTH (m)	FIELD TEST	SAMPLE	GRAPHIC LOG	USCS SYMBOL	SOIL/ROCK MATERIAL FIELD DESCRIPTION	MOISTURE	RELATIVE DENSITY / CONSISTENCY	POCKET PENETROMETER (kPa)	STRUCTURE AND ADDITIONAL OBSERVATIONS
EX	Nil	NFGWO		0		D			FILL: Clayey SILT, low plasticity, black / brown	MC<PL		350 - 400	
				0.75					FILL: Silty CLAY, medium plasticity, black			150 - 200	
				1						MC=PL			
				2		D						50	
				3								50	
				4		D				MC=PL - MC>PL			
				4.90					FILL: Clayey GRAVEL, fine to coarse grained, brown, medium plasticity clay	D			FILL
				5					END OF TEST PIT AT 5.00 m Target depth				

This Test Pit log should be read in conjunction with Parsons Brinckerhoff's accompanying standard notes.

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PARSONS BRINCKERHOFF

TITLE

Wesfarmers Curragh
Geotechnical investigation for old tailings dam
Photo - TP04

DRAWN	DATE 14/12/2015
CHECKED	DATE 14/12/2015
SCALE Not To Scale	A4
PROJECT No 2172961A	FIGURE No 1/1

PB_LIB_7.4_GJB.GLB GrfcTbl DG PHOTO TEST PIT PHOTO 1 PER PAGE CURRAGH 2172961A.GPJ <<DrawingFile>> 14/Dec/2015 09:43 8.30.002 Datgel CPT Tool gINT Add-In

PARSONS BRINCKERHOFF

TEST PIT ENGINEERING LOG

TEST PIT NO.

TP05

SHEET : 1 OF 1

Client:	**Wesfarmers Curragh**	Date Commenced:	**3/12/15**
Project:	**Geotechnical investigation for old tailings dam**	Date Completed:	**3/12/15**
Test Pit Location:	**Old Tailings Dam- Southern Cell**	Recorded By:	**AH**
Project Number:	**2172961A**	Log Checked By:	**JB**

Excavation Method:	**Long reach excavator**	Hole Angle:	**-90°**	Surface RL:	
Dimensions:	**4.00 m x 1.50 m**	Bearing:	**---**	Co-ords:	**E 689588 N 7398270 MGA94 55 K**

Test Pit Information							Field Material Description						
METHOD	SUPPORT	WATER	RL (m AHD) / DEPTH (m)	FIELD TEST	SAMPLE	GRAPHIC LOG	USCS SYMBOL	SOIL/ROCK MATERIAL FIELD DESCRIPTION	MOISTURE	RELATIVE DENSITY / CONSISTENCY (FB VL L MD D VD / VS S F ST VST H)	POCKET PENETROMETER (kPa)	STRUCTURE AND ADDITIONAL OBSERVATIONS
EX	Nil	NFGWO	0.00		D		ML	FILL: Clayey SILT, low plasticity, black / brown	MC<PL		150 - 200	
			0.50				CL-CI	FILL: Silty CLAY, low to medium plasticity, black			200	
			1.50				CI-CH	As above, but medium to high plasticity	MC=PL		50 - 100	
			2.00		D						50	
			4.60				GC	FILL: Clayey Sandy GRAVEL, fine to coarse grained, fine to medium grained sand, low plasticity clay, brown / grey	D			FILL
			5.00					END OF TEST PIT AT 5.00 m Target depth				

This Test Pit log should be read in conjunction with Parsons Brinckerhoff's accompanying standard notes.

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TITLE

Wesfarmers Curragh
Geotechnical investigation for old tailings dam
Photo - TP05

DRAWN	DATE 14/12/2015	
CHECKED	DATE 14/12/2015	
SCALE Not To Scale		A4
PROJECT No 2172961A	FIGURE No 1/1	

PB_LIB_7.4_GJB.GLB GrfcTbl DG PHOTO TEST PIT PHOTO 1 PER PAGE CURRAGH 2172961A.GPJ <<DrawingFile>> 14/Dec/2015 09:43 8.30.002 Datgel CPT Tool gINT Add-In

PARSONS BRINCKERHOFF

TEST PIT ENGINEERING LOG

TEST PIT NO.

TP06

SHEET : 1 OF 1

Client:	**Wesfarmers Curragh**	Date Commenced:	**3/12/15**
Project:	**Geotechnical investigation for old tailings dam**	Date Completed:	**3/12/15**
Test Pit Location:	**Old Tailings Dam- Southern Cell**	Recorded By:	**AH**
Project Number:	**2172961A**	Log Checked By:	**JB**

Excavation Method:	**Long reach excavator**	Hole Angle:	**-90°**	Surface RL:	
Dimensions:	**4.00 m x 1.50 m**	Bearing:	**---**	Co-ords:	**E 689530 N 7398197 MGA94 55 K**

Test Pit Information							Field Material Description						
METHOD	SUPPORT	WATER	RL (m AHD)	DEPTH (m)	FIELD TEST	SAMPLE	GRAPHIC LOG	USCS SYMBOL	SOIL/ROCK MATERIAL FIELD DESCRIPTION	MOISTURE	RELATIVE DENSITY / CONSISTENCY (FB VL L MD D VD / VS S F ST VST H)	POCKET PENETROMETER (kPa)	STRUCTURE AND ADDITIONAL OBSERVATIONS
EX	Nil	NFGWO		0				ML	FILL: Clayey SILT, low plasticity, black	MC<PL		100 - 200	
						D						300	
				1									
				1.20				CI	FILL: Silty CLAY, medium plasticity, black / dark grey	MC<PL - MC<=PL		300 - 400	
				2.00				SM	FILL: Silty SAND, fine to medium grained, light brown, traces of clay	D		50 - 100	
				2.20				CH	FILL: Silty CLAY, high plasticity, black / dark grey	MC=PL		<50	
						D							
				3					Visible moisture	MC>PL		<50	
				4									
									END OF TEST PIT AT 4.50 m Collapse				Pipe exposed with water coming out

This Test Pit log should be read in conjunction with Parsons Brinckerhoff's accompanying standard notes.

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PARSONS BRINCKERHOFF

TITLE

Wesfarmers Curragh
Geotechnical investigation for old tailings dam
Photo - TP06

DRAWN	DATE 14/12/2015
CHECKED	DATE 14/12/2015
SCALE Not To Scale	A4
PROJECT No 2172961A	FIGURE No 1/1

PB_LIB_7.4_GJB.GLB GrfcTbl DG PHOTO TEST PIT PHOTO 1 PER PAGE CURRAGH 2172961A.GPJ <<DrawingFile>> 14/Dec/2015 09:43 8.30.002 Datgel CPT Tool gINT Add-In

PARSONS BRINCKERHOFF

TEST PIT ENGINEERING LOG

TEST PIT NO.

TP07

SHEET : 1 OF 1

Client:	**Wesfarmers Curragh**	Date Commenced:	**3/12/15**
Project:	**Geotechnical investigation for old tailings dam**	Date Completed:	**3/12/15**
Test Pit Location:	**Old Tailings Dam- Southern Cell**	Recorded By:	**AH**
Project Number:	**2172961A**	Log Checked By:	**JB**

Excavation Method:	**Long reach excavator**	Hole Angle:	**-90°**	Surface RL:	
Dimensions:	**4.00 m x 1.50 m**	Bearing:	**---**	Co-ords:	**E 689473 N 7398120 MGA94 55 K**

Test Pit Information							Field Material Description						
METHOD	SUPPORT	WATER	RL (m AHD) / DEPTH (m)	FIELD TEST	SAMPLE	GRAPHIC LOG	USCS SYMBOL	SOIL/ROCK MATERIAL FIELD DESCRIPTION	MOISTURE	RELATIVE DENSITY / CONSISTENCY (VS S F ST VST H / FB VL L MD D VD)	POCKET PENETROMETER (kPa)	STRUCTURE AND ADDITIONAL OBSERVATIONS
EX	Nil	NFGWO	0.30				ML	FILL: Clayey SILT, low to medium plasticity, black	MC<PL			
					D		CI-CH	FILL: Silty CLAY, medium to high plasticity, black / dark grey	MC=PL		25 - 50	
			1								<25	
			2								<25	
			3								<25	
			4		D			END OF TEST PIT AT 4.30 m Collapse				

This Test Pit log should be read in conjunction with Parsons Brinckerhoff's accompanying standard notes.

Parsons Brinckerhoff Australia Pty Ltd. V00 8.30.002 PB_LIB_7.4_GJB.GLB Log PB NON-CORED LOG CURRAGH 2172961A.GPJ <<DrawingFile>> 14/12/2015 09:43 Developed by Datgel Pty Ltd



PARSONS BRINCKERHOFF

TITLE

Wesfarmers Curragh
Geotechnical investigation for old tailings dam
Photo - TP07

DRAWN	DATE 14/12/2015
CHECKED	DATE 14/12/2015
SCALE Not To Scale	A4
PROJECT No 2172961A	FIGURE No 1/1

PB_LIB_7.4_GJB.GLB GrfcTbl DG PHOTO TEST PIT PHOTO 1 PER PAGE CURRAGH 2172961A.GPJ <<DrawingFile>> 14/Dec/2015 09:43 8.30.002 Datgel CPT Tool gINT Add-In

PARSONS BRINCKERHOFF

TEST PIT ENGINEERING LOG

TEST PIT NO.

TP08

SHEET : 1 OF 1

Client:	**Wesfarmers Curragh**	Date Commenced:	**3/12/15**
Project:	**Geotechnical investigation for old tailings dam**	Date Completed:	**3/12/15**
Test Pit Location:	**Old Tailings Dam- Southern Cell**	Recorded By:	**AH**
Project Number:	**2172961A**	Log Checked By:	**JB**

Excavation Method:	**Long reach excavator**	Hole Angle:	**-90°**	Surface RL:	
Dimensions:	**4.00 m x 1.50 m**	Bearing:	**---**	Co-ords:	**E 689354 N 7397981 MGA94 55 K**

Test Pit Information							Field Material Description						
METHOD	SUPPORT	WATER	RL (m AHD) / DEPTH (m)	FIELD TEST	SAMPLE	GRAPHIC LOG	USCS SYMBOL	SOIL/ROCK MATERIAL FIELD DESCRIPTION	MOISTURE	RELATIVE DENSITY / CONSISTENCY (VS S F ST VST H / FB VL L MD D VD)	POCKET PENETROMETER (kPa)	STRUCTURE AND ADDITIONAL OBSERVATIONS
EX	Nil	NFGWO			D		ML	FILL: Clayey SILT, low to medium plasticity, black	MC<PL			
			0.40		D		CI-CH	FILL: Silty CLAY, medium to high plasticity, black	MC=PL		50 - 100	
			1								<25	
			2									
			2.90				CI	Silty CLAY, medium plasticity, brown to grey / brown, trace fine sand			100 - 150	RESIDUAL SOIL
			3									
			3.40					SANDSTONE, fine to medium grained, orange, low to medium strength, highly weathered				WEATHERED ROCK
								END OF TEST PIT AT 3.70 m Refusal				

This Test Pit log should be read in conjunction with Parsons Brinckerhoff's accompanying standard notes.

Parsons Brinckerhoff Australia Pty Ltd. V00 8.30.002 PB_LIB_7.4_GJB.GLB Log PB NON-CORED LOG CURRAGH 2172961A.GPJ <<DrawingFile>> 14/12/2015 09:43 Developed by Datgel Pty Ltd



PARSONS BRINCKERHOFF

TITLE

Wesfarmers Curragh
Geotechnical investigation for old tailings dam
Photo - TP08

DRAWN	DATE 14/12/2015	
CHECKED	DATE 14/12/2015	
SCALE Not To Scale		A4
PROJECT No 2172961A	FIGURE No 1/1	

PB_LIB_7.4_GJB.GLB GrfcTbl DG PHOTO TEST PIT PHOTO 1 PER PAGE CURRAGH 2172961A.GPJ <<DrawingFile>> 14/Dec/2015 09:43 8.30.002 Datgel CPT Tool gINT Add-In

PARSONS BRINCKERHOFF

TEST PIT ENGINEERING LOG

TEST PIT NO.

TP09

SHEET : 1 OF 1

Client:	**Wesfarmers Curragh**	Date Commenced:	**4/12/15**
Project:	**Geotechnical investigation for old tailings dam**	Date Completed:	**4/12/15**
Test Pit Location:	**Old Tailings Dam- Southern Cell**	Recorded By:	**AH**
Project Number:	**2172961A**	Log Checked By:	**JB**

Excavation Method:	**Long reach excavator**	Hole Angle:	**-90°**	Surface RL:	
Dimensions:	**4.00 m x 1.50 m**	Bearing:	**---**	Co-ords:	**E 689234 N 7397849 MGA94 55 K**

Test Pit Information							Field Material Description						
METHOD	SUPPORT	WATER	RL (m AHD) / DEPTH (m)	FIELD TEST	SAMPLE	GRAPHIC LOG	USCS SYMBOL	SOIL/ROCK MATERIAL FIELD DESCRIPTION	MOISTURE	RELATIVE DENSITY / CONSISTENCY (VS S F ST VST H / FB VL L MD D VD)	POCKET PENETROMETER (kPa)	STRUCTURE AND ADDITIONAL OBSERVATIONS
EX	Nil	NFGWO			D		ML	FILL: Clayey SILT, low plasticity, dark grey / black	MC<PL		300 - 350	
			0.70				CL-CI	Silty CLAY, low to medium plasticity, orange / brown			350 - 450	RESIDUAL SOIL
			1									
			2					END OF TEST PIT AT 2.20 m Target depth				

This Test Pit log should be read in conjunction with Parsons Brinckerhoff's accompanying standard notes.

Parsons Brinckerhoff Australia Pty Ltd. V00 8.30.002 PB_LIB_7.4_GJB.GLB Log PB NON-CORED LOG CURRAGH 2172961A.GPJ <<DrawingFile>> 14/12/2015 09:43 Developed by Datgel Pty Ltd



PARSONS BRINCKERHOFF

TITLE

Wesfarmers Curragh
Geotechnical investigation for old tailings dam
Photo - TP09

DRAWN	DATE 14/12/2015
CHECKED	DATE 14/12/2015
SCALE Not To Scale	A4
PROJECT No 2172961A	FIGURE No 1/1

PB_LIB_7.4_GJB.GLB GrfcTbl DG PHOTO TEST PIT PHOTO 1 PER PAGE CURRAGH 2172961A.GPJ <<DrawingFile>> 14/Dec/2015 09:43 8.30.002 Datgel CPT Tool gINT Add-In

PARSONS BRINCKERHOFF

TEST PIT ENGINEERING LOG

TEST PIT NO.

TP10

SHEET : 1 OF 1

Client:	**Wesfarmers Curragh**	Date Commenced:	**4/12/15**
Project:	**Geotechnical investigation for old tailings dam**	Date Completed:	**4/12/15**
Test Pit Location:	**Old Tailings Dam- Southern Cell**	Recorded By:	**AH**
Project Number:	**2172961A**	Log Checked By:	**JB**

Excavation Method:	**Long reach excavator**	Hole Angle:	**-90°**	Surface RL:	
Dimensions:	**4.00 m x 1.50 m**	Bearing:	**---**	Co-ords:	**E 689177 N 7397893 MGA94 55 K**

Test Pit Information							Field Material Description						
METHOD	SUPPORT	WATER	RL (m AHD) / DEPTH (m)	FIELD TEST	SAMPLE	GRAPHIC LOG	USCS SYMBOL	SOIL/ROCK MATERIAL FIELD DESCRIPTION	MOISTURE	RELATIVE DENSITY / CONSISTENCY (VS S F ST VST H / FB VL L MD D VD)	POCKET PENETROMETER (kPa)	STRUCTURE AND ADDITIONAL OBSERVATIONS
EX	Nil	NFGWO			D		ML	FILL: Clayey SILT, low plasticity, dark grey, orange / brown	MC<PL		100 - 200 400 - 450	TAILINGS
			1.00 1				CL-CI	Silty CLAY, low to medium plasticity, orange / brown, trace sandstone cobbles			300 - 350 350 - 400	RESIDUAL SOIL
			2					END OF TEST PIT AT 2.20 m Target depth				

This Test Pit log should be read in conjunction with Parsons Brinckerhoff's accompanying standard notes.

Parsons Brinckerhoff Australia Pty Ltd. V00 8.30.002 PB_LIB_7.4_GJB.GLB Log PB NON-CORED LOG CURRAGH 2172961A.GPJ <<DrawingFile>> 14/12/2015 09:43 Developed by Datgel Pty Ltd



PARSONS BRINCKERHOFF

TITLE

Wesfarmers Curragh
Geotechnical investigation for old tailings dam
Photo - TP10

DRAWN	DATE 14/12/2015	
CHECKED	DATE 14/12/2015	
SCALE Not To Scale		A4
PROJECT No 2172961A	FIGURE No 1/1	

PB_LIB_7.4_GJB.GLB GrfcTbl DG PHOTO TEST PIT PHOTO 1 PER PAGE CURRAGH 2172961A.GPJ <<DrawingFile>> 14/Dec/2015 09:43 8.30.002 Datgel CPT Tool gINT Add-In

Dynamic Cone Penetrometer Test Results

Sheet 1

CLIENT	Wesfarmers Curragh	**OFFICE**	Singleton
PROJECT	Old Tailings Dam	**TEST DATE**	4/12/2015
LOCATION	Sourthen Cell	**TESTED BY**	AH
PROJECT NO.	2172961A	**CHECKED**	JB
TEST METHOD	AS 1289 6.3.2 - Cone Penetrometer	**TEST EQUIPMENT**	

Depth	Test Location (Blows per 100mm)																
	DCP1	DCP2	DCP3	DCP4	DCP5	DCP6	DCP7	DCP8	DCP9	DCP10	DCP11	DCP12	DCP13	DCP14	DCP15		
0.0-0.1	3	2	3	2	1	2	2	2	2	2	2	3	4	4	2		
0.1-0.2	2	1	0	2	1	1	1	2	2	2	2	2	3	3	3		
0.2-0.3	3	1	1	1	1	1	1	2	1	2	1	2	3	3	3		
0.3-0.4	2	1	1	2	1	1	2	1	2	1	1	2	4	1	2		
0.4-0.5	2	1	1	1	1	1	1	1	2	2	1	1	2	2	1		
0.5-0.6	1	2	1	2	1	1	1	1	3	1	1	2	2	2	2		
0.6-0.7	2	2	1	1	2	1	1	2	1	2	1	2	2	3	2		
0.7-0.8	2	2	2	1	2	2	1	1	1	2	1	2	1	3	2		
0.8-0.9	3	1	2	2	2	2	1	1	1	3	3	1	1	3	2		
0.9-1.0	2	2	2	3	3	2	4	1	2	2	1	2	2	3	2		
1.0-1.1	1	2	4	4	3	2	2	1	2	2	3	2	1	4	3		
1.1-1.2	3	2	4	3	4	3	3	1	3	2	3	2	3	4	2		
1.2-1.3	3	3	5	1	3	3	3	1	3	2	3	3	2	3	1		
1.3-1.4	4	3	5	2	4	4	3	1	4	2	3	2	3	5	2		
1.4-1.5	5	3	5	4	4	3	3	3	2	2	2	2	3	2	3		
1.5-1.6	4	4	5	3	3	4	4	3	2	2	2	2	3	2	4		
1.6-1.7	4	5	7	3	5	4	3	4	3	1	4	3	2	2	2		
1.7-1.8	3	4	6	2	6	4	3	5	2	1	2	2	1	2	2		
1.8-1.9	4	3	8	2	5	5	3	3	1	2	2	3	2	2	2		
1.9-2.0	6	5	8	3	6	6	4	3	2	2	2	3	1	2	3		
2.0-2.1	7	9	10	4	7	7	4	2	3	2	3	3	4	3	4		
2.1-2.2	9	13	8	4	6	7	5	2	3	2	2	3	3	3	5		
2.2-2.3	9	14	7	4	7	7	5	3	3	2	3	2	3	3	3		
2.3-2.4	10	12	8	5	5	8	6	3	2	2	3	2	4	5	4		
2.4-2.5	11	12	9	5	7	7	6	2	3	3	4	2	4	4	4		
2.5-2.6	13	15	9	6	7	7	5	3	3	3	4	3	4	5	4		
2.6-2.7																	
2.7-2.8																	
2.8-2.9																	
2.9-3.0																	

Appendix D

Laboratory test certificates



Trilab
Soil Rock Calibration

Brisbane
346A Bilsen Road,
Geebung
QLD 4034
Ph: +61 7 3265 5656

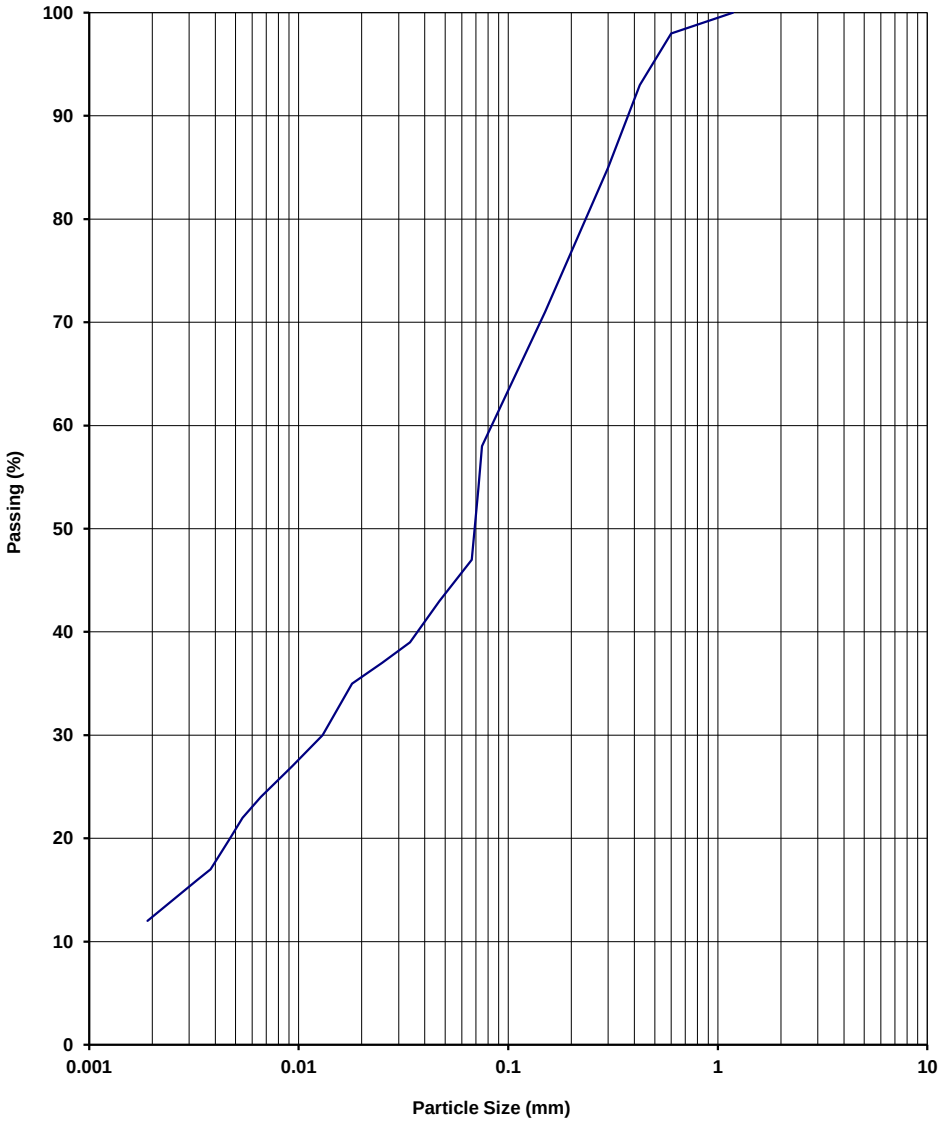
Perth
2 Kimmer Place,
Queens Park
WA 6107
Ph: +61 8 9258 8323

PARTICLE SIZE DISTRIBUTION TEST REPORT

Test Method: AS 1289 3.6.3, 3.5.1

Client	Parsons Brinckerhoff Pty Ltd	**Report No.**	15120412-G
Project	2172961A	**Test Date**	11/12/15-22/12/15
		Report Date	22/12/2015
Client ID	TP01	**Depth (m)**	1.00-1.10

Sieve Size (mm)	Passing %
150.0	
75.0	
63.0	
53.0	
37.5	
26.5	
19.0	
9.5	
4.75	
2.36	
1.18	100
0.600	98
0.425	93
0.300	85
0.150	71
0.075	58
0.072	54
0.067	47
0.047	43
0.034	39
0.025	37
0.018	35
0.013	30
0.0093	27
0.0066	24
0.0054	22
0.0047	20
0.0038	17
0.0033	16
0.0019	12



NOTES/REMARKS: -

Moisture Content 14% -2.36mm Soil Particle Density(t/m^3) 1.92

Sample/s supplied by the client

Accredited for compliance with ISO/IEC 17025.
The results of the tests, calibrations, and/or measurements included in this document are traceable to Australian/National Standards.

Tested at Trilab Brisbane Laboratory.

Authorised Signatory

C. Channon

NATA ACCREDITED FOR TECHNICAL COMPETENCE

Laboratory No. 9926

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ACCURATE QUALITY RESULTS FOR TOMORROW'S ENGINEERING

Trilab
Soil Rock Calibration

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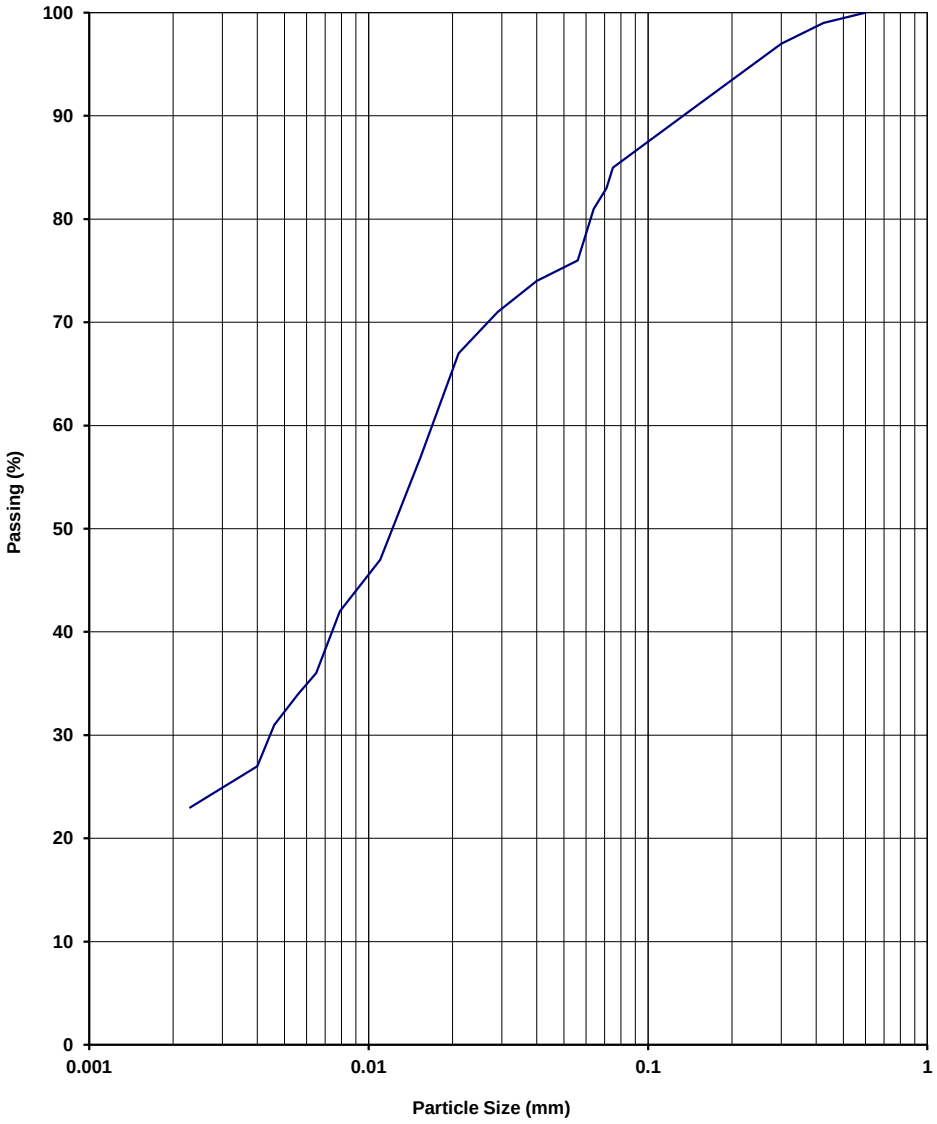
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2 Kimmer Place,
Queens Park
WA 6107
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PARTICLE SIZE DISTRIBUTION TEST REPORT

Test Method: AS 1289 3.6.3, 3.5.1

Client	Parsons Brinckerhoff Pty Ltd	**Report No.**	15120416-G
Project	2172961A	**Test Date**	17/12/15-22/12/15
		Report Date	22/12/2015
Client ID	TP03	**Depth (m)**	2.30-2.50

Sieve Size (mm)	Passing %
150.0	
75.0	
63.0	
53.0	
37.5	
26.5	
19.0	
9.5	
4.75	
2.36	
1.18	
0.600	100
0.425	99
0.300	97
0.150	91
0.075	85
0.071	83
0.064	81
0.056	76
0.04	74
0.029	71
0.021	67
0.0154	57
0.011	47
0.0079	42
0.0065	36
0.0056	34
0.0046	31
0.004	27
0.0023	23



NOTES/REMARKS: -

Moisture Content 36.5% -2.36mm Soil Particle Density(t/m^3) 1.61

Sample/s supplied by the client

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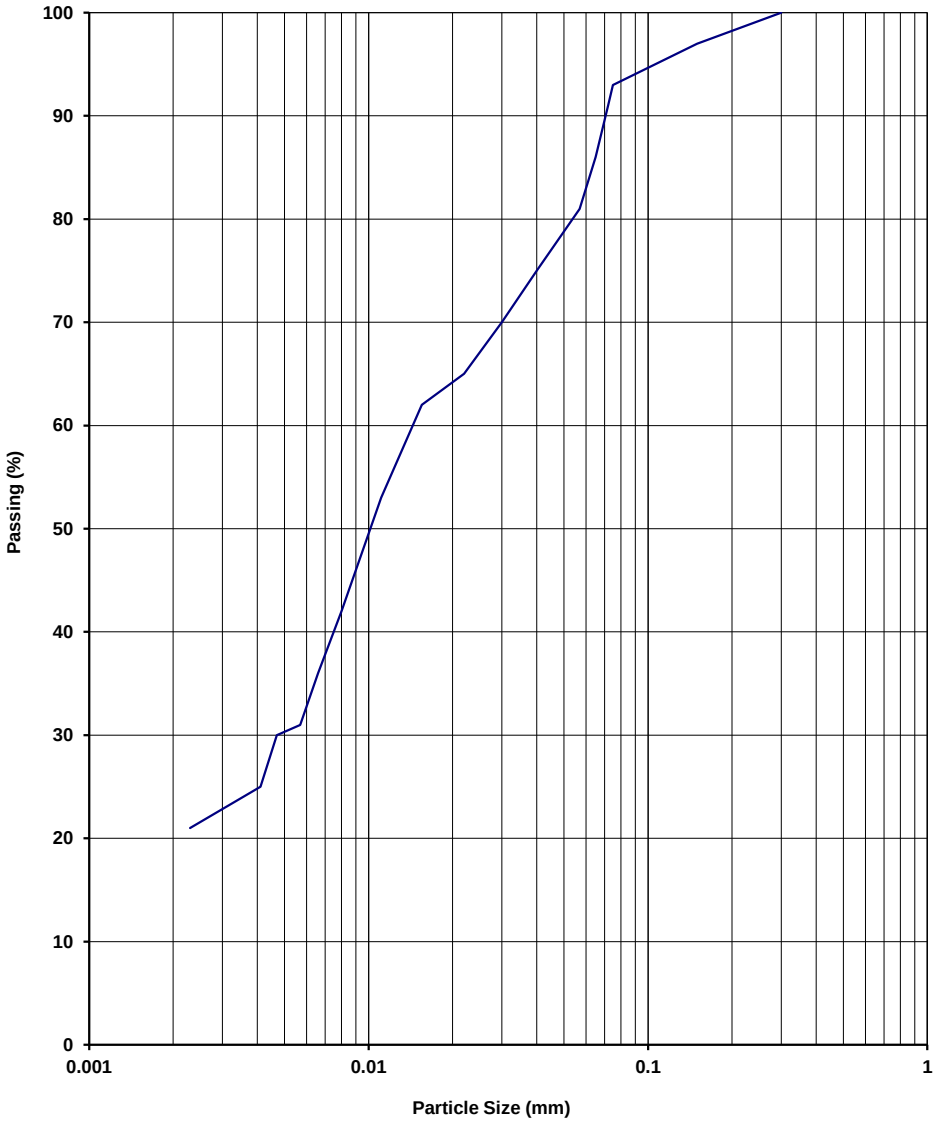
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PARTICLE SIZE DISTRIBUTION TEST REPORT

Test Method: AS 1289 3.6.3, 3.5.1

Client	Parsons Brinckerhoff Pty Ltd	**Report No.**	15120418-G
Project	2172961A	**Test Date**	17/12/15-22/12/15
		Report Date	22/12/2015
Client ID	TP04	**Depth (m)**	1.90-2.10

Sieve Size (mm)	Passing %
150.0	
75.0	
63.0	
53.0	
37.5	
26.5	
19.0	
9.5	
4.75	
2.36	
1.18	
0.600	
0.425	
0.300	100
0.150	97
0.075	93
0.072	91
0.065	86
0.057	81
0.04	75
0.03	70
0.022	65
0.0155	62
0.0111	53
0.008	42
0.0066	36
0.0057	31
0.0047	30
0.0041	25
0.0023	21



NOTES/REMARKS: -

Moisture Content 40.5% -2.36mm Soil Particle Density(t/m^3) 1.60

Sample/s supplied by the client

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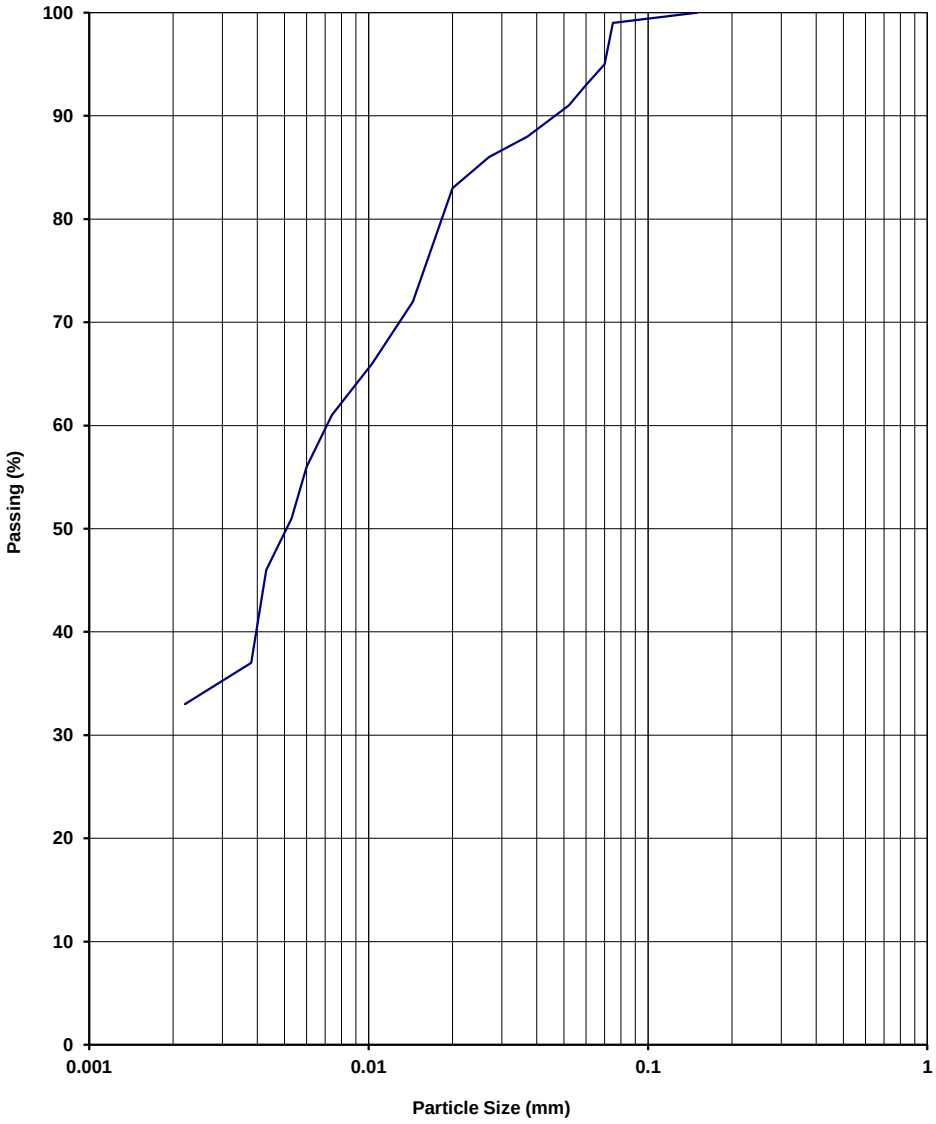
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Queens Park
WA 6107
Ph: +61 8 9258 8323

PARTICLE SIZE DISTRIBUTION TEST REPORT

Test Method: AS 1289 3.6.3, 3.5.1

Client	Parsons Brinckerhoff Pty Ltd	**Report No.**	15120420-G
Project	2172961A	**Test Date**	17/12/15-22/12/15
		Report Date	22/12/2015
Client ID	TP07	**Depth (m)**	0.40-0.60

Sieve Size (mm)	Passing %
150.0	
75.0	
63.0	
53.0	
37.5	
26.5	
19.0	
9.5	
4.75	
2.36	
1.18	
0.600	
0.425	
0.300	
0.150	100
0.075	99
0.07	95
0.06	93
0.052	91
0.037	88
0.027	86
0.02	83
0.0144	72
0.0103	66
0.0074	61
0.006	56
0.0053	51
0.0043	46
0.0038	37
0.0022	33



NOTES/REMARKS: -

Moisture Content 41% -2.36mm Soil Particle Density(t/m^3) 1.68

Sample/s supplied by the client

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Authorised Signatory

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Laboratory No. 9926

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ACCURATE QUALITY RESULTS FOR TOMORROW'S ENGINEERING

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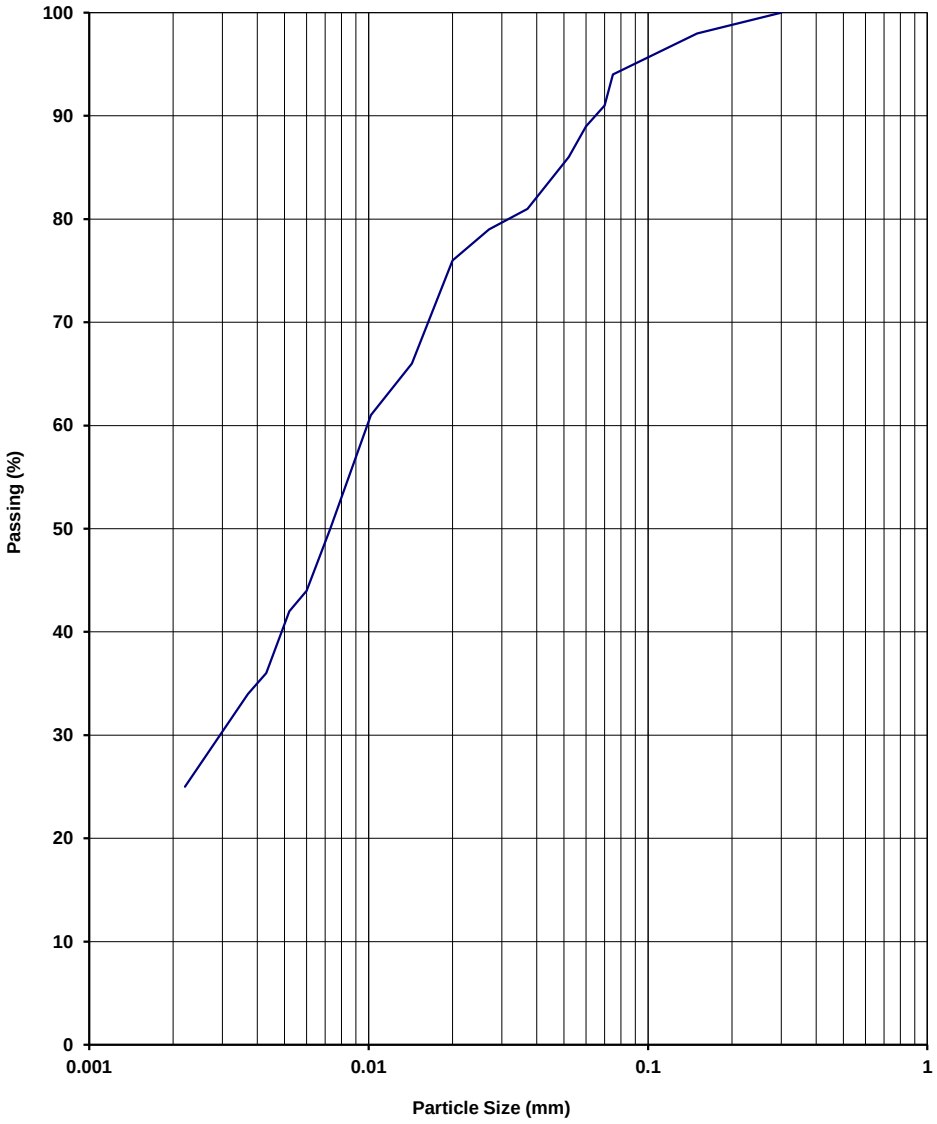
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WA 6107
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PARTICLE SIZE DISTRIBUTION TEST REPORT

Test Method: AS 1289 3.6.3, 3.5.1

Client	Parsons Brinckerhoff Pty Ltd	**Report No.**	15120422-G
Project	2172961A	**Test Date**	17/12/15-22/12/15
		Report Date	22/12/2015
Client ID	TP08	**Depth (m)**	0.20-0.40

Sieve Size (mm)	Passing %
150.0	
75.0	
63.0	
53.0	
37.5	
26.5	
19.0	
9.5	
4.75	
2.36	
1.18	
0.600	
0.425	
0.300	100
0.150	98
0.075	94
0.07	91
0.06	89
0.052	86
0.037	81
0.027	79
0.02	76
0.0143	66
0.0102	61
0.0073	50
0.006	44
0.0052	42
0.0043	36
0.0037	34
0.0022	25



NOTES/REMARKS: -

Moisture Content 40.6% -2.36mm Soil Particle Density(t/m^3) 1.70

Sample/s supplied by the client

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Tested at Trilab Brisbane Laboratory.

Authorised Signatory

C. Channon

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Laboratory No. 9926

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ACCURATE QUALITY RESULTS FOR TOMORROW'S ENGINEERING

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ATTERBERG LIMITS TEST REPORT

Test Method: AS 1289 2.1.1, 3.1.1, 3.1.2, 3.2.1, 3.3.1, 3.4.1

Client	Parsons Brinckerhoff Pty Ltd	**Report No.**	15120412-AL
Project	2172961A	**Test Date**	17/12/15-22/12/15
		Report Date	22/12/2015

Sample No.	15120412	15120416	15120418	15120420	15120422	-
Client ID	TP01	TP03	TP04	TP07	TP08	-
Depth (m)	1.00-1.10	2.30-2.50	1.90-2.10	0.40-0.60	0.20-0.40	-
Liquid Limit (%)	35	45	47	54	53	-
Plastic Limit (%)	22	29	31	33	33	-
Plasticity Index (%)	13	16	16	21	20	-
Linear Shrinkage (%)	3.5	5.0	5.0	6.0	5.5	-
Moisture Content (%)	14.0	36.5	40.5	41.0	40.6	-

Sample No.	-	-	-	-	-	-
Client ID	-	-	-	-	-	-
Depth (m)	-	-	-	-	-	-
Liquid Limit (%)	-	-	-	-	-	-
Plastic Limit (%)	-	-	-	-	-	-
Plasticity Index (%)	-	-	-	-	-	-
Linear Shrinkage (%)	-	-	-	-	-	-
Moisture Content (%)	-	-	-	-	-	-

NOTES/REMARKS: The samples were tested in a natural state, wet sieved and in a 125-250mm mould.

Sample/s supplied by the client * Cracking occurred + Curling occurred

Accredited for compliance with ISO/IEC 17025.
The results of the tests, calibrations, and/or measurements included in this document are traceable to Australian/National Standards.

Tested at Trilab Brisbane Laboratory.

Authorised Signatory

T. Ferguson

NATA ACCREDITED FOR TECHNICAL COMPETENCE

Laboratory No. 9926

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ACCURATE QUALITY RESULTS FOR TOMORROW'S ENGINEERING

Trilab
Soil Rock Calibration

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346A Bilsen Road,
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Ph: +61 7 3265 5656

Perth
2 Kimmer Place,
Queens Park
WA 6107
Ph: +61 8 9258 8323

MOISTURE CONTENT TEST REPORT

Test Method: AS 1289 2.1.1

Client	Parsons Brinckerhoff Pty Ltd	**Report No.**	15120411-MC
Project	2172961A	**Test Date**	17/12/2015
		Report Date	22/12/2015

Sample No.	15120411	15120412	15120413	15120414	15120415	15120416	15120417
Client ID	TP01	TP01	TP01	TP01	TP03	TP03	TP04
Depth (m)	0.10-0.40	1.00-1.10	2.50-2.70	3.80-4.00	0.20-0.50	2.30-2.50	0.20-0.40
Moisture Content (%)	19.5	14.0	22.2	35.5	20.4	36.5	27.8

Sample No.	15120418	15120419	15120420	15120421	15120422	15120423	-
Client ID	TP04	TP04	TP07	TP07	TP08	TP08	-
Depth (m)	1.90-2.10	4.30-4.50	0.40-0.60	4.00-4.30	0.20-0.40	1.40-1.60	-
Moisture Content (%)	40.5	37.4	41.0	46.1	40.6	36.2	-

Sample No.	-	-	-	-	-	-	-
Client ID	-	-	-	-	-	-	-
Depth (m)	-	-	-	-	-	-	-
Moisture Content (%)	-	-	-	-	-	-	-

NOTES/REMARKS:

Sample/s supplied by the client

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Authorised Signatory

T. Ferguson

NATA
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Laboratory No. 9926

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ACCURATE QUALITY RESULTS FOR TOMORROW'S ENGINEERING

Appendix E

Slope/W outputs



APPENDIX M

Pit B Design Plan

10 November 2017

WESFARMERS CURRAGH PTY LTD

B PIT TAILINGS STORAGE FACILITY DESIGN PLAN

Submitted to:
Howard Lief
Wesfarmers Curragh Pty Ltd

REPORT

Report Number. 1532295-052-R-Rev3

Golder Associates

Form of certification (Design plan)

Name of Registered Professional Engineer providing certification:

David Smallhorn

Address of Registered Professional Engineer providing certification:

Golder Associates
147 Coronation Drive
Milton QLD 4064

Statement of relevant experience

I hereby state that I am a Registered Professional Engineer of Queensland (Number 11332) and meet the requirements of the definition of 'suitably qualified and experienced person'.

Statement of certification

All relevant material relied upon by me, including subsidiary certifications of specialist components, where required by the environmental authority, is provided in the attached design plan "Wesfarmers Curragh Pty Ltd B Pit Tailings Storage Facility Design Plan", Reference 1532295-052-R-Rev3, dated 10 November 2017.

I hereby certify that the B Pit tailings storage facility as detailed in the design plan "Wesfarmers Curragh Pty Ltd B Pit Tailings Storage Facility Design Plan", Reference 1532295-052-R-Rev3, dated 10 November 2017:

(i) Has been prepared in accordance with good engineering practice and the design is also consistent with the standards required for structures of the assessed consequence category as set out in the *Manual for assessing consequence categories and hydraulic performance of structures* published by the administering authority

(ii) Is capable of delivering the performance stated in the attached design plan so as to be compliant with the relevant aspects of the EA, provided the structure is constructed or modified in consultation with the designer in the manner specified and the facility is operated and maintained as recommended.

I David Smallhorn, declare that the information provided as part of this certification is true to the best of my knowledge. I acknowledge that it is an offence under section 480 of the Environmental Protection Act 1994 to give the administering authority a document containing information that I know is false, misleading or incomplete in a material particular.

Signed:



David Smallhorn BE CPEng RPEQ 11332
Date: 10th November 2017

Record of Issue

VERSION	DESCRIPTION	CLIENT CONTACT	COMPANY	METHOD OF DELIVERY	DATE
Rev 0	For review	Howard Lief	Wesfarmers Curragh	email	04-May-17
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Rev 3	Additional comments incorporated	Howard Lief	Wesfarmers Curragh	email	10-Nov-17

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Record of Review

VERSION	AUTHORS	AUTHORS	REVIEWER	APPROVED BY	DATE
Rev 0	David Smallhorn	Scott Creighton	Mike Gowan	Scott Creighton	04-May-17
Rev 1	David Smallhorn	Scott Creighton	Mike Gowan	Scott Creighton	18-May-17
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Rev 3	David Smallhorn	Scott Creighton	Mike Gowan	Scott Creighton	10-Nov-17
Title	Principal Civil Engineer		Principal	Principal Water Resources Engineer	
Signatures					

Important information

Your attention is drawn to the document titled - "Important Information Relating to this Report", which is included in APPENDIX J of this report. The statements presented in that document are intended to inform a reader of the report about its proper use. There are important limitations as to who can use the report and how it can be used. It is important that a reader of the report understands and has realistic expectations about those matters. The Important Information document does not alter the obligations Golder Associates has under the contract between it and its client.

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Acronyms, Abbreviations and Terms

Acronyms, Abbreviations and Definitions	
AEP	Annual Exceedance Probability
ANCOLD	Australian National Committee on Large Dams
CHPP	coal handling and preparation plant
DEHP	Department of Environment and Heritage Protection (Queensland)
DSA	Design Storage Allowance
EA	Environmental Authority EPML00643713 dated 31 August 2015
ESS	Extreme Storm Storage
Golder	Golder Associates Pty. Ltd.
ha	hectares
km	kilometres
LOM	Life of Mine
m	metres
MIA	Mine infrastructure area
Ml	Mega litres
ML	Mining Lease
Mtpa	Million tonnes per annum
MRL	Mandatory Reporting Level
RE	regional ecosystem
RL	Reduced level in metres to mine level
WCPL	Wesfarmers Curragh Pty Ltd

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1.0 INTRODUCTION

Wesfarmers Curragh Pty Ltd (WCPL) operates the Curragh Mine Project (Curragh Mine) under Environmental Authority (EA) EPML00643713. WCPL has appointed Golder Associates Pty Ltd (Golder) to design a tailings storage facility (TSF) in B Pit. This report presents the design of the tailings storage facility (TSF) in B Pit, referred to as the B Pit TSF. The design proposes to repurpose an existing mine void to incorporate a containment embankment constructed within the pit using mine waste materials.

This report has generally been written in accordance with the design report format recommended by ANCOLD (2012b) and complies with the requirements of DEHP (2016).

2.0 BACKGROUND

The Curragh Mine commenced operation in 1983 and us an open cut coal mining operation located approximately 6 kilometres (km) north of the township of Blackwater in Central Queensland. The Curragh Mine produces a variety of coking, pulverized coal injected (PCI) and steaming coal products for both export and domestic markets. The Curragh Mine currently operates within 14 mining leases (MLs), ML1878, ML1990, ML80010, ML80011, ML80012, ML80086, ML80110, ML80112, ML80123, ML80171, ML700006, ML700007, ML700008 and ML700009. All tailings and coarse rejects are managed within the two Curragh Mine coal handling and process plants (CHPP). Curragh Mine produces tailings at an average rate around 1,300,000 cubic metres (m^3) per year. Tailings from the coal washing plants are stored in registered structures which are certified on an annual basis. As solids settle out the return water is pumped out of the tailings facility and into the Water Management System for recycling though the CHPPs or used for other industrial applications. Coase rejects are conveyed from the CHPPs into a rejects storage bin for transport via truck to in-pit spoil dumps. Coase rejects are also collected and buried with spoil as part of the rehabilitation process.

The Curragh Mine is currently using Pit A for tailings disposal and it is approaching full storage under the current configuration and deposition methodology. During 2014 Golder completed a Life of Mine tailings storage study, refer Golder (2014), which recommended developing B Pit as the next tailings storage area.

A general location plan for Curragh Mine is shown on Figure 2-1.



Figure 2-1: Location plan

3.0 SCOPE OF WORKS

The scope of works includes:

- A design report to address and satisfy relevant requirements of the Department of Environment and Heritage Protection (DEHP) as set out in the current Environmental Authority (EA) EPML00643713 including DEHP's '*Manual for assessing consequence categories and hydraulic performance of structures*' (2016);
- 'For Construction' drawings for the embankment and associated structures including pipeline access; and
- A construction specification to complement the For Construction drawings, as well as to establish the scope of construction works and the standards of works to be achieved.

4.0 REGULATORY CONTEXT

The B Pit TSF is subject to the regulated structure conditions in the EA No: EPML00643713 for the Curragh Mine. The relevant EA conditions and the Sections of the Design plan that meet and address the condition is summarised below in Table 1.

Table 4-1: Design Plan Sections and related EA conditions

Condition number	EPML00643713 Condition	Document reference section
D1	**Assessment of consequence category** The consequence category of any structure must be assessed by a suitably qualified and experienced person in accordance with the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (EM635)* at the following times: a) prior to the design and construction of the structure, if it is not an existing structure; or b) prior to any change in its purpose or the nature of its stored contents.	Section 9.3
D2	A consequence assessment report and certification must be prepared for each structure assessed and the report may include a consequence assessment for more than one structure.	Section 9.3; Form of certification
D3	Certification must be provided by the suitably qualified and experienced person who undertook the assessment, in the form set out in the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (EM635)*.	Form of certification
D4	**Design and construction[1] of a regulated structure** Conditions D5 to D9 inclusive do not apply to existing structures. Note [1]: Construction of a dam includes modification of an existing dam-refer to the definitions.	Not applicable
D5	All regulated structures must be designed by, and constructed[2] under the supervision of, a suitably qualified and experienced person in accordance with the requirements of the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (EM635).* Note [2]: Certification of design and construction may be undertaken by different persons.	'designed by': Form of certification 'constructed under': not applicable
D6	Construction of a regulated structure is prohibited unless the holder has submitted a consequence category assessment report and certification to the administering authority has been certified by a	Section 9.3; Form of certification;

	suitably qualified and experienced person for the design and design plan and the associated operating procedures in compliance with the relevant condition of this authority.	Section 15.0
D7	Certification must be provided by the suitably qualified and experienced person who oversees the preparation of the design plan in the form set out in the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (EM635),* and must be recorded in the Regulated Dams/Levees register.	Form of certification;
D8	**Regulated structures** must: a) be designed and constructed in accordance with and conform to the requirements of the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (EM635);* b) be designed and constructed with due consideration given to ensuring that the design integrity would not be compromised on account of: i) floodwaters from entering the regulated dam from any watercourse or drainage line; and ii) wall failure due to erosion by floodwaters arising from any watercourse or drainage line. c) have the floor and sides of the dam designed and constructed to prevent or minimise the passage of the wetting front and any entrained contaminants through either the floor or sides of the dam during the operational life of the dam and for any period of decommissioning and rehabilitation of the dam.	a) Section 9.0, Section 9.2, Section 9.3, Section 9.4 b) i) Section 5.2 (the B Pit TSF will not be impacted from floodwaters from any watercourse or drainage line due to diversion of Blackwater creek and the surrounding historic mining activities and spoil dumps). ii) Section 5.2, Section 13.2 c) Section 12.3
D9	Certification by the suitably qualified and experienced person who supervises the construction must be submitted to the administering authority on the completion of construction of the regulated structure, and state that: a) the 'as constructed' drawings and specifications meet the original intent of the design plan for that regulated structure; b) construction of the regulated structure is in accordance with the design plan.	Not applicable – not yet constructed
D10	Operation of a regulated structure, except for an existing structure, is prohibited unless: a) the holder has submitted to the administering authority: i) one paper copy and one electronic copy of the design plan and	a) i) this design plan document to be submitted ii) not applicable at this stage iii) not applicable at this . stage

	certification of the 'design plan' in accordance with condition G6; ii) a set of 'as constructed' drawings and specifications; iii) certification of those 'as constructed drawings and specifications' in accordance with condition G9; iv) where the regulated structure is to be managed as part of an integrated containment system for the purpose of sharing the DSA volume across the system, a copy of the certified system design plan; v) the requirements of this authority relating to the construction of the regulated structure have been met; vi) the holder has entered the details required under this authority, into a Register of Regulated Structures; and vii) there is a current operational plan for the regulated structures.	iv) APPENDIX G v) not applicable at this . stage vi) Operational plan to be prepared prior to commissioning as detailed in Section 15.0.
D11	For existing structures that are regulated structures: a) where the existing structure that is a regulated structure is to be managed as part of an integrated containment system for the purpose of sharing the DSA volume across the system, the holder must submit to the administering authority within 12 months of the commencement of this condition a copy of the certified system design plan including that structure; and b) there must be a current operational plan for the existing structures.	Not applicable – not an existing structure
D12	Each regulated structure must be maintained and operated, for the duration of its operational life until decommissioned and rehabilitated, in a manner that is consistent with the current operational plan and, if applicable, the current design plan and associated certified 'as constructed' drawings.	Not applicable – not yet constructed
D13	Conditions D14 - D17 inclusive only apply to Regulated Structures which have not been certified as low consequence category for 'failure to contain - overtopping'.	See D14 – D17
D14	The Mandatory Reporting Level (the MRL) must be marked on a regulated dam in such a way that during routine inspections of that dam, it is clearly observable.	Not currently applicable – not yet constructed. The MRL is defined in Section 11.3.
D15	The holder must, as soon as practical and within forty-eight (48) hours of becoming aware, notify the administering authority when the level of the contents of a regulated dam reaches the MRL.	Not currently applicable – not yet constructed

D16	The holder must, immediately on becoming aware that the MRL has been reached, act to prevent the occurrence of any unauthorised discharge from the regulated dam.	Not currently applicable – not yet constructed
D17	The holder must record any changes to the MRL in the Register of Regulated Structures.	Not currently applicable
D18	**Design storage allowance** The holder must assess the performance of each regulated dam or linked containment system over the preceding November to May period based on actual observations of the available storage in each regulated dam or linked containment system taken prior to 1 July of each year.	Not currently applicable – not yet constructed
D19	By 1 November of each year, storage capacity must be available m each regulated dam (or network of linked containment systems with a shared DSA volume), to meet the Design Storage Allowance (DSA) volume for the dam (or network of linked containment systems).	Not currently applicable – not yet constructed
D20	The holder must, as soon as possible and within forty-eight (48) hours of becoming aware that the regulated dam (or network of finked containment systems) will not have the available storage to meet the DSA volume on 1 November of any year, notify the administering authority.	Not currently applicable – not yet constructed
D21	The holder must, immediately on becoming aware that a regulated dam (or network of linked containment systems) will not have the available storage to meet the DSA volume on 1 November of any year, act to prevent the occurrence of any unauthorised discharge from the regulated dam or linked containment systems.	Not currently applicable – not yet constructed
D22	Each regulated structure must be inspected each calendar year by a suitably qualified and experienced person.	Not currently applicable – not yet constructed
D23	At each annual inspection, the condition and adequacy of all components of the regulated structure must be assessed and a suitably qualified and experienced person must prepare an annual inspection report containing details of the assessment and include recommended actions to ensure the integrity of the regulated structure.	Not currently applicable – not yet constructed
D24	The suitably qualified and experienced person who prepared the annual inspection report must certify the report in accordance with the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (EM635)*.	Not currently applicable – not yet constructed

D25	The holder must: a) Within 20 business days of receipt of the annual inspection report, provide to the administering authority: i) The recommendations section of the annual inspection report; and ii) If applicable, any actions being taken in response to those recommendations; and b) If, following receipt of the recommendations and (if applicable) actions, the administering authority requests a full copy of the annual inspection report from the holder, provide this to the administering authority within 10 business days of receipt of the request.	Not currently applicable – not yet constructed
D26	**Transfer arrangements** The holder must provide a copy of any reports, documentation and certifications prepared under this authority, including but not limited to any Register of Regulated Structures, consequence assessment, design plan and other supporting documentation, to a new holder on transfer of this authority.	Not currently applicable
D27	**Decommissioning and rehabilitation** Dams must not be abandoned but be either: a) decommissioned and rehabilitated to achieve compliance with condition D28; or b) be left in-situ for a beneficial use(s) provided that: i) it no longer contains contaminants that will migrate into the environment; and ii) it contains water of a quality that is demonstrated to be suitable for its intended beneficial use(s); and iii) the administering authority, the holder of the environmental authority and the landholder agree in writing that the dam will be used by the landholder following the cessation of the environmentally relevant activity(ies).	Not currently applicable Closure discussed in Section 13.0.
D28	After decommissioning, all significantly disturbed land caused by the carrying out of the environmentally relevant activity(ies) must be rehabilitated to meet the following final acceptance criteria: a) the landform is safe for humans and fauna; b) the landform is stable with no subsidence or erosion gullies for at least three (3) years; c) any contaminated land (e.g. contaminated soils) is remediated and rehabilitated; not allowing for acid mine drainage; or there is no	Not currently applicable

	ongoing contamination to waters (including groundwater); d) rehabilitation is undertaken in a manner such that any actual or potential acid sulfate soils on the area of significant disturbance are treated to prevent or minimise environmental harm in accordance with the Instructions for the treatment and management of acid sulfate soils (2001); e) all significantly disturbed land is reinstated to the pre-disturbed soil suitability class; f) for land that is not being cultivated by the landholder: a. a. groundcover, that is not a declared pest species is established and self-sustaining b. vegetation of similar species richness and species diversity to pre-selected analogue sites is established and self-sustaining, and c. c. the maintenance requirements for rehabilitated land is no greater than that required for the land prior to its disturbance caused by carrying out the petroleum activity(ies). i) for land that is to be cultivated by the landholder, cover crop is revegetated, unless the landholder will be preparing the site for cropping within 3 months of petroleum activities being completed.	
D29	**Register of Regulated Structures** A Register of Regulated Structures must be established and maintained by the **holder** for each **regulated structure**.	Curragh currently maintains Register of Regulated Structures. Pit B TSF will be added to the register upon commissioning.
D30	The holder must provisionally enter the required information in the Register of Regulated Structures when a design plan for a regulated structure is submitted to the administering authority.	Submitted to DEHP as part of the Design plan submission
D31	The holder must make a final entry of the required information in the Register of Regulated Structures once compliance with condition D10 and D11 has been achieved.	Not currently applicable – not yet constructed
D32	The holder must ensure that the information contained in the Register of Regulated Structures is current and complete on any given day.	Curragh complies
D33	All entries in the Register of Regulated Structures must be approved by the chief executive officer for the holder of this authority, or their delegate, as being accurate and correct.	Curragh complies

D34	The holder must, at the same time as providing the annual return, supply to the administering authority a copy of the records contained in the Register of Regulated Structures, in the electronic format required by the administering authority.	Curragh complies
D35	**Transitional arrangements** All existing structures that have not been assessed in accordance with either the Manual or the former Manual for Assessing Hazard Categories and Hydraulic Performance of Dams must be assessed and certified in accordance with the Manual within 6 months of amendment of the authority adopting this schedule.	Not applicable – not an existing structure
D36	All existing structures must subsequently comply with the timetable for any further assessments in accordance with the Manual specified in **Table D1**, depending on the consequence category for each existing structure assessed in the most recent previous certification for that structure.	Not applicable – not an existing structure
D37	**Table D1** ceases to apply for a structure once any of the following events has occurred: a) It has been brought into compliance with the hydraulic performance criteria applicable to the structure under the Manual; or b) It has been decommissioned; or c) It has been certified as no longer being assessed as a regulated structure.	Not applicable – not an existing structure
D38	Certification of the transitional assessment required by condition D35 and D36 (as applicable) must be provided to the administering authority within 6 months of amendment of the authority adopting this schedule.	Not applicable – not an existing structure

5.0 SUMMARY OF BACKGROUND CONDITIONS

The following section outlines the background conditions for the proposed B Pit TSF. The background conditions documented in this section are also relevant inputs into Section 9.3 'DEHP Consequence Category'.

5.1 B Pit TSF description

Figure 5-1 shows the location of the Pit B TSF.

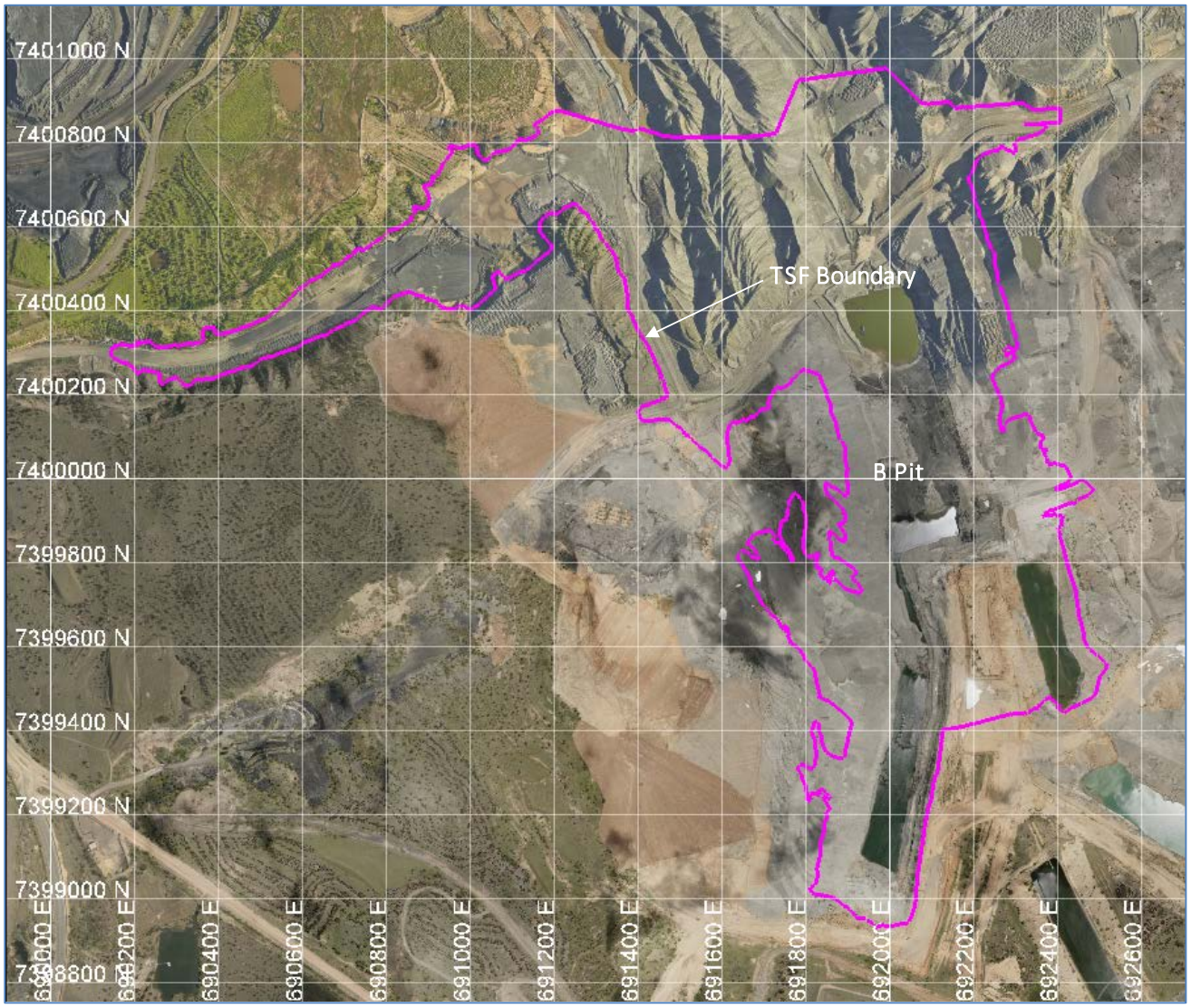


Figure 5-1: B Pit TSF site plan

The TSF can be described as having:

- An approximate footprint area of 144 ha
- To be constructed within an abandoned open cut mine void, previously operated as B Pit
- An available tailings storage volume of approximately 26.8 M m^3 under the Stage 2 design presented in this report

- Pit floor topography grading from north to south with an average slope of approximately 1%
- Variable pit depth varies approximately ranging between 45 and 75 m
- A low wall mine waste dump along the western side of the pit
- A high wall along the eastern side of the pit
- Disturbed undulating topography in the vicinity of the pit.

Figure 5-2 and Figure 5-3 show typical images of the site.



Figure 5-2: B Pit looking south from northern end.



Figure 5-3: B Pit looking north from southern end.

5.2 Water courses

5.2.1 Pre mining

The pre mining natural water courses in the vicinity of B Pit are shown on Figure 5-4 in light blue. Figure 5-5 shows the current water courses with the diversion works shown in dark blue and the natural drainage shown in light blue. Drainage flow would occur from south to north.

With reference to Figure 5-4 and Figure 5-5 any potential seepage from B Pit to outside the mining lease is unlikely to occur based on the diversion of the Blackwater Creek and the removal of existing drainage course through pit excavation to the north of B Pit.

The B Pit TSF will not be impacted from floodwaters entering from any watercourse or drainage line due to diversion of Blackwater creek and the surrounding historic mining activities and spoil dumps. Additionally, the embankment wall is within the open cut and would not be subject to erosion by floodwaters.

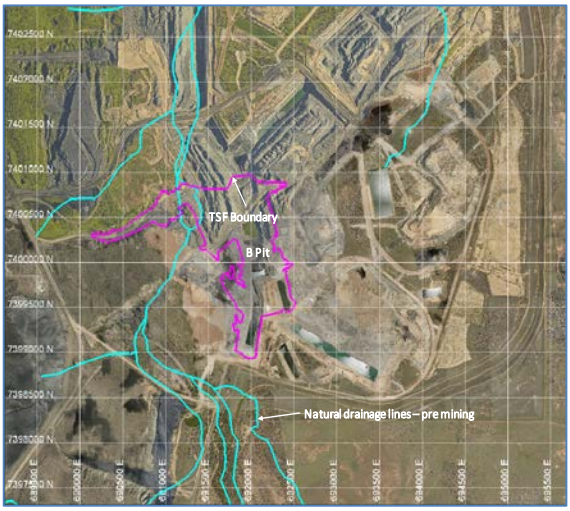


Figure 5-4: Natural drainage lines in vicinity of B Pit.



Figure 5-5: Current drainage

5.3 Site geology

The pre mined site surface geology, reproduced from Queensland Government 'Geoscientific Globe' 1:100 000 detailed geology mapping, is presented on Figure 5-6. Additional information has also been included on Figure 5-6 comprising:

- Faulting information observed during the Golder site inspection on 27 October 2016, refer APPENDIX B
- Near surface sand layers provided by Curragh.

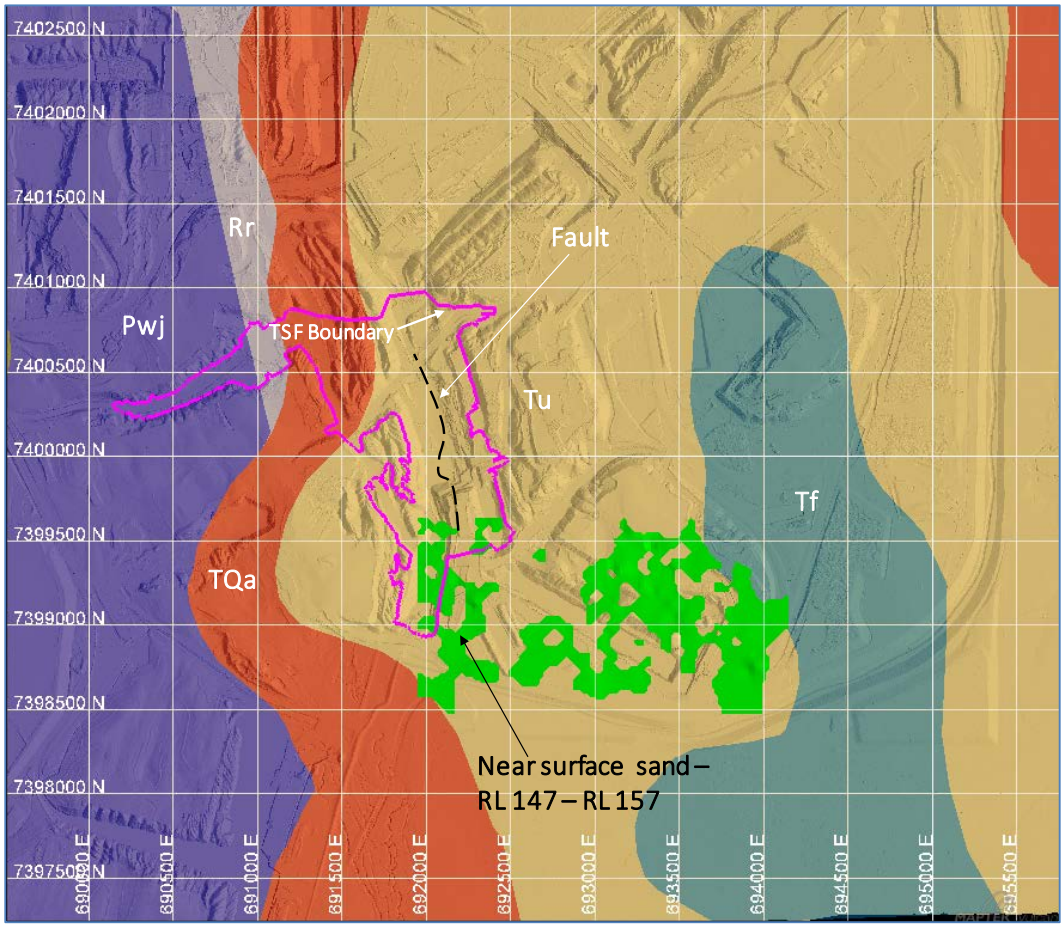


Figure 5-6: Site surface geology

The geological descriptions for the geology shown on Figure 5-6, as provided in the Queensland Government 'Geoscientific Globe, is described as:

- Duaringa formation (Tu) of early tertiary age – Mudstone, sandstone, conglomerate, siltstone, soil shale, lignite
- Late Tertiary – Quaternary aged Alluvium (TQa) – Red-brown mottled, poorly consolidated sand, silt, clay, minor gravel; high – level alluvial deposits (generally related to present stream valleys
- Rewan group of early Triassic age (Rr) - - Lithic sandstone, pebbly lithic sandstone, green to reddish brown mudstone, and minor volcanilithic pebble conglomerate (at base)
- Rangal Coal Measures of Late Permian age (Pwj) – Calcareous sandstone, calcareous shale, mudstone, coal, concretionary limestone.

The fault line shown on Figure 5-6 is believed to dip to the west with a throw of around 15 to 20 m towards the west.

Information provided by Curragh (2016) and Curragh (2017) indicates:

- Faults around the Curragh mine can act as either aquitards or aquifers although generally any water being released from fault zones is at very low flow rates
- Hydraulic conductivity for the Tertiary sediments (TQa) between A pit and Blackwater creeks (immediately south of B pit) is estimated to be low
    - With almost no possibility of vertical leakage

- With likely seepage being horizontal and being limited by the lack of lateral continuity.

The geological stratigraphy at both A Pit and D-E-F Pits has been described in Curragh (2016) and Curragh (2017) as:

- Alluvium, up to 2 m thick overlying
- Tertiary aged rock (weathered sandstone, siltstone, gravels and sands) approximately 6 m to 10 m thick overlying
- Permian aged rock (sandstone, calcareous shale, mudstone and coal).

This stratigraphy is considered to be appropriate for the B Pit TSF area.

5.4 Regional Ecosystem

The regional ecosystem details, reproduced from Queensland Government 'Vegetation Management Globe', is presented on Figure 5-7.

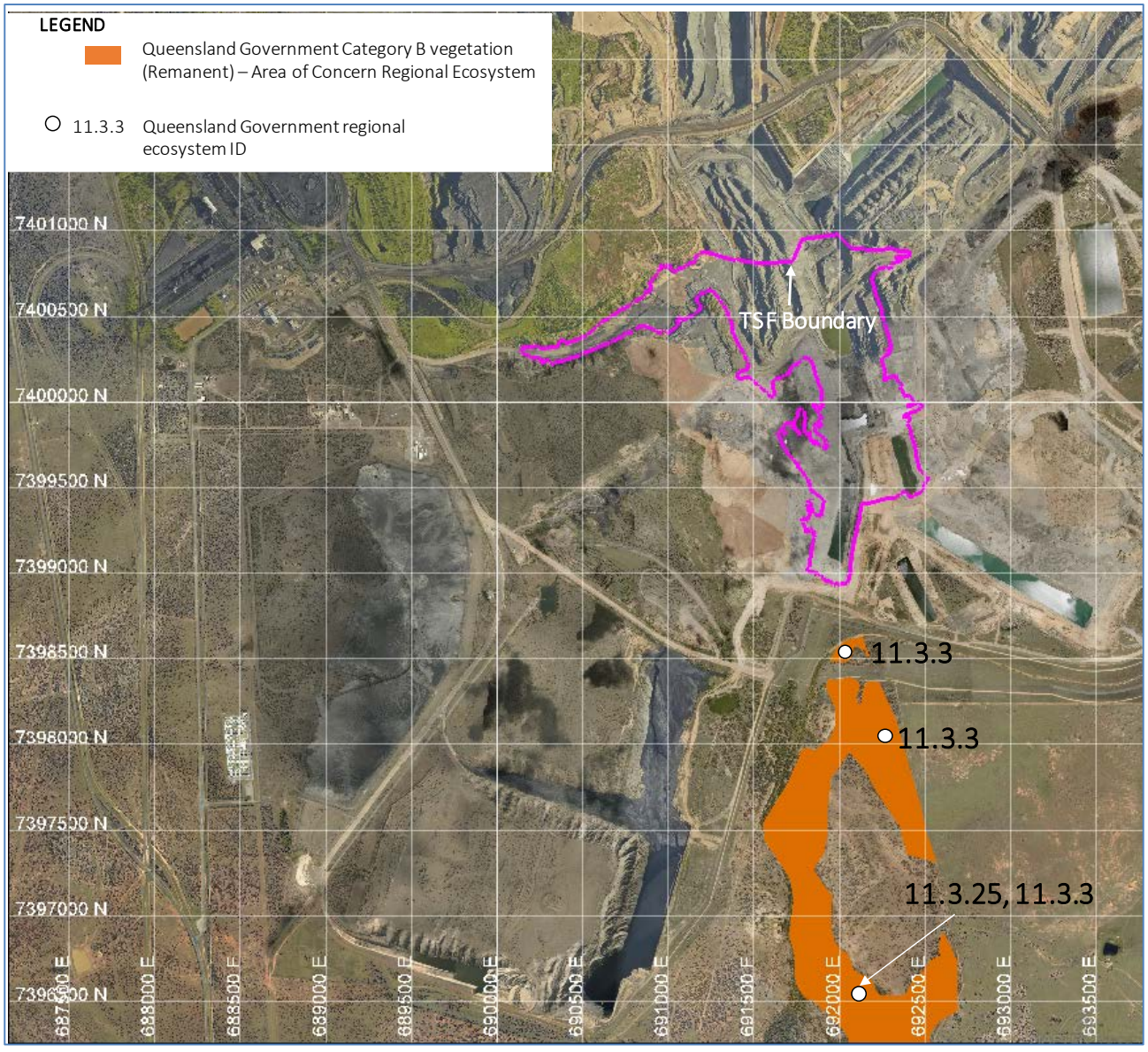


Figure 5-7: B Pit area regional ecosystem plan.

The Category B vegetation shown on Figure 5-7 is described by the Queensland Government as:

- 11.3.3 Corymbia terminalis low open woodland on basic metamorphics
- 11.3.25 Eucalyptus tereticornis or E. camaldulensis woodland fringing drainage lines.

5.5 Seismic risk

The earthquake hazard at Curragh is currently considered low by Australian Standards, when compared to other sites within Australia using hazard maps in Burbidge (2012). However, this low level of seismicity does not imply that large damaging earthquakes will not occur in the future. The low level of seismicity suggests that long recurrence intervals exist between events.

It has been observed that earthquakes larger than Magnitude 5.0 cause damage. The closet location to the TSF site that has experienced earthquakes of magnitude greater than 5.0 is Eidsvold, approximately 317 km south east of the Curragh. On 15th February 2015 the town of Eidsvold experienced a Richter local magnitude (ML) 5.2 earthquake Future seismic activity from this area is unlikely to pose a hazard to the TSF due to degradation of the ground motion over the large distance.

Historical earthquake records indicate that the past seismic events that have occurred in close proximity to TSF have earthquake magnitudes less than 5.0. Figure 5-8 shows all recorded earthquakes that have occurred within 200 km of Curragh since the year 1955 with ML magnitudes. The data has been sourced from the Geoscience Australia. :

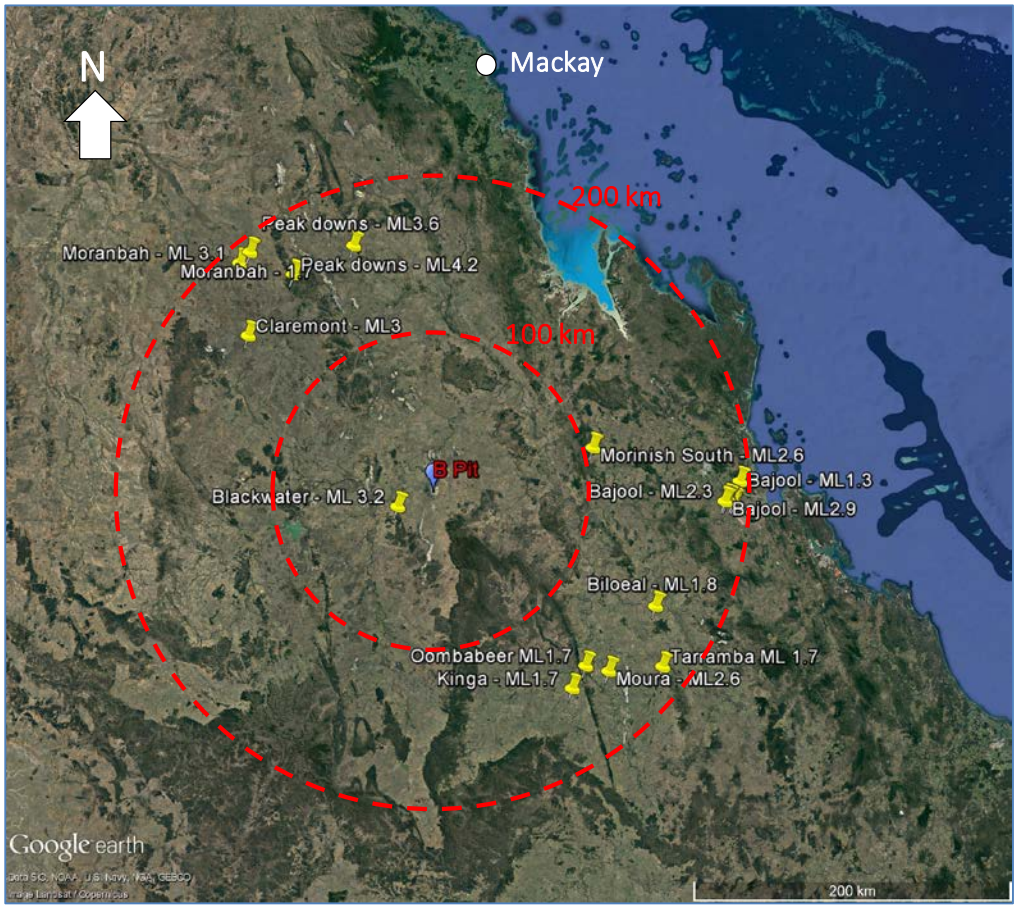


Figure 5-8: Earthquake locations within 200 km of the B Pit TSF site.

5.6 Baseline groundwater quality

Curragh (2015) documents groundwater quality information from monitoring bores located on the eastern edge of Pit A and founded in Tertiary material below the level of the Blackwater Creek, refer (Figure 5-9). The water quality results for May 2015 are shown in Table 2.

Table 5-1: Pit A North and Blackwater Creek water quality - May 2015

BORE ID	SWL (mbgl)	SWL (m RL)	Flow rate (L/min)	Field pH	Field EC µS
1301A MB (shallow)	6.18	145.65	<0.1	7.41	9 220
1301B MB (deep)	5.96	145.74	0.3	6.6	16 410
1304B MB (deep)	6.32	147.01	<0.05	6.52	2 860

No groundwater quality information was available for monitoring bore RN 165387 located on the south eastern edge B Pit.

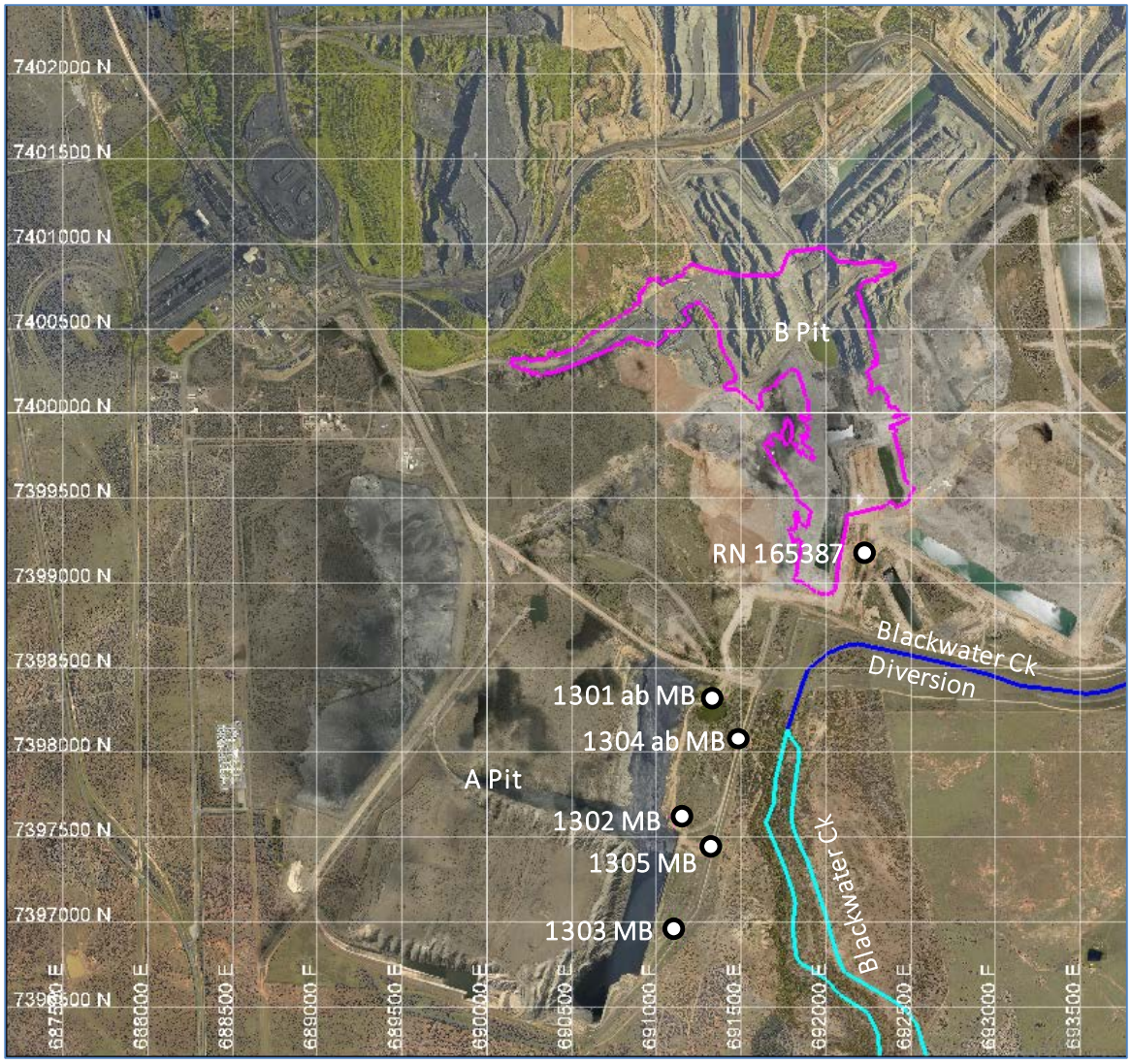


Figure 5-9: Monitoring bore locations Pit A and Pit B.

6.0 TAILINGS PROPERTIES

6.1 Physical properties

The physical properties of the tailings are shown in Table 6-1.

Table 6-1: Tailings parameters

Parameter	Value	Unit	Source
Annual production rate	1 040 000[1]	tpa	Curragh
Particle Size	≤0.5	mm	Sedgman
Particle density	1.65		Curragh
Solids concentration – m/m	37.4	%	Curragh
Solids concentration – v/v	26.5	%	Curragh
Slurry density	1.17	t/m^3	Curragh
Tailings initial settled dry density	0.8	t/m^3	Golder
Tailings beaching angle[2]			
above water	0.5	%	Golder
below water	3.0	%	Golder

6.2 Geochemical properties

The geochemical data for tailings liquor from the coal handling process plants has been provided for 2013 and is shown in Table 6-2.

Table 6-2: Geochemical tailings properties.

Date	pH		EC (µS)	
	CHPP1	CHPP2	CHPP1	CHPP2
24/9/2013	8.22	8.25	4 630	756
27/9/2013	7.38	7.89	1 656	650
30/9/2013	8.49	8.08	3 950	2 050
14/10/2013	7.66	8.21	4 750	4 000

Curragh (2015) (Appendix I) documents the tailings chemistry as:

- pH (average) = 8.02
- EC (average) = 3 000 µS.

[1] This value is equivalent to 1,300,000 m^3/annum with a tailings settled dry density of 0.8 t/m^3

[2] Based on 2013 aerial and bathymetry survey for A Pit

7.0 TAILINGS STORAGE FACILITY DESIGN FEATURES

The Pit B TSF design requires the construction of a containment embankment at about the middle of the pit to prevent tailings from entering H Pit, which is still active and located to the north east of the embankment. Design drawings are presented in APPENDIX A. Other associated works comprise:

- The extension of slurry pipelines, from the existing slurry pipe lines to the Pit A TSF, to the Pit B TSF embankment
- The installation of decant return water pontoon pumps at the southern end of the Pit B TSF
- The construction of decant return water pipe lines.

The details of the TSF earthworks and piping design are provided in the following sections.

7.1 Site selection

The TSF site (Figure 2-1 and Figure 7-2) was selected following a TSF options study reported by Golder (2014). The advantages of the site include:

- A capacity providing up to 18 years of tailings storage based on
  - An annual deposition rate of 1 040 000 t
  - A maximum tailings elevation of RL 145 m
- Reduced potential for off-site spillage as the site is located within an existing mine void
- Low off-site seepage potential based on the surrounding geology (Duaringa formation) having a reported low horizontal hydraulic conductivity in the order of 0.05 to 0.6 m/day, refer Curragh (2016) (APPENDIX I)
- Within 3 km of the CHPP.

The containment embankment alignment is shown in Figure 7-2 and was selected on the basis of:

- Existing access from Ramp 4
- Minimising the embankment material volume
- Improved pit foundation conditions when compared to the Pit H area, north of the embankment alignment, based on a geotechnical site inspection by Golder, refer site notes APPENDIX B.

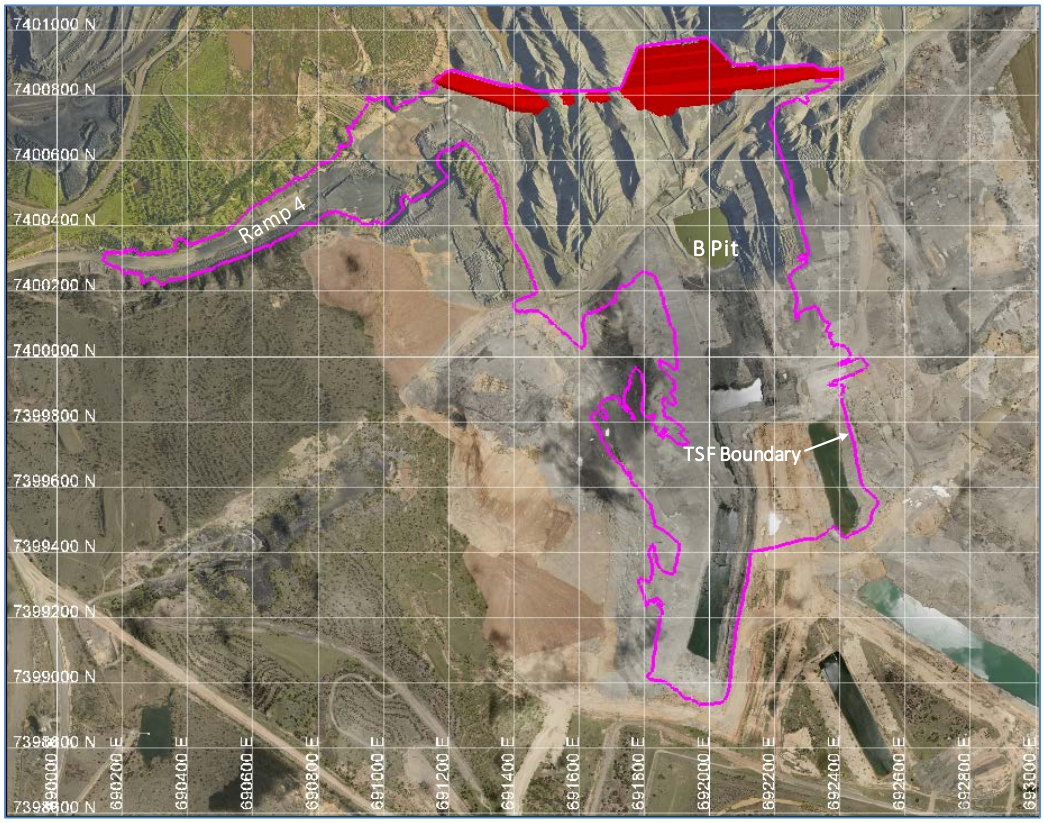


Figure 7-1: B Pit TSF site with containment embankment at Stage 1 height.

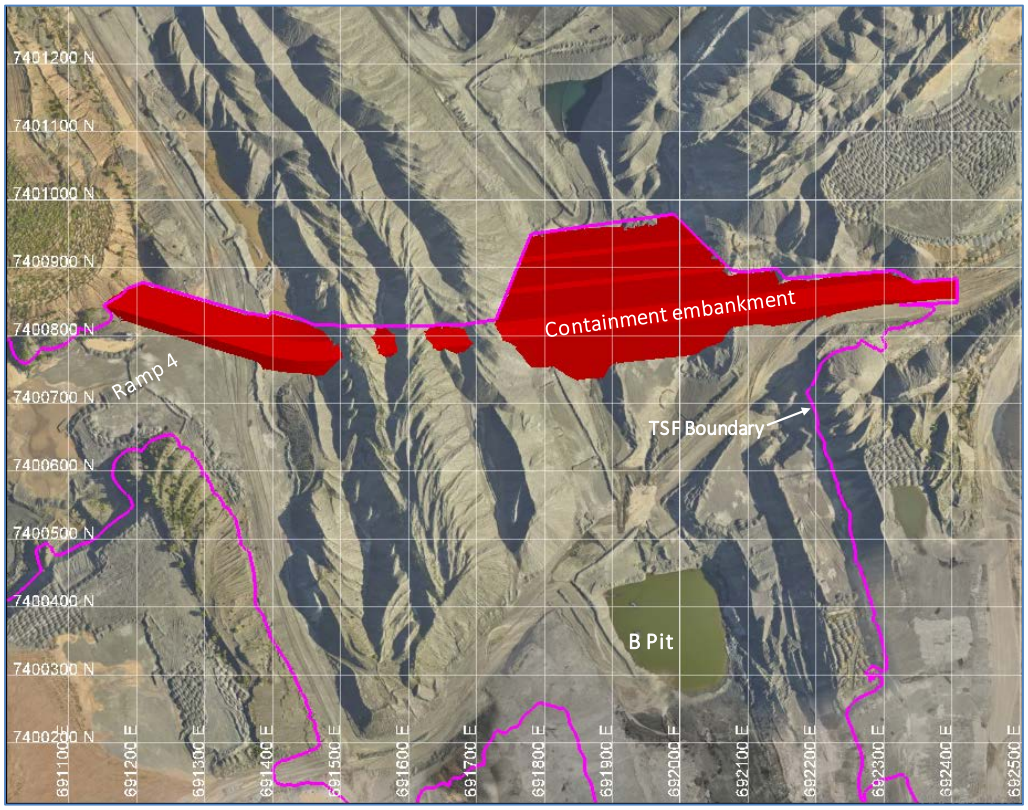


Figure 7-2: B Pit TSF containment embankment at final height.

7.2 TSF configuration

The TSF will occupy an approximate total area of 144 ha at final storage level with containment provided by the pit void and from a containment embankment at the northern end of Pit B. To defer capital expenditure the TSF development will be a staged construction with two raises.

The TSF will have a decant area located at the southern end of Pit B. There is one permanent floating pontoon pump to be used to abstract supernatant water. Temporary high wall pumps can be utilised when required.

The general TSF design configuration is summarised below.

Table 7-1: TSF design configuration

Parameter	Stage 1	Stage 2	Units
Embankment construction Type	Valley embankment	Downstream raise	na
Construction material	Mine waste and coal rejects	Coal rejects	na
Embankment crest level	125	147	RLm (mine)
Embankment crest width	33	33	m
Internal embankment slope	1V:1.3H	1V:1.3H	na
External slope bench levels	105	105, 125	RLm (mine)
External bench width	8	8	m
External embankment slope between benches	1V:1.8H	1V:2H	na
Max embankment Height above 2017 pit surface	19	57	m
Embankment length	290 m	1 245 m	m
Maximum tailings level at final storage	113.5	135	RLm (mine)
Storage surface area at final stage storage elevation	51.99	116.2	ha
Calculated Storage volume	9 705 440		Mm^3
Calculated Storage	3.8	20	years

The Pit B TSF will not have a spillway, as no external containment embankments, above the exiting ground surface, form part of the design.

7.2.1 Construction material features

The mine waste and CHPP rejects will be used to construct the embankment.

7.2.1.1 Stage 1

The Stage 1 embankment will be constructed using selected mine waste, with a layer of reject on the upstream slope to provide a filter against for tailings migration.

7.2.1.2 Stage 2

The Stage 2 raise will use only rejects, as the mine needs an area to dispose of the CHPP rejects.

7.3 Proposed operating conditions

The operational philosophy is based on the use of sub-aerial deposition i.e. deposition above water. This system:

- Maximises storage efficiency due to the development of a flatter beach slope than would occur below water
- Allows desiccation of the tailings beach, maximising settled density and thus storage efficiency
- Allows for the opportunity for rapid recovery of water for reuse and to minimise the potential for seepage.

Tailings deposition will be by one or more single point discharges, one at the eastern end of the embankment, in tailings pipe cut 2 (APPENDIX A Drawing 001) which will gradually retreat up Ramp 4 as the tailings level increases, and one off the embankment to prevent water ponding against the embankment. It should be noted that the Pit B TSF embankment has not been designed as a water retaining structure and hence ponding water is to be kept well away from it.

A decant pumping system will be operated to maintain freeboard within the TSF, with the decant water returned to the CHPP as a priority.

8.0 GEOTECHNICAL ASSESSMENT

This section provides the basis for the geotechnical material parameters adopted and used in the geotechnical analyses of the embankment, as well as an assessment of the existing foundation conditions.

8.1 Assessment of construction material geotechnical properties

As previously mentioned, the embankment is to be constructed using mine waste and rejects.

8.1.1 Laboratory testing

Laboratory testing was conducted on mine waste materials from H Pit, H Pit Pollux interburden and rejects with the test results provided in APPENDIX C. The tests conducted comprised:

- Classification tests (particle size distribution and Atterberg)
- Moisture density relationship
- Direct shear tests.

The laboratory results indicate the interburden and mine waste materials are predominantly sandy silty gravels with liquid limits varying from 31% to 33%.

Table 8-1: Particle size distribution and liquid limit summary

Material description	Particle size distribution			Liquid Limit (%)
	Clay and Silt (%)[1]	Sand (%)[1]	Gravel (%)[1]	
H Pit mine waste	35	30	35	33
H Pit pollux Interburden	27	33	40	31
Rejects	4	51	45	non plastic

1. Material descriptions based on particle size documented in AS1726

The direct shear strength results presented as cohesion (c), internal friction angle (ϕ) and density are shown in Table 8-2.

Table 8-2: Direct shear strength and density results.

Material description	Wet density at Optimum Moisture Content, ɣ (kN/m^3)	Peak strength		Residual strength	
		c (kPa)	ϕ (degrees)	c (kPa)	ϕ (degrees)
H Pit mine waste	21.5	99.9	19.1	98.8	18.9
H Pit pollux Interburden	21.7	116.1	26.0	115.6	25.8
Rejects	16.9	19.0	32.1	17.0	31.9

The cohesion values for the mine waste, interburden and rejects materials shown in Table 8-2 are much higher and the friction angle somewhat lower than historical effective shear strength assessments of mine waste materials from the Bowen Basin. We consider the direct shear test results to be representative of static total (undrained) shear strength rather than static effective shear strength.

The wet density values in Table 8-2 are also higher than historical assessments of mine waste material from the Bowen Basin. We consider the laboratory densities to be at the upper end of densities, rather than typical, based on historical information and the density testing occurring under optimum conditions.

Simmons & McManus (2004), APPENDIX D, present typical static effective shear strength and density parameters for mine waste based on back analysis of mine waste dump failures throughout the Bowen Basin, QLD.

8.1.2 Interpretation of geotechnical parameters

8.1.2.1 Static geotechnical parameters

Table 8-3 presents the adopted static shear strength and unit weighs for the construction materials. Table 8-4 documents the basis for these material parameters.

Table 8-3: Selected geotechnical parameters for construction materials.

Material	Bulk density ɣ (kN/m^3)	Effective shear strength		Undrained shear strength		Permeability	
		c' (kPa)	ϕ' (degrees)	c (kPa)	ϕ (degrees)	Hydraulic conductivity (m/s)	Ky/Kx
Mine waste - Saturated	20	20	25	100	19	1 x 10^{-4}	0.5
Mine waste - Unsaturated	18	50	30	100	19	1 x 10^{-6}	0.5
Rejects	15	0	40	0	40	1 x 10^{-2}	1

Table 8-4: Basis for selection of construction material parameters

Material	Basis
Mine waste - Saturated	■ Unit weight - Simmons & McManus (2004), category 3 material ■ Effective strength - Simmons & McManus (2004), category 3 material ■ Undrained shear strength – direct shear testing, Section 8.1 ■ Permeability – Sherwood (2013)
Mine waste - Unsaturated	■ Unit weight - Simmons & McManus (2004), category 3 material ■ Effective strength - Simmons & McManus (2004), category 3 material ■ Undrained shear strength – direct shear testing, Section 8.1 ■ Permeability – Sherwood (2013)
Rejects	■ Unit weight based on Look (2007) ■ Effective and undrained shear strength – 300 mm x 300 mm direct shear testing on rejects from Lake Vermont at strain rate of 0.5 mm / minute (APPENDIX C). ■ Permeability – US Army Corps of Engineers (1993)

8.1.2.2 Seismic geotechnical parameters

The material shear strength parameters under seismic loading conditions were obtained by reducing the undrained material parameters in Table 8-3 by 20%, in accordance with the US Army Corps (1984) method to allow for strain weakening following seismic loading.

Table 8-5: Selected seismic geotechnical strength parameters.

Material	Bulk density ɣ (kN/m^3)	Seismic shear strength	
		c (kPa)	ϕ (degrees)
Mine waste - Saturated	20	80	15
Mine waste - Unsaturated	18	80	15
Rejects	14	0	32

8.2 Embankment foundation

Curragh has provided the following information on the B Pit foundation conditions;

- Survey information
  - Lidar surface topography data following completion of mining 'Lidar1602-CS-Running.00t'
  - Surface topography at 2017 'Current surface.dxf'
  - Pit bathymetry below stored water 'bpitbatho1610.dxf'
- Geological section along the embankment axis (developed by Raine and Associates).

Based on this information the subsurface material stratigraphy occurring beneath the embankment foundation can be summarized as:

- Non engineered mine waste backfill (silts, sands, gravels, cobbles) ranging in thickness from 5 m to 25 m overlying
- Siltstone with potential zones shearing / faulting up to 20 m.

The above materials are likely to exhibit the following characteristics:

- The mine waste and the siltstone is likely to be subject to differential movement over time
- Piping could occur through the mine waste under a hydraulic gradient from the TSF.

These foundation conditions are not considered ideal geotechnical conditions for an embankment foundation, but are considered to be manageable through embankment design engineering solutions which comprise:

- A wide embankment which can tolerate settlement
- A downstream batter slope which is intended to reduce hydraulic head and minimise the potential for foundation piping based on a Lanes creep ratio of between 2.5 and 3.0 for boulders, gravel and sand.

8.2.1 Assessment of foundation geotechnical properties

8.2.1.1 Static geotechnical parameters

Table 8-6 presents the geotechnical parameters adopted for the foundation materials.

Table 8-6: Assessed foundation geotechnical parameters

Material	Bulk density ɣ (kN/m³)	Effective shear strength		Undrained shear strength		Permeability	
		c' (kPa)	ϕ' (degrees)	c (kPa)	ϕ (degrees)	Hydraulic conductivity (m/s)	Ky/Kx
Mine waste - Saturated	20	20	25	100	19	1×10^{-4}	0.5
Mine waste - Unsaturated	18	50	30	100	19	1×10^{-6}	0.5
Permian aged rock -Siltstone	20	500	28	500	28	1×10^{-8}	0.02

Table 8-7: Basis for selection of foundation parameters

Material	Basis
Mine waste - Saturated	■ Unit weight - Simmons & McManus (2004), category 3 material ■ Effective strength - Simmons & McManus (2004), category 3 material ■ Undrained shear strength – direct shear testing, Section 8.1 ■ Permeability – Sherwood (2013)
Mine waste - Unsaturated	■ Unit weight - Simmons & McManus (2004), category 3 material ■ Effective strength - Simmons & McManus (2004), category 3 material ■ Undrained shear strength – direct shear testing, Section 8.1 ■ Permeability – Sherwood (2013)
Permian aged siltstone	■ Unit weight - Look (2007) ■ Strength – Hoek and Brown (1997) ■ Permeability – Curragh (2016), Curragh (2017)

8.2.1.2 Seismic geotechnical parameters

The material shear strength parameters under seismic loading conditions were obtained by reducing the undrained material parameters in Table 8-3 by 20%, in accordance with the US Army Corps (1984) method to allow for strain weakening following seismic loading.

Table 8-8: Selected shear strength and density for embankment fill and rejects.

Material	Bulk density ɣ (kN/m³)	Seismic shear strength	
		c (kPa)	ϕ (degrees)
Mine waste - Saturated	20	80	15
Mine waste - Unsaturated	18	80	15
Permian aged Siltstone	20	400	23

8.3 Tailings properties

The tailings characterisation is provided in Table 8-9.

Table 8-9: Assessed tailings geotechnical parameters.

Parameter	Value	Basis
Undrained strength ratio (Su/σv')	0.15	Golder - Engineering experience
Settled density	12 kN/m^3	Curragh
Hydraulic conductivity	1 x 10^{-7} m/s	Golder, testing at Coppebella Coal Mine
Hydraulic conductivity ratio (k_y/k_x)	0.5	Golder

8.4 In situ sub surface material permeability near B Pit

This section provides an assessment of the permeability of the sub surface materials near B Pit, as defined in Section 5.3, for the purpose of assessing potential out of pit seepage as documented in Section 12.3.

The permeability parameters and the basis for selection are shown in Table 8-9.

Table 8-10: Permeability parameters for in situ materials.

Material	Hydraulic Conductivity (m/s)	k_y/k_x ratio	Basis
Alluvium	1.16 x 10^{-5}	0.1	Curragh (2017), Flood plain alluvium
Tertiary aged rock (weathered)	6.94 x 10^{-6}	0.1	Curragh (2017), Duaringa formation
Permian rock	1.00 x 10^{-8}	0.02	Curragh (2016)

8.5 Liquefaction potential of foundation and embankment materials

A liquefaction screening assessment was carried out on the mine waste (foundation and embankment materials) and rejects (embankment material) based on the methods outlined in Fell et. al. (2005). Figure 8-1 presents particle size distribution curves for the Pit H mine waste and interburden and rejects materials along with the approximate zone for liquefiable fill materials based on Hunter and Fell (2003) as referenced in Fell et. al. (2005).

The particle size distribution results shown in Figure 8-1 indicate that the Pit H materials and rejects may be liquefiable under certain conditions. However, additional screening criteria by Collins and Tjoumas (2003) below, as referenced in Fell et. al. (2005), indicates that the mine waste, interburden and rejects materials is unlikely to be liquefiable.

i) Liquefaction possible when water content (w_c) ≥ 0.9 liquid limit (w_L)

The water content of the mine waste and interburden materials were calculated at approximately 18% (assuming a specific gravity of 2.65 and a dry density of 1.8 t/m^3) and assuming fully saturated conditions. This was less than the liquid limit X 0.9 = 30%

The rejects could not be assessed for liquid limit as the material contains <5% fines

ii) Liquefaction possible when Liquidity Index (I_L) ≥ 0.75

The liquidity index of the mine waste and interburden materials were calculated at approximately 0.0625 which is less than 0.75.

iii) Liquefaction possible when Unconfined compressive strength (qu) ≤50 – 70 kN/m^2

The direct shear testing documented in Section 8.1.1 indicates that the rejects, mine waste and interburden materials are expected to have qu > 70 kN/m^2

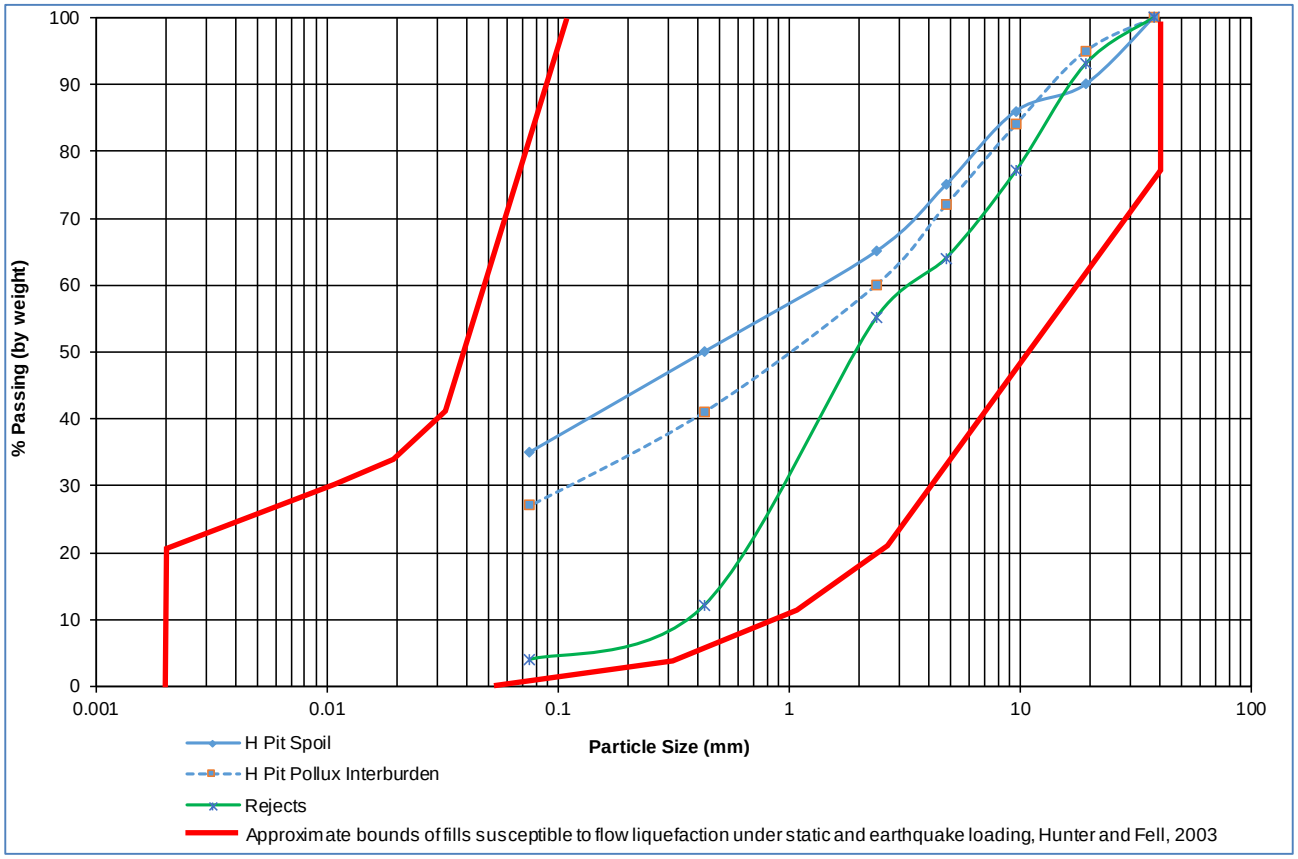


Figure 8-1: Particle size distribution curves for Pit H mine waste, Pit H interburden and rejects with zone of liquefiable fills.

8.6 Reject filter assessment

An assessment was undertaken on the coal rejects to confirm the suitability of the rejects as a filter for both the mine waste and the tailings. The assessment was undertaken in accordance with the Sherard and Dunnigan method as documented in USDA (1994).

The particle size distribution laboratory test results for Curragh mine waste and rejects (Section 8.1.1) was used for the assessment along with particle size distribution results for coal tailings from Coppabella coal mine. The Coppabella coal mine tailings are considered to have similar properties as the Curragh tailings have.

The results of the assessment are shown in Figure 8-2 (tailings filter) and Figure 8-3 (mine waste filter).

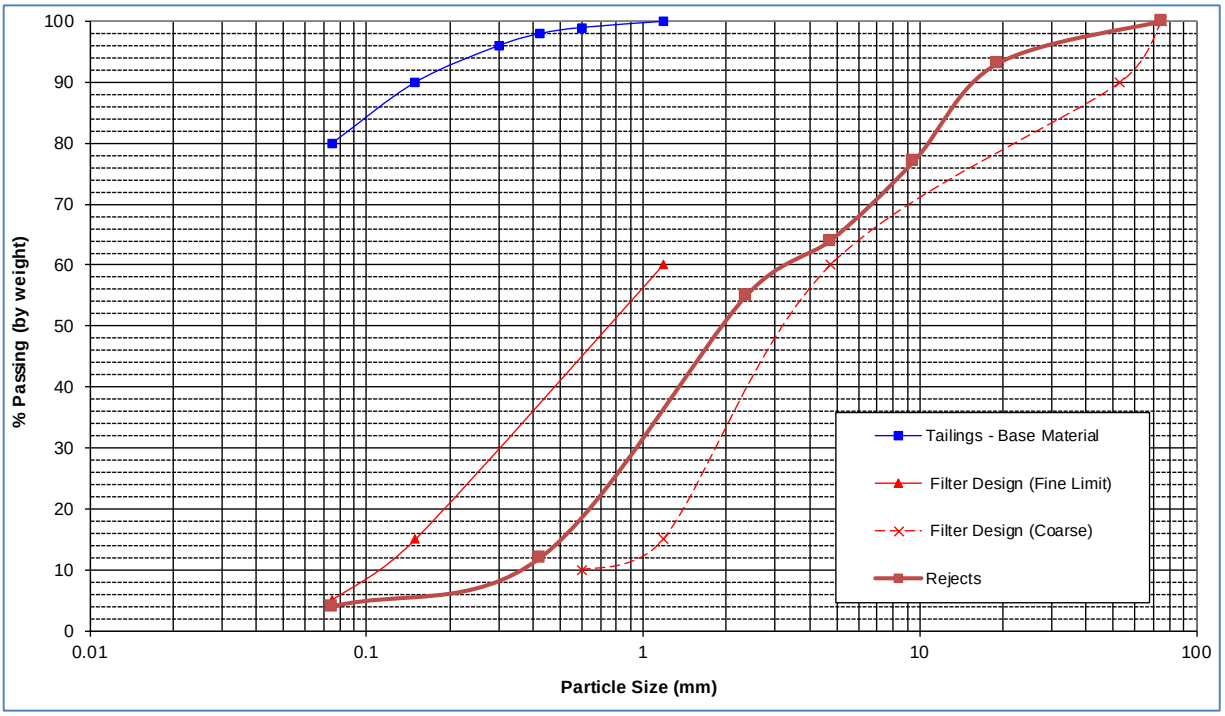


Figure 8-2: Filter PSD design envelope for tailings with rejects PSD.

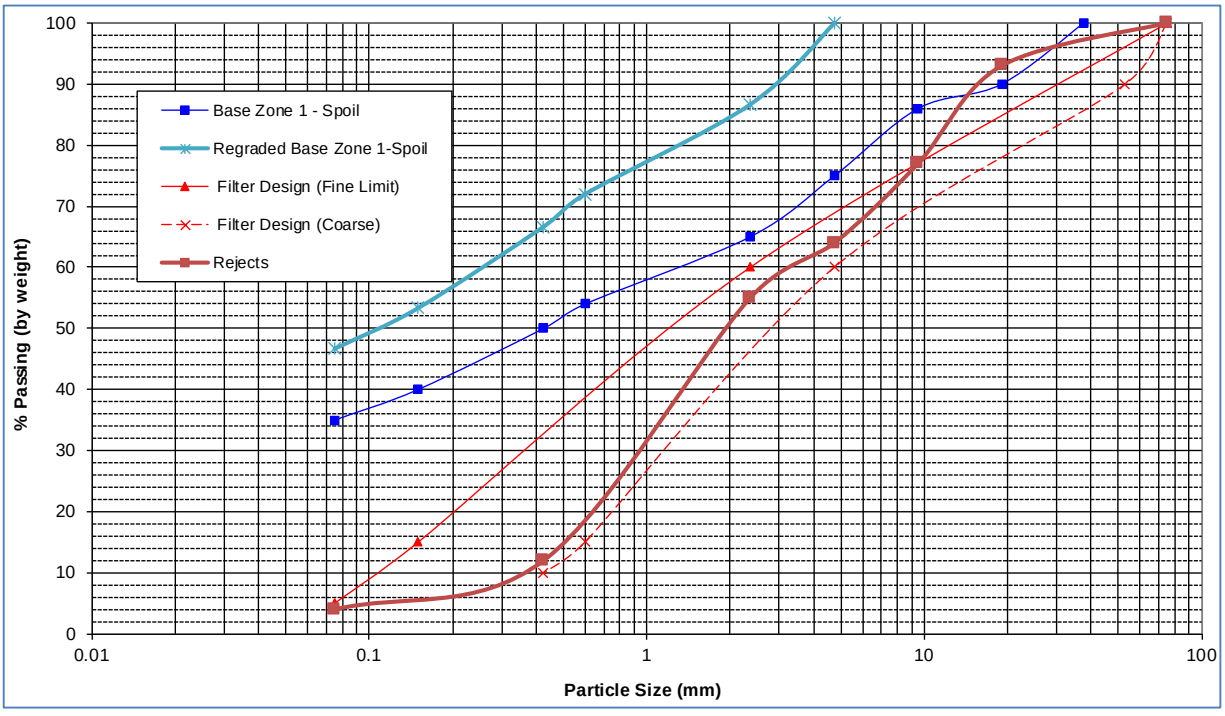


Figure 8-3: Filter PSD design envelope for mine waste with rejects PSD.

The assessment indicates that the rejects particle size distribution will be suitable as a filter for both tailings and mine waste.

9.0 DESIGN CRITERIA

The criteria adopted for the design of the TSF are based on the following key references:

- Guidelines in Tailings Dam Design, Construction and Operation (ANCOLD, 2012b).
- Manual for assessing consequence categories and hydraulic performance of structures (DEHP 2016)
- Operational data as provided by Curragh

Based on this list of references, the key aspects of design in relation to the TSF are as follows:

- Volumetric / Civil.
- ANCOLD Consequence Category
- DEHP Consequence Category
- Embankment Stability

These issues are addressed in the following sections.

9.1 Tailings and CPPs water requirements and volumetric / physical properties

The Tailings and CPPs water requirements and volumetric / physical design criteria for the TSF and decant pond is documented in Table 9-1 on the next page.

Table 9-1: Tailings and CHPP Volumetric / physical properties.

Criteria	Value	Unit
ROM	15.00	Mt/yr
Product	10.50	Mt/yr
Annual tailings rate	1.04	Mt/yr
Thickener solids	7%	
Slurry in water (thickener underflow)	13.82	Mm^3/yr
Underflow Solids	37%	
Tailings Specific gravity	1.65	
Initial dry density	0.8	t/m^3
Retained water within tailings	0.67	Mm^3/yr
Decant Supernatant Water	62%	
TSF water to decant pond for return (excluding rainfall and evaporation)	1.07	Mm^3/yr
Thickener overflow (clarifiers) recirculated back to CPPs	12.08	Mm^3/yr
Total tailings water return (decant + clarifiers)	13.15	Mm^3/yr
Rejects volume	3.12	Mt/yr
Rejects water content	12%	
Water bound with rejects	0.43	Mm^3/yr
Product water content	9%	
Water bound with product	1.04	Mm^3/yr
Total CPPs water demand	3.21	Mm^3/yr
Water demand for CPPs (for product, rejects and due to water loss to TSF)	2.14	Mm^3/yr
Operating embankment crest width	28	m

9.2 ANCOLD consequence category and criteria

ANCOLD (2012c) provides Consequence Categories that are used to determine design and operational requirements, including freeboard and recommended design earthquake loading AEPs criteria.

9.2.1 Consequence category assessment

An assessment of TSF Consequence Category was undertaken based on ANCOLD (2012b) Guidelines considering embankment failure and uncontrolled release or seepage. The assessment, presented in Table 9-2 indicated a 'High C' rating based on the potential for one or more lives being lost.

The Consequence Category for the Decant pond was also assessed to be 'High C' based on the highest level of severity of damage and loss being 'minor' and the potential loss of life being ≥ 1.

Table 9-2: ANCOLD Consequence Category TSF Assessment – Severity of Damages and Losses.

Damage and Loss		Severity Level			
		Minor	Medium	Major	Catastrophic
Total Infrastructure Cost	**COST ESTIMATE**				
Residential	No effect				
Commercial	<$10M	X			
Infrastructure	<$10M	X			
Dam replacement or repair cost	$10M to $100M		X		
Total Estimated Cost	$10M to $100M		X		
Impact on dam owner's business					
Importance to the business	Essential for tailings storage			X	
Effect on services provided by the owner	Severe restrictions on coal supply			X	
Effect on continuing credibility	Some reactions but short lived as no offsite discharge	X			
Community reaction and political implications	Some reactions but short lived as no offsite discharge	X			
Impact on financial viability	Some reactions but short lived as no offsite discharge	X			
Value of water in the storage	Can be absorbed from other storage sources	X			
Health and social impacts					
Public health	<100 people affected	X			
Loss of Services to the community	<100 people affected	X			
Cost of emergency management	<1000 person days	X			
Dislocation of people	No effect	X			
Dislocation of businesses	No effect	X			
Employment affected	No jobs lost	X			
Loss of heritage	Potential loss of scar tree on western border		X		
Loss of recreational facility	No effect	X			
Environmental Impacts					
Stock and fauna	Dam break contained in pit - would not contaminate water sources	X			
Ecosystems	Dam break contained in pit - Natural ecosystem would not be affected	X			
Rare and endangered species	No change to effect on species	X			
Highest level of severity of damage and loss				**X**	
Population at Risk (PAR)		1 to 10			

9.2.2 ANCOLD freeboard and earthquake criteria

The following freeboard and earthquake design criteria have been adopted for the TSF from ANCOLD (2012b) based on the assessment documented in Section 9.2.1.

Table 9-3: Earthquake return periods for High C ANCOLD Consequence category.

Criteria	Value
Embankment Contingency Freeboard	1:10 AEP wind plus 0.5 m
Design Earthquake Loading (AEP) for OBE	1:1 000
Design Earthquake Loading (AEP) for MDE	1:10 000

9.3 DEHP consequence category

The *Manual for assessing consequence categories and hydraulic performance of structures,* DEHP (2016), establishes hydraulic consequence categories which then establish mandatory criteria. An assessment of the consequence category for the B Pit TSF was carried out to establish the mandatory criteria comprising:

- DSA
- ESS
- MRL

The consequence categories provided in Table 1 of the Manual for assessing consequence categories and hydraulic performance of structures, DEHP (2016), was used to complete the Consequence Category Assessments below. For ease of reference, it has been reproduced in Table 9-4:

Table 9-4: Consequence Category Assessment

Environmental Harm	High	Significant	Low
Harm to humans	Location such that people are routinely present in the failure path and if present loss of life to greater than 10 people is expected[7]. Note: The requirement to consider the location of people in the failure path is only relevant to the 'dam break' scenario	Location such that people are routinely present in the failure path and if present loss of life to 1 person or greater but less than 10 people is expected[7]. Note: The requirement to consider the location of people in the failure path is only relevant to the 'dam break' scenario	Location such that people are not routinely present in the failure path and loss of life is not expected[7]. Note: The requirement to consider the location of people in the failure path is only relevant to the 'dam break' scenario
	Location such that contamination of waters (surface and/or groundwater[8]) used for human consumption could result in the health of 20 or more people being affected[9].	Location such that contamination of waters (surface and/or groundwater[8]) used for human consumption could result in the health of 10 or more people but less than 20 people being affected.	Location such that contamination of waters (surface and/or groundwater[8]) used for human consumption could result in the health of less than 10 people being affected.
General environmental harm	Location such that: a) Contaminants may be released to areas of MNES, MSES or HEV waters that are not already authorised to be disturbed to at least the same extent under other conditions	Location such that contaminants may be released so that adverse effects (that are not already authorised to be disturbed to at least the same extent under other conditions of this authority	Location such that either: a) Contaminants are unlikely to be released to areas of Significant Values or Moderate Values; or

Environmental Harm	High	Significant	Low
	of this authority subject to any applicable offset commitment (Significant Values); and b) Adverse effects[10] on Significant Values are likely; and c) The adverse effects are likely to cause at least one of the following: i) Loss or damage or remedial costs greater than $50,000,000; or ii) Remediation of damage iii) permanent alteration to existing ecosystems; or iv) The area of damage (including downstream effects) is likely to be at least 5 km².	subject to any applicable offset commitment) either: a) Would be likely to be caused to Significant Values but those adverse effects would not be likely to meet the thresholds for the High Consequence category and instead would be likely to cause at least one of the following: i) Loss or damage or remedial costs greater than $10,000,000 but less than $50,000,000; or ii) Remediation of damage is likely to take more than 6 months but less than 3 years; or iii) Significant alteration to existing ecosystems; or iv) The area of damage (including downstream effects) is likely to be at least 1 km² but less than 5 km². or b) Would be likely to be caused to environmental values classed as slightly or moderately disturbed waters[11], wetland of general ecological significance[12], riverine areas, springs or lakes and associated flora and fauna (Moderate Values), and the adverse effects are likely to cause at least one of the following :i) Loss or damage or remedial costs greater than $20,000,000; or ii) Remediation of damage is likely to take more than 1 year; or iii) Significant alteration to existing ecosystems; or iv) The area of damage (including downstream effects) is likely to be at least 2 km².	b) Contaminants are likely to be released to those areas, but would be unlikely to meet any of the minimum thresholds specified for the Significant Consequence Category for adverse effects.
General economic loss or property damage	Location such that harm (other than a different category of harm as specified above) to third party assets in the failure path would be expected to require $10 million or greater in rehabilitation, compensation, repair or rectification costs[13].	Location such that harm (other than a different category of harm as specified above) to third party assets in the failure path would be expected to require $1 million and greater but less than $10 million in rehabilitation, compensation, repair or rectification costs[13].	Location such that harm (other than a different category of harm as specified above) to third party assets in the failure path would be expected to require less than $1million in rehabilitation, compensation, repair or rectification costs[13].

Notes:

7. People routinely present in the failure path' could be considered to be people who occupy buildings or other places of occupation that lie within the failure impact zone. For the purposes of this Manual, this should refer to people other than site personnel engaged by the resource operation and located on the tenements and tenure associated with the resource operation; for other ERAs, it would be the 'premises referred to in the authority'. It should be noted that while this is appropriate for the assessment of consequence categories in accordance with this Manual, adherence to the requirements of this Manual does

not limit, amend or change in any way, any other requirements to be complied with under relevant health and safety acts or legislation that requires the safety of site personnel to be considered.

8 When considering potential impacts on groundwater, it is not envisaged that a full hydrogeological assessment will be required in all cases. Any consideration of potential impacts on groundwater systems should consider the water quality of the potential receiving aquifer as well as the quality of fluid stored in the regulated dam. Existing groundwater drawdown in areas surrounding resource operations (e.g. drawdown as a result of mine pit or underground mine dewatering) can also be considered when assessing the consequence of dam seepage on groundwater systems.

9 'An adverse effect on human health means a physiological effect on human health and does not include an impact on the quality of downstream water that merely negatively affects taste and which is unlikely to cause persons to become physically ill.

10 Adverse effects includes chronic and acute effects where an acute effect is on living organism/s which results in severe symptoms that develop rapidly, and a chronic effect is an adverse effect on a living organism/s which develops slowly. In some instances, it may be necessary to carry out or reference existing ecological/toxicological studies to assess the impacts of contaminants on living organisms.

11 See Water EPP for definitions

12 Wetland of general ecological significance' means a wetland shown on a map of referable wetland as a 'general ecologically significant wetland' or 'wetland of other environmental value'. 13 This does not include the holder's own mine or gas production, on-site industrial or commercial assets, the holder's workers' accommodation, agricultural facilities on the holder's land such as a farm shed or farm dam or infrastructure solely for servicing the holder.

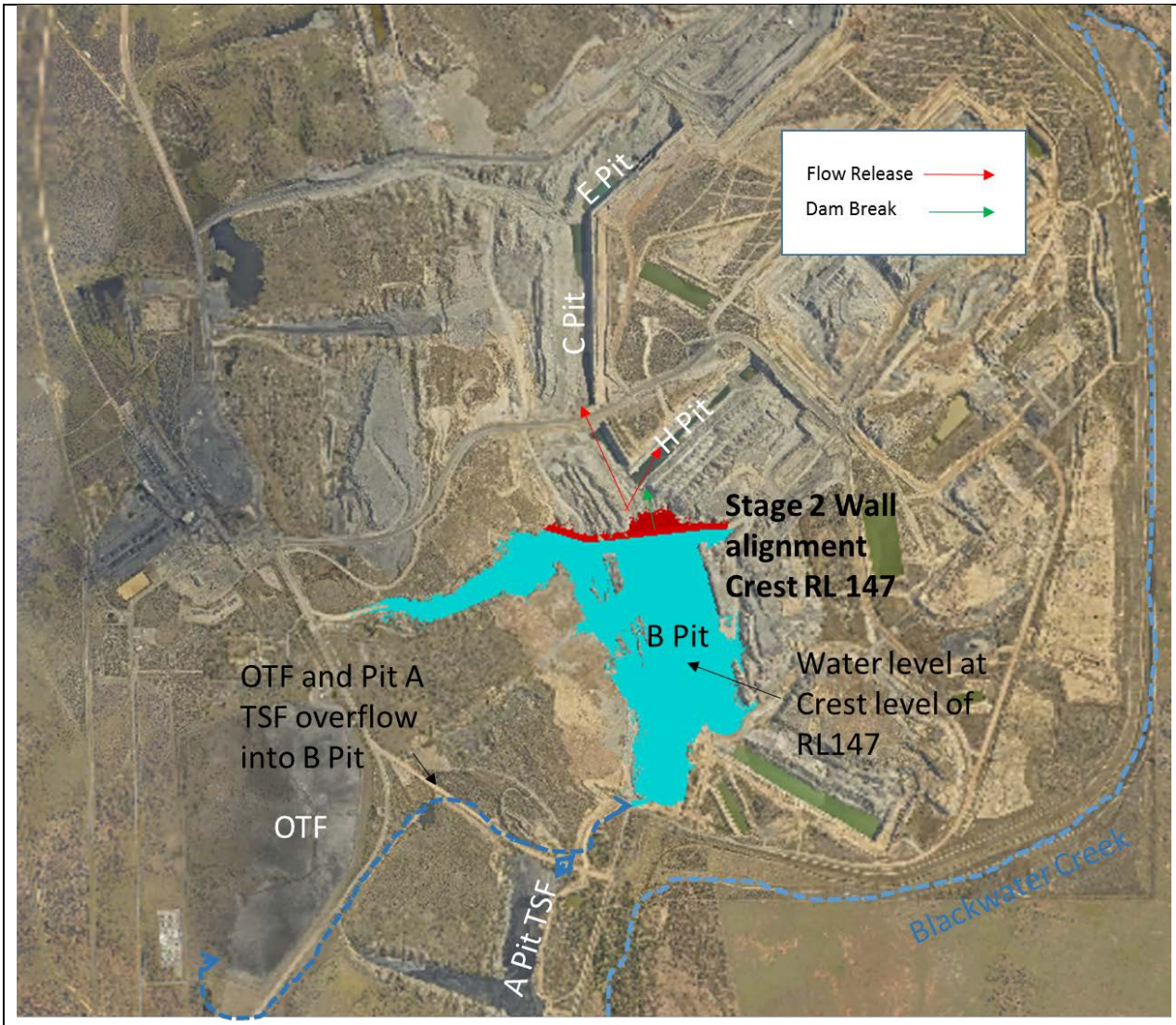
13 This does not include the holder's own mine or gas production, on-site industrial or commercial assets, the holder's workers' accommodation, agricultural facilities on the holder's land such as a farm shed or farm dam or infrastructure solely for servicing the holder.

9.3.1 Assessment

The consequence category assessment was completed in accordance with DEHP (2016) based on the following failure event scenarios:

- Failure to contain – seepage
- Failure to contain - overtopping
- Dam break.

Under this study the B Pit TSF was assessed to be 'SIGNIFICANT', based on the highest consequence category determined by the application of Section 2.1.2 of DEHP (2016). It is also the assessment that the structure should also be considered at a minimum as a Significant Category structure due to the intrinsic nature of it being an In-Pit TSF and its' size.



Location	691,763E 7401014 S Zone 55K
Function	Tailings disposal. Decant water pumped to RD30 and pumped to the CHPP's via RD1 and RD3. Pit B also contains the DSA of the Old Tailings Dam Facility (OTF) and Pit A Ramp 2 TSF.
Overflow Destination	Overflow will be contained within H Pit and C Pit
Dam Break Destination	It considered that the worst case scenario is that there is that there is a wall failure and that all water is release to adjoin pit resulting in a possible cascade failure. This location is depicted in the above figure.
Storage Volume	7,913 ML (total volume of decant, DSA and Freeboard)
Possible Release Volume from Dam Break	7,913 ML
Catchment Area	1568.3 ha - Catchment area represents the relevant catchment of Pit B, Pit A, RD3, RD1, RD30, RD7 and OTF which drain to Pit B.
Water Quality	Curragh (2015) documents the tailings chemistry as pH (average) = 8.02, EC (average) = 3 000 µS.

9.3.1.1 Failure to contain – seepage

Failure to contain seepage is defined as spills or releases to ground and / or groundwater via seepage from the floor and / or sides of the structure. In the event of 'Failure to contain – seepage' the consequence has been assessed as being 'LOW', based on the highest consequence category determined by the application of Table 1 in DEHP(2016). The qualitative assessment is shown in Table 9-5.

Table 9-5: B Pit TSF failure to contain - seepage scenario.

Environmental Harm	Assessment	Consequence Category
Harm to humans	Location such that there is no consumption of contaminated waters used for human consumption.	Low
General Environmental Harm	Adverse effects to areas of significant values are considered unlikely: Potential seepage is not expected to reach the regional ecosystem of concern (Category B vegetation, refer Section 5.4) along Blackwater Creek. This is based on the likely low hydraulic conductivity and lack of continuity of the alluvial materials between B Pit and the Category B vegetation, refer Section 5.3. Based on the Blackwater coalfield stratigraphic sequence, there is low vertical permeability of the bed material around B Pit. It was found that the coal seams are hydrologically isolated, which was confirmed by their significant different water chemistry (Curragh 2015). Potential seepage is unlikely to reach the groundwater aquifers in the Tertiary materials based on the expected lack of vertical leakage in the Tertiary materials and the lack of transmissivity associated with faults, refer section 5.3. Contamination of groundwater via seepage in the area of B Pit is therefore considered unlikely.	Low
General economic loss or property damage	The location of the TSF is such that harm to third party assets, excluding the mine's own commercial assets, is unlikely.	Low

9.3.1.2 Failure to contain – overtopping

'Failure to contain – overtopping' is defined as spills or releases from the structure that result from loss of containment due to overtopping of the structure and may be due to any cause other than a dam break. Overtopping could occur as a result of either poor management of tailings deposition resulting in increased beach angles, a failure of the decant water return system, or an extreme weather event that occurs in parallel with these.

In the event of 'Failure to contain – overtopping' the consequence has been assessed as being 'SIGNIFICANT', based on the highest consequence category determined by the application of Table 1 in DEHP(2016). The qualitative assessment is shown in Table 9-6

Table 9-6: B Pit TSF Failure to contain – Overtopping scenario.

Environmental Harm	Assessment	Consequence Category
Harm to humans	Overtopping of the structure is unlikely to contaminate any water sources for human consumption. There are no drinking water sources at a lower elevation to a point of potential discharge.	Low
General Environmental Harm	Adverse effects to significant values, e.g. the regional ecosystem of concern along Blackwater Creek to the south and to the north, are considered possible in the event of a failure to contain overtopping scenario as it part of a DSA sharing system with other adjoining TSF facilities and mine water dams and is therefore consider within the significant category due to the proximity Category A and B endangered or of concern vegetation. The adverse effects would not be likely to meet the thresholds for the HIGH consequence category as any spillage is expected to be minimal.	Significant
General economic loss or property damage	The location of the TSF is such that harm to third party assets, excluding the mine's own commercial assets, is unlikely.	Low

9.3.1.3 Failure to contain – dam break

'Failure to contain – dam break' is defined as collapse of the structure due to any possible cause. Possible causes may include:

- A failure of the containment embankment caused by an increase in the internal phreatic surface
- An overtopping of the containment wall leading to failure of the wall, following an extreme rainfall event.

In the event of 'Failure to contain –dam break' the consequence has been assessed as being 'SIGNIFICANT', based on the highest consequence category determined by the application of Table 1 in DEHP (2016). The qualitative assessment is shown in Table 9-7.

Table 9-7: B Pit TSF failure to contain – dam break scenario.

Environmental Harm	Assessment	Consequence Category
Harm to humans	Location such that there is no consumption of contaminated waters used for human consumption.	Low
General Environmental Harm	Adverse effects to significant values, e.g. the regional ecosystem of concern along Blackwater Creek to the south and to the north, are considered possible in the event of a failure to contain overtopping scenario as it part of a DSA sharing system with other adjoining TSF facilities and mine water dams and is therefore considered within the significant category due to the proximity to Category A and B endangered and/or of concern vegetation. It is the assessment that the structure should also be considered at a minimum as a Significant Category structure due to the intrinsic nature of it being an In-Pit TSF and its size. The volume of water or tailings has been estimated based on empirical equations. Although the majority would be	Significant

Environmental Harm	Assessment	Consequence Category
	contained within adjoin pits, it is not however impossible for a tailings breach of this magnitude to not have a cascade effect which could impact on the environment.	
General economic loss or property damage	The location of the Pit B TSF is such that harm to third party assets, excluding the mine's own commercial assets, is not possible.	Low

A quantitative analysis was undertaken using the calculated maximum breach discharge (simplified breach equation) from the *Queensland Guidelines for Failure Impact Assessment of Water Dams* (DEWS, 2012).

The maximum depth of water in storage for Stage 1 and Stage 2 of B Pit TSF was taken as the depth of water from the pit crest to the tailings level.

The total volume of water release for Stage 1 and Stage 2 of B Pit TSF was taken as the capacity of water from the pit crest to the tailings level.

The maximum breach discharge is 2081.9 m^3/s for Stage 1 and 3495.9 m^3/s for Stage 2 B Pit TSF.

The reach length for Stage 1 and Stage 2 of B Pit TSF was estimated using the mathematical relationship between volume of released water and maximum downstream distance outlined in Table 2 of the *Queensland Guidelines for Failure Impact Assessment of Water Dams* (DEWS, 2012). As demonstrated in Figure 9-1, the reach length for Stage 1 is 20.18 Km, whereas the reach length for Stage 2 is 23.3 Km. The provided estimate is far greater then would be expected as the estimate is based on land based structures and most if not all of the failure would be contained below ground level within the adjoining pits.

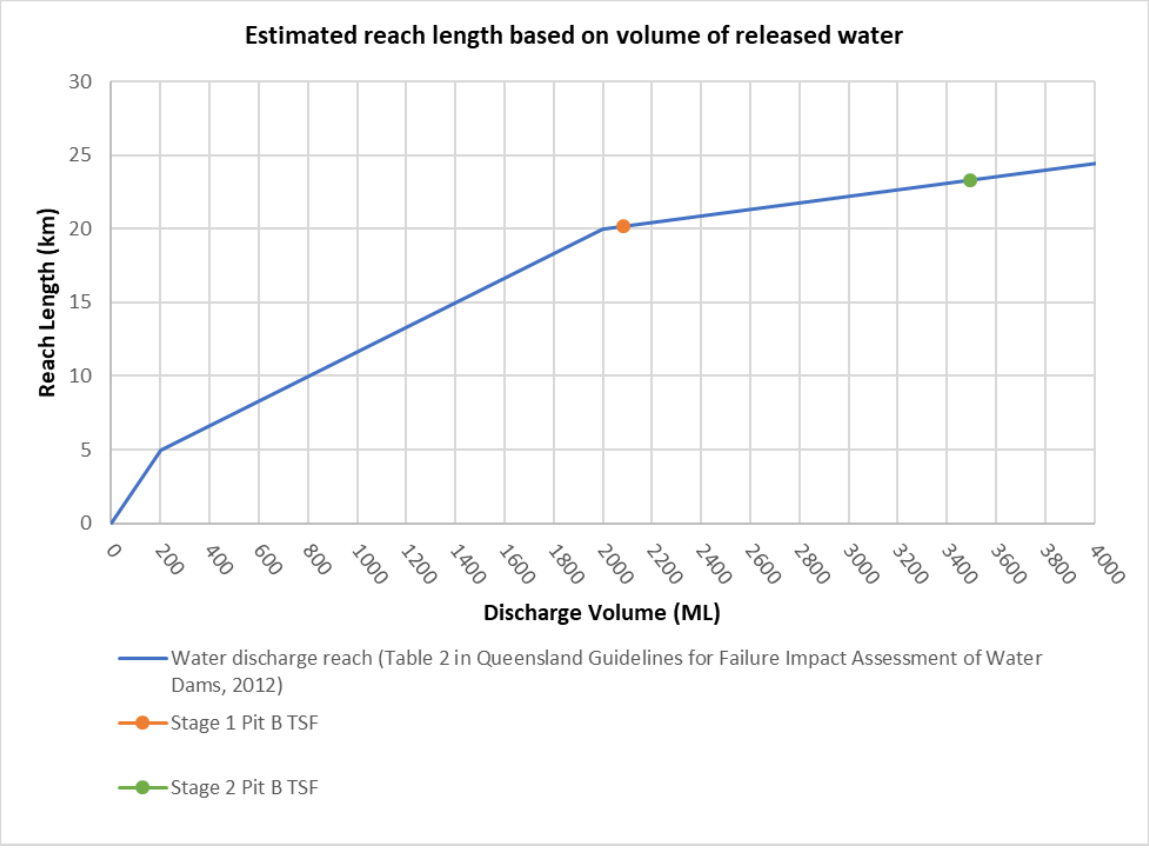


Figure 9-1: Estimated reach length based on volume of released water during dam break

9.3.2 Hydraulic performance criteria

The hydraulic performance criteria for the TSF will specify the capacity required to contain daily rainfall and safely pass flood waters. The hydraulic performance criteria, under the "Significant" consequence category, is summarised in Table 9-8.

Table 9-8: Hydraulic performance criteria

Hydraulic Performance Element	Criteria
Design Storage Allowance (DSA)	1:20 AEP
Extreme storm storage allowance (ESS)	1:10 AEP 72 hr duration
Mandatory reporting level (MRL)	Level based on ESS

It should be noted that no criteria for spillway hydraulic performance as the Pit B TSF design dose not incorporate a spillway. This is based on the design having no external containment embankments above the exiting ground surface.

The DSA, ESS and MRL requirements are shown in Figure 9-2.

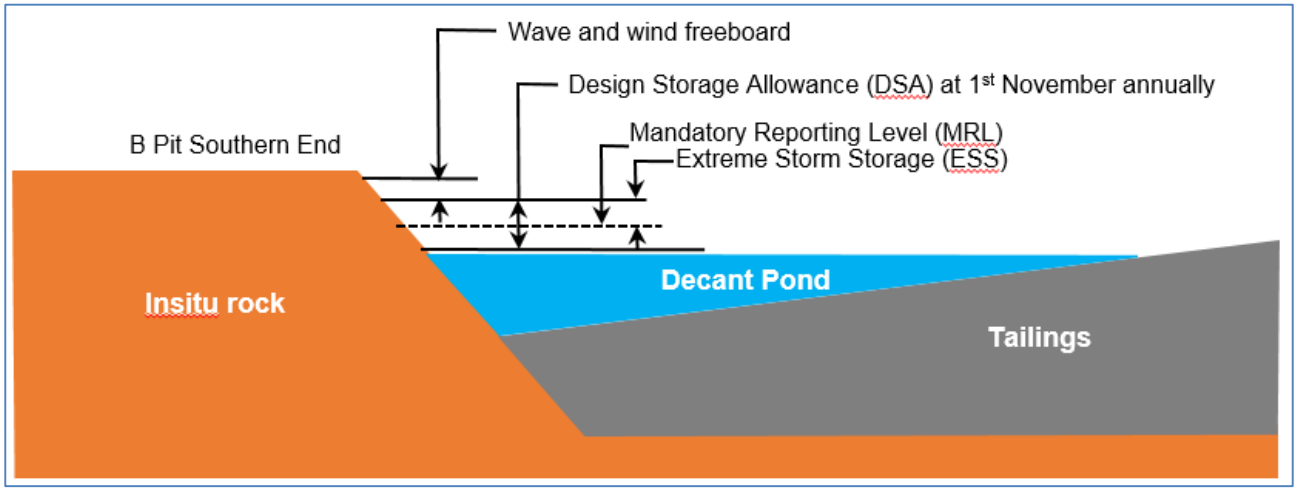


Figure 9-2: Definitions of DSA, MRL and ESS.

9.4 Embankment stability criteria

The TSF embankment is to be designed with regard to slope stability (i.e. to limit the risk of slope failure).

Detailed slope stability analysis in relation to the embankment section is to be undertaken on the basis of general limit equilibrium (GLE) conditions with the following minimum factors of safety adopted, based on ANCOLD (2012b), to withstand the most severe and unfavourable combination of static and dynamic loads.

The minimum factors of safety adopted for embankment stability are presented in Table 9-9 and are generally based on ANCOLD (2012a), for the expected range of stability conditions for the TSF embankment.

Table 9-9: Stability criteria

Loading Condition	Minimum Factor of Safety
Short term - Construction	1.3
Long term – during operations	1.5
Post-Seismic	1.0 – 1.2[3]

[3] To be related to the confidence in selection of residual shear strength

10.0 TAILINGS DEPOSITION MODELLING

10.1 Data and parameters adopted

The tailings deposition modelling was carried out using the 'Goldtails' software. The software simulates deposition over a gridded surfaces using a parabolic deposition function. Table 10-1 shows the adopted modelling data and parameters.

Table 10-1: Modelling data and parameters adopted.

Data	Description / value	Basis / Source
Survey data		
Lidar1602-CS-Running.00t	2016 pit surface	Wesfarmers
bpitbatho1610.dxf2016	Bathymetry	Wesfarmers
g_bridge_post_mining_surface_161116.00t	2016 mined peninsula	Wesfarmers
Containment embankment geometry	Refer Section 7.2	Golder / Wesfarmers
Discharge Outlet locations	Tailings pipe cut 2, ramp 4 and containment embankment	Golder
Direction	South	
Tailings beach slope	0.5%	Golder
Freeboard (minimum)	DSA volume plus wave allowance	Golder
Tailings output	1.04 Mtpa	Wesfarmers
Average dry density	0.8 t/m^3	Wesfarmers

10.2 Methodology and results

The existing topography survey data, provide by Wesfarmers around 2015, was amended to incorporate the 2016 bathymetry survey and the future mine floor surface of the peninsula area.

The southern end of B Pit was used as the control point for setting the minimum tailings full storage elevation based on the floor of the B Pit falling to the south and the maximum elevation for each stage being dependent on:

- Containment of the DSA volume above the tailings surface, refer Section 11.3.
- Establishing a steady state phreatic surface that would maintain an acceptable factor of safety for embankment stability, refer Section 12.4.

Figure 10-1 and Figure 10-2 presents the deposition surface at the maximum tailings storage for Stage 1 and Stage 2 respectively.

As shown in Figure 10-1, the maximum tailings deposition level is contained within B-Pit for Stage 1 and does not encroach onto Ramp 4. However, Ramp 4 does become inundated during Stage 2, as shown in Figure 10-2.

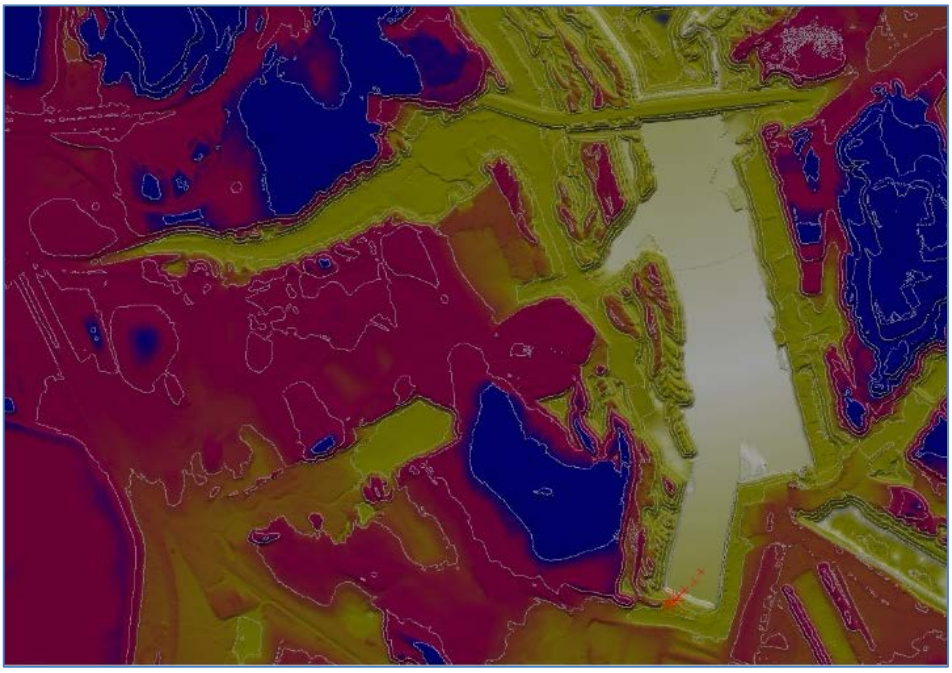


Figure 10-1: Modelled Stage 1 deposition.

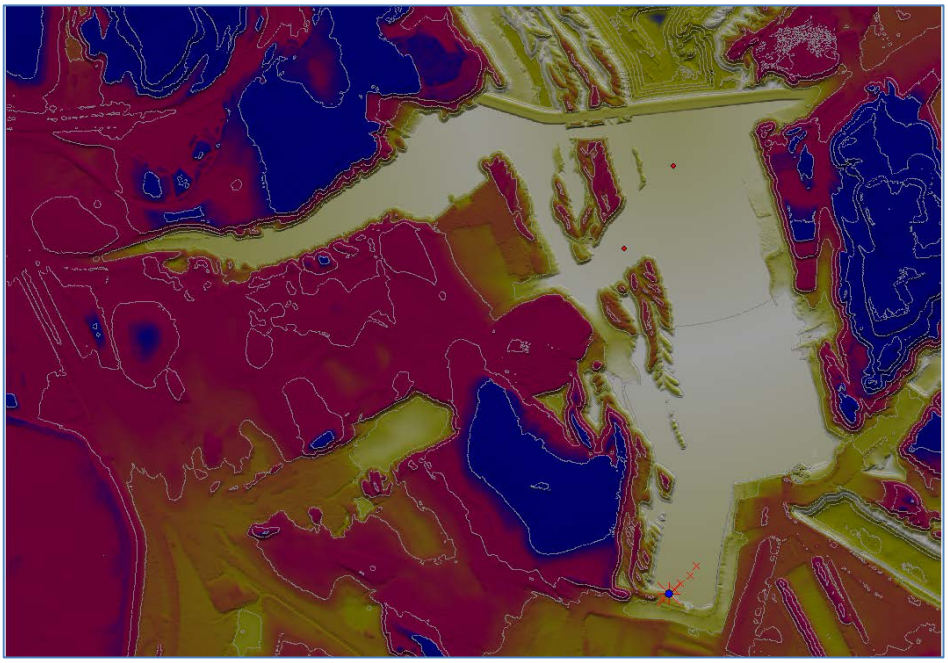


Figure 10-2: Modelled Stage 2 deposition.

10.3 Storage volume and life

The results of the tailings deposition modelling are shown in Table 10-2 with the storage life of the Pit B TSF presented in Figure 10-3 As can been seen in Figure 10-3, the Stage 1 estimated storage life is approximately 8 years. Once the TSF becomes stage 2, this has an estimated total life of 20-21 years, with the tailings beach level moving into Ramp 4 at around year 18.

Table 10-2: B Pit tailings volumes and life

Minimum tailings elevation (RLm)	Maximum tailings elevation (RLm)	Cumulative volume (m³)	Cumulative storage (t)	Cumulative life (yrs)
72	73.7	7 183	5 746	0.01
74	75.2	25 445	20 356	0.02
76	77.4	74 490	59 592	0.06
78	81.2	139 613	111 691	0.11
80	83.7	246 163	196 930	0.19
82	86.5	39 5610	316 488	0.30
84	89.7	563 869	451 095	0.43
86	89.8	796 509	637 207	0.61
88	89.9	1 133 238	906 590	0.87
90	90.1	1 515 804	1 212 643	1.17
92	98.9	1 998 696	1 598 957	1.54
94	101.5	2 488 475	1 990 780	1.91
96	103.6	3 013 728	2 410 983	2.32
98	105.6	3 594 482	2 875 586	2.76
100	107.8	4 263 392	3 410 713	3.28
102	110.	5 006 537	4 005 229	3.85
104	112.1	5 806 148	4 644 918	4.47
106	114.3	6 651 140	5 320 912	5.12
108	116.5	7 545 747	6 036 597	5.80
110	118.6	8 487 629	6 790 103	6.53
112	120.8	9 479 912	7 583 930	7.29
114	122.8	10 535 794	8 428 636	8.10
116	124.8	11 654 262	9 323 410	8.96
118	126.8	12 845 176	10 276 141	9.88
120	128.9	14 099 680	11 279 744	10.85
122	130.9	15 412 107	12 329 686	11.86
124	132.9	16 780 164	13 24 131	12.91
126	134.9	18 204 644	14 563 715	14.00
128	137.0	19 748 837	15 799 069	15.19
130	139.0	21 453 020	17 162416	16.50

Minimum tailings elevation (RLm)	Maximum tailings elevation (RLm)	Cumulative volume (m³)	Cumulative storage (t)	Cumulative life (yrs)
132	141.0	23 575 268	18 860 214	18.13
134	143.0	25 748 931	20 599 145	19.81
135	144.0	26 890 209	21 512 167	20.68

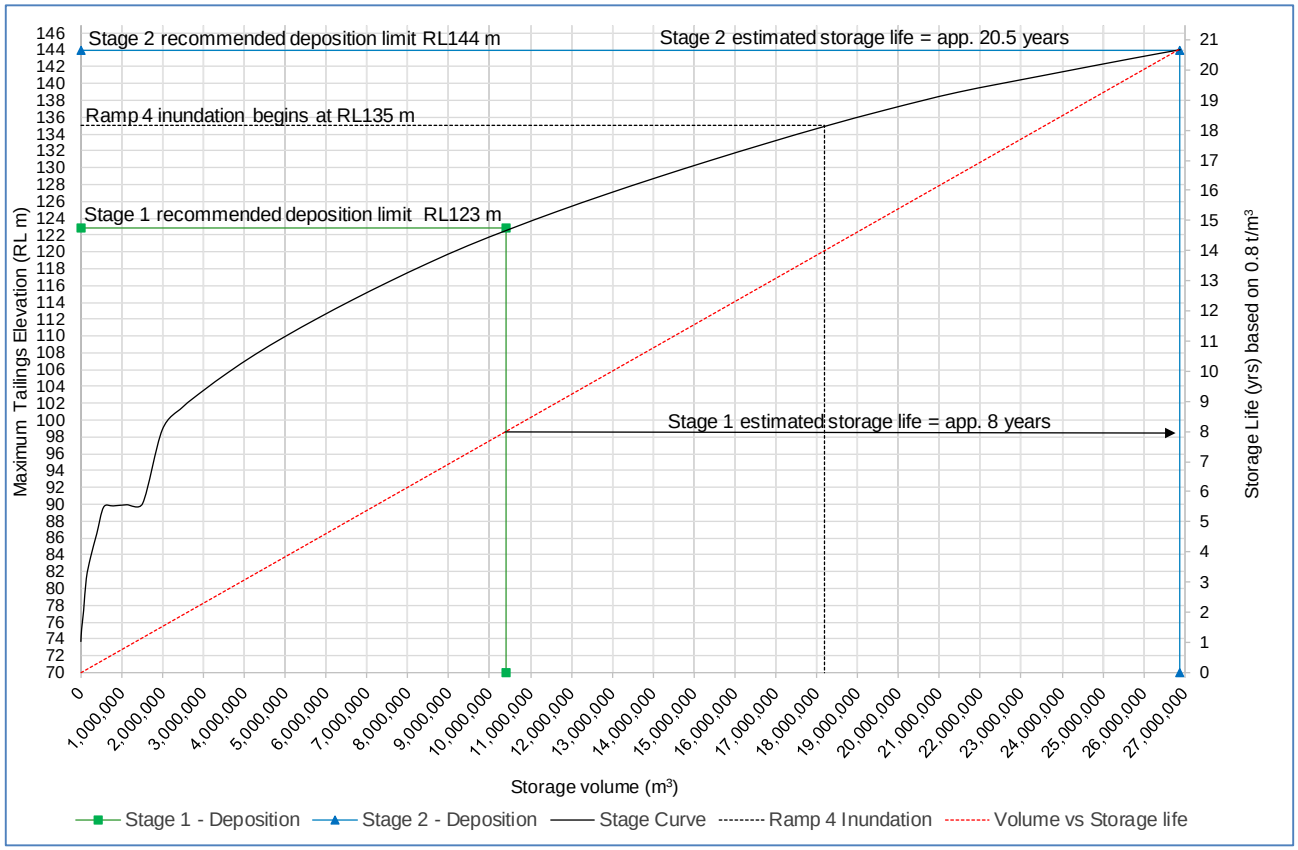


Figure 10-3: Pit B TSF tailings deposition stage curve.

The estimated storage life for each stage assumes a well distributed tailings surface across the TSF footprint and a decant pond in the order of 2 m to 3 m deep with an operating level of RL 117 and RL 141 for Stage 1 and Stage 2 embankments respectively.

11.0 HYDROLOGICAL ANALYSIS

This section documents the analyses undertaken for the DSA, MRL, ESS and wave run-up assessment

11.1 Design storage allowance

The design storage allowance (DSA) was estimated using the method of operational simulation for performance based containment. APPENDIX G provides details of the analysis.

The water balance model was based on the method and requirements outlined DEHP (2016).

The resultant DSA requirement using the method of operational simulation is 2 823 ML.

The model has been set up to run dynamically on a daily basis for the period 1 November to 30 March and for 100 model realisations. The water balance model has been developed in GoldSim[4], a graphical modelling environment which allows dynamic simulation of a particular system to represent and predict system behaviour. The model includes a sequence of 127 years of Data Drill climate data for predictive modelling. Each realisation randomly selects a new daily rainfall and the same year's corresponding daily evaporation record from the Data Drill data starting at 1 November. In this way 100 different summer climate scenarios for this location were simulated. All other variables, such as the rate of water inflow and outflows and the starting water level at 1 November; remain constant for each of the model simulations.

The model output, that is, the 100 records of resultant change in storage over the wet season; was then used to determine the DSA. The DSA is calculated from the statistical results of the plotting position analysis of operational simulation outcomes, to derive the design AEP, plus an additional volume equal to the Design Simulation Margin (DSM), applied to simulation outcomes to provide conservative compensation for model inaccuracy. The guideline recommends Pit B to maintain a DSA of the 1:20 year AEP wet season including process inputs subsequent to 1 November each year. Where there is a lack of calibration data for the model, the guideline recommends the use of a minimum DSM value of not less than 50% be applied. We have used the maximum DSM value of 100% in this case as we were not able to calibrate the model between modelled and measured site data.

11.2 Extreme storm storage

In accordance with Table 5 DEHP (2016), the extreme storm storage (ESS) for the TSF is the equivalent of the 1:10 AEP 72 hour storm event.

Table 11-1: ESS summary parameters

Criteria	Value	Unit
1:10 AEP 72 hour storm depth	0.202	m
Catchment Area	1080.1	ha
ESS	2 185 258	m^3

11.3 MRL and DSA levels

The MRL and DSA levels for stage 1 and stage 2 will need to be assessed each year by a suitably qualified person to confirm legislative compliance with DEHP (2016). The MRL and DSA levels for the modelled final tailings deposition levels for each stage are shown in Figure 11-1 and Figure 11-2 as a guide and for input into the seepage modelling in Section 12.3. Note that the final DSA levels shown allow for embankment configurations that have been assessed as having an adequate factor of safety for stability, refer Section 12.4.

The following TSF levels where applied to determine the associated DSA volume level and ESS level.

[4] GoldSim Technology Group www.goldsim.com

Table 11-2: MRL and DSA Levels

Level	Stage 1	Stage 2
Embankment Crest	RL 125	RL 147
Freeboard	0.5 m	0.5m
Max level (FSL)	RL 124.5	RL 146.5
Decant Pond Operating Level	RL 117.0	RL 141.0
DSA Volume	2823 ML	2823 ML
DSA Level	RL 124.5	RL 144.4
ESS volume /MRL	2190 ML	2190 ML
MRL	RL 120.9	RL 144.9

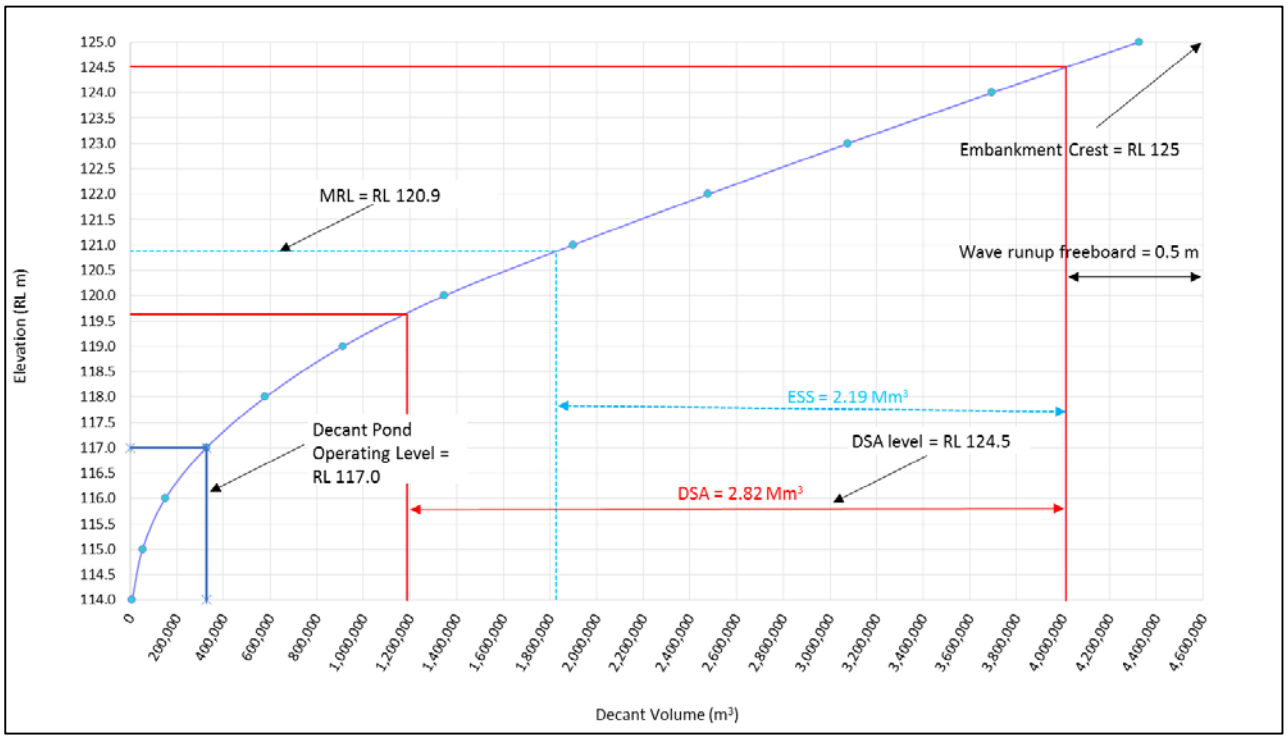


Figure 11-1: Stage 1 Decant pond stage curve at final modelled tailings level

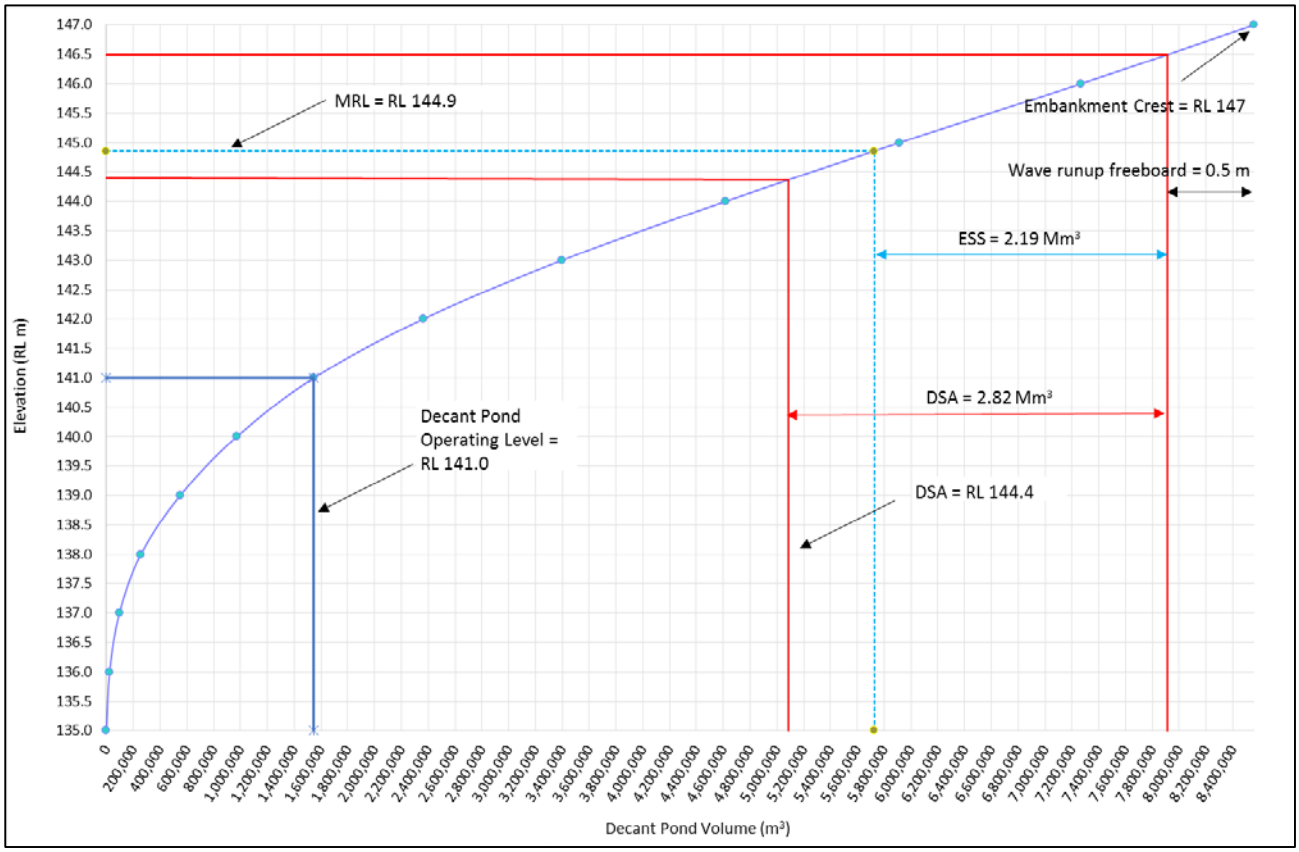


Figure 11-2: Stage 2 Decant pond stage curve at final modelled tailings level.

11.4 Wave run-up freeboard

The decant pond wave run-up assessment was undertaken in accordance with USBR (1981) and US Army Corps (1984b). APPENDIX G provides calculations for the wave run-up assessment.

The analysis indicates a wave run-up of 0.6 m based on a 1 in 10 year AEP. An additional 0.5 m should be included in accordance with ANCOLD (2012b).

11.5 Emergency Spillway

The B-Pit TSF has been designed without an emergency spillway. The reasons for this is as follows:

- The point of tailings deposition is at the embankment wall, thereby creating a beach sloping away from the embankment wall.
- It is expected that there would be sufficient capacity within the decant pond to adequately manage extreme rainfall events by mobilising additional pumping infrastructure.

This does not eliminate the risk of an overtopping failure of the B-Pit TSF, and it is up to WCPL to implement process and develop trigger action response plans (TARPs) to manage this risk.

12.0 GEOTECHNICAL ANALYSIS OF EMBANKMENT

12.1 Scope of geotechnical analysis

Geotechnical analysis has been carried out to confirm the configuration of the TSF embankment under Stage 1 (crest RL 125 m) and Stage 2 (crest RL 147 m) as described in Section 7.2.

The integrity of the analysed configuration is determined by the geotechnical characteristics of the embankment foundation and the proposed embankment fill materials, as well as the development of the phreatic surface within the embankment profile during operation. The geotechnical analyses have thus focused on coupled seepage and stability modelling to assess the suitability of the selected embankment configuration. Supplementary analyses have also been completed to assess the effects of seismicity on embankment stability.

The scope of geotechnical analyses carried out on the cross-section are summarised as follows.

Table 12-1: Geotechnical analysis scope.

Analysis	Condition	Relevant Model Output/Purpose
Seepage	■ TSF Wetting Front Assessment from Decant pond area under operating water level and DSA condition and steady state conditions	■ Quantify seepage discharge to groundwater and/or surface discharge at operating decant pond levels at final stage tailings levels
	■ Embankment Steady State/Equilibrium Conditions under operating water level and DSA condition	■ Steady state phreatic surface within embankment based on a maximum storage level for each stage ■ Input to steady state stability analysis
Slope Stability	■ Steady State/Equilibrium Conditions ■ Steady State/Equilibrium Conditions with Seismic Effects	■ Factors of safety for embankment slope failure

Details of the geotechnical analyses are provided in the following sections.

12.2 Modelled sections

Three sections were modelled comprising:

- Stage 1 Embankment section A-A' for stability and settlement assessment (Figure 12-1, Figure 12-3 and Figure 12-4)
- Stage 2 Embankment section B-B' for stability and settlement assessment (Figure 12-1, Figure 12-5 and Figure 12-6)
- Seepage section C-C' for the TSF wetting front assessment from the decant pond area (Figure 12-2 and Figure 12-7).

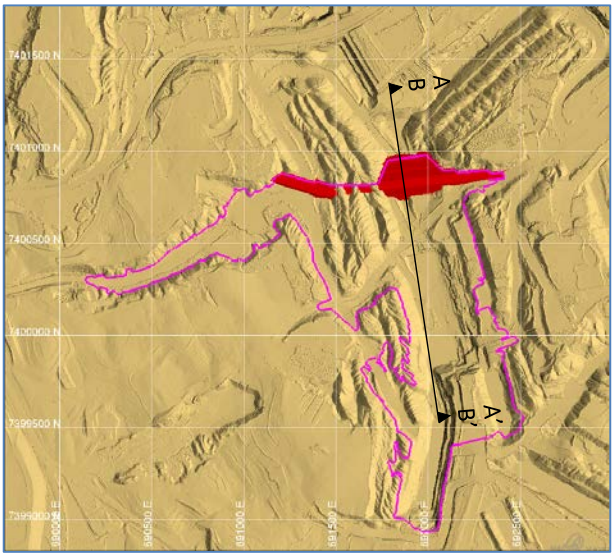


Figure 12-1: Section A-A'/ B-B' embankment sections locations.

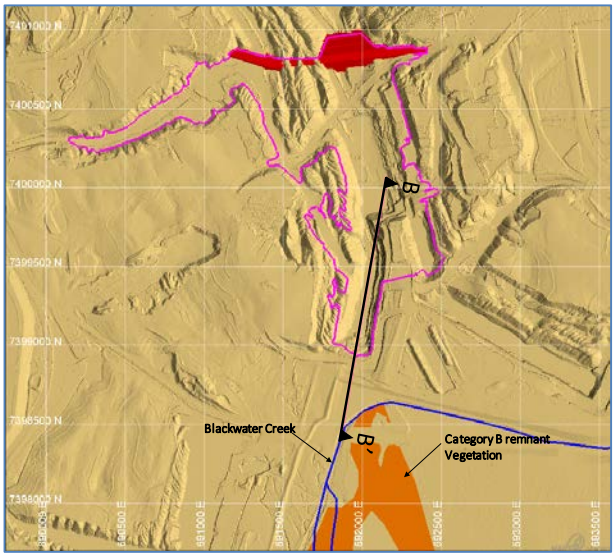


Figure 12-2: Section C-C' seepage section location showing.

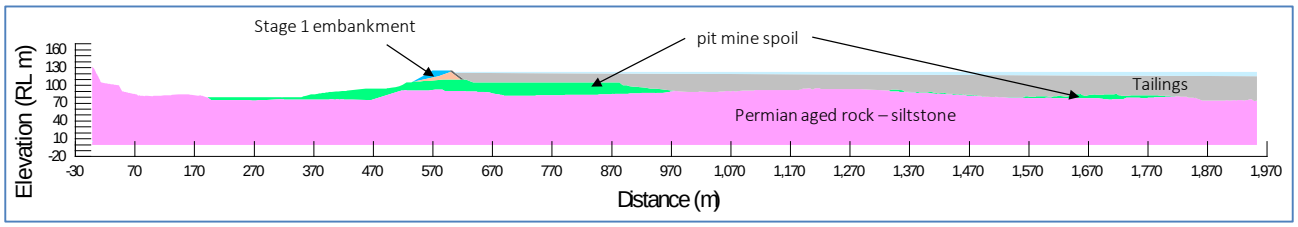


Figure 12-3: Section A-A' Stage 1 Embankment.

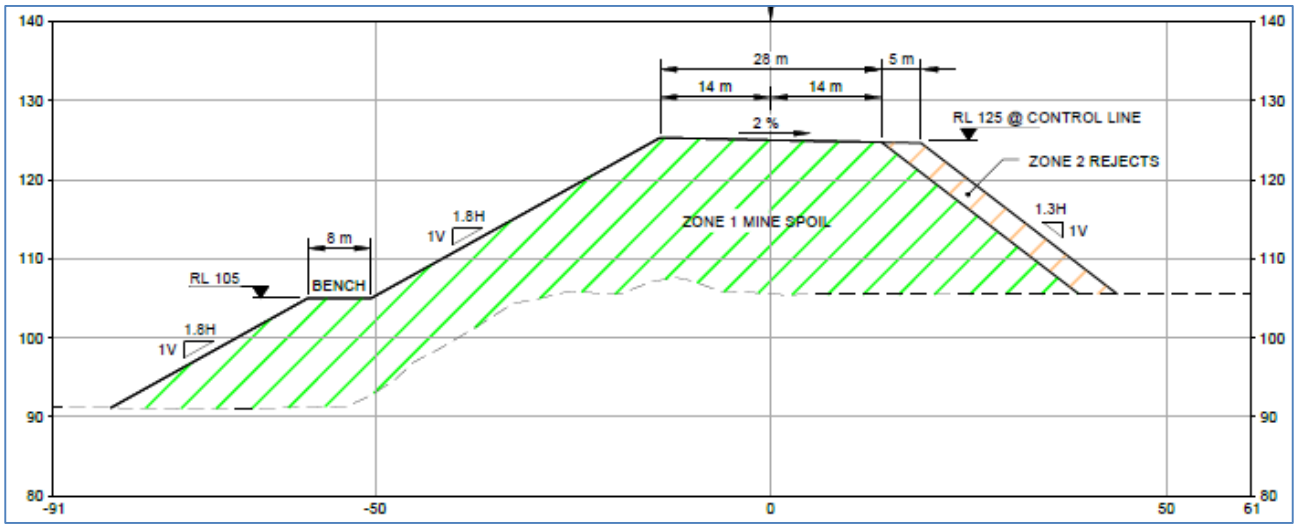


Figure 12-4: Stage 1 embankment section details.

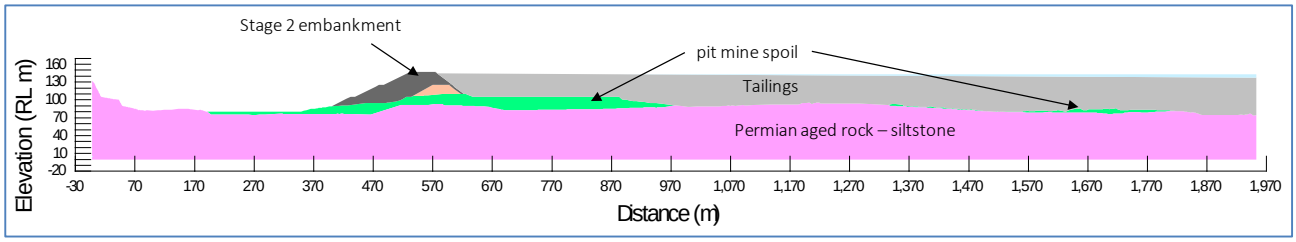


Figure 12-5: Section B-B'' Stage 2 Embankment.

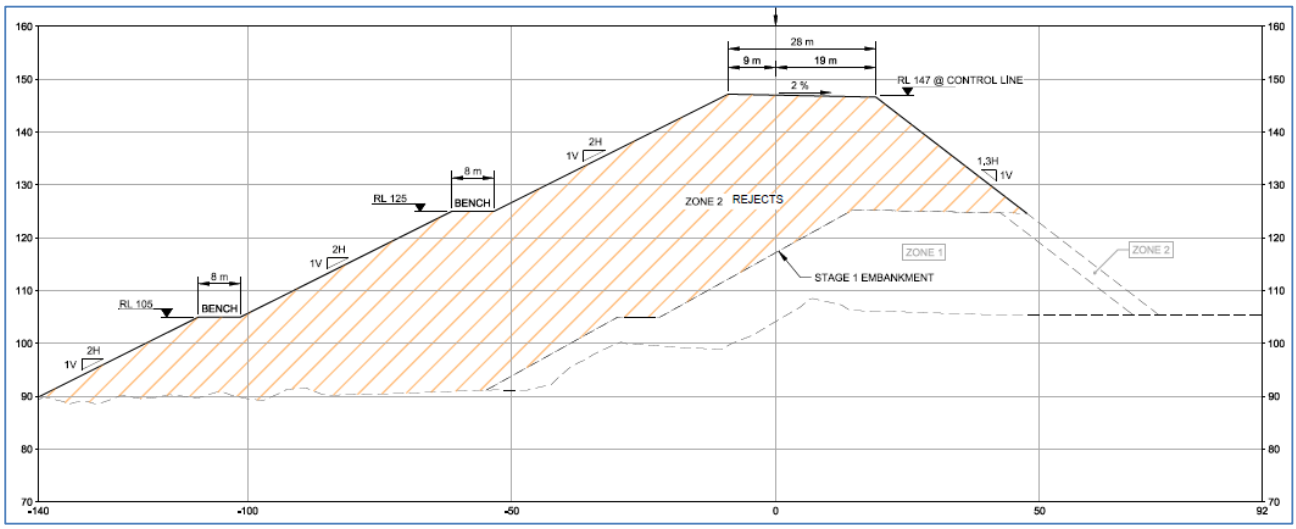


Figure 12-6: Stage 2 embankment section details.

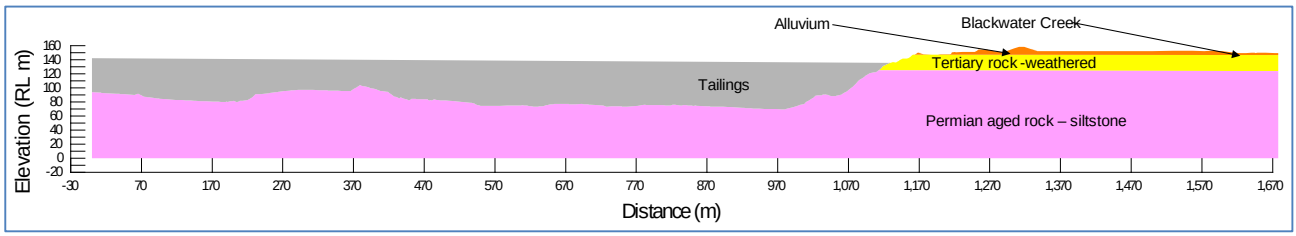


Figure 12-7: Section C-C' wetting front seepage section.

The sub-surface stratigraphy below the embankment was based on the surveys and geological mapping data provided by Curragh, refer Section 8.2.

12.3 Seepage

Seepage analysis has been carried out in relation to the model sections using the computer-based numerical (finite element) seepage modelling package, SEEP/W. SEEP/W is formulated on the basis of Darcy's Law for both saturated and unsaturated flow. The model iteratively solves mass balance differential equations for a grid of finite elements, based on appropriate boundary conditions. Modelling was carried out under steady state conditions on the basis that that rainfall infiltration and beach evaporation was ignored.

12.3.1 Seepage modelling parameters

The model inputs comprised material permeability values, decant pond water levels and groundwater levels. The adopted permeability values were based on the geotechnical assessment of materials presented in Section 8.0 and are summarised in Table 12-2.

Table 12-2: Material permeability summary.

Material	Saturated Permeability K_{sat} (m/s)	k_y/k_x ratio[5]
Natural Sequences		
Alluvium	1.2×10^{-5}	0.1
Tertiary aged rock -weathered	6.9×10^{-6}	0.1
Permian aged rock - siltstone	1.0×10^{-8}	0.02
Placed Materials		
Mine waste	1.0×10^{-5}	0.5
Rejects	1.0×10^{-2}	1
Tailings	1.0×10^{-7}	0.5

The decant pond water levels were based on:

- The operating water level at the final tailings level for each stage
- The water level at DSA at the final tailings level for each stage.

Tailings deposition modelling in Section 10.0 established the final tailings levels and the decant pond stage curves. The modelled water levels were obtained from the decant pond stage curves and are summarised in Table 12-3.

Table 12-3: TSF water level summary.

Stage	Condition	Water level (RLm)
1	Operating water level	116.7
	DSA water level	123.0
2	Operating water level	139.0
	DSA water level	143.0

The adopted groundwater level was RL 70 m on the basis that most of the A Pit monitoring bores are dry which may indicate a deep static phreatic surface.

12.3.2 Seepage modelling cases and results for the wetting front assessment

The modelled conditions are summarised below in Table 12-4 along with references to the SeepW output figures.

Table 12-4: Wetting front seepage modelling cases

Case	Embankment Stage	Water level condition	Reference Figure APPENDIX E
1A	1	Operating water level	E1
1B	1	DSA	E2
1C	2	Operating water level	E3
1D	2	DSA	E4

[5] Data represent horizontal permeabilities (x direction) with the vertical permeability (y direction)

The relevant hydraulic conductivity values obtained from the seepage assessment are shown in Table 12-5.

Table 12-5: Summary of wetting front seepage results.

Case	Description	Flux location	Estimated steady state flow (m^3/s per m)
1A	Stage 1 Operating water level	Alluvium	0
		Tertiary rock - 10 m thick (southern TSF area)	0
		Tertiary rock - 10 m thick (Blackwater creek)	0
1B	Stage 1 DSA level	Alluvium	0
		Tertiary rock - 10 m thick (southern TSF area)	0
		Tertiary rock - 10 m thick (Blackwater creek)	0
1C	Stage 2 Operating water level	Alluvium	0
		Tertiary rock - 10 m thick (southern TSF area)	2.5×10^{-7}
		Tertiary rock - 10 m thick (Blackwater creek)	2.0×10^{-7}
1D	Stage 2 DSA level	Alluvium	0
		Tertiary rock - 10 m thick (southern TSF area)	1.5×10^{-6}
		Tertiary rock - 10 m thick (Blackwater creek)	1.2×10^{-6}

These seepage flows should be viewed in relative terms as a means of comparing likely seepage rates under differing TSF pond levels rather than absolute flows. Higher seepage flows than those predicted from this analysis could be expected as a result of unforeseen sub-surface structural features (fractures, joints) which have not been modelled due to difficulty in incorporating such features.

This comparison indicates that:

- Under stage 1 conditions there is unlikely to be any seepage through the alluvium and the tertiary rock material based on the TSF decant pond operating levels.
- Under stage 2 conditions the analysis show that there is minor seepage into the tertiary material, however based on the Blackwater coalfield stratigraphic sequence, there is low vertical permeability of the bed material around B Pit and the coal seams are considered hydrologically isolated, and therefore potential seepage is unlikely to reach the groundwater aquifers in the Tertiary materials based on the expected lack of vertical leakage in the Tertiary materials and the lack of transmissivity associated with faults. Seepage is not considered likely to intersect the alluvium layers as these are at a higher elevation to the operating water levels and also there is low hydraulic conductivity and lack of continuity in the alluvial materials.

12.3.3 Seepage modelling cases and results for stability

The modelled conditions are summarised below in along with references to the SeepW output figures.

Table 12-6: Seepage modelling cases

Case	Relevant Model Output / Purpose	Embankment Stage	Water level condition	Reference Figure APPENDIX E
2A	Stability modelling	1	Operating water level	E5
2B		1	DSA	E6
2C	Stability modelling	2	Operating water level	E7
2D		2	DSA	E8

The relevant hydraulic conductivity values obtained from the seepage assessment are shown in Table 31.

Table 12-7: Summary of seepage results for embankment stability assessment.

Case	Description	Flux location	Estimated steady state flow (m^3/s per m)
2A	Stage 1 Operating water level	Downstream Embankment toe – mine waste foundation	2.4×10^{-5}
2B	Stage 1 DSA level	Downstream Embankment toe – mine waste foundation	3.5×10^{-5}
2C	Stage 2 Operating water level	Downstream Embankment toe – mine waste foundation	1.4×10^{-5}
2D	Stage 2 DSA level	Downstream Embankment toe – mine waste foundation	2.9×10^{-5}

As noted in Section 12.3.2 these seepage flows should be viewed in relative terms as a means of comparing likely seepage rates under differing TSF pond levels rather than absolute flows. This comparison indicates that:

- There is a marginal reduction in the seepage rate between Stage 1 and Stage 2
- There is a negligible increase in the seepage rate between the operating water level and the DSA

12.4 Stability modelling

Slope stability modelling of the TSF embankment has been completed using SLOPE/W which uses limit equilibrium theory to solve for the factor of safety of earth and rock slopes. The model calculates a factor of safety for a modelled two-dimensional section, satisfying both moment and force equilibrium.

Spencer's method of slices was adopted to analyse circular slip failure mechanisms. This method address inter-slice forces, which assumes a constant inter-slice force angle on all slices equivalent to the average base of slice angle.

The stability modelling was carried out under static and pseudo static (seismic) loading conditions. For seismic conditions the US Army Corps (1984a) method for assessing pseudo static seismic stability was adopted. This method assumes non liquefiable materials under seismic design loading, refer Section 8.5. Furthermore it recommends use of a seismic coefficient equal to one-half of peak ground acceleration (PGA) using undrained strength for cohesive materials and drained conditions for free draining granular materials, with a 20 percent strength reduction in all materials to allow for strain weakening during the earthquake loading.

The stability of the Stage 1 and Stage 2 embankment were assessed under the adopted minimum factors of safety noted in Section 9.4.

12.4.1 Stability cases

Three design cases were analysed to assess the critical stability condition for TSF. These cases are summarised in Table 12-8.

Table 12-8: Stability modelling cases

	Design Case	Input Parameters
3A	Stage 1 Embankment Downstream static stability under operating decant pond	■ Effective stress parameters (c', ϕ') for embankment materials. Undrained strength ratio = 0.15 for tailings. ■ Phreatic surface represented as a piezometric line from seepage modelling for operating water level
3B	Stage 1 Embankment Downstream static stability under DSA conditions	■ Effective stress parameters (c', ϕ') for embankment materials. Undrained strength ratio = 0.15 for tailings. ■ Phreatic surface represented as a piezometric line from seepage modelling for DSA water level
3C	Stage 1 Embankment under operating decant pond with seismic loading (Operational conditions)	■ Seismic strengths for all material ■ Phreatic surface represented as a piezometric line from seepage modelling for operating water level ■ Dynamic loading from OBE Peak Horizontal Ground Acceleration coefficients (to support pseudo-static analysis)
3D	Stage 1 Embankment under DSA with seismic loading (Operational conditions)	■ Seismic strengths for all material ■ Phreatic surface represented as a piezometric line from seepage modelling for DSA water level ■ Dynamic loading from OBE Peak Horizontal Ground Acceleration coefficients (to support pseudo-static analysis)
3E	Stage 1 Embankment under seismic loading (closure conditions)	■ Seismic strengths for all material ■ Phreatic surface represented as a piezometric line under DSA water level ■ Dynamic loading from MDE Peak Horizontal Ground Acceleration coefficients (to support pseudo-static analysis)
4A	Stage 1 Embankment Downstream static stability under operating decant pond	■ Effective stress parameters (c', ϕ') for embankment materials. Undrained strength ratio = 0.15 for tailings. ■ Phreatic surface represented as a piezometric line from seepage modelling for operating water level
4B	Stage 1 Embankment Downstream static stability under DSA conditions	■ Effective stress parameters (c', ϕ') for embankment materials. Undrained strength ratio = 0.15 for tailings. ■ Phreatic surface represented as a piezometric line from seepage modelling for DSA water level
4C	Stage 1 Embankment under operating decant pond with seismic loading (Operational conditions)	■ Seismic strengths for all material ■ Phreatic surface represented as a piezometric line from seepage modelling for operating water level ■ Dynamic loading from OBE Peak Horizontal Ground Acceleration coefficients (to support pseudo-static analysis)
4D	Stage 1 Embankment under DSA with seismic	■ Seismic strengths for all material

	Design Case	Input Parameters
	loading (Operational conditions)	■ Phreatic surface represented as a piezometric line from seepage modelling for DSA water level ■ Dynamic loading from OBE Peak Horizontal Ground Acceleration coefficients (to support pseudo-static analysis)
4E	Stage 1 Embankment under seismic loading (closure conditions)	■ Seismic strengths for all material ■ Phreatic surface represented as a piezometric line under a phreatic surface water level similar to operating to account for some water infiltration. It is assumed that under closure conditions there would be a capping surface which would be designed to shed water. ■ Dynamic loading from MDE Peak Horizontal Ground Acceleration coefficients (to support pseudo-static analysis)

12.4.2 Seismic loading

The seismic loading condition is based on steady state design case, but with seismic loading also considered. In accordance with ANCOLD (2012b), the TSF has been assessed subject to an Operating Basis Earthquake (OBE) and Maximum Credible Earthquake (MCE).

- The OBE produces a level of ground motion which will cause only minor and repairable damage to the structure and may be used to assess the serviceability of the dam. OBE is generally expected to cause limited damage and deformation that can be repaired without significantly disrupting operations
- The MDE produces a level of ground motion which may badly damage the TSF but the facility should maintain its integrity and not allow the release of impounded tailings and/or water.

Table 12-9 presents the adopted seismic loadings for the analysis represented by Peak Horizontal Ground Acceleration (PGA)

Table 12-9: Type table title here.

Design event	Average Recurrence Interval	PGA	Adopted Seismic Loading
OBE	1 in 1000 years	0.026 g	0.013 g
MDE	1 in 10 000 years	0.150 g	0.075 g

The seismic return periods adopted were based on ANCOLD (2012b) using a 'High C' ANCOLD consequence category documented in Section 9.2.2.

The OBE PGA coefficient was derived by:

- Using the 1 in 500 Peak Horizontal Ground Acceleration coefficient obtained from the Geoscience Australia website (web link: http://www.ga.gov.au/interactive-maps/#/theme/hazards/map/earthquakehazards)
- Using probability factor (k_p) in AS 1170.4 to convert the 1 in 500 PGA coefficient to a 1 in 1 000 PGA.

The MDE PGA was obtained from Burbidge, D.R. (ed.) (2012).

The adopted seismic loadings are in accordance with the US Army Corps (1984a) method for assessing pseudo static seismic stability whereby they recommend a seismic loading equal to one-half of the PGA.

12.4.3 Stability modelling geotechnical parameters

The adopted stability parameters were based on the geotechnical assessment of materials presented in 8.0. Table 12-10 summarises the adopted parameters.

Table 12-10: Stability modelling parameter summary.

Material	Unit weight (kM/m^3)	Static strength	Undrained Seismic Strength
Natural Sequences			
Permian aged rock - siltstone	20	c' = 500 kPa, ϕ' = 28	c = 400 kPa, ϕ = 23
Placed Materials			
Mine waste (unsaturated)	18	c' = 50 kPa, ϕ' = 30°	c = 80 kPa, ϕ = 16
Mine waste (saturated)	20	c' = 20 kPa, ϕ' = 25°	c = 80 kPa, ϕ = 16
Rejects	15	c' = 0 kPa, ϕ' = 40°	c = 0 kPa, ϕ = 34°
Tailings	12	0.15 (Su/σv')	0..12 (Su/σv')

12.4.4 Stability results

The results are shown in Table 12-11 and Table 12-12 with the Slope/W output figures attached in APPENDIX F. Global embankment failure was taken as embankment failure from crest to toe that would cause loss of containment which was assumed to be at least half the embankment crest width. Local embankment failure was taken as any failure occurring between benches. Note that for Stage 1 the existing ground surface is near the stage 1 downstream bench level and for this reason local embankment stability has not been assessed.

Table 12-11: Stage 1 stability results

Case	Global embankment		
	Factor of Safety	Achieves assessment criteria	Figure APPENDIX F
3A Static, operating pond	1.5	YES	F1
3B Static, DSA	1.3	NO	F2
3C Seismic OBE, operating pond	1.5	YES	F3
3D Seismic OBE, DSA	1.2	YES	F4
3E Seismic MDE	1.3	YES	F5

Table 12-12: Stage 2 stability results

Case	Global embankment			Local embankment		
	Factor of Safety	Achieves assessment criteria	Figure	Minimum Factor of Safety	Achieves assessment criteria	Figure
4A Static, operating pond	1.7	YES	F6	1.6	YES	F7
4B Static, DSA	1.4	NO	F8	1.3	NO	F9
4C Seismic OBE, operating pond	1.5	YES	F10	1.7	YES	F11
4D Seismic OBE, DSA	1.3	YES	F12	1.0	YES	F13
4E Seismic MDE,	1.2	YES	F14	1.5	YES	F15

The stability results under the modelled conditions indicate that:

- The stage 1 embankment meets the stability criteria for all conditions, except under static condition in combination with the DSA phreatic surface
- The stage 2 embankment meets the stability criteria for all conditions, except under static condition in combination with the DSA phreatic surface.

The DSA phreatic surface is considered a short term phenomena whereby removal of this water should be undertaken as part of mining operations as the embankment is not intended to act as a water storage structure. The Decant Ponds should be operated at a level of RL 117 and RL 141 for Stage 1 and Stage 2 embankments respectively.

On this basis a factor of safety between 1.3 and 1.5 is considered acceptable under short term conditions. However, a heightened level of dam safety inspections would need to be carried out under these conditions to look for signs of seepage and instability by measuring water levels within the monitoring piezometers.

13.0 EMBANKMENT EROSION PROTECTION

13.1 Internal batters

The internal batters are covered with a layer of rejects which is expected to assist in protecting the upstream batters from erosion. Over time tailings will gradually cover the internal batters eliminating the risk of erosion.

13.2 External batters

The crest has been graded to the upstream side to divert most of the crest drainage water which would potentially contribute to gully erosion on the downstream batters.

Under the Stage 1 embankment the cross sectional thickness of the embankment, with a minimum crest width of 28 m, is expected to tolerate a high level of erosion.

The Stage 2 embankment is to be constructed from coal rejects which is expected to be resilient to erosion.

14.0 DESIGN DRAWINGS AND SPECIFICATION

The design drawings and specification are attached in APPENDIX A.

15.0 OPERATIONAL GUIDELINES

DEHP requires the dam owner to prepare and submit an operational plan that is consistent with the requirements in the Environmental Authority. The information provided in this section does not constitute an operational plan but provides supporting information for the formation of such a plan.

The operational guidelines provided in this report are specific to the Stage 1 TSF are subject to periodic review and updating to reflect modifications to the conditions on which the document is based. The timing for such updates includes, but is not necessarily limited to the following:

- Alteration (either increase or decrease) of the capacity of the TSF by increased footprint or storage height.
- A significant incident with respect to the operation and/or performance of the facility is experienced.
- A significant change to the Environmental Authority for the Curragh Mine operation, or conditions contained therein, is made.

15.1 Tailings deposition

Tailings deposition into the Pit B TSF can occur from four tailings deposition lines (2 from each CHPP), however, it is understood that only one line from each CPP will be operational during normal operation. However it is noted that all four lines can function simultaneously.

General guidelines for tailings deposition into the TSF are provided as follows:

- Deposition is to comprise pumping through the single discharge line with deposition onto the rising tailings beach surface. No further control can be applied beyond the discharge pipeline, with the tailings beach development dependent on the deposition location.
- The overall tailings beach profile will be controlled by relocation of tailings discharge locations. The deposition sites will be from the end of the Stage 1 tailings pipe cut and from Ramp 4 (refer APPENDIX A), as required, to promote a tailings beach profile that slopes towards the centre of the TSF storage area. Slurry discharge from the containment embankment may also be required to develop the beach profile.
- Visual assessment of the decant pond location shall be made as part of the deposition process, to prompt the relocation of discharge sites. Decant water recovery is to be consistently maintained.
- The overall tailings beach profile should maintain an even level around the perimeter embankments, falling at approximately 0.5% towards the decant pond at the southern end of Pit B.

Further to the above general guidelines, on the ceasing of pumping through the delivery pipeline (i.e. at a plant shutdown or when transferring of deposition from site to site), the delivery pipeline shall be immediately flushed to assist in the prevention of settlement of tailings solids within and blockage of the pipe.

15.2 Decant pond operation

The operating objectives for the decant system are:

- To minimise the volume of water contained within the storage (thus contributing to maintenance of freeboard levels, and facilitating exposure of the deposited tailings beach to consolidation and air-drying, particularly as the capacity of the storage is approached)
- To minimise the transfer of suspended solids to the coal handling and process plant.

General guidelines for decant pond operation are as follows:

- Water will be recovered using a pontoon pump system to be designed by Curragh
- The decanting of water from the TSF is to be designed to meet the CHPP requirements

- The decant pond operating depth should be no greater than 2 to 3 m
- The decant ponds should be operated at a level of RL 117 and RL 141 for Stage 1 and Stage 2 embankments respectively.
- DEHP shall be notified if the decant pond level reaches the MRL, refer Section 11.3.
- On the 1st November each year there must be adequate storage above the decant pond to account for the DSA volume, refer Section 11.3.

15.3 Trigger levels

15.3.1 Definition

In general accordance with the US Federal Energy Regulatory Commission (Division of Dam Safety and Inspections) a trigger level can be defined as “an instrument reading that triggers increased surveillance or an emergency action”. The assigned trigger levels indicate that the stability factor of safety design criteria has been reached, Refer Section 15.4.

15.3.2 Actions under trigger levels

If the piezometric trigger levels are reached the following actions shall be undertaken:

- Review data for reliability
- Inform all responsible parties including the design engineer
- Inspect the site for signs of instability
- Design a remedial plan to increase the stability factor of safety back to the design or required value
- Carry out daily piezometer readings and provide these to the design engineer

If the piezometric levels rise above the trigger level the following shall be undertaken:

- Inform all parties working on the affected area to evacuate immediately
- Implement the emergency action plan

15.4 Inspection and monitoring

Regular site surveillance and monitoring of the TSF shall be undertaken based on the following.

15.4.1 Phreatic surface

Monitoring of the phreatic surface within the embankment and foundations – a minimum of two piezometers for each stage located on the crest and on the downstream embankment benches. Monitoring should be undertaken at a monthly frequency. Monitoring of the stored water levels should also be undertaken.

The recommended standpipe trigger levels are shown in Table 15-1:

Table 15-1: Piezometer monitoring trigger levels

Piezometer Location	Stage 1 Piezometer Trigger Level (RLm)	Stage 2 Piezometer Trigger Level (RLm)
Upstream crest edge	115	128
External batter bench RL 125 m	not applicable	100
External batter bench RL 105 m	104	96

15.4.2 Settlement

Settlement monitoring of the embankment – at least 2 monuments are required, located on the embankment crest. Monitoring should be undertaken at a frequency of not greater than 6 months during periods of high water levels.

Visual inspections (documented) of the TSF as follows:

Shift/daily and/or significant rainfall incident related inspections to inspect the physical conditions of the embankment, spillway, pipelines, seepage system and diversion system.

Annual and/or incident related dam safety inspections to review monitoring data (phreatic surface and settlement monitoring) and inspect conditions of embankment, spillway, pipelines, seepage system, diversion drains etc.

15.5 Emergency action plan

An emergency action plan for the TSF will be included in the operating manual that shall be prepared prior to commissioning the facility. This emergency action plan and routine checking procedures shall include, but not limited to the following details as provided below.

15.5.1 General overview

The plan shall provide a list of relevant steps to follow in the advent of a tailings dam pipe or embankment failure. Contact details of staff associated with the tailings dam, senior site staff responsible, safety officer and emergency services shall be provided.

It must be stressed however, that the safe operation of the tailings dam relies upon the implementation of operational procedures comprising tailings deposition, decant operation, and routine inspections and maintenance. These are to be set out in detail in related Standard Operating Procedures to minimise the potential for a catastrophic event such as a failed embankment.

15.5.2 Tailings lines and return water lines

The tailings line from the process plant to the tailings storage and the return water lines from the decant facility to the process water pond are bunded to contain any spillage of materials resulting from lines which develop leaks or burst during operation.

15.5.3 Pipeline failure

In the event of pipeline failure:

1) Shutdown the affected pipeline until repaired

2) Notify Process Supervisor

3) Collect and/or pump the spilled materials, as appropriate, and deposit in the tailings storage area.

4) Process Manager to notify the Site Senior Executive who will assess the spill and ascertain whether reporting to statutory bodies is required.

15.5.4 Tailings embankment

The embankment of the TSF has been designed with an adequate factor of safety against failure under normal operating conditions and under seismic load conditions appropriate for the location of the structure. Normal operating conditions refer to a relatively small decant water pond with no permanent free water ponding against the perimeter embankments.

Given the adoption of the tailings deposition philosophy, good decant operation, routine inspections and maintenance practices set out in other tailings dam procedures and, that the embankment construction has been or should be carried out in accordance with the design, the probability of embankment failure during normal operations is very low.

However, in the unlikely event of embankment failure, the flow of tailings from the storage will be controlled by the degree of saturation of the tailings at the time of failure.

15.5.4.1 Small scale embankment failure

Small scale embankment failures can be defined as failures that are not likely to cause loss of containment

Action to control a small scale embankment failure and limit environmental damage would include:

1) Assess the requirement to shut down the process plant, or reduce process plant throughput

5) Contact Process Manager who will coordinate the following steps

6) Notify Site Senior Executive who will assess the failure and make contact with relevant statutory bodies

7) If necessary divert or build bunds to contain tailings by using earthmoving equipment

8) Contact a consultant suitably qualified in tailings dam design and operation for technical assistance

9) Deploy pumps to recover tailings water and return it either to the process water pond or to the storage if structurally sound.

10) Prior to the commencement of any repairs undertake a thorough inspection of the area with a consultant (as above)

11) Undertake remedial and repair work of the damaged embankment or affected area

12) Clean up of tailings as soon as practical after embankment repairs have been completed and the storage is considered to be in a safe condition.

13) Prepare an incident report, detailing all factors to the incident and the situation after clean –up. The report will identify causes of the problem and what actions will be taken to prevent a similar occurrence. This report will detail the ongoing monitoring programme to fully assess the impact of the incident.

14) Site Senior Executive to advise all appropriate government departments, as necessary, of the incident, review DEHP conditions of licence in respect to further reporting on the completion of remedial works.

Contact details of relevant personnel and emergency services will be maintained in the Crisis Management and Recovery Manual.

15.5.4.2 Large scale embankment failures

Large scale embankment failures have the potential to cause loss of containment.

Action to control a large scale embankment failure and to limit environmental damage would include;

1) Shut down the process plant to eliminate escalating the failure.

2) Evacuate the area, if required, to the nearest muster point.

3) Contact Process Manager who will coordinate the following steps

4) Notify Site Senior Executive who will assess the failure and make contact with relevant statutory bodies

5) If necessary divert or build bunds to contain tailings by using earthmoving equipment

6) If tailings material has been discharged and enters possible stock water supplies the Site Senior Executive will organise a water sampling and analysis program.

7) Contact a consultant suitable qualified in tailings dam design and operation for technical assistance.

8) Site Senior Executive to advise relevant government departments of the incident as soon as possible and review the DEHP conditions on the licence in respect to further reporting on the completion of remedial works.

9) Deployment of pumps to recover tailings water and return it either to the process water pond or to the dam if structurally sound

10) Prior to the commencement of any repairs undertake a thorough inspection of the area with the assistance of a geotechnical specialist

11) Repair the damaged embankment

12) Clean up of tailings a soon a practical after the embankment repairs have been completed

13) Prepare an incident report, detailing all factors to the incident and the situation after clean-up. The report should identify causes of the problem and what actions will be taken to prevent a similar occurrence. This report should detail the ongoing monitoring programme to fully assess the impact of the incident

14) Site Senior Executive to submit report and advise all appropriate government departments, as necessary, of the incident.

Contact details of relevant personnel and emergency services will be maintained in the Crisis Management and Recovery Manual.

16.0 TECHNICAL RISK ASSESSMENT

A preliminary engineering risk assessment for the IPAC1 was undertaken utilizing a HAZOPS type risk approach. The components of the risk assessment are summarized in Appendix APPENDIX H Table 1 and the results are shown in Appendix APPENDIX H Table 2 and Table 3 for initial and residual risk under mitigation maesures.

The following risk assessment approach was undertaken:

- Identification of the risk assessment scope
- Identification of key hazards and impacts
- Assignment of probability
- Assignment of consequence
- Assignment of risk rating for each hazard
- Identification of risk reduction and mitigation measures.

The assessment approach is qualitative and is based on available information on the design and operation of the Pit B TSF. The likelihood of each hazard occurring has not been assessed on a statistical basis.

16.1 Risk categories

The impact, likelihood, consequence and overall risk of each hazard have been assessed in three general risk categories, described as follows:

- Safety and health of personnel and public
- Temporary or permanent impact on the environment, including regulatory impacts and remediation liabilities
- Cost to repair or replace damaged assets and cost of lost production / time.

16.2 Identified hazards and risk reduction measures

The major hazards identified along with the key risk reductions measures are presented in Table 16-1.

Table 16-1: HAZOP risk assessment

Hazard	Key Risk Reduction Measure
Embankment stability failure	- Maintain the decant pond at or below the DSA level - Conduct regular site visits and undertake embankment maintenance when necessary
Overtopping embankment from rainfall	- Implement additional decant pumping and divert water to external storage areas - Stop pumping tailings into Pit B if necessary and divert to other storages if available

Seepage / piping	- Conduct regular visits to external embankment toe and downstream from the external toe to look for signs of seepage and piping
	- If signs of seepage and / or piping are evident:
	  - Minimise decant pond water depth by maximising pumping
	  - Stop pumping tailings if necessary and divert to other storages if available
	  - contact the design engineer to establish control measures

Hazard	Key Risk Reduction Measure
	- Control measures may include placing a buttress along the downstream batter with coarse rejects
Tailings pipeline failure	- Containment bunds to be installed along pipeline route.

17.0 CLOSURE

The final surface cover of the TSF will be subject to investigation works and detailed assessment in the years prior to closure and would typically include an assessment of the geochemistry and leaching of the tailings material which would be used in conjunction with detailed cover analysis in determination of the preferred capping philosophy, whilst achieving the overall objectives as outlined below. Typical cover design options considered applicable at the Curragh Mine may include a barrier/low hydraulic conductivity cover or a store-and-release cover and would need to be consistent with the EA conditions. Notwithstanding the above, the following provides a conceptual strategy for the closure of the B Pit TSF, with the final cover system including all or a subset of the cover components as described below.

The typical objectives to be adopted for rehabilitation of the TSF would be to create a landform that is:

- Stable and sustainable;
- Compatible with the surrounding landform; and
- Of minimum long term environmental impact (i.e. non-polluting).

Based on these objectives, a concept for the TSF is as follows:

17.1 Landform development

It is envisaged that the final TSF landform would comprise long-term stable external batters with an upper surface formed such that ponding is substantially avoided. This would therefore necessitate a final campaign of tailings deposition at the southern end of the TSF to infill any significant depression. Final drainage formation towards a discharge channel may then be formed, as required.

17.2 Tailings surface capping

A tailings surface cap would serve the following purposes:

- Facilitate ongoing surface water drainage and prevent ponding;
- Stabilise the surface to mitigate against potential ongoing erosion; and
- Reduce potential rainfall infiltration into the tailings as recharge to seepage.

The cap would comprise the following components as described below to meet these performance standards. This configuration assumes that the tailings would remain geochemically benign.

17.2.1 Tailings surface stabilisation layer

To provide a geotechnical competent surface over the surface of the tailings, a stabilization layer may be necessary. The purpose of the stabilisation layer would be to provide a competent subgrade or bridging layer, which would evenly distribute the surcharge onto the tailings surface and thereby limit potential settlements. The area most likely to require stabilisation would be the decant pond surface, due to the likely extent of saturated slimes materials.

The stabilisation layer would typically comprise rock mattress (the rock comprising competent and durable material).

17.2.2 Sealing layer

A sealing layer may be required to reduce the downward infiltration of surface water, which would act as a recharge to seepage, as well as oxygen. The sealing layer would be constructed using a compacted clay fill material and would extend over the full surface area of the storage.

17.2.3 Surface protection layer

To protect the tailings surface from erosion and exposure deterioration (through wetting and drying), a surface protection layer would be required. This layer could also be utilized as a rooting zone for vegetation depending on the proposed end land use.

This layer would be formed typically using select mine waste rock from the existing waste rock spoil areas. Geochemically, the waste should be non-acid producing. From a geotechnical perspective, the material should be non-erosive/dispersive.

The thickness of this layer would be selected to not only maintain drainage, but also to compensate for settlement within the underlying tailings. A hummocky final land surface may also have some benefit with respect to maintaining moisture within the surface layers to support vegetation growth and to reduce erosion potential. The final surface landform would be subject to further, ongoing assessment through the life of the facility.

A more detailed assessment of a suitable capping configuration would need to be completed, subject to more data being available with respect to the physical and geochemical characteristics of the tailings. In particular, geochemical compatibility between the tailings and capping materials must be confirmed to ensure the integrity of the capping horizon is not compromised.

18.0 REFERENCES

1) ANCOLD (1998a). *Guidelines for Design of Dams for Earthquake,* August 1988, Australian National Committee on Large Dams

2) ANCOLD (2012b). Guidelines on Tailings Dams Planning, Design, Construction, Operation and Closure, May 2012, Australian National Committee on Large Dams

3) ANCOLD (2012c). *Guidelines on the Consequence Categories for Dams*, October 2012, Australian National Committee on Large Dams

4) Burbidge, D., R. (ed.) (2012). *The 2012 Australian Earthquake Hazard Map,* Record 2012/71, Geoscience Australia, Canberra

5) Curragh (2016). *D-E-F Pit Hydrology*, memorandum, 13 October 2016

6) Curragh (2015). *A Pit Geology / Groundwater Clarifications,* memorandum 14 August 2015

7) DEHP (2016). *Manual for assessing consequence categories and hydraulic performance of structures*, ESR/2016/1933, version 5, 29 March 2016, Department of Environment and Heritage Protection, Queensland Government

8) Department of of Environment and Heritage Protection, 2016. *Manual for assessing consequence categories and hydraulic performance of structures*, Version 5.0, March 2016.

9) Fell, R. (2004). Design of Embankment Dams to Withstand Earthquakes – Developments Since the ANCOLD Guidelines Were Published, ANCOLD conference

10) Golder (2014). *Curragh Coal Mine Life of Mine Tailings Storage Study,* report number 003-147635010, revision 3, Golder Associates, Brisbane

11) Hoek, E., Brown, E. T., (1997). *Practical estimates of rock mass strength,* Journal of Rock Mechanics and Mining Science, Vol 34, No 8 pp. 1165-1186

12) Sherwood (2013). *Kogan Creek Mine Ash Rehandling Geotechnical Assessment*, Report no. 34006-1-1, Sherwood Geotechnical and Research Services

13) Simmons, J., V., McMannus, D., A. (2004). *Shear Strength Framework for Design of Dumped Mine waste Slopes for Open Pit Coal Mines*, Proc. Advances in Geotechnical Engineering, The Skempton Conference, Vol. 2, 981-991, Thomas Telford

14) US Army Corps (1984a). *Rationalising the seismic coefficient method,* miscellaneous paper GL-84-13, July 1984, Vicksburg, Mississippi

15) US Army Corps (1984b). *Shore Protection Manual Volumes 1 and 2,* Coastal Engineering Research Centre, Department of the Army, Waterways Experiment Station, Corps of Engineers, Vicksburg, Mississippi

16) US Army Corps (1993). *Seepage Analysis and Control for Dams,* Engineering Manual 1110-2-1901, 30 April 1993, Washington, DC

17) USBR (1981). *Freeboard Criteria and Guidelines for Computing Freeboard Allowances for Storage Dams,* Acer Technical Memorandum No. 2, U.S. Department of the Interior Bureau of Reclamation, Denver, Colorado

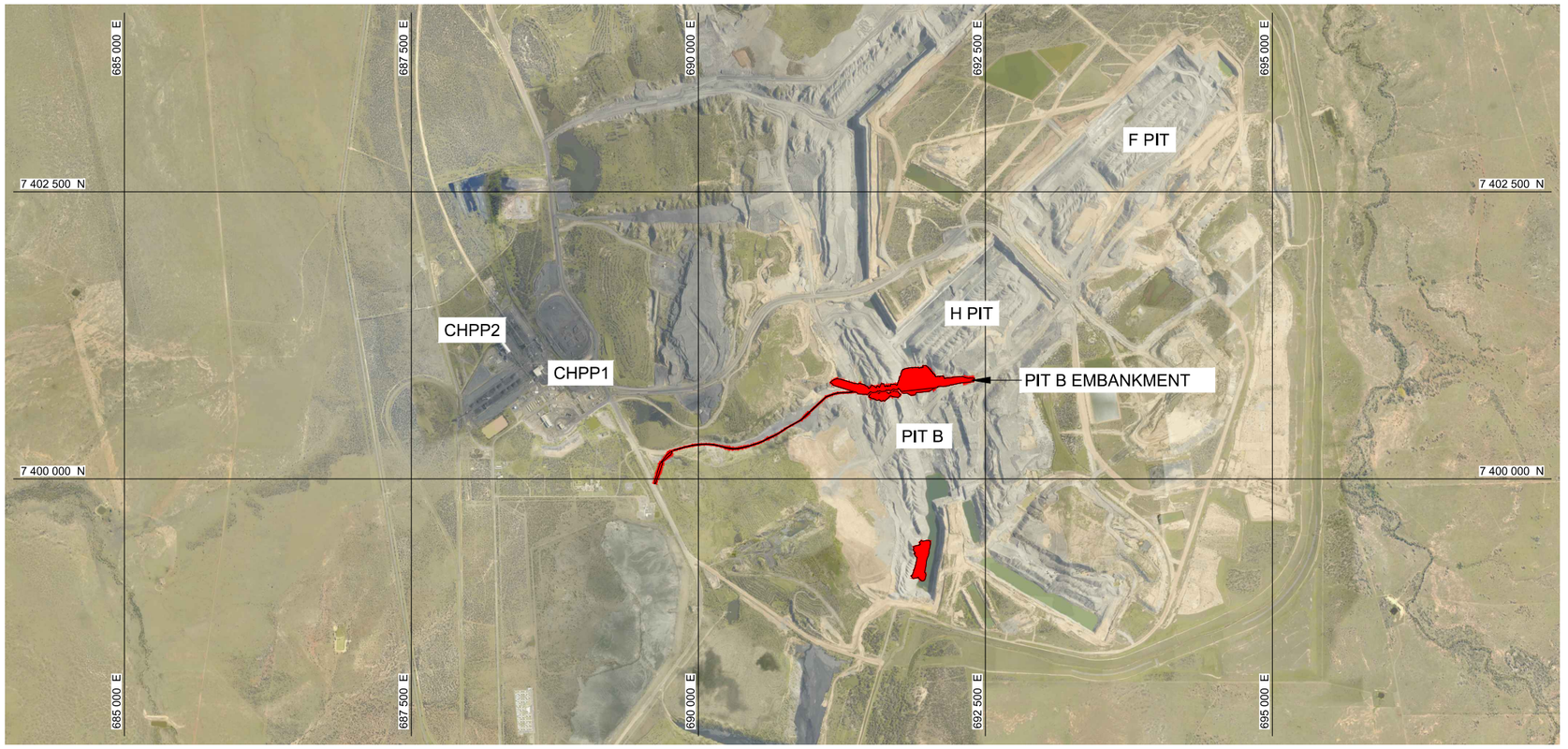
18) USDA (1994). *Part 633 National Engineering Handbook Chapter 26 Gradation Design of Sand and Gravel Filters*, , United States department of Agriculture, National Resources Conservation Services, Washington, DC

19) Wesfarmers Curragh Pty Ltd, 2016. *D-E-F Pit Hydrology*. 13 October 2016.

APPENDIX A

Technical specification and drawings

PIT B TAILINGS STORAGE FACILITY EARTHWORKS - STAGES 1 AND 2



LOCALITY PLAN
SCALE 1:50,000 m

DRAWING INDEX

DRG NO.	DESCRIPTION	REV.
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003	STAGE 1 - TAILINGS PIPE CUT 1 - PLAN VIEW AND LONGITUDINAL SECTION	1
004	STAGE 1 - TAILINGS PIPE CUT 2 - PLAN VIEW AND LONGITUDINAL SECTION	1
005	STAGE 1 - PROTECTION BUND - PLAN VIEW AND LONGITUDINAL SECTION - SHEET 1 OF 3	1
006	STAGE 1 - PROTECTION BUND - PLAN VIEW AND LONGITUDINAL SECTION - SHEET 2 OF 3	1
007	STAGE 1 - PROTECTION BUND - PLAN VIEW AND LONGITUDINAL SECTION - SHEET 3 OF 3	1
008	STAGE 1 - DECANT RAMP - PLAN VIEW AND LONGITUDINAL SECTION	1
009	STAGE 2 - EMBANKMENT RL 147 - PLAN VIEW AND LONGITUDINAL SECTION - SHEET 1 OF 2	1
010	STAGE 2 - EMBANKMENT RL 147 - PLAN VIEW AND LONGITUDINAL SECTION - SHEET 2 OF 2	1
011	TYPICAL CROSS SECTIONS - SHEET 1 OF 2	1
012	TYPICAL CROSS SECTIONS - SHEET 2 OF 2	1
013	SETOUT TABLES	1
014	ZONE 1 BORROW LOCATION	1
015	EMBANKMENT MONITORING BORES - TYPICAL DETAIL AND SETOUT TABLE	1

NOTE(S)

1. ALL DIMENSIONS ARE IN METRES (m) UNLESS NOTED OTHERWISE. ALL ELEVATIONS ARE IN METRES (m). ALL CO-ORDINATES ARE IN METRES (m).
2. VERTICAL DATUM IS LOCAL.
3. HORIZONTAL DATUM IS IN CURRAGH SITE GRID.
4. REFER SPECIFICATION FOR COMPACTION REQUIREMENTS AND MATERIAL STANDARDS.
5. SETTING OUT DIMENSIONS SHOWN ON THE DRAWINGS SHALL BE VERIFIED BY THE SITE CONTRACTOR. REFER ANY DISCREPANCY TO THE COMPANY'S REPRESENTATIVE BEFORE PROCEEDING WITH WORK.
6. DESIGN IS BASED ON LIDAR SURVEY DATA. DUE TO POTENTIAL INACCURACIES IN THE SURVEY, THE CONTRACTOR SHALL VERIFY SURFACE LEVELS AND ADVISE THE CLIENT'S REPRESENTATIVE IMMEDIATELY IF THERE IS ANY DISCREPANCY WITH THE DESIGN LEVELS.
7. REFER ALL DISCREPANCIES TO THE COMPANY'S REPRESENTATIVE BEFORE PROCEEDING WITH THE WORKS.
8. DESIGN BASED ON FOLLOWING SURVEY FILES :
   - 1602-CS RUNNING.00t (DATED 16.09.2016)
   - bpibatho1610.dxf (DATED 29.11.2016)
   - g_bridge_161116.arch_d (DATED 18.11.2016)
9. ALL VOLUMES ARE IN CUBIC METRES (m³), AREAS ARE IN SQUARE METRES (m²) AND REDUCED LEVELS ARE IN METRES (m) UNLESS NOTED OTHERWISE.
10. THESE NOTES APPLY TO ALL DRAWING'S LISTED IN THE DRAWING INDEX.

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1:50,000 METRES

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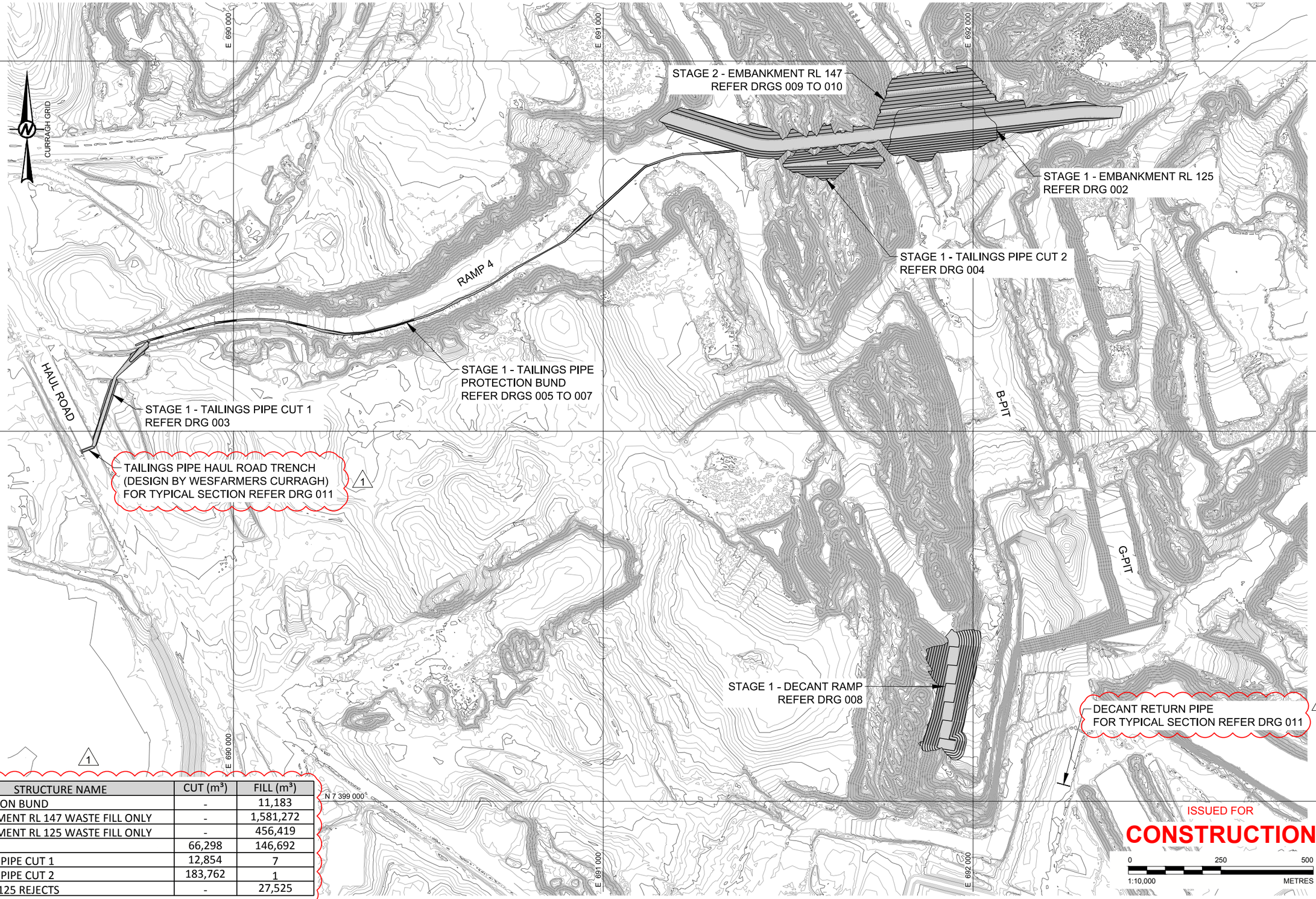
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PIT B TSF EARTHWORKS

TITLE
LOCALITY PLAN AND DRAWING INDEX

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STRUCTURE NAME	CUT (m³)	FILL (m³)
PROTECTION BUND	-	11,183
EMBANKMENT RL 147 WASTE FILL ONLY	-	1,581,272
EMBANKMENT RL 125 WASTE FILL ONLY	-	456,419
RAMP 2	66,298	146,692
TAILINGS PIPE CUT 1	12,854	7
TAILINGS PIPE CUT 2	183,762	1
WALL RL 125 REJECTS	-	27,525

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GENERAL ARRANGEMENT PLAN

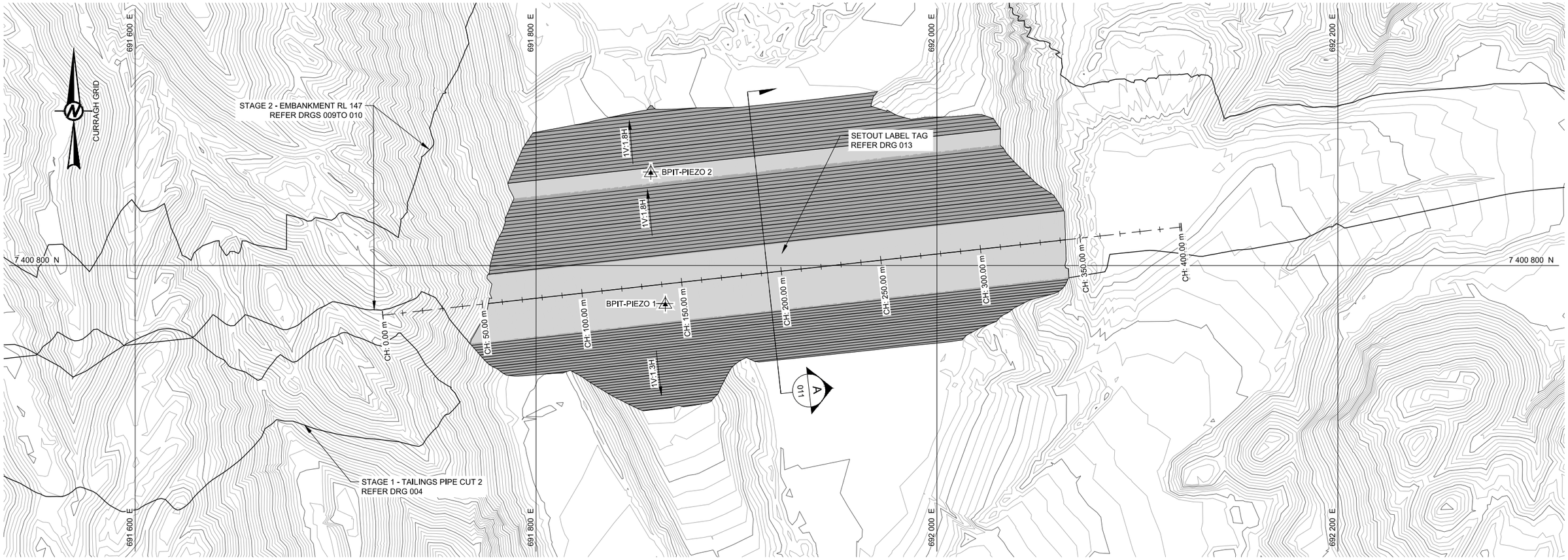
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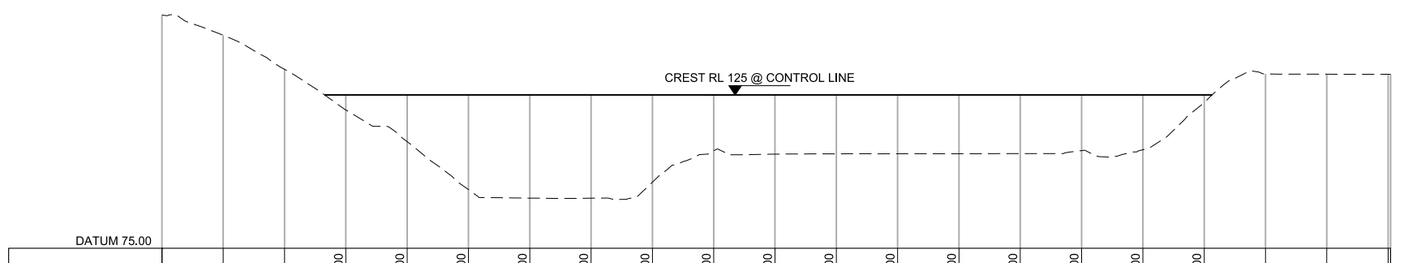
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PLAN VIEW
SCALE 1:2,000 m



DATUM 75.00																					
PROPOSED GROUND				125.00	125.00	125.00	125.00	125.00	125.00	125.00	125.00	125.00	125.00	125.00	125.00	125.00	125.00				
EXISTING GROUND	150.96	144.45	133.33	120.07	109.75	94.10	91.35	91.32	96.54	106.78	105.68	105.78	105.82	105.82	105.84	106.82	107.11	122.46	131.82	131.74	131.70
CUT AND FILL DEPTH (m)				4.93	15.25	30.90	33.65	33.68	28.46	18.22	19.32	19.22	19.18	19.18	19.16	18.18	17.89	2.54			
CHAINAGE	0.00	20.00	40.00	60.00	80.00	100.00	120.00	140.00	160.00	180.00	200.00	220.00	240.00	260.00	280.00	300.00	320.00	340.00	360.00	380.00	400.00	400.80

LONGITUDINAL SECTION
SCALE 1:2,000 m

SETOUT TABLE FOR PIEZOMETER		
PIEZOMETER No.	EASTING (m)	NORTHING (m)
BPIT-PIEZO 1	691864.50	7400781.02
BPIT-PIEZO 2	691857.24	7400846.62

NOTE
1. REFER TO DRAWING 015 FOR TYPICAL DETAIL OF PIEZOMETER

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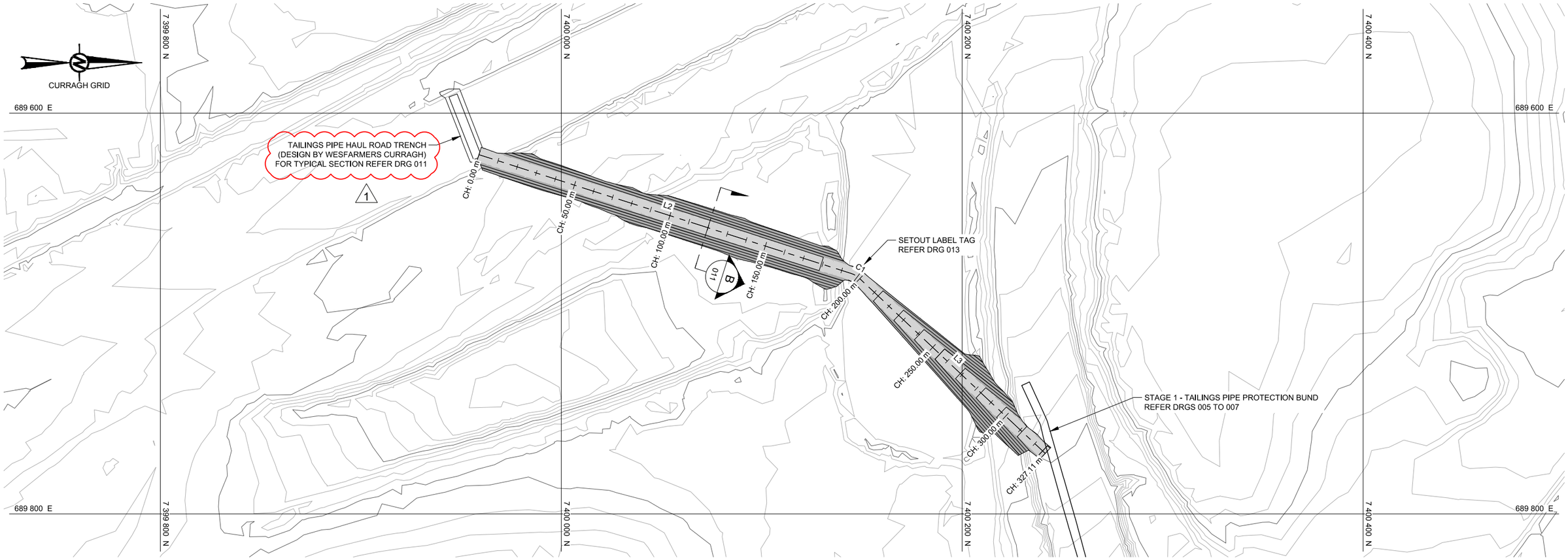
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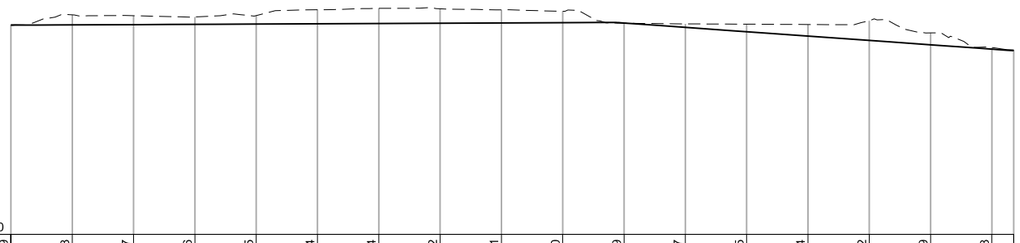
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PLAN VIEW
SCALE 1:2,000 m



DATUM 100.00

PROPOSED GROUND	168.19	168.28	168.37	168.46	168.55	168.64	168.74	168.82	168.91	169.00	168.89	167.47	166.05	164.64	163.22	161.79	160.38	
EXISTING GROUND	168.34	171.57	171.29	170.87	171.33	173.22	173.70	173.55	173.20	172.73	168.85	168.62	168.52	168.40	169.63	165.68	160.91	160.14
CUT AND FILL DEPTH (m)	-0.15	-3.29	-2.92	-2.41	-2.78	-4.58	-4.96	-4.73	-4.29	-3.73	0.05	-1.14	-2.47	-3.76	-6.41	-3.88	-0.53	
CHAINAGE	0.00	20.00	40.00	60.00	80.00	100.00	120.00	140.00	160.00	180.00	200.00	220.00	240.00	260.00	280.00	300.00	320.00	327.11

LONGITUDINAL SECTION
SCALE 1:2,000 m

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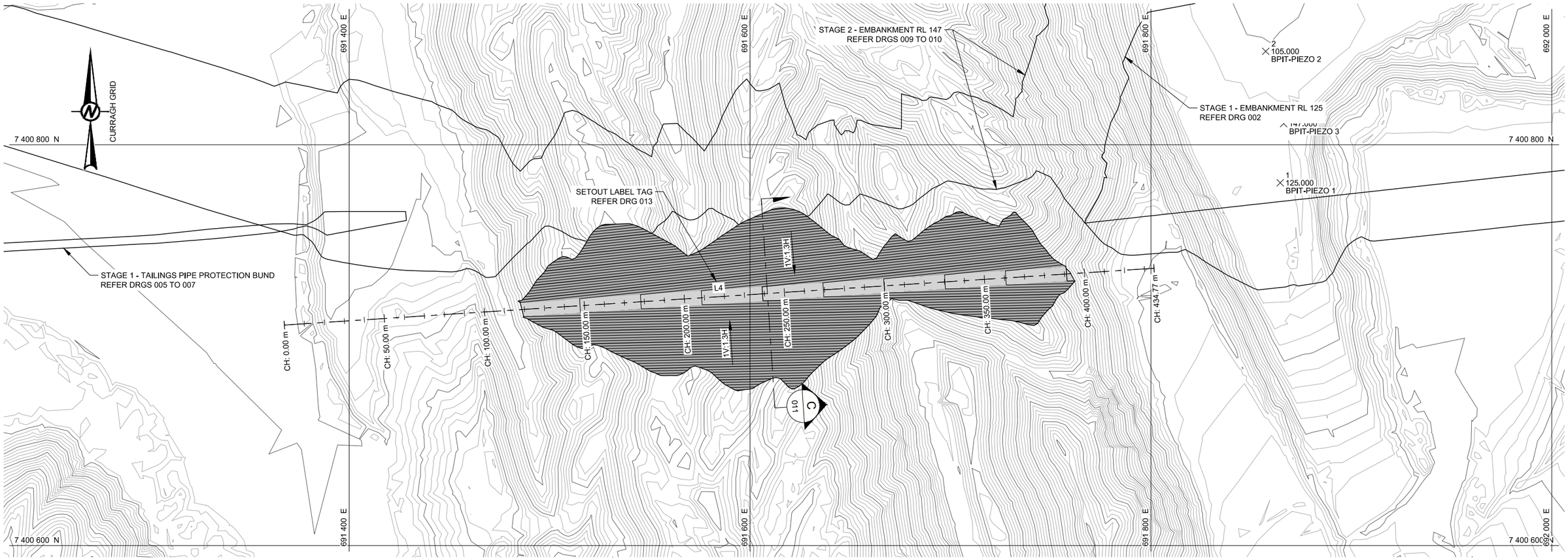
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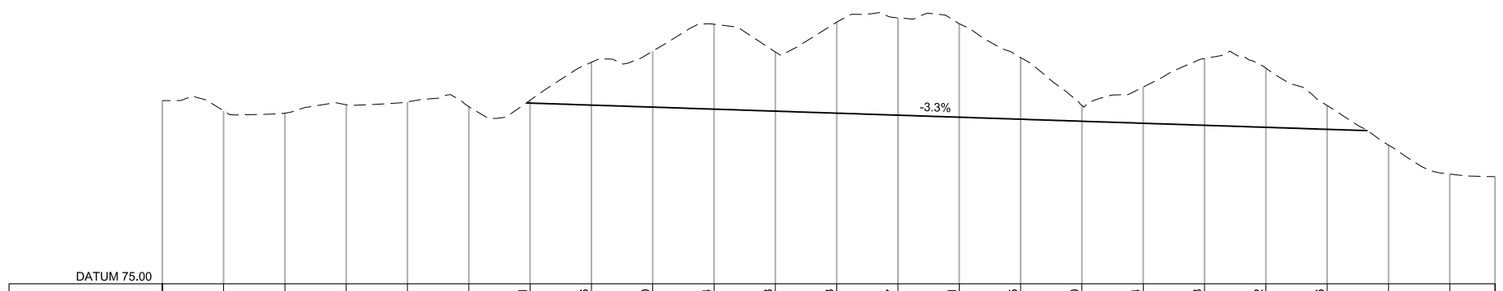
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PROJECT NO.	CONTROL	REV.		DRAWING
1532295	052-R	1	4 of 16	003

Path: \\golder.gds\gal\Brisbane\Cartomatics\WESFARMER_CURRAGH\CURRAGH\99_PROJECTS\1532295_B-G PIT DETAIL DESIGN\02_PRODUCTION\DWGS | File Name: 1532295-052-R-003.dwg | Last Edited By: vdisted Date: 2017-03-20 Time:10:28:24 AM | Printed By: dwillemse Date: 2017-11-08 Time:12:32:45 PM
IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ISO A3
25 mm
0



PLAN VIEW
SCALE 1:2,000 m



DATUM 75.00																										
PROPOSED GROUND							133.91	133.26	132.60	131.94	131.28	130.63	129.97	129.31	128.65	128.00	127.34	126.68	126.02	125.36			
EXISTING GROUND	134.71	131.39	130.64	133.37	134.31	132.74	134.85	147.21	150.85	159.62	150.58	160.28	161.70	159.78	148.73	133.16	139.15	148.47	145.31	133.15	120.23	110.80	109.92
CUT AND FILL DEPTH (m)							-0.93	-13.95	-18.25	-27.67	-19.30	-29.66	-31.73	-30.47	-20.08	-5.16	-11.81	-21.79	-19.29	-7.78			
CHAINAGE	0.00	20.00	40.00	60.00	80.00	100.00	120.00	140.00	160.00	180.00	200.00	220.00	240.00	260.00	280.00	300.00	320.00	340.00	360.00	380.00	400.00	420.00	434.77

LONGITUDINAL SECTION
SCALE 1:2,000 m

ISSUED FOR
CONSTRUCTION

0 50 100
1:2,000 METRES

REV.	YYYY-MM-DD	DESCRIPTION	DESIGNED	PREPARED	REVIEWED	APPROVED	RPEQ
1	2017-05-04	ISSUED FOR CONSTRUCTION	DAS	DDW	MJG	MJG	DA SMALLHORN
0	2017-02-01	ISSUED FOR CONSTRUCTION	DAS	DDW	MJG	MJG	DA SMALLHORN

CLIENT
CURRAGH Wesfarmers

CONSULTANT
Golder Associates

BRISBANE OFFICE
147 CORONATION DRIVE
MILTON, QLD 4064
AUSTRALIA
[+61] (7) 3721 5400
www.golder.com

PROJECT
WESFARMERS CURRAGH PTY LTD
PIT B TSF EARTHWORKS

TITLE
STAGE 1 - TAILINGS PIPE CUT 2 - PLAN VIEW AND LONGITUDINAL SECTION

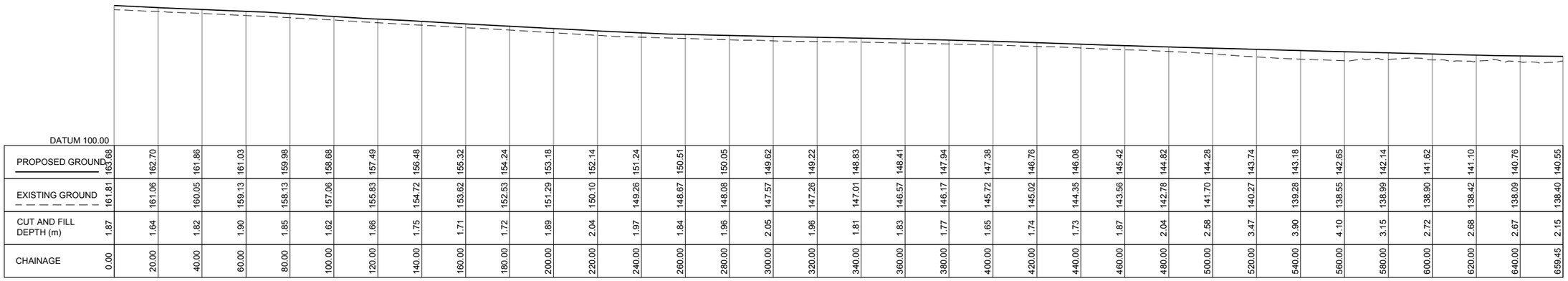
PROJECT NO.	CONTROL	REV.		DRAWING
1532295	052-R	1	5 of 16	004

Path: \\golder.gds\gal\Brisbane\Cartomatics\WESFARMER_CURRAGH\CURRAGH169_PROJECTS\1532295_B-G PIT DETAIL DESIGN\02_PRODUCTION\DWGS | File Name: 1532295-052-R-004.dwg | Last Edited By: dwillemse Date: 2017-03-14 Time:4:48:44 PM | Printed By: dwillemse Date: 2017-11-08 Time: 12:33:02 PM
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25 mm
0

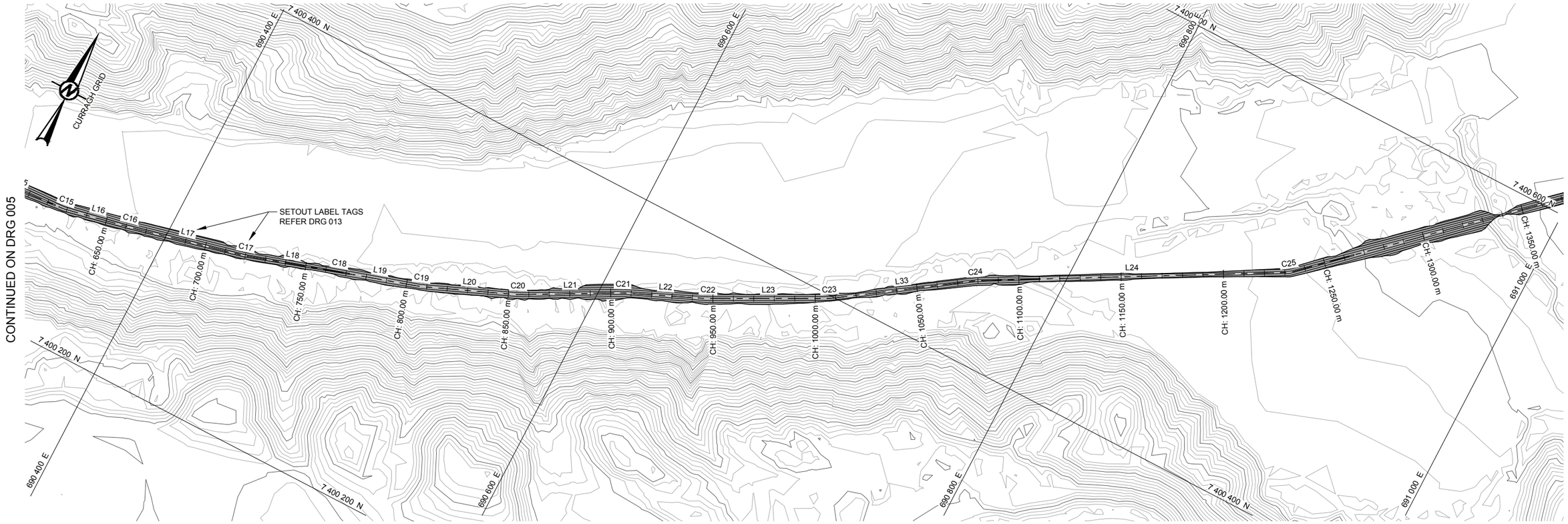


PLAN VIEW
SCALE 1:2,000 m

CONTINUED ON DRG 006



| DATUM 100.00 | | |



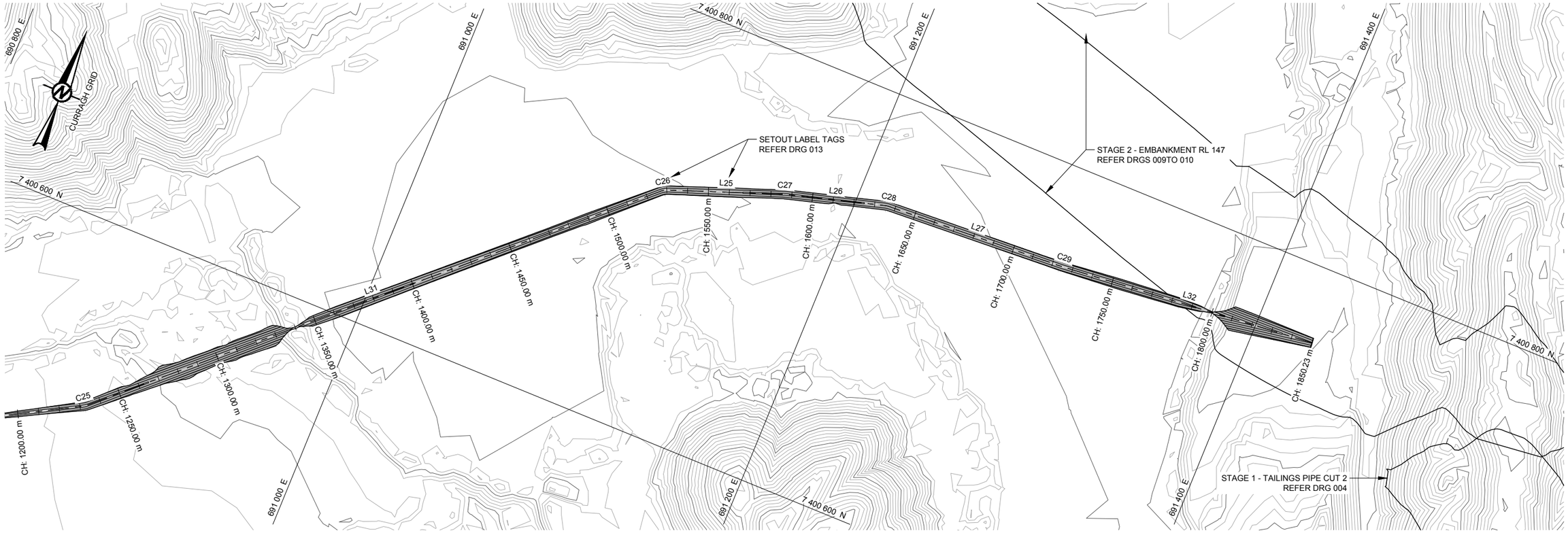
PLAN VIEW
SCALE 1:2,000 m



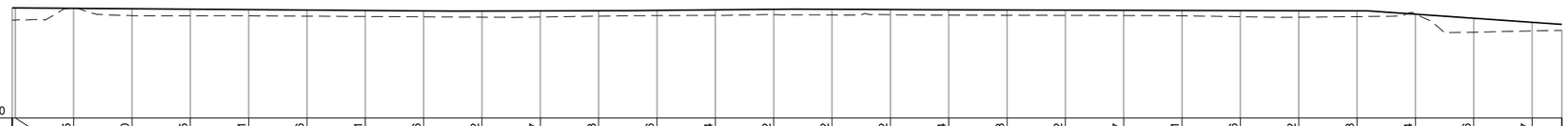
DATUM 100.00

| | | |

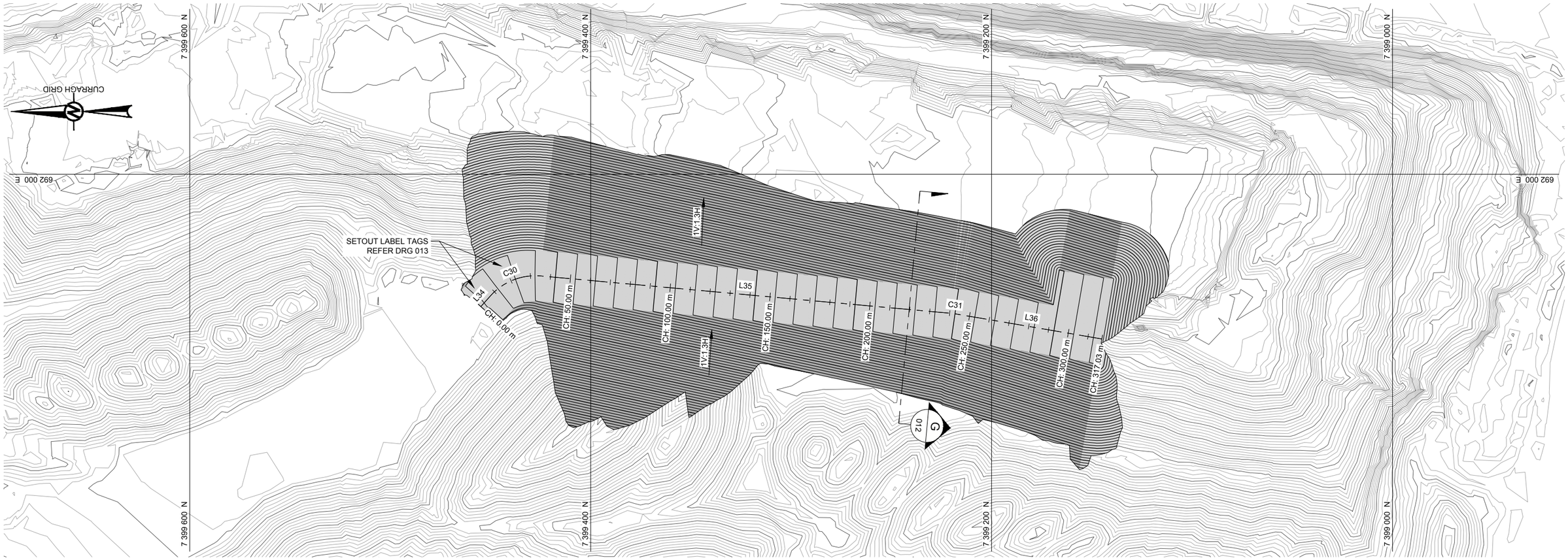
CONTINUED ON DRG 006



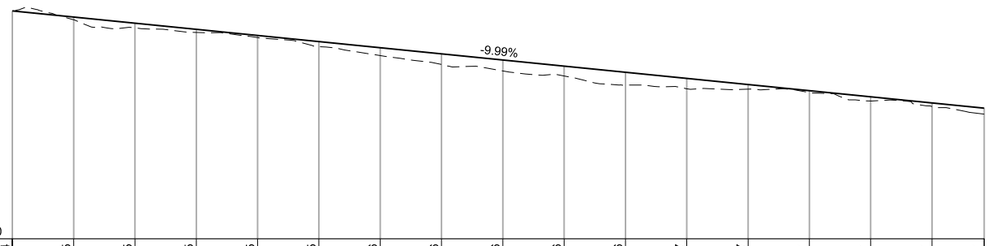
PLAN VIEW
SCALE 1:2,000 m



| | | |



PLAN VIEW
SCALE 1:2,000 m



DATUM 50,00																					
PROPOSED GROUND	124.24	122.25	120.25	118.25	116.25	114.25	112.26	110.26	108.26	106.26	104.26	102.27	100.27	98.27	96.27	94.27	92.57				
EXISTING GROUND	124.24	121.38	118.72	117.25	115.58	112.61	109.69	106.81	104.70	103.06	100.07	98.89	98.75	97.66	94.91	93.06	90.62				
CUT AND FILL DEPTH (m)	0.00	0.87	1.52	1.00	0.67	1.65	2.56	3.45	3.56	3.20	4.19	3.38	1.52	0.61	1.36	1.22	1.95				
CHAINAGE	0.00	20.00	40.00	60.00	80.00	100.00	120.00	140.00	160.00	180.00	200.00	220.00	240.00	260.00	280.00	300.00	317.03				

LONGITUDINAL SECTION
SCALE 1:2,000 m

ISSUED FOR
CONSTRUCTION

0 50 100
1:2,000 METRES

REV.	YYYY-MM-DD	DESCRIPTION	DESIGNED	PREPARED	REVIEWED	APPROVED	RPEQ
1	2017-05-04	ISSUED FOR CONSTRUCTION	DAS	DDW	MJG	MJG	DA SMALLHORN
0	2017-02-01	ISSUED FOR CONSTRUCTION	DAS	DDW	MJG	MJG	DA SMALLHORN

CLIENT
CURRAGH Wesfarmers

CONSULTANT
Golder Associates

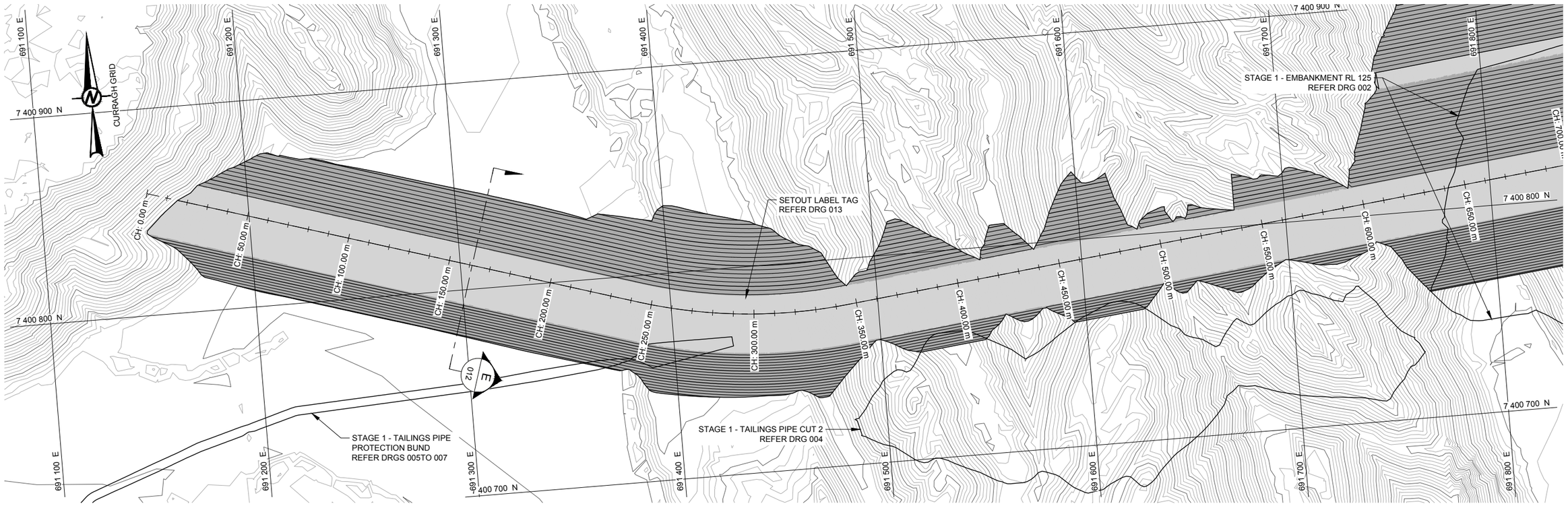
BRISBANE OFFICE
147 CORONATION DRIVE
MILTON, QLD 4064
AUSTRALIA
[+61] (7) 3721 5400
www.golder.com

PROJECT
WESFARMERS CURRAGH PTY LTD
PIT B TSF EARTHWORKS

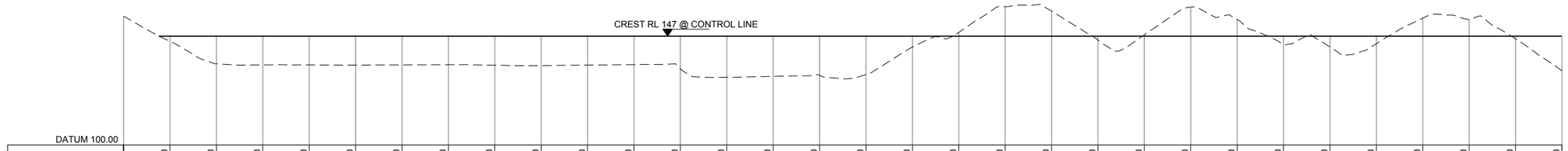
TITLE
STAGE 1 - DECANT RAMP - PLAN VIEW AND LONGITUDINAL SECTION

PROJECT NO.	CONTROL	REV.		DRAWING
1532295	052-R	1	9 of 16	008

Path: \\golder.gds\gal\Brisbane\Cartomatics\WESFARMER_CURRAGH\CURRAGH\99_PROJECTS\1532295_B-G PIT DETAIL DESIGN\02_PRODUCTION\DWG\ | File Name: 1532295-052-R-008.dwg | Last Edited By: dwillemse Date: 2017-01-17 Time:4:18:56 PM | Printed By: dwillemse Date: 2017-1-08 Time: 12:33:52 PM
IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ISO A3
25 mm
0

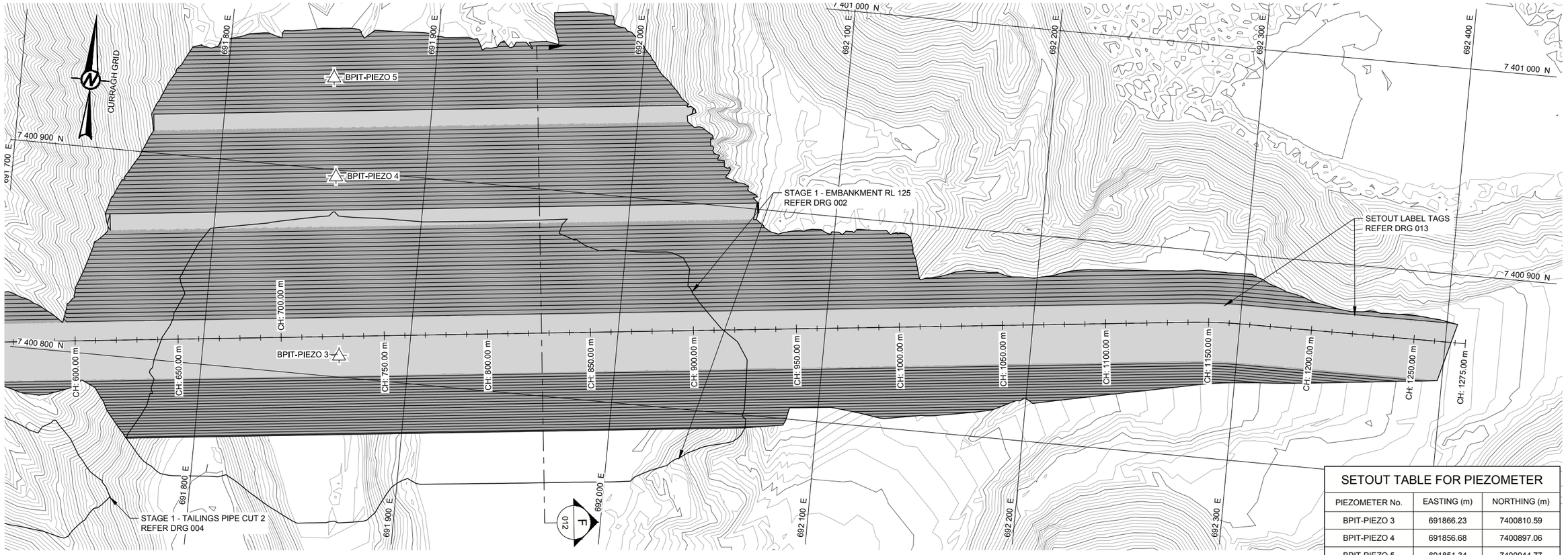


PLAN VIEW
SCALE 1:2,000 m



| | | |

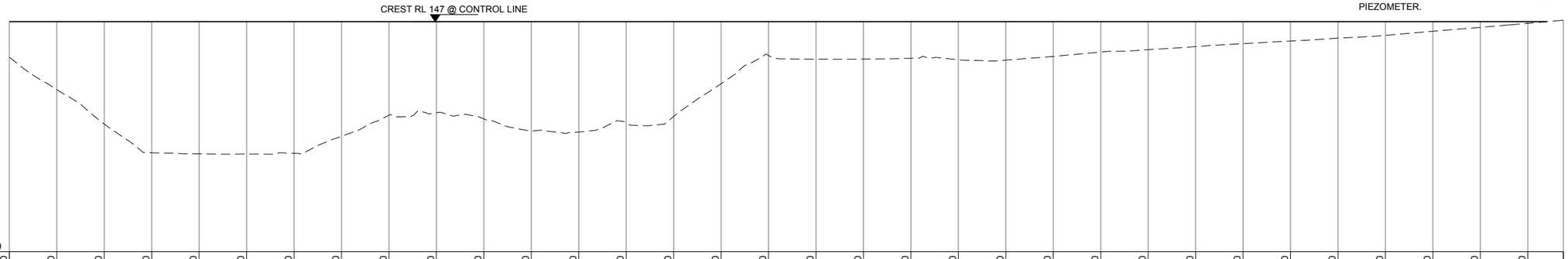
CONTINUED ON DRG 009



PLAN VIEW
SCALE 1:2,000 m

SETOUT TABLE FOR PIEZOMETER		
PIEZOMETER No.	EASTING (m)	NORTHING (m)
BPIT-PIEZO 3	691866.23	7400810.59
BPIT-PIEZO 4	691856.68	7400897.06
BPIT-PIEZO 5	691851.34	7400944.77

NOTE(S)
1. REFER TO DRAWING 015 FOR TYPICAL DETAIL OF PIEZOMETER.



DATUM 50.00

CHAINAGE	PROPOSED GROUND	EXISTING GROUND	CUT AND FILL DEPTH (m)
620.00	147.00	131.99	15.01
640.00	147.00	118.30	28.70
660.00	147.00	103.80	43.20
680.00	147.00	91.72	55.28
700.00	147.00	91.29	55.71
720.00	147.00	91.18	55.82
740.00	147.00	91.49	55.51
760.00	147.00	98.64	48.36
780.00	147.00	107.58	39.42
800.00	147.00	108.62	38.38
820.00	147.00	105.99	41.01
840.00	147.00	100.88	46.12
860.00	147.00	100.45	46.55
880.00	147.00	104.25	42.75
900.00	147.00	107.01	39.99
920.00	147.00	120.87	26.13
940.00	147.00	132.71	14.29
960.00	147.00	131.18	15.82
980.00	147.00	131.24	15.76
1000.00	147.00	131.56	15.44
1020.00	147.00	130.90	16.10
1040.00	147.00	130.80	16.20
1060.00	147.00	132.34	14.66
1080.00	147.00	134.18	12.82
00.00	147.00	135.19	11.81
20.00	147.00	136.49	10.51
1140.00	147.00	137.71	9.29
1160.00	147.00	138.82	8.18
1180.00	147.00	140.06	6.94
1200.00	147.00	141.22	5.78
1220.00	147.00	142.94	4.06
1240.00	147.00	144.61	2.39
1260.00	147.00	146.30	0.70
1275.00		147.61	

LONGITUDINAL SECTION
SCALE 1:2,000 m

ISSUED FOR
CONSTRUCTION

0 50 100
1:2,000 METRES

REV.	YYYY-MM-DD	DESCRIPTION	DESIGNED	PREPARED	REVIEWED	APPROVED	RPEQ
1	2017-05-04	ISSUED FOR CONSTRUCTION	DAS	DDW	MJG	MJG	DA SMALLHORN
0	2017-02-01	ISSUED FOR CONSTRUCTION	DAS	DDW	MJG	MJG	DA SMALLHORN

CLIENT
CURRAGH Wesfarmers

CONSULTANT
Golder Associates

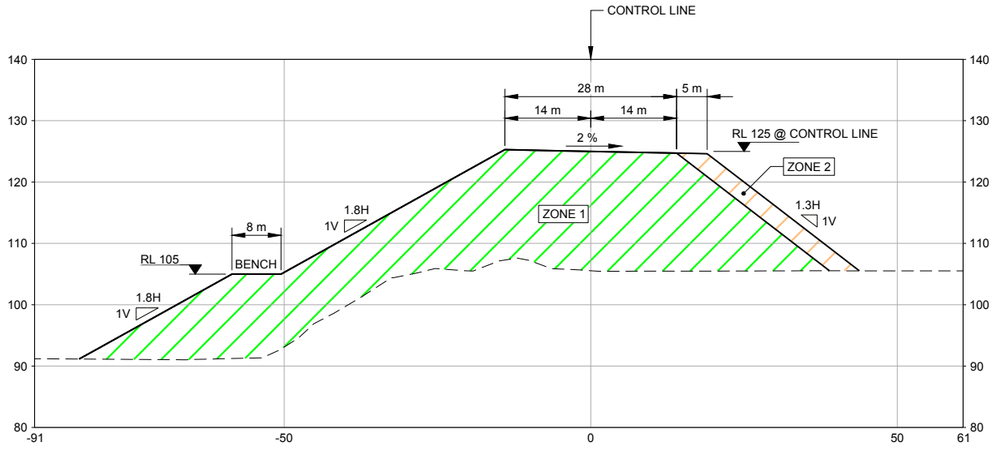
BRISBANE OFFICE
147 CORONATION DRIVE
MILTON, QLD 4064
AUSTRALIA
[+61] (7) 3721 5400
www.golder.com

PROJECT
WESFARMERS CURRAGH PTY LTD
PIT B TSF EARTHWORKS

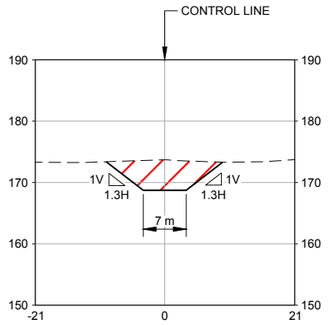
TITLE
STAGE 2 - EMBANKMENT RL 147 - PLAN VIEW AND LONGITUDINAL SECTION - SHEET 2 OF 2

PROJECT NO.	CONTROL	REV.		DRAWING
1532295	052-R	1	11 of 16	010

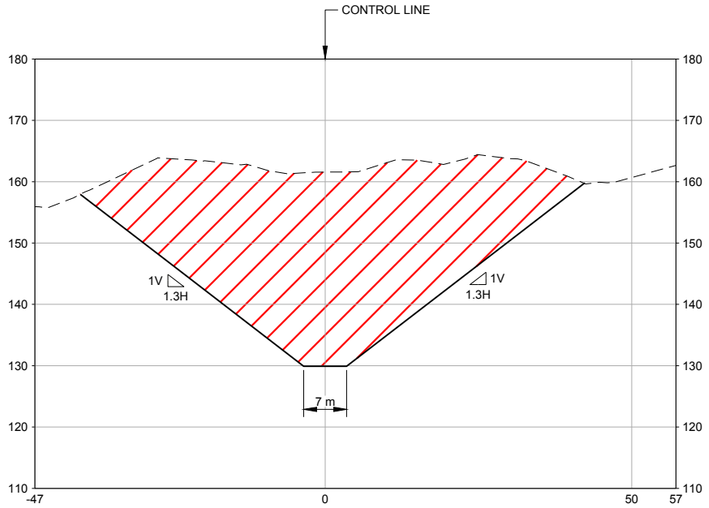
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IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ISO A3
25 mm
0



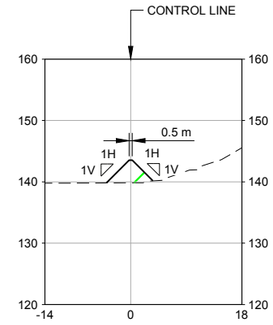
SCALE 1:1,000 m A 002 SECTION - STAGE 1 - WALL RL 125



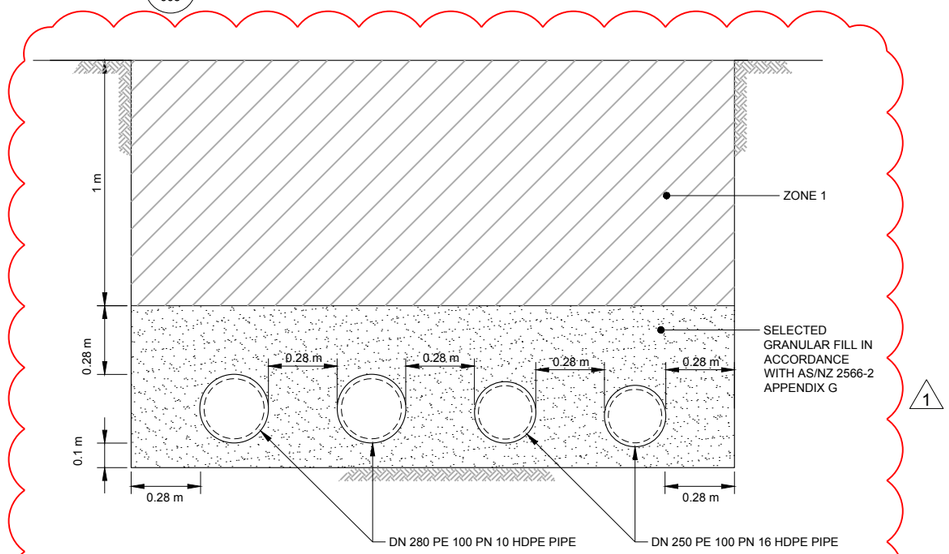
SCALE 1:1,000 m B 003 SECTION - STAGE 1 - TAILINGS PIPE CUT 1



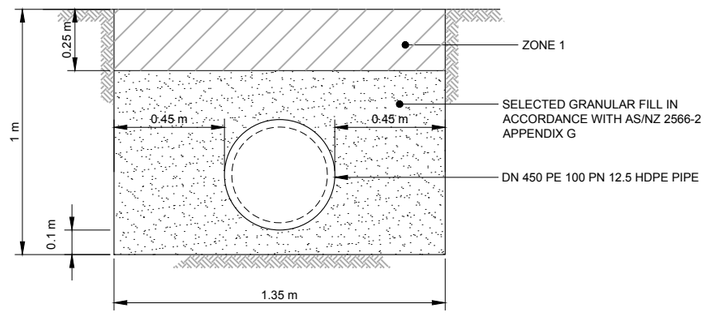
SCALE 1:1,000 m C 004 SECTION - STAGE 1 - TAILINGS PIPE CUT 2



SCALE 1:1,000 m D 005 SECTION - STAGE 1 - PROTECTION BUND



TYPICAL SECTION - TAILINGS PIPE HAUL ROAD TRENCH
SCALE 1:25 m



TYPICAL SECTION - DECANT RETURN PIPE LIGHT VEHICLE CROSSING
SCALE 1:25 m

LEGEND

- EXISTING GROUND SURFACE
- DESIGN SURFACE
- FILL - ZONE 1
- FILL - ZONE 2
- CUT

NOTES

1. ZONE 1 MATERIAL TO COMPRISE SELECTED INTERBURDEN SPOIL.
2. ZONE 1 MATERIAL TO BE PLACED IN 2 m LIFTS BY PADDOCK DUMPING AND DOZING, AND COMPACTED BY TRAFFICING HAUL PLANT.
3. ZONE 2 MATERIAL TO COMPRISE SELECTED REJECTS.
4. ZONE 2 MATERIAL TO BE TRACKED ROLLED.

ISSUED FOR
CONSTRUCTION

0 0.5 1
1:25 METRES

0 25 50
1:1,000 METRES

REV.	YYYY-MM-DD	DESCRIPTION	DESIGNED	PREPARED	REVIEWED	APPROVED	RPEQ
1	2017-05-04	ISSUED FOR CONSTRUCTION	DAS	DDW	MJG	MJG	DA SMALLHORN
0	2017-02-01	ISSUED FOR CONSTRUCTION	DAS	DDW	MJG	MJG	DA SMALLHORN

CLIENT
CURRAGH Wesfarmers

CONSULTANT
Golder Associates

BRISBANE OFFICE
147 CORONATION DRIVE
MILTON, QLD 4064
AUSTRALIA
[+61] (7) 3721 5400
www.golder.com

PROJECT
WESFARMERS CURRAGH PTY LTD
PIT B TSF EARTHWORKS

TITLE
TYPICAL CROSS SECTIONS - SHEET 1 OF 2

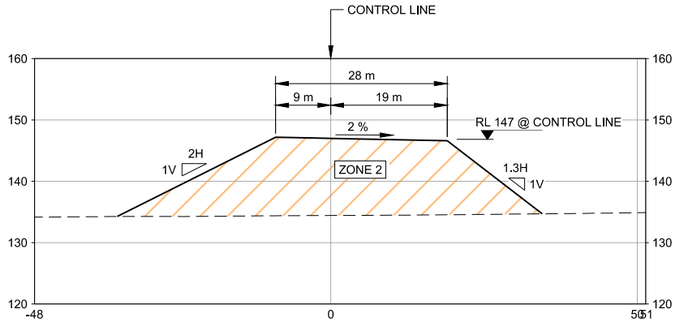
PROJECT NO.	CONTROL	REV.		DRAWING
1532295	052-R	1	12 of 16	011

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ISO A3

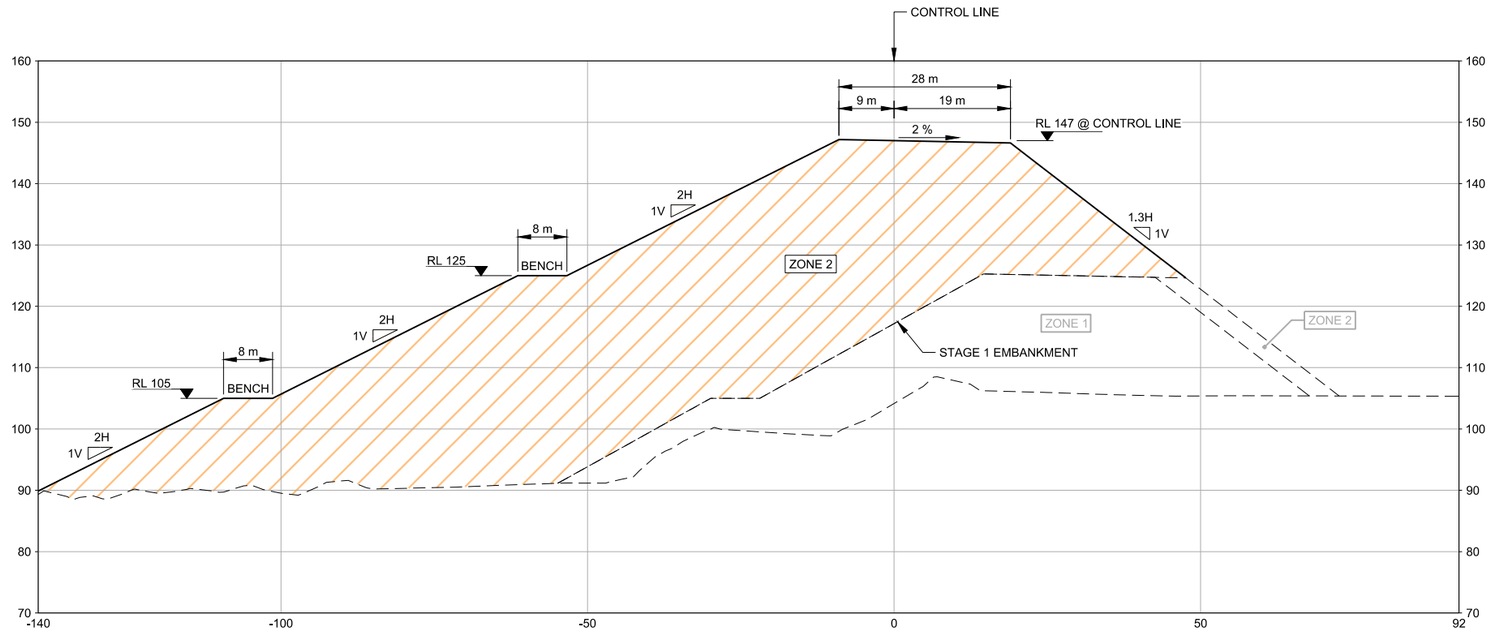
25 mm

0

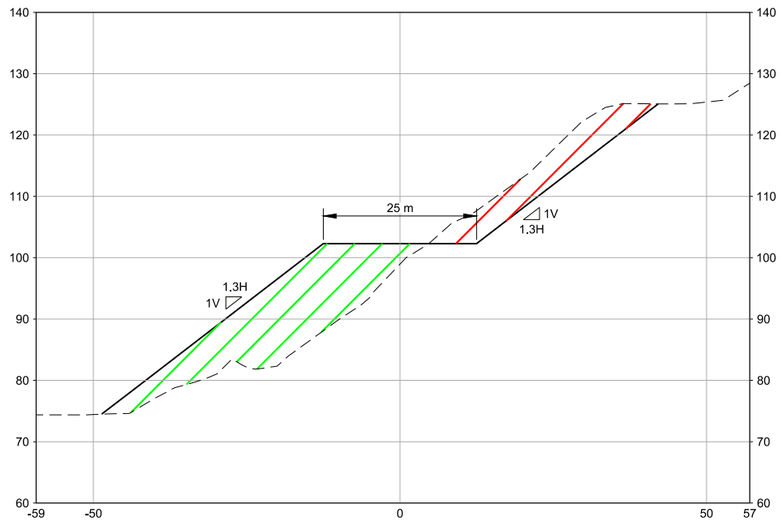
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SCALE 1:1,000 m E 009 SECTION - STAGE 2 - WALL RL 147



SCALE 1:1,000 m F 010 SECTION - STAGE 2 - WALL RL 147



SCALE 1:1,000 m G 008 SECTION - STAGE 1 - DECANT RAMP

LEGEND

- EXISTING GROUND SURFACE
- DESIGN SURFACE
- FILL - ZONE 1
- FILL - ZONE 2
- CUT

NOTES

1. ZONE 1 MATERIAL TO COMPRISE SELECTED INTERBURDEN SPOIL.
2. ZONE 1 MATERIAL TO BE PLACED IN 2 m LIFTS BY PADDOCK DUMPING AND DOZING, AND COMPACTED BY TRAFFICING HAUL PLANT.
3. ZONE 2 MATERIAL TO COMPRISE SELECTED REJECTS.
4. ZONE 2 MATERIAL TO BE TRACKED ROLLED.

ISSUED FOR

CONSTRUCTION

0 25 50

1:1,000 METRES

REV.	YYYY-MM-DD	DESCRIPTION	DESIGNED	PREPARED	REVIEWED	APPROVED	RPEQ
1	2017-05-04	ISSUED FOR CONSTRUCTION	DAS	DDW	MJG	MJG	DA SMALLHORN
0	2017-02-01	ISSUED FOR CONSTRUCTION	DAS	DDW	MJG	MJG	DA SMALLHORN

CLIENT

CURRAGH Wesfarmers

CONSULTANT

Golder Associates

BRISBANE OFFICE
147 CORONATION DRIVE
MILTON, QLD 4064
AUSTRALIA
[+61] (7) 3721 5400
www.golder.com

PROJECT
WESFARMERS CURRAGH PTY LTD
PIT B TSF EARTHWORKS

TITLE
TYPICAL CROSS SECTIONS - SHEET 2 OF 2

PROJECT NO.	CONTROL	REV.		DRAWING
1532295	052-R	1	13 of 16	012

Path: \\golder.gds\gap\Brisbane\Geomatics\WESFARMER_CURRAGH\CURRAGH99_PROJECTS\1532295_B-G PIT DETAIL_DESIGN\02_PRODUCTION\DWG\ | File Name: 1532295-052-R-011 to 012.dwg | Last Edited By: vkasted Date: 2017-03-20 Time:10:28:41 AM | Printed By: dwillemse Date: 2017-11-08 Time:12:34:38 PM

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ISO A3

0 25 mm

EMBANKMENT STAGE 1 - RL125

TAG NUMBER	START STATION END STATION	START EASTING START NORTHING	END EASTING END NORTHING	RADIUS (m)	LENGTH (m)
L1	0.00 400.80	691723.53 7400775.23	692121.92 7400819.18		400.80

TAILINGS PIPE CUT 1

TAG NUMBER	START STATION END STATION	START EASTING START NORTHING	END EASTING END NORTHING	RADIUS (m)	LENGTH (m)
L2	0.00 195.11	689620.72 7399958.93	689680.07 7400144.80		195.11
C1	195.11 199.58	689680.07 7400144.80	689682.32 7400148.61	10	4.47
L3	199.58 327.11	689682.32 7400148.61	689769.79 7400241.42		127.53

TAILINGS PIPE CUT 2

TAG NUMBER	START STATION END STATION	START EASTING START NORTHING	END EASTING END NORTHING	RADIUS (m)	LENGTH (m)
L4	0.00 434.77	691367.69 7400710.06	691801.54 7400738.37		434.77

DECANT RAMP

TAG NUMBER	START STATION END STATION	START EASTING START NORTHING	END EASTING END NORTHING	RADIUS (m)	LENGTH (m)
L34	0.00 7.27	691933.96 7399454.80	691939.38 7399449.95		7.27
C30	7.27 35.19	691939.38 7399449.95	691949.23 7399424.89	30	27.92
L35	35.19 239.56	691949.23 7399424.89	691930.69 7399221.36		204.37
C31	239.56 244.31	691930.69 7399221.36	691930.08 7399216.66	60	4.74
L36	244.31 317.03	691930.08 7399216.66	691917.78 7399144.98		72.73

EMBANKMENT STAGE 2 - RL147

TAG NUMBER	START STATION END STATION	START EASTING START NORTHING	END EASTING END NORTHING	RADIUS (m)	LENGTH (m)
L37	0.00 243.31	691151.59 7400858.94	691384.12 7400787.29		243.31
C32	243.31 345.51	691384.12 7400787.29	691485.15 7400777.71	250	102.20
L38	345.51 1140.87	691485.15 7400777.71	692275.72 7400864.92		795.36
C33	1140.87 1167.03	692275.72 7400864.92	692301.82 7400866.42	250	26.16
L39	1167.03 1275.00	692301.82 7400866.42	692409.79 7400866.98		107.97

PROTECTION BUND

TAG NUMBER	START STATION END STATION	START EASTING START NORTHING	END EASTING END NORTHING	RADIUS (m)	LENGTH (m)
L5	0.00 20.08	689735.01 7400231.67	689753.24 7400240.09		20.08
C2	20.08 21.65	689753.24 7400240.09	689754.70 7400240.63	10	1.56
L28	21.65 151.70	689754.70 7400240.63	689879.83 7400276.10		130.06
C3	151.70 152.18	689879.83 7400276.10	689880.29 7400276.22	10	0.47
L29	152.18 224.62	689880.29 7400276.22	689950.84 7400292.64		72.44
C4	224.62 225.68	689950.84 7400292.64	689951.89 7400292.83	10	1.06
L30	225.68 277.48	689951.89 7400292.83	690003.30 7400299.15		51.80
C5	277.48 277.85	690003.30 7400299,15	690003.67 7400299.19	10	0.37
L6	277.85 308.06	690003.67 7400299.19	690033.77 7400301.78		30.22
C6	308.06 308.66	690033.77 7400301.78	690034.37 7400301.81	10	0.60
L7	308.66 341.81	690034.37 7400301.81	690067.51 7400302.67		33.15
C7	341.81 342.54	690067.51 7400302.67	690068.24 7400302.66	10	0.73
L8	342.54 373.33	690068.24 7400302.66	690098.99 7400301.22		30.79
C8	373.33 373.86	690098.99 7400301.22	690099.53 7400301.18	10	0.54
L9	373.86 410.26	690099.53 7400301.18	690135.74 7400297.53		36.40
C9	410.26 411.44	690135.74 7400297.53	690136.90 7400297.34	10	1.18
L10	411.44 452.22	690136.90 7400297.34	690176.71 7400288.50		40.78
C10	452.22 452.26	690176.71 7400288.50	690176.75 7400288.49	10	0.04
L11	452.26 480.58	690176.75 7400288.49	690204.37 7400282.23		28.32
C11	480.58 481.34	690204.37 7400282.23	690205.10 7400282.03	10	0.76
L12	481.34 515.67	690205.10 7400282.03	690237.91 7400271.94		34.33
C12	515.67 517.06	690237.91 7400271.94	690239.26 7400271.62	10	1.39
L13	517.06 548.94	690239.26 7400271.62	690270.74 7400266.55		31.88
C13	548.94 549.20	690270.74 7400266.55	690271.00 7400266.51	10	0.26
L14	549.20 577.82	690271.00 7400266.51	690299.13 7400261.23		28.62
C14	577.82 580.42	690299.13 7400261.23	690301.72 7400261.09	10	2.60
L15	580.42 627.71	690301.72 7400261.09	690348.88 7400264.62		47.29
C15	627.71 629.03	690348.88 7400264.62	690350.18 7400264.81	10	1.31
L16	629.03 660.79	690350.18 7400264.81	690381.27 7400271.31		31.76
C16	660.79 661.10	690381.27 7400271.31	690381.57 7400271.38	10	0.31

PROTECTION BUND

TAG NUMBER	START STATION END STATION	START EASTING START NORTHING	END EASTING END NORTHING	RADIUS (m)	LENGTH (m)
L17	661.10 719.13	690381.57 7400271.38	690437.97 7400285.02		58.03
C17	719.13 719.84	690437.97 7400285.02	690438.66 7400285.21	10	0.72
L18	719.84 765.92	690438.66 7400285.21	690482.56 7400299.23		46.08
C18	765.92 765.97	690482.56 7400299.23	690482.60 7400299.24	10	0.05
L19	765.97 806.40	690482.60 7400299,24	690521.17 7400311.36		40.43
C19	806.40 807.32	690521.17 7400311.36	690522.03 7400311.68	10	0.92
L20	807.32 854.04	690522.03 7400311.68	690565.14 7400329.71		46.72
C20	854.04 855.05	690565.14 7400329.71	690566.05 7400330.15	10	1.01
L21	855.05 905.27	690566.05 7400330.15	690610.19 7400354.10		50.22
C21	905.27 906.12	690610.19 7400354.10	690610.95 7400354.47	10	0.85
L22	906.12 947.15	690610.95 7400354.47	690648.54 7400370.91		41.03
C22	947.15 947.84	690648.54 7400370.91	690649.16 7400371.21	10	0.69
L23	947.84 1006.59	690649.16 7400371.21	690701.23 7400398.42		58.75
C23	1006.59 1007.78	690701.23 7400398.42	690702.25 7400399.04	10	1.19
L33	1007.78 1078.59	690702.25 7400399.04	690760.65 7400439.07		70.80
C24	1078.59 1079.53	690760.65 7400439.07	690761.45 7400439.56	10	0.94
L24	1079.53 1231.37	690761.45 7400439.56	690894.22 7400513.26		151.84
C25	1231.37 1233.76	690894.22 7400513.26	690896.15 7400514.65	10	2.39
L31	1233.76 1526.84	690896.15 7400514.65	691111.53 7400713.41		293.08
C26	1526.84 1530.77	691111.53 7400713.41	691114.86 7400715.45	10	3.93
L25	1530.77 1586.07	691114.86 7400715.45	691166.77 7400734.53		55.30
C27	1586.07 1586.83	691166.77 7400734.53	691167.49 7400734.76	10	0.76
L26	1586.83 1634.84	691167.49 7400734.76	691213.68 7400747.85		48.01
C28	1634.84 1637.07	691213.68 7400747.85	691215.88 7400748.22	10	2.23
L27	1637.07 1724.43	691215.88 7400748.22	691303.11 7400752.89		87.36
C29	1724.43 1724.82	691303.11 7400752.89	691303.50 7400752.92	10	0.39
L32	1724.82 1850.23	691303.50 7400752.92	691428.38 7400764.46		125.41

ISSUED FOR

CONSTRUCTION

REV.	YYYY-MM-DD	DESCRIPTION	DESIGNED	PREPARED	REVIEWED	APPROVED	RPEQ
1	2017-05-04	ISSUED FOR CONSTRUCTION	DAS	DDW	MJG	MJG	DA SMALLHORN
0	2017-02-01	ISSUED FOR CONSTRUCTION	DAS	DDW	MJG	MJG	DA SMALLHORN

CLIENT

CURRAGH Wesfarmers

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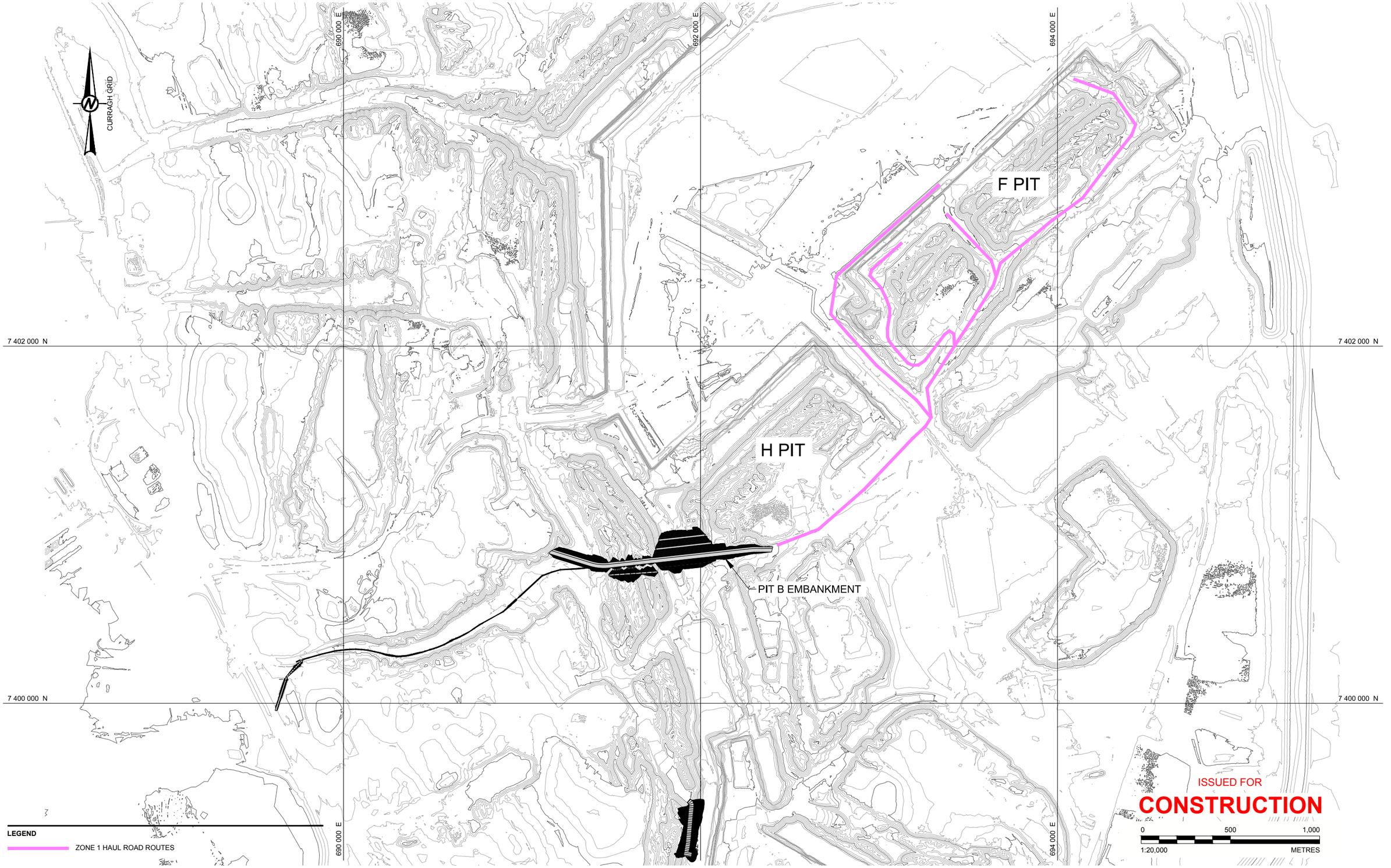
PROJECT
WESFARMERS CURRAGH PTY LTD
PIT B TSF EARTHWORKS

TITLE
SETOUT TABLES

PROJECT NO.	CONTROL	REV.		DRAWING
1532295	052-R	1	14 of 16	013

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ISO A3
25 mm
0

Path: \\golder.gds\gap\Brisbane\Geomatics\WESFARMER_CURRAGH\CURRAGH99_PROJECTS\1532295_B-G PIT DETAIL DESIGN\02_PRODUCTION\DWGS | File Name: 1532295-052-R-013.dwg | Last Edited By: dwillemse Date: 2017-11-08 Time:12:30:28 PM | Printed By: dwillemse Date: 2017-11-08 Time:12:34:42 PM



REV.	YYYY-MM-DD	DESCRIPTION	DESIGNED	PREPARED	REVIEWED	APPROVED	RPEQ
1	2017-05-04	ISSUED FOR CONSTRUCTION	DAS	DDW	MJG	MJG	DA SMALLHORN
0	2017-02-01	ISSUED FOR CONSTRUCTION	DAS	DDW	MJG	MJG	DA SMALLHORN

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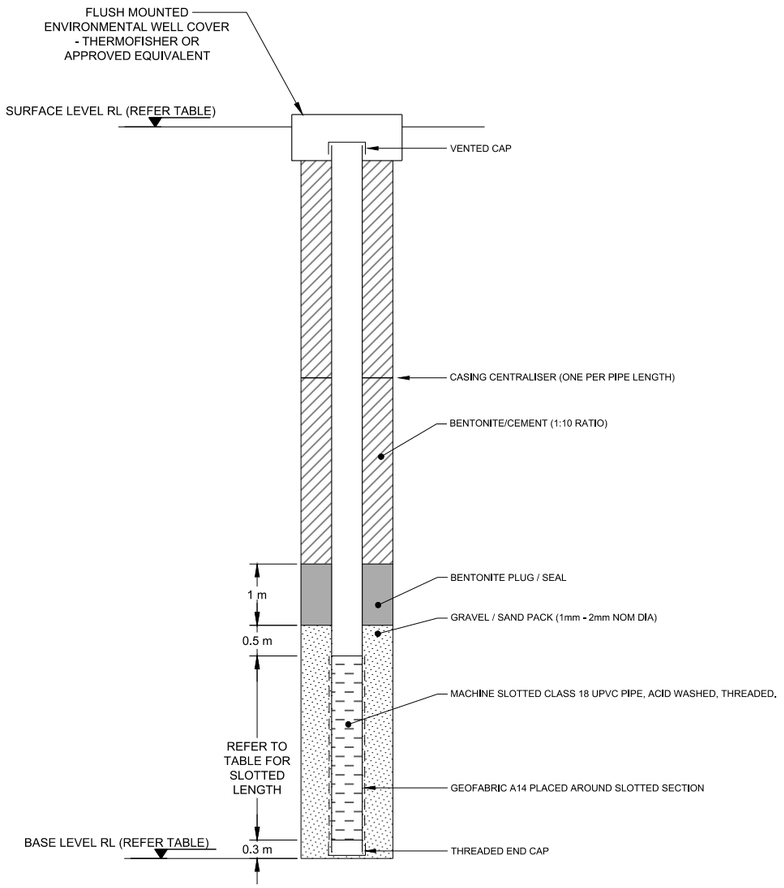
TITLE
ZONE 1 BORROW LOCATION

PROJECT NO.	CONTROL	REV.	DRAWING
1532295	052-R	1	014

15 of 16

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TYPICAL MONITORING BORE
SCALE NTS

PIEZOMETER No.	SURFACE LEVEL	BORE DEPTH BELOW SURFACE LEVEL (m)	SLOTTED PVC LENGTH (m)	BASE LEVEL RL
BPIT-PIEZO 1	125	25	16	100
BPIT-PIEZO 2	105	10	16	95
BPIT-PIEZO 3	147	49	16	98
BPIT-PIEZO 4	125	40	16	85
BPIT-PIEZO 5	105	24	16	81

ISSUED FOR
CONSTRUCTION

REV.	YYYY-MM-DD	DESCRIPTION	DESIGNED	PREPARED	REVIEWED	APPROVED	RPEQ
1	2017-05-04	ISSUED FOR CONSTRUCTION	DAS	DDW	MJG	MJG	DA SMALLHORN
0	2016-01-13	NOT ISSUED	DAS	DDW	MJG	MJG	DA SMALLHORN

CLIENT
Curragh Wesfarmers

CONSULTANT
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PROJECT
WESFARMERS CURRAGH PTY LTD
PIT B TSF EARTHWORKS

TITLE
EMBANKMENT MONITORING BORES - TYPICAL DETAIL AND SETOUT TABLE

PROJECT NO.	CONTROL	REV.	DRAWING
1532295	052-R	1	015

16 of 16

Path: \\golder.gds\gal\Brisbane\Geomatics\WESFARMER_CURRAGH\CURRAGH99_PROJECTS\1532295_B-G PIT DETAIL DESIGN\02_PRODUCTION\DWGS | Last Edited By: dwillemse Date: 2017-11-08 Time:12:30:28 PM | Printed By: dwillemse Date: 2017-11-08 Time:12:35:16 PM
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25 mm
0

02 February 2017

TECHNICAL SPECIFICATION

A world of capabilities delivered locally

CURRAGH COAL MINE

B PIT TSF EARTHWORKS

Submitted to:
Howard Lief
Wesfarmers Curragh Pty Ltd

Specification Number. 1532295-051-S-Rev0

Golder Associates

Record of Issue

Company	Client Contact	Version	Date Issued	Method of Delivery
Wesfarmers Curragh	Howard Lief	A	13 January 2017	email
Wesfarmers Curragh	Howard Lief	B	01 February 2017	email
Wesfarmers Curragh	Howard Lief	0	02 February 2017	email

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1.0 SPECIFICATION PRELIMINARIES

1.1 Extent of works

The B pit tailings construction works are required to provide ongoing tailings storage for Curragh Coal Mine. The construction works are to be staged and shall include, but shall not be limited to:

- Stage 1
  - Containment embankment – crest RL 125 m
  - Tailings pipeline cut through
  - Tailings pipeline protection bund
  - Tailings pipeline track through Ramp 4
- Stage 2 containment embankment – crest RL 147 m.

The Stage 2 works are not expected to be required for approximately 10 years after the completion of the Stage 1 works based on current tailings deposition rates. The timing for the Stage 2 works will need to be reviewed annually by Wesfarmers following the commissioning of the Stage 1 works.

1.2 Roles and responsibilities

The following roles and responsibilities apply to the work associated with this specification:

Table 1: Roles and responsibilities.

Role	Responsibility
Owner	Wesfarmers Curragh
Superintendent	Owner's representative
Constructor	Engaged by the principal to complete the construction works subject to the requirements of the specification and drawings
Surveyor	Engaged by the principal to set out of the works and to conduct the final survey of constructed works
Golder Associates	Designer providing technical advice to the Principal constructor through the Owner and inspections of critical activities and general observations to assess compliance with the technical specification and IFC drawings

1.3 Utilities

The Constructor shall take all necessary actions to identify underground services within the construction footprint. Where surface drainage works and / or underground pipes, conduits or cables exist in the vicinity of the works, the Constructor shall take care to protect such facilities from damage and, in the case of damage occurring to such facilities, the matter shall be reported to the Superintendent. The cost of the necessary repairs or renewals shall be borne entirely by the Constructor.

Should relocation of existing services be specified or directed by the Superintendent, the Constructor shall arrange for the work to be carried out under Day works charges.

1.4 Surplus spoil and rubbish disposal area

All rubbish, surplus spoil, cleared vegetation and other debris resulting from the construction of the Works shall be removed at weekly intervals as a minimum from the Site and shall be disposed of in the disposal areas approved by the Superintendent.

1.5 Survey

Reference points for the setting out of the works are shown on the drawings.

The Constructor shall arrange for a suitably qualified surveyor capable of exercising control of all survey requirements.

The surveyor shall establish survey control for all elements and associated site works as soon as practical and shall identify any conflicts or problems as soon as practical. Work shall be set out from cadastral boundaries and coordinates as shown on the drawings

All set-out coordinates shown on the plans shall be verified by the Constructor prior to the commencement of the work. Any discrepancies are to be reported to the Superintendent.

The Superintendent reserves the right to periodically check construction levels and setting out during and on completion of construction using a Wesfarmer appointed surveyor.

The following survey is a requirement:

- A monthly survey to establish the progress of the Works
- A survey of the completed works to be used by the Superintendent to prepare 'as built' drawings.

1.6 As Constructed information

1.6.1 General

As constructed information shall be acquired and prepared by a licensed surveyor. An engineering surveyor having extensive experience in the provision of 'As Constructed' information may, at the discretion of the Superintendent, be accepted in lieu of a licensed surveyor.

As constructed information shall, for acceptance, be signed by the appointed surveyor and shall be subject to endorsement by the Constructor on each form and drawing to indicate general compliance with the specified As Constructed information requirements. All work required for accurate survey and marking-up of As Constructed information shall be carried out by the Constructor.

Failure to comply with or to complete the specified As Constructed information requirements shall entitle the Principal to withhold payment in respect of all components of constructed or installed work for which As Constructed information is non-compliant or incomplete and to with-hold a Certificate of Practical Completion until As Constructed information requirements have been satisfactorily completed.

1.6.2 As Constructed information quality

As Constructed information shall be produced by the Surveyor and issued to the Superintendent in .dwg format at the end of the works. The Constructor shall annotate and capture As Constructed details including changes as the construction work proceeds in red pen on a hard cop set of drawings kept by the Constructor. The drafting of hand marked As Constructed information shall be of a quality acceptable for digitising and reproducing as determined by the Superintendent.

As Constructed drawings shall show the true position of the works in relation to known cadastral boundaries or Mine Coordinates.

1.7 Referenced standards

Except as otherwise specified in this Specification, all materials and workmanship are not required to comply with any standards.

1.8 Environmental control - dust

The Constructor shall take appropriate measures to control dust during construction work. Dust control measures shall include the use of water tankers or carts.

2.0 SCHEDULE OF DRAWINGS

The following Drawings are included in APPENDIX A and form part of the Technical Specification.

Table 2: Drawing list

Drawing No.	Title	Revision
D000	Locality Plan and Drawing Index	0
D001	General Arrangement Plan	0
D002	Stage 1 - Wall RL 125 - Plan View and Longitudinal Section	0
D003	Stage 1 - Tailings Pipe Cut 1 - Plan and Longitudinal Section	0
D004	Stage 1 - Tailings Pipe Cut 2 - Plan and Longitudinal Section	0
D005	Stage 1 - Protection Bund - Plan and Longitudinal Section - Sheet 1 of 3	0
D006	Stage 1 - Protection Bund - Plan and Longitudinal Section - Sheet 2 of 3	0
D007	Stage 1 - Protection Bund - Plan and Longitudinal Section - Sheet 3 of 3	0
D008	Stage 1 - Ramp 2 - Plan View and Longitudinal Section	0
D009	Stage 2 - Wall RL 147 - Plan View and Longitudinal Section - Sheet 1 of 2	0
D010	Stage 2 - Wall RL 147 - Plan View and Longitudinal Section - Sheet 2 of 2	0
D011	Typical Cross Sections - Sheet 1 of 2	0
D012	Typical Cross Sections - Sheet 2 of 2	0
D013	Setout Tables	0
D014	Zone 1 Borrow Location	0

3.0 SITE PREPARATION

No site preparation, stripping or grubbing is expected to be required. Where there is poor ground or vegetation that needs to be removed, the Designer will inform the Superintendent who will in turn instruct the Constructor to carry out the requirements.

4.0 EXCAVATIONS

The existing surfaces that require excavation include:

- Tailings pipe trench
- Tailings pipeline track through Ramp 4
- Tailings pipeline trench construction under main haul road

Excavations shall be excavated to the levels and dimensions shown on the drawings. The Constructor shall carry out the excavation of every type of material encountered.

All excavated material may be used as fill materials.

Roots and other organic material shall be removed from the excavated material prior to use as embankment construction or backfill.

4.1 Blasting

Blasting and the use of explosives shall not be allowed unless approved by the Superintendent.

If approved, blasting or the use of explosives, shall comply with AS 2187 Explosives - Storage, transport and use (SAA Explosive Code). Blasting work shall be carried out by a person having a current valid shot fire's permit, duly issued in Queensland.

The use of explosives shall be such as will not damage rock, pipelines or other structures beyond the prescribed limits of excavation.

4.2 Over excavation

Over excavation shall be backfilled using suitable excavated material as directed by the Superintendent and placed as specified in Section 5.0. Excavation shall only be within the lines and levels as shown on the Drawings unless such over excavation was carried out on the written instruction of the Superintendent.

4.3 Support of excavations

The Constructor shall ensure that all excavations are adequately supported as the works proceed and shall exercise every reasonable precaution by means of shoring, planking, props and progressive back-filling to ensure the safety of the works or surfaces over and adjacent to the works.

Any slips or falls of the sides of the excavations due to failure to adequately shore, brace and/or sheet such excavations shall be rectified and any materials, equipment or structures damaged by such slips or falls shall be repaired or replaced by the Constructor at his own expense.

Such shoring, bracing and/or sheeting shall be satisfactorily maintained during the whole life of the excavation and construction operations and shall be removed in a manner to prevent caving as excavations are backfilled.

Additional excavation and backfilling which results from over excavation shall be performed at the Constructors expense and to the satisfaction of the Superintendent.

4.4 Finished tolerances

All excavations and fill shall be completed to be within:

a) Horizontal alignment ±200 mm

b) Vertical level 0 to -100 mm

5.0 EMBANKMENT CONSTRUCTION

5.1 General

Detailed earthwork shall involve the construction of containment embankments and the tailings pipeline protection bund to the lines and grades shown on the drawings.

5.2 Earthworks materials

Zone 1 shall be selected spoil material used as bulk fill to construct the containment embankment and bunds. Zone 1 material shall be obtained from the Pit H interburden spoil dumps and from Pit F overburden and interburden spoil dumps.

The Zone 1 material maximum nominal particle size shall not be greater than 800 mm.

The borrow area shall not be extended without approval from the Superintendent.

Zone 2 shall be selected CHPP rejects and used as a filter material placed on the upstream face of the embankment. Zone 2 will be collected either directly from the CHPP or from the rejects dump.

5.3 Construction of Zone 1

Zone 1 used in embankment construction shall be placed by paddock dumping to form a maximum lift thickness of 4 m. The surface of the lift shall be dozed smooth to allow access and the lift compacted by using the haul plant. The thickness of each lift shall be such that a competent platform is achieved to the satisfaction of the Superintendent, containing minimal voids and not subject to significant deflection under the trafficking of the haul plant. Material used in this zone may be placed without moisture content adjustment.

5.4 Construction of Zone 2

Zone 2 shall be placed to achieve as near practical the geometry as shown on the design drawings or the geometry as agreed by the Superintendent. The material shall be compacted by a minimum of 2 passes using the spreading plant (minimum of D9 dozer or equivalent) or as directed by the Superintendent.

5.5 Protection of earthworks

5.5.1 General

The Constructor's responsibility for care of the Works shall include the protection of earthworks.

Adequate drainage of all working areas shall be maintained throughout the period of construction to ensure run-off of water without ponding, except where ponding forms part of a planned erosion and sedimentation control system.

When rain is likely or when work is not proposed to continue in a working area on the following day, precautions shall be taken to minimise ingress of any excess water into earthworks material. The material placed on embankments shall be sealed off by adequate compaction to provide a smooth tight surface.

Should in situ or stockpiled material become over wet as a result of the Constructor not providing adequate protection of earthworks, the Constructor shall be responsible for replacing and/or drying out the material and for any consequent delays to the operations.

On completion of the works all diversion and protective works shall be removed and disposed of and all temporary works shall be levelled in an approved manner to give a tidy appearance and not interfere with the operation of the works.

5.5.2 Ponded water

The B Pit area may pond runoff water during construction of the works. Such ponded water shall at all times be kept well away from earthwork construction, by pumping, or by a temporary ditches constructed in natural ground on one or both abutments.

5.6 Finished tolerances

All embankments, excluding spillway locations, shall be completed to be within:

a) Horizontal alignment along crest centreline ±200 mm

b) Vertical level 0 to +100 mm

Slopes shall not be steeper than those shown on the Drawings unless otherwise approved by the Superintendent.

APPENDIX A

Drawings

Note:
Drawings provided elsewhere in document.

At Golder Associates we strive to be the most respected global group of companies specialising in ground engineering and environmental services. Employee owned since our formation in 1960, we have created a unique culture with pride in ownership, resulting in long-term organisational stability. Golder professionals take the time to build an understanding of client needs and of the specific environments in which they operate. We continue to expand our technical capabilities and have experienced steady growth with employees now operating from offices located throughout Africa, Asia, Australasia, Europe, North America and South America.

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Golder Associates

APPENDIX B

Geotechnical site inspection documentation

RECORD OF SITE VISIT

1532295 | CURRAGH B PIT TAILINGS DAM | WESFARMERS RESOURCES

GOLDER ASSOCIATES PTY LTD
ABN 64 006 107 857 | 147 Coronation Drive, MILTON, Qld 4064

DOCUMENT NO: 1532295-032-RSV-Rev 0

DATE: 27/10/16 **LOCATION:** B PIT/H PIT, CURRAGH **VISIT BY:** David Starr

ACCOMPANIED BY: Howard Leif, Maree Gaughan (Raine), Norman Javati, Michael Bailey

ARRIVED SITE: 07:00 **LEFT** 16:00 **VISIT REQUEST BY:** Howard Leif

PURPOSE OF VISIT:

- To advance the Detail Design of the B Pit tailings dam embankment by Golder.
- Discussions were held prior to site inspection with Howard Leif, Carl Heales, Mike Bailey, Maree Gaughan (for Raine & Associates), & Norman Javati (Pit Geologist).

BACKGROUND:

- The life of the current Pit A tailings storage facility has been extended by 12 to 18 months, but will end its useful life in early 2018.
- A significant amount of planning is required to convert Pit B into a tailings storage facility.
- The main objective of the discussions and site inspection is to make a judgement on the best location for the containment embankment.
- A location as far north as possible in Pit B will maximise the tailings storage volume.
- A location immediately downstream of Pit H has been suggested which would allow inter-burden to be used for construction, thus saving haulage costs.
- However, after considering the geotechnical constraints (particularly in light of advice provided by Raine & Associates) of the Pit H location, it was decided that there were too many adverse geological and geotechnical factors.
- Two other alignment options were then proposed in Pit B, named Pit B North and Pit B South which need coordinates to locate. *Action: Block plan to be provided with records from historical mining reports, being prepared by Norman.*
- Golder requested information on locations of the material sampled for the shear box testing – i.e. reject stockpile (see photo in body of report), inter-burden and overburden. *Action: Mike Bailey to provide marked-up plan with approximate locations.*
- Howard Leif referred to Mike Gowan's report dated 14 Sept 2016 – in relation to 5 year life up to 12 m above current level.



Plate 1. Station 2 - View of overburden stockpiles, Pit H - note slumping & tension cracks



Plate 2. Station 2 - View towards south - Pit H in foreground, Pit B in distance



Plate 3. Station 2 - Zoom in of north end of Pit B



Plate 4. Station 2 - Low Point Pit H in foreground



Plate 5. Station 3 - Pit B Haul Rd viewed towards west



Plate 6. Station 3 - Northern end Pit B from Haul Rd view towards NW



Plate 7. Station 3 - View towards North, irregular mounds of overburden in Pit B north



Plate 8. Station 4 – North end flooded area Pit B (South of Haul Rd)



Plate 9. Station 4 - Flooded area of Pit B viewed towards south



Plate 10. Station 5 - View towards east along Haul Rd, Pit B



Plate 11. Station 6 - Previously mined area Pit B (just above level of mined seam)



Plate 12. Station 7 - Previously mined area south end Pit H (viewed towards north)



Plate 13. Station 8 - disturbed material in bench along fault line - Pit B



Plate 14. Station 9 - Pit B looking south



Plate 15. Station 9 - fault outcrop viewed towards north (down throw towards west)



Plate 16. Coarse rejects stockpile

COMMENT ON OBSERVATIONS: (REFER TO Plates 1 to 17)

1. It was clear looking from Stations 1 and 2 that instability is occurring in the north and west faces of the Pit H overburden stockpile (Plates 1 and 2).
2. West facing overburden stockpiles along north of the Pit B haul road have irregular side slopes (as if material has spalled or been removed) and it is understood from Matt Raine that these irregularities may be due to seepage (Plates 4 and 8).
3. The low point in Pit H (Plate 5) is a source of water seepage and while this area was inspected (Station 7), it was not possible to examine the mine floor due to the presence of overburden.
4. It is understood that the level area in the northern end of Pit B has a veneer of overburden, so the previously mined surface could not be observed (Plate 7).
5. Side slope instability can be observed around the north and northeast side of the flooded area in Pit B (Plates 9 & 10), suggesting that the side slopes are probably close to or steeper than the unsaturated angle of repose.
6. The alignment originally proposed by Golder (along the haul road) is depicted in Plates 6 and 11.
7. A surface just above the previously mined lower seam in Pit B is depicted in Plate 12 in which no structure could be clearly observed.
8. The disturbed material shown in Plate 13 is believed to represent a major north-south fault line and the clayey nature of the gouge material suggests that the fault line may be relatively impermeable.
9. The fault shown in Plate 15 is believed to dip to the west with a throw of around 15 to 20 m towards the west.

RECOMMENDATIONS:

1. It was not possible to observe the previously mined floor in either Pit B or Pit H.
2. The information provided by Raine & Associates suggests that there are numerous fault structures associated with the mined seams. Instability of a tailings dam embankment is not expected to arise as a result of geological structures in the *in situ* material beneath the mined surfaces.
3. Heave is understood to have occurred within the pit floor during mining of the lower seam. The placement of a layer of overburden is presumed to have arrested uplift movements.
4. Nevertheless, a judgement on the condition of the pit floors will need to be based on historical records
5. Clear signs of instability in overburden stockpiles within Pit H have resulted in a joint decision to preclude potential tailings dam embankments in this area.
6. It is understood that there could be voids within and immediately above the previously mined surface of B Pit. Such features could give rise to zones of higher permeability, however, settlement due to placement of overburden fill to create the staged construction of a tailings dam embankment is likely to build-out potential settlements during construction.
7. Geotechnical investigations for the embankment dam have been considered. Our opinion is that unless particular benefit can be gained from such work, the time and cost associated is difficult to justify.
8. The impact of seepage along the highwall will need to be considered during detail design. Design considerations may include:
    a. Installation of vibrating wire piezometers at selected locations to monitor water pressures.
    b. Staggered steps to tie the embankment into the highwall.
    c. Test pit excavation near Station 7 to investigate seepage at the start of dam construction.
9. The materials available for construction of the embankment dam include Pit B overburden and coarse rejects. The inter-burden is understood to contain a range of particle sizes and rock types, and could weather after placement.

Geotechnical Engineer:

_____
David C Starr

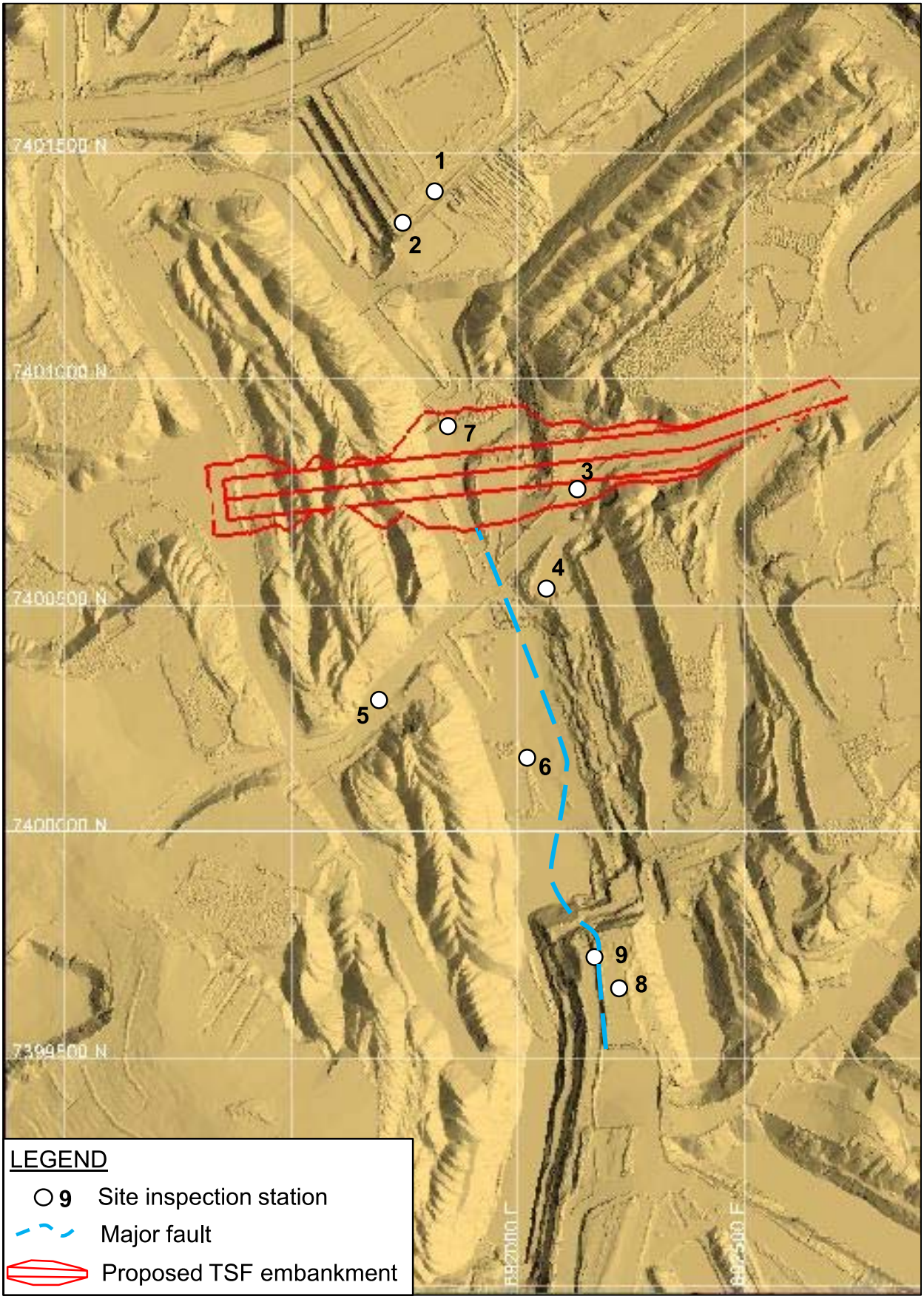
Reviewed by:



_____
Amanda Barrett

ATTACHMENTS

VULCAN Plan and Air Photo overlay showing area of interest and site visit stations



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	DRAWN: DS	DATE: 10-11-16	TITLE: Key Plan Site Inspection 27th October 2016

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	DRAWN DS	DATE 10-11-16	TITLE

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APPENDIX C

Laboratory testing - construction materials

Cardno Construction Sciences
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Laboratory: Emerald Laboratory
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Email: donna.marr@cardno.com.au

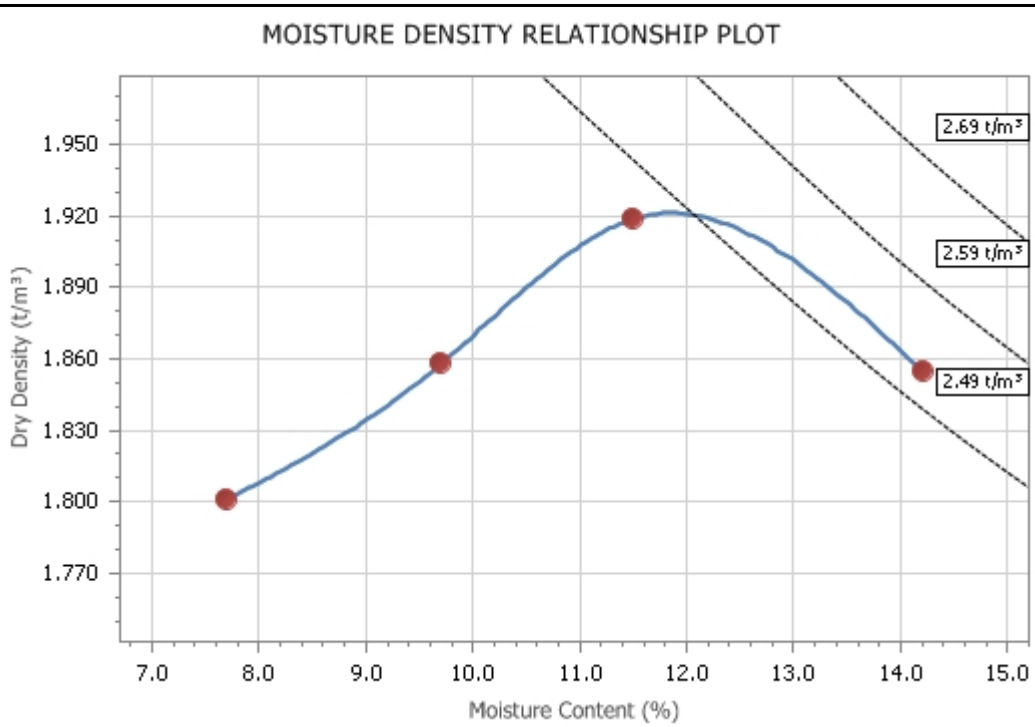
MOISTURE DENSITY RELATIONSHIP REPORT

Client:	Wesfarmers Curragh Pty Ltd	Report Number:	1692/R/8748-1
Client Address:	Private Mail Bag, Blackwater	Project Number:	1692/P/271
Project:	Pit B Tailings Dam Embankment Samples	Lot Number:	
Location:	Curragh Mine Via Blackwater	Internal Test Request:	1692/T/3145
Component:		Client Reference/s:	6/10/2016
Area Description:		Report Date / Page:	10/10/2016 Page 1 of 3

Test Procedures	AS1289.5.1.1, AS1289.2.1.1	Sample Location	
Sample Number	1692/S/18635	Location	Curragh Pit H Spoil
Sampling Method	AS1289.1.2.1 Cl 6.2		
Date Sampled	6/10/2016		
Sampled By	Andrea Fleming		
Date Tested	7/10/2016	Compactive Effort	Standard
Material Source	Onsite	Fraction Tested (mm)	< 19.0mm
Material Type	Embankment	Percent Oversize (%)	0.0
Material Description	Grey clayey gravel		

Moisture / Density Relationship Data

Moisture Content (%)	Dry Density (t/m³)
7.7	1.801
9.7	1.858
11.5	1.919
14.2	1.855



Maximum Dry Density (t/m³):	1.92	Optimum Moisture Content (%):	12.0

Remarks

The results of the tests, calibrations and/or measurements included in this document are traceable to Australian/national standards.
Accredited for compliance with ISO/IEC 17025

Accreditation Number: 1986
Corporate Site Number: 1692

Approved Signatory: Donna Marr
Form ID: W4Rep Rev 1

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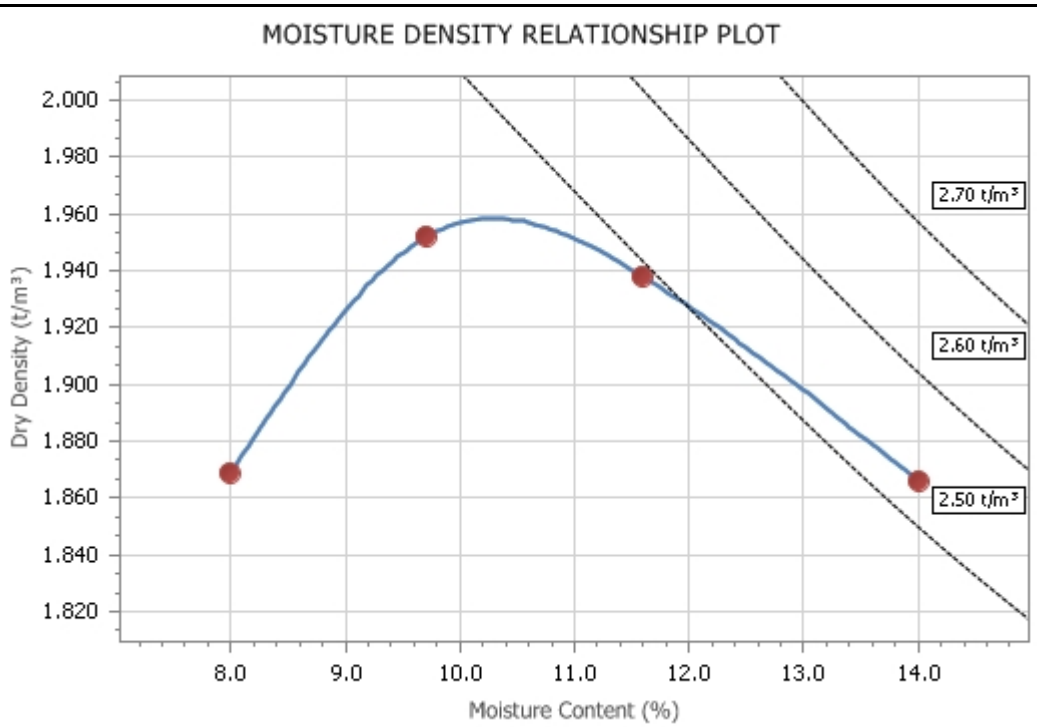
MOISTURE DENSITY RELATIONSHIP REPORT

Client:	Wesfarmers Curragh Pty Ltd	Report Number:	1692/R/8748-1
Client Address:	Private Mail Bag, Blackwater	Project Number:	1692/P/271
Project:	Pit B Tailings Dam Embankment Samples	Lot Number:	
Location:	Curragh Mine Via Blackwater	Internal Test Request:	1692/T/3145
Component:		Client Reference/s:	6/10/2016
Area Description:		Report Date / Page:	10/10/2016 Page 2 of 3

Test Procedures	AS1289.5.1.1, AS1289.2.1.1	Sample Location	
Sample Number	1692/S/18636	Location	Pit H Pollux Interburden
Sampling Method	AS1289.1.2.1 Cl 6.2		
Date Sampled	6/10/2016		
Sampled By	Andrea Fleming		
Date Tested	7/10/2016	Compactive Effort	Standard
Material Source	Onsite	Fraction Tested (mm)	< 19.0mm
Material Type	Embankment	Percent Oversize (%)	0.0
Material Description	Grey clayey gravel		

Moisture / Density Relationship Data

Moisture Content (%)	Dry Density (t/m³)
8.0	1.869
9.7	1.952
11.6	1.938
14.0	1.866



Maximum Dry Density (t/m³):	1.96	Optimum Moisture Content (%):	10.5

Remarks

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Corporate Site Number: 1692

Approved Signatory: Donna Marr
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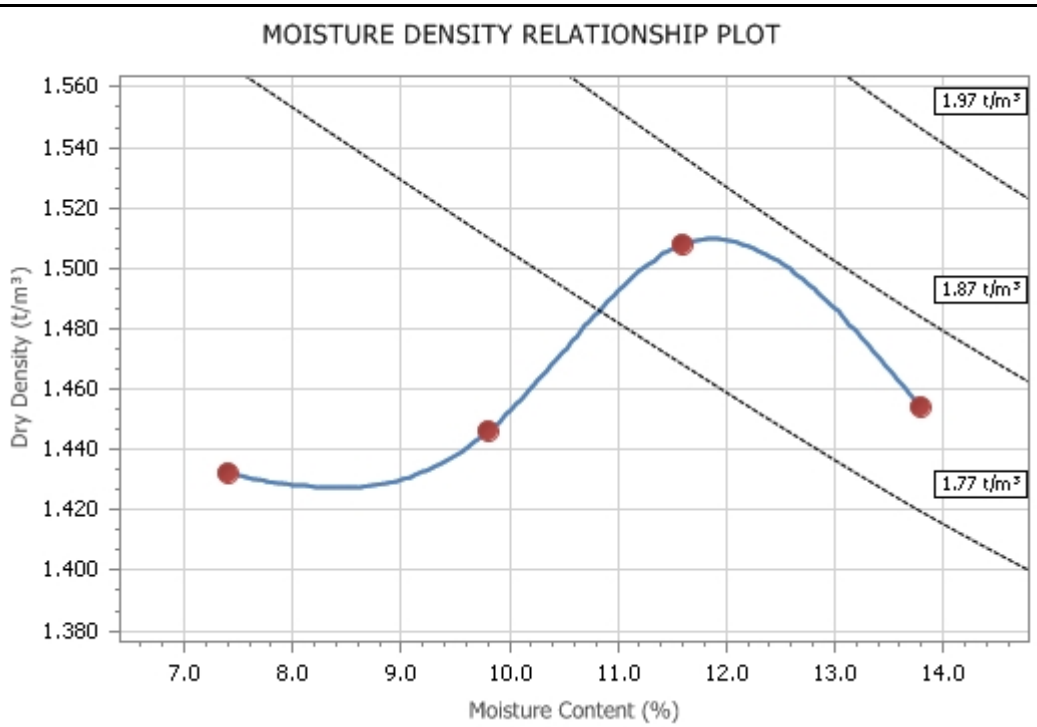
MOISTURE DENSITY RELATIONSHIP REPORT

Client:	Wesfarmers Curragh Pty Ltd	Report Number:	1692/R/8748-1
Client Address:	Private Mail Bag, Blackwater	Project Number:	1692/P/271
Project:	Pit B Tailings Dam Embankment Samples	Lot Number:	
Location:	Curragh Mine Via Blackwater	Internal Test Request:	1692/T/3145
Component:		Client Reference/s:	6/10/2016
Area Description:		Report Date / Page:	10/10/2016 Page 3 of 3

Test Procedures	AS1289.5.1.1, AS1289.2.1.1	Sample Location	
Sample Number	1692/S/18637	Location	CPP#1 CPP#2 Coarse Rejects
Sampling Method	AS1289.1.2.1 Cl 6.2		
Date Sampled	6/10/2016		
Sampled By	Andrea Fleming		
Date Tested	7/10/2016	Compactive Effort	Standard
Material Source	Onsite	Fraction Tested (mm)	< 19.0mm
Material Type	Embankment	Percent Oversize (%)	0.0
Material Description	Black coal rejects		

Moisture / Density Relationship Data

Moisture Content (%)	Dry Density (t/m³)
7.4	1.432
9.8	1.446
11.6	1.508
13.8	1.454



Maximum Dry Density (t/m³):	1.51	Optimum Moisture Content (%):	12.0

Remarks

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Corporate Site Number: 1692

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Form ID: W4Rep Rev 1

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DIRECT SHEAR TEST REPORT

Test Method: ASTM D3080

Direct Shear Test of Soils Under Consolidated Drained Conditions.

Client	Cardno Construction Sciences Pty Ltd	**Report No.**	16100158-DS
Address	13 Glasson St, Emerald QLD 4720	**Test Date**	18/10/2016
		Report Date	19/10/2016
Project	1692/P/271 - Pit B Tailings Dam Embankment Samples		
Client ID	1692/S/18636 - Pit H Pollux Interburden	**Depth (m)**	Not Supplied
Description	-		
Sample Type	Three individual soil specimens - Remoulded.		

SAMPLE DETAILS

	Stage 1	Stage 2	Stage 3	Stage 4
Maximum Dry Density (t/m^3)	1.96	1.96	1.96	
Optimum Moisture Content (%)	10.5	10.5	10.5	
Density Ratio Required (%)	95	95	95	
Specimen Condition	Saturated	Saturated	Saturated	
Specimen Dimensions (mm)	305 x 305	305 x 305	305 x 305	
Initial Sample Height (mm)	172.3	172.3	172.3	
Rate of Strain (mm/min)	1.00	1.00	1.00	
Initial Moisture Content (%)	10.4	10.5	10.7	
Initial Wet Density (t/m^3)	2.06	2.06	2.06	
Final Moisture Content (%)	13.0	12.5	11.6	

Notes/Remarks:

Graph not to scale

Sample/s supplied by the client

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Authorised Signatory
C. Purvis

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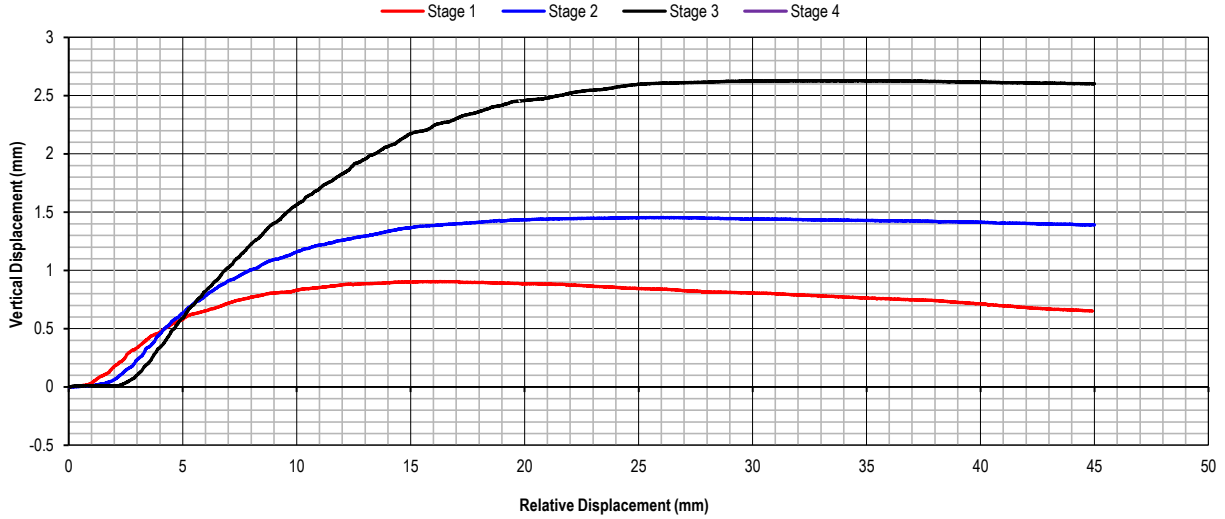
DIRECT SHEAR TEST REPORT

Test Method: ASTM D3080

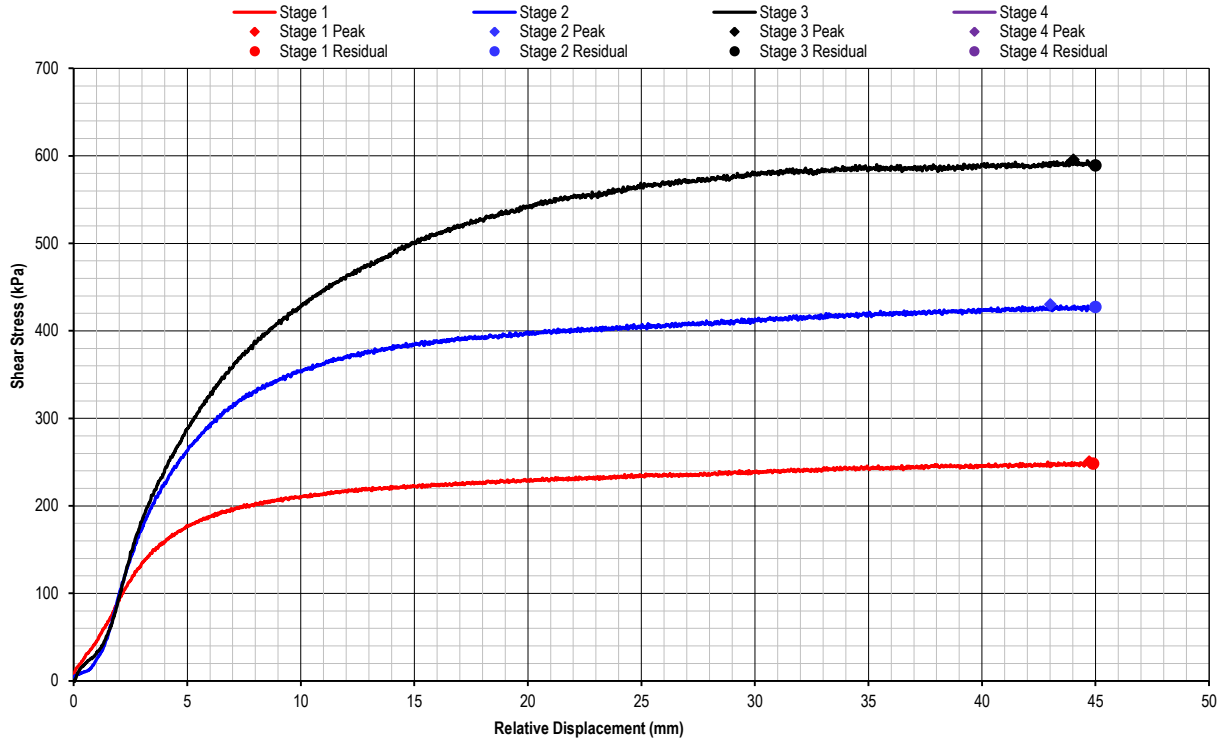
Direct Shear Test of Soils Under Consolidated Drained Conditions.

Client	Cardno Construction Sciences Pty Ltd	**Report No.**	16100158-DS

Vertical Displacement/Relative Displacement Plot



Shear Stress/Displacement Plot



Notes/Remarks:

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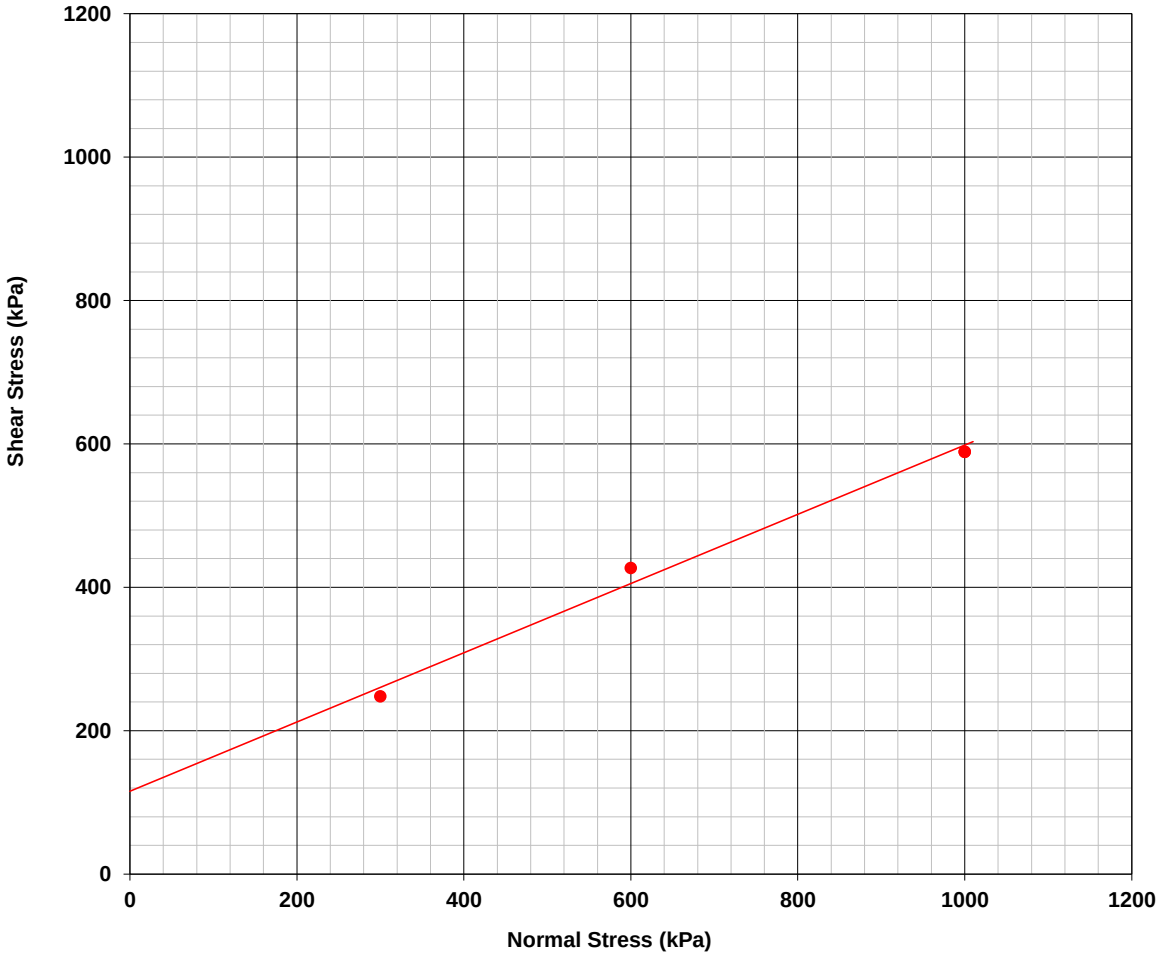
Test Method: ASTM D3080

Direct Shear Test of Soils Under Consolidated Drained Conditions.

Client	Cardno Construction Sciences Pty Ltd	**Report No.**	16100158-DS

Failure Criteria **Residual**

Residual - Normal Stress vs Shear Stress



		Stage	Residual Displacement	Normal Stress	Shear Stress
Shear Angle (°)	**25.8**		(mm)	(kPa)	(kPa)
Cohesion (kPa)	**115.6**	1	44.90	300.0	248.0
		2	45.00	600.0	426.9
R^2	**0.994**	3	45.00	1000.0	588.9

Machine Description: Constant Normal Stress Direct Shear

Notes/Remarks:

Graph not to scale

Sample/s supplied by the client

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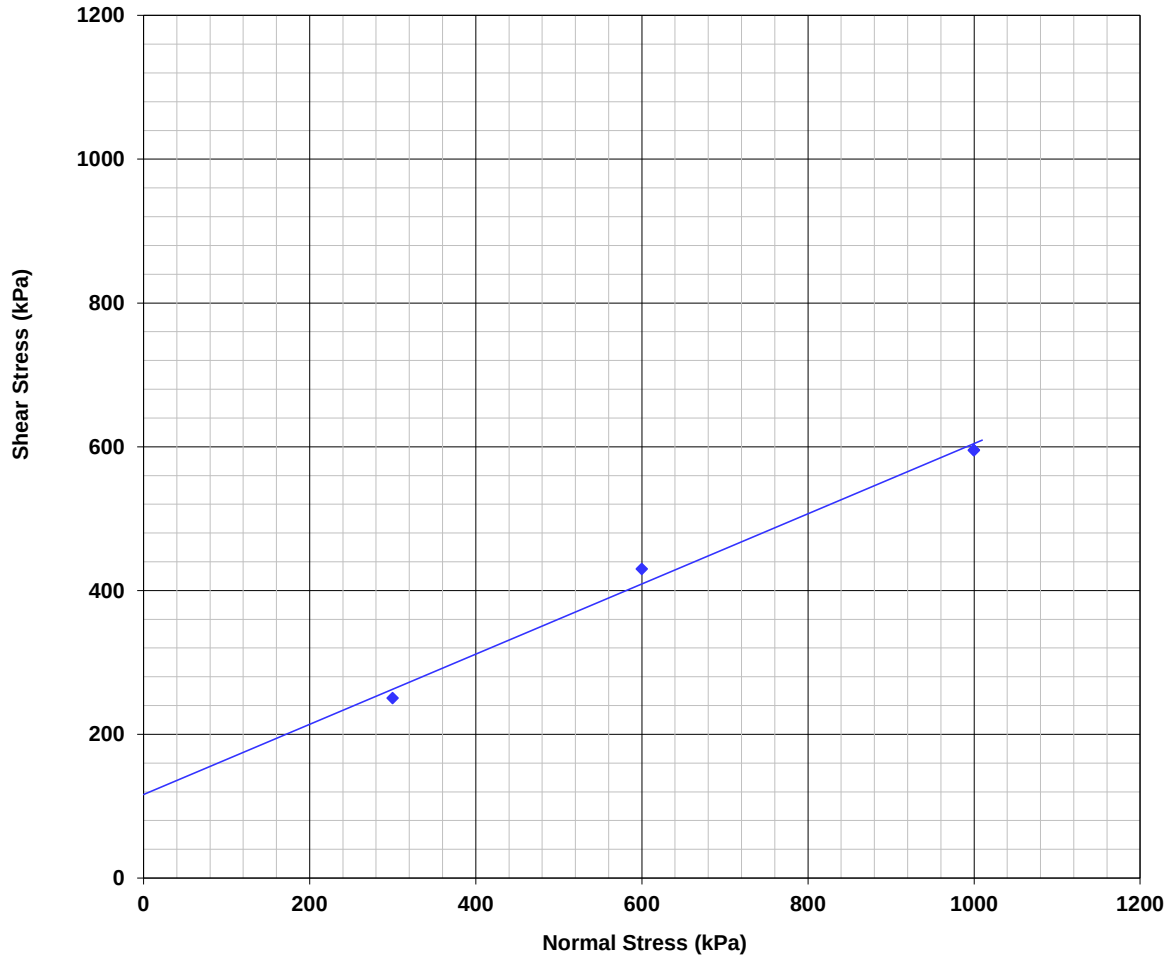
Test Method: ASTM D3080

Direct Shear Test of Soils Under Consolidated Drained Conditions.

Client	Cardno Construction Sciences Pty Ltd	**Report No.**	16100158-DS

Failure Criteria **Peak**

Peak - Normal Stress vs Shear Stress



		Stage	Displacement at Peak Stress	Normal Stress	Shear Stress
Shear Angle (°)	**26.0**		(mm)	(kPa)	(kPa)
Cohesion (kPa)	**116.1**	1	44.73	300.0	250.5
R^2	**0.994**	2	43.01	600.0	430.1
		3	44.03	1000.0	595.2

Machine Description Constant Normal Stress Direct Shear

Notes/Remarks:

Graph not to scale Sample/s supplied by the client

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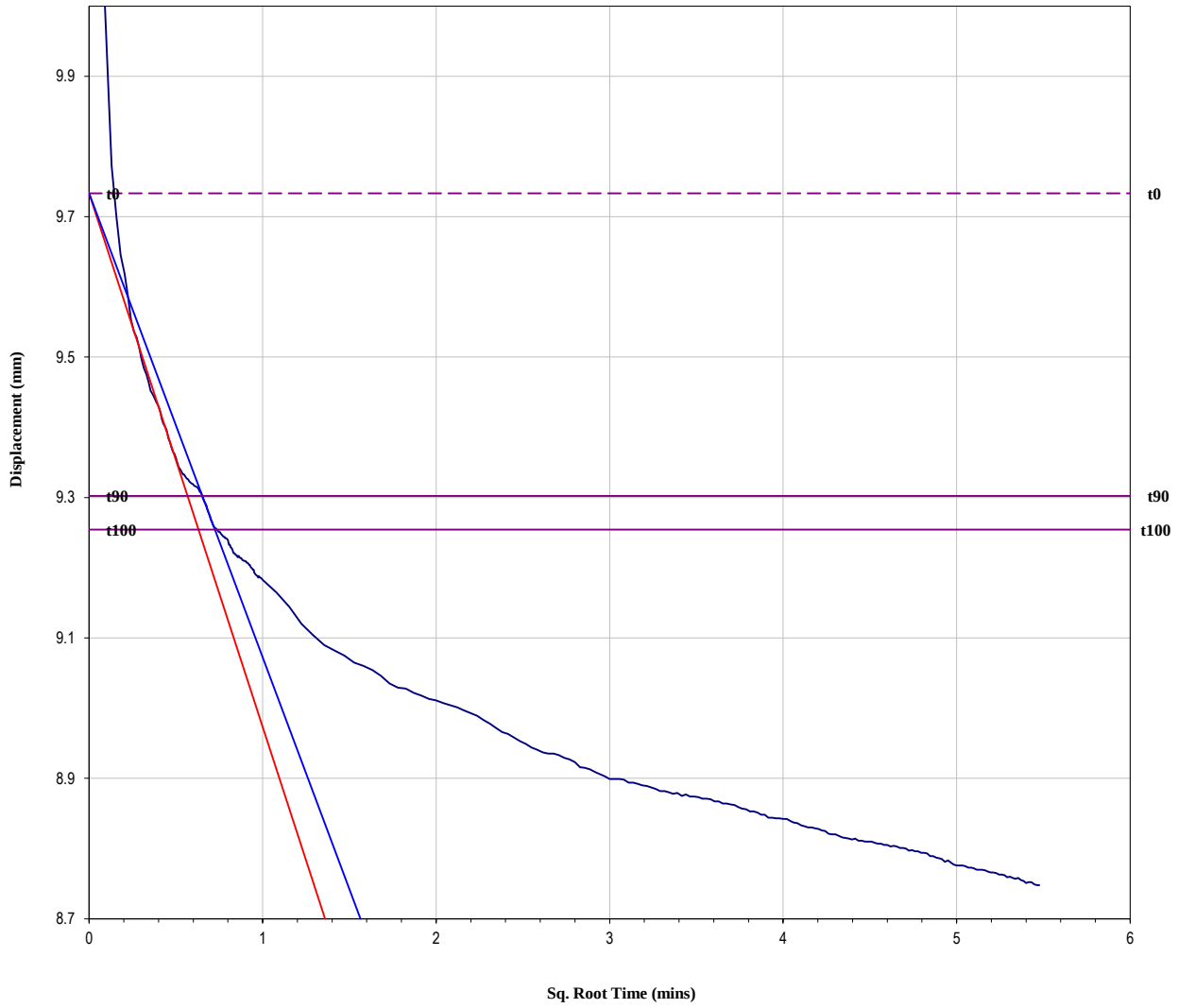
Test Method: ASTM D3080

Direct Shear Test of Soils Under Consolidated Drained Conditions.

Client	Cardno Construction Sciences Pty Ltd	**Report No.**	16100158-DS

Stage 1 Consolidation

Displacement v's Time (Sq. Root Scale)



t_{90}	0.43	**mins**
Time to Failure =	4.94	**mins**
Estimated Displacement to Failure =	5	**mm**
Displacement Rate =	1.01276	**mm/min**

Notes/Remarks:

Graph not to scale

Sample/s supplied by the client

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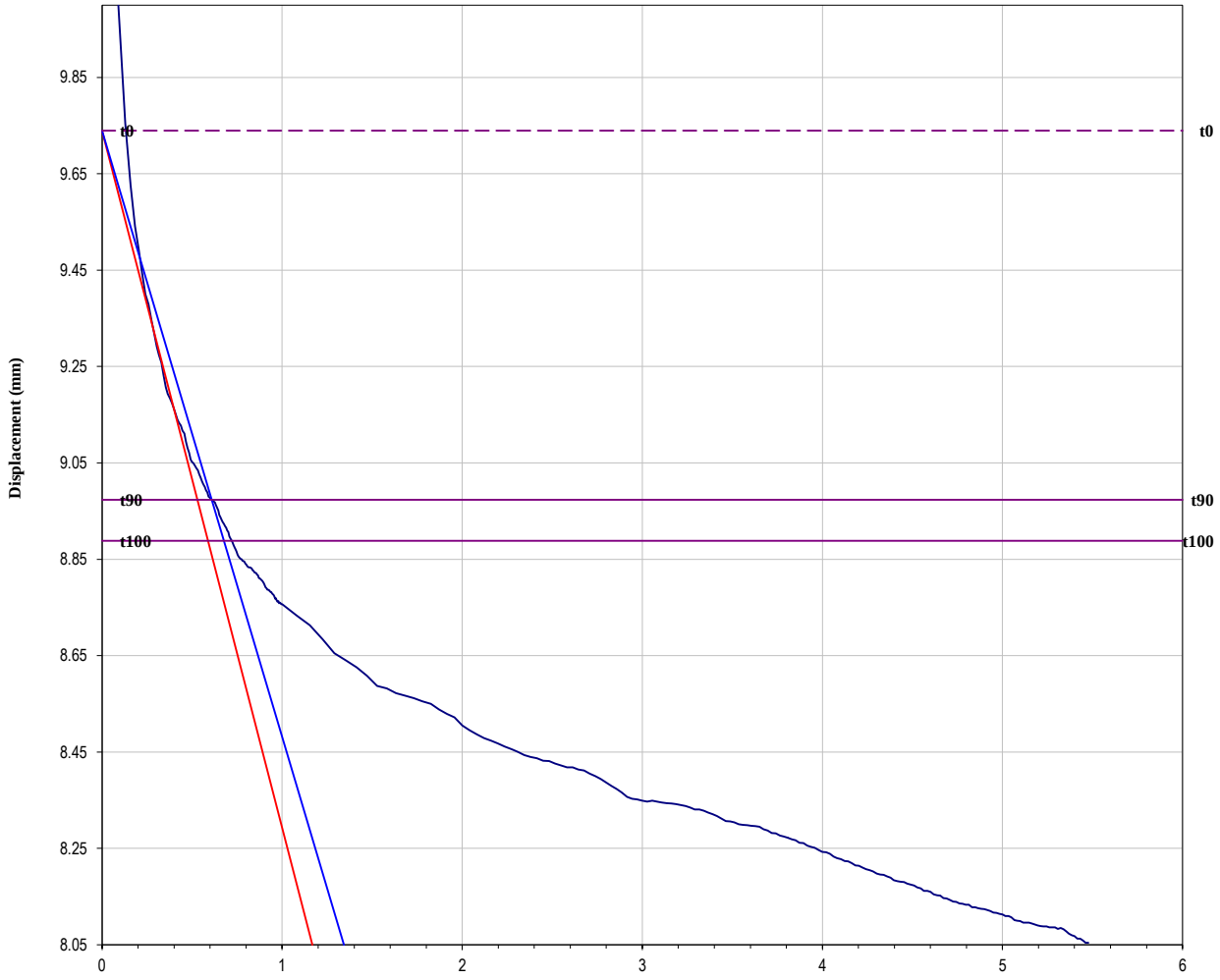
Test Method: ASTM D3080

Direct Shear Test of Soils Under Consolidated Drained Conditions.

Client	Cardno Construction Sciences Pty Ltd	**Report No.**	16100158-DS

Stage 2 Consolidation

Displacement v's Time (Sq. Root Scale)



t_{90}	0.37	**mins**
Time to Failure =	4.30	**mins**
Estimated Displacement to Failure =	5	**mm**
Displacement Rate =	1.16231	**mm/min**

Notes/Remarks:

Graph not to scale

Sample/s supplied by the client

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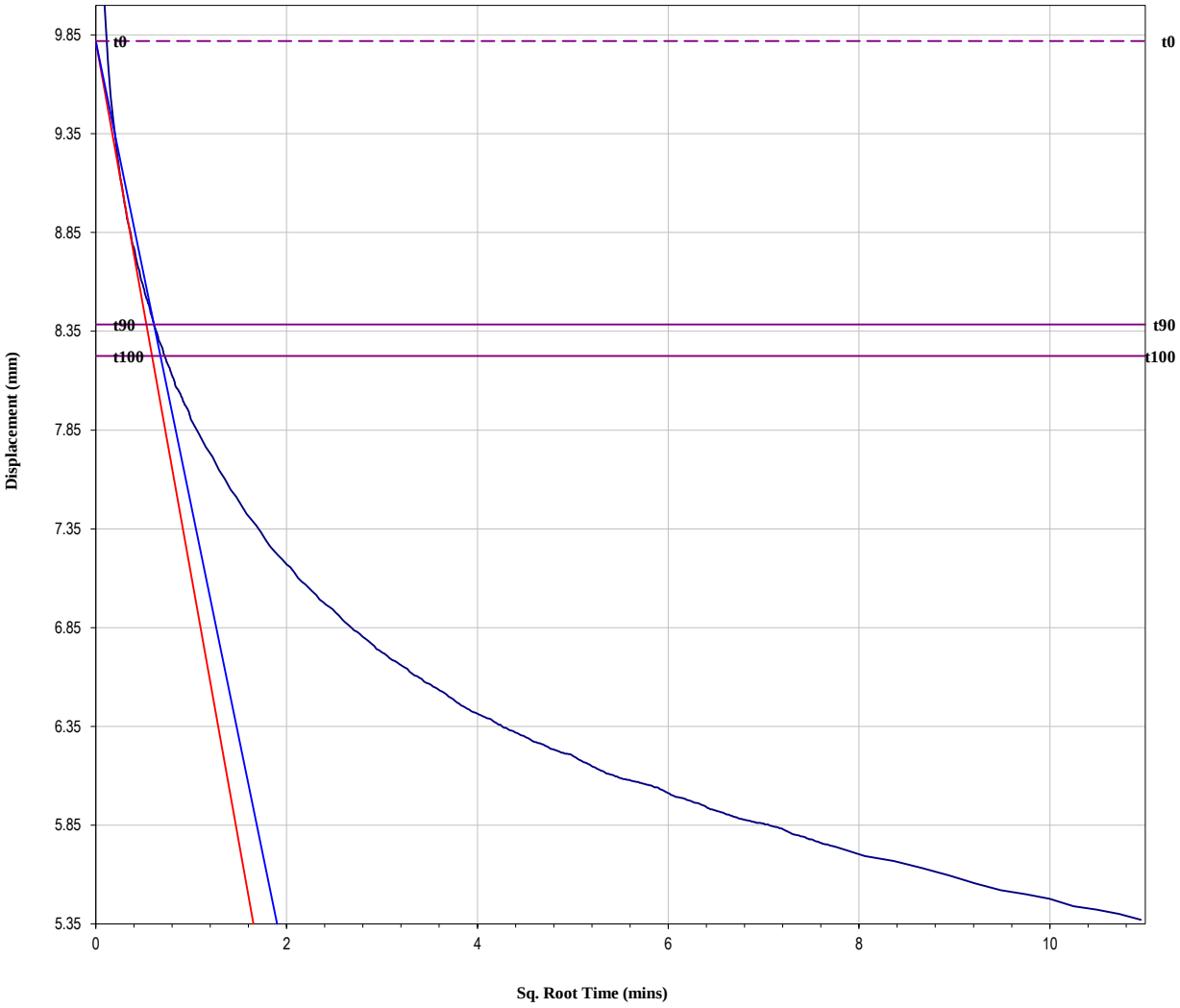
Test Method: ASTM D3080

Direct Shear Test of Soils Under Consolidated Drained Conditions.

Client	Cardno Construction Sciences Pty Ltd	**Report No.**	16100158-DS

Stage 3 Consolidation

Displacement v's Time (Sq. Root Scale)



t_{90}	0.37	**mins**
Time to Failure =	4.32	**mins**
Estimated Displacement to Failure =	5	**mm**
Displacement Rate =	1.15757	**mm/min**

Notes/Remarks:

Graph not to scale

Sample/s supplied by the client

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Authorised Signatory
C. Purvis

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13 Glasson, Street,
Emerald QLD 4720

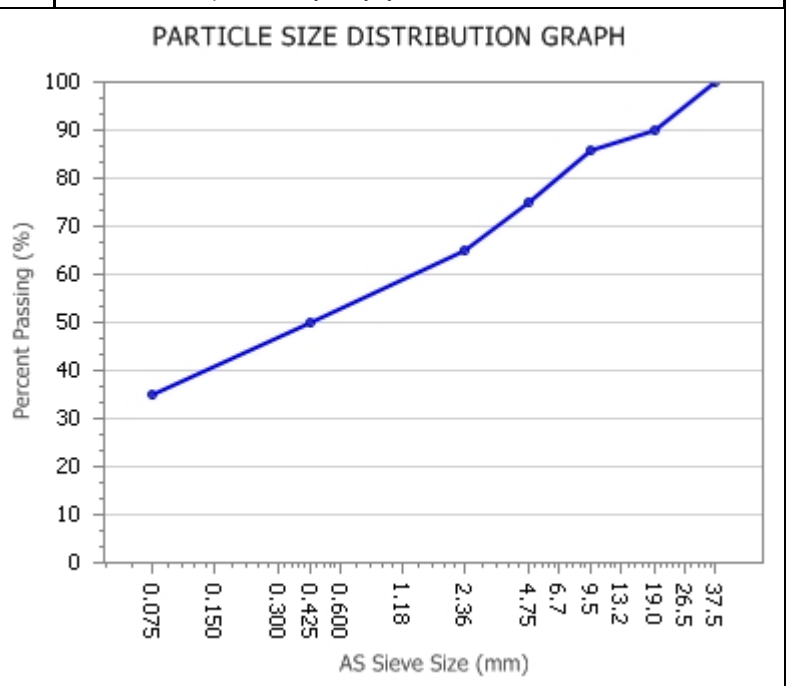
Laboratory: Emerald Laboratory
Phone: 07 4982 0044 Fax: 07 4982 3102
Email: donna.marr@cardno.com.au

QUALITY OF MATERIALS REPORT

Client:	Wesfarmers Curragh Pty Ltd	Report Number:	1692/R/8747-1
Client Address:	Private Mail Bag, Blackwater	Project Number:	1692/P/271
Project:	Pit B Tailings Dam Embankment Samples	Lot Number:	
Location:	Curragh Mine Via Blackwater	Internal Test Request:	1692/T/3145
Component:		Client Reference/s:	6/10/2016
Area Description:		Report Date / Page:	10/10/2016 Page 1 of 3

Test Procedures	AS1289.3.6.1, AS1289.3.1.1, AS1289.3.2.1, AS1289.3.4.1, AS1289.2.1.1, AS 1289.3.3.1		
Sample Number	1692/S/18635	Location	Curragh Pit H Spoil
Sampling Method	AS1289.1.2.1 Cl 6.2		
Date Sampled	6/10/2016		
Sampled By	Andrea Fleming		
Date Tested	6/10/2016	Material Source	Onsite
Att. Drying Method	Oven Dried	Material Type	Embankment
Atterberg Preparation	Dry Sieved	Material Description	Gray Clayey Gravel

AS Sieve (mm)	Specification Minimum	Percent Passing (%)	Specification Maximum
37.5		**100**	
19.0		**90**	
9.5		**86**	
4.75		**75**	
2.36		**65**	
0.425		**50**	
0.075		**35**	



Test Result	Specification Minimum	Result	Specification Maximum	Test Result	Specification Minimum	Result	Specification Maximum
Liquid Limit (%)		**33**		0.075/0.425 Fines Ratio		**0.69**	
Plastic Limit (%)		**17**		PI x 0.425 Ratio (%)		**808.0**	
Plastic Index (%)		**16**		LS x 0.425 Ratio (%)		**404.0**	
Linear Shrinkage (%)		**8.0**		Linear Shrinkage Defects	-		

Remarks

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Accreditation Number: 1986
Corporate Site Number: 1692

Approved Signatory: Donna Marr
Form ID: W85Rep Rev 1

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ABN: 74 128 806 735
Address:
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Emerald QLD 4720

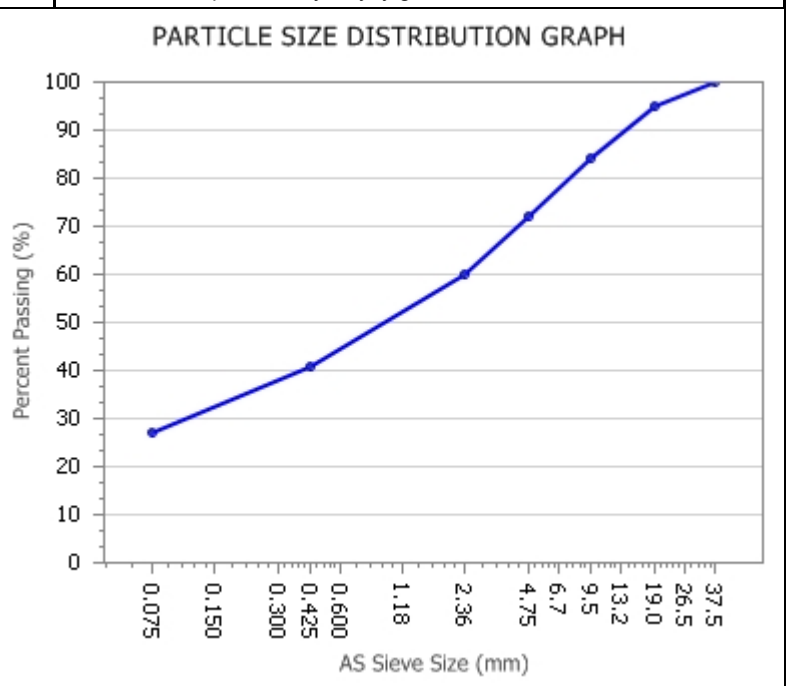
Laboratory: Emerald Laboratory
Phone: 07 4982 0044 Fax: 07 4982 3102
Email: donna.marr@cardno.com.au

QUALITY OF MATERIALS REPORT

Client:	Wesfarmers Curragh Pty Ltd	Report Number:	1692/R/8747-1
Client Address:	Private Mail Bag, Blackwater	Project Number:	1692/P/271
Project:	Pit B Tailings Dam Embankment Samples	Lot Number:	
Location:	Curragh Mine Via Blackwater	Internal Test Request:	1692/T/3145
Component:		Client Reference/s:	6/10/2016
Area Description:		Report Date / Page:	10/10/2016 Page 2 of 3

Test Procedures	AS1289.3.6.1, AS1289.3.1.1, AS1289.3.2.1, AS1289.3.4.1, AS1289.2.1.1, AS 1289.3.3.1		
Sample Number	1692/S/18636	Location	Pit H Pollux Interburden
Sampling Method	AS1289.1.2.1 Cl 6.2		
Date Sampled	6/10/2016		
Sampled By	Andrea Fleming		
Date Tested	6/10/2016	Material Source	Onsite
Att. Drying Method	Oven Dried	Material Type	Embankment
Atterberg Preparation	Dry Sieved	Material Description	Grey clayey gravel

AS Sieve (mm)	Specification Minimum	Percent Passing (%)	Specification Maximum
37.5		**100**	
19.0		**95**	
9.5		**84**	
4.75		**72**	
2.36		**60**	
0.425		**41**	
0.075		**27**	



Test Result	Specification Minimum	Result	Specification Maximum	Test Result	Specification Minimum	Result	Specification Maximum
Liquid Limit (%)		**31**		0.075/0.425 Fines Ratio		**0.65**	
Plastic Limit (%)		**18**		PI x 0.425 Ratio (%)		**534.3**	
Plastic Index (%)		**13**		LS x 0.425 Ratio (%)		**308.2**	
Linear Shrinkage (%)		**7.5**		Linear Shrinkage Defects	-		

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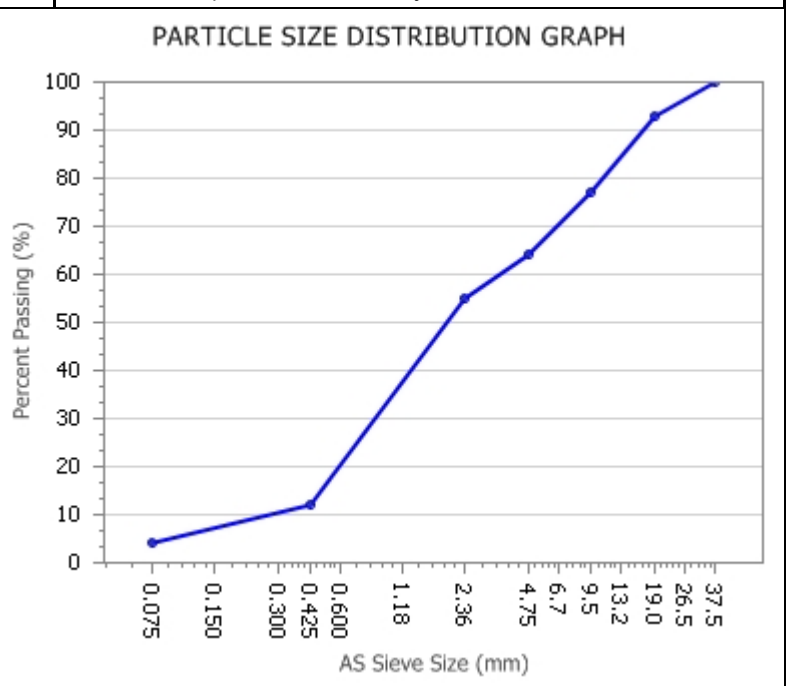
Laboratory: Emerald Laboratory
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Email: donna.marr@cardno.com.au

QUALITY OF MATERIALS REPORT

Client:	Wesfarmers Curragh Pty Ltd	Report Number:	1692/R/8747-1
Client Address:	Private Mail Bag, Blackwater	Project Number:	1692/P/271
Project:	Pit B Tailings Dam Embankment Samples	Lot Number:	
Location:	Curragh Mine Via Blackwater	Internal Test Request:	1692/T/3145
Component:		Client Reference/s:	6/10/2016
Area Description:		Report Date / Page:	10/10/2016 Page 3 of 3

Test Procedures	AS1289.3.6.1, AS1289.3.1.1, AS1289.3.2.1, AS1289.3.4.1, AS1289.2.1.1, AS 1289.3.3.1		
Sample Number	1692/S/18637	Location	CPP#1 CPP#2 Coarse Rejects
Sampling Method	AS1289.1.2.1 Cl 6.2		
Date Sampled	6/10/2016		
Sampled By	Andrea Fleming		
Date Tested	6/10/2016	Material Source	Onsite
Att. Drying Method	Oven Dried	Material Type	Embankment
Atterberg Preparation	Dry Sieved	Material Description	Black Coal Rejects

AS Sieve (mm)	Specification Minimum	Percent Passing (%)	Specification Maximum
37.5		**100**	
19.0		**93**	
9.5		**77**	
4.75		**64**	
2.36		**55**	
0.425		**12**	
0.075		**4**	



Test Result	Specification Minimum	Result	Specification Maximum	Test Result	Specification Minimum	Result	Specification Maximum
Liquid Limit (%)		**Not Obtainable**		0.075/0.425 Fines Ratio		**0.29**	
Plastic Limit (%)		**Not Obtainable**		PI x 0.425 Ratio (%)		**-**	
Plastic Index (%)		**Non Plastic**		LS x 0.425 Ratio (%)		**0.0**	
Linear Shrinkage (%)		**0.0**		Linear Shrinkage Defects	-		

Remarks

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Approved Signatory: Donna Marr
Form ID: W85Rep Rev 1

This report is prepared on behalf of
UNSW Global Pty Limited

Large Shear Box Test Report - 1

for

Australian Soil Testing P/L

Author:
Professor Nasser Khalili

8 September 2010

Authorised Contact:
Rachel Brooks

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1. Sample identification 1
2. Sample preparation and Testing Procedure 1
3. Summary of Test Results 1

Annexes

Annex 1 :Test Records of Shear Stress and Vertical Displacement

1. Sample identification

Sample number: Job 113-117

Sample location: Lake Vermont

Sample description: Disturbed samples of sandy gravel supplied by the client.

2. Sample preparation and Testing Procedure

The samples were placed in the shear box in three layers and compacted to the specified dry density at its natural moisture content. The samples were consolidated without flooding at the prescribed normal stress and sheared at a strain rate of 0.5mm/min until a constant volume was achieved.

3. Summary of Test Results

Sample No	Normal Stress (kPa)	Peak Shear Stress (kPa)	Strength Parameters*
Job 113-117	50 100 200	54.41 101.51 194.32	$\phi = 43.0^o$ c = 8.0 kPa

* Note – The strength parameters were computed from three sets of test data.

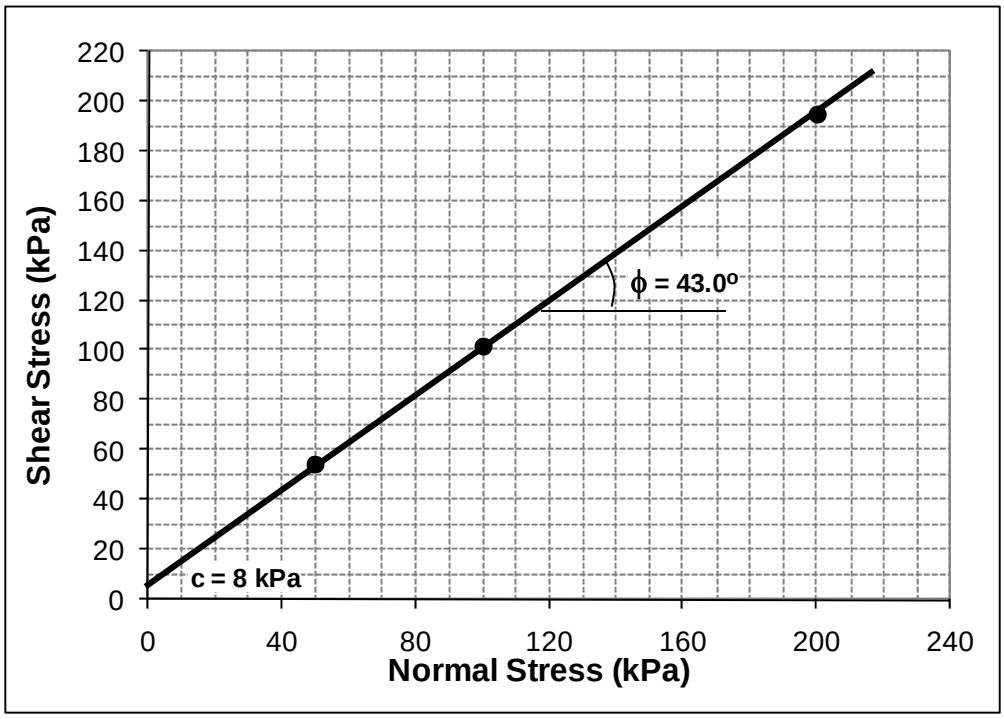


Fig 1 – Plot of shear strength versus normal stress for the test soil with dry unit weight of 1.1 t/m^3

Professor Nasser Khalili
BSc Teh., MSc Birm., PhD

for UNSW Global Pty Limited

Annexes

Annex 1

Test Records of Shear Stress and Vertical Displacement

.

Large Shear Box Test

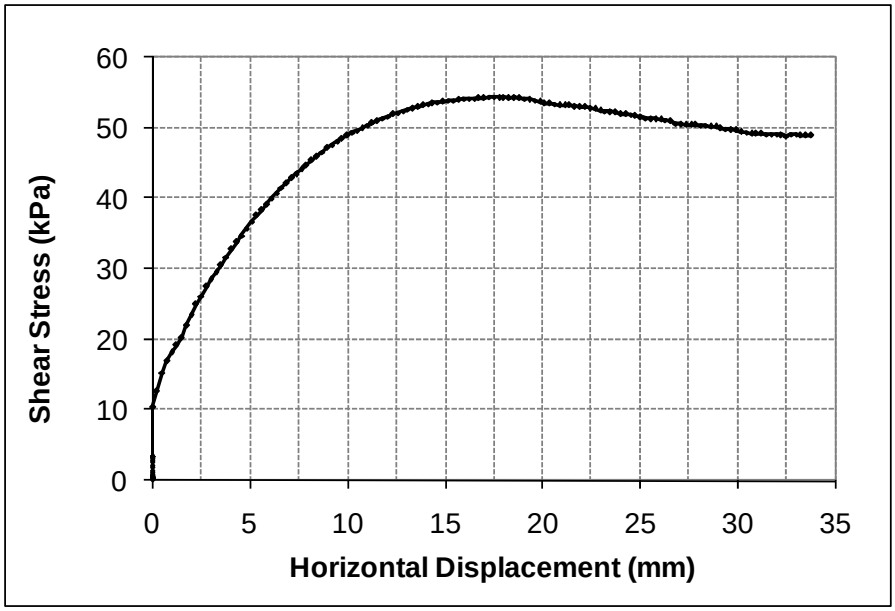
(AS 1289.6.2.2)

Normal Stress = 50 kPa

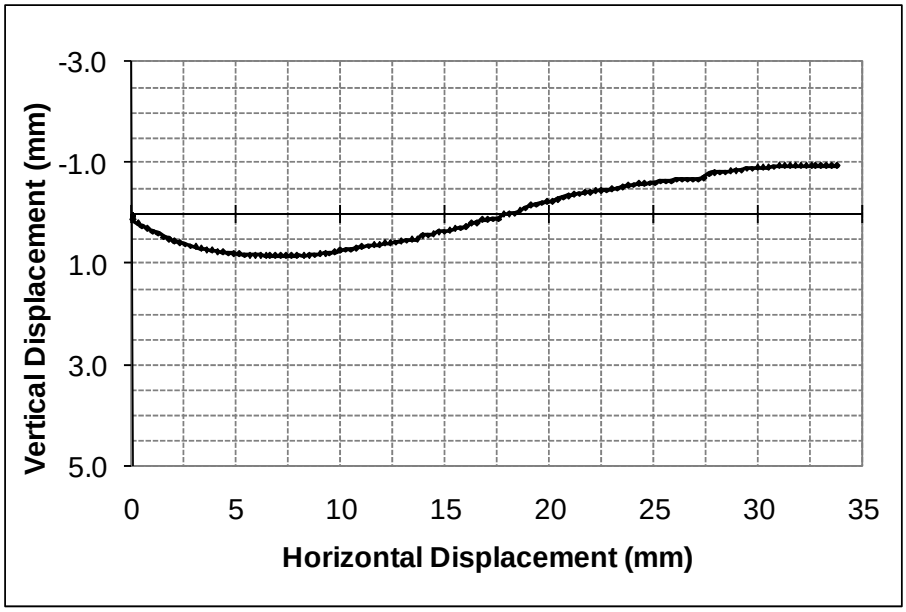
Client:	*Golder Associates Pty. Ltd.*	Test Date:	*24 August, 2010*
Project:		Dry Density:	*1.1 t/m^3*
Location:	Lake Vermont	Moisture Content:	*2.84%*
Sample ID:	Job 113-117	Strain Rate:	*0.5 mm/min*
Test No:	*SGS-LST001*	Shear Box Size:	*304 mm×304 mm*

Sample Preparation: Disturbed sample supplied by the client (initial moisture content ranging from 2.56 to 2.86%) compacted to the specified dry density.

Plot of Shear Stress vs Horizontal Displacement



Plot of Vertical Displacement vs Horizontal Displacement



Peak Shear Stress: **54.41 kPa**

Note: Tilting of the upper cap was observed during shearing; the volume changes measured may not be reliable.

Large Shear Box Test

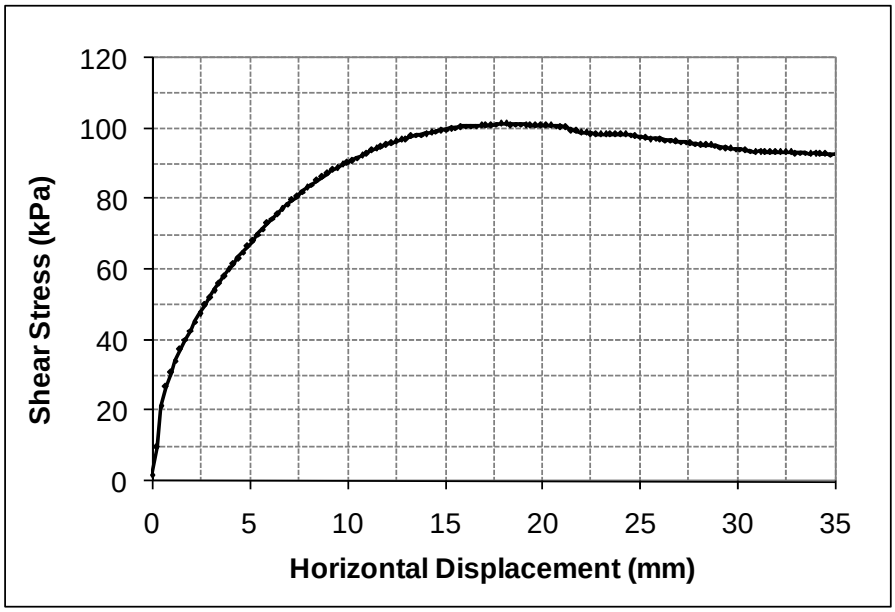
(AS 1289.6.2.2)

Normal Stress = 100 kPa

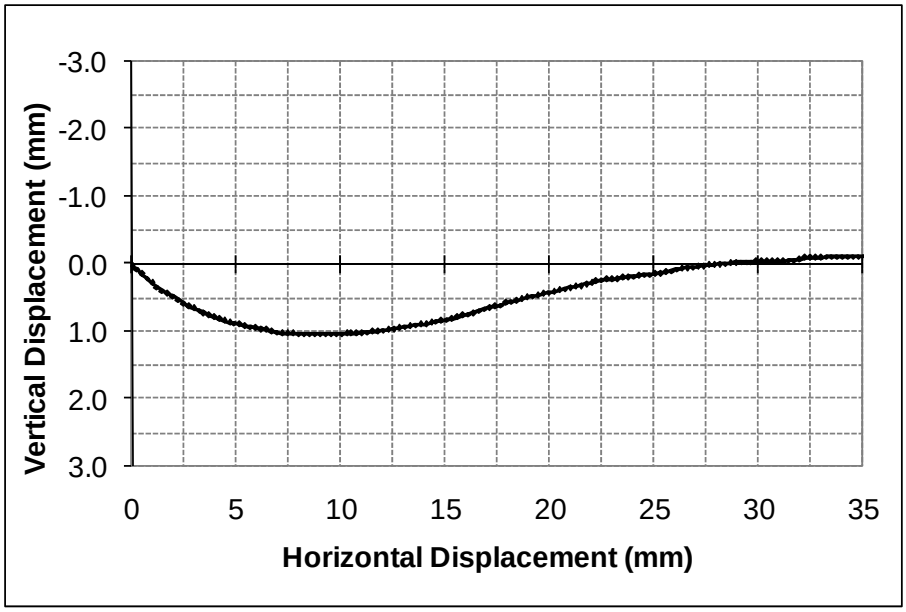
Client:	*Golder Associates Pty. Ltd.*	Test Date:	*25 August, 2010*
Project:		Dry Density:	*1.1 t/m³*
Location:	Lake Vermont	Moisture Content:	*2.84%*
Sample ID:	Job 113-117	Strain Rate:	*0.5 mm/min*
Test No:	*SGS-LST002*	Shear Box Size:	*304 mm×304 mm*

Sample Preparation: Disturbed sample supplied by the client (initial moisture content ranging from 2.56 to 2.86%) compacted to the specified dry density.

Plot of Shear Stress vs Horizontal Displacement



Plot of Vertical Displacement vs Horizontal Displacement



Peak Shear Stress: **101.52 kPa**

Note: Tilting of the upper cap was observed during shearing; the volume changes measured may not be reliable.

Large Shear Box Test

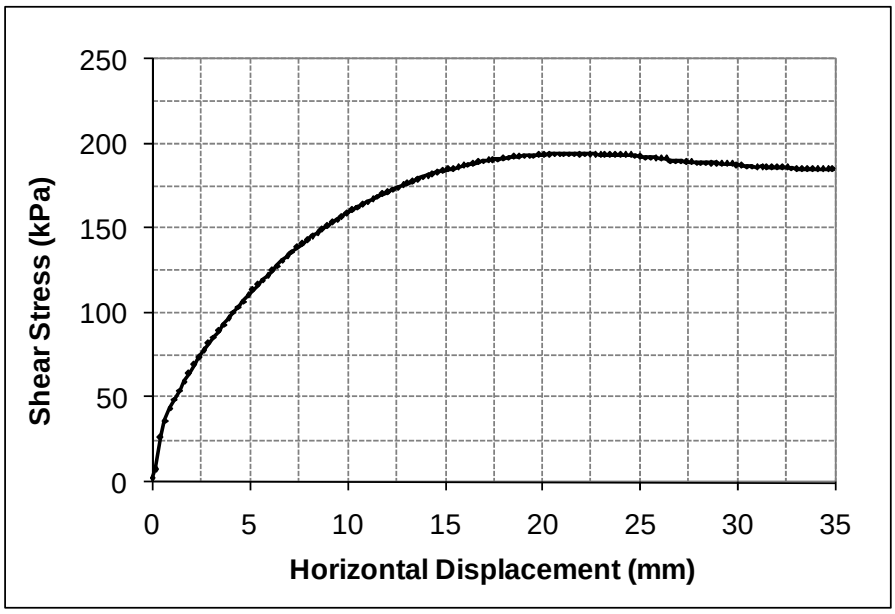
(AS 1289.6.2.2)

Normal Stress = 200 kPa

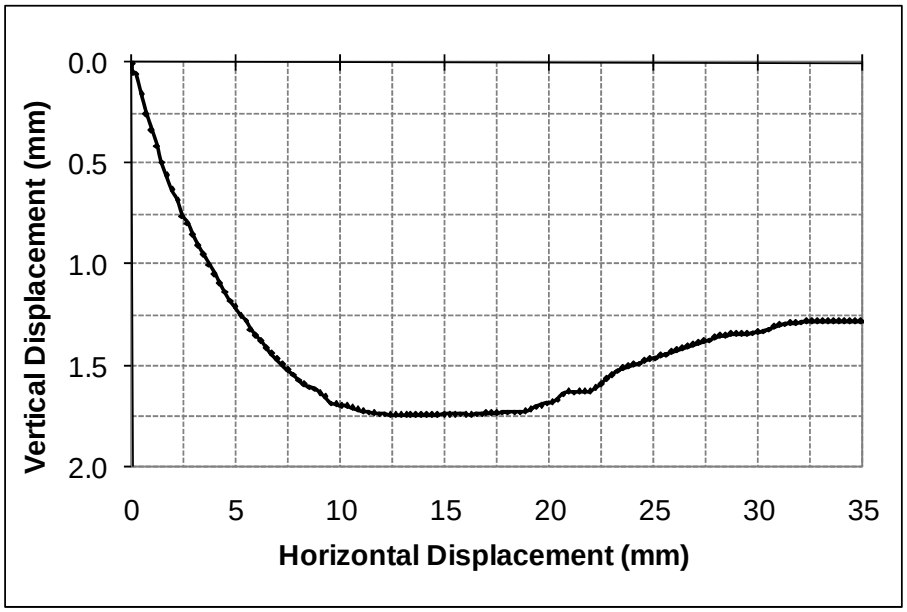
Client:	*Golder Associates Pty. Ltd.*	Test Date:	*26 August, 2010*
Project:		Dry Density:	*1.1 t/m^3*
Location:	Lake Vermont	Moisture Content:	*2.84%*
Sample ID:	Job 113-117	Strain Rate:	*0.5 mm/min*
Test No:	*SGS-LST003*	Shear Box Size:	*304 mm×304 mm*

Sample Preparation: Disturbed sample supplied by the client (initial moisture content ranging from 2.56 to 2.86%) compacted to the specified dry density.

Plot of Shear Stress vs Horizontal Displacement



Plot of Vertical Displacement vs Horizontal Displacement



Peak Shear Stress: **194.32 kPa**

Note: Tilting of the upper cap was observed during shearing; the volume changes measured may not be reliable.

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DIRECT SHEAR TEST REPORT

Test Method: ASTM D3080

Direct Shear Test of Soils Under Consolidated Drained Conditions.

Client	Cardno Construction Sciences Pty Ltd	**Report No.**	16100157-DS
Address	13 Glasson St, Emerald QLD 4720	**Test Date**	25/10/2016
		Report Date	26/10/2016
Project	1692/P/271 - Pit B Tailings Dam Embankment Samples		
Client ID	1692/S/18635 - Curragh Pit H Spoil	**Depth (m)**	Not Supplied
Description	-		
Sample Type	Three individual soil specimens - Remoulded.		

SAMPLE DETAILS

	Stage 1	Stage 2	Stage 3	Stage 4
Maximum Dry Density (t/m^3)	1.92	1.92	1.92	
Optimum Moisture Content (%)	12.0	12.0	12.0	
Density Ratio Required (%)	95	95	95	
Specimen Condition	Saturated	Saturated	Saturated	
Specimen Dimensions (mm)	305 x 305	305 x 305	305 x 305	
Initial Sample Height (mm)	172.3	172.3	172.3	
Rate of Strain (mm/min)	0.10	0.10	0.10	
Initial Moisture Content (%)	11.7	11.8	12.3	
Initial Wet Density (t/m^3)	2.04	2.04	2.04	
Final Moisture Content (%)	12.9	13.0	13.3	

Notes/Remarks:

Graph not to scale

Sample/s supplied by the client

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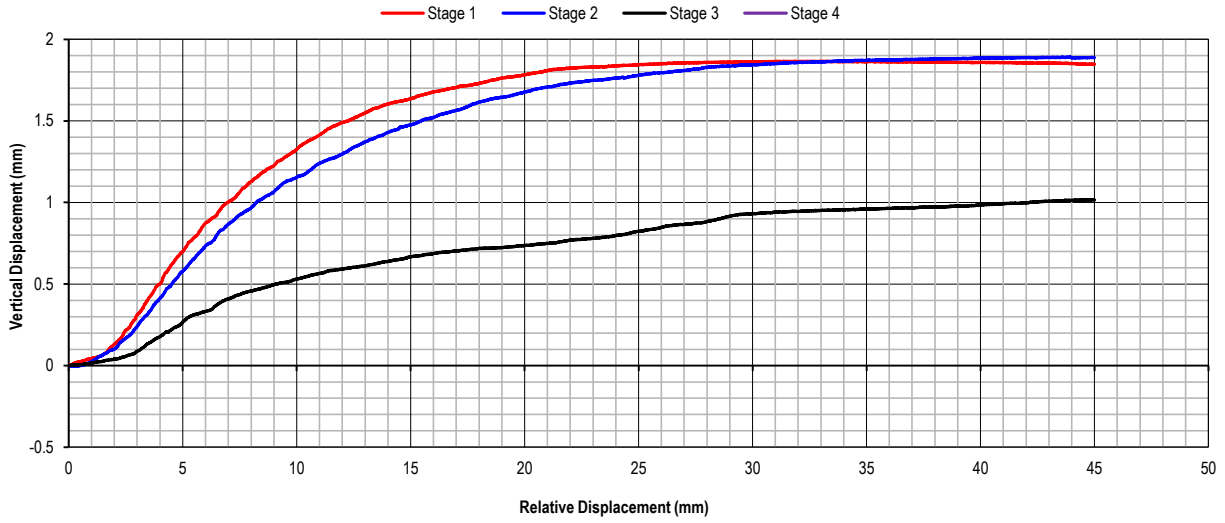
DIRECT SHEAR TEST REPORT

Test Method: ASTM D3080

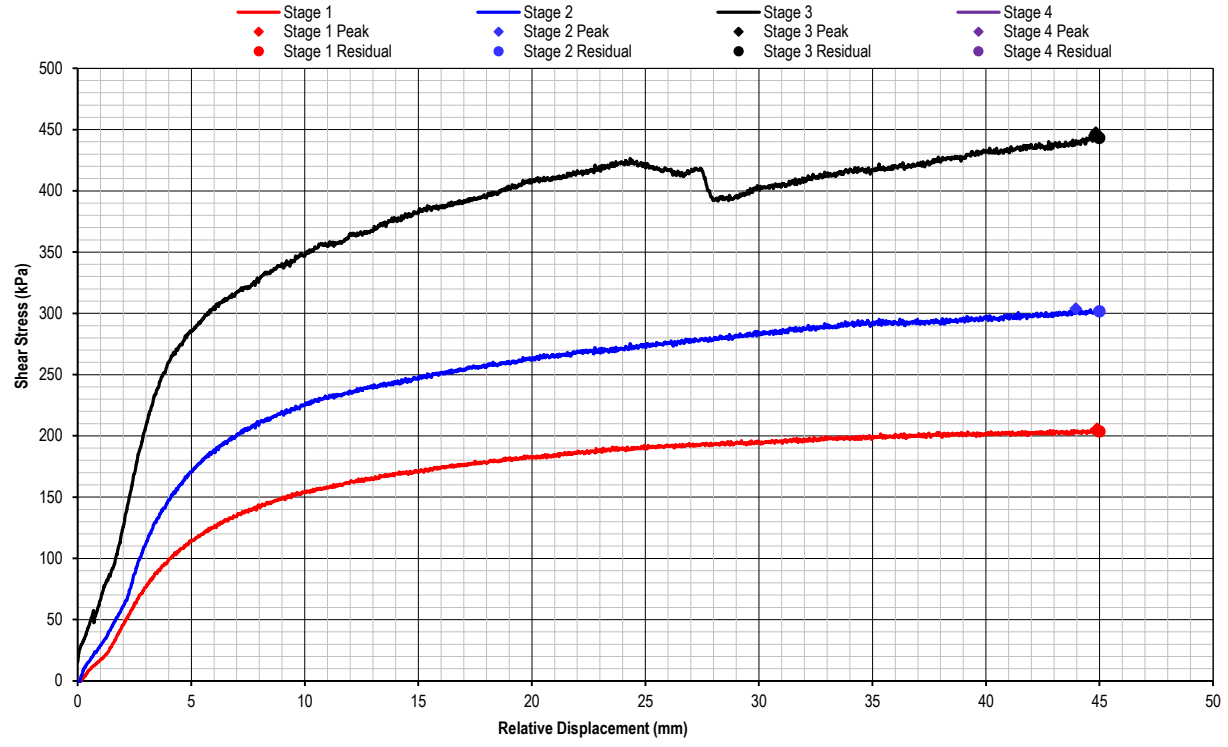
Direct Shear Test of Soils Under Consolidated Drained Conditions.

Client	Cardno Construction Sciences Pty Ltd	**Report No.**	16100157-DS

Vertical Displacement/Relative Displacement Plot



Shear Stress/Displacement Plot



Notes/Remarks:

Graph not to scale

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DIRECT SHEAR TEST REPORT

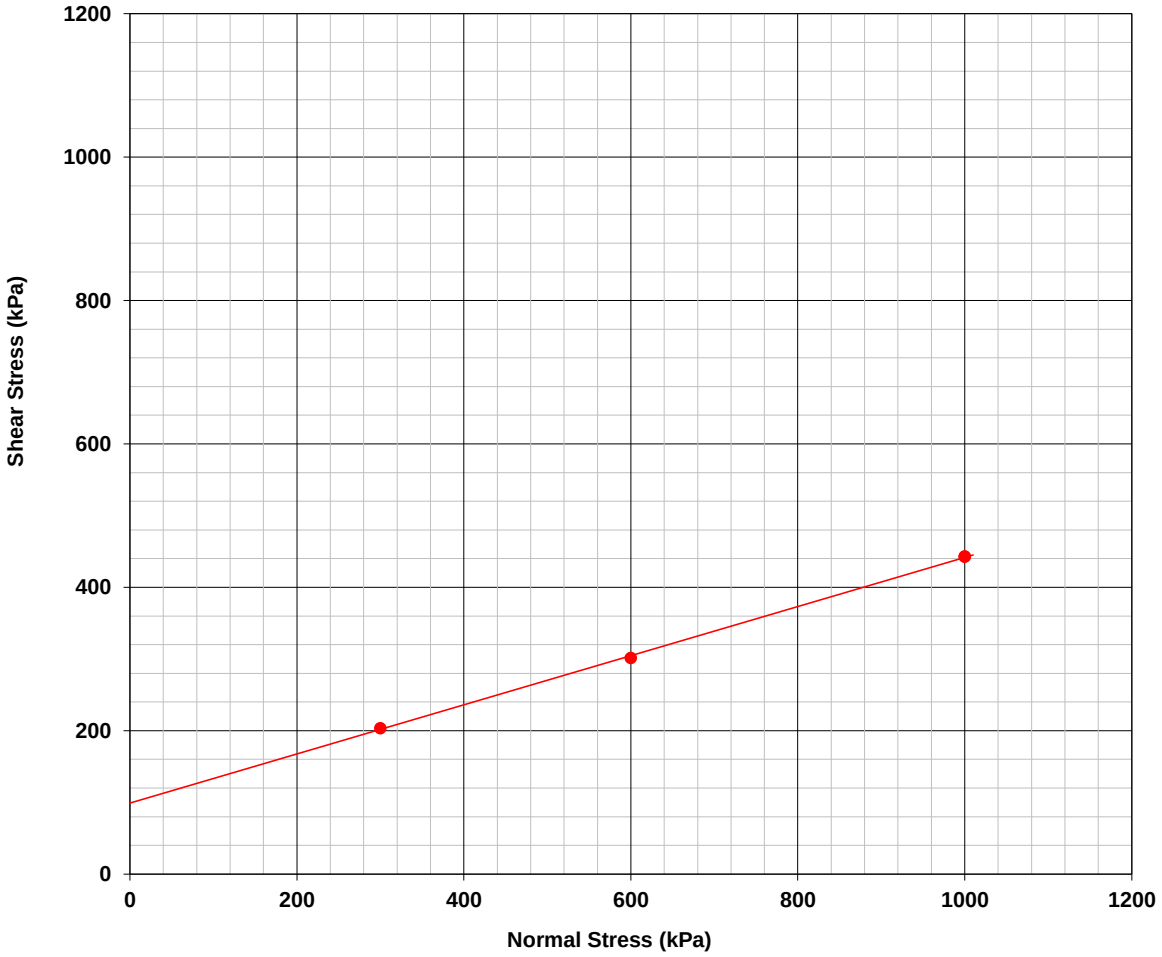
Test Method: ASTM D3080

Direct Shear Test of Soils Under Consolidated Drained Conditions.

Client	Cardno Construction Sciences Pty Ltd	**Report No.**	16100157-DS

Failure Criteria **Residual**

Residual - Normal Stress vs Shear Stress



		Stage	Residual Displacement	Normal Stress	Shear Stress
Shear Angle (°)	**18.9**		(mm)	(kPa)	(kPa)
Cohesion (kPa)	**98.8**	1	45.00	300.0	203.4
		2	45.00	600.0	301.5
R^2	**1.000**	3	44.99	1000.0	443.0

Machine Description Constant Normal Stress Direct Shear

Notes/Remarks:

Graph not to scale Sample/s supplied by the client

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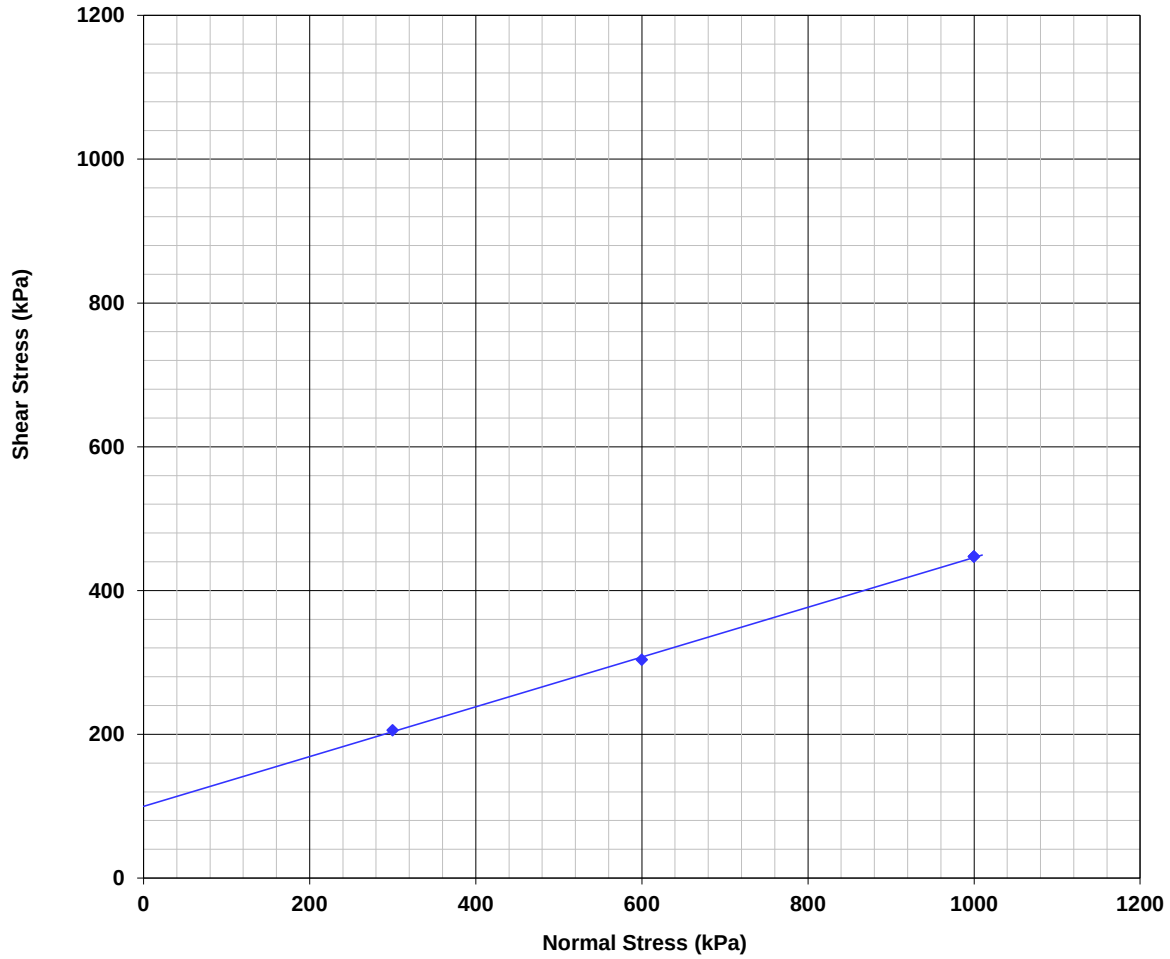
Test Method: ASTM D3080

Direct Shear Test of Soils Under Consolidated Drained Conditions.

Client	Cardno Construction Sciences Pty Ltd	**Report No.**	16100157-DS

Failure Criteria **Peak**

Peak - Normal Stress vs Shear Stress



		Stage	Displacement at Peak Stress	Normal Stress	Shear Stress
Shear Angle (°)	**19.1**		(mm)	(kPa)	(kPa)
Cohesion (kPa)	**99.9**	1	44.90	300.0	205.8
		2	43.96	600.0	303.8
R^2	**1.000**	3	44.84	1000.0	447.4

Machine Description: Constant Normal Stress Direct Shear

Notes/Remarks:

Graph not to scale

Sample/s supplied by the client

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DIRECT SHEAR TEST REPORT

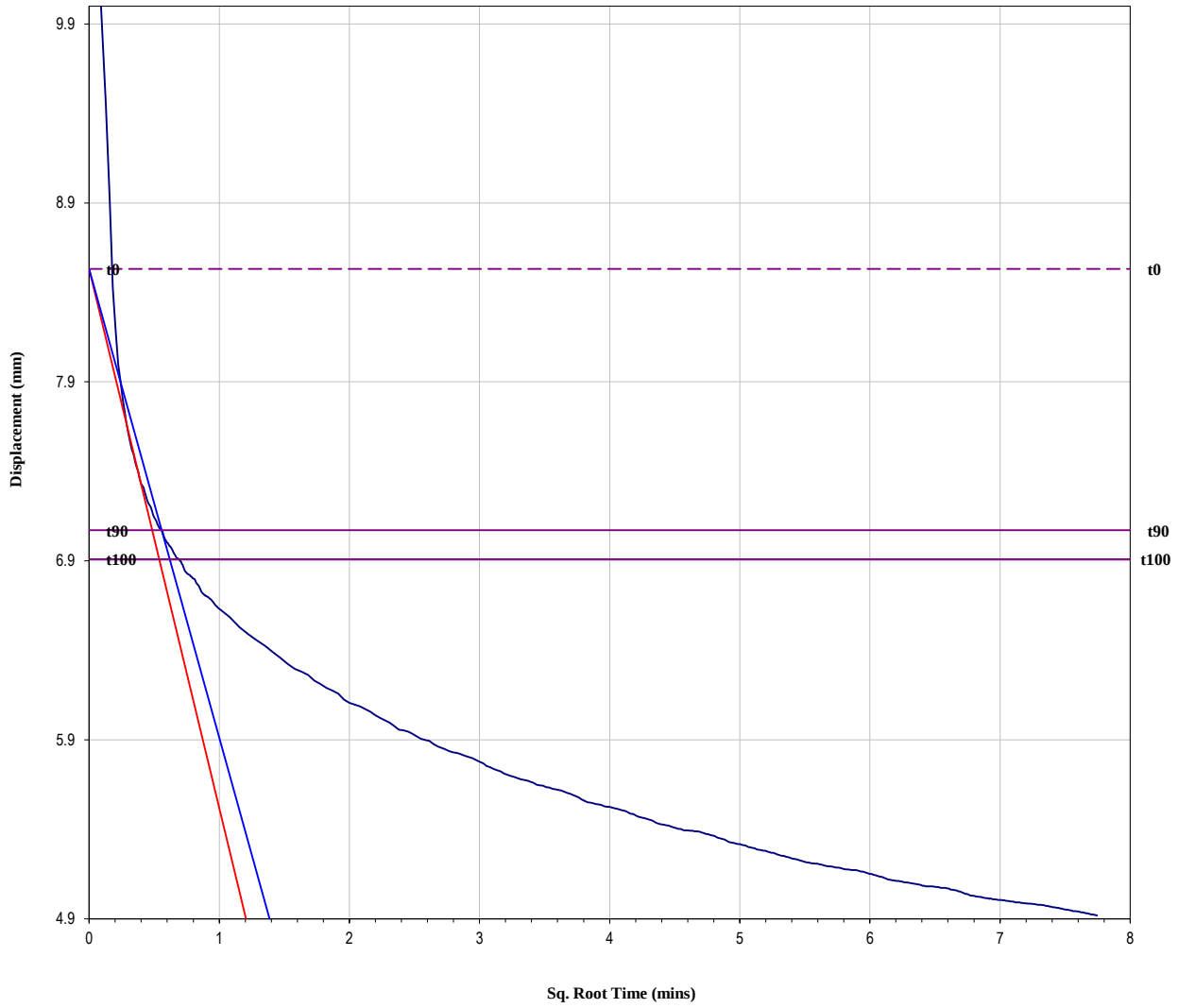
Test Method: ASTM D3080

Direct Shear Test of Soils Under Consolidated Drained Conditions.

Client	Cardno Construction Sciences Pty Ltd	**Report No.**	16100157-DS

Stage 1 Consolidation

Displacement v's Time (Sq. Root Scale)



t_{90}	0.31	**mins**
Time to Failure =	3.60	**mins**
Estimated Displacement to Failure =	5	**mm**
Displacement Rate =	1.38717	**mm/min**

Notes/Remarks:

Graph not to scale

Sample/s supplied by the client

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DIRECT SHEAR TEST REPORT

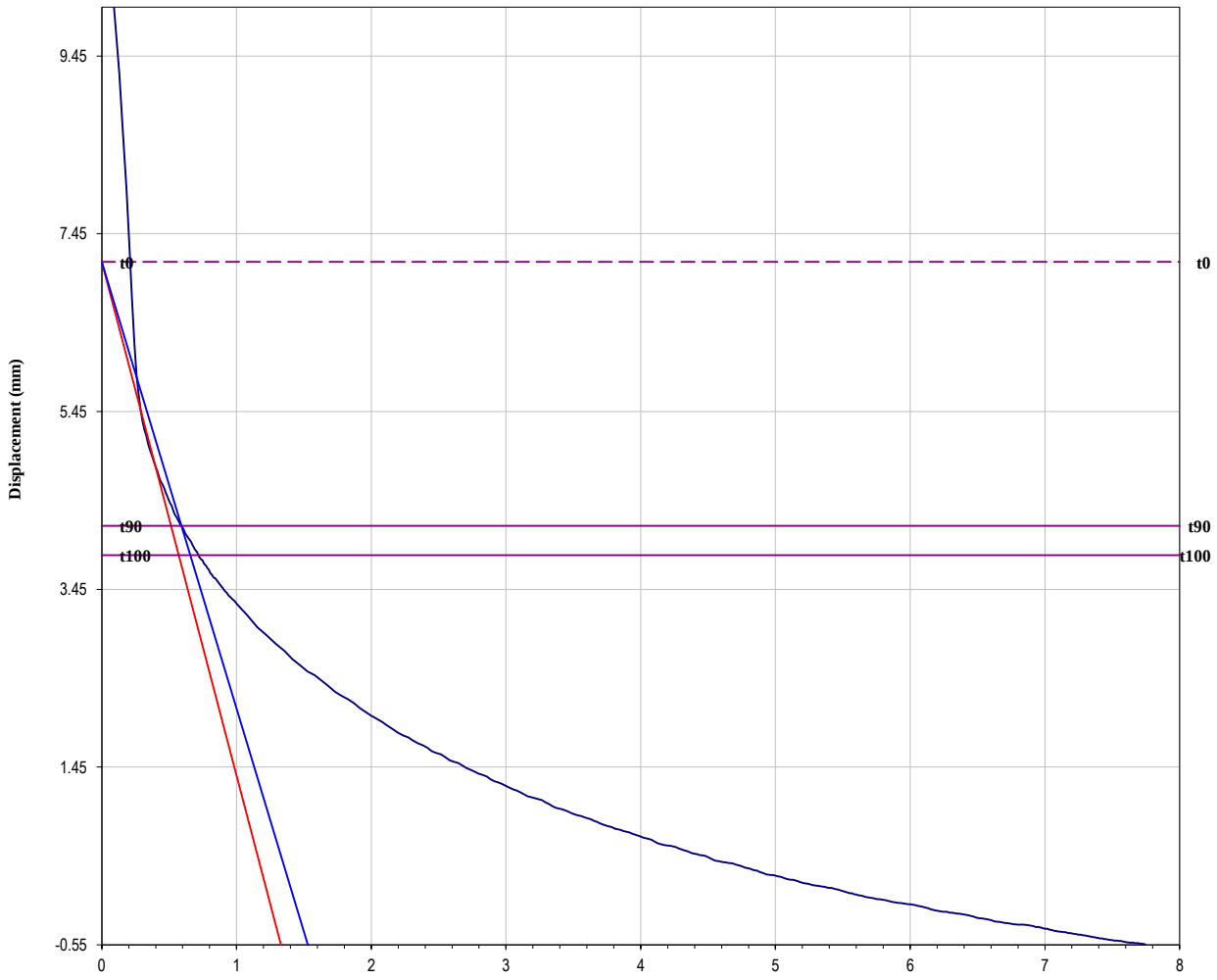
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Direct Shear Test of Soils Under Consolidated Drained Conditions.

Client	Cardno Construction Sciences Pty Ltd	**Report No.**	16100157-DS

Stage 2 Consolidation

Displacement v's Time (Sq. Root Scale)



t_{90}	0.35	**mins**
Time to Failure =	4.05	**mins**
Estimated Displacement to Failure =	5	**mm**
Displacement Rate =	1.23332	**mm/min**

Notes/Remarks:

Graph not to scale

Sample/s supplied by the client

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C. Purvis

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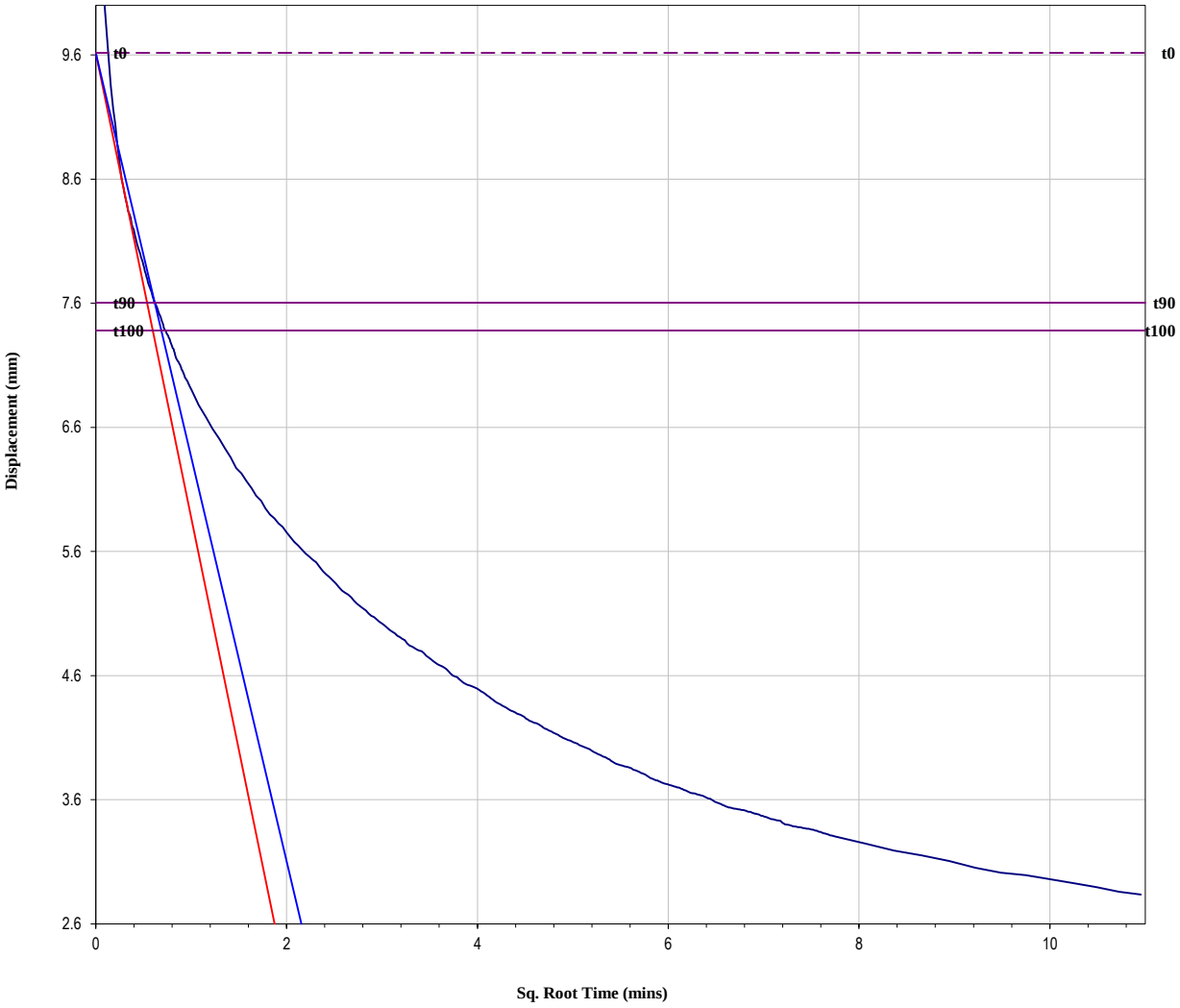
Test Method: ASTM D3080

Direct Shear Test of Soils Under Consolidated Drained Conditions.

Client	Cardno Construction Sciences Pty Ltd	**Report No.**	16100157-DS

Stage 3 Consolidation

Displacement v's Time (Sq. Root Scale)



t_{90}	0.38	mins
Time to Failure =	4.44	mins
Estimated Displacement to Failure =	5	mm
Displacement Rate =	1.12728	mm/min

Notes/Remarks:

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DIRECT SHEAR TEST REPORT

Test Method: ASTM D3080

Direct Shear Test of Soils Under Consolidated Drained Conditions.

Client	Cardno Construction Sciences Pty Ltd	**Report No.**	16100159-DS
Address	13 Glasson St, Emerald QLD 4720	**Test Date**	20/10/2016
		Report Date	21/10/2016
Project	1692/P/271 - Pit B Tailings Dam Embankment Samples		
Client ID	1692/S/18637 - CPP#1 CPP#2 Coarse Rejects	**Depth (m)**	Not Supplied
Description	Tailings		
Sample Type	Three individual soil specimens - Remoulded.		

SAMPLE DETAILS

	Stage 1	Stage 2	Stage 3	Stage 4
Maximum Dry Density (t/m^3)	1.51	1.51	1.51	-
Optimum Moisture Content (%)	12.0	12.0	12.0	-
Density Ratio Required (%)	95	95	95	-
Specimen Condition	Saturated	Saturated	Saturated	-
Specimen Dimensions (mm)	305 x 305	305 x 305	305 x 305	-
Initial Sample Height (mm)	172.3	172.3	172.3	-
Rate of Strain (mm/min)	1.00	1.00	1.00	-
Initial Moisture Content (%)	12.1	12.0	11.8	-
Initial Wet Density (t/m^3)	1.61	1.61	1.61	-
Final Moisture Content (%)	19.0	17.0	18.9	-

Notes/Remarks:

Graph not to scale

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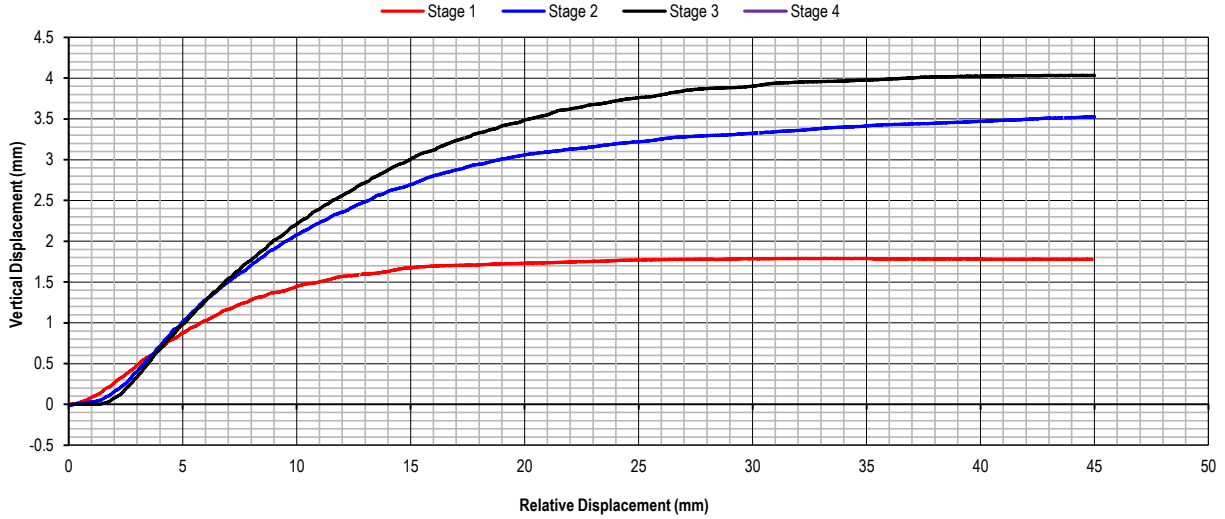
DIRECT SHEAR TEST REPORT

Test Method: ASTM D3080

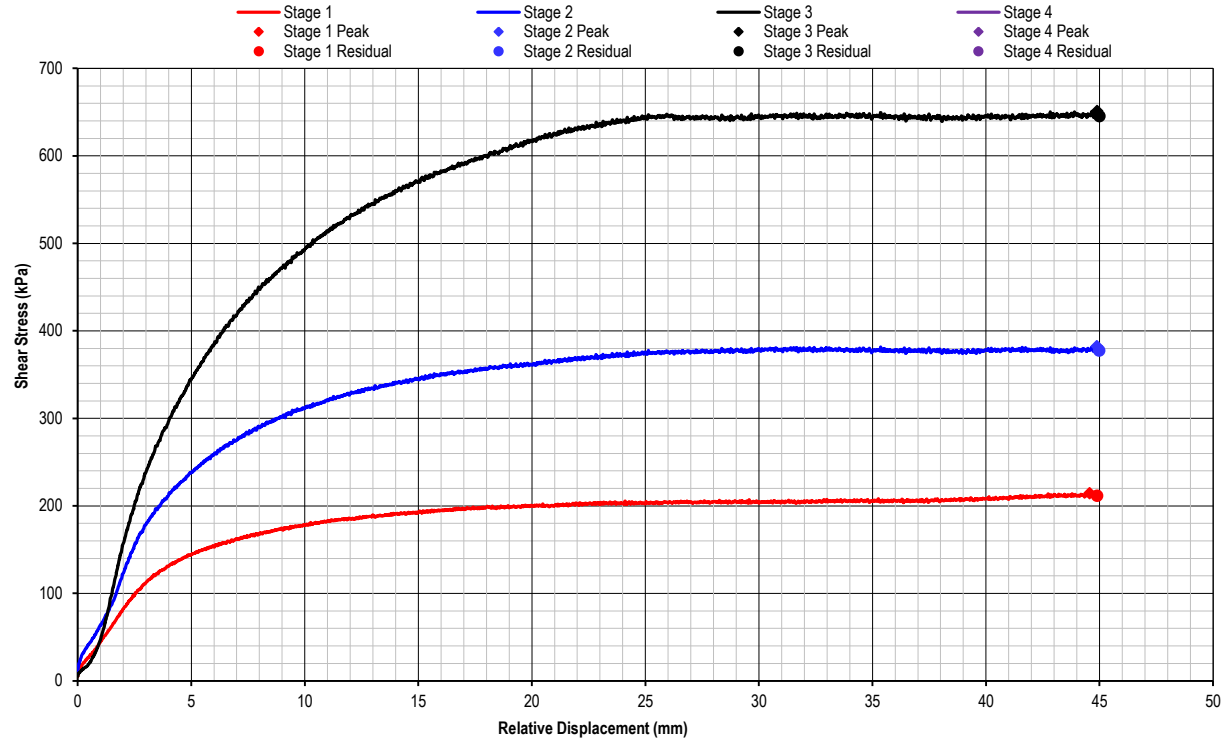
Direct Shear Test of Soils Under Consolidated Drained Conditions.

Client	Cardno Construction Sciences Pty Ltd	**Report No.**	16100159-DS

Vertical Displacement/Relative Displacement Plot



Shear Stress/Displacement Plot



Notes/Remarks:

Graph not to scale

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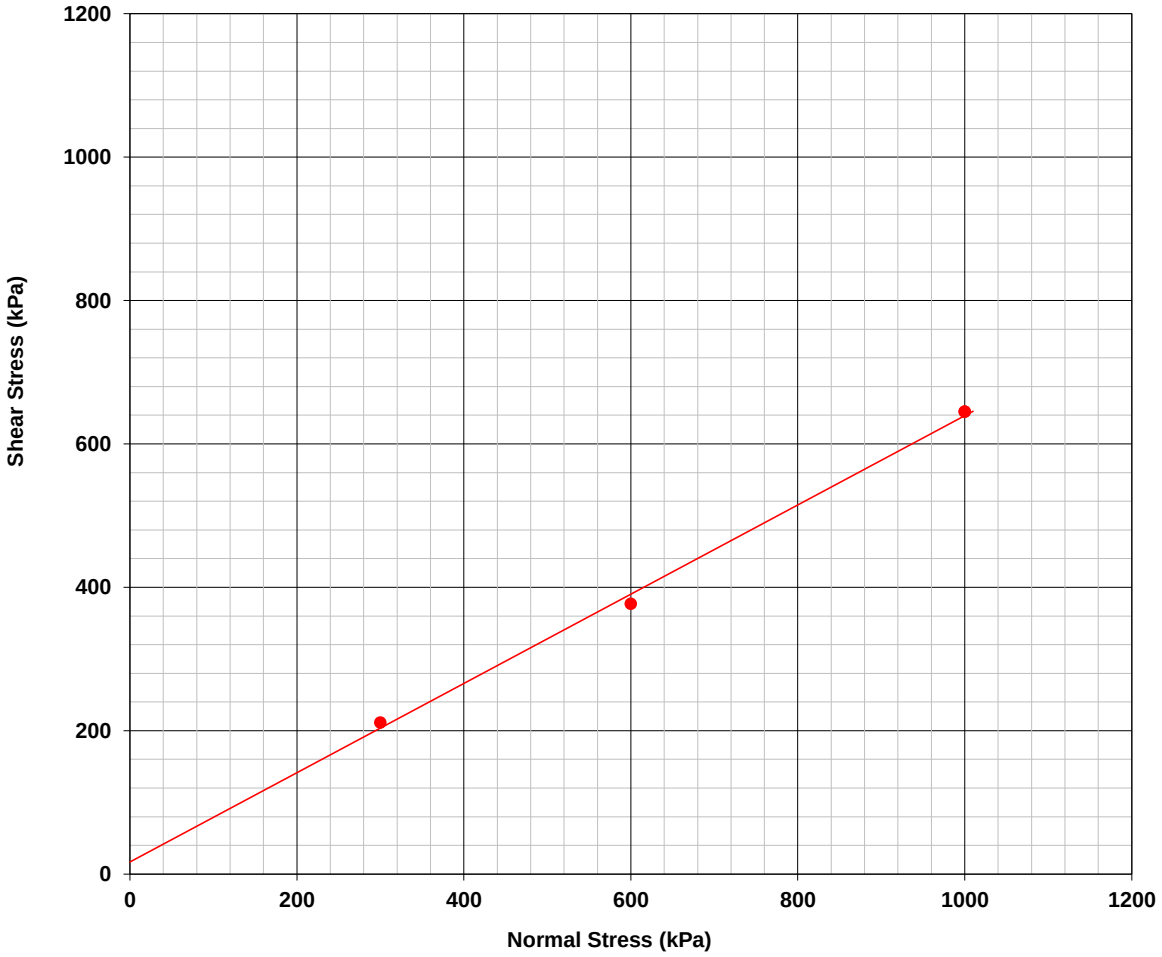
Test Method: ASTM D3080

Direct Shear Test of Soils Under Consolidated Drained Conditions.

Client	Cardno Construction Sciences Pty Ltd	**Report No.**	16100159-DS

Failure Criteria **Residual**

Residual - Normal Stress vs Shear Stress



		Stage	Residual Displacement	Normal Stress	Shear Stress
Shear Angle (°)	**31.9**		(mm)	(kPa)	(kPa)
Cohesion (kPa)	**17.0**	1	44.90	300.0	211.3
		2	44.99	600.0	377.1
R^2	**0.999**	3	45.00	1000.0	645.1

Machine Description Constant Normal Stress Direct Shear

Notes/Remarks:

Graph not to scale Sample/s supplied by the client

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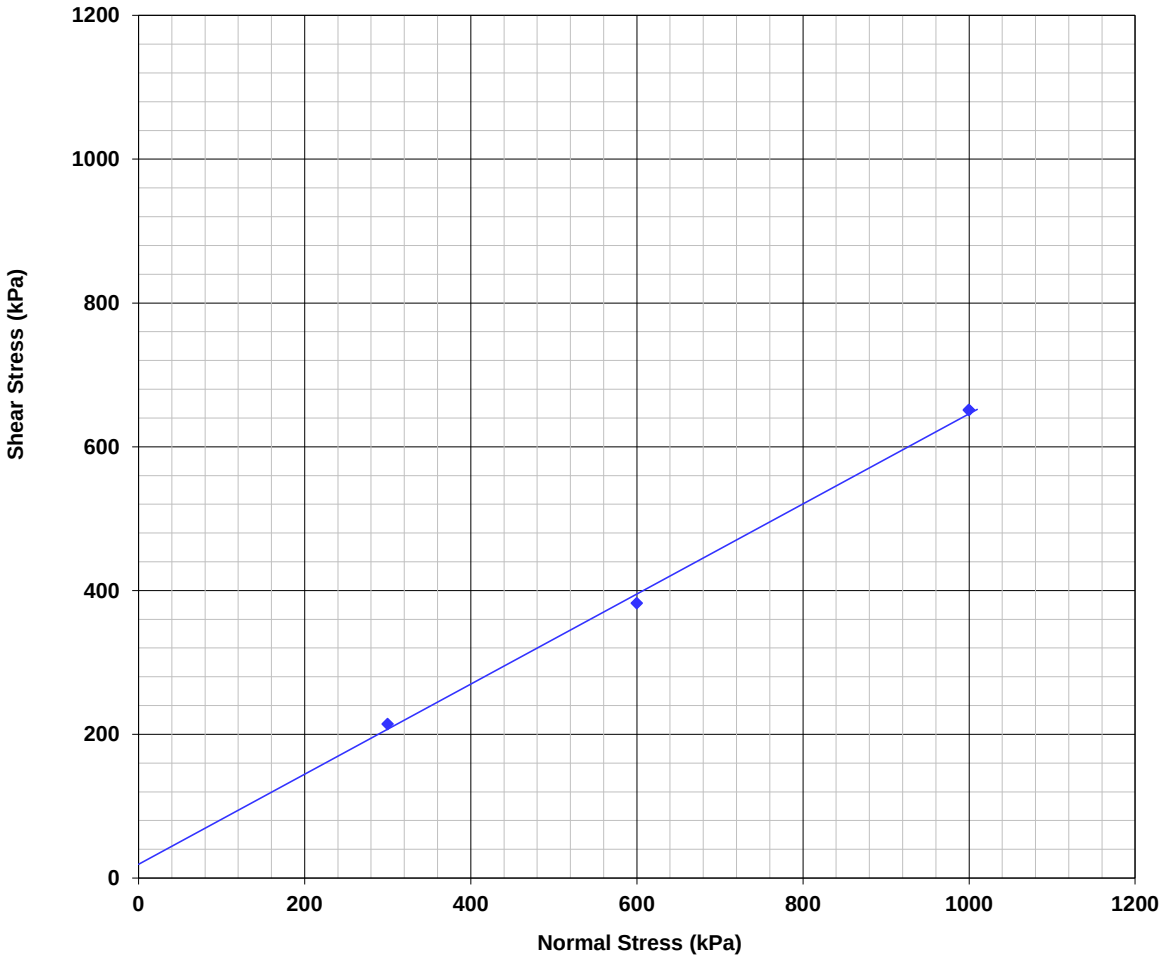
Test Method: ASTM D3080

Direct Shear Test of Soils Under Consolidated Drained Conditions.

Client	Cardno Construction Sciences Pty Ltd	**Report No.**	16100159-DS

Failure Criteria **Peak**

Peak - Normal Stress vs Shear Stress



		Stage	Displacement at Peak Stress	Normal Stress	Shear Stress
Shear Angle (°)	**32.1**		(mm)	(kPa)	(kPa)
Cohesion (kPa)	**19.0**	1	44.56	300.0	214.2
R^2	**0.999**	2	44.89	600.0	382.3
		3	44.90	1000.0	651.0

Machine Description Constant Normal Stress Direct Shear

Notes/Remarks:

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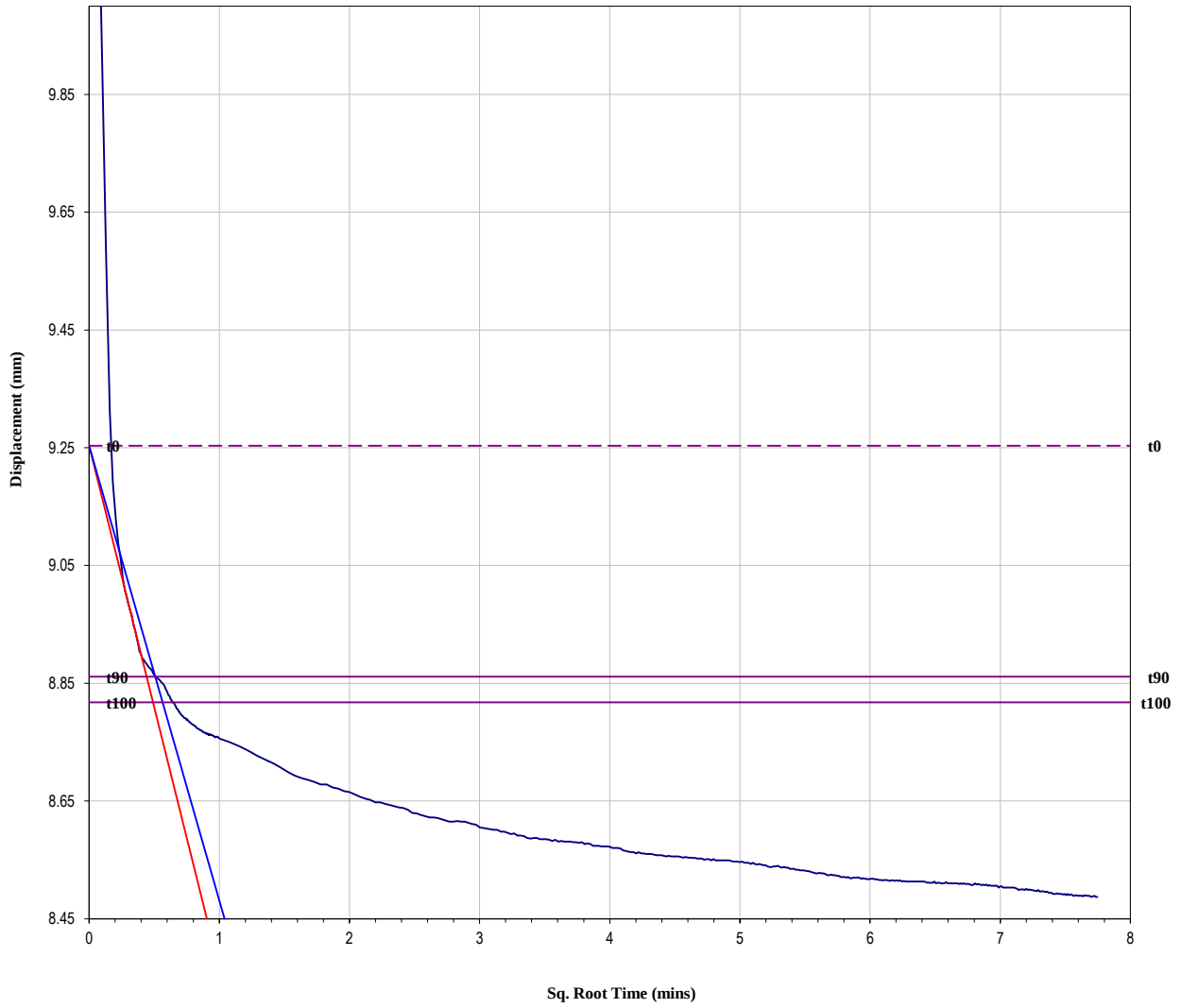
Test Method: ASTM D3080

Direct Shear Test of Soils Under Consolidated Drained Conditions.

Client	Cardno Construction Sciences Pty Ltd	**Report No.**	16100159-DS

Stage 1 Consolidation

Displacement v's Time (Sq. Root Scale)



t_{90}	0.26	**mins**
Time to Failure =	2.99	**mins**
Estimated Displacement to Failure =	5	**mm**
Displacement Rate =	1.67111	**mm/min**

Notes/Remarks:

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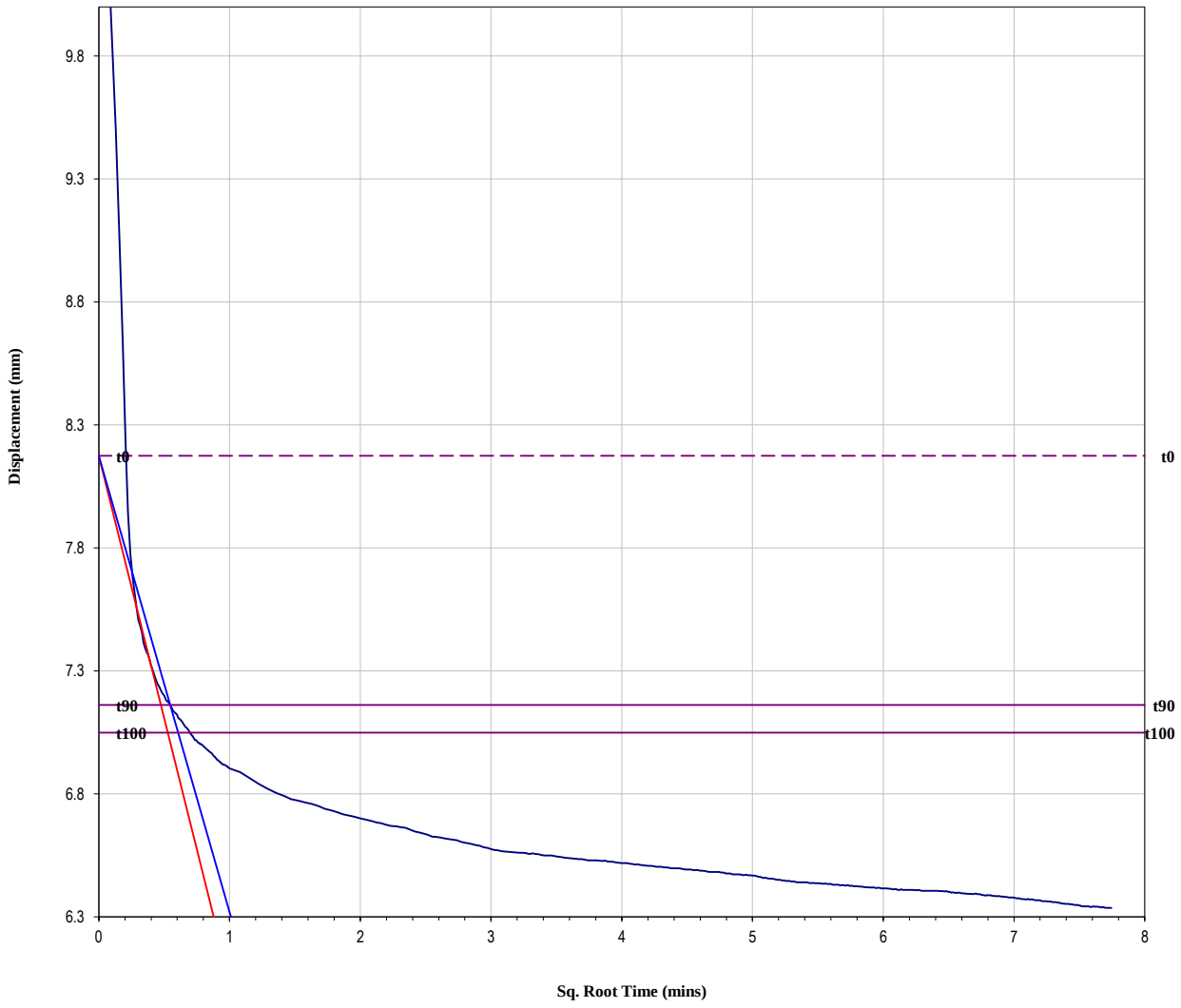
Test Method: ASTM D3080

Direct Shear Test of Soils Under Consolidated Drained Conditions.

Client	Cardno Construction Sciences Pty Ltd	**Report No.**	16100159-DS

Stage 2 Consolidation

Displacement v's Time (Sq. Root Scale)



t_{90}	0.30	**mins**
Time to Failure =	3.46	**mins**
Estimated Displacement to Failure =	5	**mm**
Displacement Rate =	1.44484	**mm/min**

Notes/Remarks:

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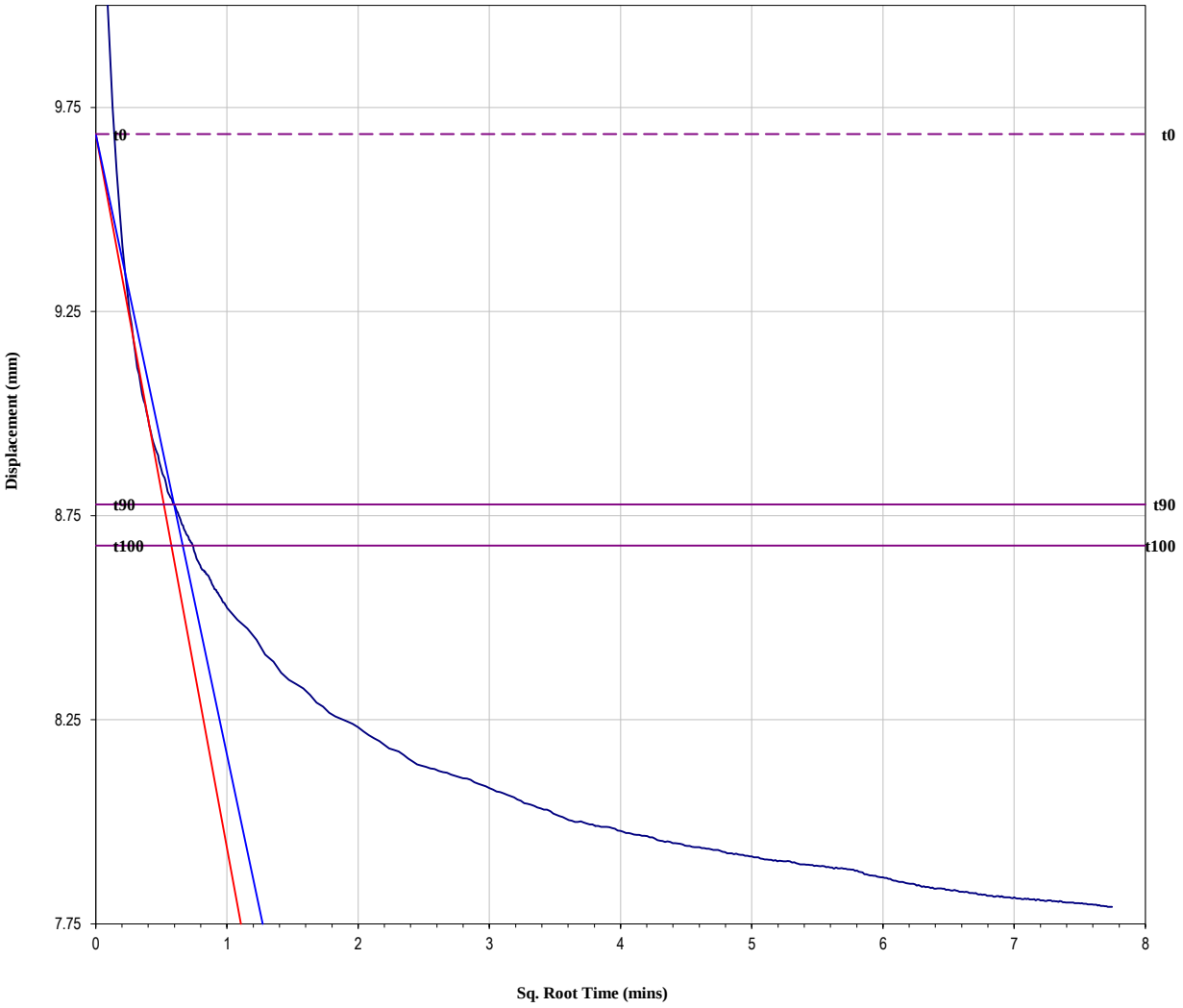
Test Method: ASTM D3080

Direct Shear Test of Soils Under Consolidated Drained Conditions.

Client	Cardno Construction Sciences Pty Ltd	**Report No.**	16100159-DS

Stage 3 Consolidation

Displacement v's Time (Sq. Root Scale)



t_{90}	0.36	**mins**
Time to Failure =	4.13	**mins**
Estimated Displacement to Failure =	5	**mm**
Displacement Rate =	1.21115	**mm/min**

Notes/Remarks:

Graph not to scale

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APPENDIX D

Published documentation - mine waste geotechnical parameters

Proc. Advances in Geotechnical Engineering: The Skempton Conference, R.J. Jardine, D.M. Potts and K.G. Higgins (eds). Vol 2, 981-991, Thomas Telford, 2004.

Shear Strength Framework for Design of Dumped Spoil Slopes for Open Pit Coal Mines

John V Simmons Principal, Sherwood Geotechniques, Brisbane, Australia
Dennis A McManus Principal Engineering Geologist, BMA Coal, Moranbah, Australia

Abstract

Modern open pit coal mining results in dumped spoil slopes typically between 80m and 250m high. Stability can be compromised by weak geological conditions, seepage, slaking of clayey spoil materials, and dumping processes. The consequences of failure are expensive and may be catastrophic. Dump design is challenging because there is usually no opportunity for site-specific investigations and testing. A shear strength framework for open pit coal spoil dump materials has been developed for reliable assessment of shear strength parameters from visual-tactile observations. Although originally developed for the Permian Bowen Basin of eastern Australia, it is argued that the framework is applicable for coal measures materials generally. Vital to the framework are an understanding of geological conditions and a robust process for assessing relevant attributes of dumped material. The factors that must be taken into account for dump stability assessment are described. Verification of the strength parameters involved rigorous backanalysis, requiring the Sarma method for non-vertical slices in order to replicate observed characteristics of dump slope failures. The framework has limitations, and the most significant of these are discussed. Non-routine problems still require sound application of engineering judgement and risk management principles.

Introduction

The Bowen Basin coking and thermal coal resource of central Queensland, Australia (Figure 1), has been the locus of large-scale open pit and underground mining since the mid-1970's. Relatively flat seam dips have resulted in open pit mining based on long strips with overburden removal using walking draglines and shovel/truck methods. Cast blasting and dozer-assistance have been widely adopted to improve cost efficiencies.

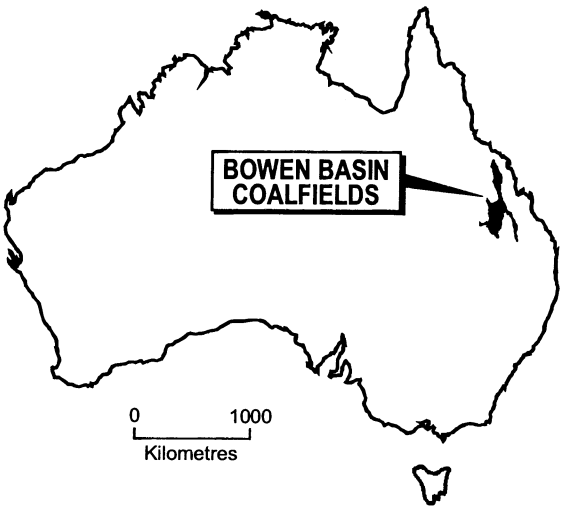


Figure 1 Location of Bowen Basin coalfields

Very large volumes of dumped spoil material are generated by strip mining. Dump slopes must be as

steep as possible while maintaining acceptable stability. Spoil material typically consists of boulders, cobbles, gravels, and fines. Particle size distribution is a function of initial lithology, blast fragmentation, comminution during handling, and post-depositional breakdown. Spoil material from near-surface is typically weathered and more fine-grained than spoil from deeper horizons. Differences between dragline and shovel/truck spoil materials are minor, and due only to the method of placement and to depositional fabric.

Spoil dump stability is controlled by shear strength, inclination and strength of the dump foundation, and influences of water. In most cases the foundation is the mined-out floor of the previous pit. Sub-floor strength is generally adequate, except where geological conditions include either weak clay seams or sheared surfaces of tectonic origin. While it is often simplest to dump the uppermost overburden onto the previous pit floor, this places the weakest material in the most highly stressed zone of the dump and is avoided where possible.

Geotechnical evaluation of Bowen Basin spoil materials commenced in the mid-1970's (Mallett et al, 1983), but was generally limited to characterisation as an extension of geological investigations. Because of the practical difficulty of sampling and testing spoil materials, emphasis was placed on observing and interpreting mechanisms of spoil dump failure, and on backanalysis to determine operational shear strength parameters.

BMA Coal operates a number of Bowen Basin mines spread over a distance of about 200km, in a variety of Permian coal measures lithologies, and with varying cover of Tertiary and Quaternary age. In-house geotechnical information, including laboratory tests and backanalysis results, indicated that certain geological conditions produced spoils of similar geotechnical properties irrespective of location. Routine slope design charts were developed (BHP Engineering, 1991), with spoil assigned to one of four categories based on the simplest possible geological descriptions. For each spoil category, design strength parameters were based on in-house information. This framework for categorising spoil was widely adopted within BMA Coal, and its use was extended generally to open pit mines in the Bowen Basin (Simmons and McManus, 1995).

Generalisation of Framework

Coal measures rocks are sedimentary sequences formed within alluvial or estuarine depositional systems where peat mires developed and were buried. Sediments range from stream channel conglomerates and sandstones to alluvial floodplain sandstone-siltstone interbeds, siltstones, and claystones, and sometimes to shallow marine units. Products of volcanic ash falls or flows, or igneous intrusions, may also be present. Effects of burial, uplift, and tectonism are limited to certain ranges of pressure and temperature conditions coincident with the structures and ranks of commercially significant coals. Given the limited ranges of mineralogy, lithification, and structure of coal measures rocks, it is reasonable that spoil materials should have properties related more to geological attributes than to location.

Use of the BMA Coal spoil shear strength framework has been extended to the Permian, Triassic, and Jurassic coal basins of eastern Australia. This has involved confirmation through backanalysis of many spoil slope failures, as well as routine design of stable slopes where validity of strength is necessarily less precise. Confidence in the framework has now been established over a period of more than a decade and at more than 20 mine sites. Based on limited comparisons of unpublished data, the BMA Coal strength parameters appear to be applicable to the Cretaceous coal basins of western Canada. Within Miocene coal measures in Kalimantan, Indonesia, the BMA Coal strength parameters have been successfully used to

post-predict dump failures, and are very similar to results of subsequent site-specific field and laboratory testing (Simmons, 2003). Based on this experience, and considering the applicable range of geological conditions, the framework is believed to be applicable to spoil material from coal measures and geologically similar rocks generally.

Open pit coal spoil dump design is often carried out without formal checks of geotechnical stability, and with profile design based on mine planning considerations or on precedence. Site-specific investigation and strength testing is typically regarded as too difficult and costly, so shear strength parameters are assumed when stability analyses are undertaken. A reliable framework for estimating shear strength of dump materials is therefore critically important.

This paper describes factors to be considered in geotechnical design of dumped spoil slopes. Development of the BMA Coal strength framework, which involved observations, testing, and inferences about material behaviour based on backanalysis, is also described.

Geotechnical Stability Design

Geometric Constraints

Draglines work from operating benches at heights of 40m to 60m, limited by seam floor dips and the reaches and dig depths of the machines. Spoil is dumped at a typical rill angle of 37° to heights of 45m to 65m above operating bench level, by sequentially digging away below the bench to form an 'undercut' batter in the range of 37° to 45°. Greatest efficiency requires the dragline spoil dump profile to be as steep as possible, but overall stability may be improved by leaving a remnant bench that in practice must be 25m or less in width.

Trucked spoil dumps are more geometrically flexible than dragline dumps. In principle, truck dump slopes may be built to unlimited heights at the typical rill angle of 37°, but in practice dump face heights are limited to between 5m and 30m by dump-point stability and safety considerations. Where appropriate, the overall dump slope is terraced to achieve the desired slope for the rehabilitated landform.

Dragline spoil profiles are limited to between 80m and 120m total thickness, depending on machine specifications. As strips progress deeper, the dragline spoil has to be surcharged by prestrip spoil dumping using trucks or spreader systems. Surcharged dragline spoil profiles currently approach 200m in height, with final planned heights of 250m or greater. Overall truck dump heights up to 400m exist or are planned.

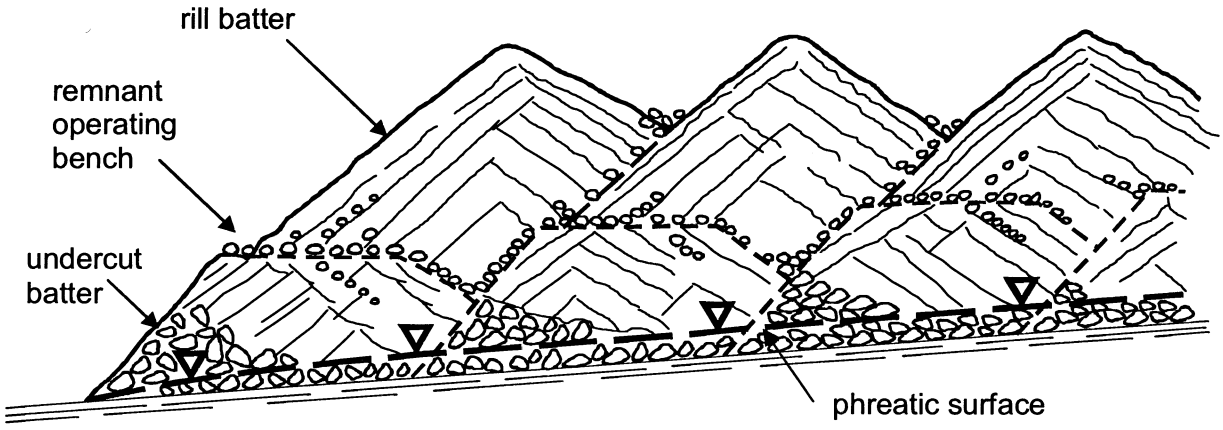


Figure 2 Schematic section of dragline spoil dump fabric and phreatic surface

Depositional Fabric

The internal stratigraphy and depositional sequence of spoil dumps is complex. Spoil profiles are generally built by rilling, but may include a component of cast-blasted overburden. Rilling of both dragline and truck dumped spoil causes larger particles to roll preferentially towards the base of the rill profile but otherwise leaves a fabric of preferentially-aligned particles at the rill angle. Base and operating bench levels of dragline dumps become repositories for segregated coarse spoil that may be overlain by loose zones of relatively high permeability. Figure 2 is a schematic view of the fabric of a dragline dump profile.

The fabric of truck dumps varies depending on the adopted face heights, advancement procedures, and variability of materials. Dump running surfaces form compacted and sealed subhorizontal surfaces which are repositories for segregated coarse spoil and which become overlain by loose zones of relatively highly permeability. Figure 3 is a schematic view of the fabric of a truck dump profile.

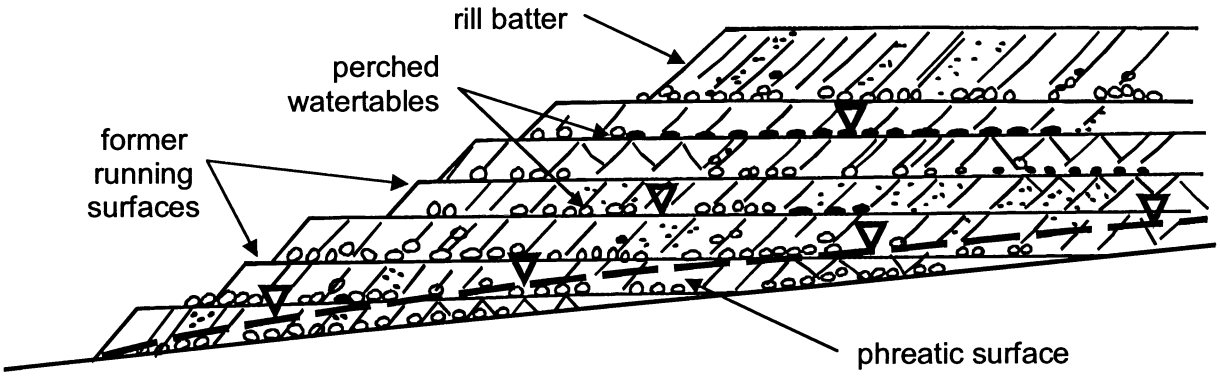


Figure 3 Schematic section of truck spoil dump fabric and phreatic surface

In surcharged dragline dumps, the lower part of the profile is typically formed in more blocky fresh rock spoil, while the upper part may be formed either wholly or partly of weaker and less permeable finer-grained material. This distribution of permeability strongly affects water infiltration and transmission.

Dump Foundation Preparation

Foundation preparation is limited by economic factors, and inadequate preparation is the primary cause of dump failures. If weak floor conditions are known or suspected, floor disruption by blasting, formation of spoil-backfilled keys, cross-ripping, or terracing may be required to achieve stability. Even when floor strength is adequate, remnant pit water or mud must be removed, at least to designed limits. Instability usually results when spoil is dumped in an uncontrolled manner into pit water or mud.

Seepage and Groundwater

Groundwater inflows may occur from the pit floor, pit walls, and older dump areas. The pit floor is usually an interface between relatively low permeability natural rock and relatively high permeability spoil. Because of complex internal dump stratigraphy, infiltrating water follows irregular flowpaths through zones of coarser spoil material. Internal flows percolate downwards towards the dump floor and then laterally in a generally downdip manner.

Measurement of groundwater conditions within dumps is rare, but direct observations from some BMA Coal Bowen Basin mines and from a mine in Indonesia show that a zone of saturated spoil builds up to form a phreatic surface to a thickness not exceeding 5m above the dump floor and tapering to the downslope toe. Local seepages suggest that groundwater

within truck dumps may also form thin and locally perched water tables developed on internal former running surfaces. Figures 2 and 3 also show typical dump phreatic surfaces.

BMA Coal data show that the internal phreatic surface adapts to the elevation of an externally ponded water surface. When an external pond is drawn down, the zone of effectively saturated spoil material zone remains but the phreatic surface is drawn down to the external control. As with any embankment, rapid drawdown may trigger instability.

Where dumps are built over initially horizontal surfaces, the compression of the foundation may induce ponding of external runoff water in the lowered ground surface against the dump toe. This situation has been observed to result in face instability caused by slaking and strength reduction at the base of the dump.

Spoil Shear Strength Framework

Guiding Principles

The framework is based upon assigning any given spoil material to one of four possible categories, each defined by attributes that are identifiable through field observation. For each category, laboratory triaxial and direct shear test results have been grouped in terms of three modes of strength mobilisation, as described below. Linear Mohr-Coulomb shear strength parameters for each mode and category were then determined for the effective normal stress range equivalent to a maximum dump height of about 90m. Prior to adoption, the strength parameters were verified by backanalysis using observed mechanisms of failure and the Sarma method as implemented in the computer code that is now called GALENA (Clover Technology, 1999). A field-based worksheet assists the identification of spoil categories. The framework is subject to review and development as new information becomes available and design demands change. Each of these aspects is discussed below.

Strength Mobilisation Modes

Insitu coal measures rocks may be either saturated or unsaturated prior to excavation, but the resulting spoil masses normally have no free water in the void spaces between particles. Dumped material may compress to a limited extent degree due to particle crushing and rearrangement under the action of additional load. This is the normal "unsaturated" spoil condition, and corresponds to the strongest state that can be mobilised in the spoil mass. Due to the preferred orientations of particles and contacts, the unsaturated strength mode is believed to be anisotropic in character.

When significant quantities of water enter the void spaces within the spoil mass, the interparticle contacts and even the particles themselves are likely to slake, soften, and weaken. Test results show an accompanying significant reduction in mobilised shear strength, to what is termed the "saturated" strength mode, regardless of whether true saturation is achieved. Because there is still some preferred orientation of particles and contacts, the saturated strength is also anisotropic in character. Backanalyses have shown that the saturated strength mode is not reversible, even after free water is drained from the void space.

Saturation of a spoil mass with susceptible mineralogies can result in a third mode of strength development when sufficient shear distortion of the mass occurs by large deformation between softened particles. Backanalyses have shown this state to have, in practical terms, mobilised strength equivalent to the residual shear strength determined by direct shear tests on spoil fines. In the terminology of the framework, this is the "remoulded" mode. This mode has been recognised in relatively thin zones when spoil is dumped into water or wet mud,

when very loose and strongly slaking spoil is saturated, or as a consequence of shearing due to slope instability. Once developed, the remoulded strength mode is not reversible.

Relationships among the three strength mobilisation modes for spoil material are shown in conceptual form in Figure 4. Results from triaxial tests support the forms of the unsaturated and saturated modes, while results from direct shear tests support the form of the remoulded mode. Based on the authors' observations and understanding of the mobilisation characteristics, the saturated and remoulded modes may be considered as equivalent to the "fully softened" and "residual" strength states as understood in classical soil mechanics.

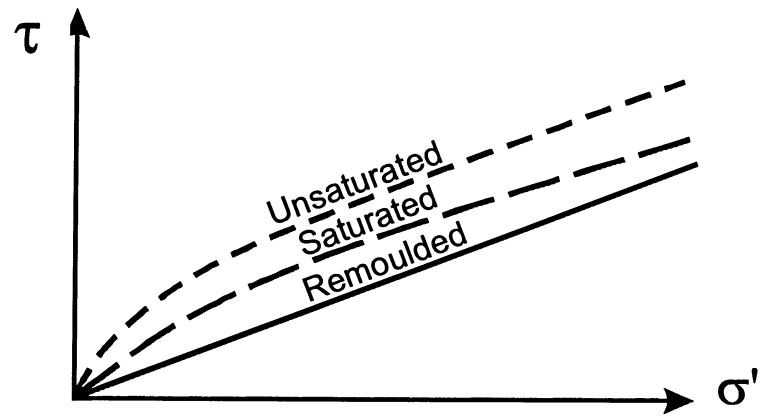


Figure 4 Three conceptual strength modes for spoil

Table 1 shows the Mohr-Coulomb shear strength parameters associated with the three strength mobilisation modes for each of the four spoil categories. These are the means and standard deviations from linear fits to more than 150 tests, assuming that c' and ϕ' are independent variables. The tabulated unit weights were checked using both mass and volume reconciliation and by geophysical drillhole logging.

Table 1
Shear Strength Parameters for Categories and Mobilisation Modes
(Parameter standard deviations in italicised parentheses)

Category	Unsaturated			Saturated			Remoulded
	γ (kN/m^3)	c' (kPa)	ϕ' (deg)	γ (kN/m^3)	c' (kPa)	ϕ' (deg)	c'=0 kPa, ϕ' (deg)
1	18 *(1)*	20 *(10)*	25 *(2.5)*	20 *(1)*	0 *(0)*	18 *(3)*	18 *(1.5)*
2	18 *(1)*	30 *(15)*	28 *(3)*	20 *(1)*	15 *(7.5)*	23 *(2.5)*	18 *(1.5)*
3	18 *(1)*	50 *(15)*	30 *(2)*	20 *(1)*	20 *(10)*	25 *(2.5)*	18 *(1.5)*
4	18 *(1)*	50 *(15)*	35 *(2.5)*	20 *(1)*	0 *(0)*	30 *(1.5)*	28 *(2)*

Linkages to Instability Mechanisms

The forms of instability observed in spoil dumps, are indicated in Figure 5. Superficial planar-surface or shallow-arc mechanisms result primarily from undercutting of batters at angles steeper than the rill angle. Larger-scale deep-seated failure modes are observed to develop as multi-wedges, with well-developed bulging or heave at the toe of the passive wedge, steep backscarps, and characteristic graben structures with reverse mid-scarps. Intermediate forms of multi-wedge mechanisms are observed in high rilled slopes, involving

toe bulging, mass sliding along a rill surface, and an upper steep sliding surface or vertical tension crack. Multi-wedge mechanisms are a consequence of lower strength at the base of the dump profile (saturated zone) or within the immediate pit floor (weak clay bands or bedding-parallel shears).

Backanalysis of large-scale failure mechanisms requires multi-wedge geometries and appropriate methods of calculation. The Sarma method was used for all backanalyses during the original verification of the strength framework, with non-vertical slice boundaries as observed in actual failures. Methods based on vertical slice boundaries often give different results. This is inferred to be because anisotropic strength states exist in spoil dumps due to the depositional fabric. For design purposes it is recommended that the nominated strength parameters be used together with the Sarma method based on observed slice geometries.

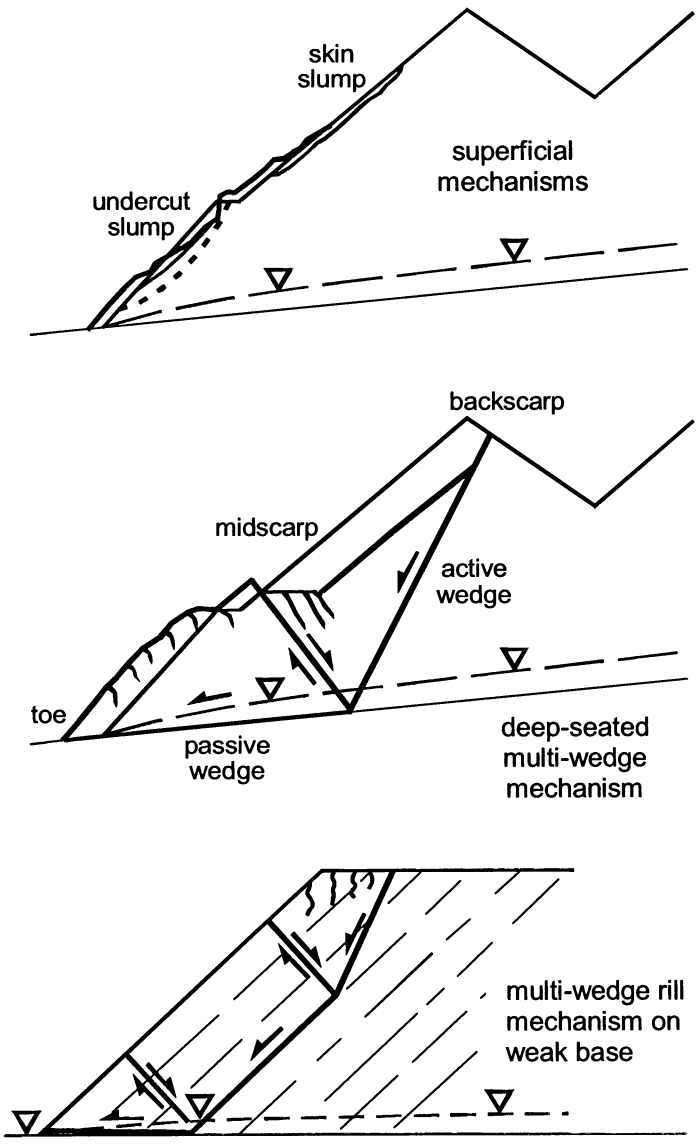


Figure 5 Failure mechanisms for spoil dumps

Identification of Spoil Categories

BMA Coal experience has been that for reliable and consistent category identification, five attributes should be assessed. Each attribute within each category has a characteristic description. Weightings have been assigned to each attribute based on experience and judgement. Using visual and tactile methods and a worksheet, the best category description for each attribute is selected. Addition of the weightings by selected category gives the overall likelihood of that material being assigned to each of the four categories.

The need for reliable procedures for categorising spoil arose during a project on long-term stability of dump slopes (Rust PPK, 1996). An initial visual classification of 105 spoil bulk samples resulted in 45 samples that were categorised differently by personnel with different training and experience. The worksheet approach was developed and blind-tested using 13 bulk samples that had previously proven difficult to categorise, and involved two personnel again with different levels of experience. Agreement on categorisation using the worksheet was 100%.

Table 2 shows the category and attribute descriptions and the relative weightings attached to each attribute. Users are trained to observe attributes consistently. Recognised geological techniques are used to visually identify "Predominant Particle Size". "Consistency" is based on the material in the moist condition, and either cohesive or cohesionless attributes are described using familiar tactile procedures. "Plasticity" is based either on the Liquid Limit test, or on visual-tactile assessment according to site investigation standards. "Age" refers to the observed effects of weathering whereby the strength of freshly dumped spoil decreases until it reaches the strength of "old" spoil of similar provenance. Recent and therefore less weathered spoil is ranked less favourably than old spoil. Table 2 also shows the weightings of the attributes for operational purposes, where long-term stability considerations are not significant and the age attribute is ignored.

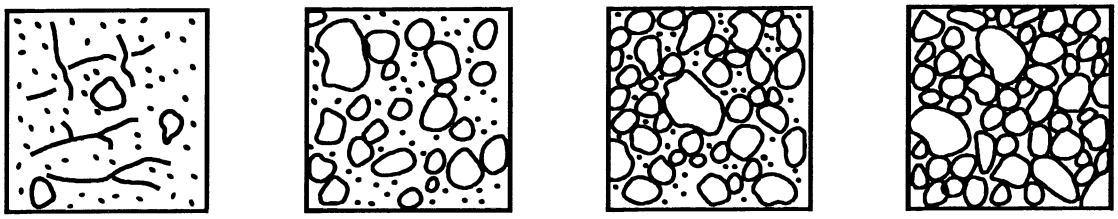
"Structural Control" is critical to interpreting spoil strength. This simplistic fabric-related parameter is illustrated in Figure 6. Spoil material is considered to consist of larger particles (the "framework") and finer particles (the "matrix"). The subdivision between framework and matrix depends on the overall particle size distribution. For training purposes, framework is described as the larger-sized fraction that, when in particle-to-particle contact, is relatively stiff and transmits most of the forces within the spoil mass. Correspondingly, matrix is described as the finer-sized component that fills the void spaces between framework particles. When there is a relative abundance of matrix, good framework particle contact cannot be mobilised and the spoil mass will be relatively more compressible and weaker.

Preferred particle orientation, as a result of fabric development by rilling and rolling, is not explicit in the categorisation process. However, strength anisotropy is believed to be implicit in the mechanisms and shear strengths verified by backanalysis, and this emphasises the requirement to use the Sarma method and appropriate mechanisms for design.

Table 2
Spoil Categories and Attributes

CATEGORY		1	2	3	4
Description Attributes	**Weighting** *(excl. Age)*	Fine-grained clay-rich high plasticity	Fine-grained low plasticity with larger clasts	Larger clasts with fine matrix, low plasticity	Large blocks, minor fines, minor slaking
Predominant Particle Size	3/31=**9.7%** *(11.6%)*	Clay	Sand	Gravel	Cobbles
Consistency: cohesive cohesionless	7/31=**22.6%** *(26.9%)*	Soft to Firm Loose	Stiff Med. Dense	Hard Dense	XLS+ rock Very Dense
Structure	7/31=**22.6%** *(26.9%)*	Matrix only	Matrix supported	Framework supported	Framework only
Liquid Limit	9/31=**29.0%** *(34.6%)*	High (>50)	Intermediate (35 – 50)	Low (20 – 35)	Not Plastic (<20)
Age	5/31=**16.1%**	0 - 2y	2 - 10y	10 - 30y	>30y

(Note: XLS+ rock refers to rock of extremely low strength, or higher)



Category 1 (matrix only) | Category 2 (matrix supported) | Category 3 (framework supported) | Category 4 (framework only)

Figure 6 Spoil structure control ranking (use with Table 2)

Framework Extensions and Limitations

Stress Ranges and Nonlinear Envelopes

Triaxial tests result in spoil shear strength envelopes that are distinctively nonlinear (Simmons, 2003). This is particularly so at lower effective normal stresses where contractant shear deformation is greatest. Such nonlinearity, as well as the effects of matrix suction in unsaturated material, helps explain why spoil slopes may be excavated to batters steeper than the angle of repose and why such batters are often stable only for limited timeframes.

The parameters in Table 1 were derived for typical dragline spoil dump heights of 60m to 90m. These parameters will significantly overestimate available shear strength for slopes less than 30m high, but underestimate the effective friction angle in the low stress range. The same parameters will also significantly overestimate available shear strength at the base of spoil slopes in excess of 130m high. In principle, nonlinear envelopes could be developed. The authors believe that there is merit to nonlinear envelopes, if determined thoughtfully.

Refinement of Parameter Choices

Categories 1 and 4 spoils are relatively rare in comparison with Categories 2 and 3 spoils. The selection of a design category has in many cases been complicated either by variability of the spoil material, or by very similar likelihoods for Categories 2 and 3 from the identification procedure. On occasion, particularly where supported by backanalysis, the authors have selected design parameters mid-way between category values. Such choices are a matter of judgement, but when applied consistently have produced reliable outcomes.

This possibility of increasing the number of categories was considered as part of the identification procedures. Review of the triaxial test data could not identify an alternative sorting that was considered more reliable. The authors view use of the framework as a suitable starting-point for design, with more "refined" assumptions used only where justified.

Verification by testing

In recent years the authors have encountered situations in weathered and/or clay-rich lithologies where additional strength testing was warranted. The resulting shear strength data were fitted with piecewise linear envelopes for design calculations. By comparison, use of the framework approach did not result in significant differences for slope designs. While reassuring in these cases, such outcomes should not be assumed generally. Testing of spoil

materials is neither simple not straightforward, but due consideration should be given to testing for clarification of matters considered important for reliability of design outcomes.

Probabilistic Slope Stability Assessment

Probabilistic stability assessment, usually takes the form of a computed distribution of Factors of Safety (FOS) based on statistical properties of strength parameters and other variables. Table 1 lists means and standard deviations for the category strength parameters treated as independent variables. The authors have computed approximate FOS distributions using the point estimate technique. Expression of stability in terms of failure probabilities is often preferred by mining engineers, but the validity of this process requires further consideration. The authors have found it to be most helpful in sensitivity studies of stabilisation treatments.

Possibly Inadequate Treatment of Strongly Slaking Spoil Materials

At Kaltim Prima Coal mine in Kalimantan, Indonesia, triaxial testing was carried out for Category 2 spoil derived from very low strength claystone or siltstone that showed strong slaking behaviour and dispersion (Simmons, 2003). From backanalysis, the spoil dumps were determined to develop only unsaturated or remoulded strength modes. Direct observations were limited, but it is believed that the strongly slaking spoil remained quite blocky when initially dumped. The dumps were characterised by corrected SPT blowcounts of close to zero in rilled material located within 1m above the pit floor and above former trafficked surfaces. The saturated basal zone of these dumps is believed to have become remoulded directly through the effects of slaking, dispersion, and interparticle void collapse.

There is no specific reference to slaking behaviour within the BMA Coal framework. Until such time as the framework can be justifiably extended to include slaking behaviour, it is recommended that tests be made of slaking behaviour. If judged to be necessary, design allowances may then be made for the likelihoods and consequences of basal remoulding.

Stability Assessment Example for Surcharged Spoil Profile

Figure 7 shows a dragline dump profile on a floor dip of 6° and with a shovel/truck surcharge of 25m. The dragline spoil material is BMA Category 2 and the profile consists of a 40m bench with a 40° undercut batter, no remnant bench width, and a 40m rill batter at 37°. All spoil is assigned to Category 2. Shown on the figure is the critical mechanism corresponding to a minimum computed FOS of 1.19 using the Sarma method and GALENA. When the toeline of the shovel/truck spoil is located no closer than the second dragline spoil peak, the critical stability condition involves the immediate dragline spoil profile only. The mechanism including the shovel/truck spoil loading has a minimum computed FOS of 1.68.

To further illustrate the importance of the effects of inferred strength anisotropy, analyses using circular arc mechanisms with the Spencer method and GALENA resulted in a minimum computed FOS of 1.06 for the dragline spoil and 1.34 including the shovel/truck spoil loading. Circular arc mechanisms of this form have not been observed in practice. The use of circular arc methods with vertical slices for design is not considered to be credible, despite the lower FOS values obtained.

Conclusions

The BMA Coal shear strength framework has been developed and applied over more than 12 years, to literally hundreds of design and backanalysis situations. It originated from confidential research and development activity, but spread widely with the training and movement of personnel between sites and between businesses. It is believed to be applicable

to open cut coal mine spoils generally, as a robust and reliable method for deriving strength parameters for routine applications. It also provides a rational basis for determining additional testing requirements for non-routine situations.

Acknowledgements

The authors acknowledge permission from BHPBilliton Mitsubishi Alliance Coal Pty Ltd for publication of details of the framework. BMA Coal has applied vision and resources to develop the framework over the past 25 years. Also acknowledged is the permission of PT Kaltim Prima Coal Indonesia to refer to outcomes of spoil shear strength investigations. Alan Davies and Michael Dunbavan are acknowledged for their vital roles in the development of the spoil strength framework, particularly with the original data grouping and parameter selections. The assistance of Ross Stephens with graphics, and the helpful comments and suggestions from an anonymous reviewer, are greatly appreciated.

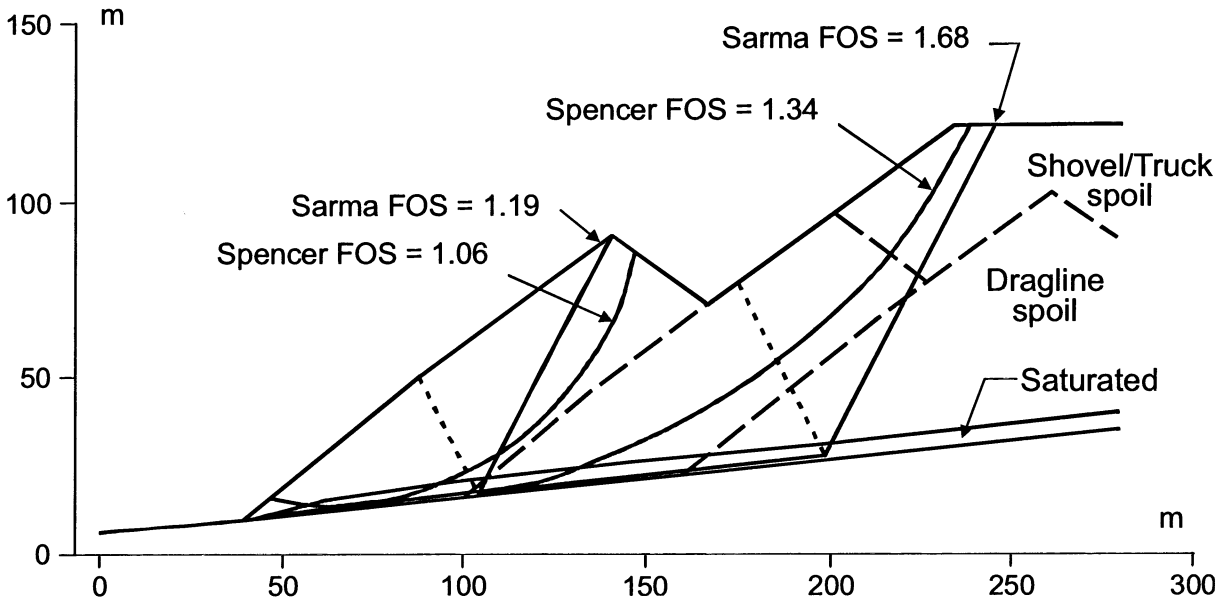


Figure 7 Example surcharged spoil profile stability analysis results

References

BHP Engineering Pty Ltd (1991). Pit Slope Manual Project Report. Report No. G91/4 to BHP-Utah Coal Technical Services.

Clover Technology (1999). GALENA Slope Stability Analysis System Code and Users' Manual. www.GalenaSoftware.com.

Mallett, CW et al (1983). Stability of Spoil Piles and Highwalls in Deep Surface Mines. End of Grant Report Number 150, National Energy Research Development and Demonstration Program, Australian Government, Canberra.

Rust PPK Pty Ltd (1996). An Improved Geotechnical Categorisation Method For Bowen Basin Spoil. Spoil Hydrology Project Report to BHP Australia Coal Pty Ltd, Ref. 84H125A-PR0024cd.

Simmons, J V and D McManus (1995). Categorisation of Bowen Basin spoil materials for open pit mining. Proceedings, Bowen Basin Symposium 1995, Geological Society of Australia Coal Geology Group and Bowen Basin Geologists Group, pp 137-145.

Simmons, J V (2003). Spoil Shear Strength Testing and Usage. Report 22003-3 to PT Kaltim Prima Coal, Sherwood Geotechnical and Research Services, 45p.

APPENDIX E

Seepage modelling results

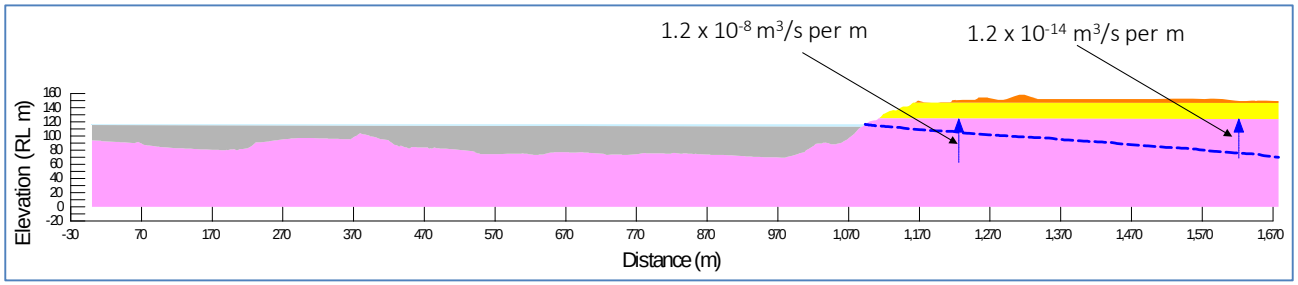


Figure E1 – Wetting front assessment under stage 1 operating decant level

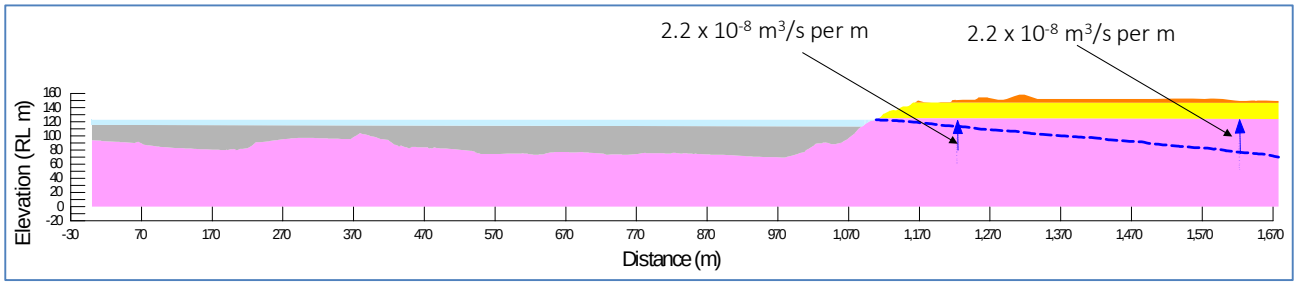


Figure E2 – Wetting front assessment under stage 1 DSA level

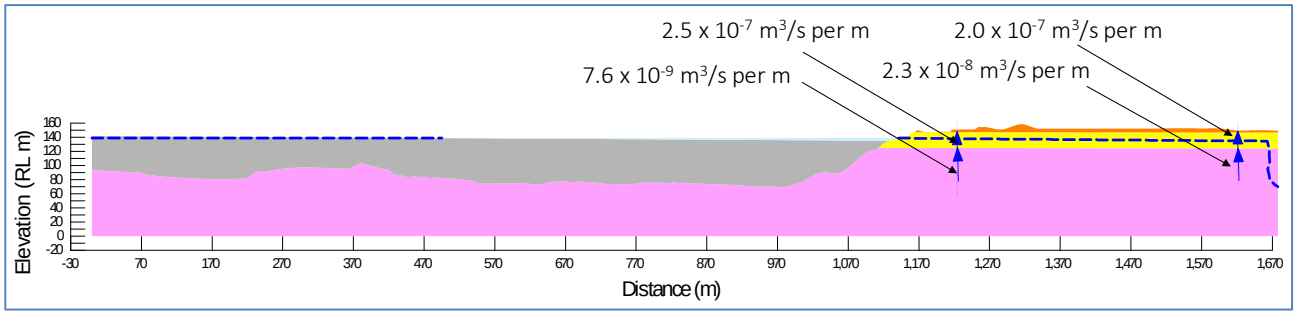


Figure E3 – Wetting front assessment under stage 2 operating decant level

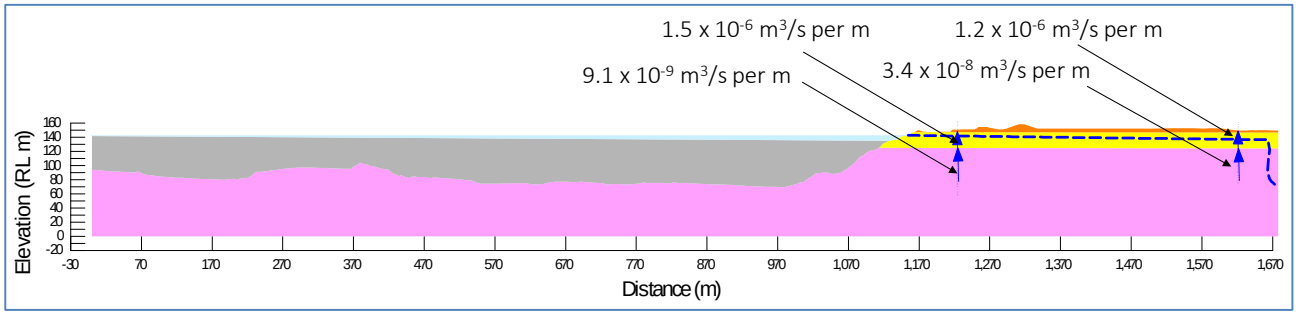


Figure E4 – Wetting front assessment under stage 2 DSA level

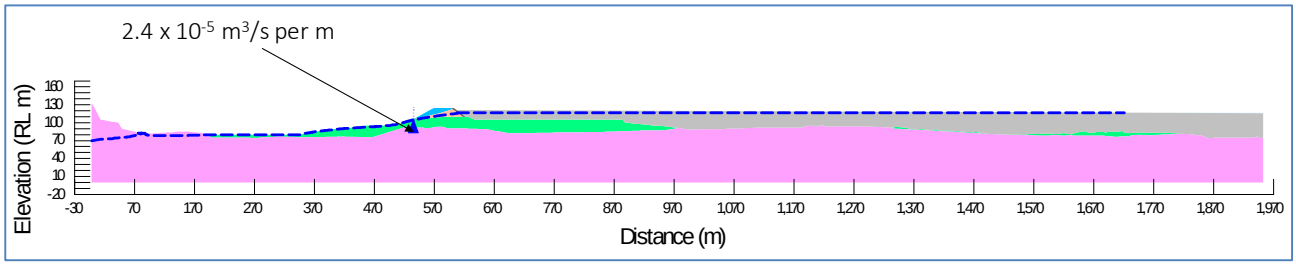


Figure E5 –Seepage assessment for stability under stage 1 operating decant level

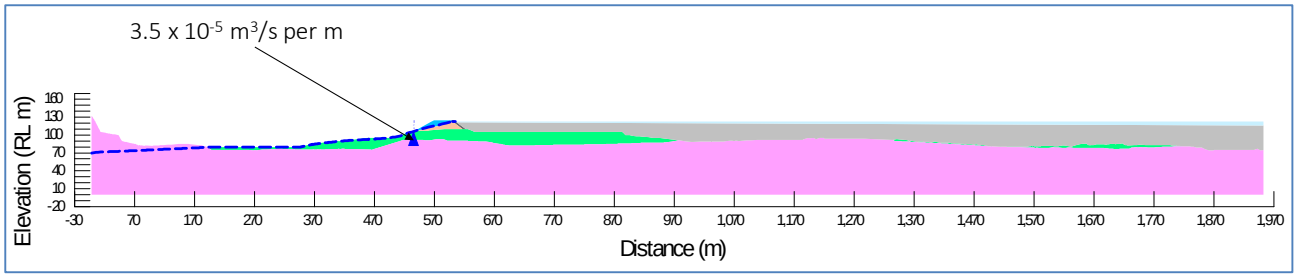


Figure E6 –Seepage assessment for stability under stage 1 DSA

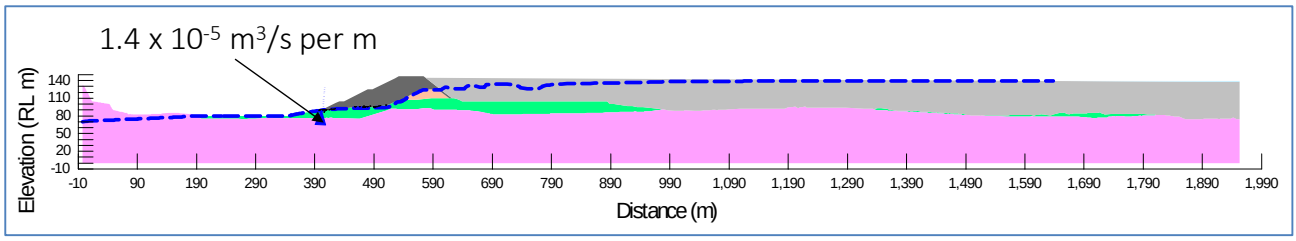


Figure E7 –Seepage assessment for stability under stage 2 operating water level

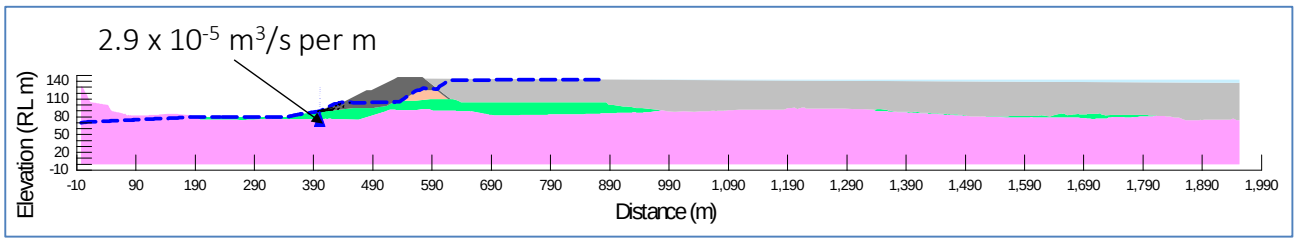


Figure E8 –Seepage assessment for stability under stage 2 DSA

APPENDIX F

Stability modelling results.

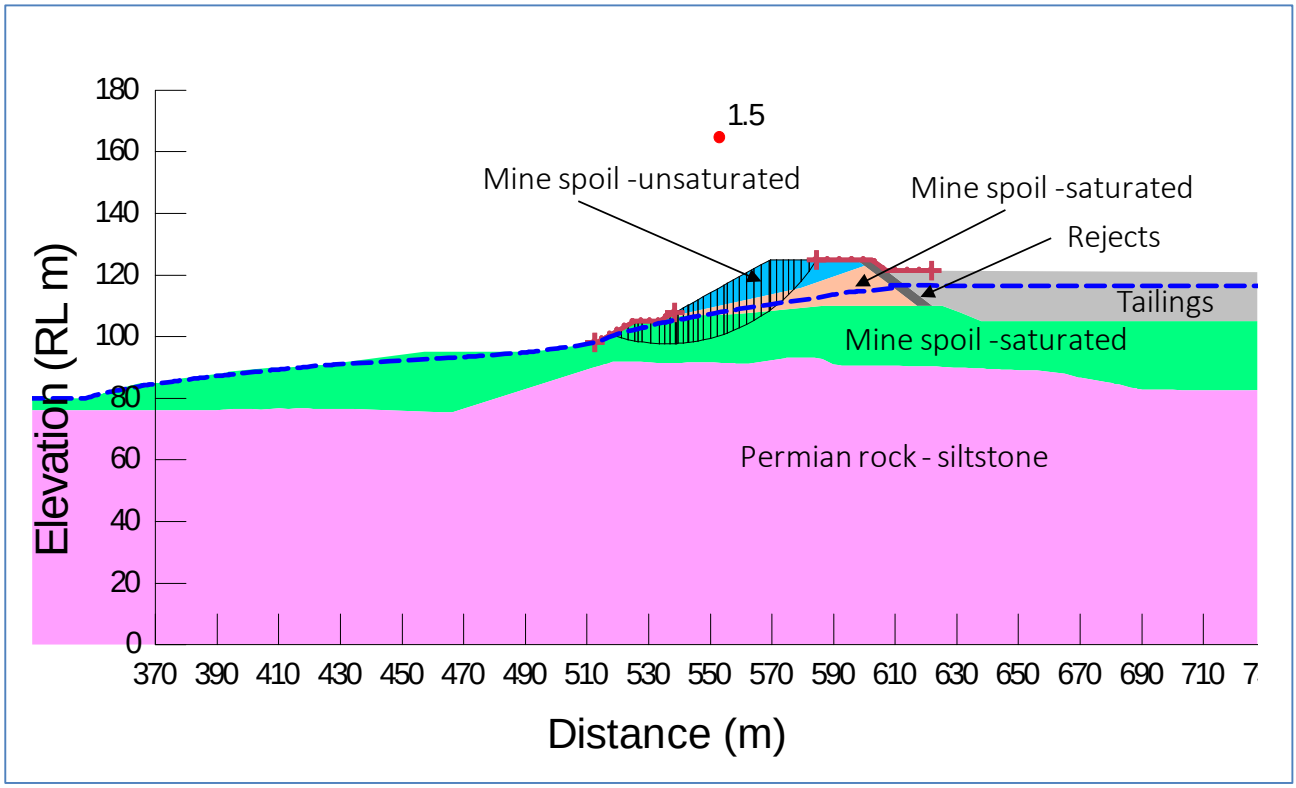


Figure F1 – Stage 1 Static stability, global failure under operating water level RL 116.7 m

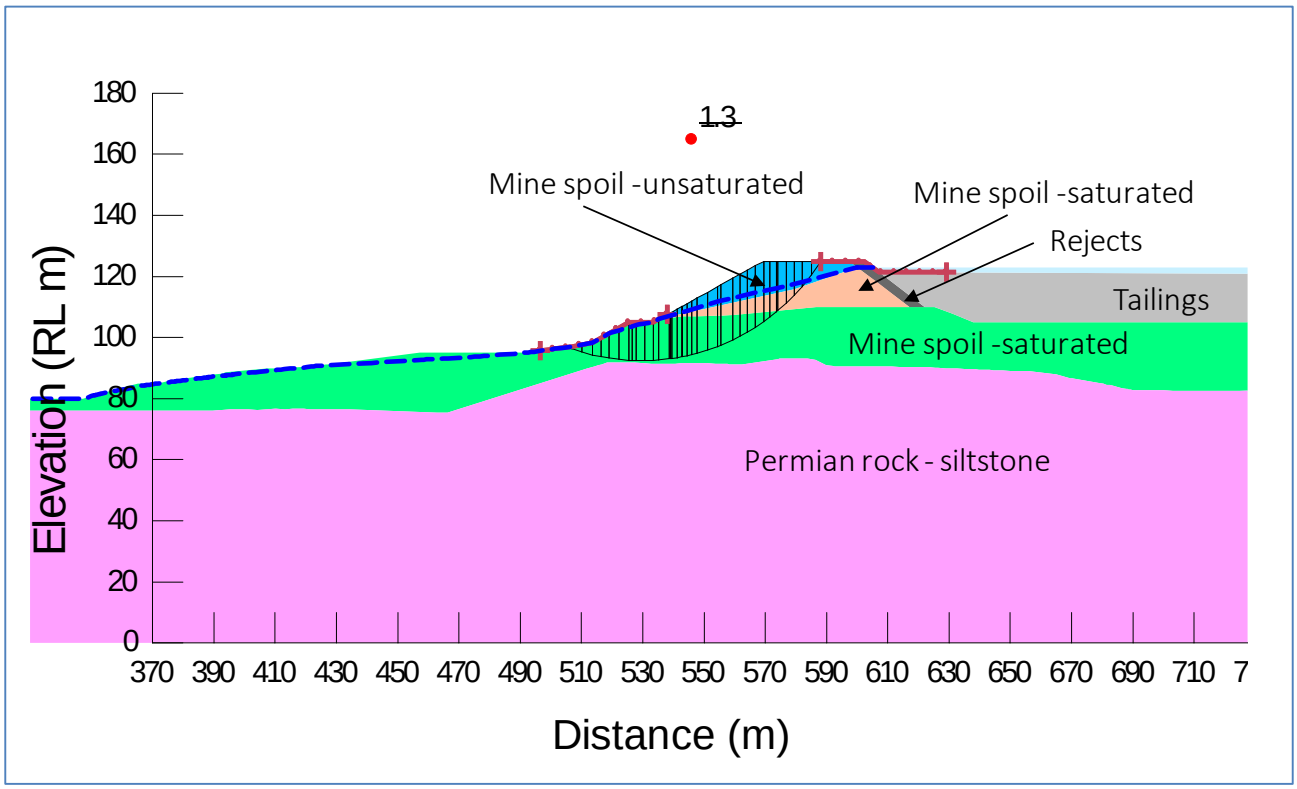


Figure F2 – Stage 1 Static stability, global failure under DSA level RL 123 m

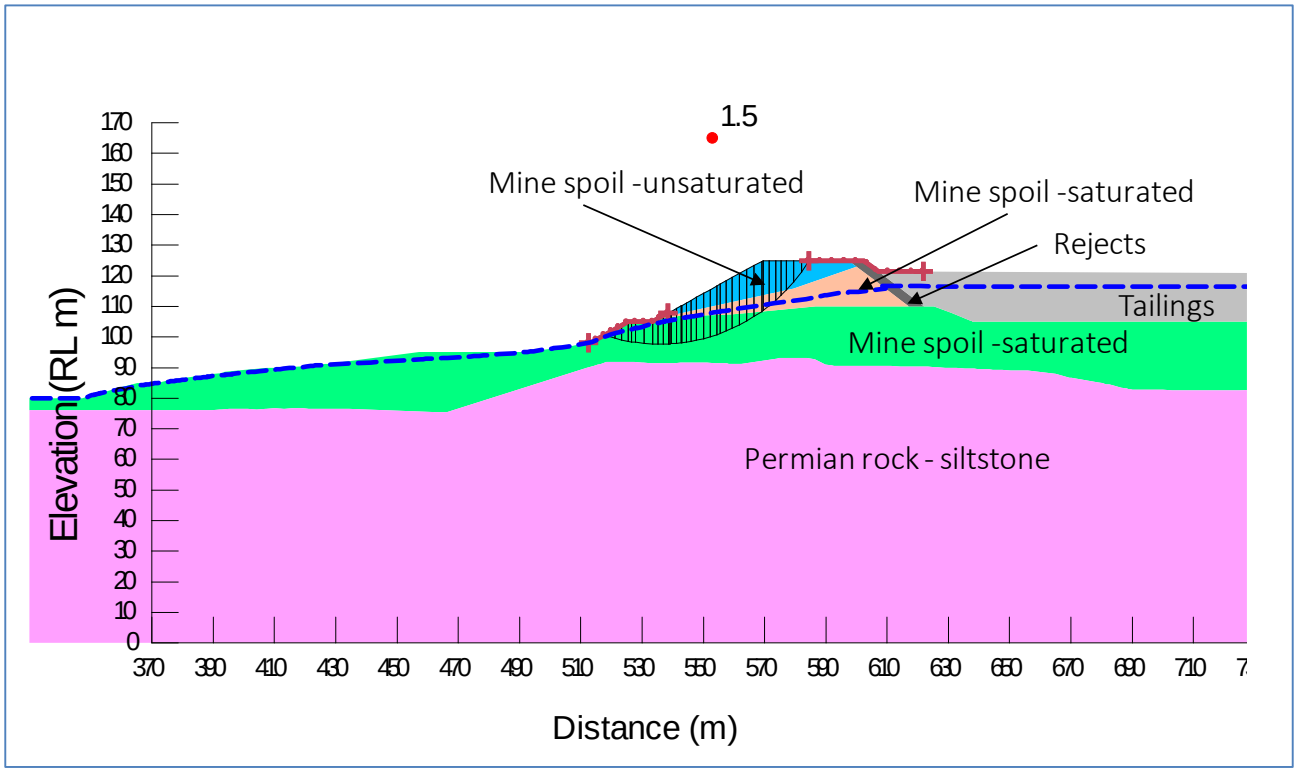


Figure F3 – Stage 1 Seismic OBE stability, global failure under operating water level RL 116.7 m

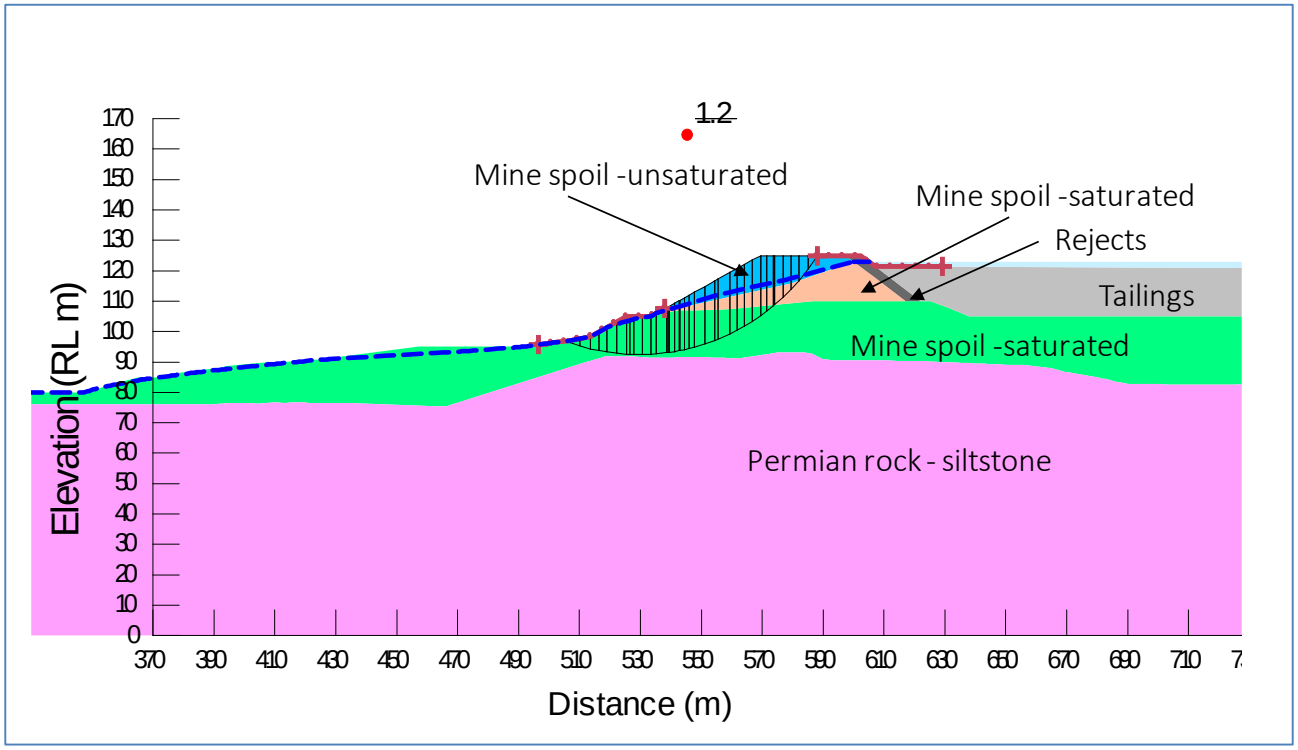


Figure F4 – Stage 1 Seismic OBE stability, global failure under DSA level RL 123 m

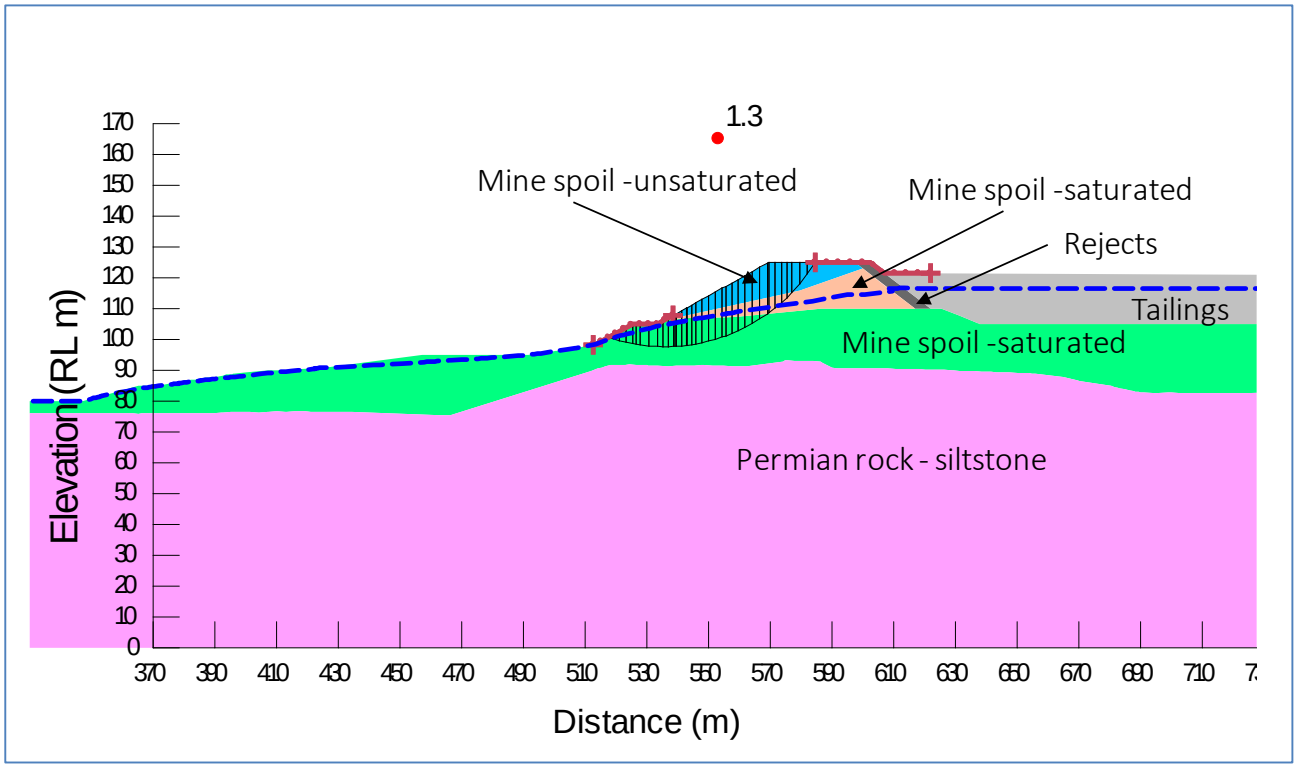


Figure F5 – Stage 1 Seismic MDE stability, global failure under operating water level RL 116.7 m

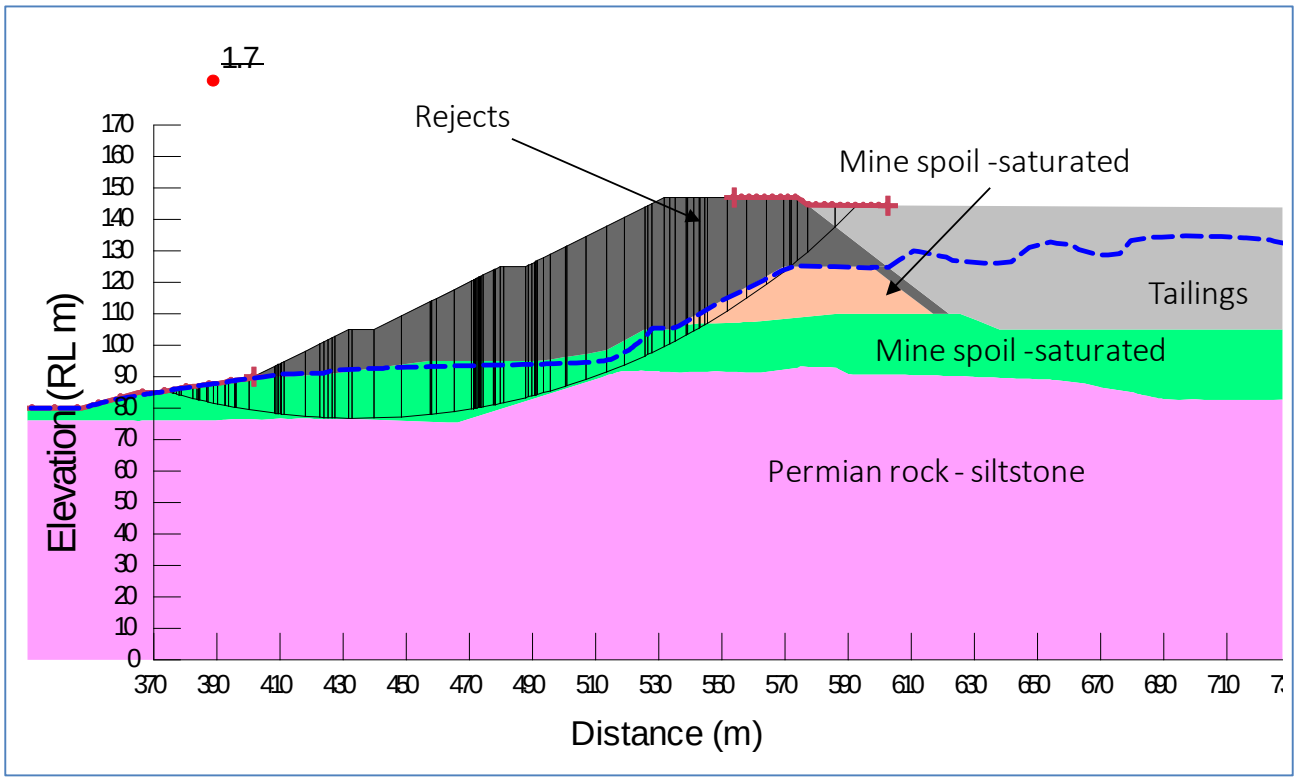


Figure F6 – Stage 2 Static stability, global failure under operating water level RL 139 m

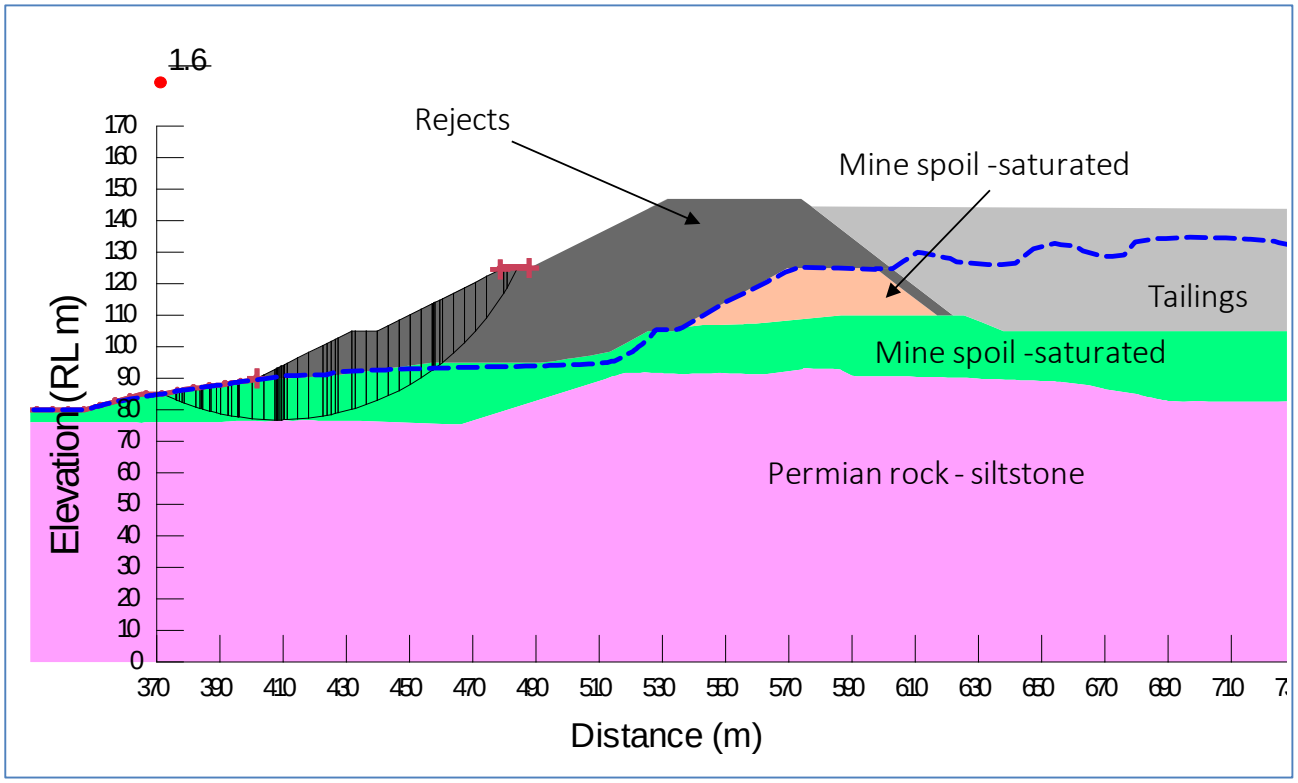


Figure F7 – Stage 2 Static stability, local failure under operating water level RL 139 m

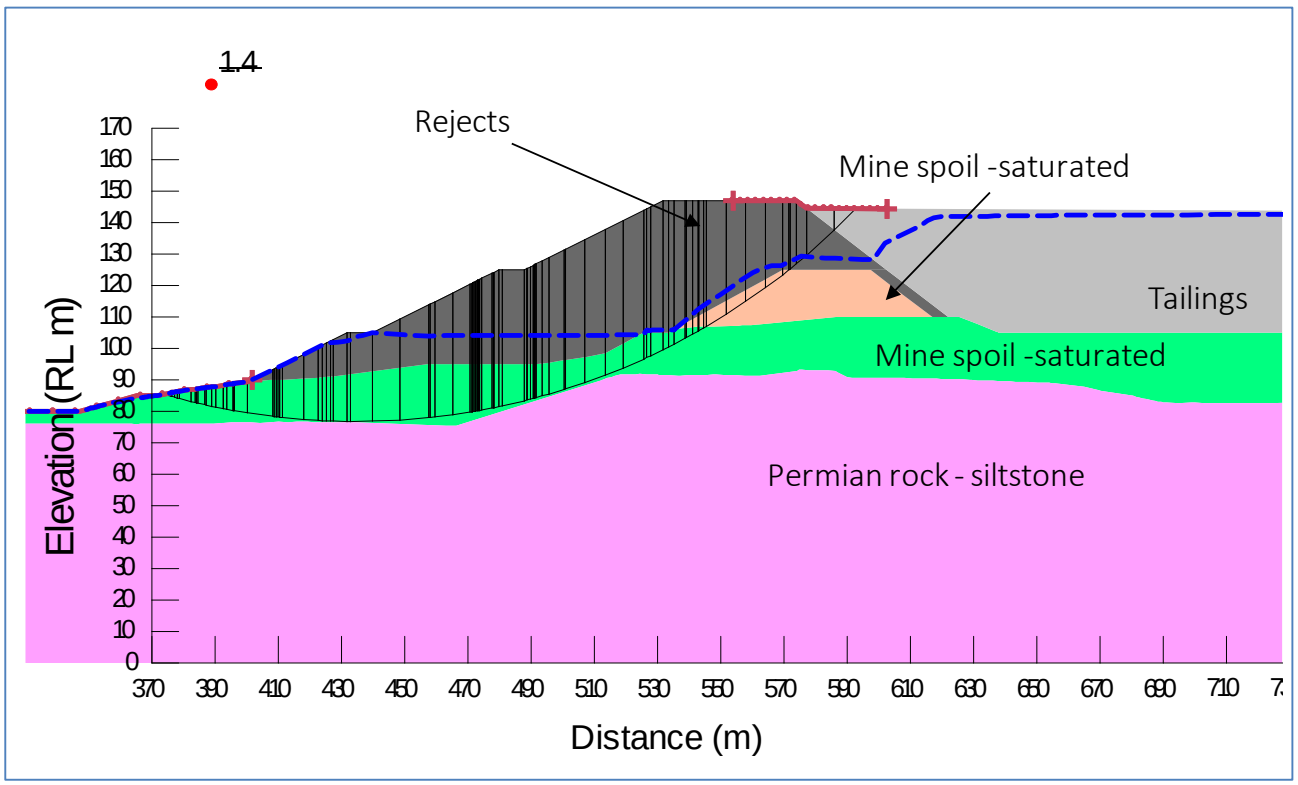


Figure F8 – Stage 2 Static stability, global failure under DSA level RL 143 m

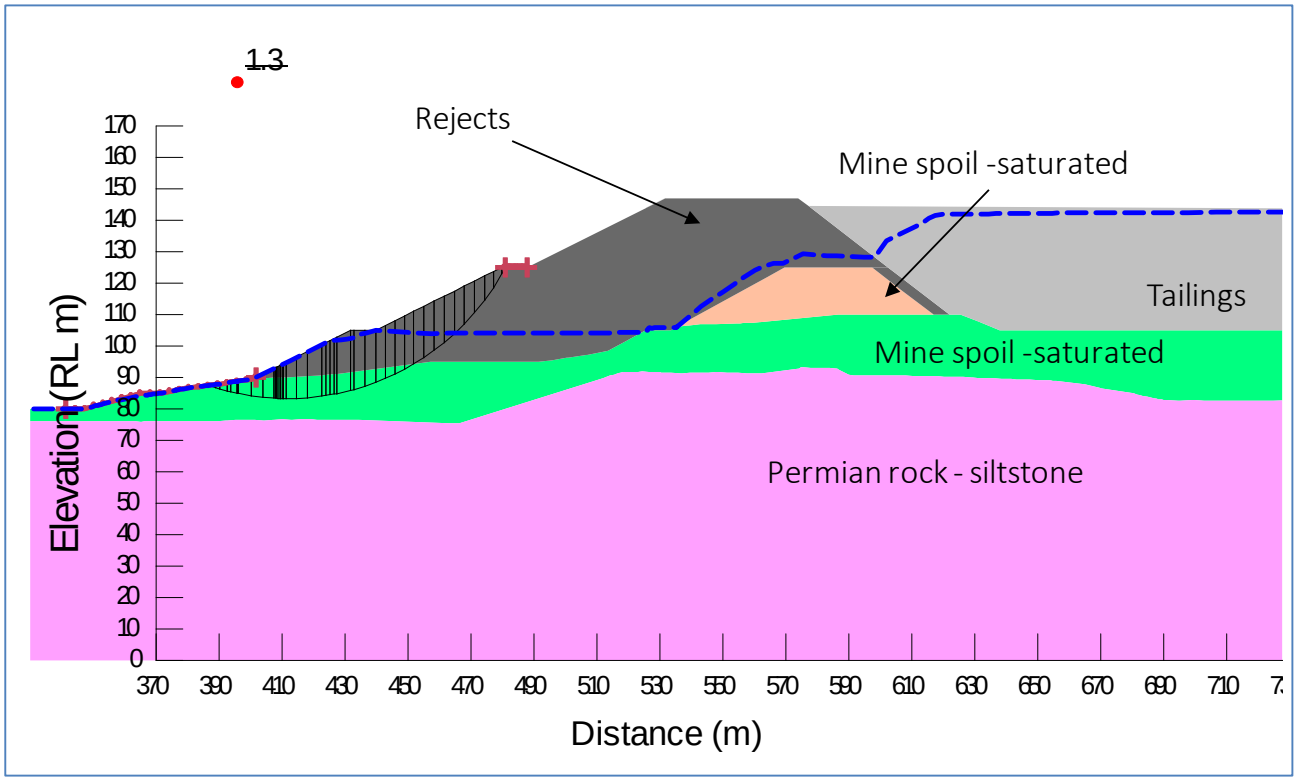


Figure F9 – Stage 2 Static stability, local failure under DSA level RL 143 m

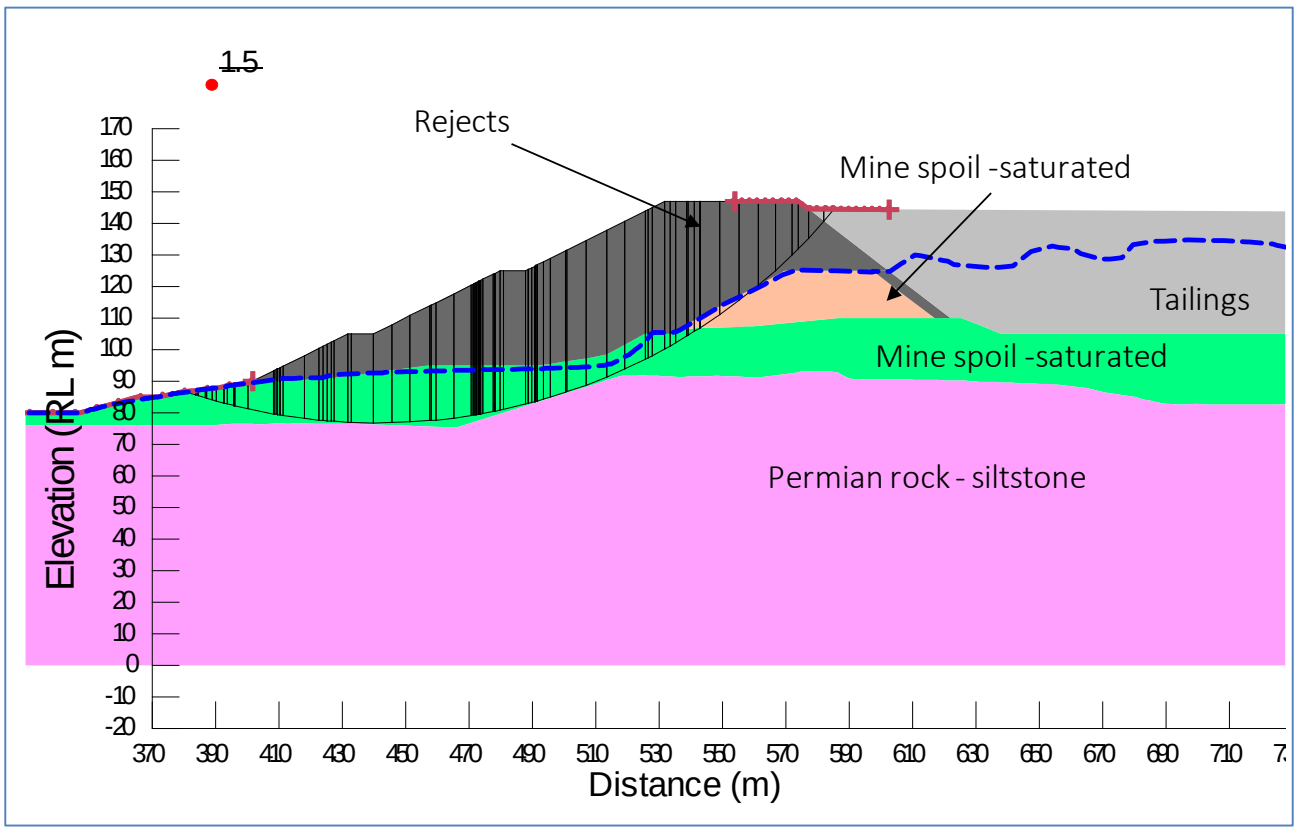


Figure F10 – Stage 2 Seismic OBE stability, global failure under operating water level RL 139 m

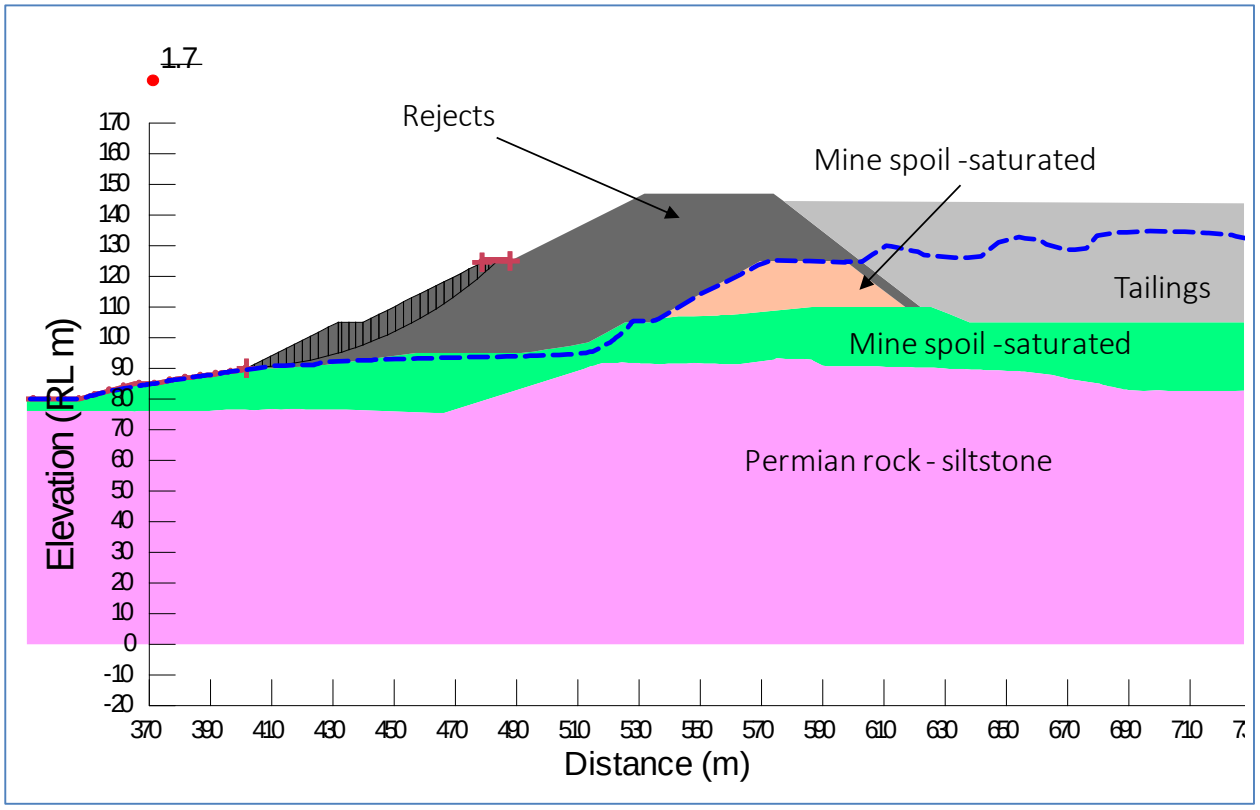


Figure F11 – Stage 2 Seismic OBE stability, local failure under operating water level RL 139 m

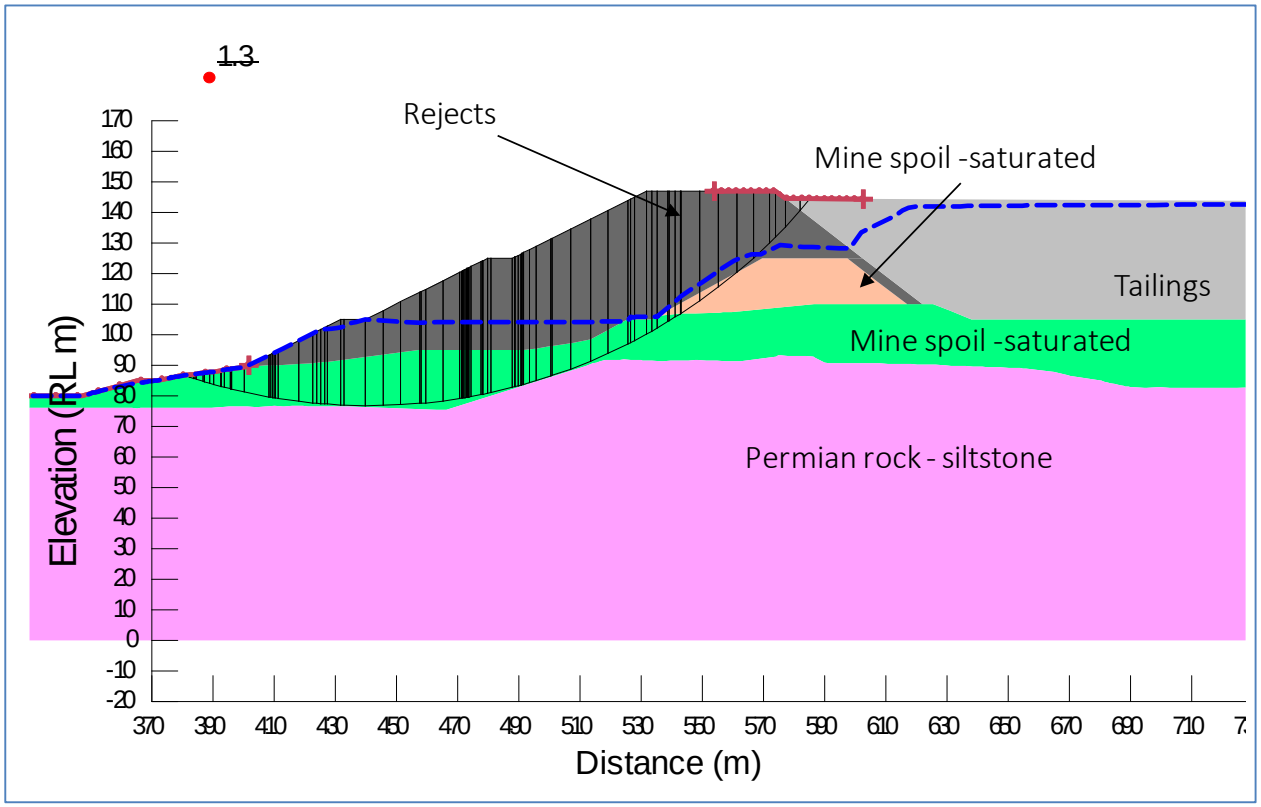


Figure F12 – Stage 2 Seismic OBE stability, global failure under DSA level RL 143 m

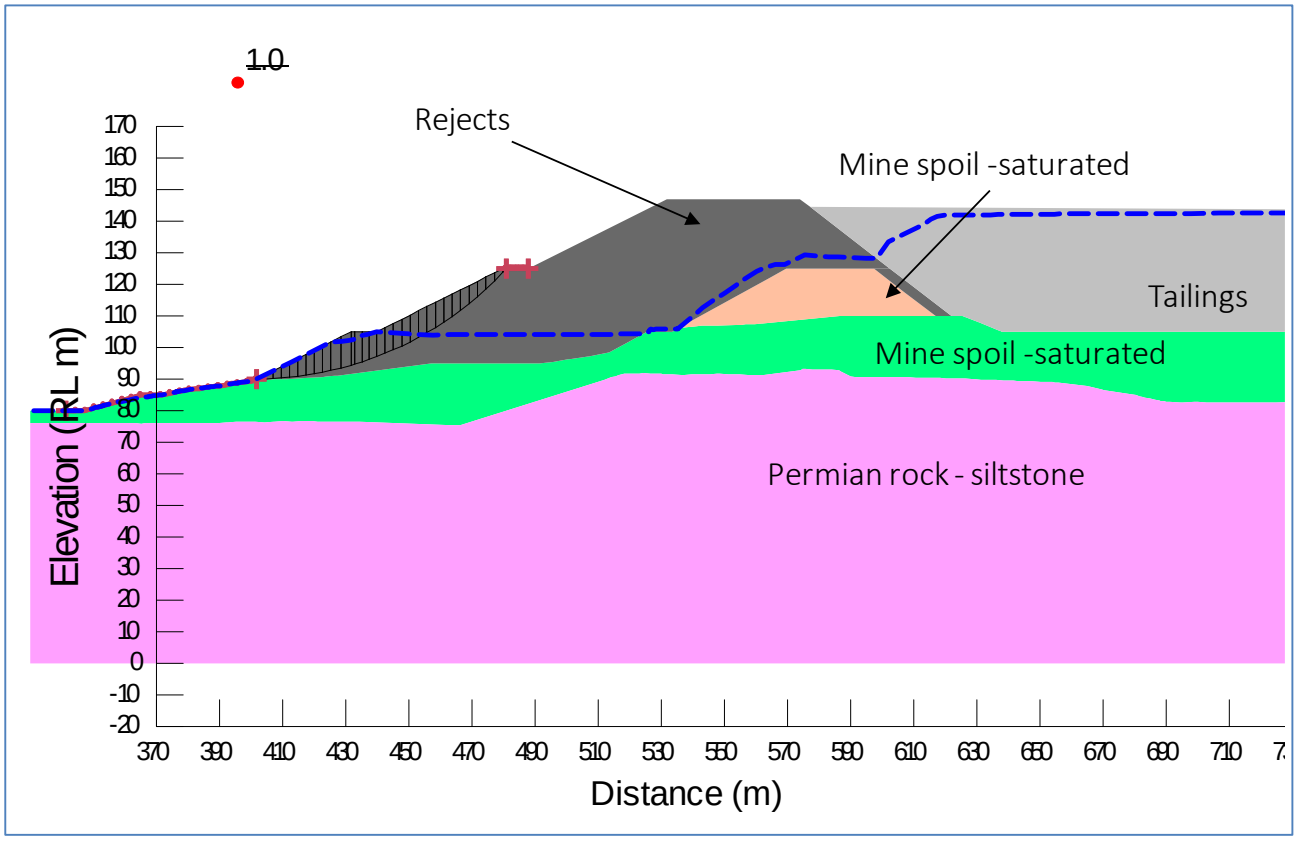


Figure F13 – Stage 2 Seismic OBE stability, local failure under DSA level RL 143 m

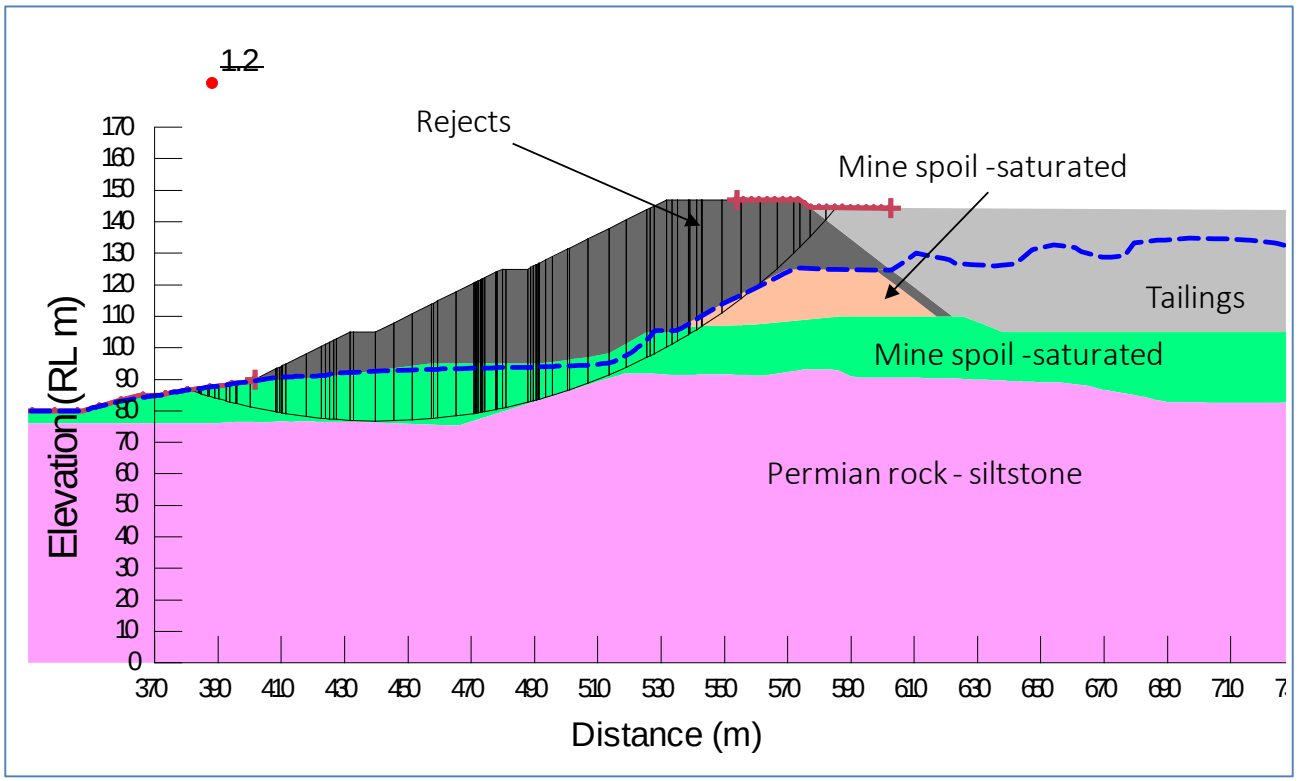


Figure F14 – Stage 2 Seismic MDE stability, global failure under operating water level RL 139 m

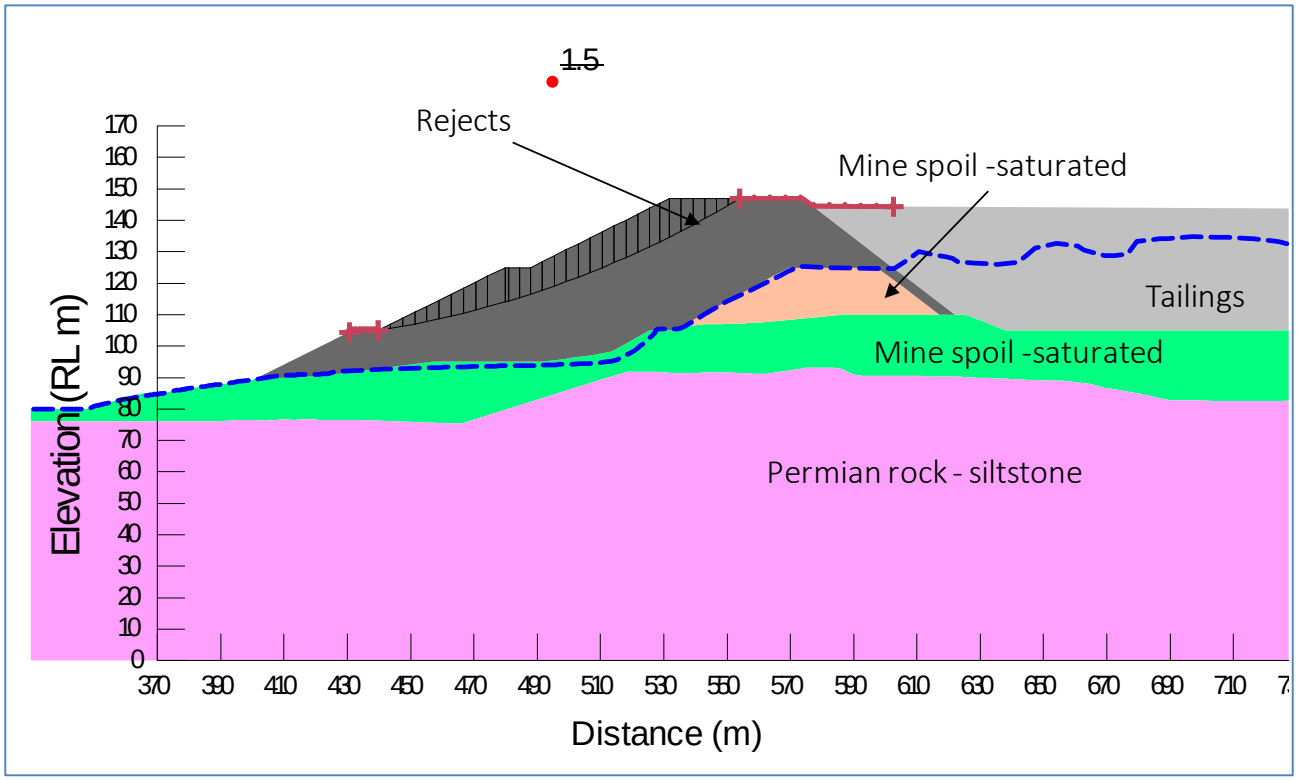


Figure F15 – Stage 2 Seismic MDE stability, local failure under operating water level RL 139 m

APPENDIX G

Hydrological analyses

- Design storage allowance
- Wave runup

TECHNICAL MEMORANDUM

DATE 15 September 2017 **PROJECT No.** 1532295-040-TM-Rev2

TO Howard Lief
Wesfarmers Curragh Pty Ltd

FROM Scott Creighton **EMAIL** screighton@golder.com.au

B PIT TSF - DSA ESTIMATION BY METHOD OF OPERATIONAL SIMULATION

1.0 INTRODUCTION

Wesfarmers Curragh Pty Ltd (WCPL) commissioned Golder Associates Pty Ltd (Golder) to design the new in-pit Tailings Storage Facility (TSF) that is to be located within the existing void of B Pit. A requirement of the design is for the provision of a Design Storage Allowance (DSA). This memorandum outlines the methodology and results of the DSA analysis. The DSA was estimated based on the method of operational simulation for performance based containment. Golder has developed a water balance model based on the method and requirements outlined in *Version 5 the Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (March 2016)* [1] (the guideline).

The resultant DSA requirement using the method of operational simulation is **2823 ML**.

This technical memorandum provides details of the model components and method sufficient to allow independent replication of the modelling by a suitably qualified and experienced person.

2.0 MODEL METHOD

The site water balance will vary significantly from year to year, due to climatic variability. To account for this variability, the performance of the water management system was assessed using a daily time step historical simulation water balance model developed in GoldSim[2]. GoldSim is a graphical modelling environment which allows dynamic simulation of a particular system to represent and predict system behaviour. Any system which can be described mathematically can be simulated.

GoldSim is particularly suitable to water balance modelling, and has specific elements to represent water reservoirs and their behaviour. It is also dimensionally aware having an internal database of units and conversion factors which means that data can be entered in any unit recognised by the software. The model components (detailed in Section 3.0) represent water storages including water inflows, outflows and retained water.

The model was configured to simulate the operation of all major components of the water management system including:

- rainfall and evaporation;
- catchment runoff and collection;
- pit dewatering;

[1] Department of of Environment and Heritage Protection, March 2016, *Manual for assessing consequence categories and hydraulic performance of structures*, Version 5.0

[2] GoldSim Technology Group www.goldsim.com

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- pump and gravity transfers;
- water storage filling and spilling; and
- water extraction, usage and transfers.

To assess a range of historical climate conditions that could be encountered by the project, the model includes a sequence of 127 years of available Data Drill climate data for predictive modelling. Data Drill climate data is supplied for a specific location from SILO enhanced meteorological data and is, as indicated in the guideline, an acceptable form of climate data to be used in operational simulation modelling. The Data Drill accesses grids of data derived either by splining or kriging the observational data from point observations from the Bureau of Meteorology recording stations around Australia.

The model has been set up to run dynamically on a daily basis for the period 1 November to 30 March and for 100 model realisations. Each realisation randomly selects a new daily rainfall and the same year's corresponding daily evapotranspiration record from the Data Drill data starting at 1 November. In this way 100 different summer climate scenarios for this location were simulated. All other variables, such as the rate of water inflow and outflows and the starting water level at 1 November; remain constant for each of the model simulations.

The model output, that is, the 100 records of resultant change in storage over the wet season; is then used to determine the DSA. The DSA is calculated from the statistical results of the plotting position analysis of operational simulation outcomes, to derive the design Annual Exceedance Probability (AEP), plus an additional volume equal to the Design Simulation Margin (DSM), applied to simulation outcomes to provide conservative compensation for model inaccuracy. The guideline recommends Pit B to maintain a DSA of the 1:20 year AEP wet season including process inputs subsequent to 1 November each year, consistent with a significant consequence rating. Where there is a lack of calibration data for the model, the guideline recommends the use of a minimum DSM value of not less than 50% be applied. Due to the absence of data for calibration, but applying input parameters consistent with other mine site in the area, we have applied a DSM value of 50% in this case as we were not able to calibrate the model between modelled and measured site data.

3.0 MODEL SETUP

The movement of water in the simulation is demonstrated in Figure 1. The water network was developed based on Golder's understanding of Curragh's water management system from previous work, site visits, and communications with Curragh representatives. The network has been updated to reflect the proposed project case of constructing an in-pit TSF within B Pit and holding deposition of tailings to Pit A. Components of the network was reviewed against a previous water balance completed by WRM in June 2016[3].

The water balance contains three independent circuits: B Pit, G Pit and I Pit circuits. B Pit circuit is relevant for the DSA operation simulation and thus will only be discussed in this memorandum. A separate memorandum will be issued by Golder focusing on the side-wide water balance model.

[3] WRM Water & Environment Pty Ltd, June 2016, *Curragh Extension Project – Submission to IESC, Surface water balance impact assessment report*, Document reference: 0990-04-D2

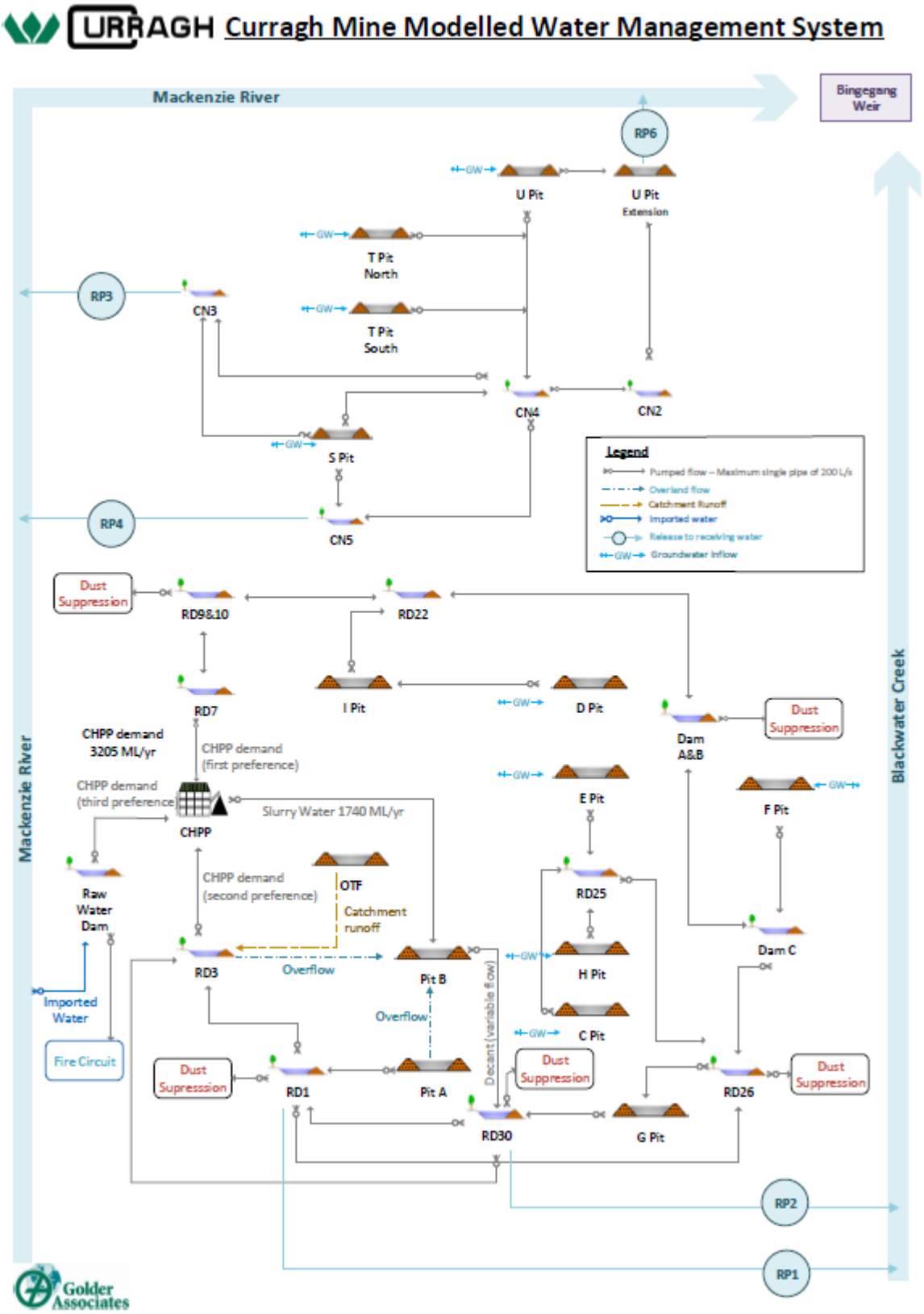


Figure 1: Flow diagram of model setup, including B Pit TSF

4.0 MODEL COMPONENTS

The model primary container view is shown in Figure 2, which provides the schematic representation of model components, including inflows, outflows, the decant water reservoir and relevant stage area storage curves for Pit B. Brief descriptions of the model components are provided below.

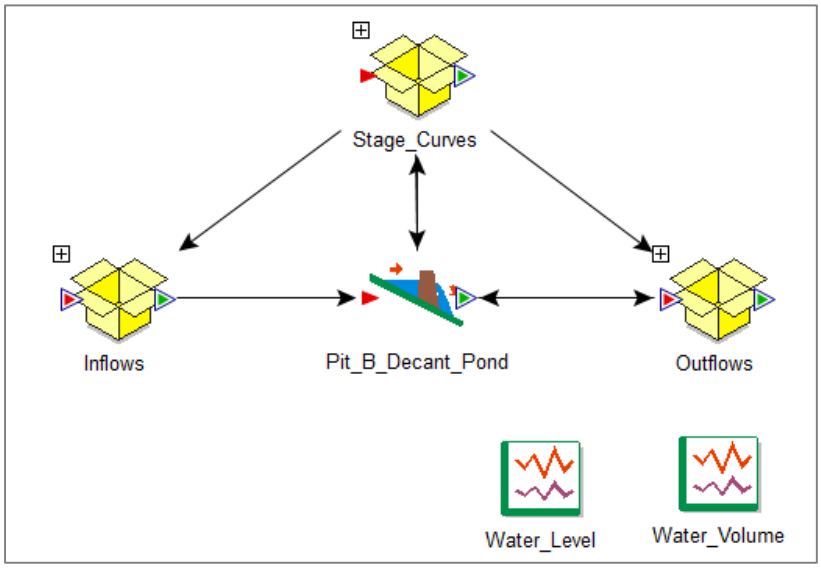


Figure 2: Model Schematic.

4.1 Stage-area-storage of the ponds

Relationships between stage (elevation) and associated surface area, and between stage and associated storage volume (Stage-Area-Storage) for water above the floor of the water storages were obtained from data 'Weekly Volumes – July 2016 to June 2017.xlsx) provided by Curragh (November 2016).

This Stage-Area-Storage data is directly referenced by the water storage element in GoldSim. The Stage-Area-Storage tables are provided in Attachment A.

4.2 Catchment areas

Catchment areas reporting to each modelled water storage was input into the model. Catchment areas from from WRM (2016) were referenced. The catchment area for Pit B and the surrounding catchments were revised to reflect the post diversion conditions for Pit A. The catchment areas for the mine have been determined from 2016 aerial photography, 2016 Lidar and previous water management reports for the operation.

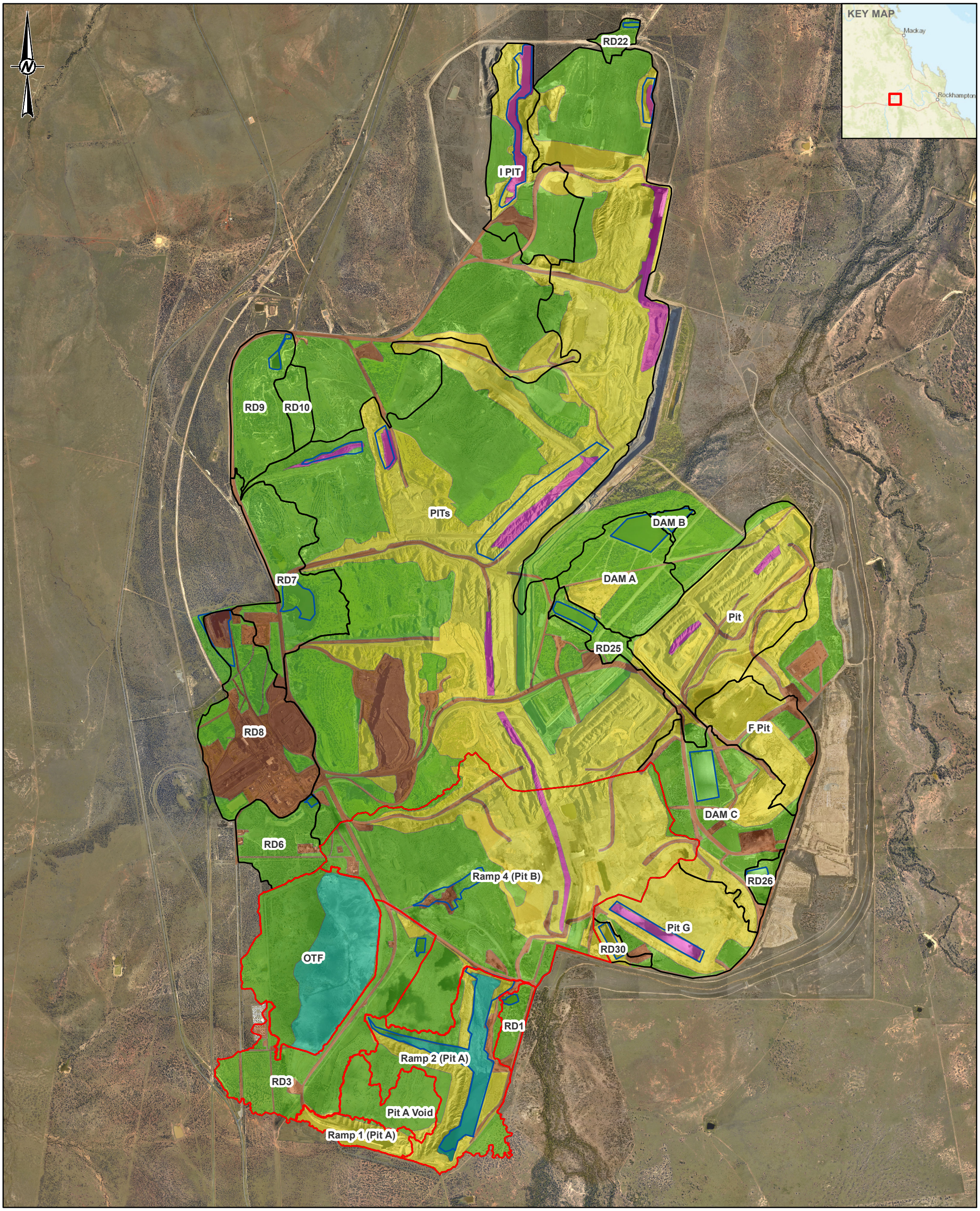
See Table 1 for the catchment area. The land use categories were developed by WRM (2016).

See Figure 3 for the updated adopted catchments. The catchments in red represent the revised catchments.

Table 1: Relevant catchment areas

Storage	Natural (ha)	Spoil (ha)	Hardstand (ha)	Pit/Tailings (ha)	Total (ha)
Pit B	287.2	320.3	57.0	9.8	674.2
Pit A	124.3	112.4	11.2	51.9	299.7
RD3	154.7	5.9	19.2	0.5	180.2
RD1	19.1	0	5.8	0	24.9
RD30	1.7	9.6	2.0	0	13.4
RD7	119.9	0	22.2	0	142.1
OTF	106.9	0	0.2	126.8	233.8

PATH: J:\Hyd\2015\1532295 Curragh RPEQ Mine Water Services\Figures Drawings\1532295-014-001-Catchment Area Post-Diversion Rev2.mxd



LEGEND

Landuse

- Pit
- Spoil
- Natural
- Tailings
- Hardstand

- Revised Golder Catchment Area 2017
- Catchment Area (WRM 2016)
- Water storage

0 500 1,000 1,500

METRES

REFERENCE(S)

1. BASE IMAGE PROVIDED BY WESFARMERS CURRAGH AS AT 16 FEBRUARY 2016
2. INSET MAP SOURCES: ESRI, DELORME, NAVTEQ, USGS, INTERMAP, IPC, NRCAN, ESRI JAPAN, METI, ESRI CHINA (HONG KONG), ESRI
3. LAND USE INFORMATION PROVIDED BY WRM (MARCH 2017)

CLIENT
WESFARMERS CURRAGH PTY LTD

CONSULTANT
Golder Associates

YYYY-MM-DD	2016-03-27
DESIGNED	SL
PREPARED	SL
REVIEWED	SAC
APPROVED	SAC

PROJECT
RPEQ MINE WATER SERVICES
CURRAGH MINE

TITLE
CATCHMENT AREAS POST-DIVERSION

PROJECT NO.	CONTROL	REV.	FIGURE
1532295	040	1	**F001**

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ISO A3

0 25mm

4.3 Climate data

Data Drill data (127 years) for the approximate site location (latitude S 23.30°, longitude E 148.54°), was obtained for use in the predictive model simulation. Data Drill data is gridded synthetic data interpolated from point observations from the Bureau of Meteorology (BOM) records. Morton's evaporation over shallow lakes estimates were used to estimate evaporation loss from storages. Soil moisture evapotranspiration losses in the AWBM model were estimated using Morton's wet environment areal evapotranspiration over land.

Mean monthly rainfall is highest between November and March. This is illustrated in Figure 4, along with mean monthly evaporation and evapotranspiration, which is highest between October and March. Mean annual evapotranspiration is estimated to be 1,737 mm (with annual totals ranging between 1,487 mm and 1,866 mm). Mean annual open lake evaporation is estimated to be 1,814 mm (with annual totals ranging between 1,533 mm and 1,961 mm).

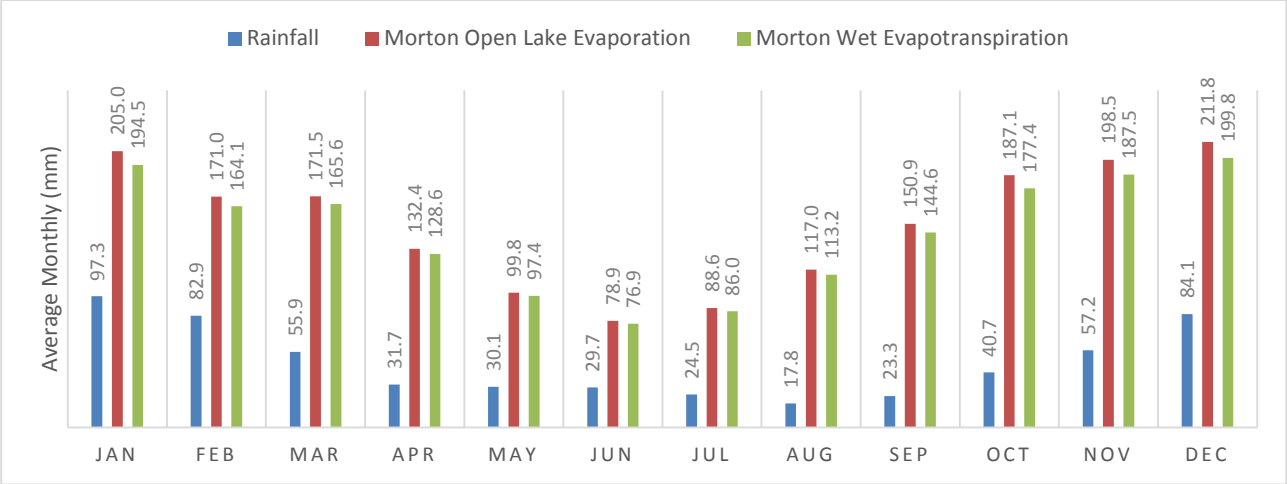


Figure 4: Average monthly rainfall, Morton lake evaporation and Wet evapotranspiration – Data Drill data from 1889 to 2016

4.4 Inflows

4.4.1 Rainfall (all catchments)

Direct rainfall to all water storages is calculated in the model on a daily basis from the rainfall record and the dynamic area of the pond surface.

4.4.2 Runoff (all catchments)

The Australian Water Balance Model (AWBM) was incorporated in the water balance model to simulate the catchment rainfall runoff. The AWBM is a catchment scale water balance model that relates runoff to rainfall. It is based on a conceptualised representation of a catchment's temporary surface and baseflow stores, rainfall loss to evaporation and gradual release of water from both stores to streamflow.

The AWBM separates surface runoff and baseflow, see Figure 5. The parameters C_1, C_2 and C_3 specify the surface storage capacities. The baseflow index (BFI) specify the amount of runoff that becomes baseflow. The baseflow recession constant (K_b) specify the rate of discharge of water from the baseflow store. The surface recession constant (K_s) specify the rate of discharge of water from the surface store.

Catchments across the site have been characterised into the following land use types:

- Natural/undisturbed;
- Open cut / mine pit;
- Spoil;
- Rehabilitated spoil;

- Tailings; and
- Hardstand.

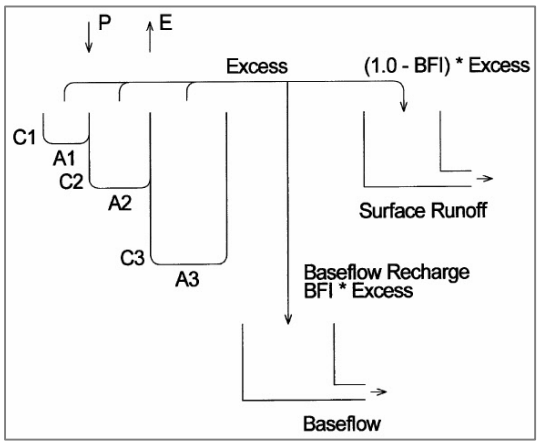


Figure 5: AWBM conceptual model

Table 2 shows adopted AWBM parameters, presented in WRM (2016), are based on past experience of similar mining projects. These parameters are within the expected range of values for the adopted land use types.

Table 2: AWBM parameters

Parameter	Natural / Rehab	Spoil	Hardstand	Pit / Tailings
A_1	0.134	0.134	0.1	0.1
A_2	0.433	0.433	0.9	0.9
A_3	0.433	0.433	0	0
C_1	11	14	38	12
C_2	114	70	12	38
C_3	229	168	38	0
BFI	0.17	0	0	0
K_s	0.95	0	0	0
K_b	0	0	0	0

Source: Table 6.1 from WRM (2016)

Catchment runoff to all water storages is calculated in the model on a daily basis using the rainfall record, evaporation, and AWBM parameters specified in Table 2.

4.4.3 Water in tailings slurry to Pit B TSF and decant

The tailings slurry water was modelled as an inflow to Pit B at 1,740,749 m^3/yr. The water retained within the tailings was estimated to be 669,697 m^3/yr, with 1,071,052 m3/yr reporting into the TSF decant pond for return to the CPP. See the process plant input parameters listed in Table 3.

Table 3: Tailings and CHPP Volumetric / physical properties.

Criteria	Value	Unit
ROM	15.00	Mt/yr
Product	10.50	Mt/yr
Annual tailings rate	1.04	Mt/yr
Thickener solids	7%	
Slurry in water (thickener underflow)	13.82	Mm^3/yr
Slurry water (water in tailings pipeline to TSF)	1.74	Mm^3/yr
Underflow Solids	37%	
Tailings Specific gravity	1.65	
Initial dry density	0.8	t/m^3
Retained water within tailings	0.67	Mm^3/yr
Decant Supernatant Water	62%	
TSF water to decant pond for return (excluding rainfall and evaporation)	1.07	Mm^3/yr
Thickener overflow (clarifiers) recirculated back to CPPs	12.08	Mm^3/yr
Total tailings water return (decant + clarifiers)	13.15	Mm^3/yr
Rejects volume	3.12	Mt/yr
Rejects water content	12%	
Water bound with rejects	0.43	Mm^3/yr
Product water content	9%	
Water bound with product	1.04	Mm^3/yr
Total CPPs water demand	3.21	Mm^3/yr
Water demand for CPPs (for product, rejects and due to water loss to TSF)	2.14	Mm^3/yr

4.4.4 Pumped water (various ponds)

Excess water from water storages is pumped to designated storages. See the pumped water section in Section 4.5.

4.4.5 Groundwater

The analysis and estimation of groundwater inflow are addressed in the groundwater impact assessment report (refer to Appendix B1 of the Supplementary Report) (WSP Parsons Brinckerhoff,2016). The following information is quoted from that report.

"The Curragh North pits (S, T and U) experience inflows from the alluvium, which is thick and comprised of sand and gravel in this area, and the Rangal Coal Measures. At Curragh, alluvium is less than 2 m thick and comprised of clay, and inflows are predominantly from Rangal Coal Measures.

The groundwater modelling (WSP Parsons Brinckerhoff, 2016) predicted groundwater inflows to operational pits over the proposed life of the approved operations. The inflows presented were cumulative inflows for Curragh Mine and do not include inflows to residual voids.

On this basis, it is assumed that there are no groundwater inflows to the mine voids within the contributing catchment of Pit B.

4.5 Outflows

4.5.1 Evaporation (all catchments and ponds)

Site evaporation records are not available and Morton's evaporation over shallow lakes estimates has been used in both the calibration and predictive simulations to estimate evaporation loss from storages. Soil moisture evapotranspiration losses in the AWBM model were estimated using Morton's wet environment areal evapotranspiration over land.

In the predictive model daily evaporation data is used from the corresponding 1 November start year to the Data Drill rainfall record. Evaporation from the water storages is calculated in the model on a daily basis from the Data Drill evaporation record and the dynamic area of the pond surface.

4.5.2 CHPP Clarifier and CHPP water demand (RD7 and RD3)

Water is extracted from RD3 and RD7 for make-up water which is the volume of water that is loss to water entrained in the product, rejects and Tailings. A total water supply to the CHPPs is 3.21 Mm^3/yr, which is the water required for the rejects (0.43 Mm^3/yr), water required for the product (1.04 Mm^3/yr), water retained in the tailings (0.67 Mm^3/yr), and water retuned from the TSF decant (1.07 Mm^3/yr). Water is preferentially taken from RD7 as RD7's catchment area is over two times larger than the catchment area for RD3 (i.e more catchment runoff reporting to the RD7). The remaining CHPP water demand is taken from RD3, and any shortfall is taken from the Raw water Dam (RWD).

A summary of the CHPP water requirements is presented in

Table 3.

4.5.3 Dust suppression (various ponds)

Haul road dust suppression requirements were applied to haul roads on dry days (with a depth of rainfall less than 5 mm) at an average width of 22 m, and at a rate to replace water lost to evaporation. The existing length of watered haul roads was estimated to be approximately 37 km (WRM 2016). Across the 100 model realisations, the dust suppression demand was equivalent to approximately 5.7 mm/day.

Haul road water demands were contributed evenly between four storages in the model: RD7, RD26, RD1 and Dam A & B (see Figure 1).

4.5.4 Pumped water (various ponds)

Excess water from water storages is pumped to designated storages when the water level is within 1 m below the spillway invert. Golder previously estimated the maximum potential pump rate within Curragh was approximately 200 L/s[4], therefore this simplified rate was assumed for the purpose of modelling.

An exception is the pumping from Pit B to RD30. A maximum decanting pump rate of 250 L/s was specified when the water level in Pit B is within 3 m below the spillway invert. The maximum pump rate was estimated for Pit B in a separate Golder memo (Golder ref: 1532295-057-TM-Rev1, February 2017).

The modelled pumping network is shown in Figure 1.

4.5.5 Seepage

As required by the method there was no allowance for seepage loss in the modelled system.

5.0 RESULTS

The model was used to predict the increase in stored water inventory over the wet season subsequent to 1 November each year. Stage-area-storage information provided by Curragh was used in the predictive model, along with the Data Drill rainfall data. The initial water volume in the predictive model (100 ML) is the pond volume in Pit B at 1 November 2015. All water transfers were assumed to be operational as defined in the water balance model development, in Section 3.0.

The model was simulated using daily time steps for the period 1 November to 30 March and 100 model realisations. The resultant water volume of the decant for each of the 100 realisations is shown in Figure 6.

[4] Golder Associates, November 2016, *Curragh Wet Weather Preparation 2016/2017*, Document reference: 1532295-028-TM-Rev0

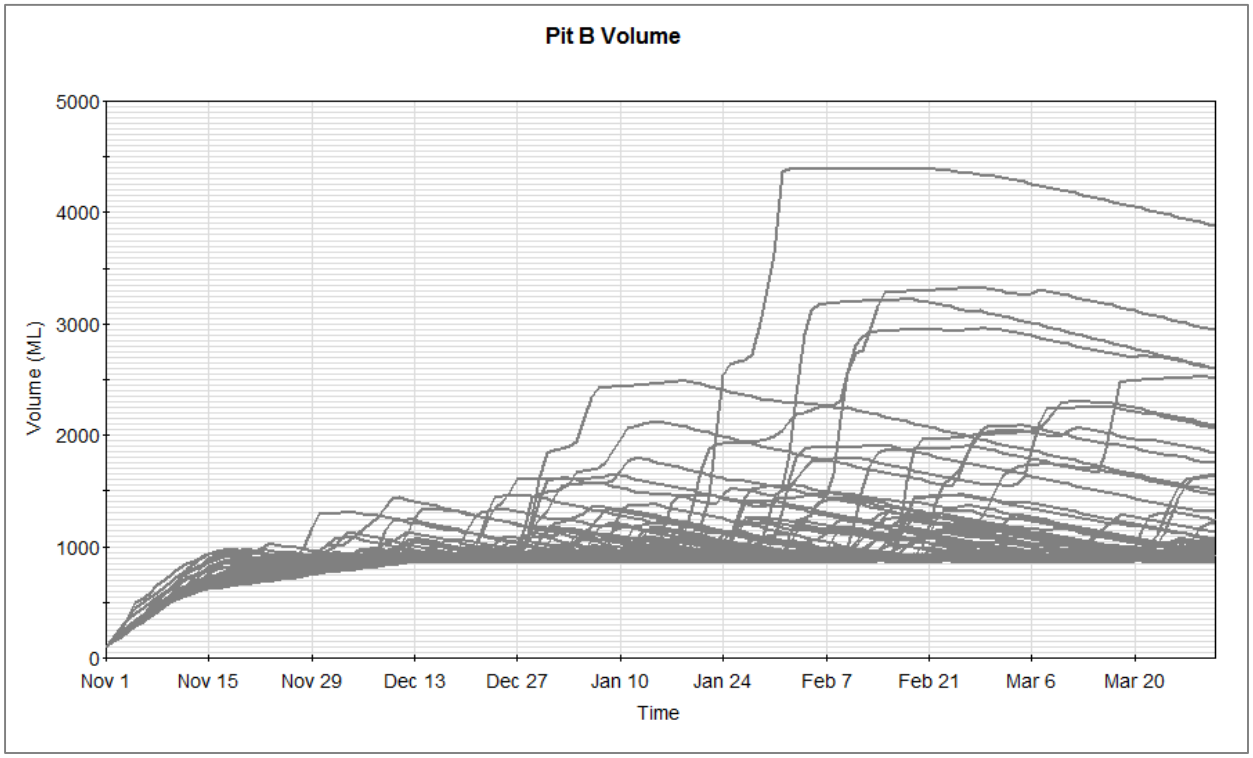


Figure 6: Pit B decant water volume for each of 100 realisations.

The maximum change in storage volume during the simulation for each of the 100 realisations was extracted from the model results. A Log-Pearson 3 (LP3) frequency analyses using the software TUFLOW FLIKE was then undertaken to determine the 1:20 AEP wet season water inventory increase. A DSM value of 50% has been applied due to insufficient data to calibrate the model (as described in Section 2.0).

The DSA is then calculated by:

DSA = (100% + DSM) x (1:20 AEP Increase in Water Inventory).

Based on the LP3 analysis, the 1:20 AEP wet season water inventory increase = 1882 ML (see figure below).

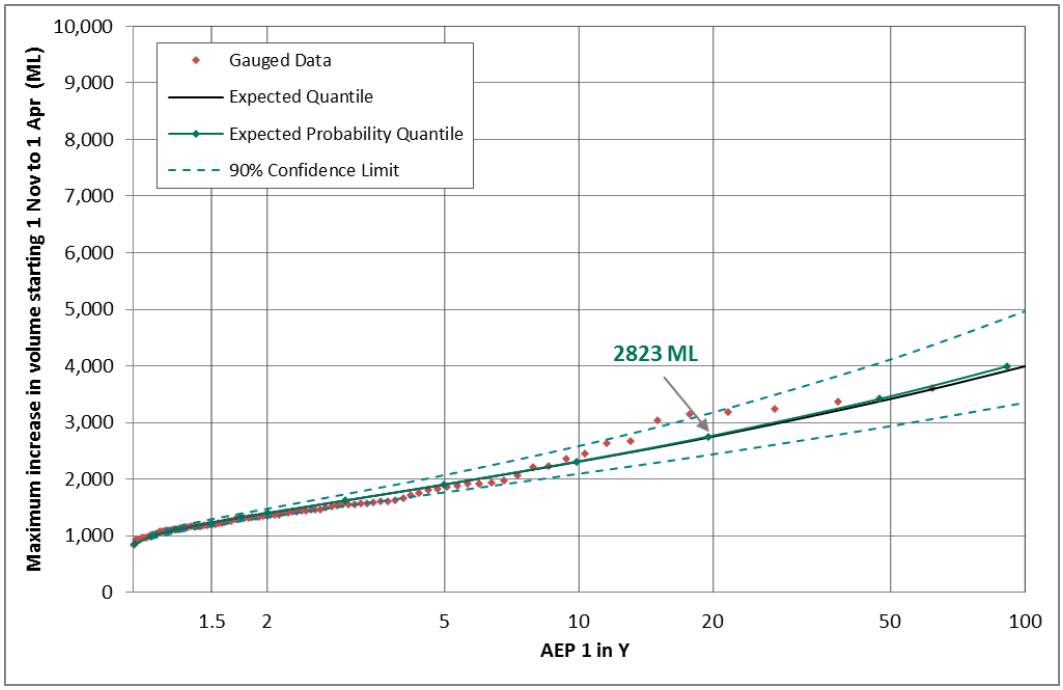


Figure 7: Log-Pearson 3 analysis of the maximum increase in volume starting 1 November to 1 April

Therefore the DSA of Pit B = 2823 ML.

Note the calculation of the DSA by the method of operational simulation applies to the wet season subsequent to the start water level and storage capacity at 1 November 2015. The DSA if using the method of operational simulation will need to be re-modelled and re-evaluated on an annual basis.

6.0 LIMITATIONS OF THE WATER BALANCE MODEL

The water balance model developed for the project is assumed to be representative of the proposed mine water management system. However, as the project is not yet operating there are several limitations of this model which must be understood when analysing the results:

1) There is no site-specific data available to calibrate the rainfall runoff behaviour for the mine site catchments. The Australian Water Balance Model (AWBM) parameters adopted for the model appear reasonable based in past experience and calibration to available stream flow data (calibrated model of Blackwater Creek) at Curragh (PB, 2004). However, mine site catchment runoff behaviour can vary from site to site and catchment to catchment.

2) The site water transfers developed in the model have been assumed to be accurate and a true representation of how the site may transfer water. It is however important to note that the sites pumping infrastructure and transfers are not static, and can be changed by the site operators at any time to suit operational requirements.

3) The water balance model does not include any allowance for seepage or transmission loss from dams and open channel drains. This assumption will tend to overestimate mine water volumes in the mine water management system and potential salt loads. This is conservative from the perspective of assessing containment performance and release compliance, and also risks of prolonged water accumulation in the open cut mine pits. This assumption is not conservative for assessing the availability of mine water to be reused in mine operations.

4) The mine water balance model simulations are undertaken for a static configuration of the mine representative of a given point in time, which for the purposes of the project mine water balance assessment and baseline is nominally 2016, in accordance with the 16 August 2016 Lidar and Aerials.

The simulation periods are performed with the complete 127 years of climate data (to test extremes of climate influence) and time series results are produced for water volumes (or flows in waterways).

7.0 CLOSURE

We trust that this technical memorandum meets your immediate requirements in relation to DSA calculation by the method of operational simulation. Please contact us if you have any questions regarding the modelling method or results.

8.0 REFERENCES

Morton (1983)	Operational estimates of areal evapotranspiration and their significance to the science and practice of hydrology. Journal of Hydrology, Volume 66, 1-76.
PB (2004)	Curragh North Coal Mine – Hydrology, Flooding and Groundwater Report, Parsons Brinckerhoff, June 2004
WSP Parsons Brinckerhoff (2016)	'Curragh Extension Project, Groundwater Technical Report', Appendix B1 – supplementary advice. Parsons Brinckerhoff, June 2016.
WRM (2016)	Curragh Extension Project, Submission to IESC, Surface water balance impact assessment report, 16 June 2016.

Sarah Luu
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SL/SC/sl

Attachments: Stage Area Storage Tables

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Attachment 1: Stage Area Storage Tables

Table 4: RD7 Stage storage curve

Stage	Volume (m^3)	Area (m^2)
145	0	0
146	3,458	4,286
147	7,310	5,160
148	12,730	5,520
149	18,460	5,760
150	24,400	6,000
151	30,540	6,200
152	36,890	6,400
153	43,440	6,600
154	50,180	6,780
155	57,150	7,020
156	73,650	24,480
157	139,800	78,420
158	260,000	133,400
159	408,132	166,038
160	592,682	202,652
160.4	678,221	220,733

Summarised from ‘'Weekly Volumes July 2016 - June 2017' provided by Curragh (November 2016)

Table 5: RD3 Stage storage curve

Stage	Volume (m^3)	Area (m^2)
138	0	0
139	2,820	3,686
140	6,328	10,014
141	8,280	18,294
142	9,277	27,571
143	9,567	37,138
144	1,251	38,389
145	1,251	39,640
146	1,251	40,891
147	1,251	42,142
148	1,251	43,393
149	1,251	44,644
150	1,251	45,895
151	1,251	47,146
152	1,251	48,397

Summarised from ‘'Weekly Volumes July 2016 - June 2017' provided by Curragh (November 2016)

Table 6: Pit A Stage storage curve

Stage	Volume (m^3)	Area (m^2)
139.1	0	0
140	12,700	23,000
141	42,900	36,000
142	85,900	52,000
143	157,300	92,000
144	276,100	141,000
145	440,700	175,000
146	620,900	185,000
147	838,300	272,000
148	1,179,100	389,000
149	1,617,100	473,000
150	2,136,900	560,000
151	2,701,700	565,000

Summarised from ‘'Weekly Volumes July 2016 - June 2017' provided by Curragh (November 2016)

Table 7: Pit B Stage storage curve

Stage	Volume (m^3)	Area (m^2)
141.86	0	0
142.86	40,870	94,417
143.86	225,368	306,202
144.86	693,635	641,273
145.86	1,496,893	975,547
146.86	2,627,771	1,275,361
147.14	3,001,417	1,340,991
148.14	4,389,305	1,414,988

Developed by Golder

Table 8: RD1 Stage storage curve

Stage	Volume (m^3)	Area (m^2)
140	900	9,000
141	3,280	2,380
142	9,313	6,033
143	12,954	3,641
144	16,595	3,641
145	20,236	3,641
146	23,877	3,641
147	27,518	3,641
148	31,159	3,641
149	34,800	3,641
150	38,441	3,641
151	42,082	3,641
151.4	43,538	3,641

Summarised from ‘'Weekly Volumes July 2016 - June 2017' provided by Curragh (November 2016)

Table 9: RD30 Stage storage curve

Stage	Volume (m^3)	Area (m^2)
148.5	0	0
149	6,725	13,450
150	20,175	13,450
151	33,625	13,450
152	47,075	13,450
153	60,525	13,450
154	73,975	13,450
155	87,425	13,450
156	100,875	13,450
157	114,325	13,450
158	127,775	13,450
158.5	134,500	13,450

Summarised from ‘'Weekly Volumes July 2016 - June 2017' provided by Curragh (November 2016)

Golder Associates	Project	B Pit TSF
	Description	Stage 1 Embankment Wave Runup
	Job No.	1531363
	Eng.	DS
	Date	2-Mar-17

WIND ASSESSMENT			
Description	**Symbol**		**Unit**
Return Period	R	10	years
Wind Region (as per AS1170.2 Figure 3.1)	-	A (1 to 7)	m/s
3-second wind gust speed	V_R	34	m/s
Factor for Region C and D	F_C , F_D	1	-
Wind Direction Multiplier	M_d	1	-
Terrain/Height Multiplier	$M_{z,cat}$	0.75	-
Shielding Multiplier	M_s	1	-
Topographic Multiplier	M_t	1	-
Design Wind Speed	$V_{des,\theta}$	25.5	m/s
Gust Factor	$G_{T,to}$	1.6	-
n-year wind speed	**V_n**	**15.94**	**m/s**
required wind duratrion	t	**0.18**	hr

WAVE CLASSIFICATION			
Description	**Symbol**		**Unit**
Effective Fetch Length	F	0.47	km
Average Reservoir Depth	d	6.00	m
Over-land wind speed	U_L	15.94	m/s
Over-water wind speed	U_W	19.13	m/s
Wind Stress Factor	**U_A**	**26.77**	**m/s**
Deep Water Significant Wave Length	L_o	3.28	m
Required Wind Duration	t	0.18	hr
Depth/Wavelength	d/L	1.83	-
Wave Classification	**-**	**DEEP**	**-**

WAVE HEIGHT			
Description	**Symbol**		**Unit**
Deep Water Significant Wave Height	H_{mo}	0.30	m
Deep Water Significant Wave Period	T_o	1.45	s
Deep Water Significant Wave Length	L_o	3.28	m
Shallow Water Significant Wave Height	H	N/A	m
Shallow Water Significant Wave Period	T	N/A	s
Shallow Water Significant Wave Length	L	N/A	m

FREEBOARD REQUIREMENT			
Description	**Symbol**		**Unit**
Significant Wave Height	H_s	0.30	m
Significant Wave Period	T	1.45	s
Significant Wave Length	L	3.28	m
Embnakment Slope	α	1.00	m/m
Embankment Armor Material	-	wo or more layers of rock, (Hs/D=1.5 - 6.(	-
Influence angle of Incidence (direction of fetch relative to the dam axis)	β	0.00	°
Surf Similarity Factor	ξ_p	3.33	-
reduction factor for slope roughness	γ_r	0.50	-
reduction factor for influence of a berm	γ_b	1.00	-
reduction factor for shallow water conditions	γ_h	1.00	-
reduction factor for angle of incidence	γ_β	1.00	-
Coefficent dependant on ξp	A	-0.20	-
Coefficent dependant on ξp	C	4.50	-
Set-up Fetch	F_s	0.94	km
Wave Runup	**R**	**0.57**	**m**
Wind Setup	**S**	**0.01**	**m**
Minimum Required Freeboard	**(R+S)**	**0.58**	**m**

Golder Associates	Project	B Pit TSF
	Description	Stage 2 Embankment Wave Runup
	Job No.	1531363
	Eng.	DS
	Date	2-Mar-17

WIND ASSESSMENT			
Description	**Symbol**		**Unit**
Return Period	R	10	years
Wind Region (as per AS1170.2 Figure 3.1)	-	A (1 to 7)	m/s
3-second wind gust speed	V_R	34	m/s
Factor for Region C and D	F_C , F_D	1	-
Wind Direction Multiplier	M_d	1	-
Terrain/Height Multiplier	$M_{z,cat}$	0.75	-
Shielding Multiplier	M_s	1	-
Topographic Multiplier	M_t	1	-
Design Wind Speed	$V_{des,\theta}$	25.5	m/s
Gust Factor	$G_{T,to}$	1.6	-
n-year wind speed	**V_n**	**15.94**	**m/s**
required wind duratrion	t	**0.21**	hr

WAVE CLASSIFICATION			
Description	**Symbol**		**Unit**
Effective Fetch Length	F	0.59	km
Average Reservoir Depth	d	6.00	m
Over-land wind speed	U_L	15.94	m/s
Over-water wind speed	U_W	19.13	m/s
Wind Stress Factor	**U_A**	**26.77**	**m/s**
Deep Water Significant Wave Length	L_o	3.82	m
Required Wind Duration	t	0.21	hr
Depth/Wavelength	d/L	1.57	-
Wave Classification	**-**	**DEEP**	**-**

WAVE HEIGHT			
Description	**Symbol**		**Unit**
Deep Water Significant Wave Height	H_{mo}	0.33	m
Deep Water Significant Wave Period	T_o	1.57	s
Deep Water Significant Wave Length	L_o	3.82	m
Shallow Water Significant Wave Height	H	N/A	m
Shallow Water Significant Wave Period	T	N/A	s
Shallow Water Significant Wave Length	L	N/A	m

FREEBOARD REQUIREMENT			
Description	**Symbol**		**Unit**
Significant Wave Height	H_s	0.33	m
Significant Wave Period	T	1.57	s
Significant Wave Length	L	3.82	m
Embnakment Slope	α	1.00	m/m
Embankment Armor Material	-	Two or more layers of rock, (Hs/D=1.5 - 6.0)	-
Influence angle of Incidence (direction of fetch relative to the dam axis)	β	0.00	°
Surf Similarity Factor	ξ_p	3.39	-
reduction factor for slope roughness	γ_r	0.50	-
reduction factor for influence of a berm	γ_b	1.00	-
reduction factor for shallow water conditions	γ_h	1.00	-
reduction factor for angle of incidence	γ_β	1.00	-
Coefficent dependant on ξp	A	-0.20	-
Coefficent dependant on ξp	C	4.50	-
Set-up Fetch	F_s	1.18	km
Wave Runup	**R**	**0.63**	**m**
Wind Setup	**S**	**0.01**	**m**
Minimum Required Freeboard	**(R+S)**	**0.65**	**m**

APPENDIX H

Risk Assessment

HAZOP RISK ASSESSMENT – TABLE 1

RISK CATEGORY	CONSEQUENCE	
SAFETY Safety and health of personnel and public	1	loss of life or life threatening illness
	2	injury or illness causing maiming, loss of function or permanent disability
	3	recoverable injury or illness requiring immediate medical attention
	4	minor injury or illness requiring first aid or self treatment
	5	reportable incident, no injury
ENVIRONMENTAL HARM / REGULATORY Temporary or permanent impact on the environment, including regulatory impacts and remediation liabilities	1	severe impact requiring costly remediation, effects may be long term or unrecoverable
	2	significant impact requiring significant remediation
	3	significant temporary impact or minor permanent impact requiring remediation
	4	temporary or minor impact requiring clean-up or minor remediation
	5	no measureable impact
ENGINEERING / OPERATIONS / ASSETS Cost to repair or replace damaged assets and cost of lost production / time	1	>$10 million
	2	$1 million to $10 million
	3	$100,000 to $1 million
	4	$10,000 to $100,000
	5	<$10,000

PROBABILITY	
A	Almost certain, common (e.g. occurs weekly)
B	Likely (e.g. occurs several times a year)
C	Possible (e.g. occurs several times over the operational life)
D	Unlikely (e.g. occurs less than once in the operational life)
E	Rare (e.g. occurs less than once in 100 years)

OVERALL RISK MATRIX

PROBABILITY	CONSEQUENCE 1	2	3	4	5
A					
B					
C					
D					
E					

Legend:

Extreme Risk	Senior management decision making
High Risk	Senior management attention and additional engineering, if required
Moderate Risk	Manage by specific monitoring, operation and response procedures
Low Risk	Manage by routine procedures

Table 2: Pit B TSF Hazard Table - Initial Risks

HAZARD NUMBER	DESCRIPTION	RISK CATEGORY	IMPACT	INITIAL RISK		
				PROBABILITY	CONSEQUENCE	OVERALL RISK
1	Failure of embankment	Safety	Failiure of embankment leading to personnel being inundated	D	1	High
		Environmental Harm / Regulatory	Nil environmental harm, failure to meet regulatory conditions	E	1	Moderate
		Engineering / Operations / Assets	Damage to assets; potential for lost production time; reduction in tailings storage	D	1	High
2	Overtopping of embankment due to extreme rainfall	Safety	Failiure of embankment leading to personnel being inundated	D	1	High
		Environmental Harm / Regulatory	Nil environmental harm, failure to meet regulatory conditions	E	1	Moderate
		Engineering / Operations / Assets	Damage to assets; potential for lost production time; reduction in tailings storage; potential embankment failure	E	1	Moderate
3	Significant leak through embankment or foundation (piping/internal erosion)	Safety	Failiure of embankment leading to personnel being inundated	D	1	High
		Environmental Harm / Regulatory	Nil environmental harm, failure to meet regulatory conditions	E	1	Moderate
		Engineering / Operations / Assets	Damage to assets; potential for lost production time; reduction in tailings storage; potential embankment failure	D	1	High
4	Significant leak from tailings pipeline	Safety	Potential impact on vehicle taffficability where pipelines are located near roads	E	1	Moderate
		Environmental Harm / Regulatory	Possible flow into surface water drainage systems leading to Blackwater Creek ; damage to flora and fauna; land and water contamination	E	1	Moderate
		Engineering / Operations / Assets	Damage to assets; potential for lost production time	E	1	Moderate

Table 3: Pit B TSF Hazard Table - Residual Risks

HAZARD NUMBER	DESCRIPTION	RISK CATEGORY	IMPACT	RESIDUAL RISK UNDER MITIGATION MEASURES			RISK REDUCTION AND MITIGATION MEASURES
				PROBABILITY	CONSEQUENCE	OVERALL RISK	
1	Failure of embankment	Safety	Failiure of embankment leading to personnel being inundated	E	1	Moderate	- Monitor slope movement - Monitor phreatic conditions in embankment and tailings and maintain decant pond at or below the maximum design operating water level which will be subject to tailings placement. - Stop pumping tailings into the TSF, if necessary - Implement water level reduction measures such as pumping from vertical spears/bores in tailings and pumping decant water to external storages - Monitor embankment erosion - Conduct regular visits maintenance in accordance with regulatory guidelines (e.g. DERM and ANCOLD) and with Curragh Mine's Operation and Maintenance manuals - Prepare and implement plans for operations, monitoring, and emergency response
		Environmental Harm / Regulatory	Nil environmental harm, failure to meet regulatory conditions	E	5	Low	
		Engineering / Operations / Assets	Damage to assets; potential for lost production time; reduction in TSF storage	E	1	Moderate	
2	Overtopping of embankment due to extreme rainfall	Safety	Failiure of embankment leading to personnel being inundated	E	1	Moderate	- Reduce personnel exposure near TSF during wet weather - Maintain freeboard in accordance with regulatory guidelines (DERM, ANCOLD) - Monitor water level - Stop pumping tailings into the TSF, if necessary and divert to other avaiable storages - Implement water level reduction measures such as pumping decant water to external storages - Conduct regular visits maintenance in accordance with regulatory guidelines (e.g. DERM and ANCOLD) - Prepare and implement plans for operations, monitoring, and emergency response
		Environmental Harm / Regulatory	Nil environmental harm, failure to meet regulatory conditions	E	5	Low	
		Engineering / Operations / Assets	Damage to assets; potential for lost production time; reduction in tailings storage; potential embankment failure	E	5	Low	
3	Significant leak through embankment or foundation (piping/internal erosion)	Safety	Failiure of embankment leading to personnel being inundated	D	3	Moderate	- Conduct regular visits and maintenance in accordance with regulatory guidelines (e.g. DERM and ANCOLD) - Monitor phreatic conditions in embankment - Stop pumping tailings into the TSF, if necessary - Implement water level reduction measures such as pumping decant water to external storages - Monitor embankment erosion - Prepare and implement plans for operations, monitoring, and emergency response - If signs of piping / seepage are detected contact the design engineer to seek advice - Piping / seepage control measures may include placing a butress of coarse rejects against the downstream emabnkment
		Environmental Harm / Regulatory	Nil environmental harm, failure to meet regulatory conditions	D	3	Moderate	
		Engineering / Operations / Assets	Damage to assets; potential for lost production time; reduction in tailings storage; potential embankment failure	D	3	Moderate	
4	Significant leak from tailings pipeline	Safety	Potential impact on vehicle taffficability where pipelines are located near roads	E	5	Low	- Construct tailings pipeline to design specifications - Maintain design slurry composition with low water content so as to restrict the flow distance of a spill - Install automatic flow meters in pipes, with possible alarm and automatic shutdown - Include engineering measures such as low pressure water line for clearing blockages, injection points and cross over stations to re-direct slurry in event of failure or blockage - Construct a bund (catchment drain) the full length of the pipeline, with containment ponds - Construct a containment pond as a facility for flushing of the line during maintenance - Conduct regular visits and maintenance - Prepare and implement plans for operations, monitoring, and emergency response
		Environmental Harm / Regulatory	Possible flow into surface water drainage systems leading to Blackwater Creek ; damage to flora and fauna; land and water contamination	E	4	Low	
		Engineering / Operations / Assets	Damage to assets; potential for lost production time	E	5	Low	

Table 2: Pit B TSF Hazard Table - Initial Risks

HAZARD NUMBER	DESCRIPTION	RISK CATEGORY	IMPACT	INITIAL RISK		
				PROBABILITY	CONSEQUENCE	OVERALL RISK
1	Failure of embankment	Safety	Failiure of embankment leading to personnel being inundated	D	1	High
		Environmental Harm / Regulatory	Nil environmental harm, failure to meet regulatory conditions	E	1	Moderate
		Engineering / Operations / Assets	Damage to assets; potential for lost production time; reduction in tailings storage	D	1	High
2	Overtopping of embankment due to extreme rainfall	Safety	Failiure of embankment leading to personnel being inundated	D	1	High
		Environmental Harm / Regulatory	Nil environmental harm, failure to meet regulatory conditions	E	1	Moderate
		Engineering / Operations / Assets	Damage to assets; potential for lost production time; reduction in tailings storage; potential embankment failure	E	1	Moderate
3	Significant leak through embankment or foundation (piping/internal erosion)	Safety	Failiure of embankment leading to personnel being inundated	D	1	High
		Environmental Harm / Regulatory	Nil environmental harm, failure to meet regulatory conditions	E	1	Moderate
		Engineering / Operations / Assets	Damage to assets; potential for lost production time; reduction in tailings storage; potential embankment failure	D	1	High
4	Significant leak from tailings pipeline	Safety	Potential impact on vehicle taffficability where pipelines are located near roads	E	1	Moderate
		Environmental Harm / Regulatory	Possible flow into surface water drainage systems leading to Blackwater Creek ; damage to flora and fauna; land and water contamination	E	1	Moderate
		Engineering / Operations / Assets	Damage to assets; potential for lost production time	E	1	Moderate

Table 3: Pit B TSF Hazard Table - Residual Risks

HAZARD NUMBER	DESCRIPTION	RISK CATEGORY	IMPACT	RESIDUAL RISK UNDER MITIGATION MEASURES			RISK REDUCTION AND MITIGATION MEASURES
				PROBABILITY	CONSEQUENCE	OVERALL RISK	
1	Failure of embankment	Safety	Failiure of embankment leading to personnel being inundated	E	1	Moderate	- Monitor slope movement - Monitor phreatic conditions in embankment and tailings and maintain decant pond at or below the maximum design operating water level which will be subject to tailings placement. - Stop pumping tailings into the TSF, if necessary - Implement water level reduction measures such as pumping from vertical spears/bores in tailings and pumping decant water to external storages - Monitor embankment erosion - Conduct regular visits maintenance in accordance with regulatory guidelines (e.g. DERM and ANCOLD) and with Curragh Mine's Operation and Maintenance manuals - Prepare and implement plans for operations, monitoring, and emergency response
		Environmental Harm / Regulatory	Nil environmental harm, failure to meet regulatory conditions	E	5	Low	
		Engineering / Operations / Assets	Damage to assets; potential for lost production time; reduction in TSF storage	E	1	Moderate	
2	Overtopping of embankment due to extreme rainfall	Safety	Failiure of embankment leading to personnel being inundated	E	1	Moderate	- Reduce personnel exposure near TSF during wet weather - Maintain freeboard in accordance with regulatory guidelines (DERM, ANCOLD) - Monitor water level - Stop pumping tailings into the TSF, if necessary and divert to other avaiable storages - Implement water level reduction measures such as pumping decant water to external storages - Conduct regular visits maintenance in accordance with regulatory guidelines (e.g. DERM and ANCOLD) - Prepare and implement plans for operations, monitoring, and emergency response
		Environmental Harm / Regulatory	Nil environmental harm, failure to meet regulatory conditions	E	5	Low	
		Engineering / Operations / Assets	Damage to assets; potential for lost production time; reduction in tailings storage; potential embankment failure	E	5	Low	
3	Significant leak through embankment or foundation (piping/internal erosion)	Safety	Failiure of embankment leading to personnel being inundated	D	3	Moderate	- Conduct regular visits and maintenance in accordance with regulatory guidelines (e.g. DERM and ANCOLD) - Monitor phreatic conditions in embankment - Stop pumping tailings into the TSF, if necessary - Implement water level reduction measures such as pumping decant water to external storages - Monitor embankment erosion - Prepare and implement plans for operations, monitoring, and emergency response - If signs of piping / seepage are detected contact the design engineer to seek advice - Piping / seepage control measures may include placing a butress of coarse rejects against the downstream emabnkment
		Environmental Harm / Regulatory	Nil environmental harm, failure to meet regulatory conditions	D	3	Moderate	
		Engineering / Operations / Assets	Damage to assets; potential for lost production time; reduction in tailings storage; potential embankment failure	D	3	Moderate	
4	Significant leak from tailings pipeline	Safety	Potential impact on vehicle taffficability where pipelines are located near roads	E	5	Low	- Construct tailings pipeline to design specifications - Maintain design slurry composition with low water content so as to restrict the flow distance of a spill - Install automatic flow meters in pipes, with possible alarm and automatic shutdown - Include engineering measures such as low pressure water line for clearing blockages, injection points and cross over stations to re-direct slurry in event of failure or blockage - Construct a bund (catchment drain) the full length of the pipeline, with containment ponds - Construct a containment pond as a facility for flushing of the line during maintenance - Conduct regular visits and maintenance - Prepare and implement plans for operations, monitoring, and emergency response
		Environmental Harm / Regulatory	Possible flow into surface water drainage systems leading to Blackwater Creek ; damage to flora and fauna; land and water contamination	E	4	Low	
		Engineering / Operations / Assets	Damage to assets; potential for lost production time	E	5	Low	

APPENDIX I

Background Hydrogeology Reports

Curragh (2016). *D-E-F Pit Hydrology*, memorandum, 13 October 2016

Curragh (2015). *A Pit Geology / Groundwater Clarifications,* memorandum 14 August 2015

Wesfarmers Curragh Pty Ltd

MEMORANDUM

Date:	14 August 2015
To:	A Dawson-Evenhuis, E Ballot, S Bourke, C Heales
Copy:	G Gribble
From:	Susan Dippel Forster
Subject:	A Pit Geology/Groundwater Clarifications

Background

Two documents were produced in January 2013 regarding the hydrogeology of A Pit in view of plans to increase the volume of tails storage within that facility. The memos were written from a basis of a very conservative, 'worst case scenario' viewpoint in regard to the likelihood of tailings leakage into the adjacent Blackwater Creek. This document provides further information and clarification on the geology and likely groundwater interactions that were originally discussed in the 2013 memos.

Geology

The terminology of Recent sands/sediments was taken from and used in conjunction with information derived from the Parsons Brinckerhoff 2003 report (Tite and Grady, 2003) on Curragh North, which in turn was extracted from the Minserve Task No 10 and Task No 11 reports of 1998 (Boyd *et al.* 1998 and Hill *et al.* 1998). 'Recent' is the geological time scale terminology for the last 10,000 years and is also known as the Holocene Epoch. The sedimentary deposits which are included under this banner in the reference documents are referred to on site as Quaternary sands and Tertiary rocks.

The Quaternary Period dates from 2.58 million years ago to the present and at the Curragh mine sites refers exclusively to the thick, unconsolidated to semi-consolidated clay, sand and gravel alluvial deposits which overlie the Permian coal strata at Curragh North. Similar strata are rare to absent at Curragh (location of A Pit). The Tertiary (also known as the Cainozoic) Era covers a much broader range, beginning at 66 million years before present (b.p.) and stretches to the present day. At the mine sites the Tertiary is applied to those sediments which are older than the Quaternary sands but younger than the Permian (299-252 million years b.p.) coal strata. The Tertiary rocks are semi-consolidated to full cemented (former) gravels, sands and clays and are the dominant surface material around Curragh mine, including A Pit. Figure 1 shows the general distribution of surface rock types and is derived from the Geological Survey of Queensland QDEX data set.

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Private Mail Bag, Blackwater, Queensland, 4717 | Phone: (07) 4986 9211 | Fax: (07) 4986 9327

See More. Be More

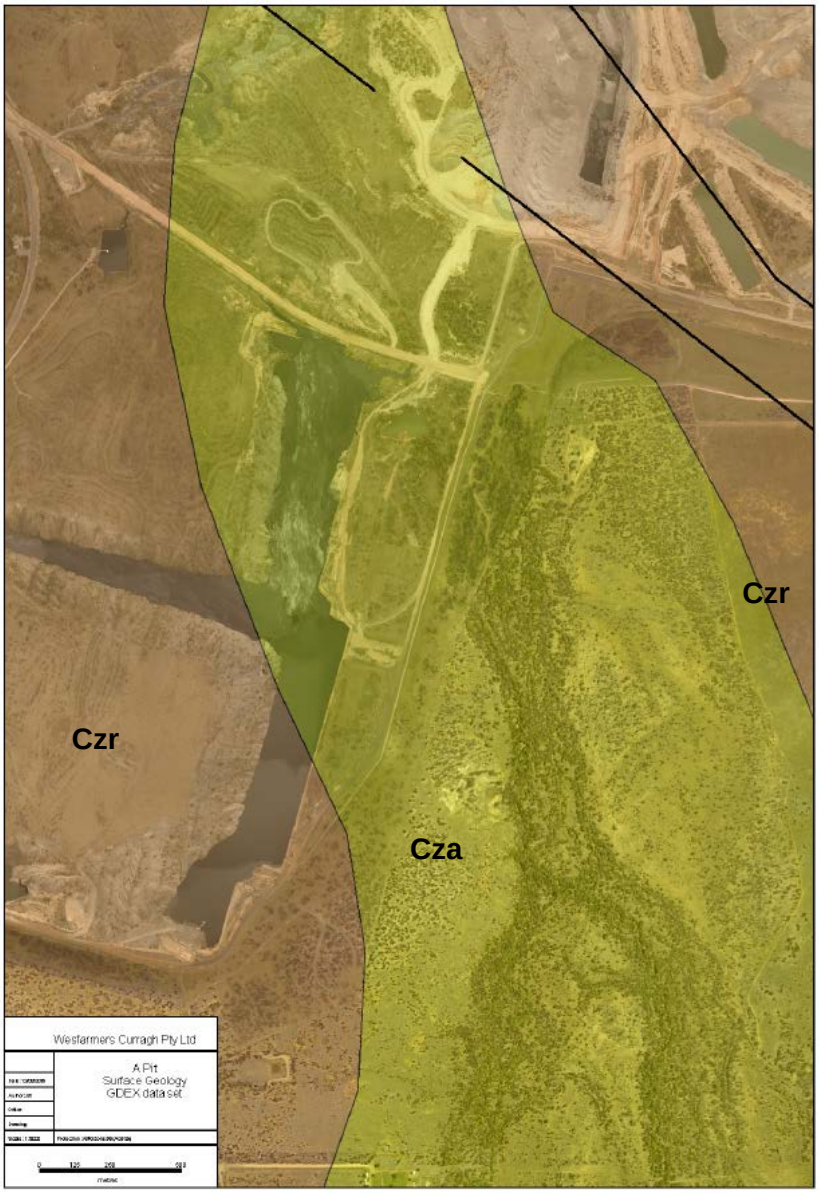


Figure 1. Surface Geology of the A Pit area

As shown on Figure 1, the QDEX datased identifies the two major rock types as follows:

Cza (river sediments):	Cainozoic Alluvium consisting of mainly clay, silt, sand and gravel.
Czr (either side of the river sediments)	Cainozoic Miscellaneous Unconsolidated Sediments – soil, alluvium, gravel, scree, 'billy', sand, duricrust.

Note that there is no further breakdown of the Cainozoic material into younger units.

At site, the Tertiary horizon is known to consist of closely interlayered, thin horizontal beds of lithified, fine-medium grained, quartzose clayey sandstone, siltstones and claystones with the occasional more friable, clayey-silty/sandy beds (poorly-consolidated sandstones) (Plate 1). The beds are generally of the scale of 5-10cm thick within an overall range of ~2.5-20cm and lie unconformably on the Permian Rangal Coal Measures. The major weathering profile generally extends to around two (2) metres below the contact. These sediments are lacustrine/fluviatile in origin, consisting of remnant channel or valley fill deposits that are 'somewhat re-cemented' (Boyd *et al.,* 1998; Malone *et al.*, 1969). The younger, unconsolidated to semi-consolidated Blackwater Creek sediments (mainly clays with occasional thin, sand/gravel lag beds) are thin and closely restricted to the path of the creek channels. These are identified as comprising mainly of reworked Tertiary sediments and laterites (Malone *et al.,* 1969).

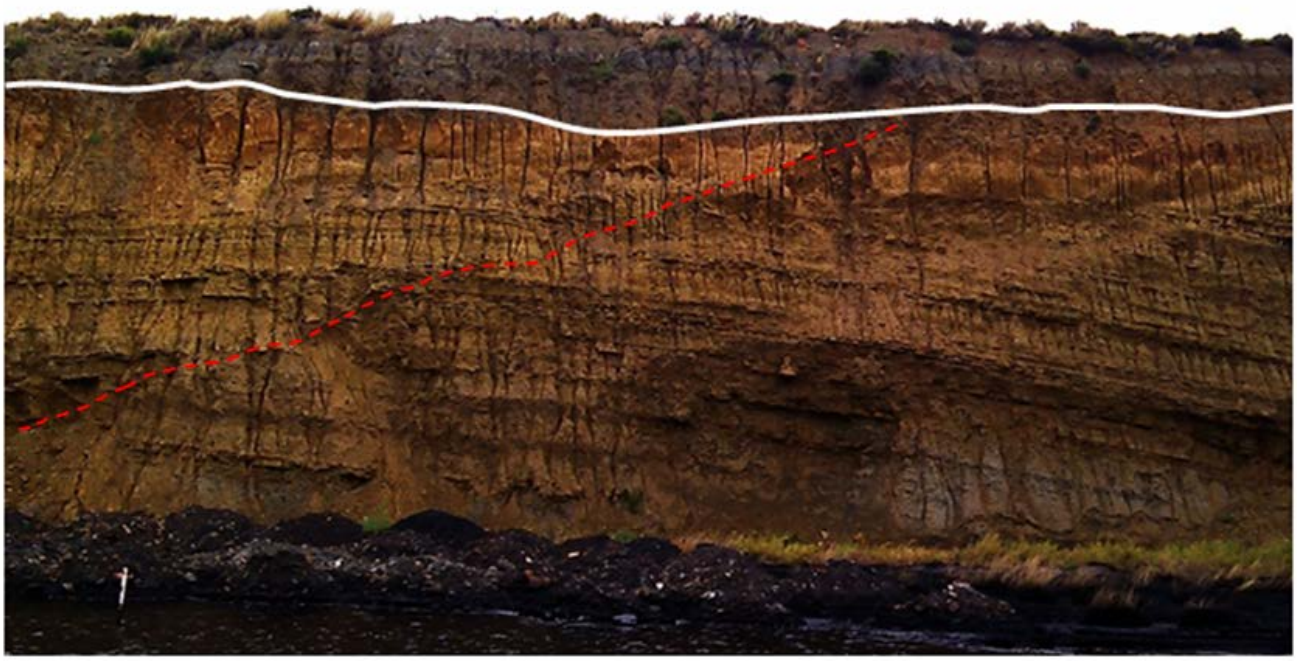


Plate 1. Exposed section of Tertiary sediments, north-eastern wall of A Pit. ~1m Quaternary alluvium (above white line) unconformaby overlies thinly interbedded Tertiary siltstone, claystone, sandstone and more friable sandy beds. The full profile is weathered and a fault (red dashed line) interrupts the bedding planes. Vertical extent is approximately 7m.

Overburden drilling consists of open holes which produce fines and small chips. As such it is almost impossible to accurately determine whether 'sand' horizons are from friable sands or from the consolidated sandstone beds. Samples are taken from metre down-hole intervals which, in the Tertiary

unit, will inevitably consist of a number of individual beds so the terms ‘sand’ or ‘sandy’ should be approached with caution when interpreting the bore logs for hydrogeological reasons and it should always be kept in mind that, unlike Curragh North, there are no thick (>0.5m) free sand beds and/or medium-coarse gravel lags at Curragh. Medium-coarse grained Tertiary sediments do occur at Curragh North but they are discontinuous and strongly cemented in the form of a conglomerate.

In line with their lacustrine/fluviatile deposition, the individual beds will be laterally discontinuous due to primary depositional onlap/offlap and interruption by palaeochannels and local structure as seen in Plate 1. The entirety of the Curragh leases is structurally complex, dominated by thrust faulting with subsidiary transcurrent faults. At the Curragh mine site thrust faulting is generally orientated around NNE-SSW with the transcurrent faults ENE-SSW. A Pit is slightly rotated to the east and has a major thrust fault mapped through the centre, offset at around Ramp 2 from the western side of the pit to the east by a transcurrent fault (Figure 2). Faults around the Curragh mine can act as either aquitards or aquifers although generally any water being released from fault zones is as seepage or at very low flow rates. It has not yet been identified whether there is any particularly consistent relationship between type and/or orientation of faulting and groundwater flow.



Figure 2. Major structures at the Curragh Mine Site.

Hydrogeology

Historically, groundwater work at Curragh as a whole has focussed on the coal seams rather than the overburden. The information contained in the 2013 memos was taken from the Tite and Grady (2003) who in turn had summarised it from the Minserve Task 10 and 11 reports (Boyd *et al.* and Hill *et al.*, 1998). In these, the Tertiary deposits were reported as being "quartz rich" with a "clay matrix which was variably cemented", containing between 20-50% fines in all materials and were considered as a whole to be "very stiff to hard, clay-rich sand, gravels and thick beds of ferruginous clays of medium to high plasticity" (Boyd *et al.*, 1998).

Tite and Grady (2003) summarised aquifer hydraulic data obtained from field testing from the 1998 reports, these being the results shown in Table 1 in the original 2013 documents as well as below. Although the hydraulic conductivity *(K)* of the Tertiary Sandy Gravels appears to be high, it is orders of magnitude less than that of the Quaternary sands from Curragh North which is reflected in the adopted *K* values used for modelling the Tertiary being at the lower end of the range for the equivalent Quaternary unit.

Table 1. Summary of hydraulic properties (from Tite and Grady, 2003)

	Measured hydraulic conductivity — K (cm/s)	Inferred hydraulic conductivity — K (cm/s)	Adopted K Values	
			cm/s	m/day
Quaternary Strata				
Silty clay	N/A	1×10^{-7} to 1×10^{-6}	1×10^{-6}	0.0009
Sand	3×10^{-4}	4×10^{-4} to 3×10^{-2}	1×10^{-4} to 1×10^{-2}	0.09 to 9
Sand/gravel	7×10^{-4} to 2×10^{-2}	1×10^{-2} to 6×10^{-2}	1×10^{-3} to 1×10^{-2}	0.9 to 9
Tertiary Strata				
Sandy gravels	N/A	1×10^{-4} to 1×10^{-2}	1×10^{-3}	0.9
Claystone/other cemented strata	N/A	1×10^{-5} to 1×10^{-4}	5×10^{-4}	0.43
Permian Strata				
Sheared/fractured Coal	$1x\ 10^{-5}$ to $1x\ 10^{-4}$	—	$1x\ 10^{-5}$ to $1x\ 10^{-4}$	0.009 to 0.09
Intact Coals	$1x\ 10^{-5}$ to 2×10^{-5}	—	$2x\ 10^{-5}$	0.02
Overlying rocks (Intact)				
K Horizontal	—	$1x\ 10^{-5}$ to 1×10^{-6}	5×10^{-6}	0.004
K Vertical		$1x\ 10^{-6}$ to $1x\ 10^{-7}$	1×10^{-6}	0.0009

Table 2 shows the adopted *K* values on a chart of average hydraulic properties. From this it can be seen that the Tertiary sandy gravels (orange) fall in the range of semi-pervious for Relative Permeability and would be classed towards the top end of a Poor aquifer while the claystone/cemented strata (pink) are lower down the Relative Permeability range and in the middle of the Poor aquifer classification.

Table 2. Summary of average hydraulic properties. (modified from Bear, 1972, downloaded from Wikipedia 13 Aug 2015)

K (cm/s)	10^{2}	10^{1}	10^{0}=1	10^{-1}	10^{-2}	10^{-3}	10^{-4}	10^{-5}	10^{-6}	10^{-7}	10^{-8}	10^{-9}	10^{-10}
K (ft/day)	10^{5}	10,000	1,000	100	10	1	0.1	0.01	0.001	0.0001	10^{-5}	10^{-6}	10^{-7}
Relative Permeability	Pervious				Semi-Pervious					Impervious			
Aquifer	Good					Poor				None			
Unconsolidated Sand & Gravel	Well Sorted Gravel		Well Sorted Sand or Sand & Gravel			Very Fine Sand, Silt, Loess, Loam							
Unconsolidated Clay & Organic					Peat		Layered Clay			Fat / Unweathered Clay			
Consolidated Rocks	Highly Fractured Rocks				Oil Reservoir Rocks			Fresh Sandstone		Fresh Limestone, Dolomite		Fresh Granite	

Due to the stratified nature of the deposit, if any fluid leaks from the A Pit tails it may be horizontal and via the semi-pervious, poor aquifer sandy layers. These are confined above and below by the cemented strata which are likely to be impermeable with similar vertical *K* values as shown in Tables 1 and 2 (shaded green) for the Permian rocks (sandstones and siltstones). These results, when considered in conjunction with the lack of horizontal continuity (depositional and structural) and high fines (clay/silt) content, suggest that the potential for leakage from A Pit is severely limited and would occur very slowly. The water quality of the tails is alkaline (average pH 8.02) which may also be expected to assist in slowing fluid progress by effectively chemically interacting with the individual grain particles to reduce existing pore throat sizes by precipitation of mineralisation onto the existing particles.

The regional topographic surface dips around east and plunges north-east, driving the regional drainage patterns generally towards the north-east. The base of weathering in the area of A Pit (modelled from drilling) follows the surface topography, with the low point being association with

Blackwater Creek. The three sections shown below (Figures 3 and 4) illustrate the relationship between the topography, interpreted sand-dominated unit, the modelled base of the Tertiary and base of weathering through the northern half of A Pit.

Material surrounding the 'sandy' unit within the Tertiary is clay. For the northern and central sections it should be noted that the 'sand' stops well short of the levee and major creek channels and that there is a dip in the base of the Tertiary between the 'sand' and the creek channels with the surface rising again to ~146m RL below the main creek channels east of the levee. The low point is at approximately 141m RL while the current surface of the creek beds (identified from Lidar) ranges from around 151m to 149m RL. There is currently some standing water in the main creek channel, with a surface (from Lidar) of around 149.8m RL, although the rest of the channels are dry. This water is believed to be effluent from the Blackwater town sewerage treatment and water treatment plants, located approximately two kilometres upstream. Note that the southern section modelling is severly constrained by lack of drilling data away from A Pit. Currently (July 2015 Lidar) the beach surface of the tails on the north-eastern side of A Pit is at around 149.5m RL and the pit water is at 145.6m RL.

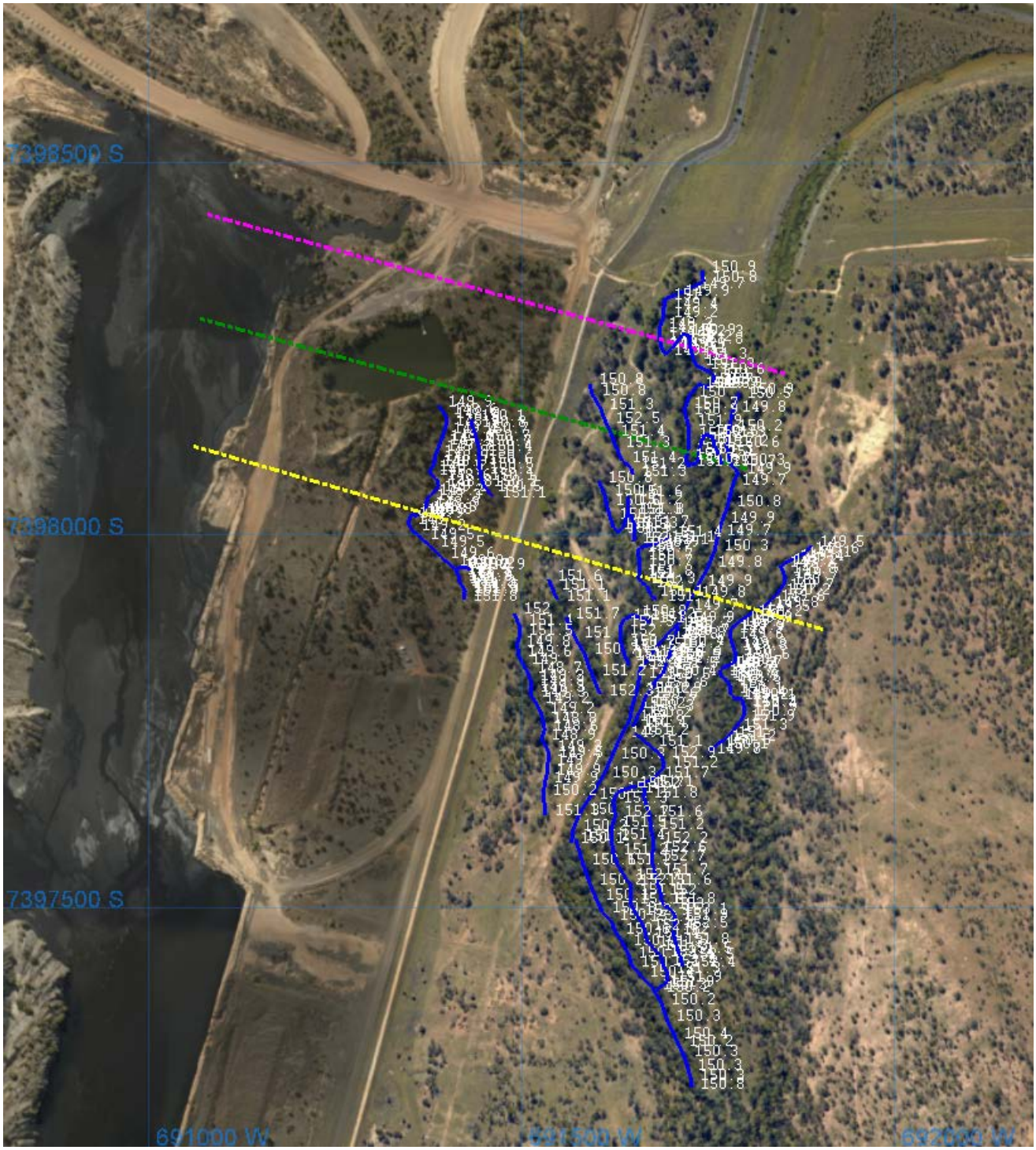


Figure 3. Creek channel RLs (from Lidar) and section line locations as shown in Figure 4.

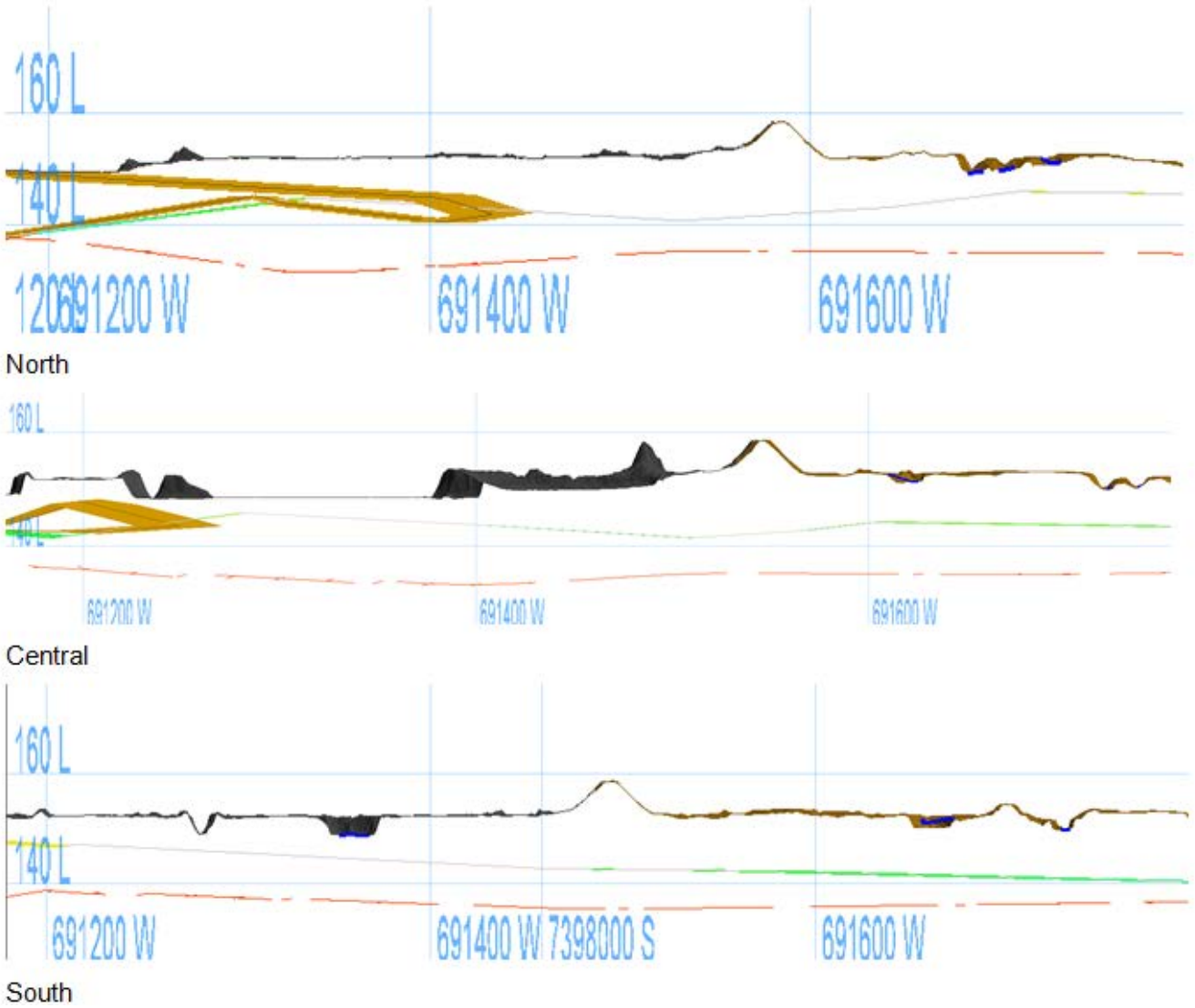


Figure 4. Cross-sections, northern A Pit to Blackwater Creek. 3x vertical exaggeration.

Seven water monitoring bores were drilled in 2013 to form two lines of monitoring points between A Pit and Blackwater Creek. 1301A/1301B are between the northern end of the pit and Retention Dam 1 (RD1), which is located within the nearest sub-channels of the creek while 1304A/1304B are south-east of RD1, still within the creek sub-channels. Both sites are west of the main creek channel and of the levee separating the mine area from the creek (Figure 5).

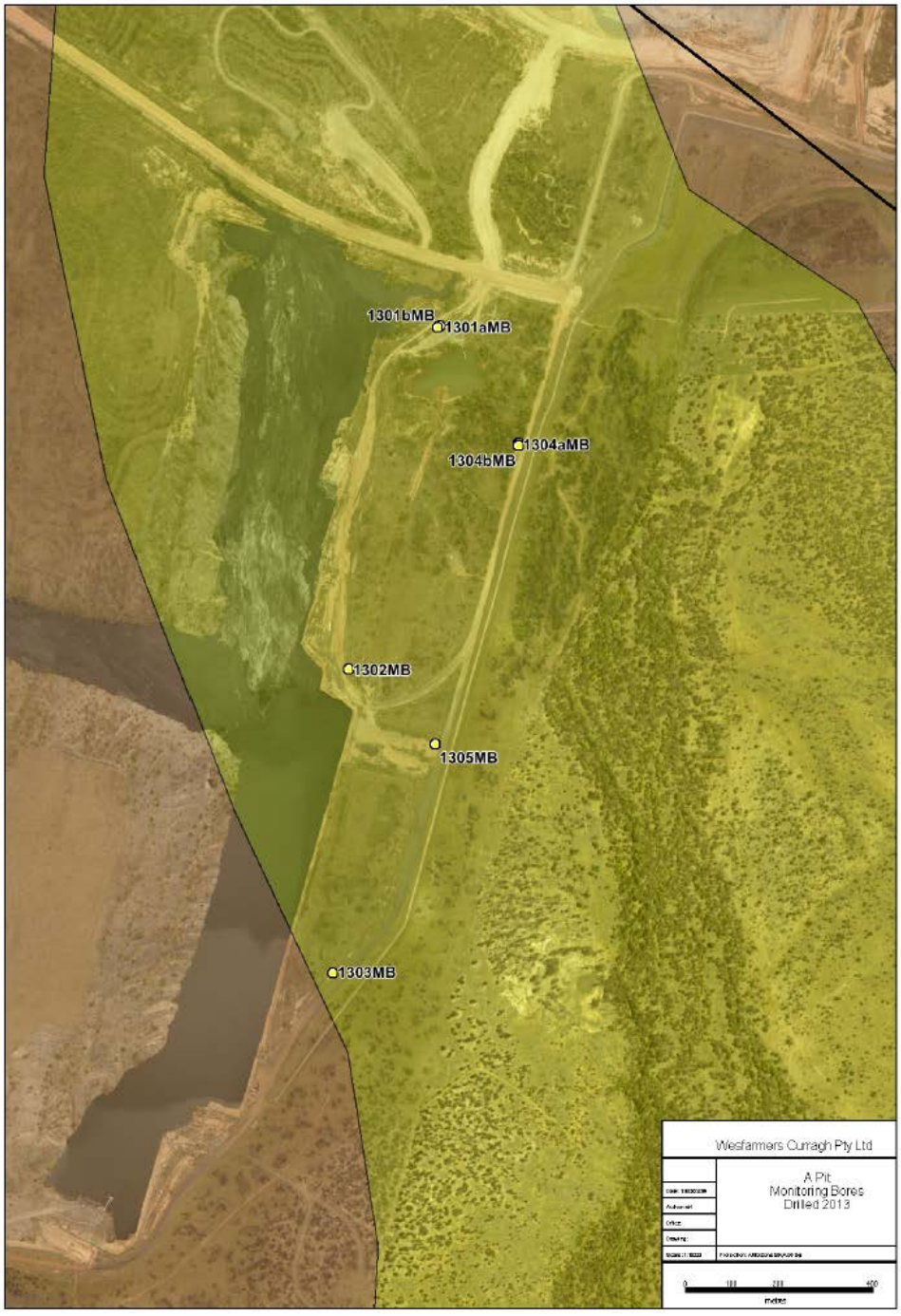


Figure 5. Monitoring bore network, A Pit

Bores 1302MB, 1303MB and 1305MB are dry, with 1301A/B and 1304A/B being regularly monitored and sampled. During drilling all bores were drilled to intersect the Tertiary and were logged as being dominated by clay, silty/sandy clay or mudstone/claystone, with few horizons identified as 'sand'. The two bores designated as A were shallower and designed to intersect the sandier horizons while those designated B were deeper and interstected the clay rich zones immediately above the contact with the

intact, although weathered, Permian sub-strata. At the last round of water monitoring (May 2015) the available standing water levels were:

Table 3. Standing water levels and water quality in monitoring bores between A Pit north and Blackwater Creek

BORE ID	SWL (mbgl)	SWL (m RL)	Flow rate (L/min)	Field pH	Field EC µS
1301A MB (shallow)	6.18	145.65	<0.1	7.41	9220
1301B MB (deep)	5.96	145.74	0.3	6.6	16410
1304B MB (deep)	6.32	147.01	<0.05	6.52	2860

These are all below the surface of the dry creek beds and the water contained within the main creek channel east of the levee but similar to the SWL of the pit water. Flow rates were extremely low. The water quality in the bores is, however, notably different to that in the tails, where the average pH is 8.02 and the average EC is around 3000µs.

Summary

The Tertiary sediments of concern between A Pit and Blackwater creek and a thinly interlayered sequence of clay-rich, quartzose sandstone/siltstone/claystone with some beds of more friable sandy material which is also dominated by fine (silt/clay) particles. Individual beds are laterally discontinuous due to both depositional and structural factors and the friable beds are confined above and below by cemented units. The Tertiary 'sand' units to the west of the main creek tend to pinch out to the east while any younger (Quaternary) material at the topographical surface is thin (around 2m deep) and dominated by clays away from the immediate creek beds. The base of the Tertiary material drops to a low point 100-200m west of the main creek channel before rising again to a high beneath the current creek.

K is estimated to be low for all types of material with almost no possibility of vertical leakage. Any likely leakage will be horizontal and this will be limited by the lack of lateral continuity within the most permeable units as well as chemical interactions between the alkaline pit tails water and the rock particles. As such, it appears highly unlikely that anything other than very minor seepage would occur if the surface level of the tailing beach was raised and the seepage would concentrate in the low point of the stratigraphy and be at least partly self-sealing through chemical interactions along its flow path.

References

Bear, M. 1972. *Dynamics of Fluids in Porous Media.* Dover Publications.

Boyd, G., Henderson, S., Gough, J. 1998. Task No. 10. Geotechnical Services. IN Minserve. 1998. *Report on the Feasibility Study for the Development of the Jellinbah Station Coal Deposit.* Stanwell Corporation Report

Hill, C., Henderson, S., Dixon, M., Isaacs, L. 1998. Task No. 11. Hydrogeology. IN Minserve. 1998. *Report on the Feasibility Study for the Development of the Jellinbah Station Coal Deposit.* Stanwell Corporation Report.

Malone, E.J., Olgers, F., Kirkegaard, A.G. 1969. *The Geology of the Duaringa and Saint Lawrence 1:250,000 Sheet Areas, Queensland.* Bureau of Mineral Resources Report No. 121.

Tite, B. and Gray, J. 2003. *Curragh North Coal Mine. Hydrology, Flooding and Groundwater Report.* Parsons Brinckerhoff report 2132105!-PR001Cbt.

Memorandum

Date:	13 October 2016
To:	B McIntyre, M Stewart
Copy:	S O'Leary, P Wood
From:	S Dippel Forster
Subject:	D-E-F PIT HYDROLOGY

A request was received on Friday 7 October last for information on the hydrology of D Pit. This memo summarises the currently available information for the entire area between D, E and F Pits.

Physical Setting

The area of concern straddles the remnants of the original course of Blackwater Creek (Figure 1). Blackwater Creek is a tributary of the Mackenzie River and drains to the north-east. It is an ephemeral creek with deeply incised, braided channels which split and re-join each other through the central part of the proposed mining zone. In the immediate area the channels, although now detached from their headwaters by means of the creek diversion to the east of the current mine, still retain water for some time after major rain events. However, for the majority of the time the creek beds are dry, indicating no natural baseflow from groundwater (Rochford & Kwantes, 2016).

Geology

The stratigraphy for the area is shown in Figure 2 and Table 1. Within the zone Quaternary alluvium (a fining upwards, laterally variable fluvial channel fill sequence of clay, silt, sand and gravel) is closely tied to the current river channels with older Tertiary material (soil, alluvium, gravel, screen, billy, sand and duricrust) found at surface further away on either side (Figure 3). These Cainozoic-age sequences overlie the Permian rocks containing the coal measures (Rewan Formation, Rangal Coal Measures and the Burngrove Formation).

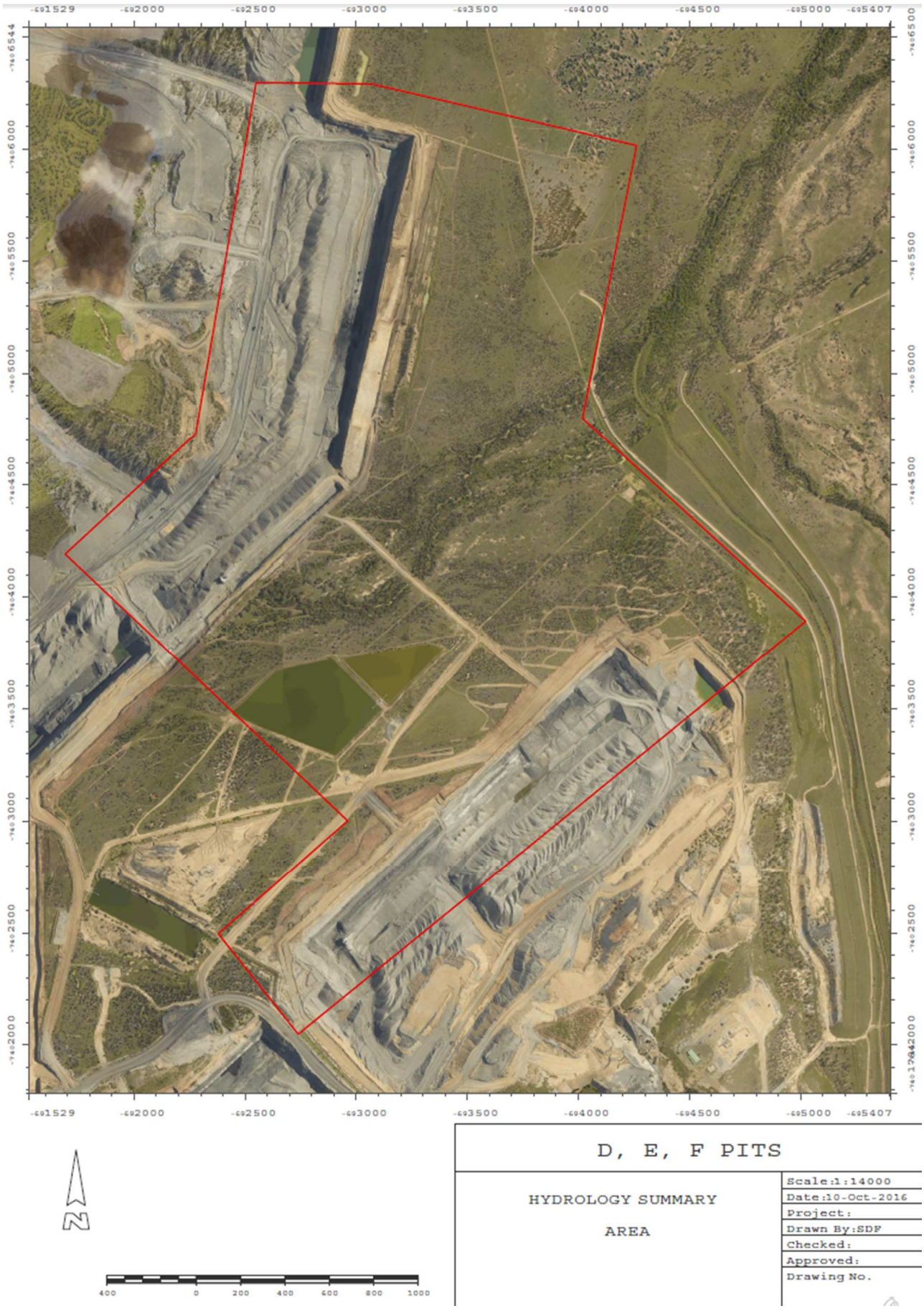


Figure 1. Study Area

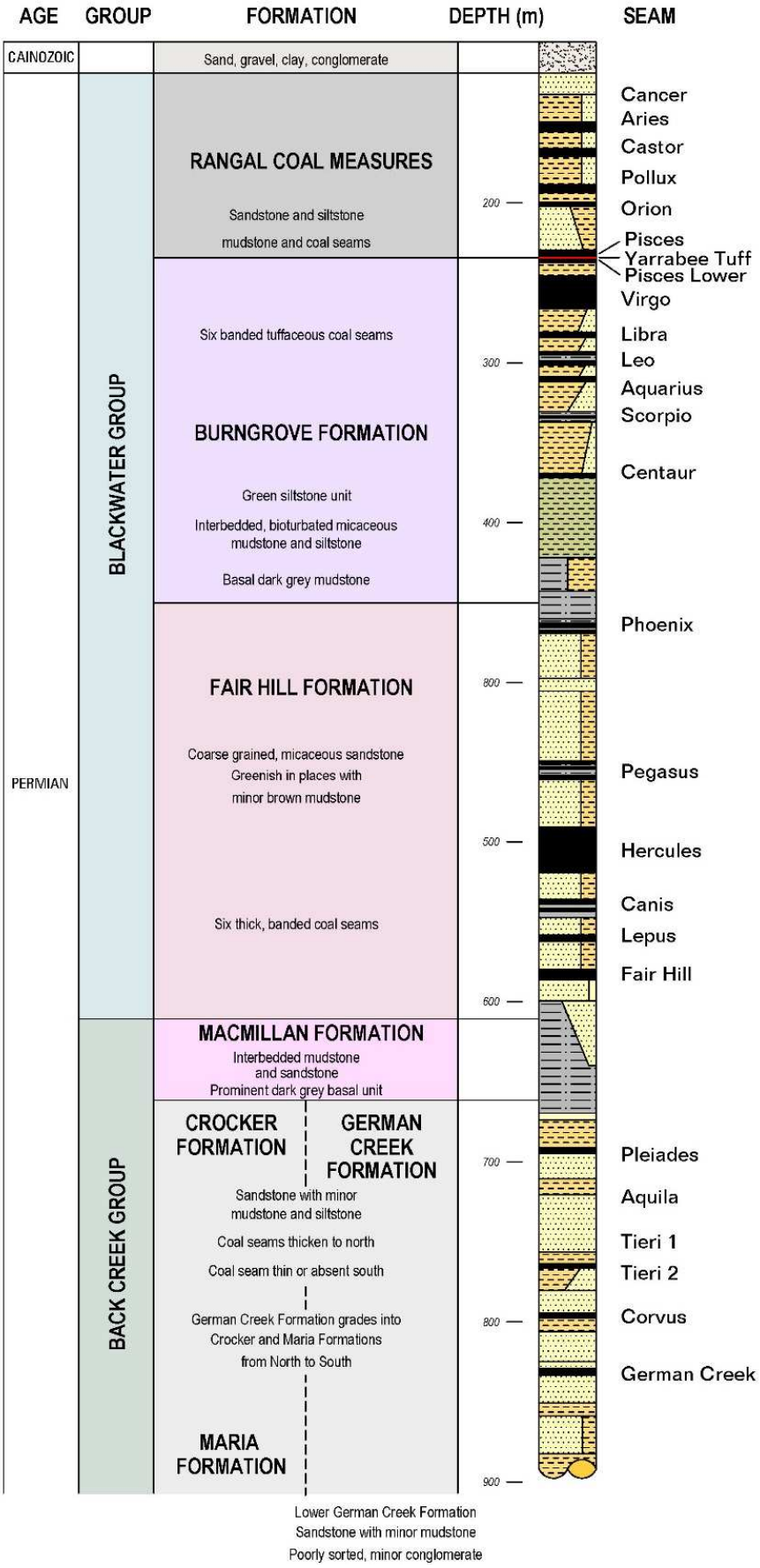


Figure 2. Blackwater coalfield stratigraphic sequence.

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Age	Group	Stratigraphic unit	Lithology
Quaternary and Tertiary		Alluvium	Alluvial sand, silt and gravel.
Tertiary		Duaringa Formation/Emerald Formation	Mudstone, sandstone, conglomerate, siltstone, oil shale, lignite and basalt. Sediments are weakly consolidated in parts.
Triassic	Mimosa Group	Rewan Formation	Mudstone, interbeds of lithic sandstone.
Late Permian	Blackwater Group	Rangal Coal Measures (including the Bandanna Formation and Baralaba Coal Measures)	Carbonaceous mudstone, siltstone, coal, feldspathic and lithic sandstone, calcareous in places, tuff.
		Burngrove Formation	Carbonaceous mudstone, thinly interbedded mudstone and fine lithic sandstone, siliceous siltstone, calcareous lithic and feldspathic sandstone.
		Fair Hill Formation	Lithic and feldspathic labile sandstone, quartzose sublabile sandstone, siltstone, mudstone, calcareous and tuffaceous sandstone, volcanic conglomerate, carbonaceous mudstone, coal.
Permian	Back Creek Group	Macmillan Formation	Interbedded mudstone and sandstone, prominent dark grey basal unit.

Table 1. **Stratigraphy** (from Rochford & Kwantes, 2016)

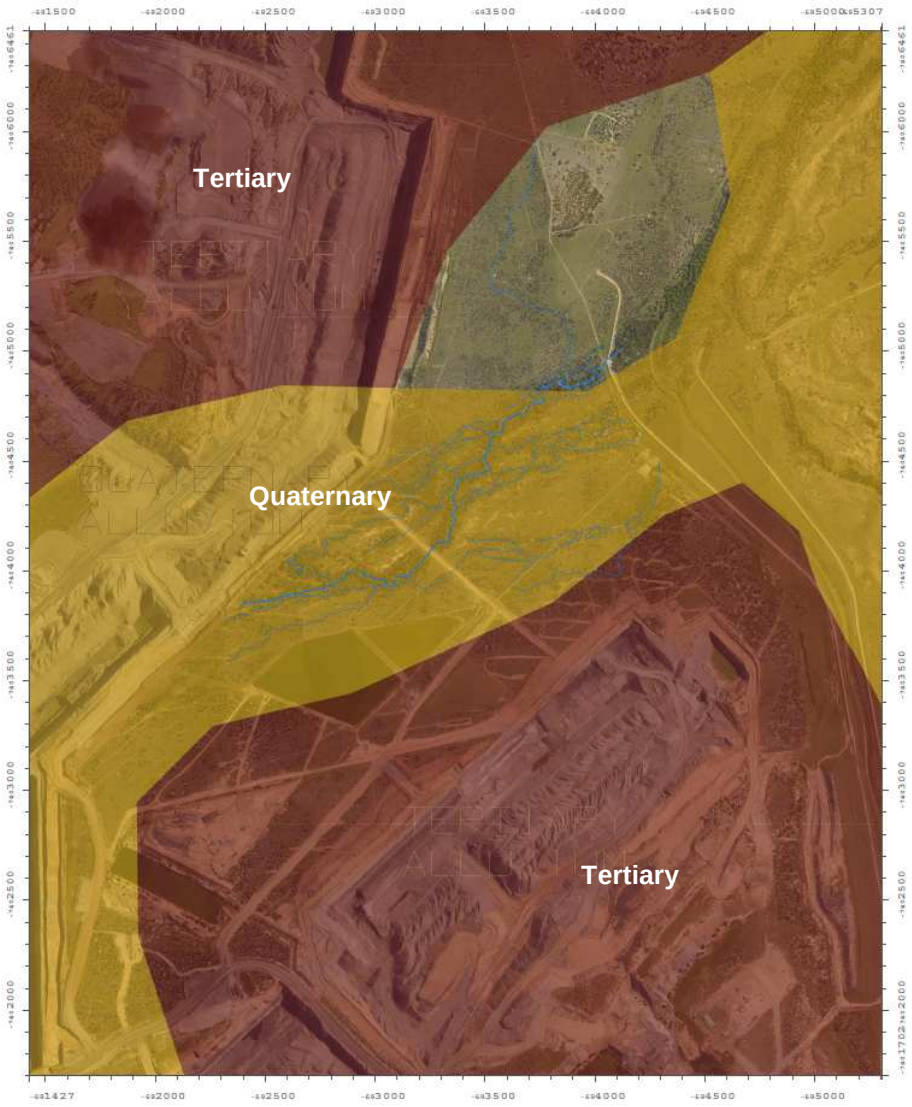


Figure 3. Quaternary and Tertiary unit extents

Quaternary sands are generally less than two metres thick with the major deposits (4-12m thick) constrained to the central parts of the current river system (Figure 4). These tend to occur as lenses with minimal to no interconnection that are in alignment with the creek directions and range in size from as little as 100m x 100m to 500m x 250m. The average thickness of the Quaternary sequence as a whole is 4-6m overall and around 10m in the deeper channel areas. The sand lenses are enclosed by silts and clays within the thickest and deepest parts of the Quaternary alluvium and are incised into the more consolidated, clay-rich Tertiary sediments and so are likely to only form discrete perched aquifers rather than one larger aquifer (Figure 5).

The Tertiary sediments have been identified as interbedded stiff to hard clay rich sands, gravels and thick beds of ferruginous clays of medium to high plasticity from the Duaringa Formation. They are remnant channel (fluvial) or valley (colluvial) fill and are partly cemented (Minserve, 1998).

The underlying Triassic and Permian sediments are the Rewan Formation and the Rangal Coal Measures respectively (Figure 6). The Rewan Formation consists of thinly interbedded mudstones, lithic standstones and siltstones and the Rangal Coal Measures are fine-medium grained lithic sandstone with siltstones and mudstones enclosing the coal seams and some carbonaceous mudstone. Overall the dip of this units is around 3° to the east but this can increase to grea ter than 10° in areas affected by structure. Due t o the predominance of very fine grains, silt and mud/clay in these units and from evidence visible in open pit highwall faces these rocks act as aquitards rather than aquifers, resulting in little or no filtration of groundwater through the rocks themselves although there is minor weeping from some structures or bedding planes.

The upper parts of these units are weathered where they come into contact with the overlying Tertiary/Quaternary sediments or structure. The average depth of the weathering profile in the Triassic/Permian sediments in the area is six to eight metres below the contact with the alluvium but can increase to over 12m in areas of faulting. The area is structurally complex with the deeper weathering profile occurring below the current river channels between major transcurrent faults (Figure 7). Taken from surface, the average depth to the base of weathering is 12-15m through the centre, extending to more than 20m to the north and south.

Dominant structures in the zone are closely spaced NNW-SSE trending thrust faults. These are off-set by a number of approximately east-west transcurrent faults. The latter tend to be very steeply dipping while the former are more flat-lying and comprise mostly fore-thrusts with some back-thrusts. All faults have a sinuous trace (Figure 8).

Conceptual geological cross-sections through D pit and E-F pits taken from Rochford & Kwantes (2016) are shown in Figures 9 to 11.

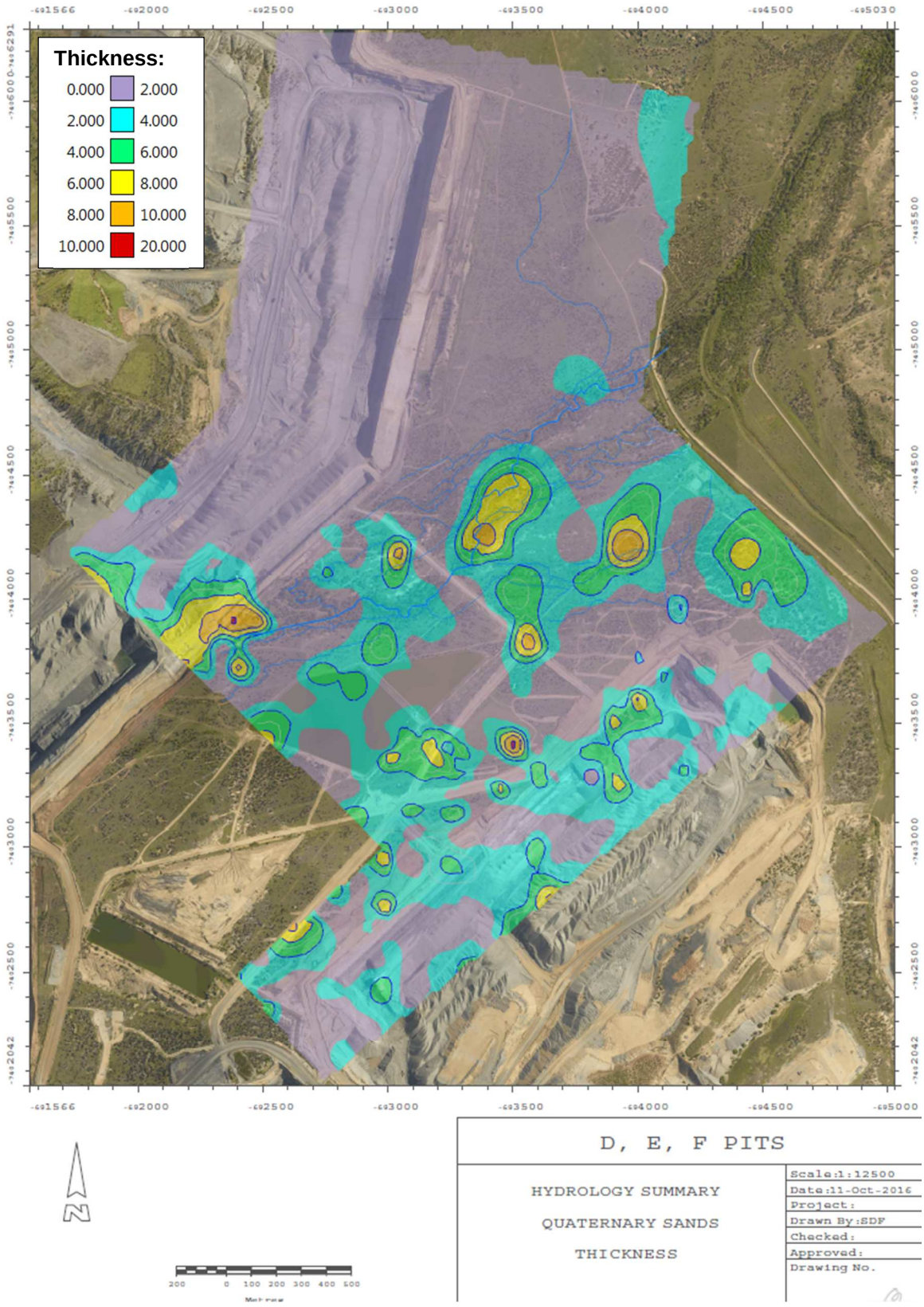


Figure 4. Quaternary sand thickness plot

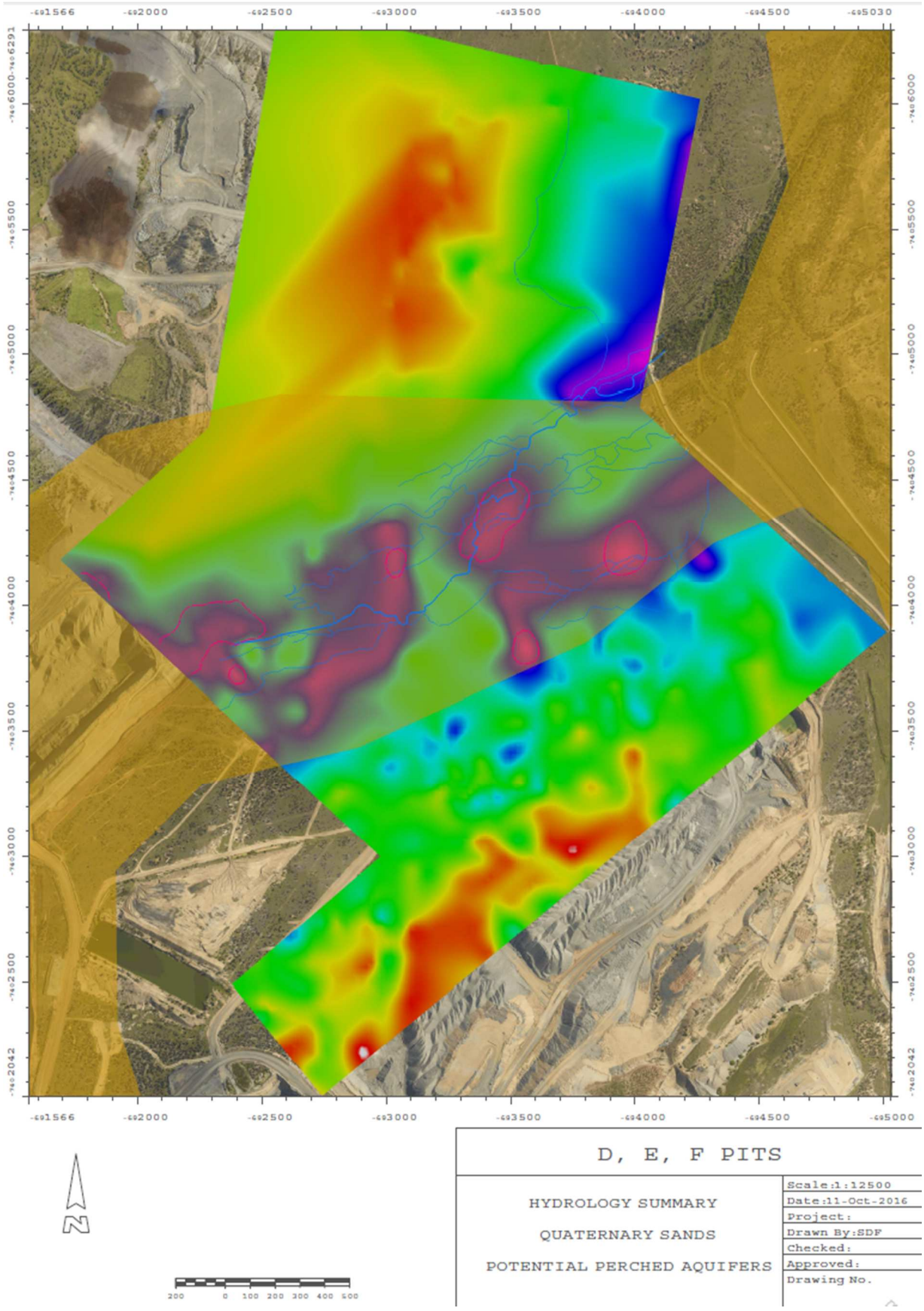


Figure 5. Potential perched aquifers (outlined in pink) on modelled base of Quaternary

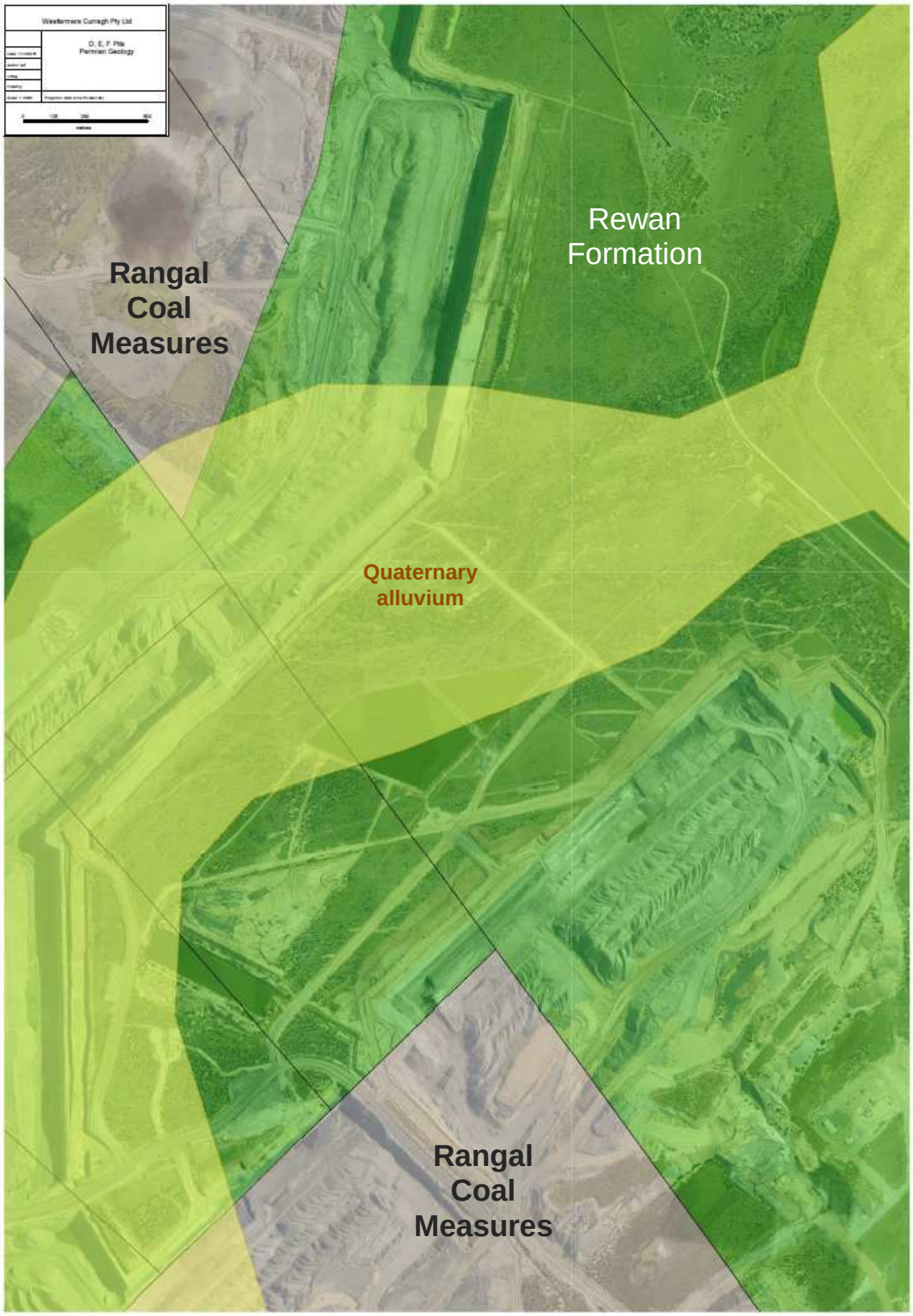


Figure 6. Triassic and Permian Geology

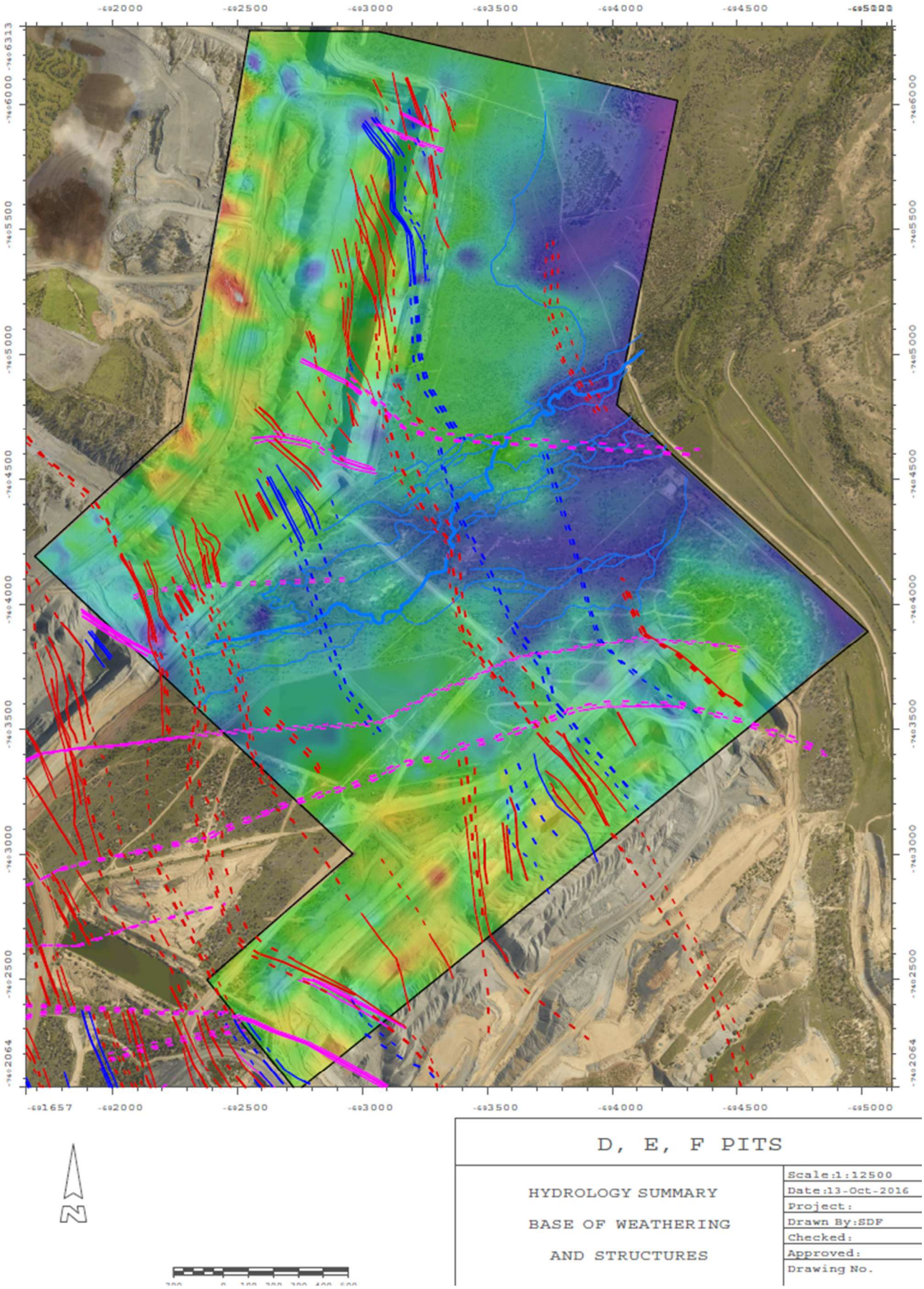


Figure 7. Base of weathering and structures (Red = shallow → Purple = deep)

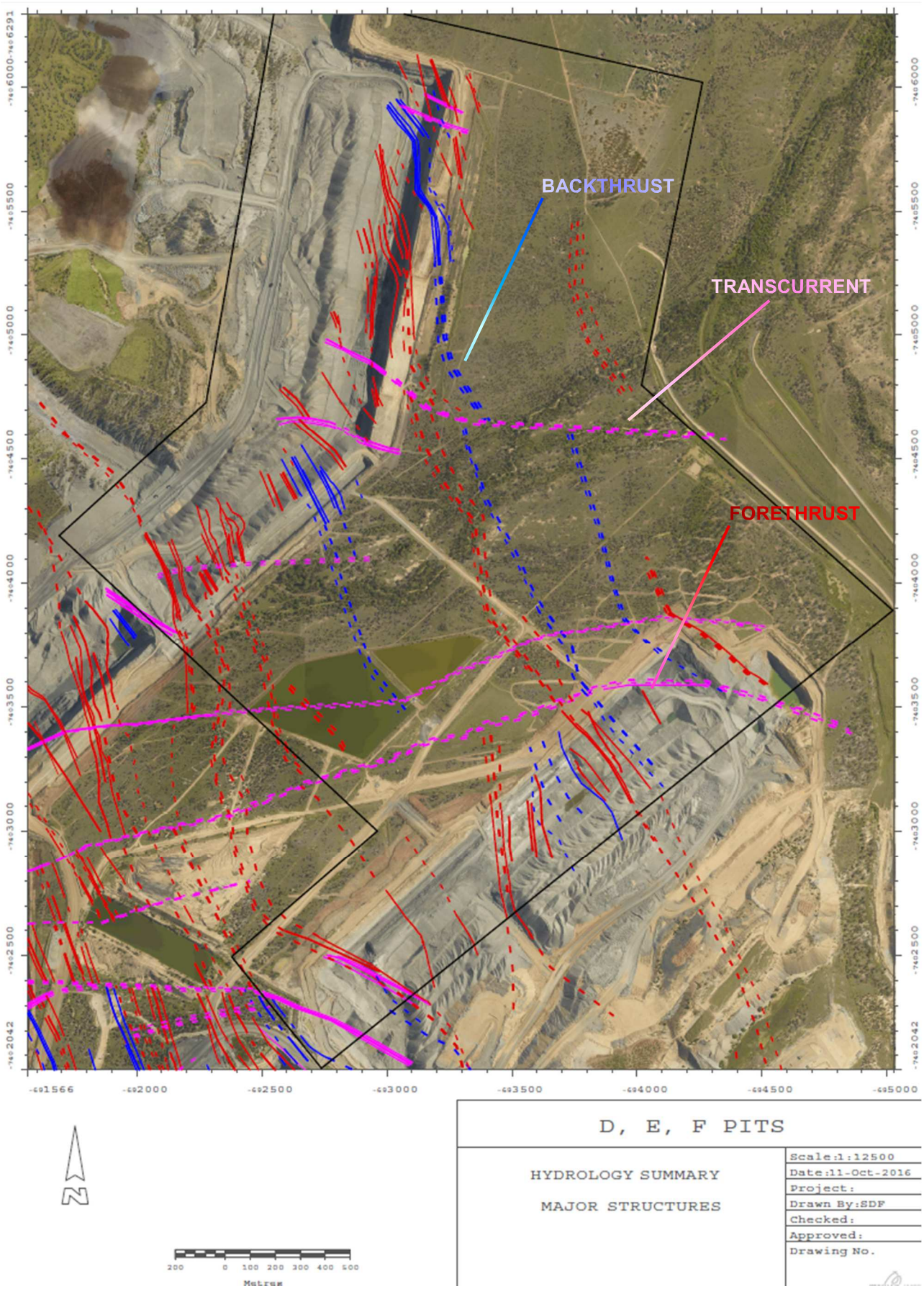


Figure 8. Major structures

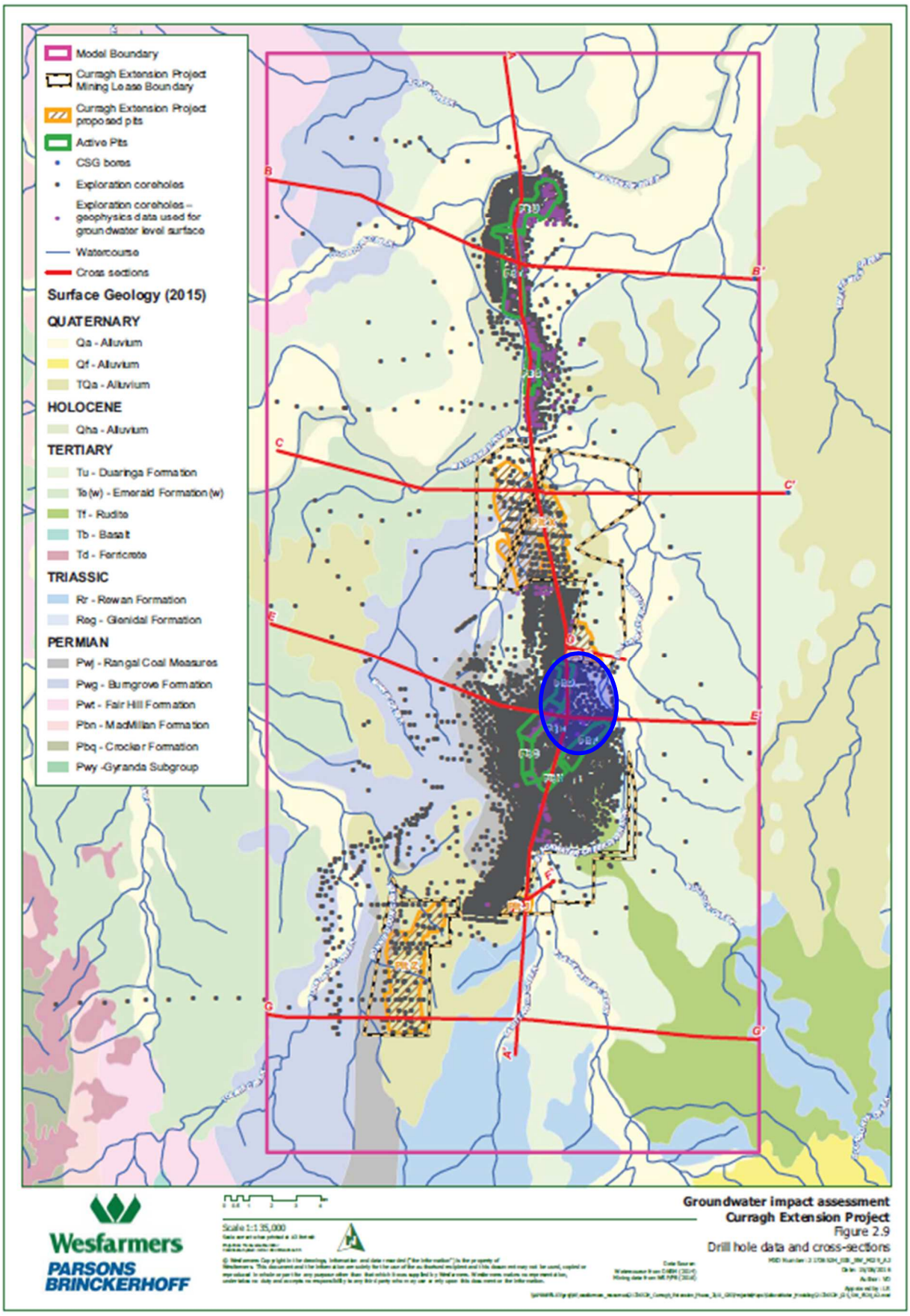


Figure 9. Cross section D-D' and E-E' location (from Rochford & Kwantes, 2016)

This study area circled in blue

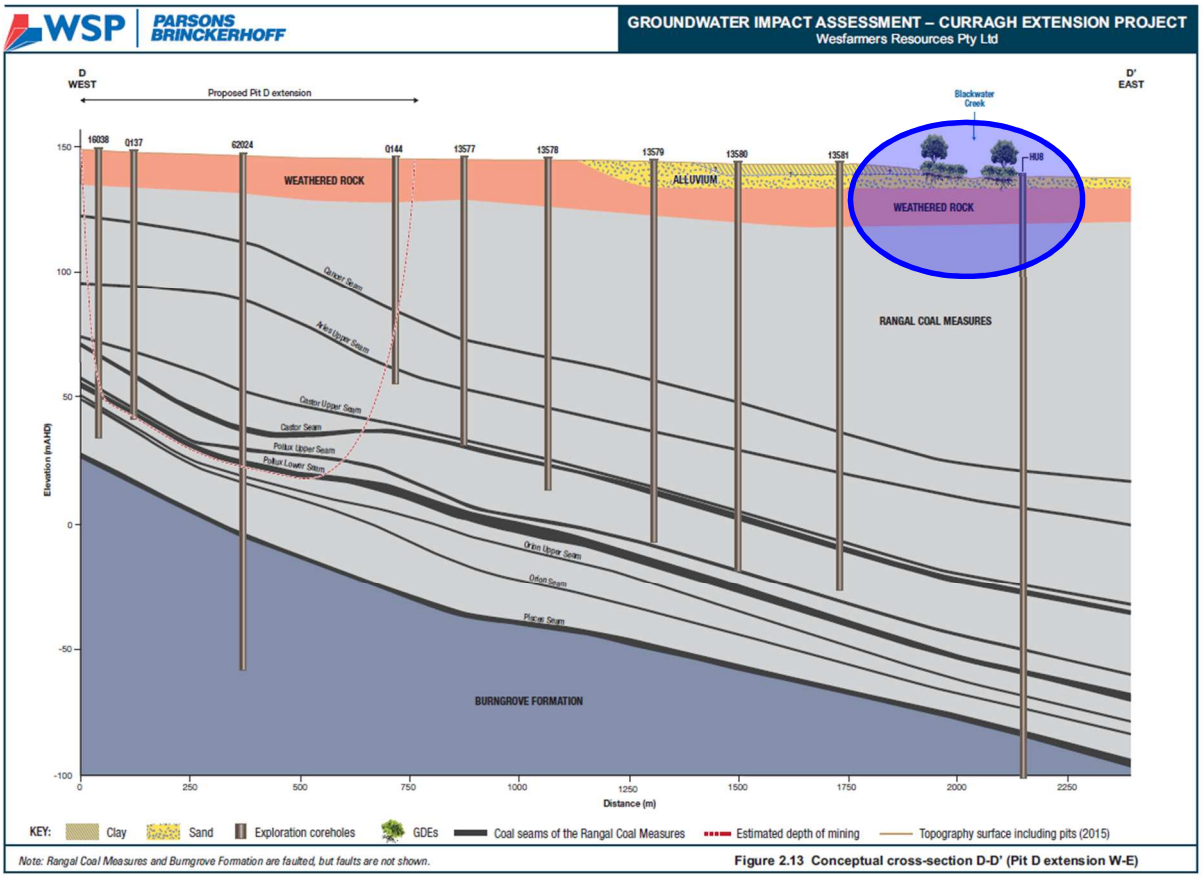


Figure 10. Geology Cross-section D-D' (from Rochford & Kwantes, 2016)

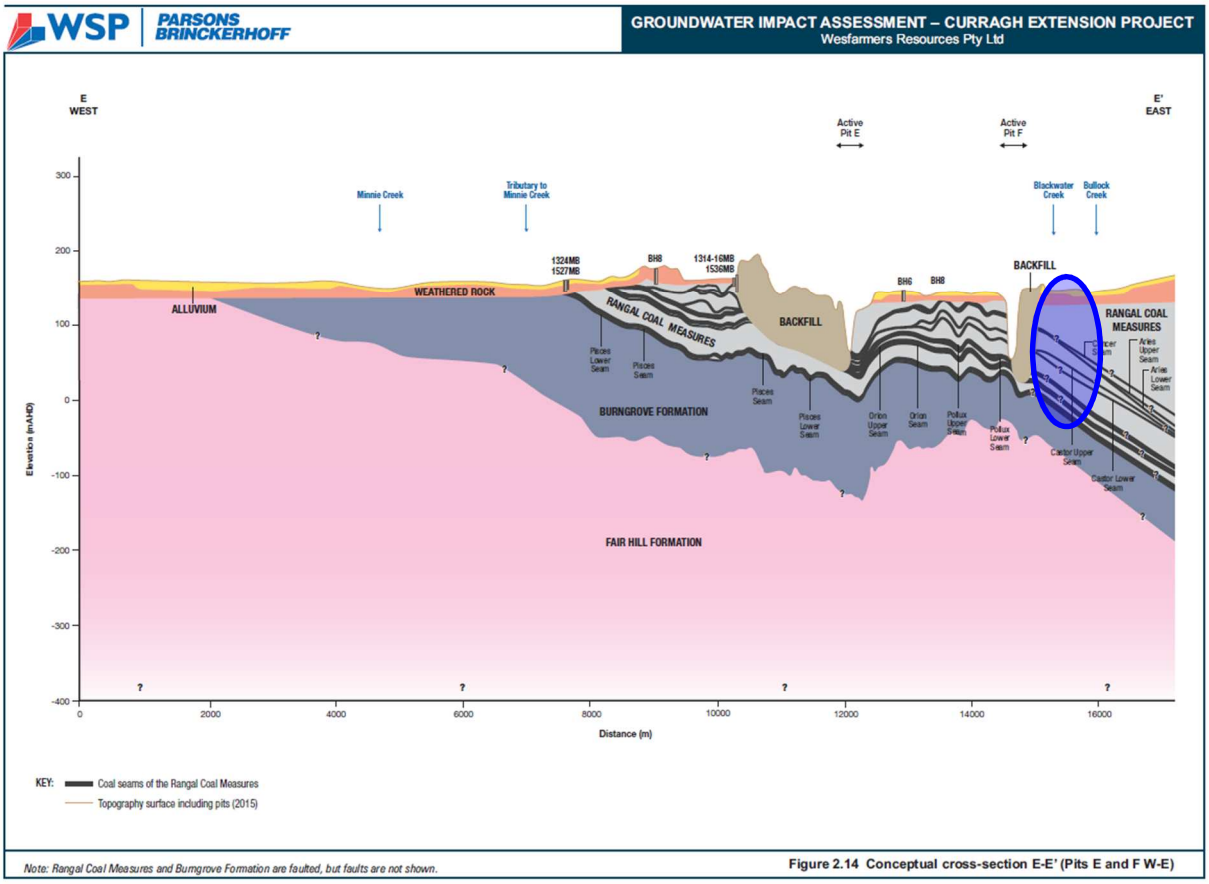


Figure 11. Geology Cross-section E-E' (from Rochford & Kwantes, 2016)

Hydrogeology

The hydrostratigraphy of the geological units is shown in Table 2. For the study area the most important unit is the alluvium. As noted above this material is generally dry apart from in the immediate vicinity of any rainwater held in the ephemeral remnant channels of Blackwater Creek with the latter also drying out reasonably quickly (depending on the size, duration and frequency of rain events), which is indicative of the SWL being below the base of the channels. From Lidar the bed of the main remnant channel drops from 138.9m RL at the south-west to 136.2m RL at the north-east while monitoring bore 1307MB, located at the western tip of Dam A (approximately 500m SSW of the head of the remnant channel) has recorded an SWL ranging from 134.93m RL to 136.53 (6.6-8.2m below ground level) over the past year (Figure 12). This bore may be affected by the presence of Dam A but, as it is constructed in the clay-rich Tertiary sequence, this is considered unlikely. The creek channels are deeply incised with near-vertical walls in the deeper channels and their absolute depth is unknown so it is possible that they are within the groundwater at their base but if so the area of creek bed exposed and/or the volume of groundwater intercepted is not sufficient to recharge the streams in any meaningful way.

Hydrostratigraphic Unit	**Occurrence**	**Aquifer Characteristics**
Quaternary and Tertiary alluvium	Clay, silt, sand, gravel	Dry in many areas. Unconfined water bearing sand and gravel units may occur at the base of the alluvium but unlikely to be significant.
Weathered rock	Residual rock from Duaringa/Emerald/Rewan Formations and Rangal Coal Measures.	Variable permeability with water bearing zones in more permeable or fractured layers and low permeability zones where rock has weathered to clay.
Tertiary Duaringa/Emerald Formations	Cemented sands and gravels, sandstones, siltstones and mudstones.	Water bearing zones may occur in more permeable layers, unconfined to semi-confined.
Triassic Rewan Formation	Mudstone and interbeds of lithic sandstone.	Aquitard.
Permian Rangal Coal Measures	Sandstones, siltstones, coal. Affected by thrust faulting. Interburden has very low primary porosity and void spacing in sandstones typically cemented by clay providing poor interconnection of void space.	Water bearing cleated coal seams and faulted interburden, confined to unconfined fractured rock aquifer. Faulting restricts flow due to lateral discontinuity of water bearing coal seams. Interburden forms aquitards.
Permian Burngrove Formation	Fractured coal seams and sandstone units.	Water bearing cleated oal seams, confined to unconfined fractured rock aquifer.

Table 2. Hydrostratigraphy (adapted from Rochford & Kwantes, 2016)

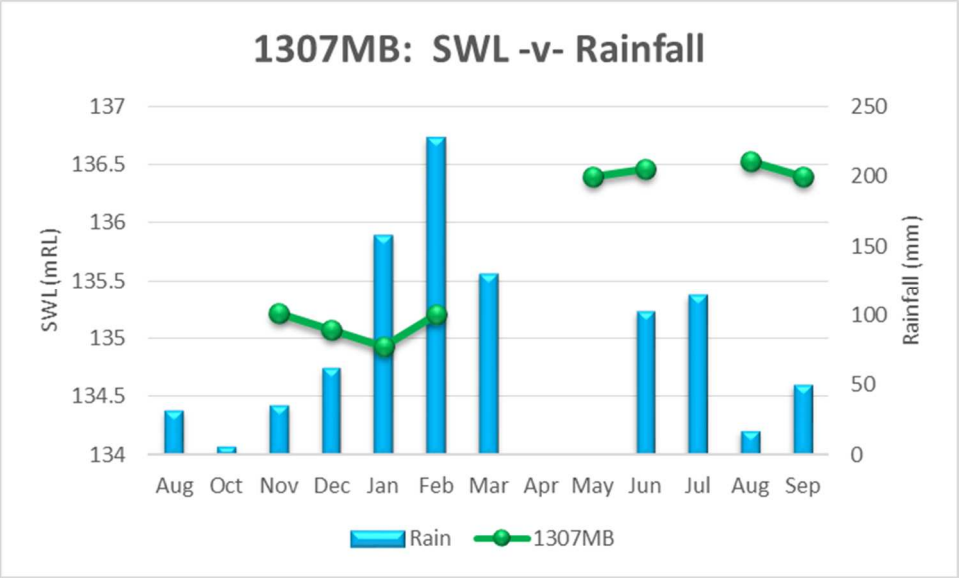


Figure 12. SWL in 1307MB plotted against rainfall.

Modelling of the base of the Quaternary (BQ) shows that the current Blackwater Creek channels occur above a zone where the BQ is significantly deeper than on either the northern or southern sides (Figure 13) in the same manner as the base of weathering (Figure 7). BQ is generally around 132-133m RL here, with the deepest parts (holding the thickest sand units) reaching depths below 130m RL. This zone may represent a palaeochannel possibly exploiting transcurrent faulting (Figure 14). The average natural surface RL across the area is around 142m RL and the average BQ outside of the deeper zone is 138-140m RL; taking the average SWL from 1307MB of 135.7 Figure 15 shows the areas that are most likely to contain any groundwater within the mining zone.

Parsons Brinckerhoff (2016) show that the groundwater flow direction in the alluvium follows the dip of the topography to the north and north-east apart from where it is intercepted by mining voids so any water contained within the identified zones will naturally drain to the north-east.

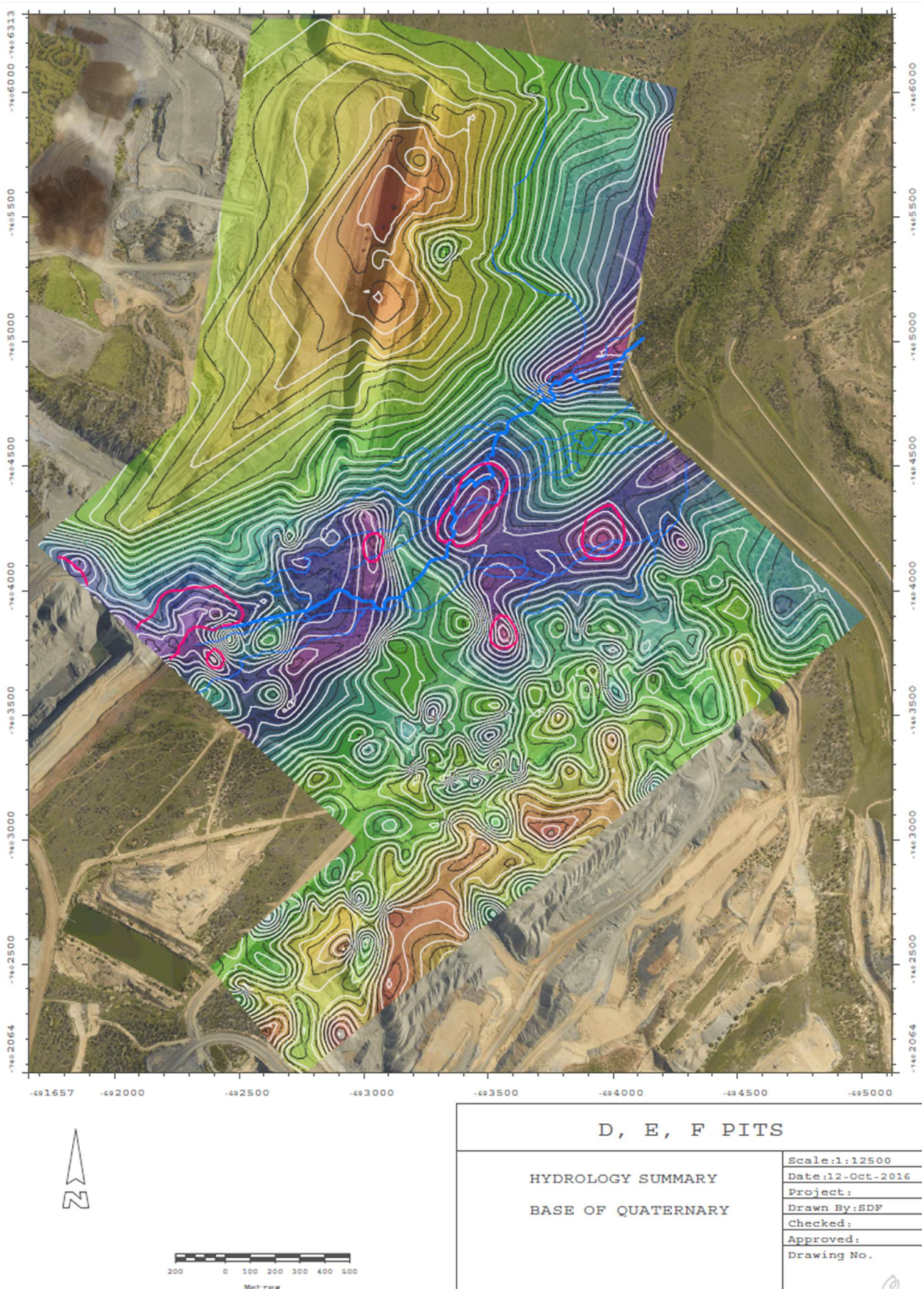


Figure 13. Base of Quaternary with potential perched sand aquifers (outlined in pink)

(Red = shallow → Purple = deep)

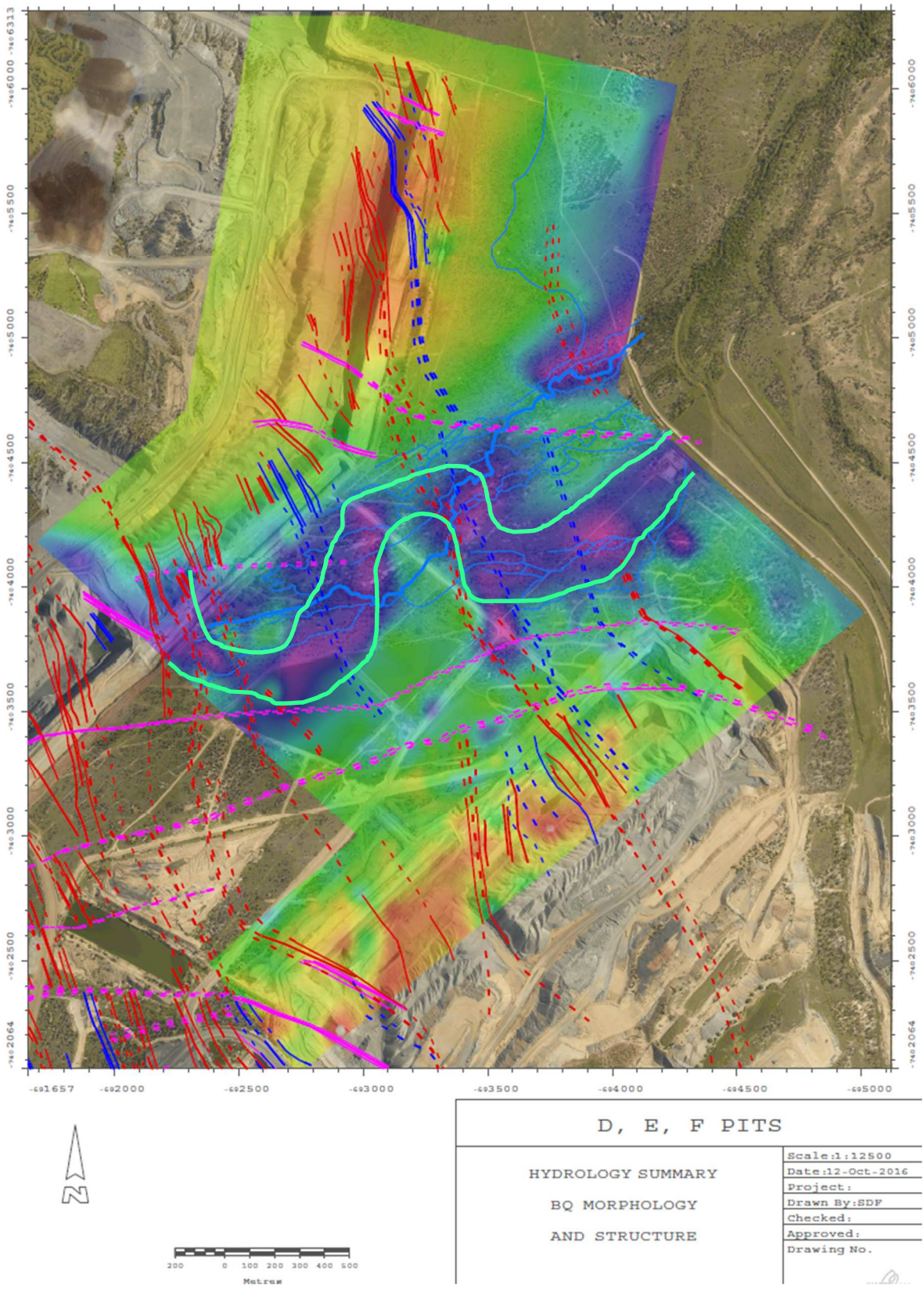


Figure 14. BQ Morphology with possible palaeochannel, geological structure and current creek channels

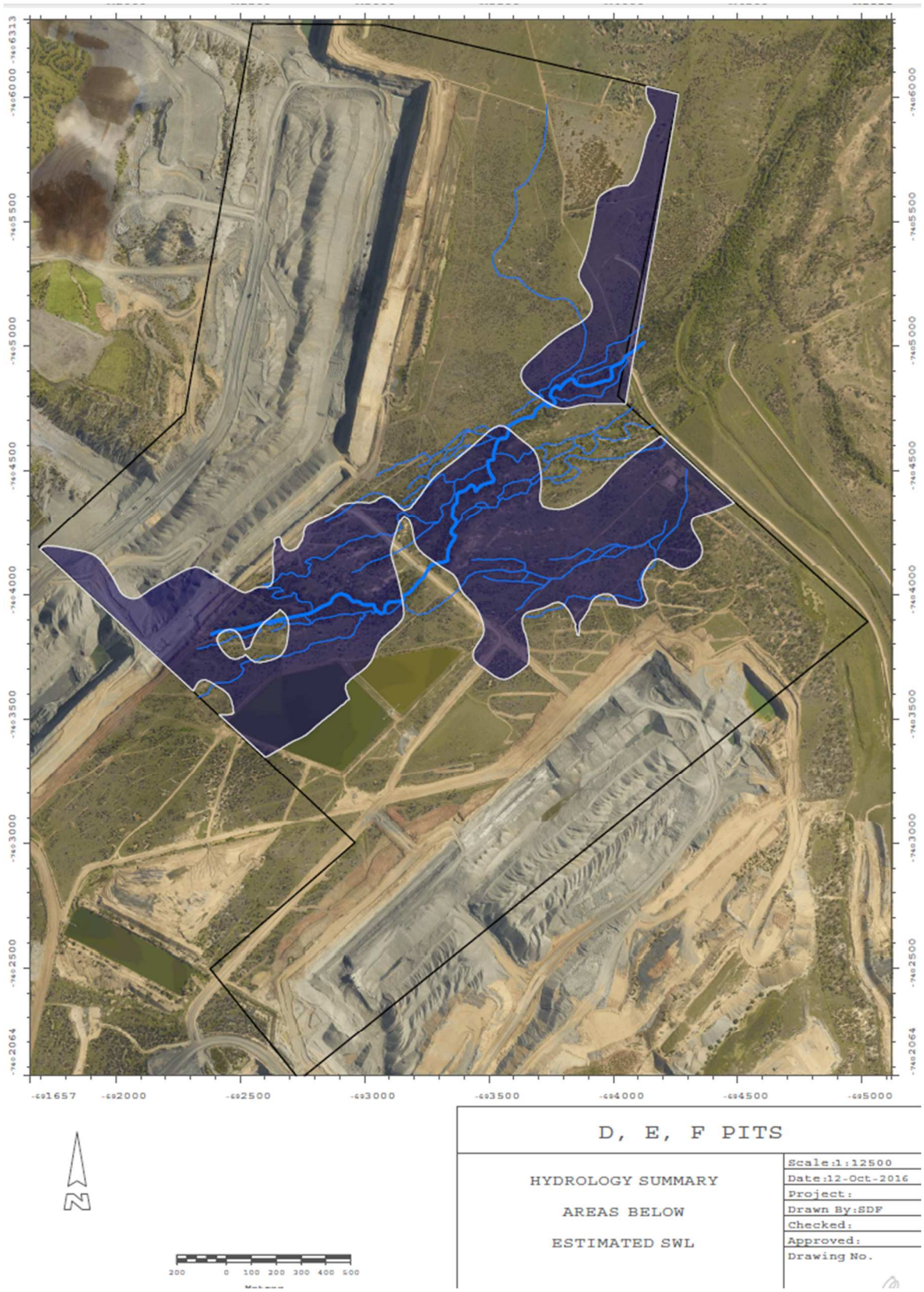


Figure 15. Likely areas of alluvium containing groundwater

Table 3 contains the known hydraulic properties for the alluvium. Because of the fluvial nature of the deposit permeability will be highly variable both vertically and laterally depending on the relative amounts of clay, silt, sand and gravels in any given area. With clay being the dominant secondary mineral identified with the sand units in the borehole logs and with clay being the dominant lithology identified generally in the alluvium it is expected that permeability will generally be low, resulting in low hydraulic conductivity (*K*), storage (*Ss*) and yield (*Sy*) throughout the area.

Geological Age	**Formation**	**Lithology**	**Kh (m/d)**	**Kv (m/d)**	**Ss (m^{-1})**	**Sy**
Quaternary	Alluvium	Blackwater Creek alluvium	0.4-0.6	0.018		
		Floodplain/river alluvium	1-40	0.1-2	0.0005	0.05-0.18
Tertiary	Duaringa Formation	Sedimentary Rocks	0.05-0.6	0.005-0.018	0.00005	0.12
	Weathered rock	Sandy gravels	0.9			
		Claystone/other cemented strata	0.43			

Table 3. Hydraulic Properties (adapted from Rochford & Kwantes, 2016

Kh: horizontal hydraulic conductivity. Kv: vertical hydraulic conductivity. Ss: specific storage. Sy: specific yield

Recharge of alluvium groundwater occurs by way of both rainwater infiltration and stream flow (Rochford & Kwantes, 2016). As noted above the zone of interest is no longer connected to a catchment basin due to mining activities so any groundwater currently remaining in the area can only be recharged by way of rain infiltration.

Coal aquifers

Both the Aries/Castor and Pollux coal seams at Curragh were investigated for their hydrogeology in the 1980s. Muller and Hair (1980) and Hair (1987) noted that both seams (testing was done in an area where there was no parting between Aries and Castor) are confined by low permeability strata of fine grained sandstone, siltstone, mudstone and shale. Groundwater is found in both seams and occurs within bedding fractures and joints (cleats) with testing indicating that both seams are highly fractured, producing a porous rock aquifer. Thrust faults act as probable impermeable boundaries. The Aries/Castor seam showed considerable lateral and vertical variation in permeability (Castor having significantly higher permeability) and is identified as a semi-confined aquifer with some possible leakage from its overlying shale/siltstones while the Pollux seam is considered to be a confined aquifer and has more consistent permeability (Table 4). Both show considerable anisotropy. Interseam sediments have significantly lower permeability (about two orders

of magnitude less) than the coal seams and thus the coal seam aquifers are hydrologically isolated which is confirmed by their significantly different water chemistry.

Site	Aries-Castor seam		Pollux seam		Interseam sediments	
	Range	Average	Range	Average	Range	Average
A	6.8×10^{-3} to 5.6×10^{-1}	1.3×10^{-1} (15 values)	8.3×10^{-4} to 5.3×10^{-1}	1.1×10^{-1} (16 values)	1.4×10^{-4} to 3.1×10^{-2}	9.7×10^{-3} (4 values)
B	1.5×10^{-1} to 5.0×10^{-1}	2.9×10^{-1} (6 values)		2.6×10^{-2} (1 value)		

Table 4. Average permeability values for coal seams (from Hair, 1987)

Summary

The D-E-F pit area consists of Quaternary and Tertiary alluvium overlying Triassic and Permian strata. The Quaternary consists of semi- to unconsolidated clays, silts, sands and gravels while the Tertiary are consolidated to semi-consolidated sands, gravels and ferruginous clays. The older rocks underlying the alluvium are the usual package of siltstones, fine-grained sandstones and coal seams. Groundwater occurs in the coal seams and can be expected to be found in the alluvium. In the latter it is likely to be in the form of hydrologically isolated perched aquifers associated with thicker, less silty sand lenses in the Quaternary material. Due to their isolated nature, poor permeability and consequent very low hydraulic properties it is not expected that groundwater will pose much of an issue in the alluvium while water from the coal seams can be managed in the usual manner.

REFERENCES

Hair, I.D. 1987. *Hydrogeology of Coal Seams at Curragh, Central Queensland.* Geological Survey of Queensland Record 1987/20.

Minserve. 1998. *Report on the Feasibility Study for the Development of the Jellinbah Station Coal Deposit.* Stanwell Corporation Report.

Muller, P.J. & Hair, I.D. 1980. *Curragh Coal Aquifer Testing. Report on Hydrogeological Investigations.* Geological Survey of Queensland Record 1980/39.

Rochford, L. & Kwantes, E. 2016. *Curragh Extension Project – Groundwater Technical Report.* Parsons Brinckerhoff Report produced for Wesfarmers Resources Pty Ltd, Document No. 2172652H-WAT-REP-002 RevB

APPENDIX J

Important information relating to this report.

IMPORTANT INFORMATION RELATING TO THIS REPORT

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APPENDIX N

Geotechnical Stability Analysis

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Curragh Mine
Final Landform Design

Initial Geotechnical Slope Stability Analysis

Prepared for:

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Appendices

Appendix A – Limit Equilibrium Slope Stability Analysis Outputs
Appendix B – Design Risk & Opportunities Register

1. Introduction

This report has been prepared by Raine & Associates (R&A) for Coronado Curragh Pty Ltd (CCPL) in relation to their Curragh Coal Mine (Curragh). This report presents the results of initial two-dimensional limit equilibrium slope stability analyses undertaken by R&A in relation to the final landform designs developed for Curragh.

1.1 Purpose

The purpose of this report is to assist CCPL, as part of the Curragh Planning System (CPS), identify, assess, manage, and document pre-emptively, potential geotechnical hazards associated with the longer-term slope stability of the Curragh final landform designs.

Qualifications and Limitations associated with the work presented in this report are provided in Section 8.

1.2 Available Data

The following data was made available by CCPL (Table 1-1).

Table 1-1 Supplied Data

Data Name and Format	Supplier	Comment
20200922.dhd	CCPL	Vulcan dataset of Geobank Output
CN Pit 20211101.dxf	CCPL	DXF contour model of the Curragh North final landforms
X Pit 20211030.dxf	CCPL	DXF contour model of the X Pit final landform
Y Pit 20211101.dxf	CCPL	DXF contour model of the Y Pit final landform
Z Pit 20211030.dxf	CPPL	DXF contour model of the Z Pit final landform
CM Pit 20211103b 2m.dxf	CCPL	DXF contour model of the Curragh Main final landforms, using 2m contours
CM Pit 20211103b half m.dxf	CCPL	DXF contour model of the Curragh Main final landforms, using 0.5m contours
CN Mining Surface 20211102.dxf	CCPL	DXF model of the Curragh North final mining surface, prior to remediation
2020Aug_LT_WOA_PublishedMOdel	CCPL	Life of Mine grids, inclusive of all coal seams and unconformable
Ramp 9	CCPL	A directory of Vulcan layers for Ramp 9, inclusive of powerlines, infrastructure, permanent roads, waterways and pit shell
210621.dhd.isix & .isis	CCPL	Borehole database for all of Curragh
0684-08-C1_FloorStudyDesignReport.pdf	WRM	Flood study for northern levee design – Jellinbah Mackenzie North Pit
211014 – pit shell plus dumps 0.5m contours.dxf	CCPL	DXF contour model of Y Pit final pit shell, including dumps, using 0.5m contours
211014 – void and footprint outlines.dxf	CCPL	DXF model of void and footprint outlines for Y Pit
1532295-052-R-Rev3-PitB-Design-Plan FINAL 20171124.pdf	CCPL	B Pit tailings storage facility design plan

Data Name and Format	Supplier	Comment
2172961A-GEO-REP-002 RevB.pdf	CCPL	Geotechnical investigation and assessment for capping, Curragh Coal Mine – Old Tailings Dam Rehabilitation
AGD84_AMG_Z55_Curragh_2107_Submission	CCPL	Registered images and topographic models from Curragh's survey department – Current as at July 2021
AGD84_AMG_Z55_Curragh_2108_Submission	CCPL	Registered images and topographic models from Curragh's survey department – Current as at August 2021
1911.stat.blackwater.creek.arch_d	CCPL	Vulcan layer outlining Blackwater Creek
1911.stat.levee.arch_d	CCPL	Vulcan layer outlining the current position of levees
1911.stat.mackenzie.river.arch_d	CCPL	Vulcan layer outlining the Mackenzie River
FW_ Hydraulic conductivities (email)	SLR	Hydraulic Permeabilities
1in1000_E009_Waterlevel_Curragh.pdf	SLR	Flood levels

1.3 References

The slope stability analyses presented in this report reference the following documents:

- R&A Report: *RA002_201706_02_Rev0 Slope Stability Analysis for Out of Pit Dumps_Rev0*, dated November 2017;
- Hawley, M. and Cunning, J. (2017), *Guidelines for Mine Waste Dump and Stockpile Design*, CSIRO;
- Martin, D. and Stacey, P., (2018) *Guidelines for Open Pit Slope Design* in Weak Rocks, CSIRO;
- Read, J. and Stacey, P., (2009) *Guidelines for Open Pit Slope Design*, CSIRO; and,
- Simmons, J. and McManus, D. (2004), *Shear Strength Framework for Design of Dumped Spoil Slopes for Open Pit Coal Mines*.

1.4 Safe Design

As noted in Section 1.1, the purpose of this report is to help CCPL, as part of the CPS, identify, assess, manage and document pre-emptively, potential geotechnical hazards associated with the longer-term slope stability of the Curragh final landform designs.

As a result, it is necessary that this report conforms with the legislated reporting requirements under the Qld Work Health & Safety Act 2011, the Work Health & Safety Regulation 2011 and the Coal Mining Safety and Health Act 1999. As part of this obligation R&A recommend and encourage that discussions, design reviews and risk workshops be undertaken in relation to the final landform designs considered in this report (Appendix B).

2. Geological Conditions, Structural Analysis and Interpretation

The Curragh Coal Mine is located approximately 30 km north of the town of Blackwater in Central Queensland's Bowen Basin and is comprised of two active mining areas, which are referred to as Curragh Main and Curragh North.

Curragh is located on the western flank of the Bowen Basin and resides in the Upper Blackwater Group, which comprises of the Rangal Coal Measures, the Burngrove Formation and the Fair Hill Formation. In general, the Rangal Coal Measures are mined at Curragh. These deposits are comprised of grey mudstone and siltstone, light grey fine-grained sandstone and the productive coal seams of Cancer, Aries, Castor, Pollux, Orion and Pisces. Mining of the Burngrove Formation coal seams is also being considered. The local basin coal seam stratigraphy is presented in Figure 2-2.

Locally, the Aries and Castor Coal Seams, and the Pollux, Orion, and Pisces Coal Seams are observed to coalesce. Where the Aries and Castor Coal Seams coalesce, they are named the Mammoth Seam (Figure 2-1). The Mammoth Coal Seam is observed in the footprint of the current S-Pit Main and S-Pit South mining areas. Where the Pollux, Orion, and Pisces Coal Seams coalesce, they are named the Mackenzie Seam (Figure 2-1). The Mackenzie Seam (sometimes also referred to as the Pisces Seam) is mined at Curragh North and is directly underlain by the Yarrabee Tuff and Pisces Lower Coal Seam.

Curragh is located adjacent to the northwest trending Jellinbah Thrust Belt, which is believed to exhibit vertical stratigraphic throws in the order of 100's of metres. The dominant geological structures at Curragh are observed to be north-northwest to south-southeast trending thrusts faults crosscut by younger transcurrent and normal faults.

Zones of significant rock mass and coal seam shearing are likely in the vicinity of larger-scale faults. These zones are characterised by extensive shearing, repeating and/or stripping of stratigraphic units and represent areas of structural and geological complexity. Pitwall design revisions are often implemented at Curragh to mitigate the risks associated with geological faults and pitwall stability.

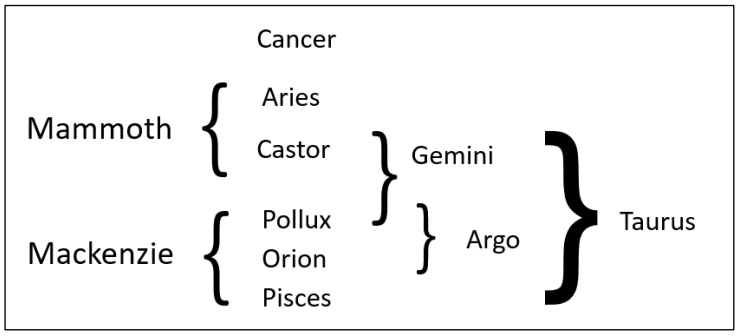


Figure 2-1 Rangal Coal Measure coalesces naming convention (Curragh Geology Training Manual, CCPL)

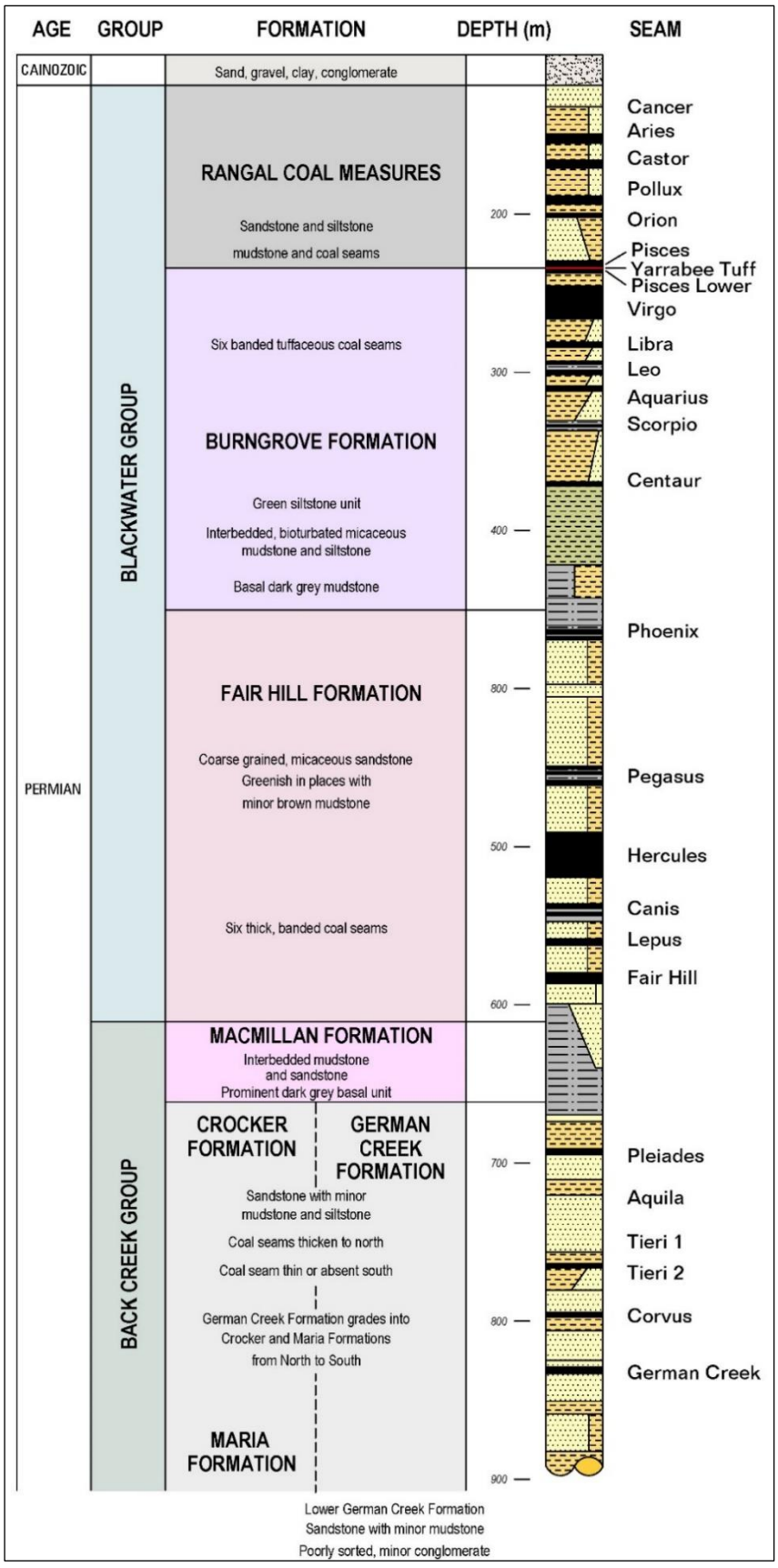


Figure 2-2 Coal Seam Stratigraphy (Curragh Geology Training Manual, CCPL)

2.1 Quaternary and Tertiary Lithology

The alluvial soil materials observed at Curragh are comprised of Quaternary Sands, Gravels and Clays, and Tertiary Clays and Sandy Clays.

2.2 Permian Interburden Lithology

The Permian stratigraphy observed at Curragh Main is comprised predominately of the Rangal Coal Measures, generally consisting of coal, sandstone, siltstone, claystones, and carbonaceous units (refer to Table 2-1).

Table 2-1 General Permian Material Classifications – Curragh Main

Material Name	Material Description
Siltstones, Sandstones, Claystones and Carbonaceous Units	Interlaminated and bedded siltstone and sandstones with occasional mudstone and / or carbonaceous units occurring in the Aries Overburden, Castor Interburden, Pollux Interburden and Orion Interburdens.
Coal	Black coal.

The Permian stratigraphy observed in Curragh North generally consists of coal, sandstone, and siltstone, with occasional mudstone and carbonaceous units, and stratigraphically continuous tuffaceous layers (i.e. Yarrabee Tuff and Tuff Lower; refer to Table 2-2).

Table 2-2 General Permian Material Classifications – Curragh North

Material Name	Material Description
Siltstones & Sandstones	Interlaminated and bedded siltstone and sandstone with occasional mudstone and/or carbonaceous units occurring in the Aries Overburden, Castor Interburden and Mackenzie Interburden.
Massive Sandstones	Massive to thickly bedded sandstone, typically medium to coarse grained occurring predominately in the Mackenzie Interburden.
Coal	Black coal.
Yarrabee Tuff	Stratigraphically continuous tuffaceous layer.
Tuff Lower	Stratigraphically continuous tuffaceous layer located approximately 1m to 2m below the Yarrabee Tuff.
Burngrove Formation	Sandstone and siltstone residing in the pit floor.

2.3 Seismic Risk

The Geoscience Australia Earthquake Hazard Maps (Earthquake Hazard Maps) present peak ground acceleration (response spectral period of 0.01 seconds) on rock expected for a 50 year return period, in units of *g*, evaluated for the geometric mean of the horizontal components.

For Curragh, the following have been obtained from the Earthquake Hazard Maps (Figure 2-3 and Figure 2-4):

- Exceedance probability of 10% in 50 years = 0.0-0.005g; and
- Exceedance probability of 2% in 50 years = 0.0-0.02g.

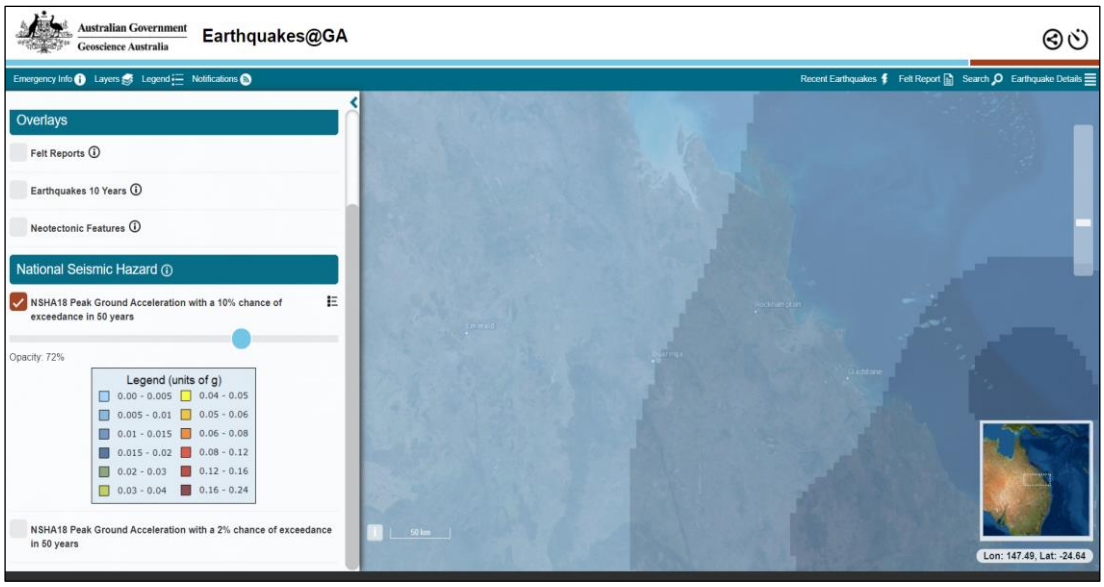


Figure 2-3 Geoscience Australia Earthquake Hazard Map - 10% chance of exceedance in 50 years

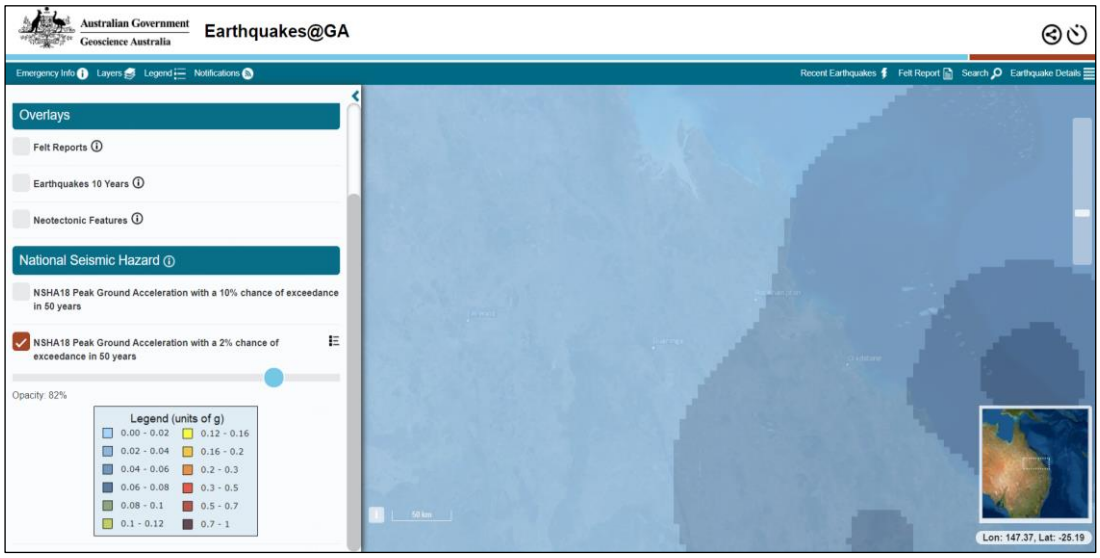


Figure 2-4 Geoscience Australia Earthquake Hazard Map - 2% chance of exceedance in 50 years

2.4 Predicted Flood Levels

Predicted flood levels for a 1:1000 AEP flood have been provided by SLR Consulting Australia Pty Ltd (SLR) and are outlined in Table 2-3. Refer to Section 4 of this report for Section locations and orientations.

Table 2-3 Supplied Flood Levels for selected section locations

Section	Flood Level (AGD66)	Section	Flood Level (AGD66)
Section 1	137.62 mAHD	Section 6	156.6 mAHD
Section 2	140.0 mAHD	Section 7	162.7 mAHD
Section 3	140.5 mAHD	Section 8	Dry
Section 4	142.7 mAHD	Section 9	Dry
Section 5	143.4 mAHD	-	-

3. Geotechnical Laboratory Data

3.1 Soil Test Results

Laboratory test results for soil and alluvial materials utilised in these works were obtained from the following sources:

- The Minserve Group Pty Ltd (1998), Jellinbah Station Project (CN) Report. The following data were obtained from this report:
    - 4 Emerson Class Tests;
    - 21 Atterberg Limits Test Results; and,
    - 25 Particle Size Distribution Test Results.
- Golder Associates Pty Ltd (2012), Design Report Curragh U, S & T Pit Levee Raising Report. The following data were obtained from this report:
    - 44 CPT Profiles (located in the vicinity of the S-Pit and T-Pit South levee);
    - 26 Emerson Class Tests;
    - 38 Atterberg Limits Test Results; and,
    - 40 Particle Size Distribution Test Results.
- Drilling through alluvial soils and weathered rock in S-Pit South (2016):
    - 11 Atterberg Limits Test Results; and,
    - 6 Particle Size Distribution Test Results.
- Grab samples obtained from exposed alluvial materials in S-Pit and S-Pit South (2018 and 2019):
    - 10 Emerson Class Tests;
    - 17 Atterberg Limits Test Results; and,
    - 17 Particle Size Distribution Test Results.

Atterberg Limits, and Particle Size Distribution test data are presented in Figure 3-1, Figure 3-2 and Figure 3-3. Laboratory certificates and associated reports are provided on the CCPL systems.

3.2 Rock Core Laboratory Test Results

Uniaxial Compressive Strength data obtained from cored boreholes drilled at Curragh are provided in Table 3-1 and Table 3-2. Direct shear test results for the Yarrabee Tuff are provided in Figure 3-4. Laboratory certificates are provided on the CCPL system.

Table 3-1 Summary of Uniaxial Compressive Strength Data Available for Curragh Main

Material Unit	Lithology	Mean Strength (UCS)	No of Samples
Aries Overburden	Siltstones, Sandstones, Mudstones & Carbonaceous Materials	15.73	55
Castor Interburden	Siltstones, Sandstones, Mudstones & Carbonaceous Materials	17.96	38
Pollux Interburden	Siltstones, Sandstones, Mudstones & Carbonaceous Materials	23.59	59
Virgo Interburden	Sandstones & Siltstones	17.75	10
Coal	Black Coals	7.13	12
Yarrabee Tuff	Tuff	25.30	5
Pit Floor	Sandstone, Siltstone & Carbonaceous Materials	28.69	49

Table 3-2 Summary of Uniaxial Compressive Strength Data Available for Curragh North

Material Unit	Lithology	Mean Strength (UCS)	No of Samples
Aries Overburden	Siltstones, Sandstones, Mudstones, Claystones & Carbonaceous Materials	24.24	109
Castor Interburden	Siltstones, Sandstones & Carbonaceous Materials	27.61	21
Mackenzie Interburden	Siltstones, Sandstone, Carbonaceous Materials & Massive Sandstone	26.87	162
Aries, Castor & Mackenzie Seams	Black Coals	6.92	15
Yarrabee Tuff	Tuff	15.61	3
Pit Floor	Sandstone, Siltstone & Carbonaceous Materials	28.69	43

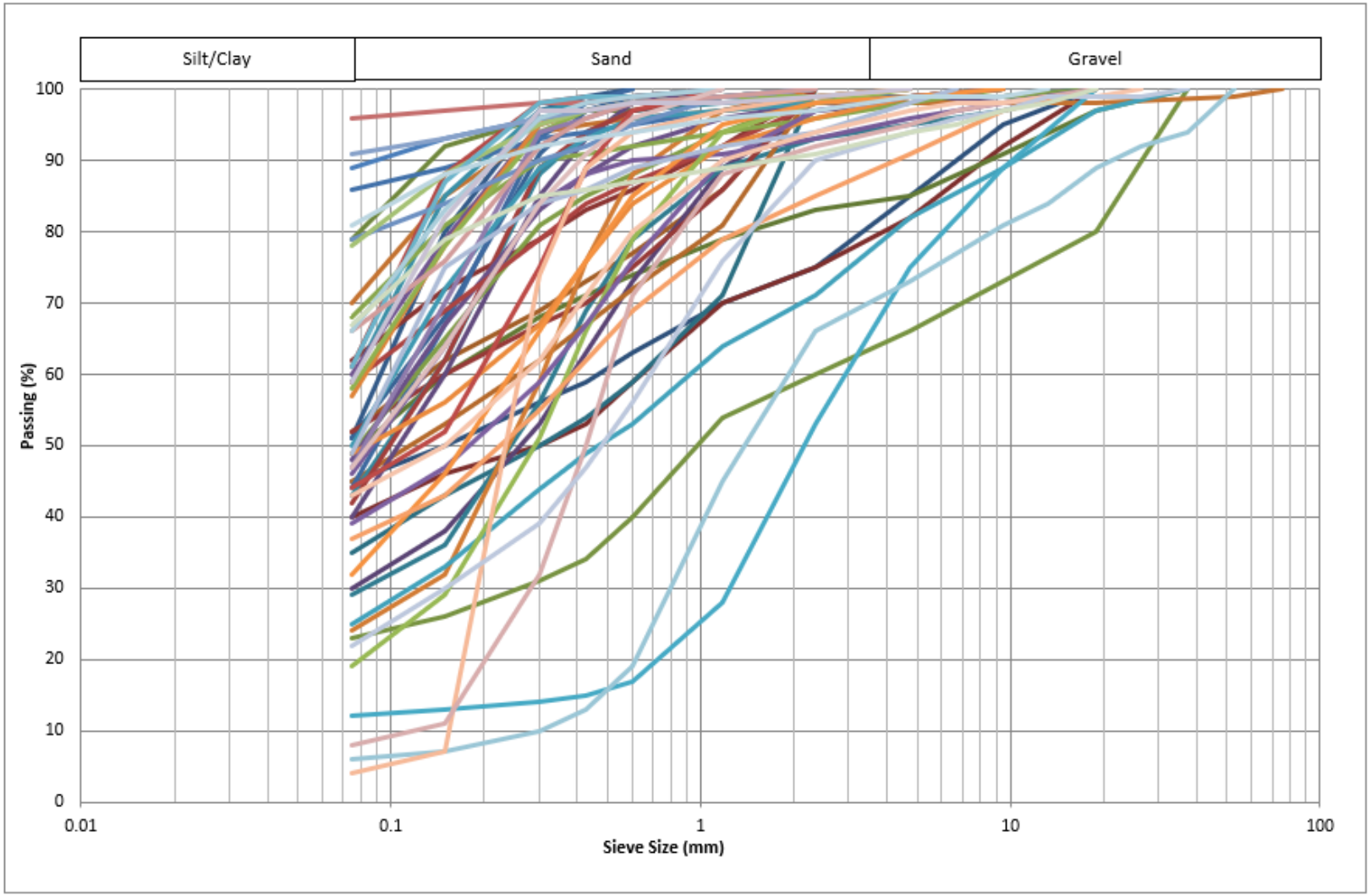


Figure 3-1 Particle Size Distribution Chart – Quaternary Soil Materials

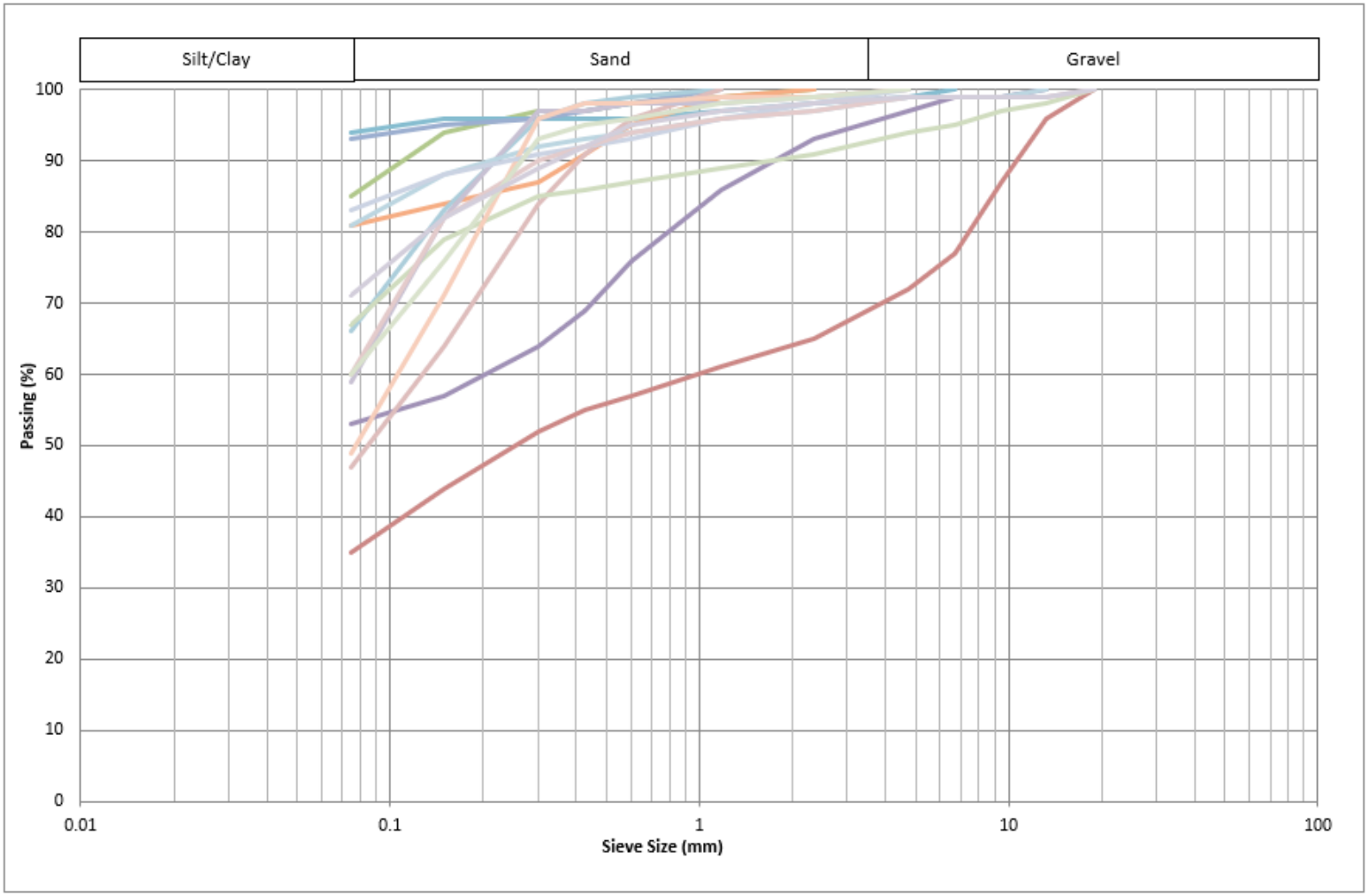


Figure 3-2 Particle Size Distribution Chart – Tertiary Soil Materials

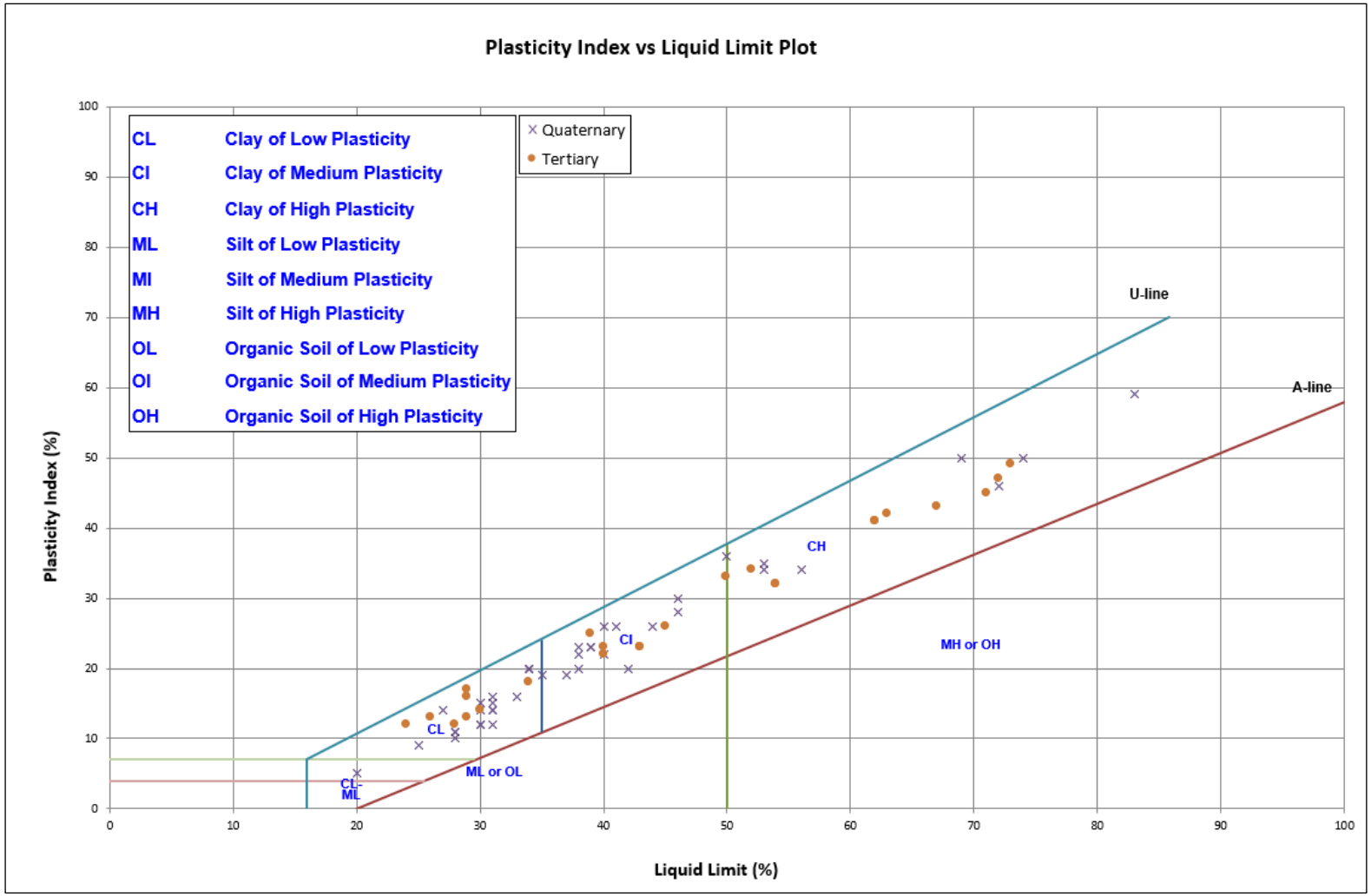


Figure 3-3 Casagrande Chart – Quaternary & Tertiary Clays

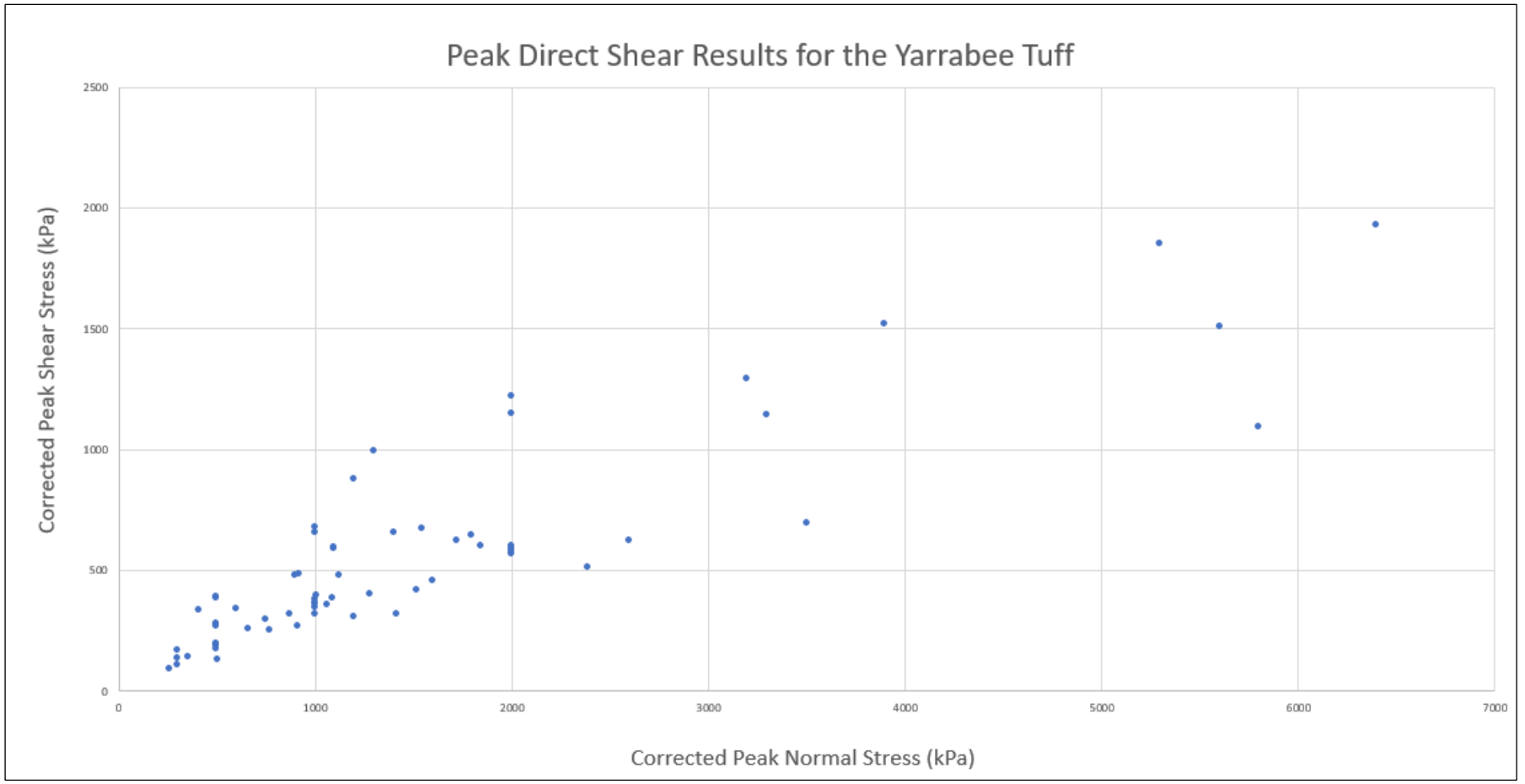


Figure 3-4 Peak Direct Shear Data for the Yarrabee Tuff at Curragh

4. Final Landform Designs

The final landform designs, which form the basis for this works, have been provided by CCPL (refer to Section 1.2).

As noted in Section 2, pitwall design revisions are often developed and implemented to mitigate the risks associated with geological faults and pitwall stability. As a result, where the current final landform design comprises remnant pitwalls alternative pitwall design options are presented for consideration. These alternative options provide some contingency for the possibility that adverse ground conditions, including geological faults, could be encountered at the planned final pitwall locations.

To account for the flood levels supplied for X-Pit the supplied final landform surface has been raised by approximately 10m for the purpose of the analyses presented in this report.

The following cross-sections and scenarios have been considered (refer to Figure 4-1 to Figure 4-11):

- Section 1 U-Pit Cross Section;
- Section 2 S-Pit South Cross Section;
- Section 3 X-Pit Cross Section;
- Section 4 D-Pit Cross Section;
- Section 5 F-Pit South Cross Section;
- Section 6 K-Pit Cross Section;
- Section 7 J-Pit Cross Section;
- Section 8 Y-Pit Cross Section; and,
- Section 9 Z-Pit Cross Section.

The adopted geotechnical ground model scenarios are provided in Table 4-1.

Table 4-1 Adopted Ground Model Scenarios

Cross Section	Scenario
Section 1: U-Pit	Planned Final Landform Option - Highwall Side
Section 2: S-Pit South	Planned Final Landform Option - Highwall Side
	Planned Final Landform Option - Lowwall Side
Section 3: X-Pit	Planned Final Landform Option - Highwall Side
Section 4: D-Pit	Planned Final Landform Option - Highwall Side
	Alternative Final Landform Option - Highwall Side
	Alternative Final Highwall Re-Shaped Final Slope Option - Highwall Side

Cross Section	Scenario
Section 5: F-Pit South	Planned Final Landform Option - Highwall Side
	Alternative Final Highwall Re-Shaped Final Slope Option - Highwall Side
	Planned Final Landform Out Board Slope
	Planned Final Landform Option - Lowwall Side
Section 6: K-Pit	Planned Final Landform Option - Highwall Side
	Alternative Final Landform Option - Highwall Side
	Alternative Final Highwall Re-Shaped Final Slope Option - Highwall Side
Section 7: J-Pit	Planned Final Landform Option - Highwall Side
	Planned Final Highwall Re-Shaped Final Slope - Highwall Side
Section 8: Y-Pit	Planned Final Landform Option - Highwall Side
	Planned Final Highwall Re-Shaped Final Slope - Highwall Side
Section 9: Z-Pit	Planned Final Landform Option - Highwall Side
	Planned Final Highwall Re-Shaped Final Slope - Highwall Side

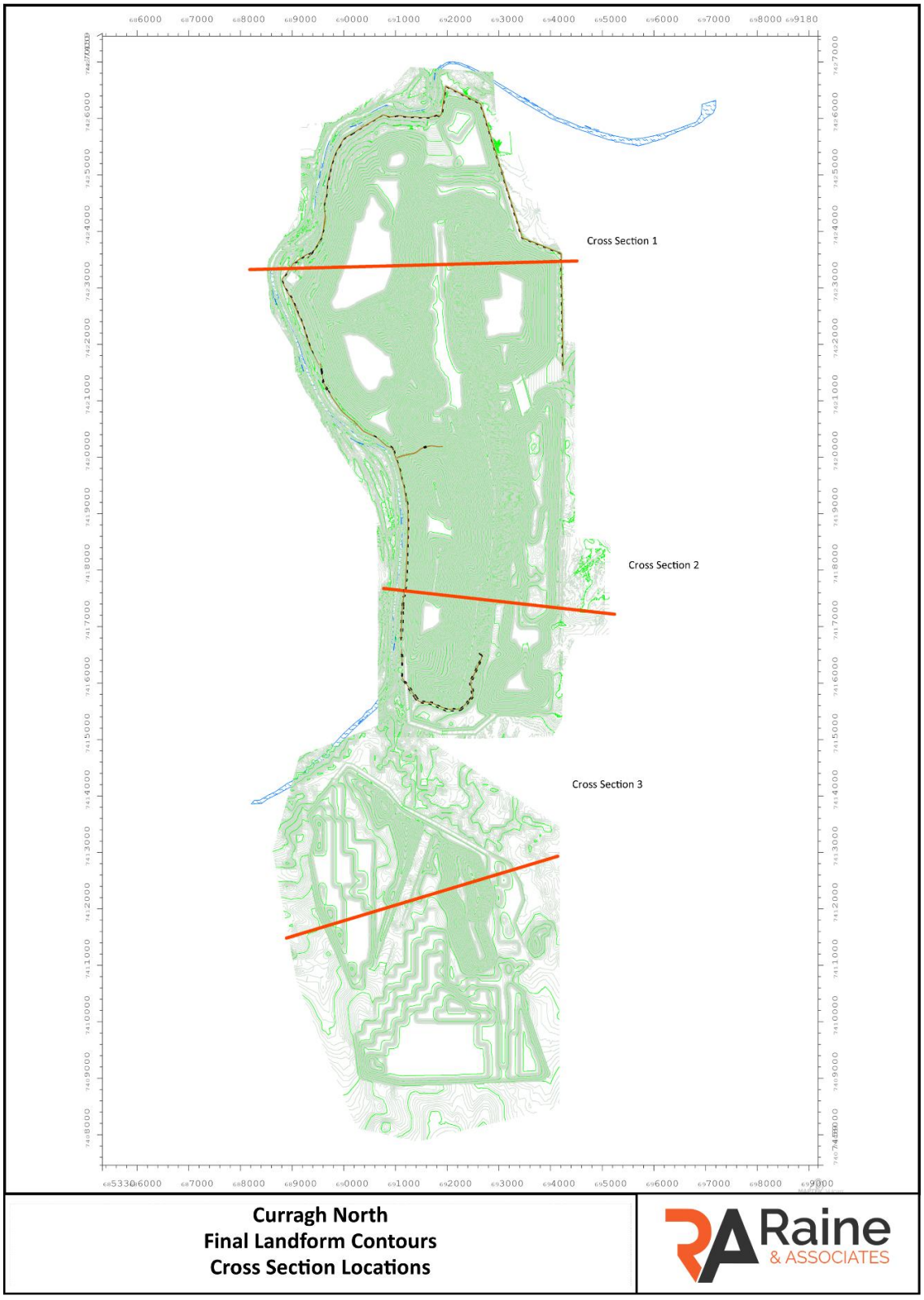


Figure 4-1 Curragh North Final Landform & Cross Section Locations

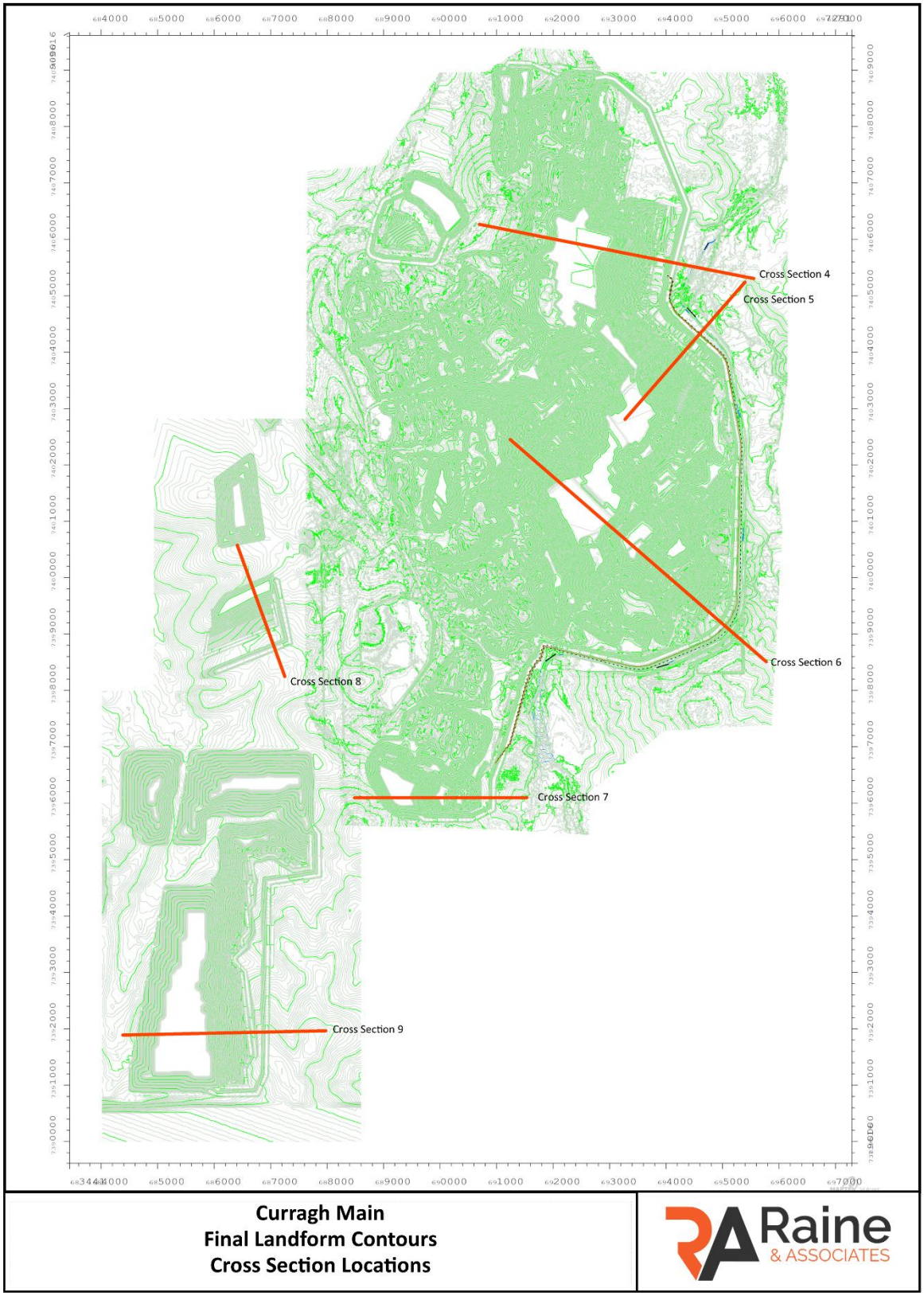


Figure 4-2 Curragh Main Final Landform& Cross Section Locations

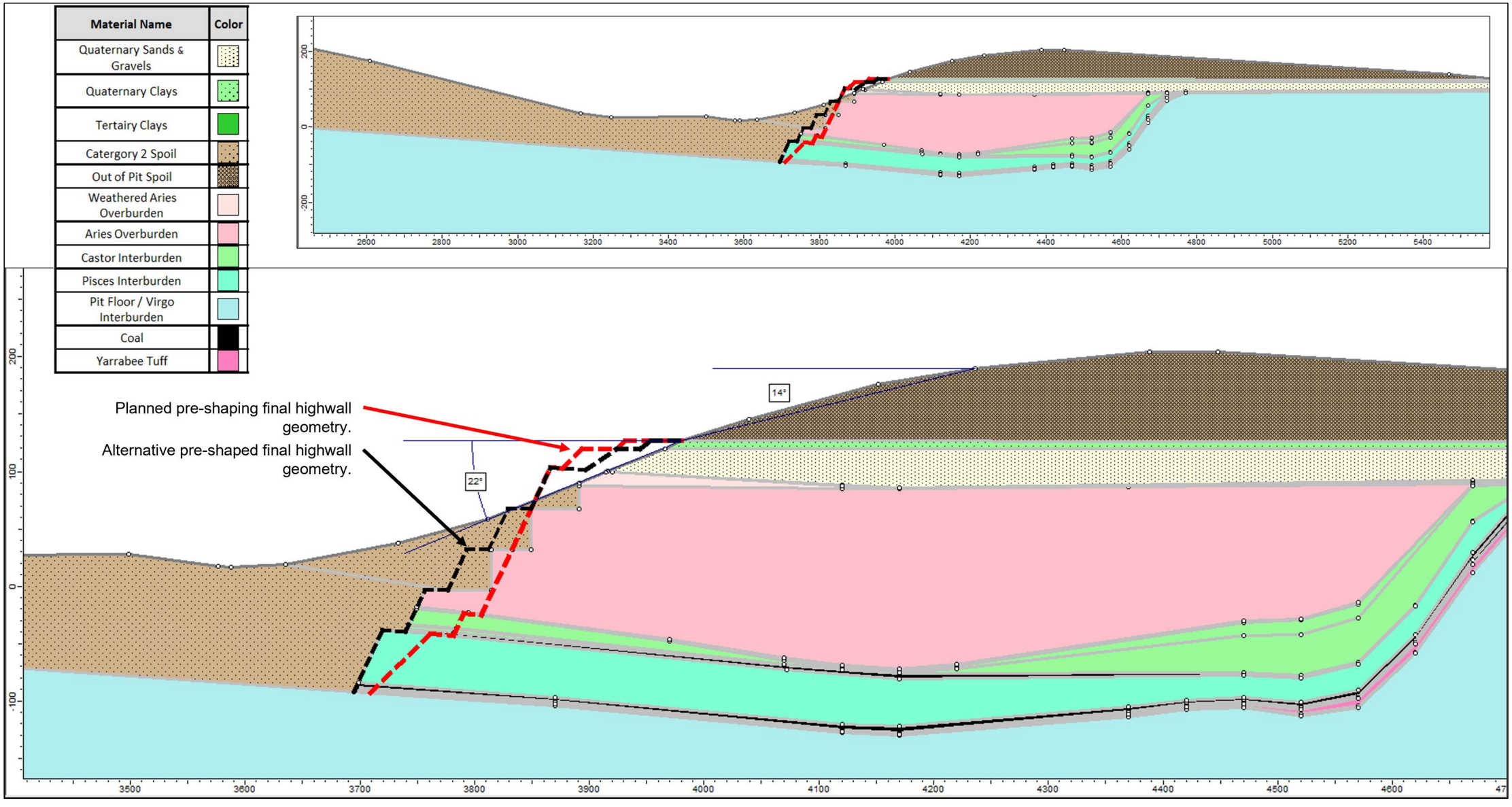


Figure 4-3 Cross Section 1 – Curragh North U-Pit

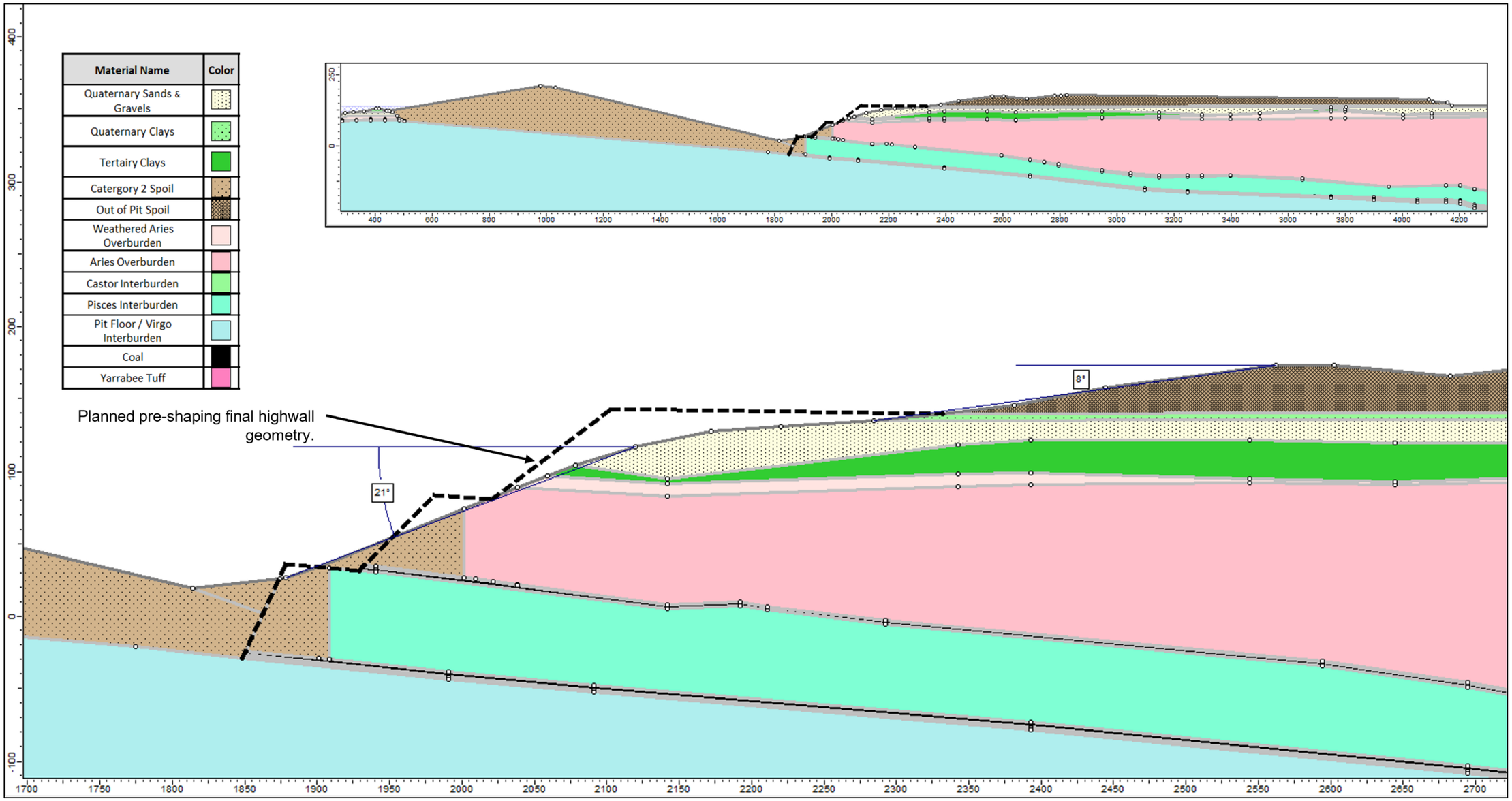


Figure 4-4 Cross Section 2 – Curragh North S-Pit South

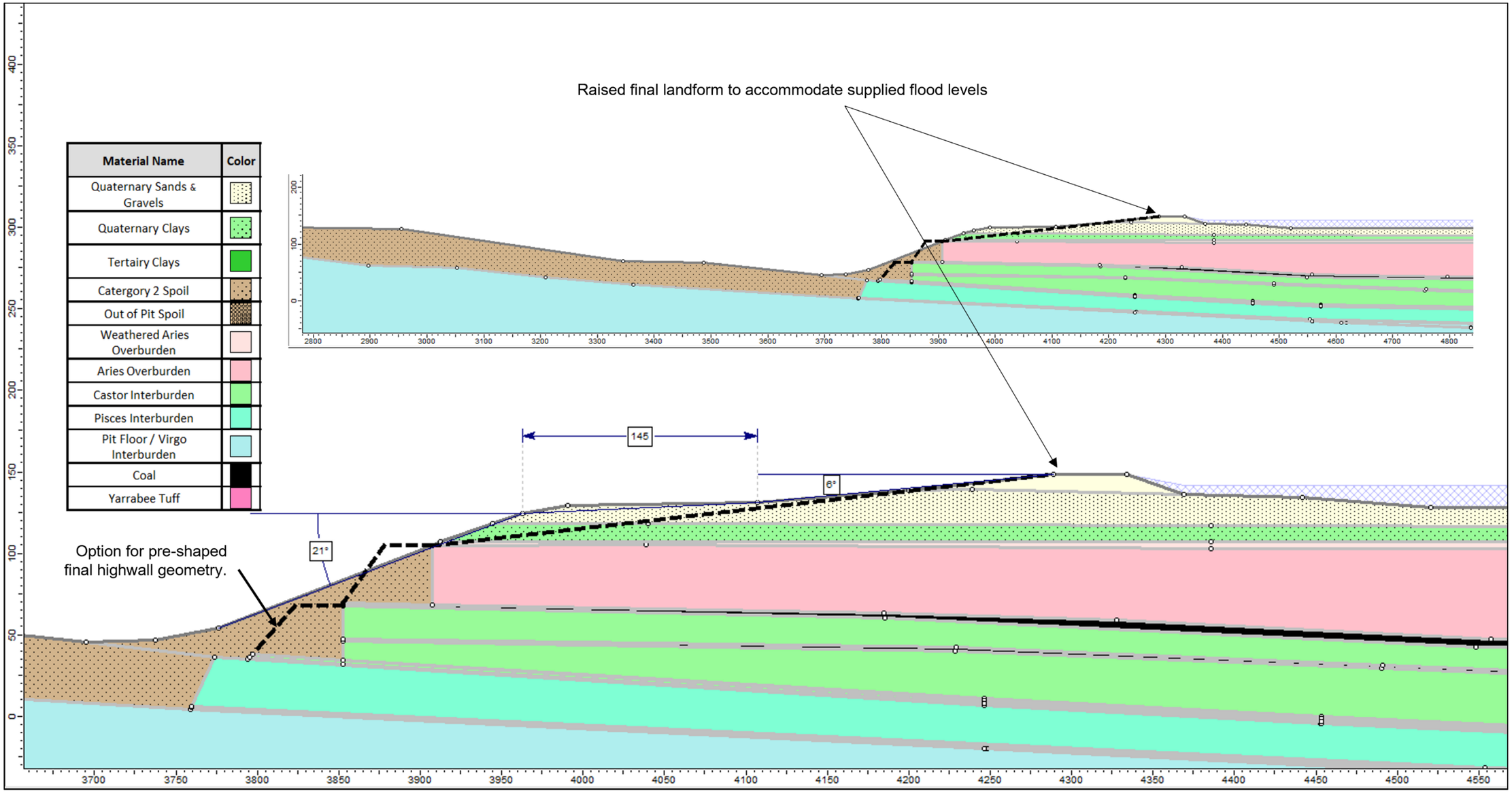


Figure 4-5 Cross Section 3 – X-Pit

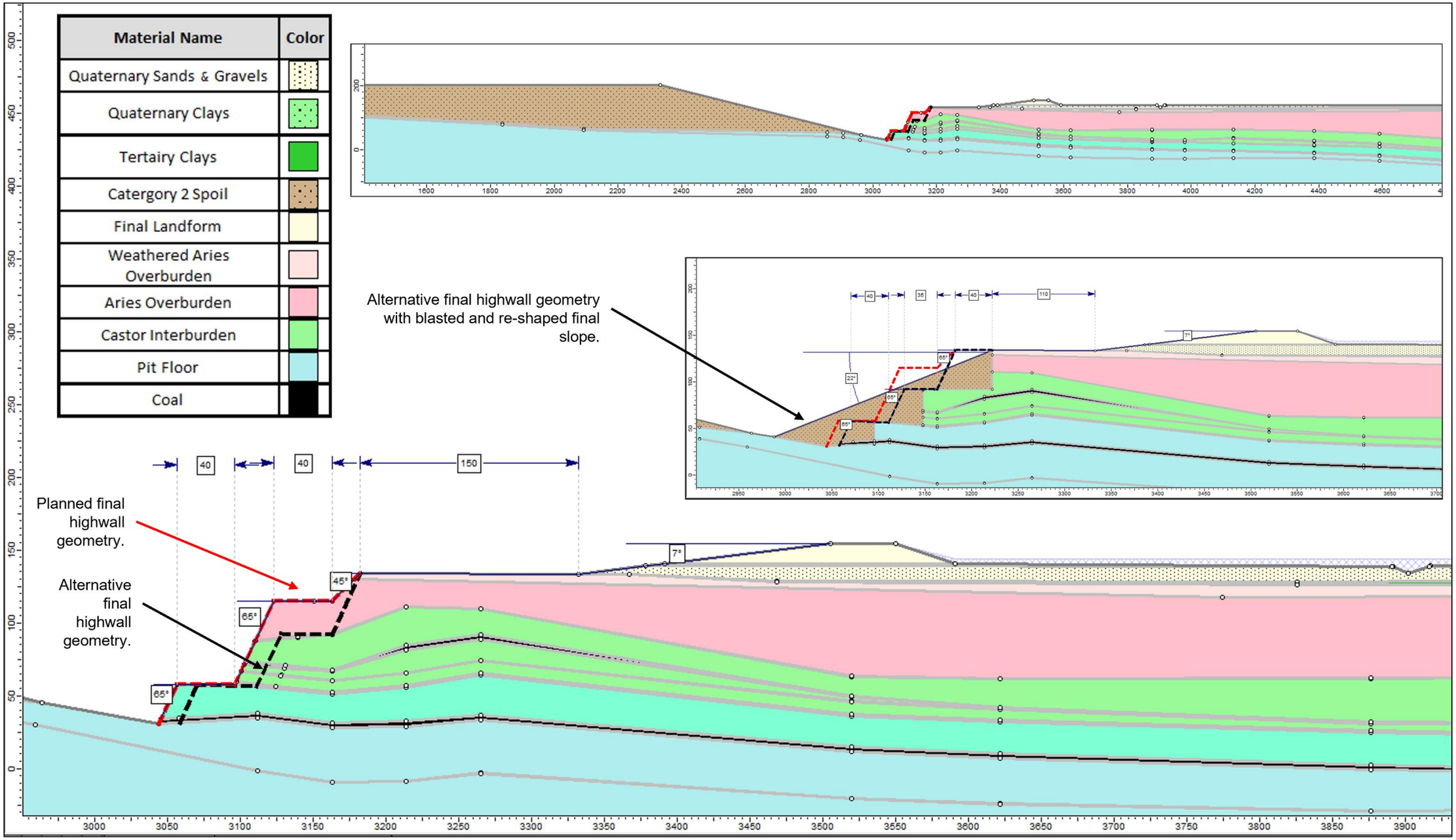


Figure 4-6 Cross Section 4 – Curragh Main D-Pit

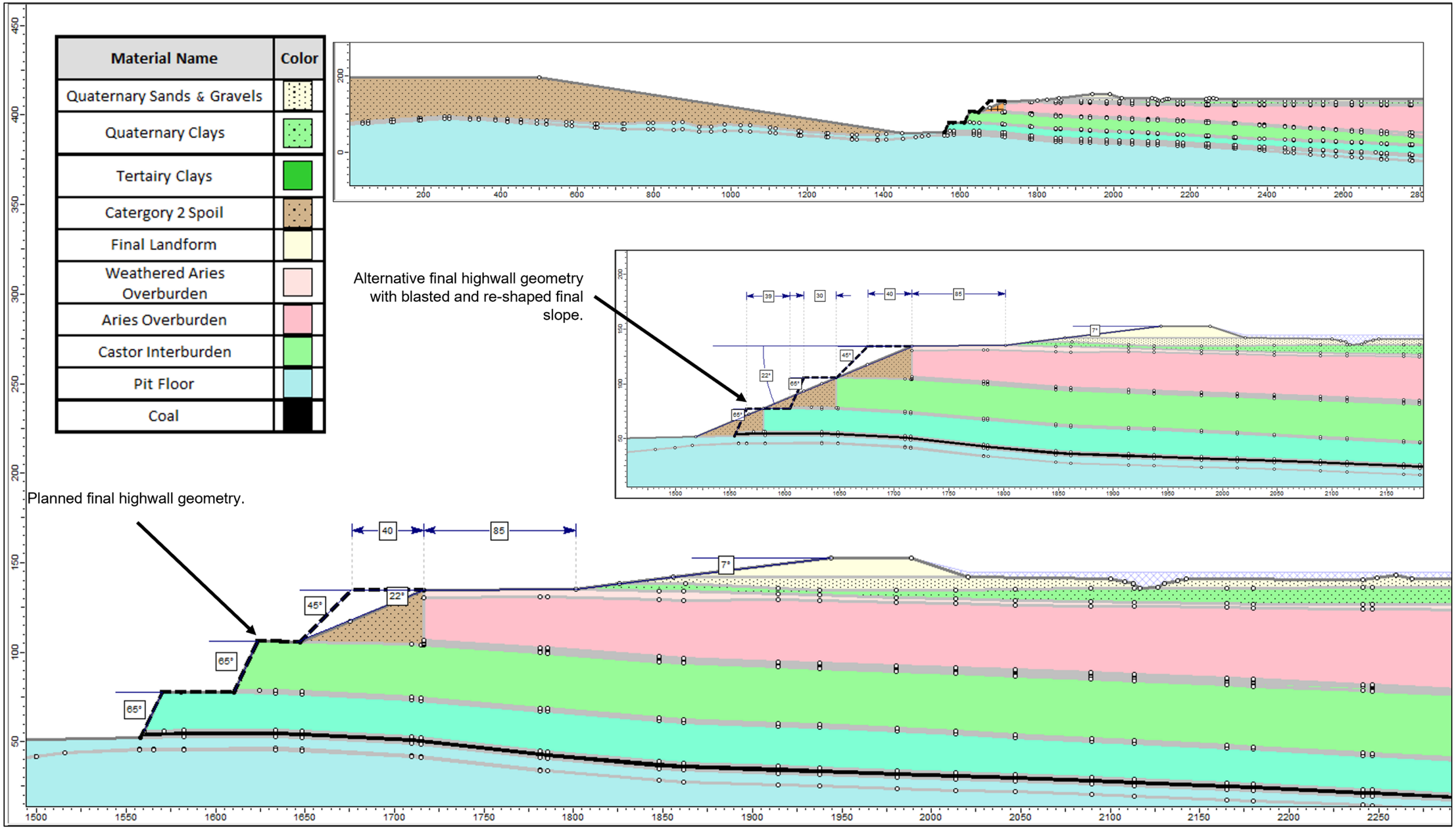


Figure 4-7 Cross Section 5 – Curragh Main F-Pit

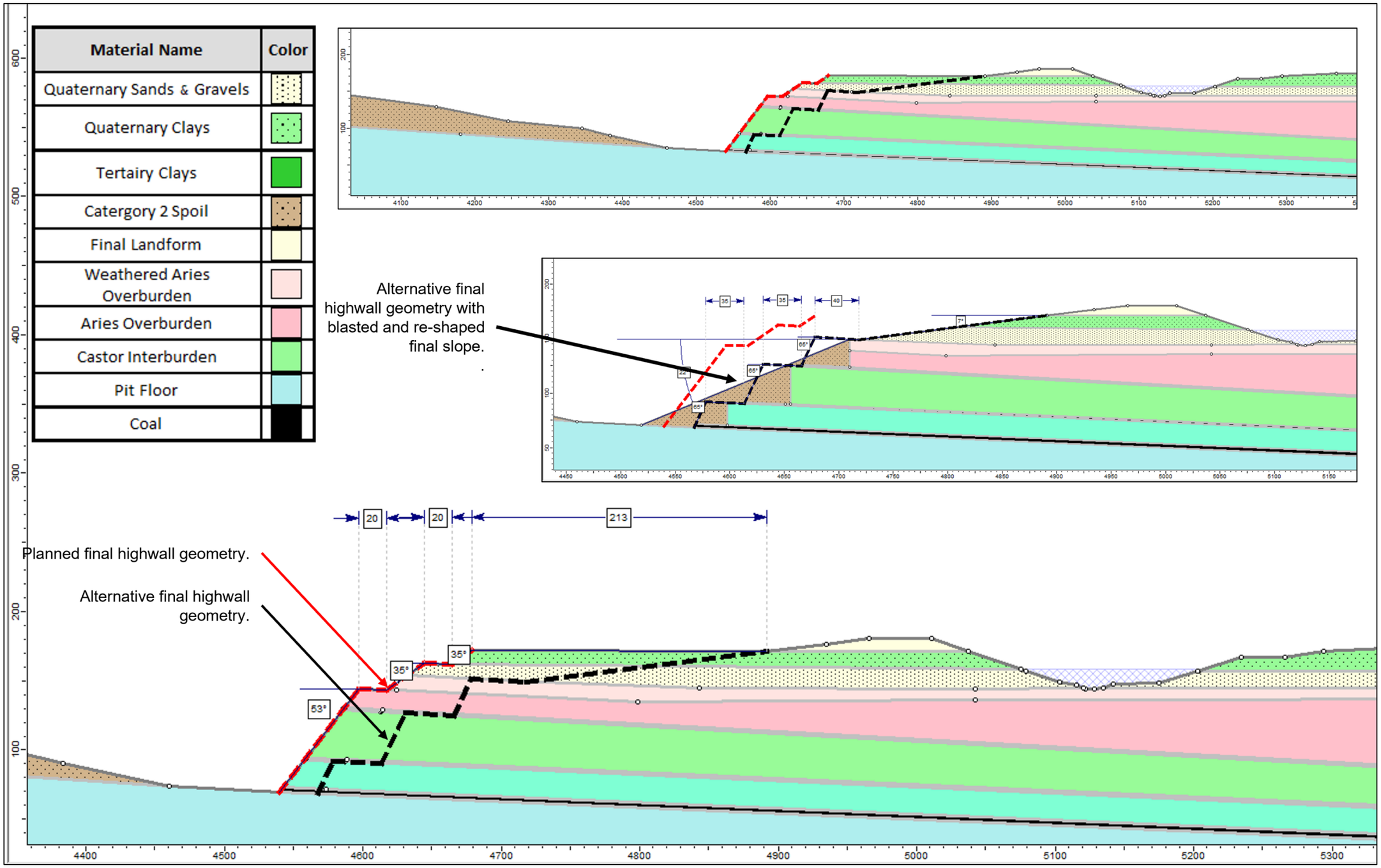


Figure 4-8 Cross Section 6 – Curragh Main K-Pit

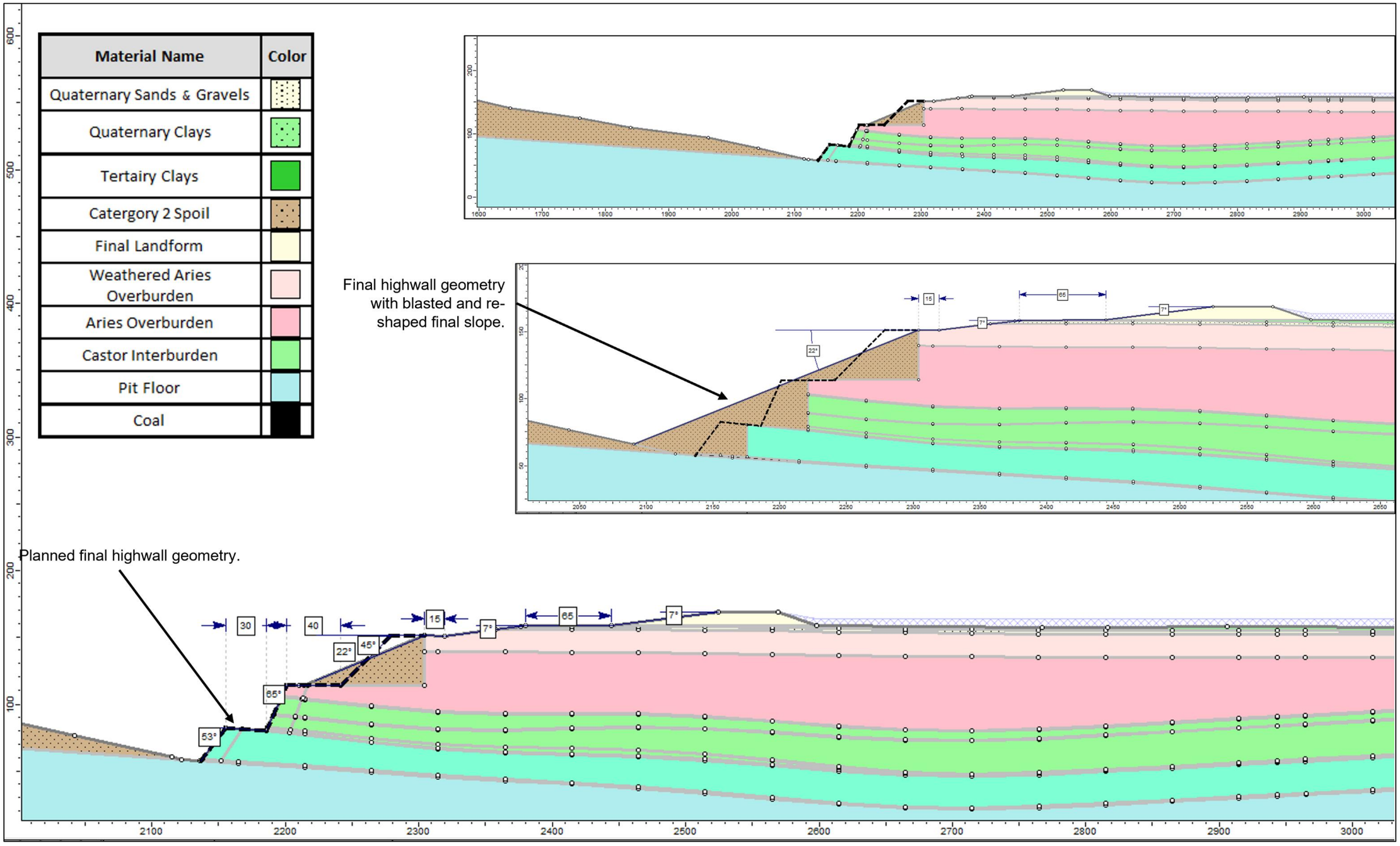
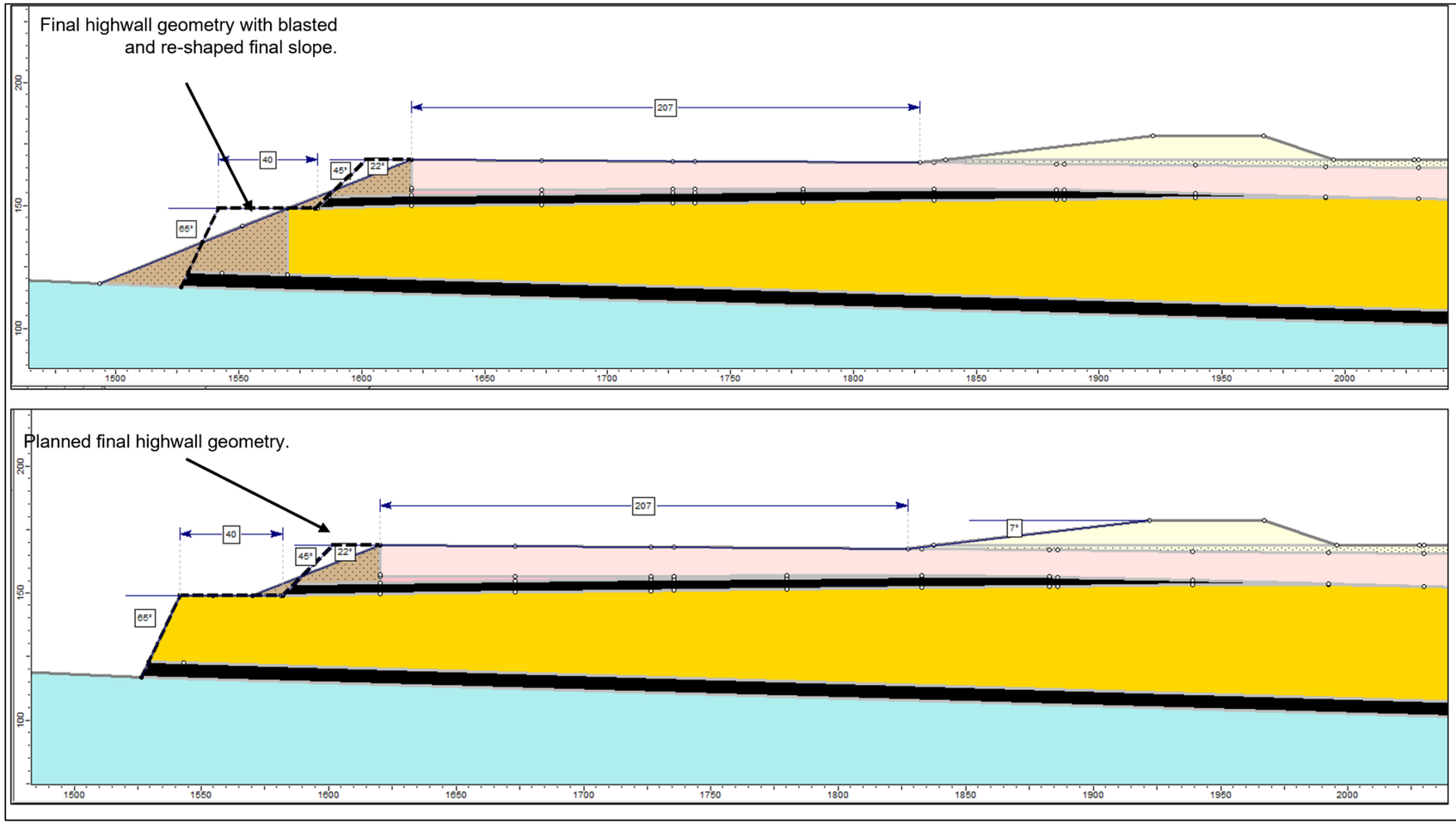


Figure 4-9 Cross Section 7 – Curragh Main J-Pit



Material Name	Color
Quaternary Sands & Gravels	
Catergory 2 Spoil	
Final Landform	
Weathered Aries Overburden	
Aries Overburden	
Pit Floor	
Coal	
Virgo Interburden	

Figure 4-10 Cross Section 8 – Y-Pit

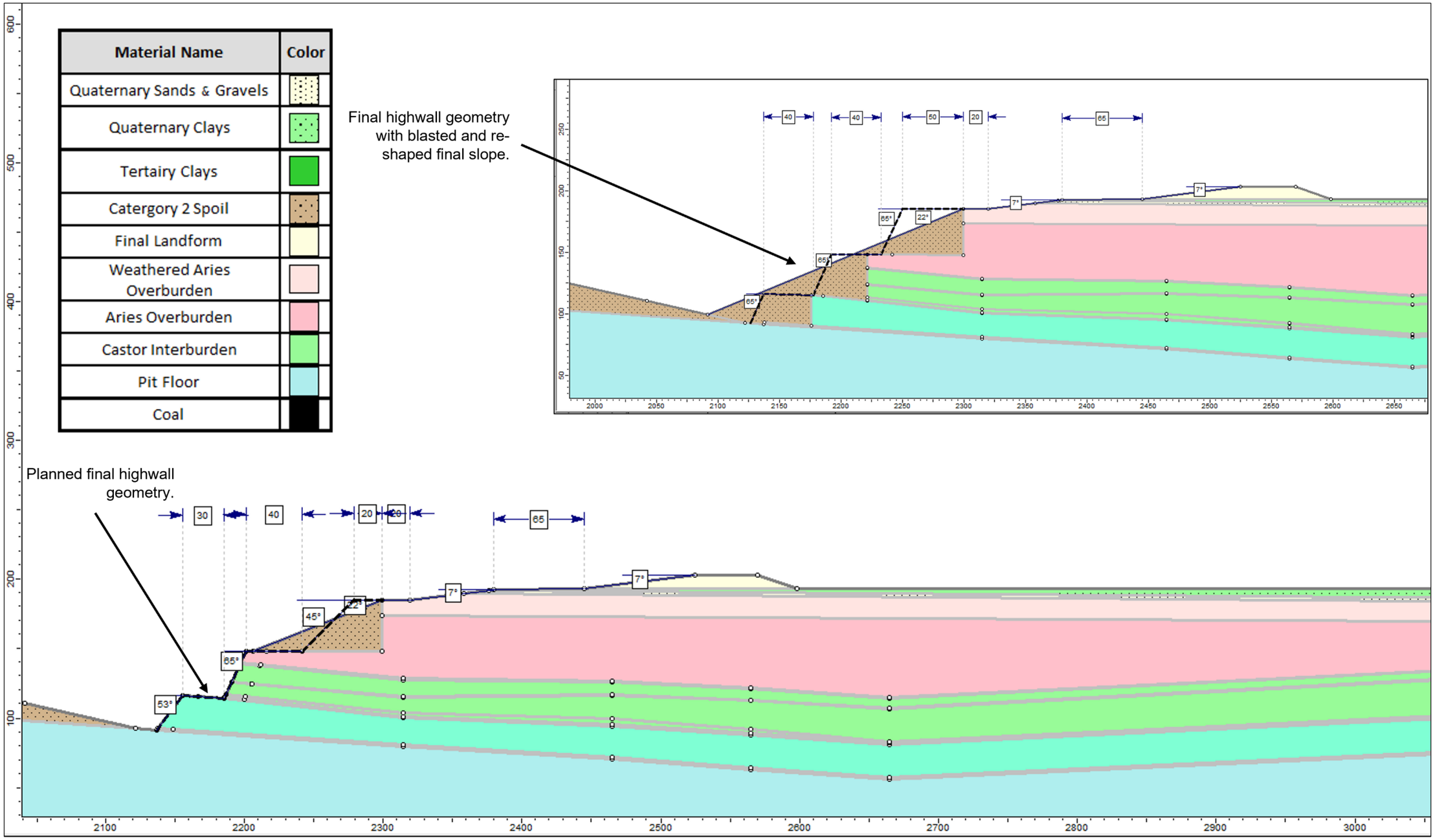


Figure 4-11 Cross Section 9 – Z-Pit

5. Slope Stability Analysis – Adopted Methodology

5.1 Adopted Geotechnical Ground Models

The adopted geotechnical ground models have been developed in Rocscience's proprietary software SLIDE 2.0 (SLIDE) and are based on the supplied final landform designs, flood levels and geological, geotechnical and hydrogeological data.

Two-dimensional limit equilibrium slope stability analysis has been completed for nine (9) cross-section final landform slope geometries, which are presented in Section 4.

5.2 Material Parameters

5.2.1 Spoil Dump Material Parameters

5.2.2 In-Pit Spoil Dumps

In general, the dragline spoil is observed to consist of spoil materials derived from fresh to weathered Permian rock. In considering the data presented in Simmons and McManus (2004) Hawley and Cunning (2017), and site observations, the spoil materials have been classified as Category 2 Spoil (refer to Figure 5-1 and Figure 5-2).

The truck dump terraces, which form the upper portions of the in-pit dumps, are considered to comprise materials similar to those described in Section 5.2.3 below.

5.2.3 Out-of-Pit Spoil Dumps

The out-of-pit dump composition appears to be highly variable with the following material types observed:

- Sands and Gravels;
- Clayey Sands;
- Low to High Plasticity Clays, Silty Clays and Sandy Clays; and,
- Highly Weathered to Slightly Weathered Permian Rock.

The adopted material strength parameters (Table 5-1) for the out-of-pit dump spoil have been taken from the following report:

- *RA002_201706_02_Rev0 Slope Stability Analysis for Out of Pit Dumps_Rev0*, dated November 2017.

Table 5-1 Adopted Out-of-Pit Spoil Dump Material Parameters

Material Name	Unit Weight (kN/m3)	Apparent Cohesion (kPa)	Friction Angle (°)
Spoil Dump Materials	18	3	28

Table 1
Shear Strength Parameters for Categories and Mobilisation Modes
(Parameter standard deviations in italicised parentheses)

Category	Unsaturated			Saturated			Remoulded
	γ (kN/m³)	c' (kPa)	ϕ' (deg)	γ (kN/m³)	c' (kPa)	ϕ' (deg)	c'=0 kPa, ϕ' (deg)
1	18 *(1)*	20 *(10)*	25 *(2.5)*	20 *(1)*	0 *(0)*	18 *(3)*	18 *(1.5)*
2	18 *(1)*	30 *(15)*	28 *(3)*	20 *(1)*	15 *(7.5)*	23 *(2.5)*	18 *(1.5)*
3	18 *(1)*	50 *(15)*	30 *(2)*	20 *(1)*	20 *(10)*	25 *(2.5)*	18 *(1.5)*
4	18 *(1)*	50 *(15)*	35 *(2.5)*	20 *(1)*	0 *(0)*	30 *(1.5)*	28 *(2)*

Figure 5-1 Shear Strength Parameters for Categories and Mobilisation Modes (Simmons & McManus, 2004).

Table 2
Spoil Categories and Attributes

CATEGORY		1	2	3	4
Description Attributes	**Weighting** *(excl. Age)*	Fine-grained clay-rich high plasticity	Fine-grained low plasticity with larger clasts	Larger clasts with fine matrix, low plasticity	Large blocks, minor fines, minor slaking
Predominant Particle Size	3/31=**9.7%** *(11.6%)*	Clay	Sand	Gravel	Cobbles
Consistency: cohesive cohesionless	7/31=**22.6%** *(26.9%)*	Soft to Firm Loose	Stiff Med. Dense	Hard Dense	XLS+ rock Very Dense
Structure	7/31=**22.6%** *(26.9%)*	Matrix only	Matrix supported	Framework supported	Framework only
Liquid Limit	9/31=**29.0%** *(34.6%)*	High (>50)	Intermediate (35 – 50)	Low (20 – 35)	Not Plastic (<20)
Age	5/31=**16.1%**	0 - 2y	2 - 10y	10 - 30y	>30y

(Note: XLS+ rock refers to rock of extremely low strength, or higher)

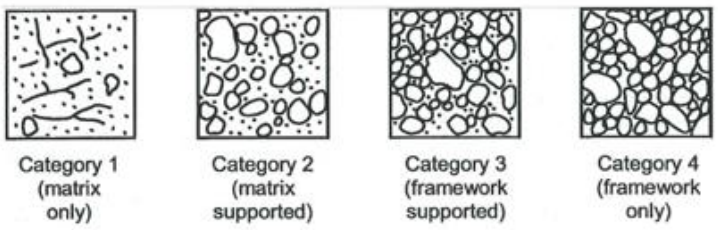


Figure 6 Spoil structure control ranking (use with Table 2)

Figure 5-2 Spoil Categories and Attributes (Simmons and McManus, 2004).

5.3 In-Situ Alluvial Material Parameters

5.3.1 Alluvial Clays

The material strength parameters adopted for in-situ clays have been based on available Atterberg Limits test data available for Curragh. Mesri (1993) calculations were undertaken to develop the material parameters presented in Table 5-2 and Table 5-3.

which represent a curved Mohr-Coulomb failure envelope, with friction angle reducing with increasing normal stress.

Table 5-2 Adopted Clay Material Parameters – Quaternary Clays

Normal Stress (kPa)	Shear Stress (kPa)
0.5	0.9
2	2.7
5	5.8
10	10.3
20	18.3
50	39.1
100	69.6
150	97.4
225	136.4
300	173.2
400	219.9
1000	470.5

Table 5-3 Adopted Clay Material Parameters – Tertiary Clays

Normal Stress (kPa)	Shear Stress (kPa)
0.5	1.5
2	4.3
5	8.6
10	14.5
20	24.4
50	48.5
100	81.6
150	110.7
225	150.0
300	186.1
400	230.9
1000	459.1

5.3.2 Alluvial Sands and Gravels

Consideration has been given to available laboratory test data and the observed pitwall performance associated with these materials. Adopted material strengths for the Sands and Gravels are provided in Table 5-4.

Table 5-4 Adopted Sand Material Parameters

Material Name	Unit Weight (kN/m3)	Apparent Cohesion (kPa)	Friction Angle (°)
Sands & Gravels	18	0	35

5.4 Permian Rock Mass Strength

The rock mass strength parameters presented in Table 5-8 and Table 5-9 have been developed from available geological and geotechnical data (i.e. geotechnical borehole data and laboratory test data) and field observations using Rocscience's proprietary software RocData incorporating disturbance factors (D) of 0 and 0.7, for a non-blast affected and a blast affect rock mass, respectively

5.4.1 Coal Material Strength

The adopted Coal material strength parameters were obtained from Martin & Stacey (2018) (Table 5-5).

Table 5-5 Adopted Coal Material Strength Parameters

Material	Unit Weight	Apparent Cohesion (kPa)	Friction Angle (°)
Coal	15	35	35

5.4.2 Tuff Material Strength

The adopted tuff material strength parameters are presented in Table 5-6 and have been derived from available direct shear test results.

Table 5-6 Adopted Tuff Material Strength Parameters

Material	Unit Weight	Apparent Cohesion (kPa)	Friction Angle (°)
Yarrabee Tuff	24	50	23

5.4.3 Adopted Hydraulic Conductivity

Adopted hydraulic conductivity values are presented in Table 5-7 and were provided by SLR for the presented analysis.

Table 5-7 Adopted hydraulic conductivity values for the considered material types

Material Name	Hydraulic Conductivity	
	K_h (m/s)	K_v/K_h (factor)
Quaternary Sands & Gravels	$1.509x10^{-5}$	0.0167
Quaternary Clays	$9.516x10^{-6}$	0.0167
Tertiary Clays	$3.617x10^{-8}$	0.0147
Weathered Permian Rock	$1.894x10^{-5}$	0.0474
Permian Rock	$9.00x10^{-10}$	0.0922
Coal Seams	$2.679x10^{-8}$	0.0156
Spoils	$1.736x10^{-4}$	0.246

Table 5-8 General Rock Mass Strength Parameters – Curragh Main

Parameter	Weathered Permian	Aries Overburden	Castor Interburden	Pollux Interburden	Pit Floor	Virgo Interburden
Unit Weight	22	24	24	24	24	24
Rock Strength (MPa)	3.62	15.73	17.96	23.59	23.96	16.85
GSI*	50	65	65	65	70	70
Mi	7	7	7	10	10	10
D	0	0	0	0	0	0
Apparent Cohesion (kPa)	87	549	537	633	1704	534
Friction Angle (°)	36	44	44	49	36	51
Parameter	Weathered Permian	Aries Overburden	Castor Interburden	Pollux Interburden	Pit Floor	Virgo Interburden
Unit Weight	22	24	24	24	24	24
Rock Strength (MPa)	3.62	15.73	17.96	23.59	23.96	16.85
GSI*	50	65	65	65	70	70
Mi	7	7	7	10	10	10
D	0.7	0.7	0.7	0.7	0.7	0.7
Apparent Cohesion (kPa)	58	309	364	437	-	372
Friction Angle (°)	28	39	39	44	-	47

*GSI is based on available geotechnical borehole data (Figure 5-3).

Table 5-9 General Rock Mass Strength Parameters – Curragh North

Parameter	Weathered Permian	Aries Overburden	Castor Interburden	Pisces Interburden	Pit Floor
Unit Weight	22	24	24	24	24
Rock Strength (MPa)	2.1	24.24	27.61	26.87	28.69
GSI*	50	65	65	65	70
Mi	7	7	7	10	10
D	0	0	0	0	0
Apparent Cohesion (kPa)	49	637	485	692	2040
Friction Angle (°)	36	47	42	49	36
Parameter	**Weathered Permian**	**Aries Overburden**	**Castor Interburden**	**Pisces Interburden**	**Pit Floor**
Unit Weight	22	24	24	24	24
Rock Strength (MPa)	2.1	24.24	27.61	26.87	28.69
GSI*	50	65	65	65	70
Mi	7	7	7	10	10
D	0.7	0.7	0.7	0.7	0.7
Apparent Cohesion (kPa)	33	414	740	473	-
Friction Angle (°)	29	42	46	45	-

*GSI is based on available geotechnical borehole data (Figure 5-3).

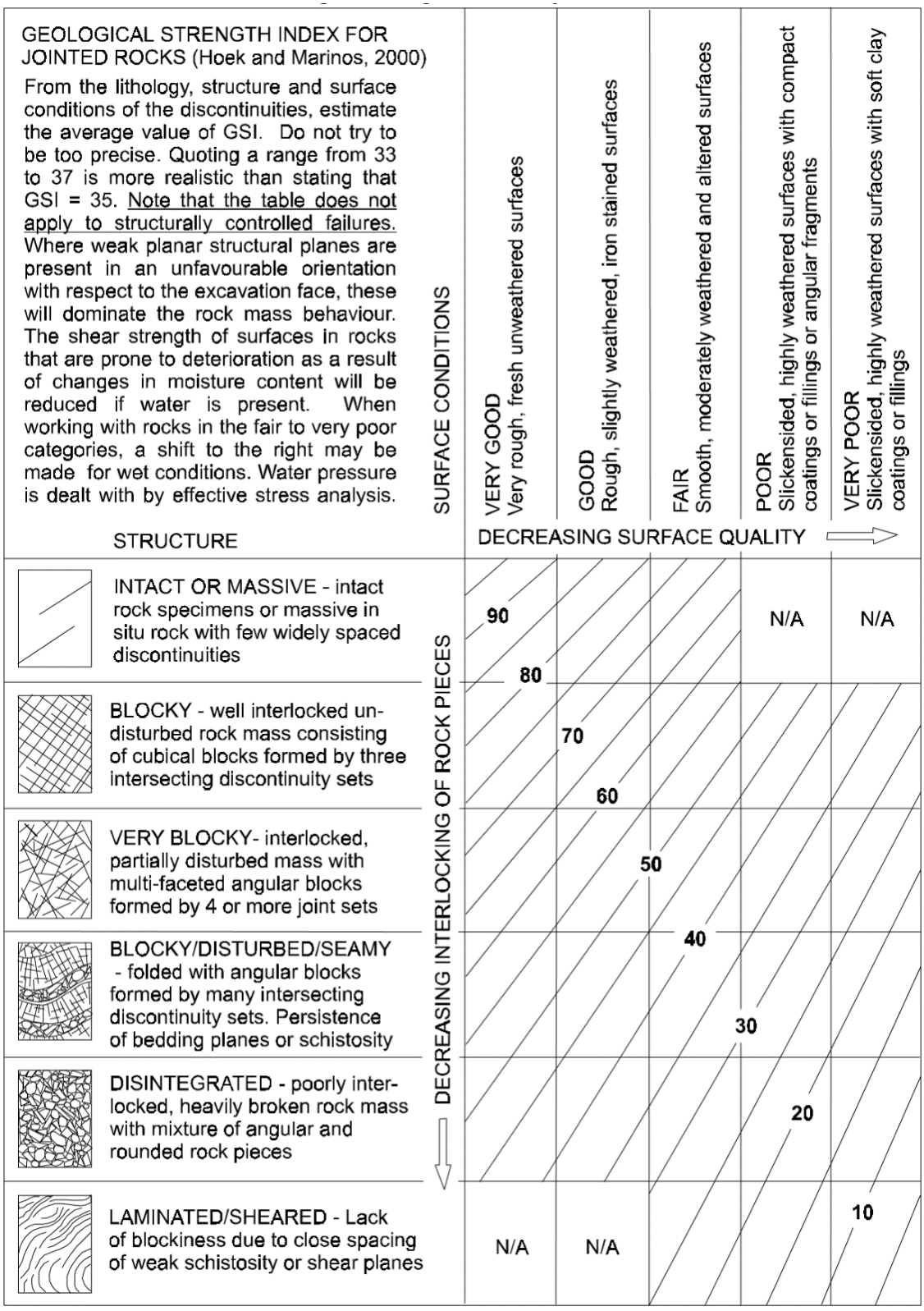


Figure 5-3 Summary of GSI classifications (Hoek and Marinos, 2000)

5.5 Adopted Slope Stability Analysis Methodology

Deterministic slope stability analysis, using two-dimensional limit equilibrium methods and Rocscience's proprietary software SLIDE 2.0 (SLIDE), has been undertaken for the nine (9) selected cross-section locations through the supplied final landform designs for Curragh.

The following assumptions, comments and qualifications are made in relation to the analyses completed:

- Static and dynamic scenarios have been considered. To consider the potential impacts of earthquakes (i.e. dynamic scenarios) a peak ground acceleration (g) of 0.02 has been applied, equivalent to an event with an exceedance probability of 2% in 50 years (refer to Section 2.3).
- For design acceptance criteria, a minimum factor of safety (FoS) of 1.5 for static conditions and 1.1 for dynamic conditions have been adopted for these analyses;
- The Spencer method has been adopted for these analyses;
- The Path Search search method has been adopted for these analyses;
- The slope stability analysis considers Global Stability of the slope;
- For the purpose of these analyses a slope angle of 7-degrees in the soil materials has been assumed. It is understood that this is to help prevent and minimise surface erosion, rather than to maintain long term stability of the relevant final landform slopes;
- A Disturbance (D) Factor of 0.7 has been applied when determining Hoek-Brown material parameters for a blast affect Permian rock mass;
- A Disturbance (D) Factor has been applied to a width equal to approximately half the bench height, where the final landform comprises final excavated pitwall geometries in the Permian rock;
- The analysis of final excavated pitwall geometries in the Permian rock only considers potential failures through the rock mass and does not consider the potential impact(s) of individual fault planes, fault orientation(s) and fault interaction(s);
- Groundwater and surface water can have a significant and adverse impact on the stability of pitwalls and must therefore be appropriately understood and considered. Limited groundwater and/or hydrogeological information is available.
    - The Steady State FEA tool provided in SLIDE has been utilised to model groundwater movement and hydrostatic pressures through the materials based on the adopted ground models, for the assumed water levels and adopted material hydraulic conductivities (Table 5-7).
    - Flood levels have been adopted as per Section 2.4. A 1m freeboard was added to the provided flood levels for the presented analysis. Values were converted to the CCPL mine grid coordinate system prior to use.
    - The final voids have been assumed to be dry for the presented analyses.
    - Perched water tables have not been considered.

6. Slope Stability Analysis Results

The analysis results for the critical failure surfaces analysed are provided in Table 6-1 to Table 6-9. Analysis outputs are provided in Appendix A.

Table 6-1 Analysis Results for the Adopted Geotechnical Ground Models -Section 1 U-Pit

Cross Section	Scenario	Estimated Static Factor of Safety	Estimated Dynamic Factor of Safety
Section 1: U-Pit	Planned Final Landform Option - Highwall Side	1.8	1.7

Table 6-2 Analysis Results for the Adopted Geotechnical Ground Models -Section 2 S-Pit South

Cross Section	Scenario	Estimated Static Factor of Safety	Estimated Dynamic Factor of Safety
Section 2: S-Pit South	Planned Final Landform Option - Highwall Side	1.8	1.7
	Planned Final Landform Option - Lowwall Side	1.7	1.6

Table 6-3 Analysis Results for the Adopted Geotechnical Ground Models -Section 3 X-Pit

Cross Section	Scenario	Estimated Static Factor of Safety	Estimated Dynamic Factor of Safety
Section 3: X-Pit	Planned Final Landform Option - Highwall Side	1.8	1.7

Table 6-4 Analysis Results for the Adopted Geotechnical Ground Models -Section 4 D-Pit

Cross Section	Scenario	Estimated Static Factor of Safety	Estimated Dynamic Factor of Safety
Section 4: D-Pit	Planned Final Landform Option - Highwall Side	2.4	2.3
	Alternative Final Landform Option - Highwall Side	3.2	2.7
	Alternative Final Highwall Re-Shaped Final Slope Option - Highwall Side	1.6	1.5

Table 6-5 Analysis Results for the Adopted Geotechnical Ground Models -Section 5 F-Pit

Cross Section	Scenario	Estimated Static Factor of Safety	Estimated Dynamic Factor of Safety
Section 5: F-Pit South	Planned Final Landform Option - Highwall Side	1.9	1.8
	Alternative Final Highwall Re-Shaped Final Slope Option - Highwall Side	1.8	1.7
	Planned Final Landform Out Board Slope	1.7	1.6
	Planned Final Landform Option - Lowwall Side	2.9	2.6

Table 6-6 Analysis Results for the Adopted Geotechnical Ground Models -Section 6 K-Pit

Cross Section	Scenario	Estimated Static Factor of Safety	Estimated Dynamic Factor of Safety
Section 6: K-Pit	Planned Final Landform Option - Highwall Side	2.5	2.4
	Alternative Final Landform Option - Highwall Side	3.2	3.1
	Alternative Final Highwall Re-Shaped Final Slope Option - Highwall Side	1.7	1.6

Table 6-7 Analysis Results for the Adopted Geotechnical Ground Models -Section 7 J-Pit

Cross Section	Scenario	Estimated Static Factor of Safety	Estimated Dynamic Factor of Safety
Section 7: J-Pit	Planned Final Landform Option - Highwall Side	1.7	1.6
	Planned Final Highwall Re-Shaped Final Slope - Highwall Side	1.6	1.5

Table 6-8 Analysis Results for the Adopted Geotechnical Ground Models -Section 8 Y-Pit

Cross Section	Scenario	Estimated Static Factor of Safety	Estimated Dynamic Factor of Safety
Section 8: Y-Pit	Planned Final Landform Option - Highwall Side	2.7	2.5
	Planned Final Highwall Re-Shaped Final Slope - Highwall Side	2.0	1.9

Table 6-9 Analysis Results for the Adopted Geotechnical Ground Models -Section 9 Z-Pit

Cross Section	Scenario	Estimated Static Factor of Safety	Estimated Dynamic Factor of Safety
Section 9: Z-Pit	Planned Final Landform Option - Highwall Side	1.8	1.7
	Planned Final Highwall Re-Shaped Final Slope - Highwall Side	1.6	1.5

7. Discussion and Recommendations

Two-dimensional limit equilibrium slope stability analysis has been completed with the estimated static and dynamic Factors of Safety (FoS) for the critical failure surface analysed presented for CCPL's consideration. The estimated FoS should only be used as a general guide for assessing potential geotechnical hazards and risks associated with the longer-term stability of the final landform designs.

Deterministic analysis results for the final landform designs, based on the adopted ground models and analysis methodology and assumptions, indicate that the final landform designs meet the adopted design acceptance criteria (Section 5.5).

It must be noted that the material parameters used in these analyses are consistent with those currently used for in-pit slope design. These are typically based on mean strength parameters, which lead to relatively high probabilities of failure when uncertainty is considered. For example, Table 9.7 in Read & Stacey (2009) suggests that for in-pit slope design a factor of safety of 1.5 may have a Probability of Failure (PoF) of up to 10 or 15%, and a factor of safety of 1.6 still has a PoF of up to 8%. These are unlikely to be acceptable in areas to which the public has access, where a factor of safety of 1.5 is expected to have a much lower PoF as a result of the use of more conservative design parameters. It is therefore necessary for CCPL to confirm that the adopted FoS are acceptable.

Past pitwall performance at Curragh indicates that geological structures are a key factor requiring consideration as part of the design process and CPS. The analysis of sections that include remnant pitwalls in the Permian rock only considers potential failures through the rock mass and does not consider the potential impact(s) of individual fault planes, fault orientation(s) and fault interaction(s). Where adverse fault orientations and interactions, relative to pitwall geometries and locations are present, the planned final pitwall geometries (as provided) may not be appropriate for CCPLs long-term final landform stability requirements. In such cases alternative design options such as the construction of softwalls in blasted Permian rock may be required. Due to potential surface erosion mitigation requirements and in order to meet the adopted design acceptance criteria for long-term slope stability, it may be necessary to re-shape softwalls to reduce slope angles. A re-shaped slope angle of approximately 22-degrees has been considered in the analysis undertaken for ground models that consider re-shaping of softwalls constructed in blasted Permian rock. The associated cut-fill balance of these options is to be further investigated as detailed design works are completed.

The ability to identify geological fault locations and geometries accurately for the final pitwall is limited by existing data coverage and density. Fault interpretations and geotechnical ground models for final pitwalls are to be developed as mining progresses and/or additional geology and geotechnical data is collected and obtained.

To consider the provided flood levels for X-Pit the proposed final landform has been raised by approximately 10m for the purpose of these analyses.

The slope stability analyses presented in this document should be reviewed and updated when new geological, geotechnical and/or hydrogeological data becomes available or as material changes are made to existing data or the design options are developed.

The following recommendations are provided in relation to detailed design of the final landforms:

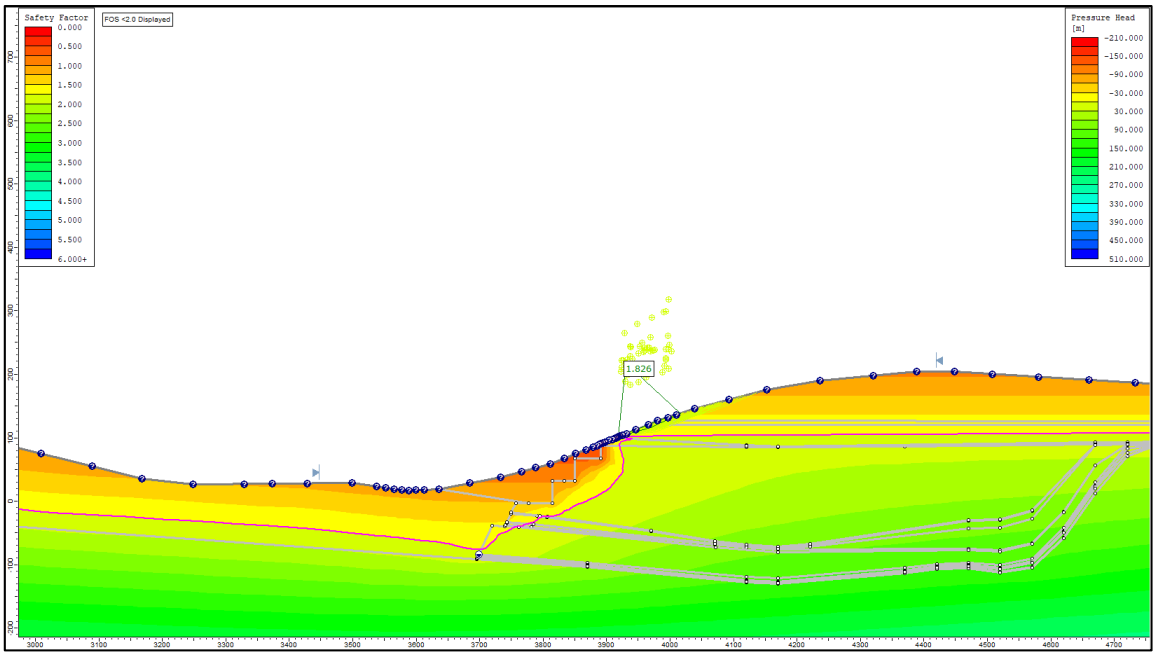
- The construction of the final landform designs, including cut-fill volumes, are to be reviewed and developed;
- An erosional assessment is necessary to confirm the maximum slope angles for the various soil strength materials (including spoil materials). The final landform designs, and if deemed necessary the slope stability analysis, are to be updated based on the outcomes of the erosion assessment;
- Geological, geotechnical and hydrogeological data collection strategies for the final pitwalls are to be developed and implemented to inform the detailed design process;
- The hydrogeological and hydrological models should be developed, and an associated groundwater investigation program implemented;
- Investigations and studies should be undertaken to identify the potential location and extent of Paleochannels in the alluvial soil profile; and,
- As the final landform designs are progressed, and additional geological, geotechnical, hydrogeological and/or hydrological data is obtained, more detailed and extensive slope stability analysis may be required. This should include assessment of all slope geometries, remnant pitwalls and final voids. It is recommended that detailed design include probabilistic slope stability analysis.

8. Qualification

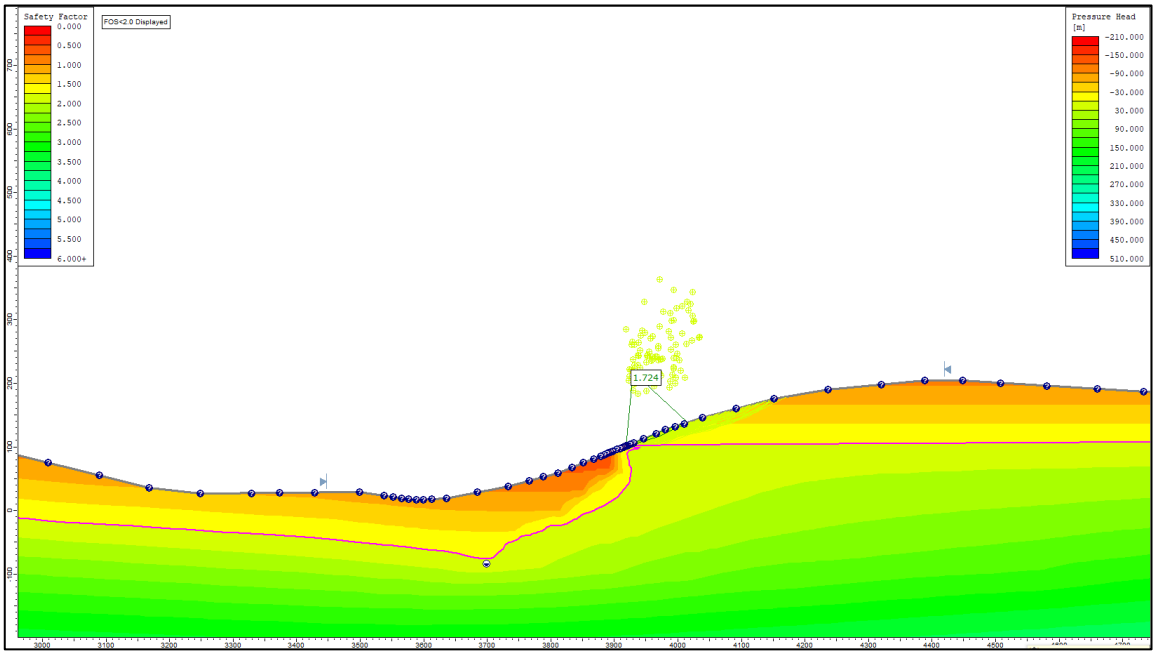
The following qualifications are made in relation to the analysis and recommendations presented in this report:

- This document has been prepared by R&A for CCPL and may only be used and relied upon by CCPL for the purpose agreed between R&A and CCPL as set out in relevant sections of this memorandum. R&A otherwise disclaims responsibility to any person other than CCPL arising in connection with this memorandum.
- It has been assumed that all data supplied by CCPL is true and accurate and that all available and relevant data has been supplied. R&A has not independently verified or validated the data supplied by CCPL and does not accept liability in connection with unverified information, including errors and omissions in this document which were caused by errors or omissions in that information.
- The outputs, opinions, conclusions and recommendations provided in this document are based on the adopted geotechnical ground models and analysis methods. The adopted geotechnical ground models presented in this report may be constrained by available data type, density and accuracy. Therefore there is potential for interpreted ground conditions to vary from those assumed in the adopted ground models. R&A assume that CCPL will undertake detailed design and risk analysis for the design option part of the design process.
- No geotechnical investigations or laboratory testing have been commissioned or undertaken as part of this work.
- The groundwater levels and phreatic surfaces adopted as per data supplied by SLR.
- If the content of this document, including the adopted methods and terminology, is unclear or not fully understood clarification should be sort.
- If it is known, or subsequently becomes known, that any of the qualifications, assumptions or interpretations made in this memorandum are incorrect, R&A must be notified immediately, and the applicability of the slope stability analysis and any associated recommendations reviewed. If considered necessary, the slope stability analysis and report may need to be updated.

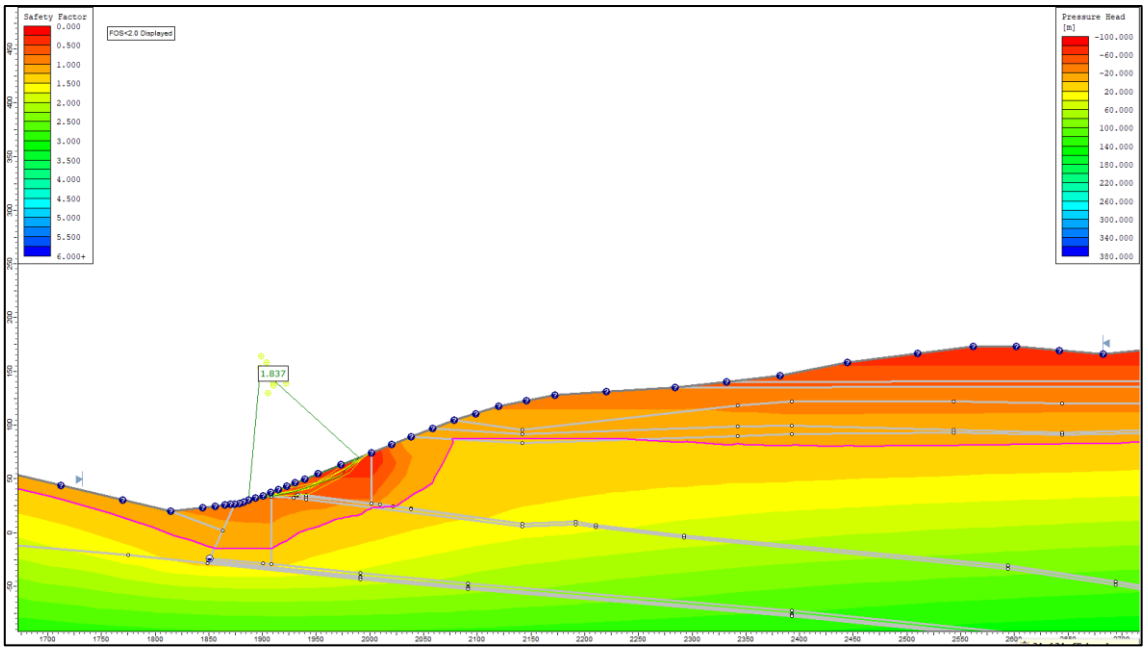
Appendix A – Limit Equilibrium Slope Stability Analysis Outputs



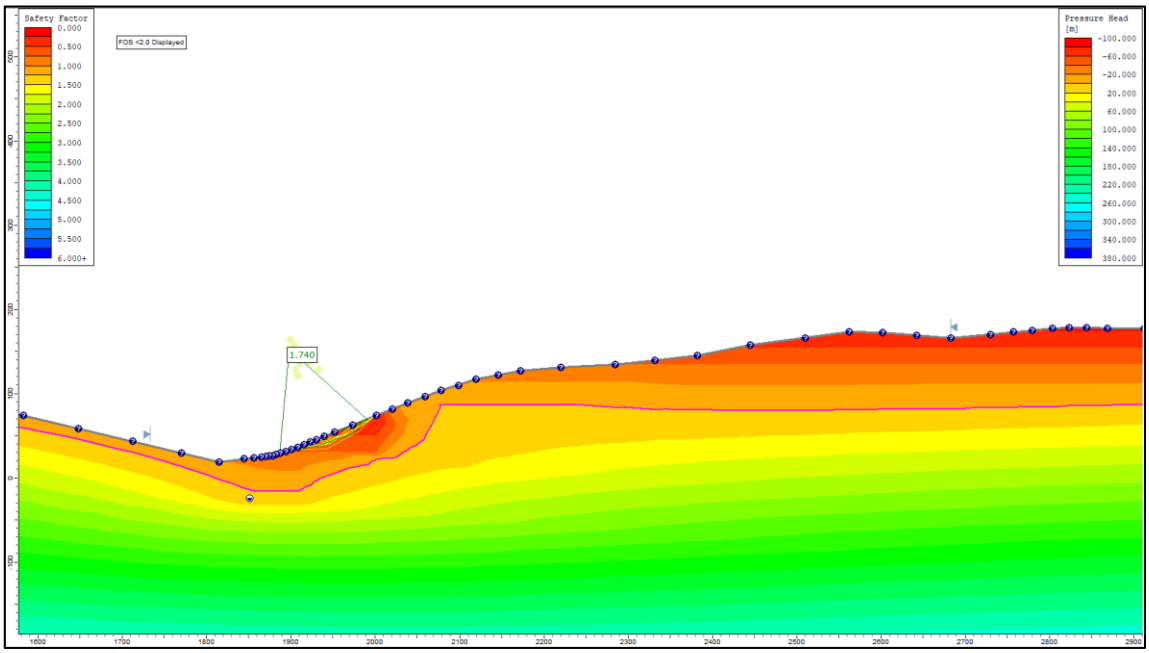
Appendix A 1 Cross Section 1 – Curragh North U-Pit - Static



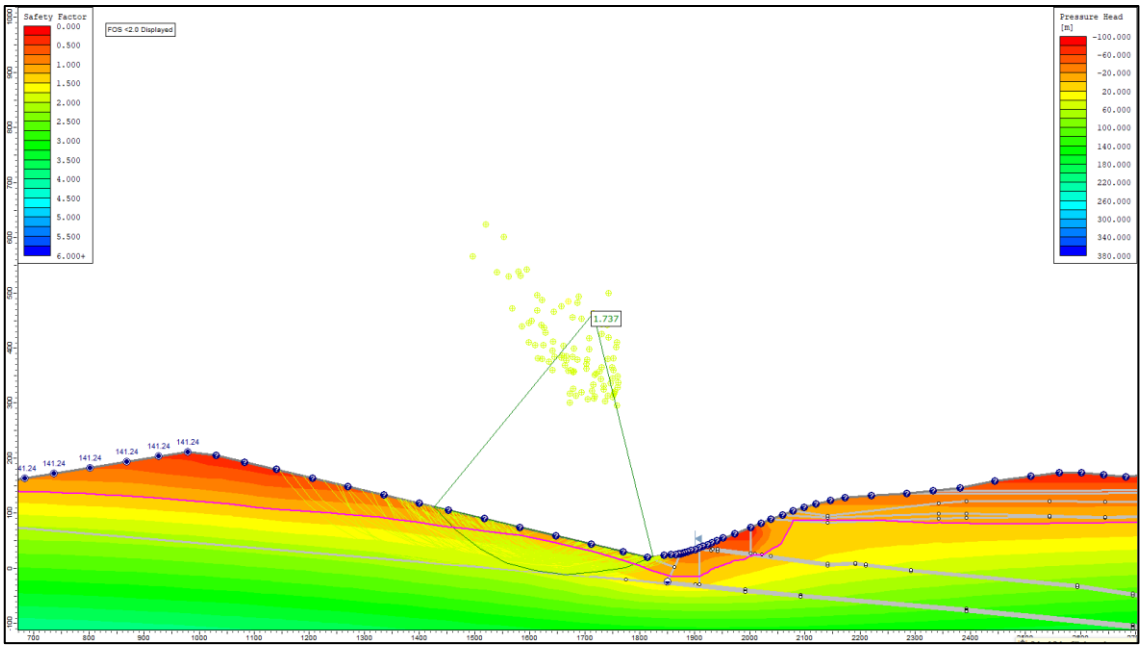
Appendix A 2 Cross Section 1 – Curragh North U-Pit - Dynamic



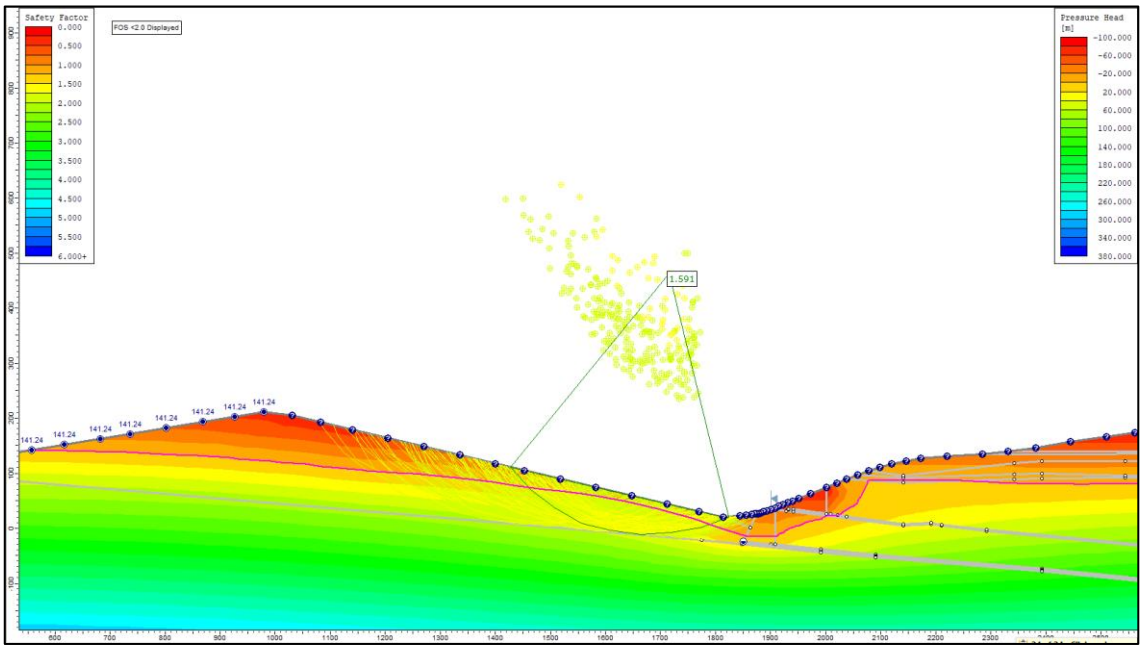
Appendix A 3 Cross Section 2 – Curragh North S-Pit South - Static



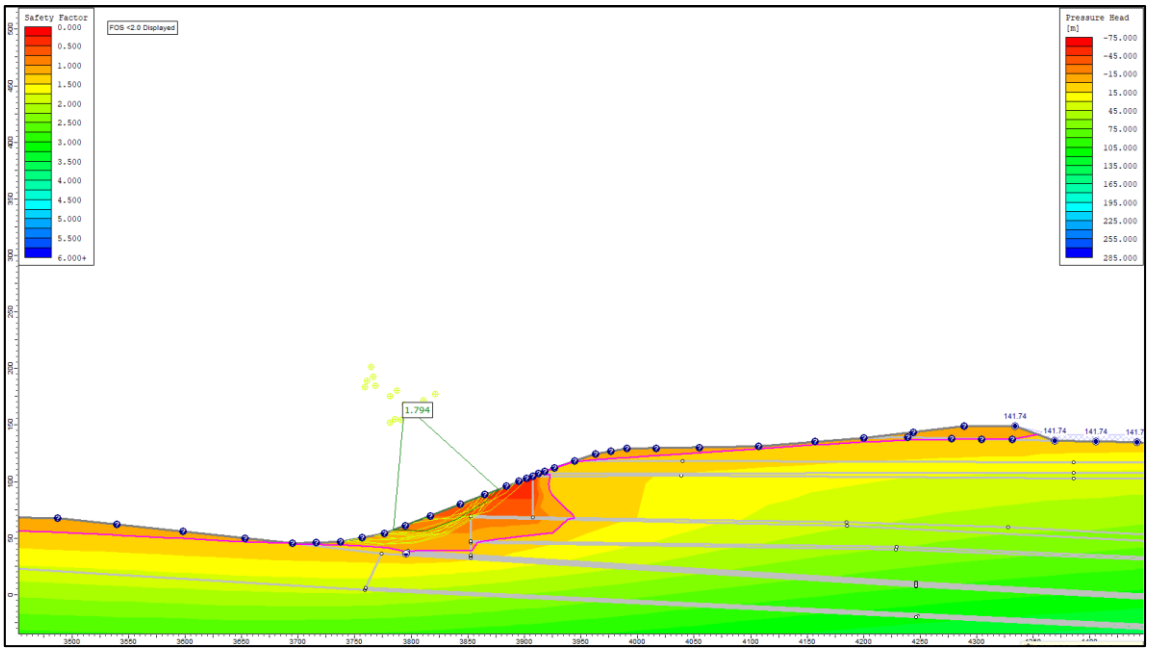
Appendix A 4 Cross Section 2 – Curragh North S-Pit South - Dynamic



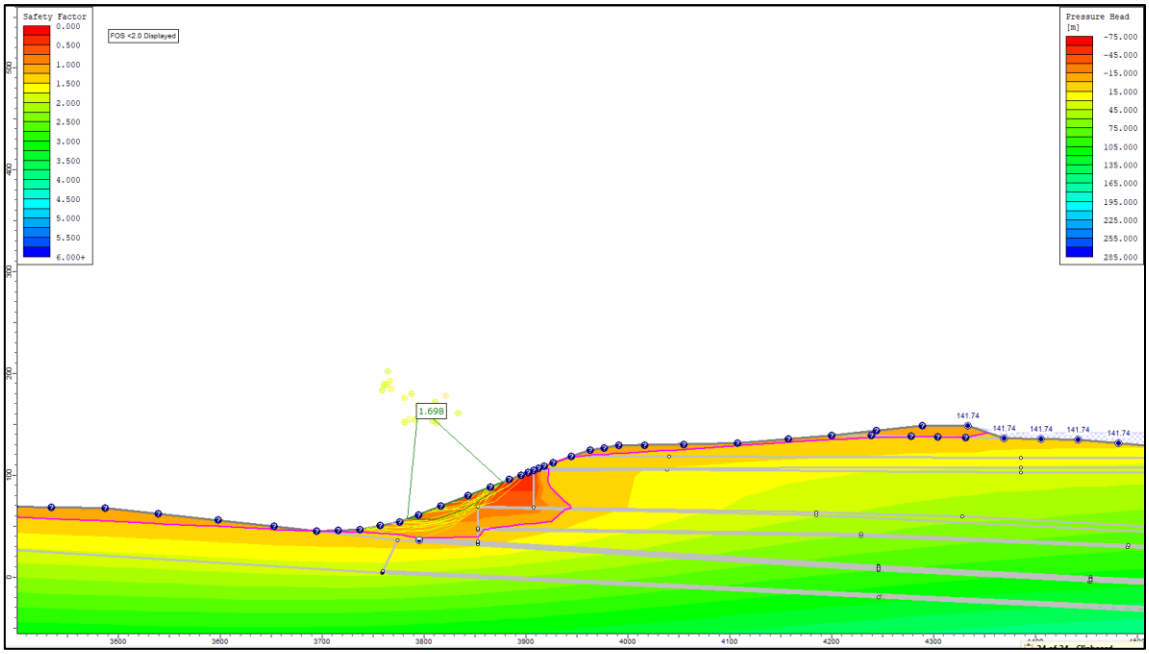
Appendix A 5 Cross Section 2 – Curragh North S-Pit South Lowwall – Static



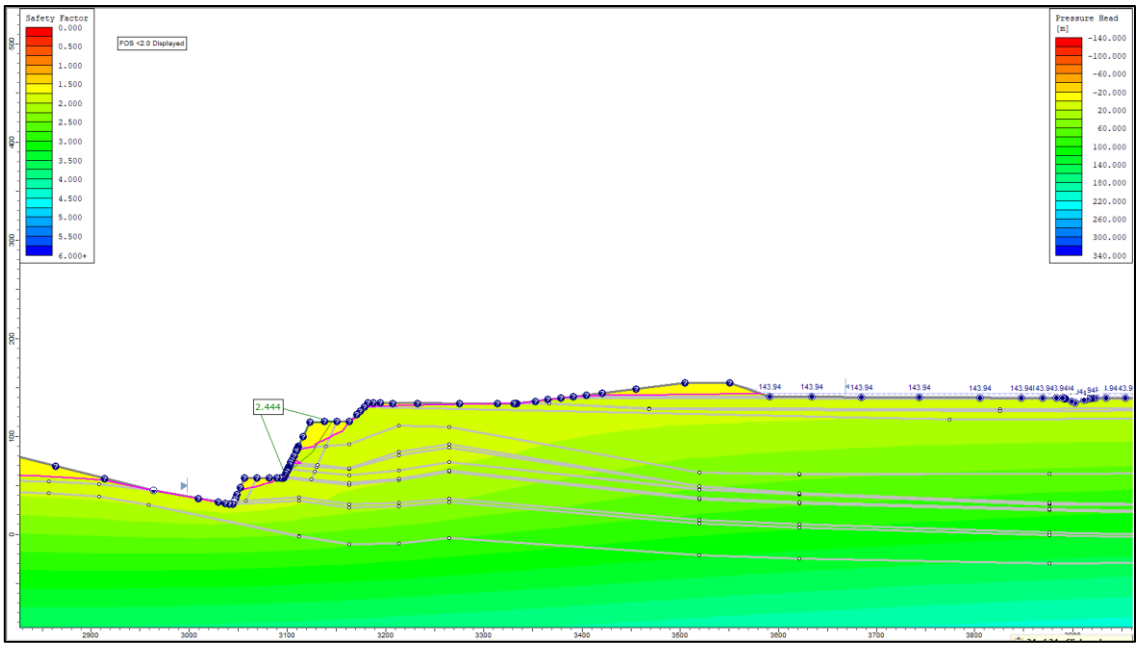
Appendix A 6 Cross Section 2 – Curragh North S-Pit South Lowwall - Dynamic



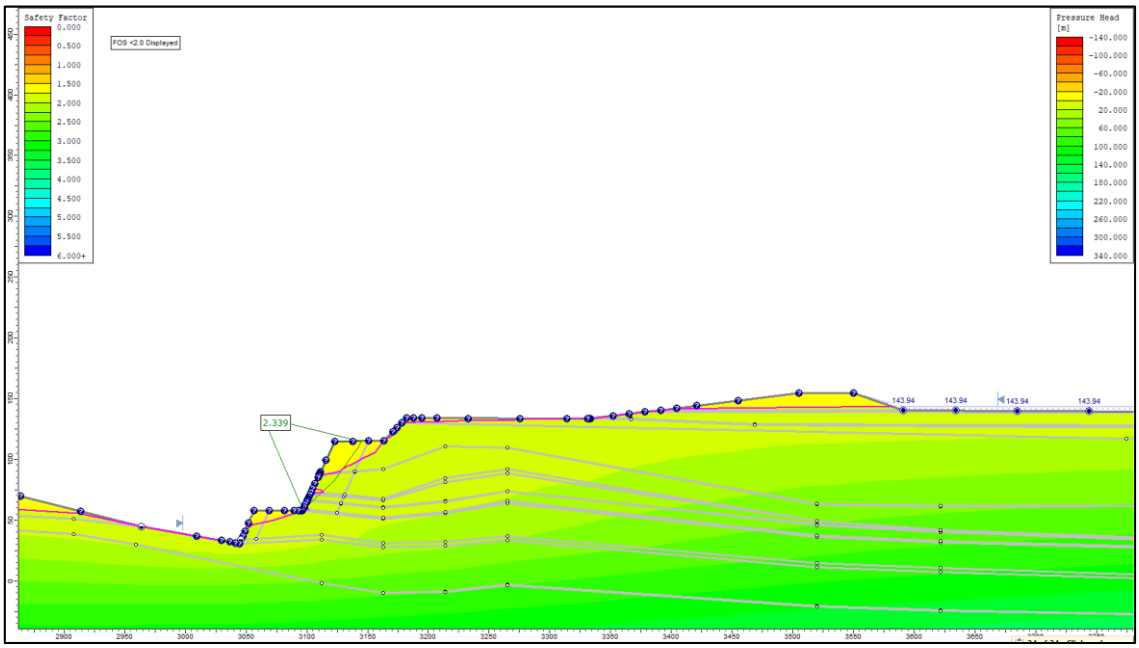
Appendix A 7 Cross Section 3 – X-Pit – Raised final landform to accommodate supplied flood levels - Static



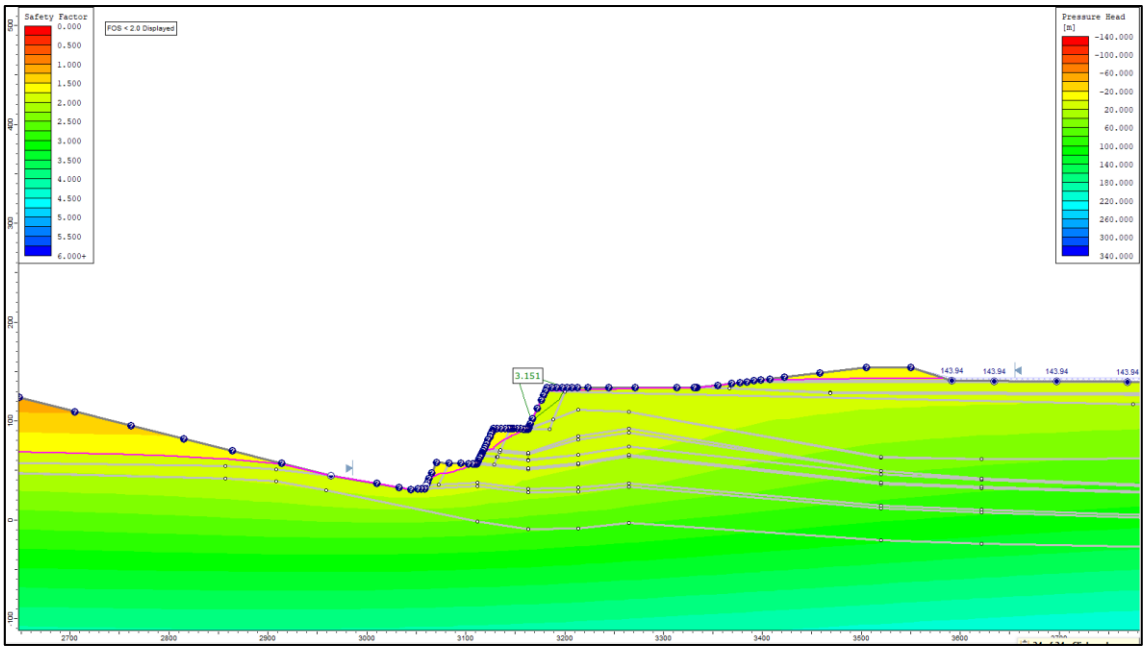
Appendix A 8 Cross Section 3 – X-Pit – Raised final landform to accommodate supplied flood levels - Dynamic



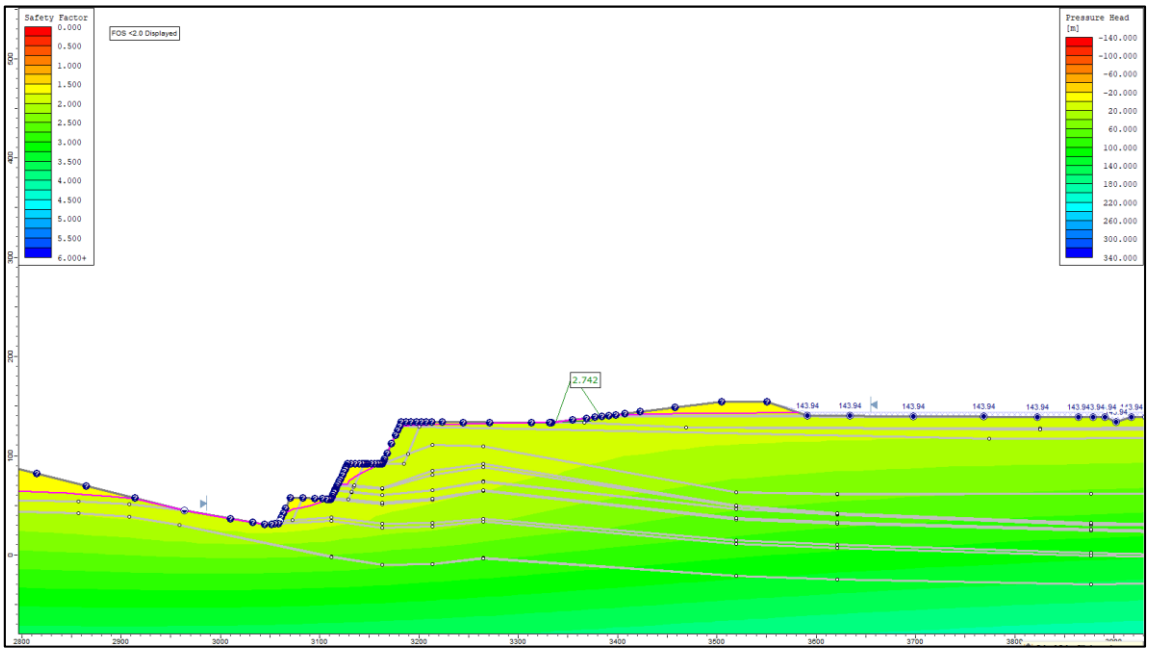
Appendix A 9 Cross Section 4 – Curragh Main D-Pit - Static



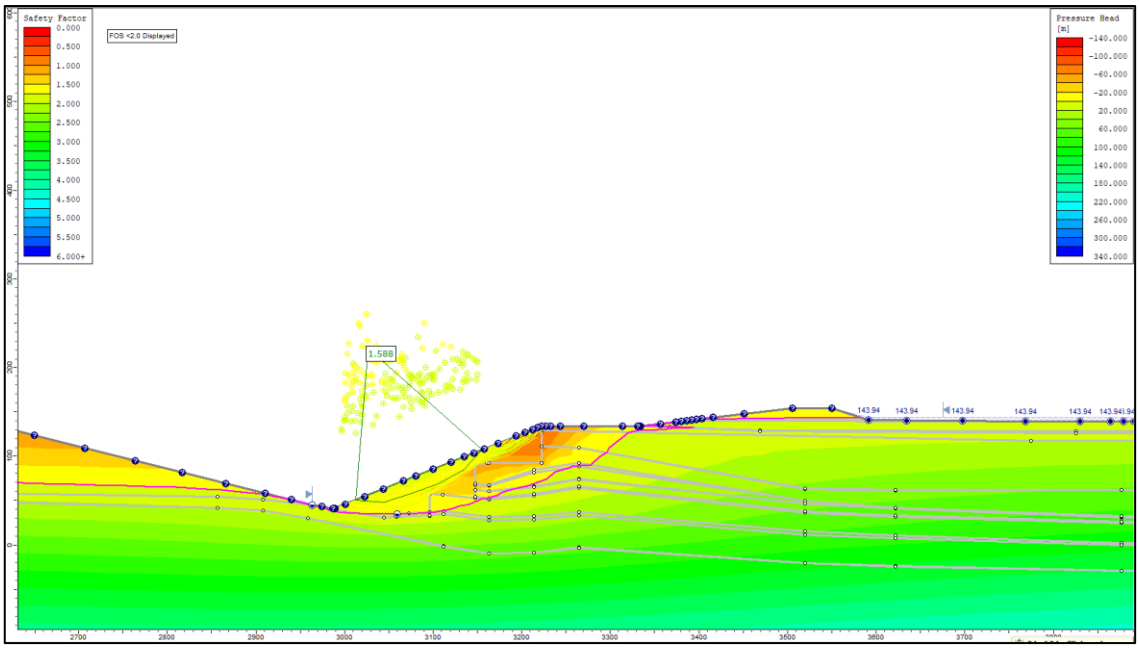
Appendix A 10 Cross Section 4 – Curragh Main D-Pit - Dynamic



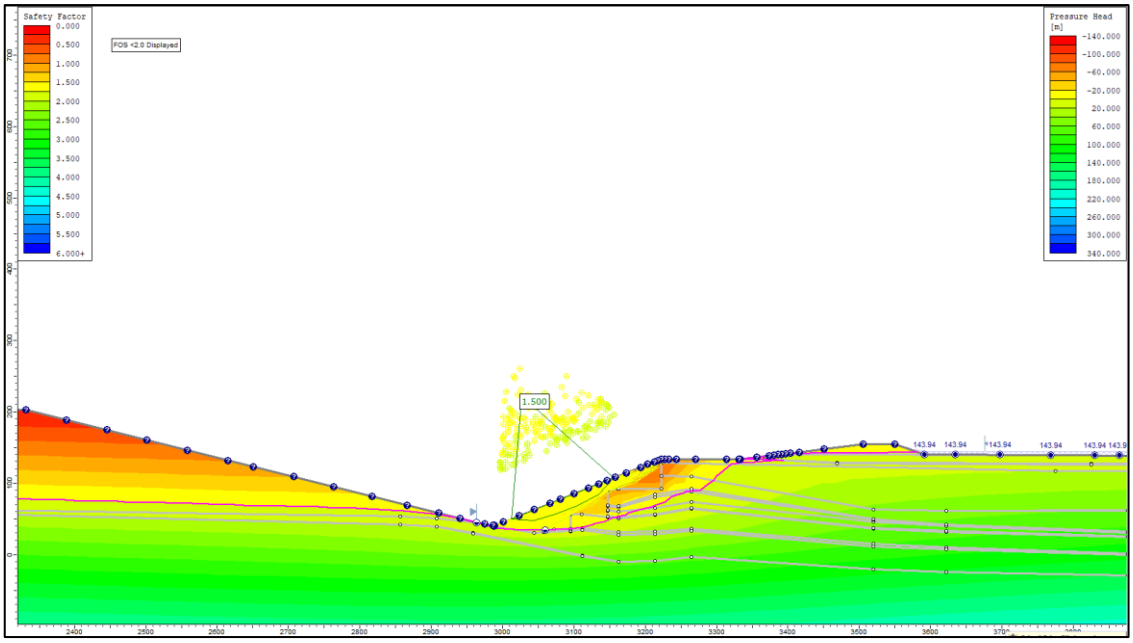
Appendix A 11 Cross Section 4 – Curragh Main D-Pit Alternative final highwall geometry – Static



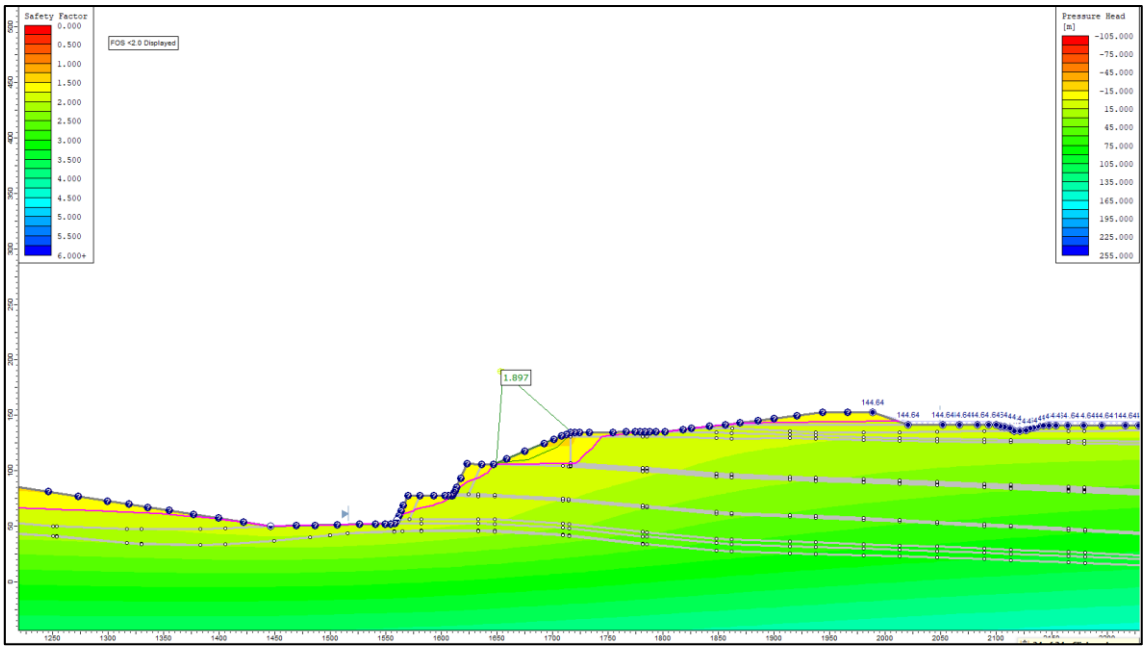
Appendix A 12 Cross Section 4 – Curragh Main D-Pit Alternative final highwall geometry – Dynamic



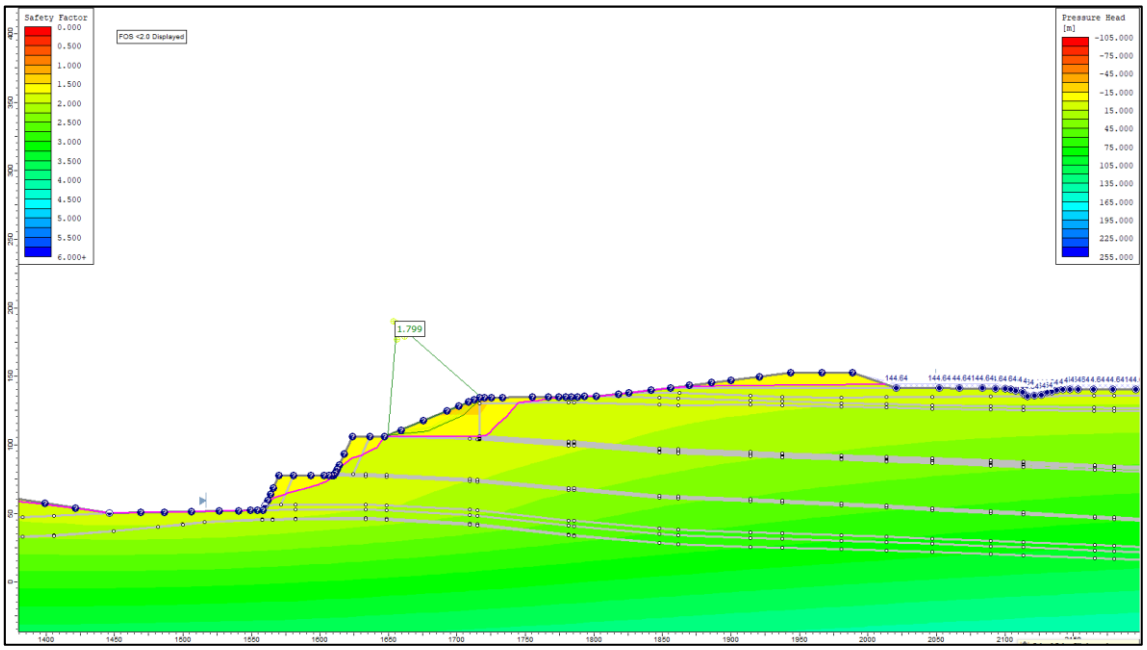
Appendix A 13 Cross Section 4 – Curragh Main D-Pit Alternative final highwall geometry with blasted and re-shaped final slope – Static



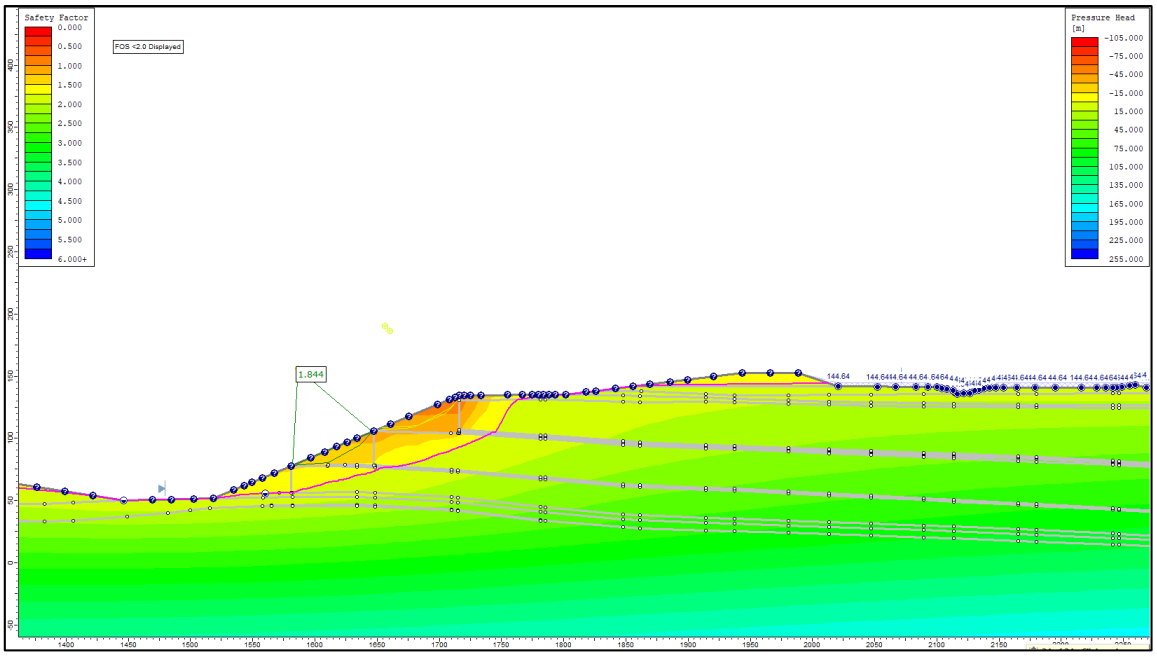
Appendix A 14 Cross Section 4 – Curragh Main D-Pit Alternative final highwall geometry with blasted and re-shaped final slope – Dynamic



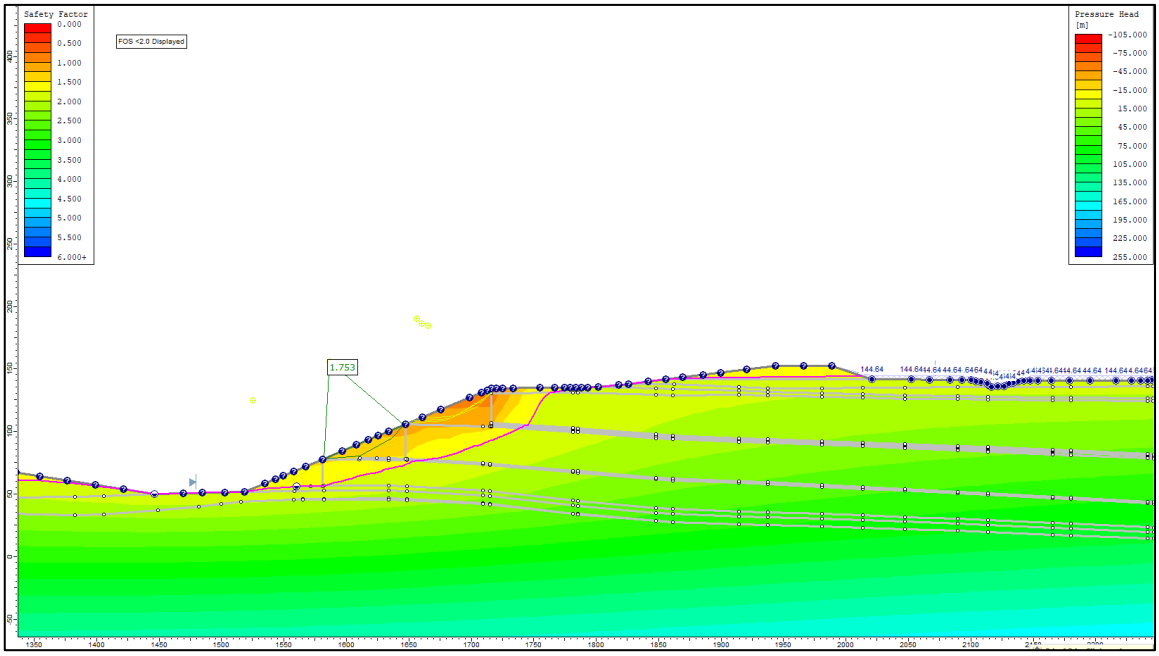
Appendix A 15 Cross Section 5 – Curragh Main F-Pit - Static



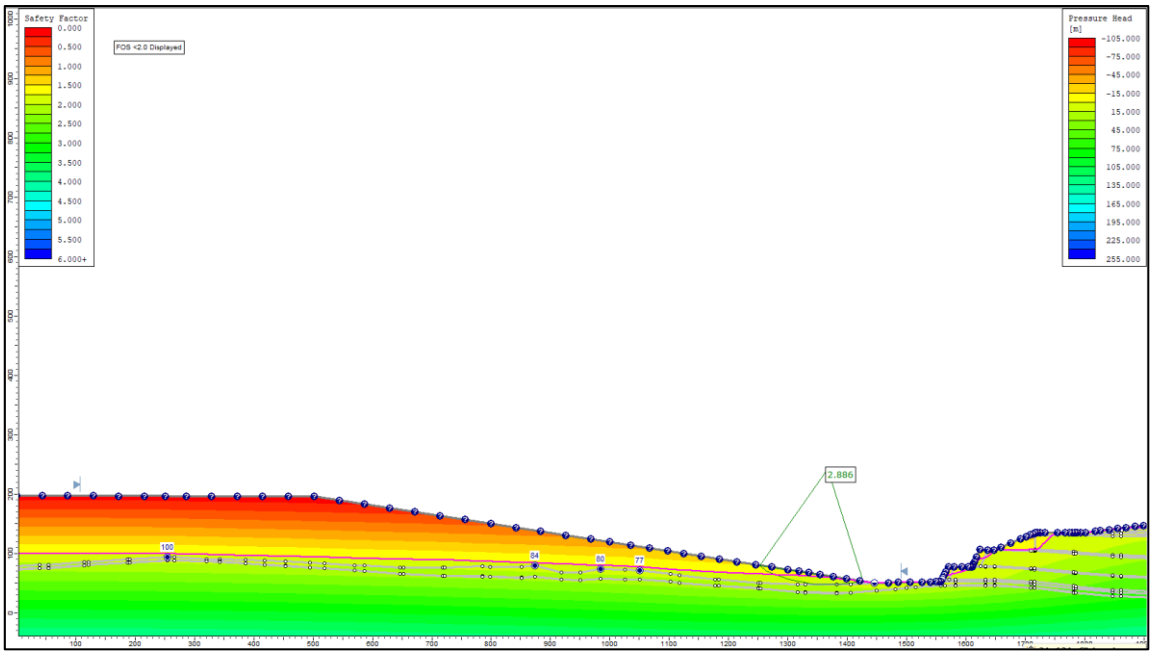
Appendix A 16 Cross Section 5 – Curragh Main F-Pit - Dynamic



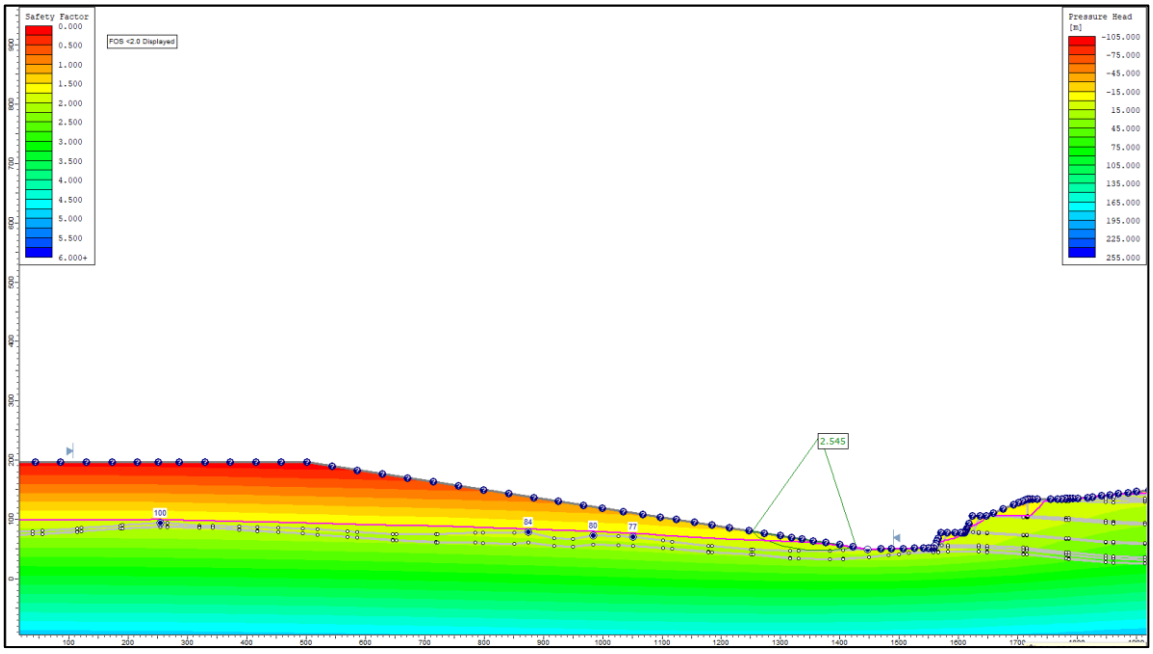
Appendix A 17 Cross Section 5 – Curragh Main F-Pit Final highwall geometry with blasted and re-shaped final slope – Static



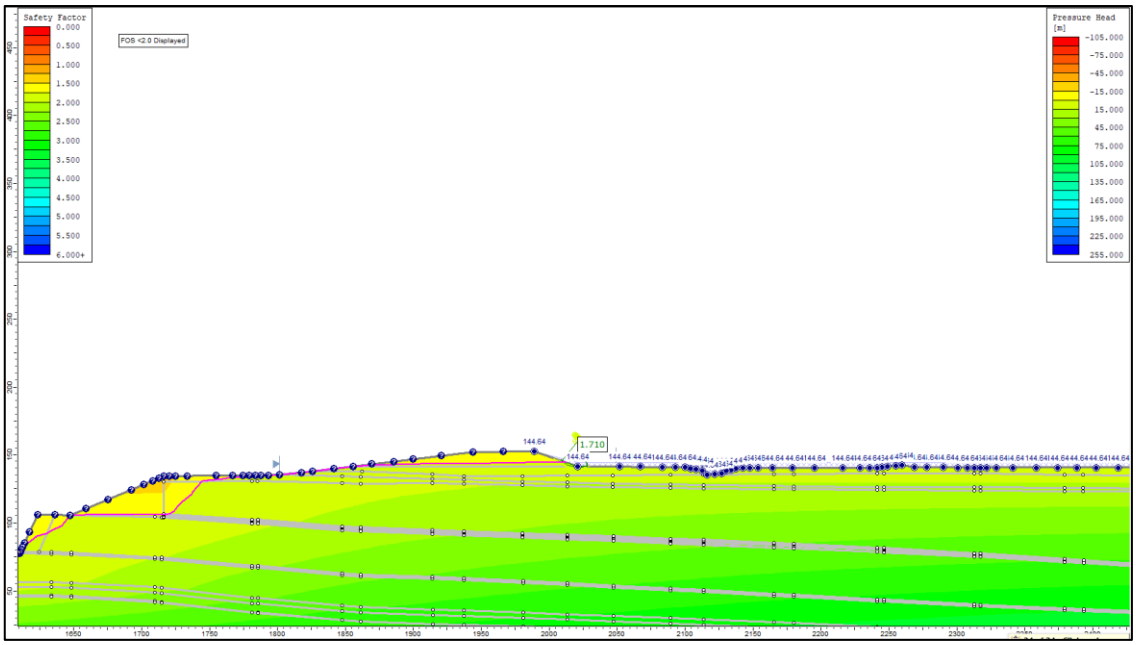
Appendix A 18 Cross Section 5 – Curragh Main F-Pit Final highwall geometry with blasted and re-shaped final slope – Dynamic



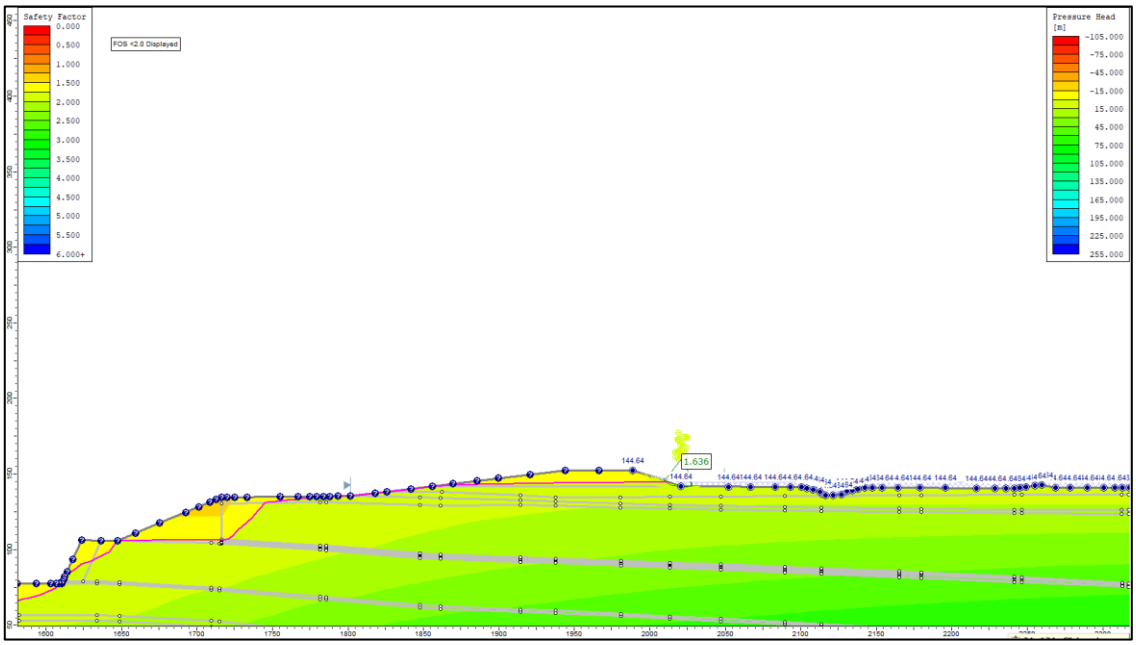
Appendix A 19 Cross Section 5 – Curragh Main F-Pit Lowwall - Static



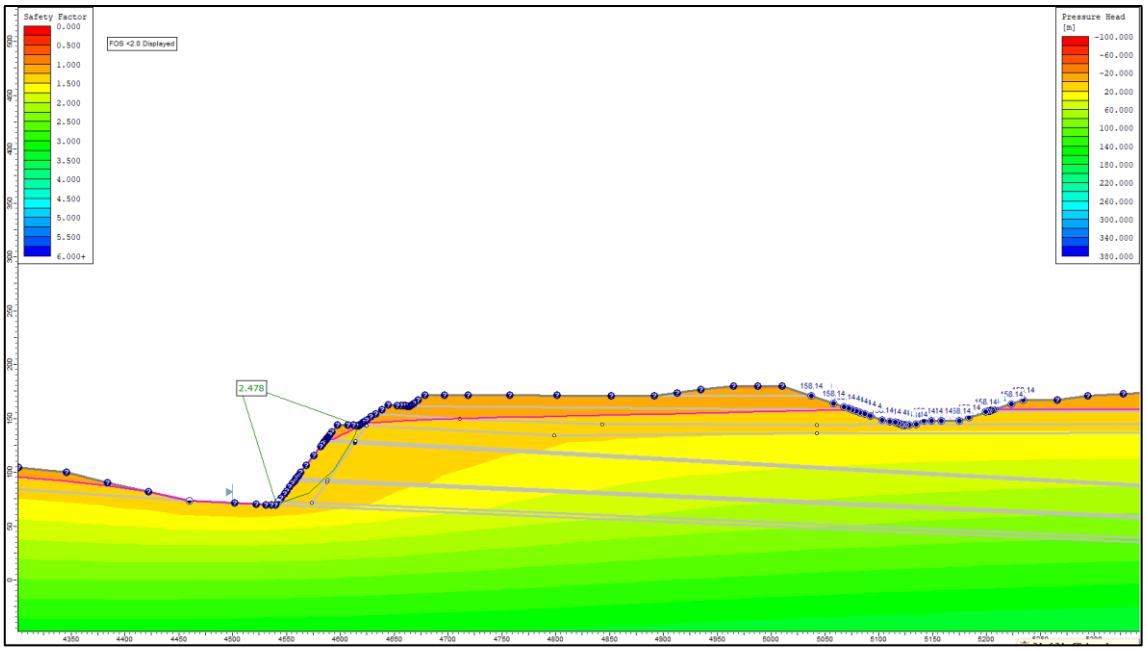
Appendix A 20 Cross Section 5 – Curragh Main F-Pit Lowwall – Dynamic



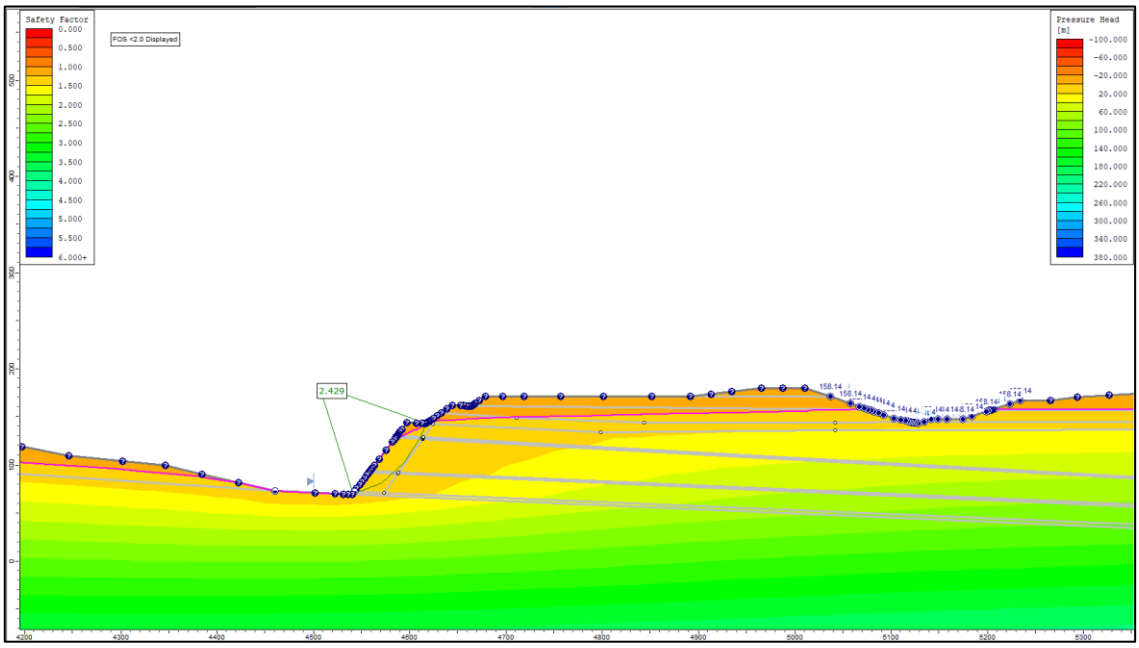
Appendix A 21 Cross Section 5 – Curragh Main F-Pit Final Landform Out Board Slope - Static



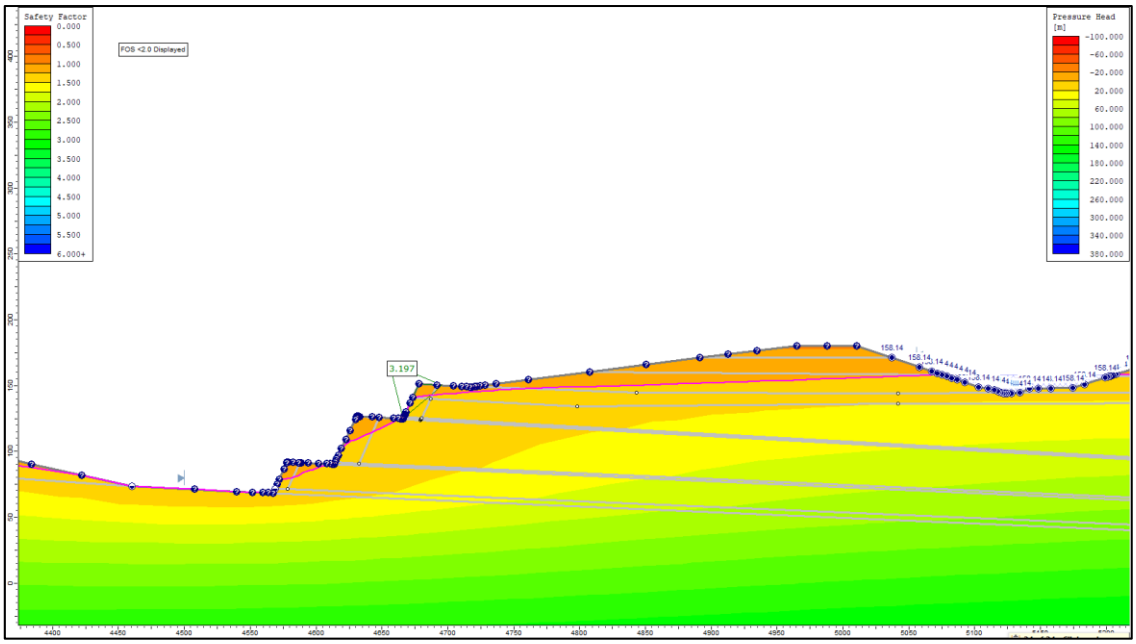
Appendix A 22 Cross Section 5 – Curragh Main F-Pit Final Landform Out Board Slope - Dynamic



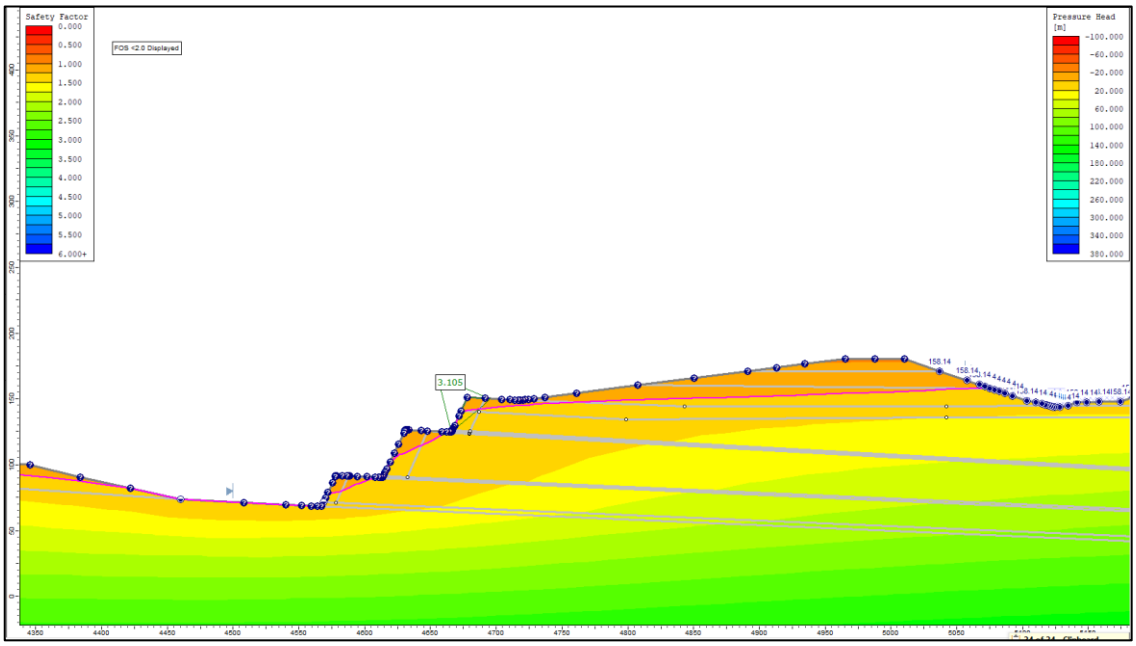
Appendix A 23 Cross Section 6 – Curragh Main K-Pit - Static



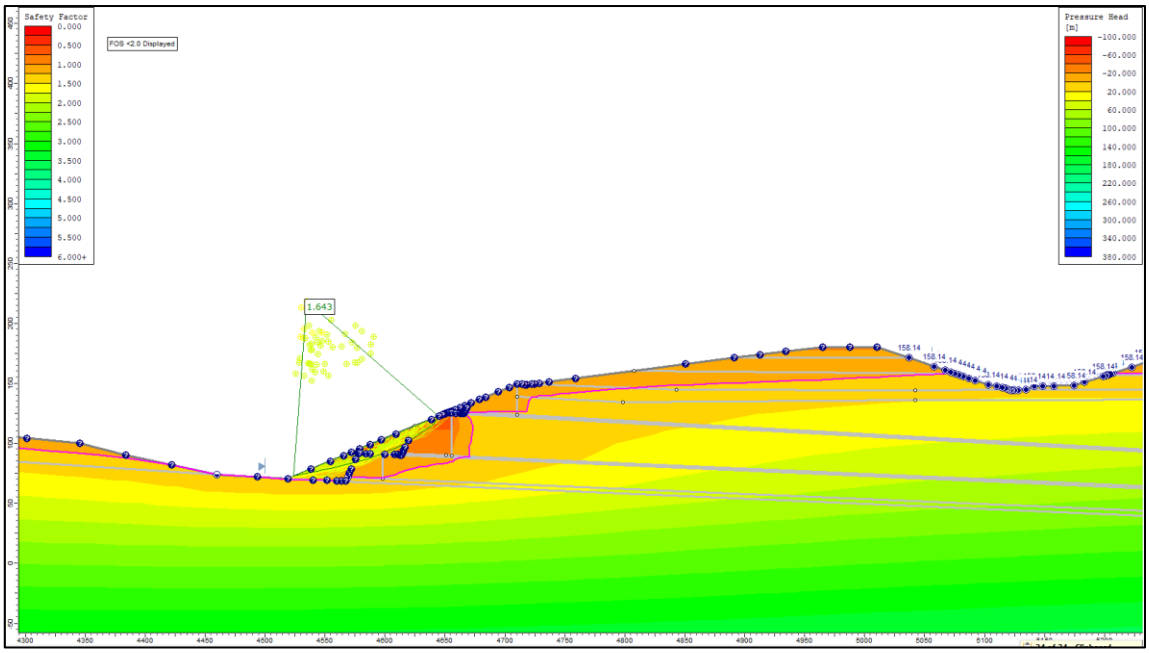
Appendix A 24 Cross Section 6 – Curragh Main K-Pit - Dynamic



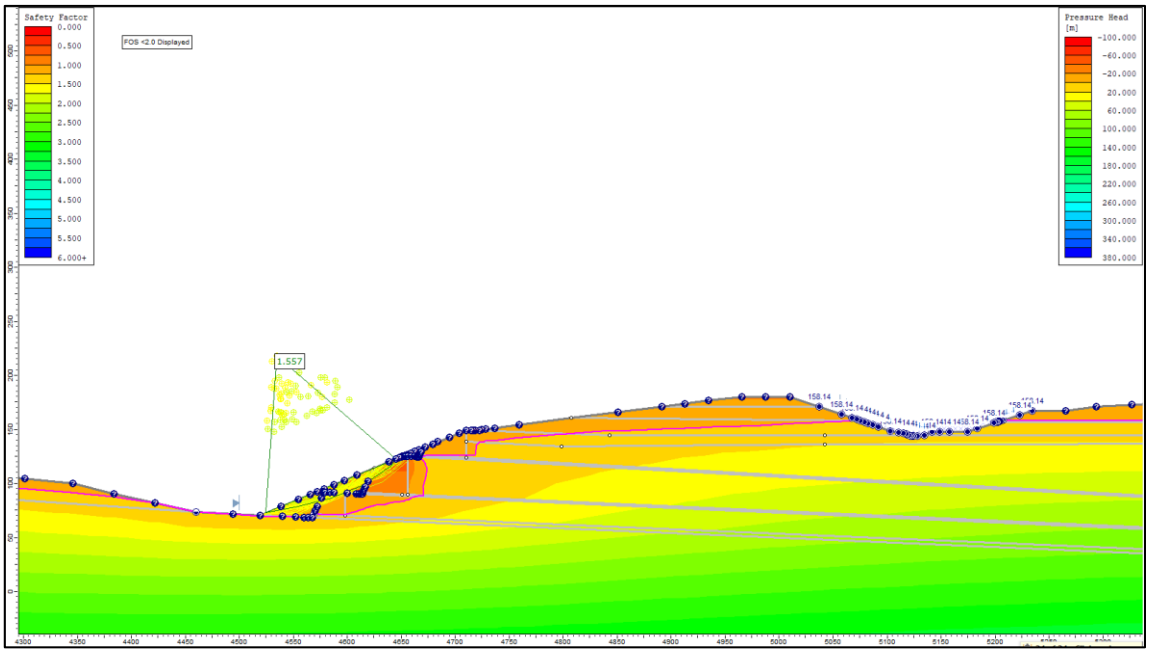
Appendix A 25 Cross Section 6 – Curragh Main K-Pit Alternative final highwall geometry – Static



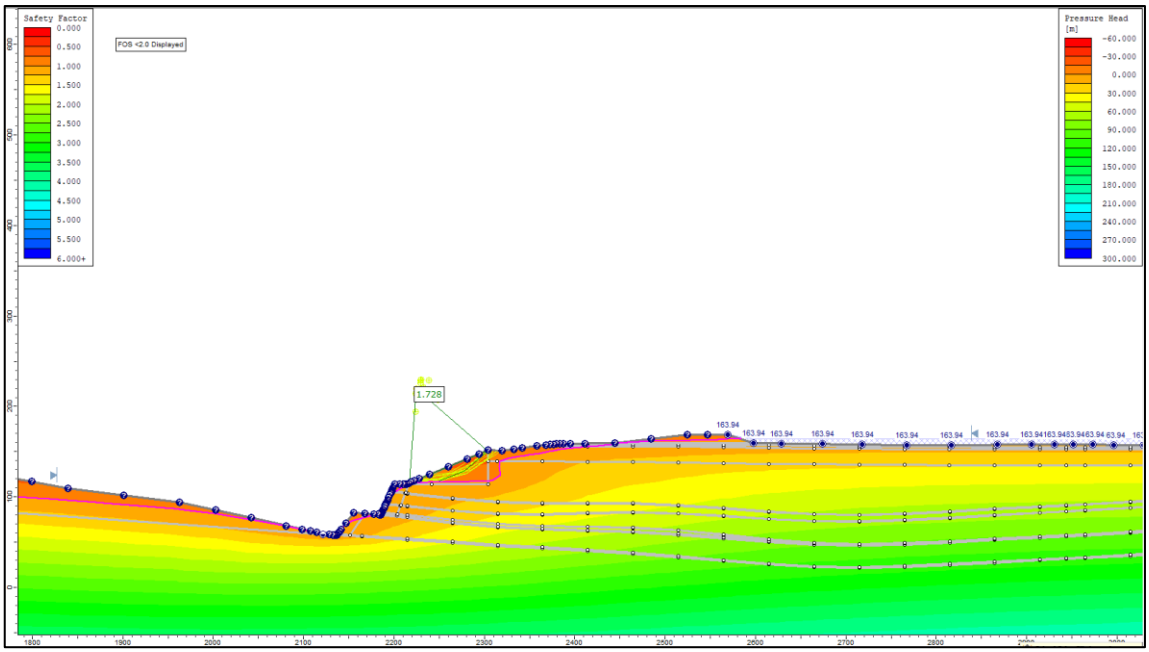
Appendix A 26 Cross Section 6 – Curragh Main K-Pit Alternative final highwall geometry – Dynamic



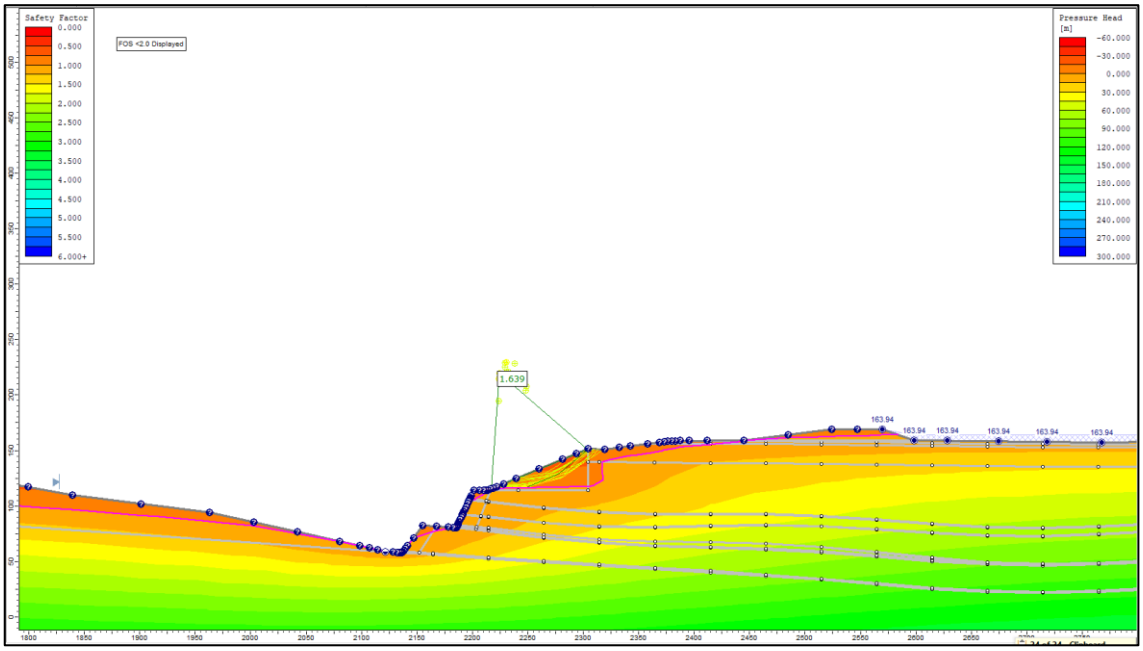
Appendix A 27 Cross Section 6 – Curragh Main K-Pit Alternative final highwall geometry with blasted and re-shaped final slope – Static



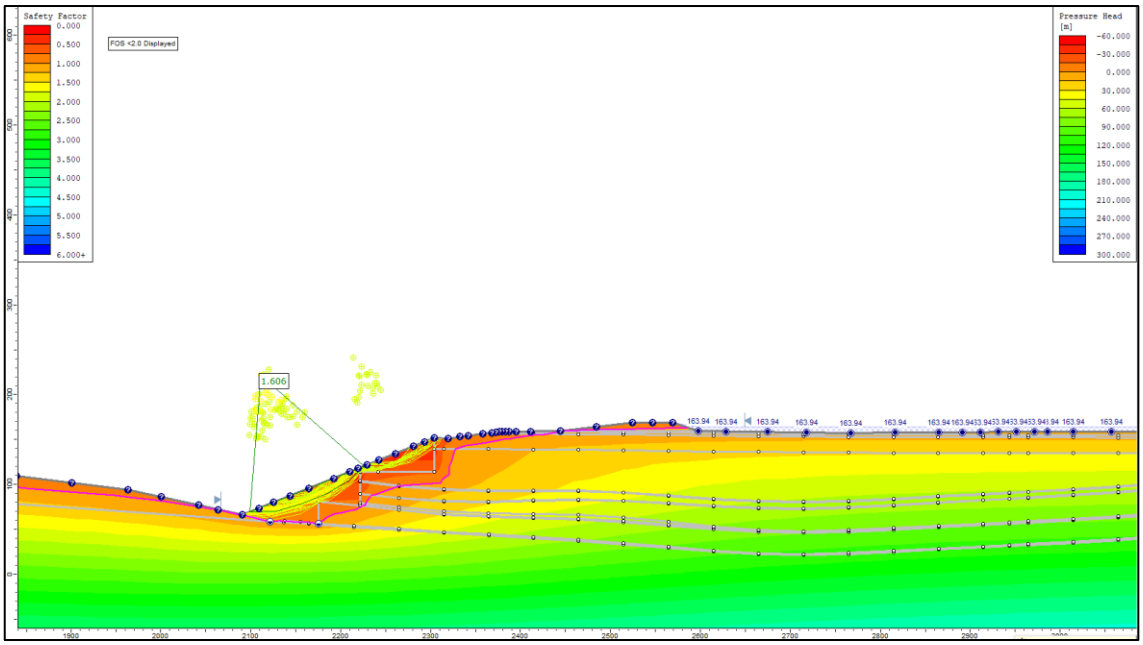
Appendix A 28 Cross Section 6 – Curragh Main K-Pit Alternative final highwall geometry with blasted and re-shaped final slope – Dynamic



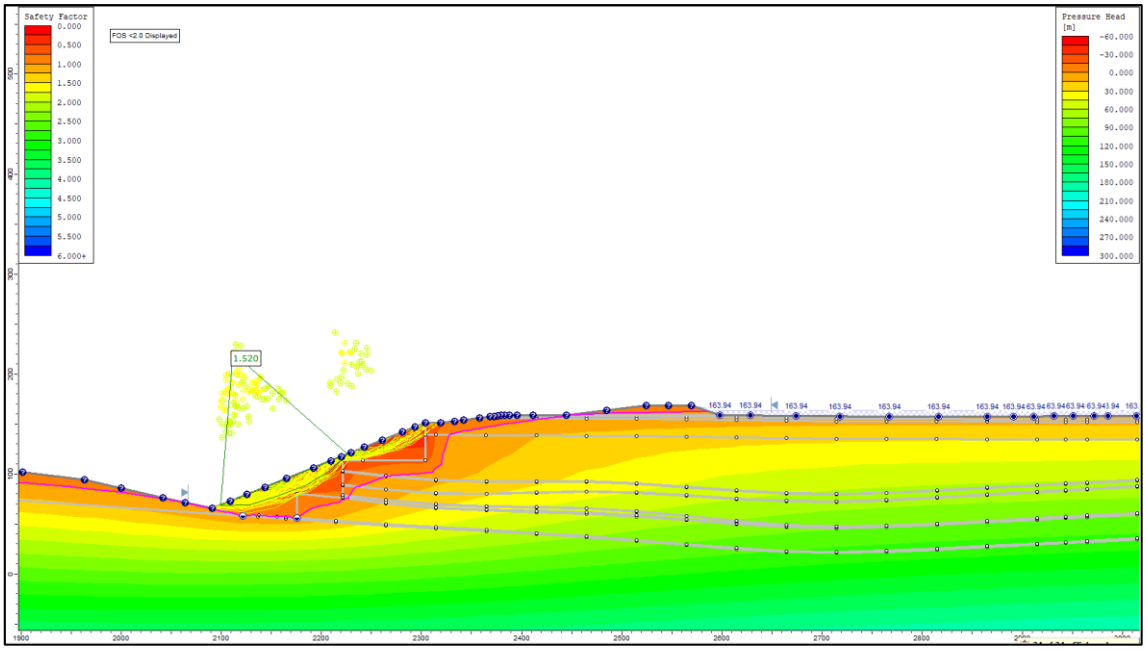
Appendix A 29 Cross Section 7 – Curragh Main J-Pit - Static



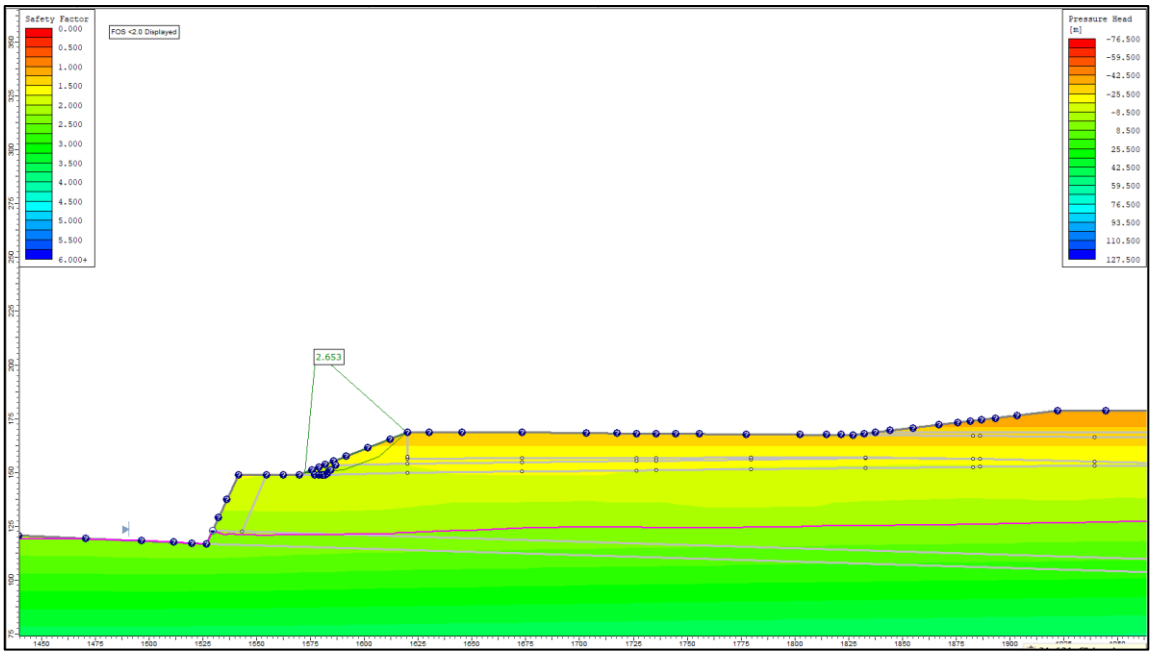
Appendix A 30 Cross Section 7 – Curragh Main J-Pit - Dynamic



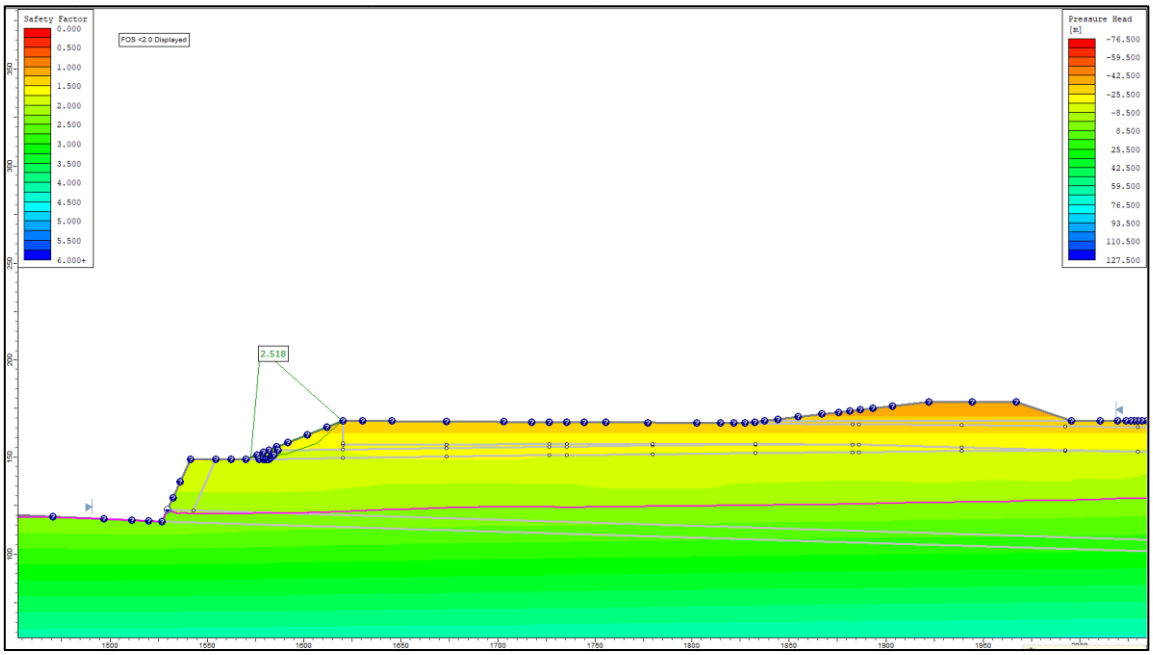
Appendix A 31 Cross Section 7 – Curragh Main J-Pit Final highwall geometry with blasted and re-shaped final slope – Static



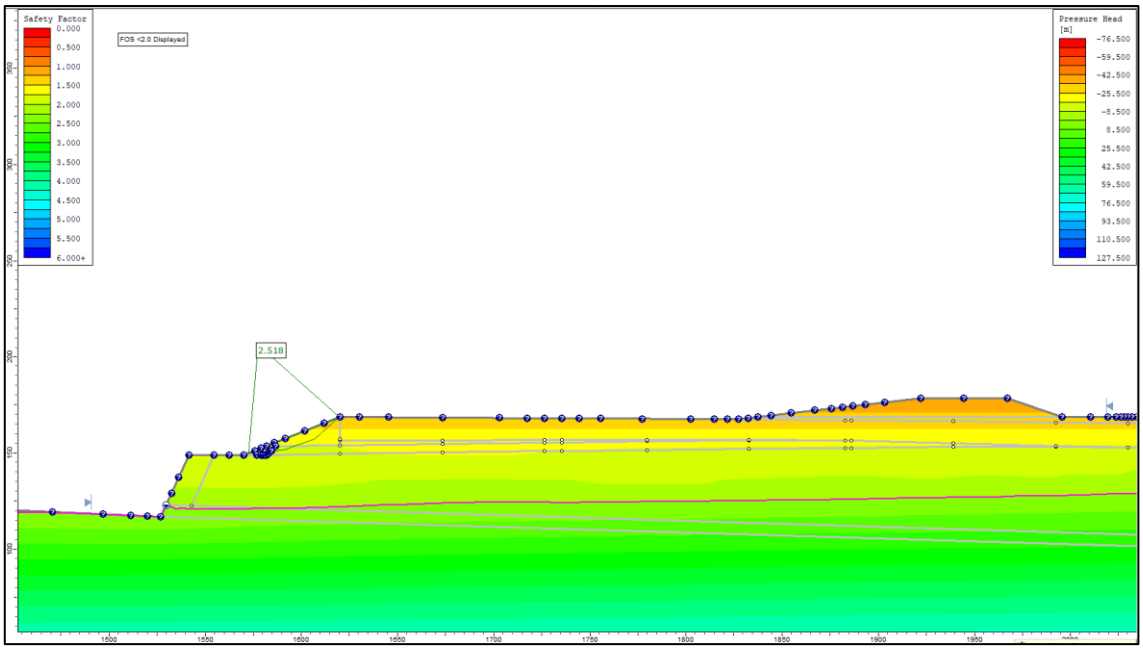
Appendix A 32 Cross Section 7 – Curragh Main J-Pit Final highwall geometry with blasted and re-shaped final slope – Dynamic



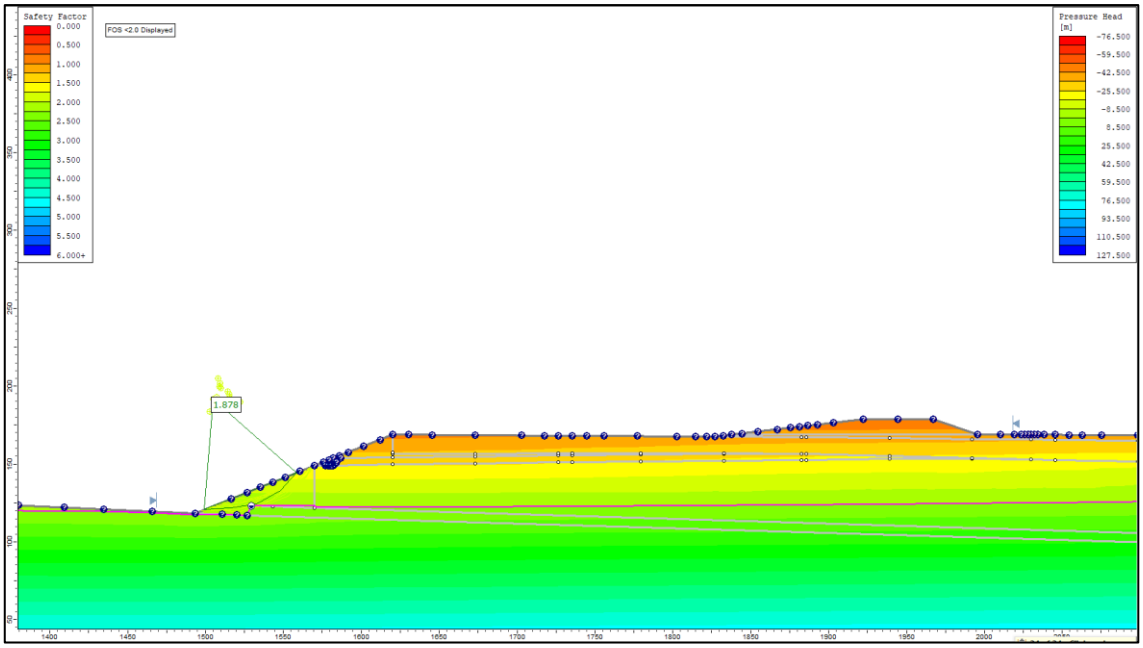
Appendix A 33 Cross Section 8 – Curragh Main Y-Pit - Static



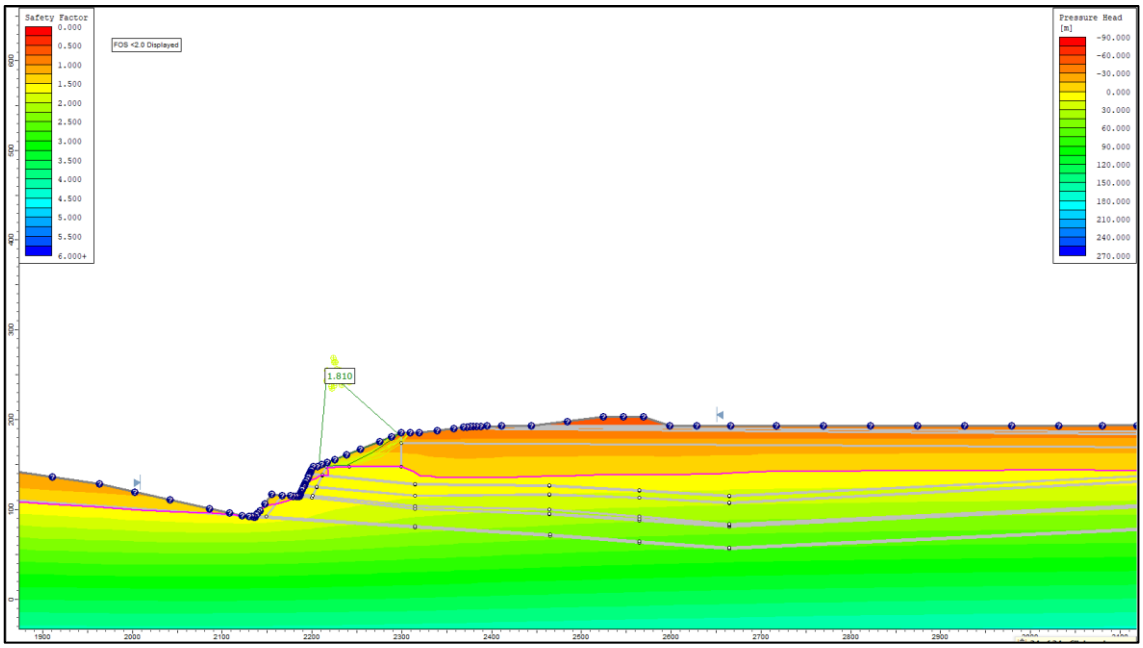
Appendix A 34 Cross Section 8 – Curragh Main Y-Pit - Dynamic



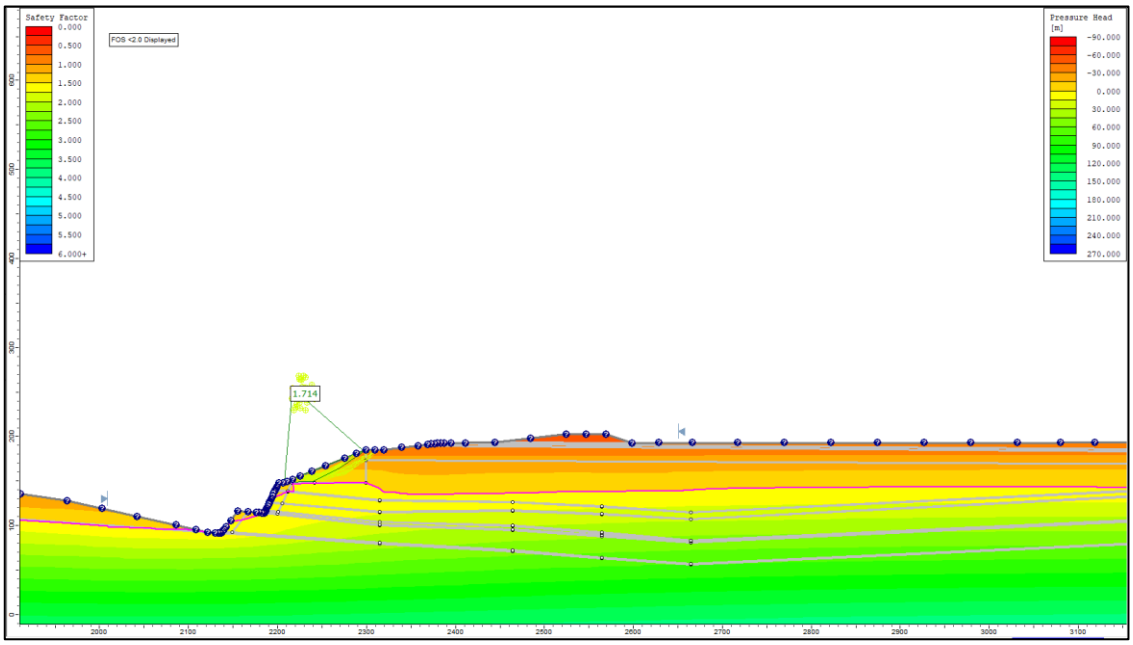
Appendix A 35 Cross Section 8 – Curragh Main Y-Pit Final highwall geometry with blasted and re-shaped final slope – Static



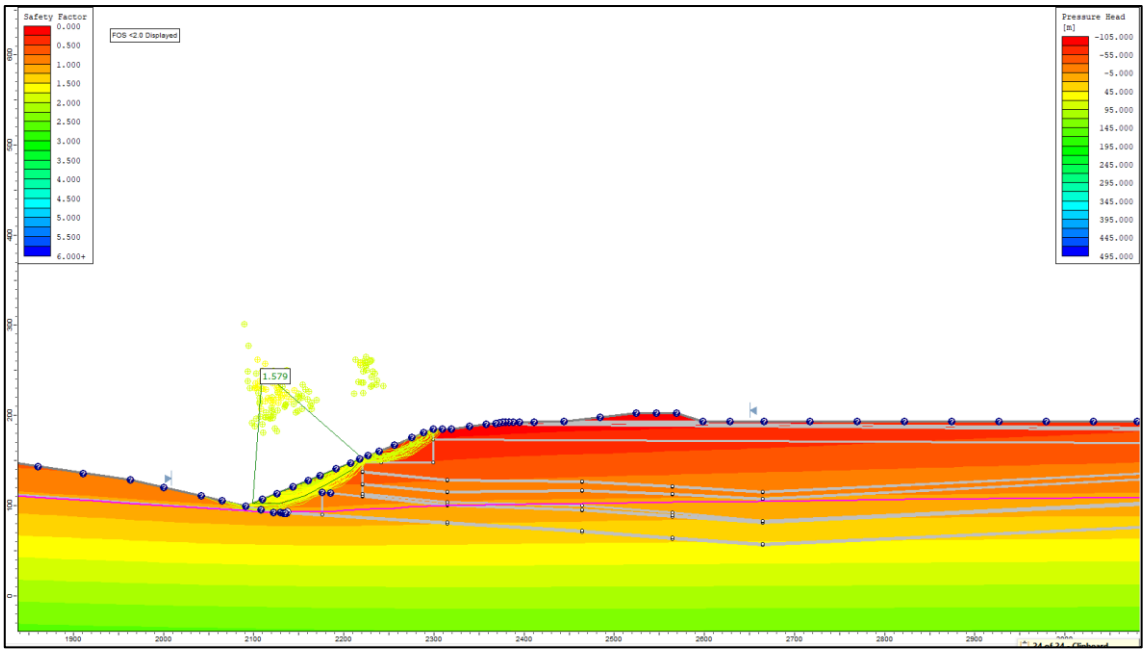
Appendix A 36 Cross Section 8 – Curragh Main Y-Pit Final highwall geometry with blasted and re-shaped final slope – Dynamic



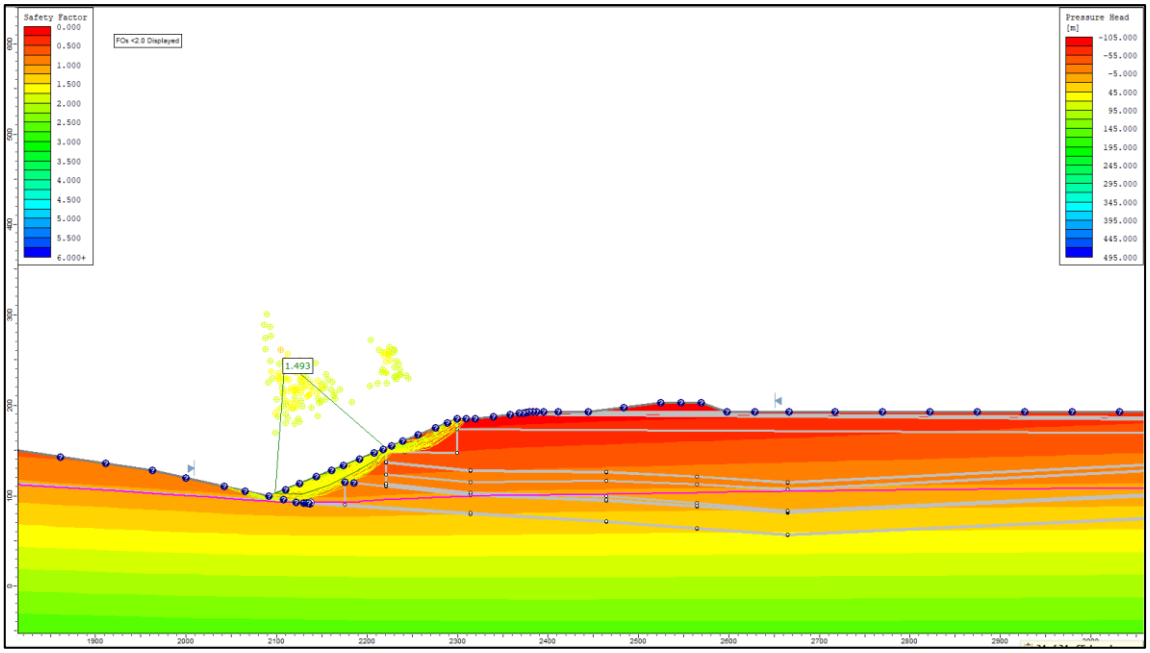
Appendix A 37 Cross Section 9 – Curragh Main Z-Pit - Static



Appendix A 38 Cross Section 9 – Curragh Main Z-Pit - Dynamic



Appendix A 39 Cross Section 9 – Curragh Main Z-Pit Final highwall geometry with blasted and re-shaped final slope – Static



Appendix A 40 Cross Section 9 – Curragh Main Z-Pit Final highwall geometry with blasted and re-shaped final slope – Dynamic

Appendix B – Design Risk & Opportunities Register

Item	Risk Scenario	Actions & Recommendations
1	Geological and geotechnical risk and uncertainty: • Variations in the geological and structural models resulting in changes to adopted lithological unit, unit thicknesses, geological structures (i.e. faults, joints etc.), rock mass conditions, material properties etc. impacting the final landform design option include pitwall crest and toe limits.	Geological and geotechnical data collection programs for the final pitwalls are to be developed and implemented. An erosion assessment is completed to define the required slope angles for the soil strength materials and inform the design development. The proposed final landform is to be updated based on the outcomes of the erosion study.
2	Hydrogeological and hydrological risk and uncertainty: • Variations in the hydrogeological and hydrological models resulting in changes to adopted lithological unit hydraulic properties, changes in groundwater levels, changes in flood water level etc. impacting the final landform design option.	The hydrogeological and hydrological models should be developed, and an associated ground water investigation program implemented, to further inform the slope stability analysis. Investigations and studies should be undertaken to identify the potential location and extent of Paleochannels.
3	Variations to the proposed final landform design options arising from: • Variations in the geological and structural model; • Variations in the hydrogeological and hydrological models; • Outcomes of erosion studies; • Changes to or limitations in the final pitwall construction methodology, crest and toe locations, and availability of materials.	The proposed final landform design option construction methodologies, and design options are developed. Undertake detailed design work to develop final pitwall construction methodologies.

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Revision Number	Author		Approved for Issue		
	Name	Signature	Name	Signature	Date
A	**MGaughan**		**MRaine**		**22/11/2021**
B	**MGaughan**		**MRaine**		**23/11/2021**
0	**MGaughan**		**MRaine**		**25/11/2021**
1	**MGaughan**		**MRaine**		**30/11/2021**

APPENDIX O

Risk Assessment

		Risk Assessment						Risk Treatment Plan						
Risk no.	**Category**	**Risks at Closure**	**Hazards / source of risks / threats**	**Description of Consequences / Impacts**	**Consequence rating**	**Likelihood of event**	**Risk Rating**	**Controls/treatment/actions**	**Reasons for treatment selection**	**Performance measures and constraints**	**Reporting and Monitoring Requirements**	**Resource Requirements**	**Timing**	**Responsibility**
1	Mine Layout, LOM and Sequencing	Changes to mine planning resulting in non-compliance with PRCP schedule.	Uncertainty in mining areas that have not yet commenced Economic drivers Unable to anticipate final void locations over long time periods accurately Future conversion of MDLs to MLs	Need to amend PRCP schedule for delivery of rehabilitation Delays to rehabilitation Final void locations	3 - Moderate	3 - Possible	13 - Significant	Communication of PRCP schedule to all employees including mine engineers and planners. Regular reviews of the mine plan against the PRCP Schedule If mine changes are unavoidable, undertake PRCP amendment. PRCP schedule to have general year timeframes until mining commencement.	There are limited controls available as changes to mine plan occur regularly. However, informing the business of the impacts to the PRCP is a suitable control. Different mine plan may mean disturbance is not undertaken, PRCP schedule not met and therefore rehabilitation is not required.	Not applicable	Not applicable	Not applicable	As required	Environment Team
2	Mine Layout, LOM and Sequencing	Change in mining methods	Technology advances Geology Potential for underground operations Switching between truck and shovel and dragline in pit	Delay in rehabilitation Change in EOML landform resulting in rehabilitation delivery changes Change in final landform therefore may not meet milestone criteria	3 - Moderate	3 - Possible	13 - Significant	Communication of PRCP schedule to all employees including mine engineers and planners. Regular reviews of the mine plan against the PRCP Schedule If mine changes are unavoidable, undertake PRCP amendment.	There are limited controls available as changes to mine plan occur regularly. However, informing the business of the impacts to the PRCP is a suitable control. Different mine plan may mean disturbance is not undertaken, PRCP schedule not met and therefore rehabilitation is not required.	Not applicable	Not applicable	Not applicable	As required	Environment Team
3	Mine Layout, LOM and Sequencing	Changes in infrastructure requirements over mine life (e.g. tailings/rejects storage)	Infrastructure performance	Final landform changes caused by changed waste volumes / sources / swell factors	2 - Minor	5 - Almost Certain	16 - Significant	Develop life of mine tailings/rejects strategy	A life of mine tailings/rejects strategy will assess the long term storage over the life of mine. This has been identified as an action out of the PRCP risk assessment and will be managed internally by Coronado Curragh.	Not applicable	Not applicable	Not applicable	As required	Environment Team
4	Pits	Pits walls are geotechnically unstable	Uncertain geology Unforeseen faulting Significant climatic events Pit walls not shaped to landform design Seismic activity	Unable to achieve milestone criteria Unable to relinquish Wider landform impacts Final void widens	2 - Minor	3 - Possible	8 - Medium	Geotechnical study completed by Raine Associates Final landform design includes geotechnical considerations Final landform construction QA/QC Geotechnical inspections	A geotechnical assessment has been undertaken and included in the final landform design. QA/QC processes will be in place for the construction of the final landform highwalls to ensure the design criteria is met. Annual inspections will then take place to ensure that the design is suitable.	Geotechnical criteria	Geotechnical inspections	Personnel to perform inspections	Annually	Environment Team
5	Pits	Unauthorised access to site resulting in injury or fatality due to fall from height	Public interest and illegal attempts to access Fall from height	Serious injury or fatality	4 - Significant	1 - Rarely	10 - Medium	Fencing and security measures will be installed to prevent unauthorised access to the site while works are occurring. Signage and bunds	Unauthorised access will be managed on site and these controls will continue during rehabilitation.	Unauthorised access to be prevented through the use of general site practices	Any incidents or security breaches will be investigated	Existing site security processes	During rehabilitation until the site is deemed safe and secure	Environment Team
6	Pits	Contamination of groundwater from void water.	Void water Not fully understood groundwater movements	Groundwater modelling shows voids act as sinks and won't interact with shallow aquifers. Contaminated groundwater which could seep to the surface Unable to meet milestone criteria.	2 - Minor	2 - Unlikely	5 - Low	Groundwater modelling shows that the pits will act as sinks Groundwater and surface water monitoring.	There is no evidence of groundwater contamination from the current voids filled with water. Ongoing groundwater monitoring will identify any potential contamination	Groundwater water quality criteria	Groundwater quality monitoring	Monitoring personnel and equipment	Annually	Environment Team
7	Levees / Stable Embankments	Stable embankments fail resulting in floodwater inundation of voids.	Inappropriate design Inadequate construction / not to design / QA/QC Incorrect material used in construction Livestock or other activities impacting stability Events greater than 0.1% AEP Changes to the catchment from current flood modelling Climatic variation Lack of maintenance	Erosion and instability of landform Landform unable to prevent floodwater entering the residual void Void water unlikely to enter floodplain due to void capacity	2 - Minor	2 - Unlikely	5 - Low	Obtain signoff on design, construction and rehabilitation treatment from appropriately qualified person Undertake regular monitoring and observation Establish groundcover to avoid erosion Undertake any maintenance or repair work as required Rehabilitation inspections	QA/QC signoff will ensure that the construction meets the design Ongoing monitoring and observation will allow any maintenance or repair needed to be identified early and rectified.	Final landform design	Rehabilitation inspection	Environmental Practitioner for inspection	Annually	Environment Team
8	Overburden	Final landform is not constructed to design.	Contractors not abiding by design Inadequate QA/QC	Landform failure could erosion and sedimentation, unsustainable vegetation and therefore increased costs for remediation.	3 - Moderate	1 - Rarely	6 - Medium	Implement a QA/QC process for the construction of landforms. Third party PRCP schedule audits	QA/QC processes for the construction of landforms will reduce the chance of the landform not being to design.	Final landform design	Rehabilitation inspection	Personnel to perform QA/QC	During construction of landform	Environment Team
9	Overburden	Incorrect placement of materials resulting in erosion and/or geotechnical instability.	Contractors not abiding by design. Characterisation of materials inadequate Mine scheduling impacting placement in dump	Erosion and sedimentation of landform impacting waterways Unable to relinquish or meet milestone criteria	4 - Significant	3 - Possible	18 - Significant	Visual assessment of area prior to rehabilitation to assess material type. Waste characterisation for current and forward disturbance Waste characterisation program Develop a Life of Mine Material Balance and Dumping Strategy	By including the final landform in the mine planning this would result in less second handling of material. A visual inspection by an environmental practitioner	Final landform design	Erosion and stability criteria	Environmental Practitioner for inspection	Prior to construction of landform	Environment Team
10	Overburden	Waste characterisation inadequate	Waste rock is not properly characterised Historical works	Erosion Rework of historical rehabilitation required Double handling of material resulting in higher costs	3 - Moderate	3 - Possible	13 - Significant	Spoil and soil characterisation report has been completed by SLR. Ongoing waste characterisation sampling.	Plans to undertake ongoing waste characterisation will reduce this risk and associated impacts.	Not applicable	Waste material sampling	Sampling personnel and equipment	During operations and closure	Environment Team
11	Tailings	Failure of cover/embankment leads to internal and external instability of out-of-pit storage facility.	Breach of cover Not built to design	Loss of tailings material Environmental harm Non-compliance with EA Significant remediation.	2 - Minor	1 - Rarely	3 - Low	RPEQ signoff on design and construction of cover.	It is best practice to have a RPEQ design the cover and certify the construction.	Full RPEQ signoff	Rehabilitation monitoring	RPEQ	After constructing cover	Environment Team
12	Tailings	Seepage of in-pit tailings contaminants into alluvium groundwater.	Insufficient containment measures / cover design Over filling the void	Cover design will be developed by a RPEQ and therefore is likely to be effective. Environmental harm Unable to relinquish.	3 - Moderate	1 - Rarely	6 - Medium	RPEQ signoff on design and construction of cover Groundwater monitoring. No more filling of A Pit with tailings	As above. Groundwater monitoring will provide an early detection system for identifying seepage.	Full RPEQ signoff Groundwater criteria	Groundwater monitoring	Monitoring personnel and equipment	Annually	Environment Team
13	Diversion	Permanent watercourse diversion failure	Design not suitable Diversion not constructed to design Severe weather events impacting diversion integrity Livestock, feral animals or other activities impacting diversion Insufficient maintenance	Sedimentation and erosion of watercourse Exceedance in water quality criteria Watercourse does not stabilise	3 - Moderate	2 - Unlikely	9 - Medium	Develop appropriate design by RPEQ Obtain RPEQ signoff on design, construction and rehabilitation treatment Undertake regular monitoring and observation of diversion stability Establish riparian zone to assist with stability Undertake any maintenance or repair work as required.	RPEQ signoff will ensure that the design meets the current standards for diversion longevity Ongoing monitoring and observation will allow any maintenance or repair needed to be identified early and rectified.	Diversion design	Diversion completion criteria	RPEQ	Annually	Environment Team
14	Infrastructure	Unknown contamination i.e. hydrocarbons, PCBs, asbestos, radiation, PFAS.	Spills that were not reported Minor leaks over time Activities that cause contamination that was previously unknown (e.g. fire extinguisher)	Environmental harm to surrounding area Unable to meet milestone criteria	3 - Moderate	2 - Unlikely	9 - Medium	Hazardous substances SOP Water management plan Waste management plan Mine affected water storage Bunding Inspections Any uncertain material disposed of in pit with rejects/tailings Contaminated sites register Land contamination assessments	Best practice standards in place for preventing, reporting, monitoring and remediating any potential contamination	Milestone criteria	Inspection of potentially contamination activities	Company representative to undertake inspection	Annually	Environment Team
15	Infrastructure	Insufficient capacity for disposal of infrastructure demolition on site.	In pit disposal at the time of rehabilitation.	Increased costs for disposal of demolition waste to a licensed facility.	2 - Minor	2 - Unlikely	5 - Low	Waste Management Plan Develop Detailed Demolition Plan closer to closure Approved landfill on site	An internal Detailed Demolition and Decommissioning Plan will be developed prior to closure in accordance with the CCPL Closure Standards.	N/A	N/A	Contractor to develop Plan	5 years from closure	Environment Team

16	Water Management Infrastructure and Dams	Stored water does not meet stock water quality requirements.	Erosion and runoff from final landform Ineffective drainage in final landform Presence of mine affected water	Unable to meet milestone criteria Delay in relinquishment.	2 - Minor	3 - Possible	8 - Medium	Sample water quality regularly Desilt water storages if required Ongoing water quality monitoring.	Ongoing water quality sampling and monitoring will identify any issues that require treatment or remediation.	Surface water quality criteria	Surface water quality monitoring	Monitoring personnel.	Annually	Environment Team
17	Revegetation	Topsoil / growth media quality is not suitable/sufficient for revegetation establishment.	Insufficient or incorrect amelioration applied Topsoil sampling not undertaken Incorrect stockpiling of topsoil Insufficient topsoil Incompetent topsoil Over stripping topsoil Not stripping topsoil Dumping over topsoil stockpiles Inaccurate inventory	Revegetation does not establish and therefore criteria cannot be met Increase in erosion Delays in rehabilitation delivery.	3 - Moderate	1 - Rarely	6 - Medium	Amelioration to be applied in accordance with evidence based recommendations. Topsoil stockpiling as per PRCP methodology Progressive rehabilitation Rehabilitation history and trials (>20 years)	Testing of topsoil will provide the evidence needed for amelioration recommendations	Sampling and analysis	Maintain topsoil sampling records Undertake maintenance as required	Soil Scientist	Prior to stripping and application	Environment Team
18	Revegetation	Grass competition results in insufficient woodland development	Topsoil contains Buffel/grass seed	Unable to meet post mining land use and milestone criteria	3 - Moderate	3 - Possible	13 - Significant	Controlled burns Insufficient surface preparation (e.g. ripping depths) Rehabilitation history and trials (>20 years) Strategic topsoil placement Minimise exotic grass seed in woodland areas	Rehabilitation checks after each milestone will be undertaken	Material availability or type Topsoil thickness	Maintain rehabilitation records	Rehabilitation auditor	Following topsoil application	Environment Team
19	Revegetation	Seed mix does not meet specifications for required PMLU.	Incorrect seed mix used Inappropriate application Not available Quality of seed mix	Rehabilitation does not meet the criteria in PRCP schedule.	2 - Minor	2 - Unlikely	5 - Low	Seed mix contains minimum species requirements Seed QA/QC and certification Pre-order seed mix in advance to ensure availability Appropriate storage of seed	The correct seed mix promotes vegetation which aligns with the proposed PMLU	Viability testing of seed to ensure effectiveness	Maintain records of seed mix supplied and used	Rehabilitation specialist	Prior to seeding	Environment Team
20	Revegetation	Declared weeds in excess of milestone criteria allowance and impacting revegetation success.	Cattle bringing in weeds Main road adjacent to site Machinery introducing weeds Weeds on underlying property	Weeds impact the success of desired species Unable to meet milestone criteria.	2 - Minor	4 - Likely	12 - Medium	Undertake weed control measures e.g. weed spraying Machinery to be washed prior to site entry Weed declarations Rehabilitation monitoring Analogue sites to establish baseline weed	The weed control measures in the PRCP include best practice methodologies.	Surrounding properties and underlying land users may impact the control of weeds. The PRCP schedule contains criteria relating to weeds.	Vegetation monitoring including weeds	Monitoring personnel and equipment.	Annually and prior to topsoil stripping	Environment Team
21	Revegetation	Overgrazing damaging rehabilitation areas.	Overgrazing	Introduction of weeds Damage to rehabilitation Unable to meet milestone criteria Delay in relinquishment Erosion and sedimentation	3 - Moderate	2 - Unlikely	9 - Medium	Fencing of rehabilitation areas until well established Landholder engagement Rehabilitation Monitoring	The control measures have been selected with a focus on engaging with the landholder and limiting live stock accessibility.	The PRCP schedule includes final milestone criteria for meeting the post mining land use.	Rehabilitation Monitoring	Monitoring personnel and equipment.	Annually or as required	Environment Team
22	General	Pests damaging rehabilitation areas.	Feral animals e.g. pigs	Impact on vegetation establishment Cause erosion and sedimentation	2 - Minor	3 - Possible	8 - Medium	Undertake pest eradication measures Engage with neighbours for joint management Fence rehabilitation areas until established	The feral animal control measures in the PRCP include best practice methodologies.	Surrounding properties and underlying land users may impact the control of pests. The PRCP schedule contains criteria relating to pests.	Pest control (weed and feral animal) monitoring	Monitoring personnel and equipment.	Annually or as required	Environment Team
23	General	Inadequate monitoring data to support relinquishment.	Failure to undertake monitoring Insufficient records/data control Monitoring data doesn't align with milestone criteria Insufficient monitoring sites	Unable to relinquish Non-compliance with criteria Potential failures in rehabilitation.	4 - Significant	3 - Possible	18 - Significant	Undertake rehabilitation monitoring in accordance with the PRCP Sufficient record keeping Review monitoring against milestone criteria	Internal record keeping procedures will be used to ensure monitoring is undertaken in accordance with the Rehabilitation Monitoring Program.	Weather may act as a constraint for monitoring at times but this should be supplemented when appropriate.	Rehabilitation Monitoring	Monitoring personnel and equipment.	Annually or as required	Environment Team
24	Weather	Significant rainfall event and flood impacting rehabilitation success (excluding pit).	Significant flood event (>0.1 % AEP event)	Excessive erosion Loss of material resources Damaged revegetation Additional costs to re-establish vegetation Weed introduction Delay in relinquishment Unestablished rehabilitation failure	4 - Significant	1 - Rarely	10 - Medium	The proposed final landform has been designed to prevent flood water impacting the residual void Added erosion and sediment controls in flood risk areas Progressive rehabilitation to minimise exposed areas Seeding at optimal time for rainfall Seed immediately after topsoil application to establish groundcover as soon as possible Establish species suitable for the climate Exclusion of grazing until rehabilitation has stabilised Rehabilitation monitoring	The mine plan has been designed to consider flood risk as a first defence. As added protection erosion and sedimentation controls, a specialised revegetation plan and monitoring will be implemented.	The PRCP schedule includes final milestone criteria for meeting the post mining land use.	Rehabilitation Monitoring	Monitoring personnel and equipment.	Annually	Environment Team
25	Weather	Drought impacting rehabilitation success.	Drought Limited water supplies Climate change	Impacts to revegetation success Potential impacts to soil quality Additional costs to re-establish vegetation Delay in relinquishment Delay in rehabilitation schedule.	4 - Significant	2 - Unlikely	13 - Significant	Limited controls available Allow additional time in PRCP schedule to compensate for potential risk Reference to analogue sites in criteria to account for regional fluctuations in weather Allow contingency for weather events in PRCP schedule Consider acceleration of rehabilitation rates in the wet years where land is available Species selection	There are limited controls available for a drought situation and therefore comparisons to reference sites should be used.	The PRCP schedule includes final milestone criteria for meeting the post mining land use.	Rehabilitation Monitoring	Monitoring personnel and equipment.	Annually	Environment Team
26	Weather	Uncontrolled bushfire damaging rehabilitation.	Bushfire Lightening strike Public road adjacent to site (Cigarette butts) Machinery / vehicle	Impacts to revegetation success Additional costs to re-establish vegetation Delay in rehabilitation delivery	4 - Significant	3 - Possible	18 - Significant	Low vegetation cover or connectivity in surrounding area Controlled burns Grazing to manage fuel loads Landholder bushfire management Fire breaks Rural fire service Water trucks, carts, equipment and people available	There are limited controls available for a bushfire. However, bushfire management and consultation with surrounding landholders is the appropriate treatments available.	The PRCP schedule includes final milestone criteria for meeting the post mining land use.	Rehabilitation Monitoring	Monitoring personnel and equipment.	Annually	Environment Team
27	Social / HR	Landholder agreements for retainment of infrastructure	No current landholder agreements Change in landholder	Missed opportunity for using infrastructure to support PMLU Uncertainty on future land owners and their expectations on retaining infrastructure Unable to leave infrastructure post-mining	2 - Minor	2 - Unlikely	5 - Low	Engage with stakeholders over life of mine Obtain agreements where for infrastructure the landholders wish to retain	Landholder engagement over the life of mine will ensure that opportunities to retain infrastructure for post mining use is optimised.	Not applicable	Update Community Consultation Register	Personnel to engage with landholders	Over mine life and closure	Environment Team
28	Social / HR	Stakeholder support of post-mining land uses change	Change in community / stakeholder priorities / expectations	Damage to relationships Impacts on ongoing operations/engagement	3 - Moderate	3 - Possible	13 - Significant	Ongoing stakeholder engagement over life of mine	Ongoing consultation to manage post mining land use expectations of stakeholders.	Not applicable	Update Community Consultation Register	Personnel to engage with stakeholders	Over mine life and closure	Environment Team
29	Social / HR	Impacts of closure on local community	Reliance of community on Curragh	Employment loss Business loss	3 - Moderate	2 - Unlikely	9 - Medium	Ongoing stakeholder engagement over life of mine Communication of PRCP schedule and planned closure	Ongoing consultation to manage post mining land use expectations of stakeholders.	Not applicable	Update Community Consultation Register	Personnel to engage with stakeholders	Over mine life and closure	Environment Team
30	Social / HR	Potential changes to regulator rehabilitation expectations / interpretation impacting PRCP schedule amendments	Political drivers Community complaints/interest Climate change Lack of industry performance	Regulatory non-compliance Additional costs to address changed expectations / interpretations Delay in relinquishment	3 - Moderate	3 - Possible	13 - Significant	Industry interest groups. Departmental consultations Approved PRCP schedule	Limited controls available. Awareness and consultation have been proposed.	Not applicable	Not applicable	Not applicable	Over mine life and closure	Environment Team

APPENDIX P

PRCP Schedule

Progressive Rehabilitation and Closure Plan Schedule template

Instructions

General Instructions:

- **This form can be used for completing a PRCP schedule for the submission of a progressive rehabilitation and closure plan (PRC plan).**
- **See the PRCP schedule section of the PRC plan guideline (ESR/2019/4964) for further information requirements.**

- A default value of one (1) Rehabilitation Area (RA) is represented by one RA sheets below (RA1).
- A default value of one (1) Improvement Area (IA) is represented by one IA sheet below (IA1).

- To record additional RAs for your project make a copy of the RA sheet below and update it to the relevant RA number (i.e. RA2).
- To record additional IAs for your project make a copy of the IA sheet below and update it to the relevant IA number (i.e. IA2).
- To remove the IA sheet if there is no IA for your project, delete the IA sheet below.

- Each RA and IA sheet contains **two separate excel tables** (yellow and blue) for recording the time-based rehabilitation milestones.
- Add a new column or row to each table as required for your information requirements.

- Two (2) separate sheets below exist for recording the "Rehabilitation Area Milestones" and "Improvement Area Milestones".
- Delete the Improvement Area Milestone sheet if it does not apply to your project.
- Delete additional rows in either sheet if they do not apply to your project.
- See the PRC plan guideline for a list of reference milestones and further information for developing additional site-specific milestones where appropriate.

Further Instructions when inputting PMLUs

Headings under Rehabilitation Area (RA) sheets

Rehabilitation area - The rehabilitation area must align with the spatial information included in the rehabilitation planning part of the PRC plan. This area must have the same PMLU and same milestones applied to the whole area.

Relevant activities - The relevant activities must align with the activities identified in the rehabilitation planning part of the PRC plan. The relevant activities are those undertaken within the rehabilitation area prior to land becoming available for rehabilitation.

Total size of rehabilitation area (ha) - Total size of rehabilitation area in hectares.

Commencement of first milestone - The applicant must nominate a date for when the first milestone for the rehabilitation area will commence. The milestone reference for the first milestone must be included in the heading.

PMLU - The PMLU must align with those identified in the rehabilitation planning part of the PRC plan and in the proposed final site design.

Date area is available - The PRCP schedule must identify when land within the rehabilitation area becomes available for rehabilitation. If the whole rehabilitation area becomes available at once there should be only one date. If the rehabilitation areas becomes available progressively there should be multiple dates. These dates should reflect the information provided in the rehabilitation planning part of the PRC plan.

Cumulative area available (ha) - The PRCP schedule must identify the area of land within the rehabilitation area that will become available at a given time.

Milestone completed by - The PRCP schedule must identify completion dates for milestones to be completed.

Cumulative area achieved (ha) - The PRCP schedule must show how progressive rehabilitation is being achieved over the life of the mine. This section must reflect the proposed rehabilitation work required for the rehabilitation area to achieve stable condition. The milestone reference to be included refers back to the Rehabilitation Area Milestones sheet with the detailed milestone criteria. The milestones must be achieved consecutively.

Headings under Rehabilitation Area Milestones sheet

Rehabilitation milestone & Milestone criteria - The “rehabilitation milestone” is a short description of the rehabilitation activities. The "milestone criteria" must be able to demonstrate achievement of the milestone.

Further Instructions when inputting NUMAs

Headings under Improvement Area (IA) sheets

Improvement area - The improvement area must align with the spatial information included in the rehabilitation planning part of the PRC plan. This area must have the same NUMA and same milestones applied to the whole area.

Relevant activities - The relevant activities must align with the activities identified in the rehabilitation planning part of the PRC plan. The relevant activities are those undertaken within the improvement area prior to land becoming available for improvement.

Total size (ha) - Total size of improvement area in hectares.

Commencement of first milestone - The applicant must nominate a date for when the first milestone for the improvement area will commence. The milestone reference for the first milestone must be included in the heading.

NUMA - The NUMA must align with those identified in the rehabilitation planning part of the PRC plan and in the proposed final site design.

Date area is available - The PRCP schedule must identify when land within the improvement area becomes available for improvement. If the whole improvement area becomes available at once there should be only one date. If the improvement areas becomes available progressively there should be multiple dates. These dates should reflect the information provided in the rehabilitation planning part of the PRC plan.

Cumulative area available (ha) - The PRCP schedule must identify the area of land within the improvement area that will become available at a given time.

Milestone completed by - The PRCP schedule must identify completion dates for milestones to be completed.

Cumulative area achieved (ha) - The PRCP schedule must show how progressive improvement is being achieved over the life of the mine. This section must reflect the proposed management work required for the improvement area to achieve sufficient improvement. The milestone reference refers back to the Improvement Area Milestones sheet with the detailed milestone criteria. The milestones must be achieved consecutively.

Headings under Improvement Area Milestones sheet

Post-mining land uses (PMLU)														
Rehabilitation area	RA1													
Relevant activities	Overburden Dumps, Ramps, In Pit Tailings, Stable Embankments													
Total rehabilitation area size (ha)	11,253													
Commencement of first milestone: RM2	2022													
PMLU	Light Grazing and Open Woodland													
Date area is available	10-12-2021	10-12-22	10-12-23	10-12-24	10-12-25	10-12-26	10-12-27	10-12-28	10-12-29	10-12-30	10-12-31	10-12-32	10-12-33	10-12-34
Cumulative area available (ha)	1,553	1,867	1,867	1,867	1,867	2,365	2,614	2,978	3,145	3,904	5,391	5,420	5,940	5,977
Milestone completed by	10-12-2022	10-12-23	10-12-24	10-12-25	10-12-26	10-12-27	10-12-28	10-12-29	10-12-30	10-12-31	10-12-32	10-12-33	10-12-34	10-12-35
Milestone Reference	**Cumulative area achieved (ha)**													
RM2	1467	1587	1687	1787	1937	2087	2237	2387	2537	2737	2937	3137	3337	3537
RM3	1417	1467	1467	1587	1687	1787	1937	2087	2237	2387	2537	2737	2937	3137
RM4	1275	1467	1467	1587	1687	1787	1937	2087	2237	2387	2537	2737	2937	3137
RM5	1256	1256	1256	1256	1256	1467	1587	1687	1787	1937	2087	2237	2387	2537
RM6	1256	1256	1256	1256	1256	1256	1256	1256	1467	1587	1687	1787	1937	2087

1) Insert new columns to the yellow table to include further rehabilitation milestone dates.
2) Insert new columns to the blue table to match rehabilitation milestone dates.
3) Insert new rows to the blue table to include additional rehabilitation milestone references.
4) Insert the relevant number in the "Milestone reference" column (i.e. RM1).

10-12-35	10-12-36	10-12-37	10-12-38	10-12-39	11-12-40	12-12-41	12-12-42	12-12-43	12-12-44					
6,922	7,244	7,244	8,891	8,891	8,891	8,891	10,384	10,507	11,253					
10-12-36	10-12-37	10-12-38	10-12-39	10-12-40	10-12-41	10-12-42	10-12-43	10-12-44	10-12-45	10-12-46	10-12-47	10-12-48	10-12-49	10-12-50

3837	4137	4537	4937	5437	5937	6437	6937	7702	8467	9232	9997	10762	11253	
3337	3537	3837	4137	4537	4937	5437	5937	6437	6937	7702	8467	9232	9997	10762
3337	3537	3837	4137	4537	4937	5437	5937	6437	6937	7702	8467	9232	9997	10762
2737	2937	3137	3337	3537	3837	4137	4537	4937	5437	5937	6437	6937	7702	8467
2237	2387	2537	2737	2937	3137	3337	3537	3837	4137	4537	4937	5437	5937	6437

10-12-51	10-12-52	10-12-53	10-12-54	10-12-55	10-12-56	10-12-57

11253						
11253						
9232	9997	10762	11253			
6937	7702	8467	9232	9997	10762	11253

Post-mining land uses (PMLU)										
Rehabilitation area	RA2									
Relevant activities	Infrastructure activities requiring a land contamination study									
Total rehabilitation area size (ha)	128									
Commencement of first milestone: RM1	2051									
PMLU	Light Grazing and Open Woodland									
Date area is available	10-12-51									
Cumulative area available (ha)	127.8									
Milestone completed by	10-12-53	10-12-55	10-12-57	10-12-58	10-12-61	10-12-65				
Milestone Reference	**Cumulative area achieved (ha)**									
RM1	128									
RM7		128								
RM2			128							
RM3				128						
RM4				128						
RM5					128					
RM6						128				

1) Insert new columns to the yellow table to include further rehabilitation milestone dates.
2) Insert new columns to the blue table to match rehabilitation milestone dates.
3) Insert new rows to the blue table to include additional rehabilitation milestone references.
4) Insert the relevant number in the "Milestone reference" column (i.e. RM1).

Post-mining land uses (PMLU)										
Rehabilitation area	RA3									
Relevant activities	Miscellaneous Activities									
Total rehabilitation area size (ha)	542									
Commencement of first milestone: RM1	2051									
PMLU	Light Grazing and Open Woodland									
Date area is available	10-12-51									
Cumulative area available (ha)	542									
Milestone completed by	10-12-53	10-12-55	10-12-57	10-12-60	10-12-65					
Milestone Reference	**Cumulative area achieved (ha)**									
RM1	542									
RM2		542								
RM3			542							
RM4			542							
RM5				542						
RM6					542					

1) Insert new columns to the yellow table to include further rehabilitation milestone dates.
2) Insert new columns to the blue table to match rehabilitation milestone dates.
3) Insert new rows to the blue table to include additional rehabilitation milestone references.
4) Insert the relevant number in the "Milestone reference" column (i.e. RM1).

Post-mining land uses (PMLU)										
Rehabilitation area	RA4									
Relevant activities	Blackwater Creek Watercourse Diversion									
Total rehabilitation area size (ha)	185									
Commencement of first milestone: RM8	2012									
PMLU	Light Grazing and Open Woodland									
Date area is available	10-12-12									
Cumulative area available (ha)	185									
Milestone completed by	10-12-16	10-12-65								
Milestone Reference	**Cumulative area achieved (ha)**									
RM8	185									
RM9		185								

1) Insert new columns to the yellow table to include further rehabilitation milestone dates.
2) Insert new columns to the blue table to match rehabilitation milestone dates.
3) Insert new rows to the blue table to include additional rehabilitation milestone references.
4) Insert the relevant number in the "Milestone reference" column (i.e. RM1).

Post-mining land uses (PMLU)										
Rehabilitation area	RA5									
Relevant activities	Water Infrastructure									
Total rehabilitation area size (ha)	65									
Commencement of first milestone: RM11	2051									
PMLU	Light Grazing and Open Woodland									
Date area is available	10-12-51									
Cumulative area available (ha)	65									
Milestone completed by	10-12-55	10-12-56	10-12-57	10-12-63	10-12-67					
Milestone Reference	**Cumulative area achieved (ha)**									
RM7	65									
RM10		65								
RM3			65							
RM4			65							
RM5				65						
RM6					65					

1) Insert new columns to the yellow table to include further rehabilitation milestone dates.
2) Insert new columns to the blue table to match rehabilitation milestone dates.
3) Insert new rows to the blue table to include additional rehabilitation milestone references.
4) Insert the relevant number in the "Milestone reference" column (i.e. RM1).

Post-mining land uses (PMLU)										
Rehabilitation area	RA6									
Relevant activities	Out-of-Pit Tailings Storage Facility									
Total rehabilitation area size (ha)	185									
Commencement of first milestone: RM12	2029									
PMLU	Light Grazing and Open Woodland									
Date area is available	10-12-21									
Cumulative area available (ha)	185									
Milestone completed by	10-12-30	10-12-32	10-12-33	10-12-36	10-12-39					
Milestone Reference	**Cumulative area achieved (ha)**									
RM11	185									
RM3		185								
RM4			185							
RM5				185						
RM6					185					

1) Insert new columns to the <u>yellow table</u> to include further rehabilitation milestone dates.
2) Insert new columns to the <u>blue table</u> to match rehabilitation milestone dates.
3) Insert new rows to the <u>blue table</u> to include additional rehabilitation milestone references.
4) Insert the relevant number in the "Milestone reference" column (i.e. RM1).

Post-mining land uses (PMLU)										
Rehabilitation area	RA7									
Relevant activities	Stable Embankments									
Total rehabilitation area size (ha)	331									
Commencement of first milestone: RM12										
PMLU	Light Grazing and Open Woodland									
Date area is available	10-12-42									
Cumulative area available (ha)	331									
Milestone completed by	10-12-45	10-12-47	10-12-50	10-12-53						
Milestone Reference	**Cumulative area achieved (ha)**									
RM12	331									
RM3		331								
RM4		331								
RM5			331							
RM6				331						

1) Insert new columns to the yellow table to include further rehabilitation milestone dates.
2) Insert new columns to the blue table to match rehabilitation milestone dates.
3) Insert new rows to the blue table to include additional rehabilitation milestone references.
4) Insert the relevant number in the "Milestone reference" column (i.e. RM1).

Non-use management area (NUMA)								
Improvement area				IA1				
Relevant activities				Voids				
Total size (ha)				1499				
Commencement of first milestone: MM1				2021				
NUMA				Residual Void				
Date area is available	10-12-21	10-12-28	10-12-30	10-12-31	10-12-35	10-12-38	10-12-42	10-12-43
Cumulative area available (ha)	2	32	153	398	543	690	1340	1499
Milestone completed by	10-12-21	10-12-29	10-12-30	10-12-31	10-12-32	10-12-33	10-12-34	10-12-35
Milestone Reference								
MM1	2	2	2	52	102	152	202	252
MM2								

1) Insert new columns to the yellow table to include further management milestone dates.
2) Insert new columns to the blue table to match management milestone dates.
3) Insert new rows to the blue table to include additional management milestone references.
4) Insert the relevant number in the "Milestone reference" column (i.e. MM1).

10-12-36	10-12-37	10-12-38	10-12-39	10-12-40	10-12-41	10-12-42	10-12-43	10-12-44	10-12-45
Cumulative area achieved (ha)									
302	352	422	492	552	642	732	842	952	1062

10-12-46	10-12-47	10-12-48	10-12-49	10-12-54
1172	1282	1392	1499	
				1499

Milestone reference	Rehabilitation milestone	Milestone criteria
RM1	Infrastructure Decommissioning and Removal	1. All infrastructure has been decommissioned and removed from site. 2. All roads, where not being retained, have been removed. 3. Any infrastructure retained has a written agreement from the post mining landholder or owner. 4. All demolition and hazardous waste have been treated and disposed of. 5. All services have been disconnected and terminated. 6. Machinery and equipment not required for rehabilitation have been removed.
RM2	Landform Development and reshaping/reprofiling	1. All major earthworks completed. 2. Maximum slope of 16%. 3. Installation of erosion and sediment control systems to design and certified by an appropriately qualified person. 4. In pit tailings will be covered with at least 1 m of inert rock cover.
RM3	Surface Preparation	1. Topsoil strips spread to >200 mm over approximately 65% of overburden dump area. 2. Topsoil applied to >200 mm will be applied to all other areas including in pit tailings. 3. Ripping to a depth of 600-750 mm has been completed. 4. Amelioration products have been applied where appropriate and required.
RM4	Revegetation	1. Completed seeding at same time as ripping. 2. Application of fertiliser where required.
RM5	Achievement of Surface Requirements	1. Mean vegetative groundcover is >30%. 2. Native tree and shrub abundance >100 stems/ha
RM6	Achievement of Light Grazing and Open Woodland	1. Presence of at least 1 Eucalyptus species and at least 2 Acacia species. 2. Mean vegetative groundcover is >50%. 3. 60% of native species present in the reference sites are present in rehabilitation. 4. Presence of native grass and pasture species. 5. Fauna presence and habitat evident. 6. Soil salinity content is <800 dS/m, pH is between 5.5-9 and exchangeable sodium percentage is <15%. 7. Factor of Safety >1.2. 8. <16 % slope. 9. Absence of rill/gully erosion >0.3 m. 10. Groundwater quality in accordance with EA limits. 11. Surface water quality in accordance with EA limits. 12. Water storages meet the water quality requirements for stock watering under the ANZEEC Guidelines.
RM7	Remediation of Contaminated Land	1. Completion of a contaminated land investigation. 2. Certification that all measures required by the preliminary land investigation have been implemented.
RM8	Maintenance of Diversion	1. Meets design criteria. 2. Absence of active rill/gully erosion.
RM9	Achievement of Open Woodland and Light Grazing (Watercourse)	1. Groundcover is >75%. 2. Weed coverage is <5%. 3. Groundcover diversity is > 6 species.
RM10	Rehabilitation of Dams	1. Dam walls battered in for all dams to be decommissioned. 2. Sediment removed from all raw water dams to be retained.
RM11	Installation of cover system / cap	1. Cover system constructed to Detailed Design specifications. 2. Certification from RPEQ that the cover system has been constructed to design.
RM12	Stable Embankment Development	1. Stable embankment is built to a height suitable to keep 0.1% AEP flood event from infiltrating residual voids. 2. The watercourse side slope is built to a maximum of 19° and is applied with rock mulch.

1) Insert new rows below the table to record more Rehabilitation Area Milestones for the project
2) Ensure all Rehabiitation Milestones recorded in this table align with those included in the RA sheets in this form.
3) See the PRCP guideline before developing site-specific Rehabilitation Area Milestones

Milestone reference	Management milestone	Milestone criteria
MM1	Landform Development and reshaping/reprofiling	1. Highwall slopes maximum of 65°.
MM2	Achievement of sufficient improvement	1. Static Factor of Safety >1.5 and Dynamic Factor of Safety >1.1. 2. The final landform does not form rill erosion >30 cm. 3. Groundwater meets the requirements in the EA. 4. Bund highwall area.

1) Insert new rows below the table to record more Improvement Area Milestones for the project
2) Ensure all Management Milestones recorded in this table align with those included in the IA sheets in this form.
3) See the PRCP guideline before developing site-specific Improvement Area Milestones

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