Central Queensland Coal Project

Appendix 3c – Land Stability Assessment

Central Queensland Coal

CQC SEIS, Version 3

October 2020

TECHNICAL REPORT

Land Stability Assessment

Central Queensland Coal Project

Prepared for: **Central Queensland Coal Pty Ltd**

RGS

MINE WASTE AND
WATER MANAGEMENT

Land Stability Assessment

Central Queensland Coal Project

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DOCUMENT CONTROL	
Document Number	**2020023_002**
Project Number	**2020023**
File Location	**Z:\004_Projects\Projects 2020\2020023 (CQC Project)_WFM\Reporting\Land Stability Report**
Date	**24-08-2020**

DOCUMENT DISTRIBUTION			
Document Name	**Document Status**	**Distributed to**	**Date distributed**
2020023_001_CQC_Land Stability Report_	**Revision 1**	**Orange Environmental Pty Ltd**	**11-05-2020**
2020023_001_CQC_Land Stability Report_22062020	**Revision 2**	**Orange Environmental Pty Ltd**	**22-06-2020**
2020023_001_CQC_Land Stability Report_05082020	**Revision 3**	**Orange Environmental Pty Ltd**	**05-08-2020**
2020023_001_CQC_Land Stability Report_05082020	**Revision 4**	**Orange Environmental Pty Ltd**	**24-08-2020**
2020023_001_CQC_Land Stability Report_05082020	**Revision 5**	**Orange Environmental Pty Ltd**	**25-08-2020**

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1 Introduction

Central Queensland Coal Proprietary Limited (Central Queensland Coal) and Fairway Coal Proprietary Limited (Fairway Coal) (the joint Proponents), propose to develop the Central Queensland Coal Mine Project (the Project). As Central Queensland Coal is the senior proponent, Central Queensland Coal (CQC) is referred to throughout this report.

The Project is located in the Styx Basin, Central Queensland, approximately 130km north of Rockhampton. The key components of the Project include:

- Two open cut operations, two waste rock stockpiles, dams, and two separate mine industrial areas and Coal Handling Preparation Plants (CHPP), a conveyor and associated mining activities
- A Train Loadout Facility (TLF) to load coal onto trains and provide a new connection to the North Coast Rail Line, and
- A transport corridor to transport coal from the mine to the TLF.

The Project involves mining a maximum combined tonnage of up to 10 Mtpa of semi-soft coking coal (SSCC) and high grade thermal coal (HGTC) that will be mined using a truck and shovel methodology. The run of mine (ROM) coal will ramp up to approximately 2 Mtpa during Stage 1, where coal will be crushed, screened and washed to SSCC grade with an estimated 80% yield. Stage 2 of the Project will include further processing of up to an additional 4 Mtpa ROM coal to SSCC and up to 4 Mtpa of HGTC. Rehabilitation works will occur progressively through mine operation.

The Project is progressing through the Queensland and Commonwealth Government approvals processes under the Environmental Protection Act 1994 (EP Act) and Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act), respectively. Departmental submissions and comments have been received on a Supplementary Environmental Impact Statement (SEIS) (version 2), which are to be responded to as part of the revised SEIS version 3 (SEISv3).

The layout of the coal mine and associated infrastructure is shown on **Figure 1-1.**

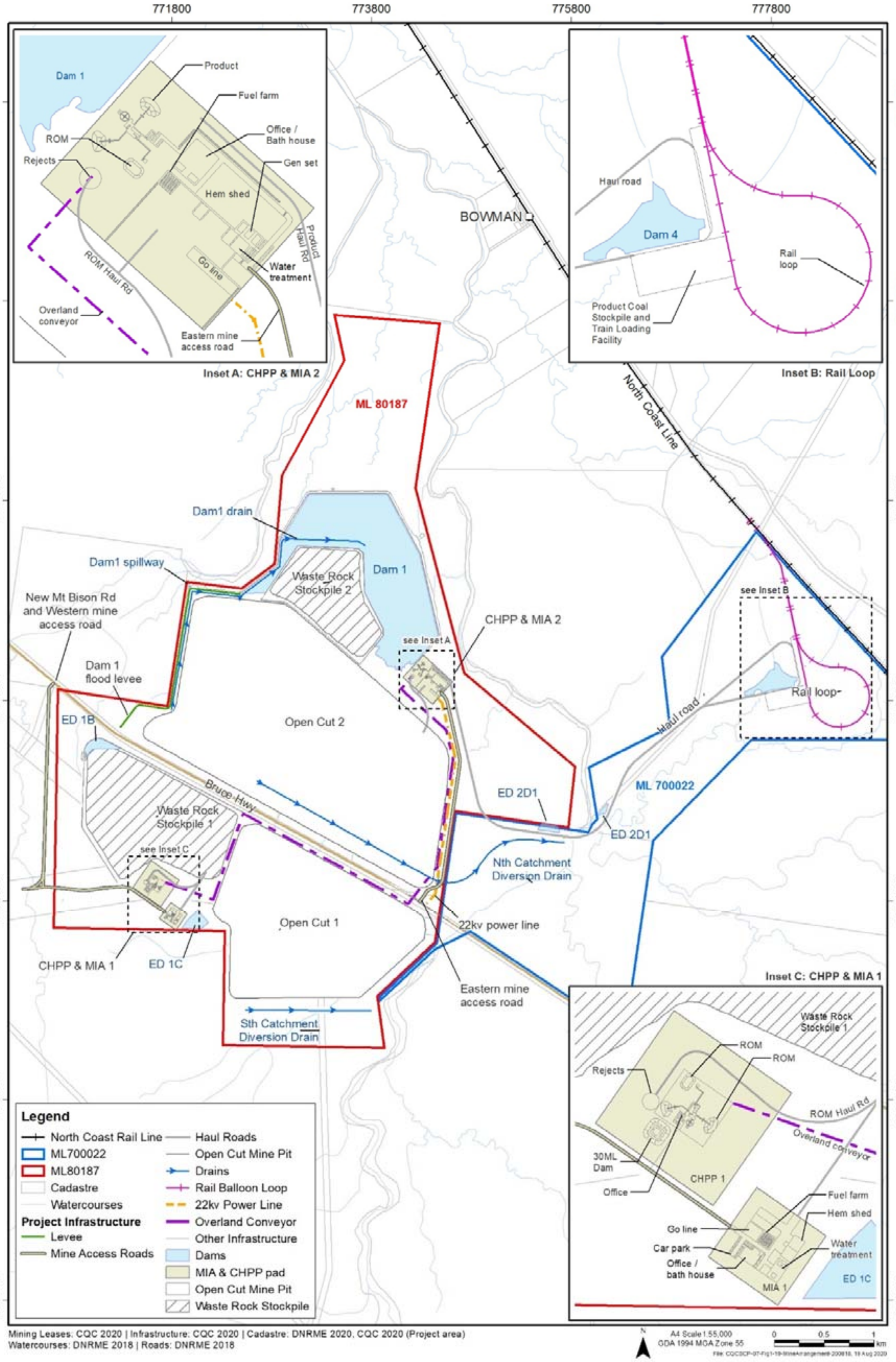


Figure 1-1: Mine arrangement

2 Scope of this document

This document:

- addresses comments on the CQC final landform by the Queensland Department of Environment and Science (DES)
- includes a technical discussion of natural landform evolution including soil and regolith development
- evaluates the stability aspects as they relate to the constructed mine landforms in the CQC Project area
- contains a forward work program summary that is proposed to be put in place to address SEIS data gaps and provide a pathway to achieve landform stability of the constructed mine landforms.

The DES comments on the final landform include the following.

- The Department considers the proponent has not provided adequate detail, with supporting evidence, on the proposed construction and management of the final landform to ensure it does not pose an ongoing risk to the downstream environment, including the Great Barrier Reef World Heritage area (GBRWHA).
- The SEIS did not explain how the factors relevant to the final landform (i.e. soil characteristics, landform design, controls, etc.) have been considered to minimise erosion, contamination, and manage dispersive and erosive soil.
- The proponent is proposing to backfill the final voids with coarse and fine coal rejects, which the Department considers will provide an additional source of contaminants that could be mobilised in groundwater. The Department considers the proponent has not adequately addressed this risk in the SEISv2 (December 2018), including assessing alternate final landform options.
- The Department considers that just a commitment to develop and implement a Rehabilitation Framework, Progressive Rehabilitation and Closure Plan (PRCP), and Erosion and Sediment Control Plan (ESCP), without providing specific detail to manage impacts, is not adequate.

Other aspects considered by DES (2017) relating to rehabilitation and therefore landform stability include the following.

- High risk of sodicity and erosion and sediment
- Post-closure flooding impacts of diversions
- Post rehabilitation management
- PRCP
- Waste rock management
- Waste rock dump design
- Residual voids
- Rehabilitation objective

This document concludes by assessing the potential risk of adverse impacts to the downstream environment and the GBRWHA and, provides further recommendations to manage mining operations to avoid adverse impacts to the downstream environment.

3 Landform evolution and landform stability

Natural landforms evolve over millennia. Constructed mine landforms on the other hand are created in years. The CQC Project construction period will be in the order of 20 years. As constructed mine landforms evolve, they undergo accelerated rates of physical, chemical and biological weathering until they attain equilibrium with the surrounding landforms.

Constructed mine landforms can have significantly different topographic, geochemical and physical attributes to the pre-mine landform. The ecological functions that the constructed mine landforms need to serve to attain long term stability must be amenable to the new landform i.e. if the pre-mine topography was seasonally inundated with floodwater and the local vegetation and land use accommodated those conditions, will large external waste dumps constructed tens of metres above the groundwater table be able to serve the same ecological functions, or will the ecological capability and functions of the new landform need to change as well?

Landform stability has traditionally been considered in terms of geotechnical stability. In this report, landform stability has been evaluated in terms of:

- geotechnical stability and the potential for slips, slumps or major slope failure (AMEC, 2017, Cardno, 2018 and Cardno, 2020)
- geochemical stability and the rate at which major ions (salts), metals (such as aluminium, copper and zinc) and metal(loids) (such as arsenic, molybdenum or selenium) may be leached from or sorbed to geological materials (RGS, 2020a)
- surface stability that determines if the soil profile is likely to aggrade or erode and whether the soil profile can retain its ability to support vegetation (HESSE, 2020)
- hydraulic stability that might consider if the soil: water balance within the strata is in equilibrium with the vegetation or the way water moves through the strata (Engeny, 2020 and WRM, 2020)
- ecological stability and post mine land use to determine whether the vegetation communities stable or changing (Chapter 11 of the SEIS).

4 Existing environment

Natural landforms evolve in the landscape in response to tectonism, geography and climate and its effect on weathering, topography, the underlying geology, geomorphology, and at a human scale, land use management. The following sections define the baseline conditions of the Project area.

4.1 Climate

The climate assessment of the region identified that the Project area experiences a tropical climate which is characterised by high variability rainfall, evaporation and temperature (Chapter 4 of the SEIS). The Project region experiences warmer summer months and cooler winter months with the majority of rainfall occurring in the warmer months between December and March. This is typical of the tropical Queensland climate.

The average annual rainfall in the area ranges from 754 to 1,018 mm: the highest daily rainfall records in Rockhampton range from 57 mm/day to 347 mm/day. Daily rainfall events such as these can be highly erosive and cause substantial adverse impacts. It is these intermittent high energy events that pose a high risk to landform stability.

Intermittent and destructive events such as cyclones and floods and droughts, heatwaves and bushfires also pose potential risk to landform stability.

The CQC constructed mine landforms will need to be designed with this in mind.

4.2 Topography

Elevations across the Styx River catchment range from 0 to 540 m above sea level. The broader area predominantly comprises flat or undulating lands, draining via several smaller creeks and tributaries to the Styx River and estuary, and into the Coral Sea. Elevations within the project area vary between 4.5 and 155 m Australian Height Datum (AHD).

Within the proposed mining lease, the topography is limited to variations in elevation of between 11.4 and 43.8 m AHD **(Figure 4-2)**.

Based on the Capricornia Coastal Lands program (DPI, 1995), the ML area contains the following geomorphological land units:

- Broad, level to gently undulating alluvial plains and fans on alluvium, including some areas of gilgai microrelief (melon hole);
- Level to gently undulating plains and rises on sedimentary rocks and unconsolidated sediments, including some minor to severe melon hole;
- Undulating rises and low hills on deeply weathered sedimentary and metamorphic rocks;
- Dissected low plateaus on gently dipping sedimentary rocks; and
- Rolling low hills and rises on hard sedimentary rocks.

The area of interest discussed in this document is limited to the constructed mine landforms that include the backfilled open pits and external waste rock storage facilities.

During floods, it is possible that inundation of the lower lying parts of the final landforms including the backfilled open pits may occur. This will need to be considered when constructing the final landforms.

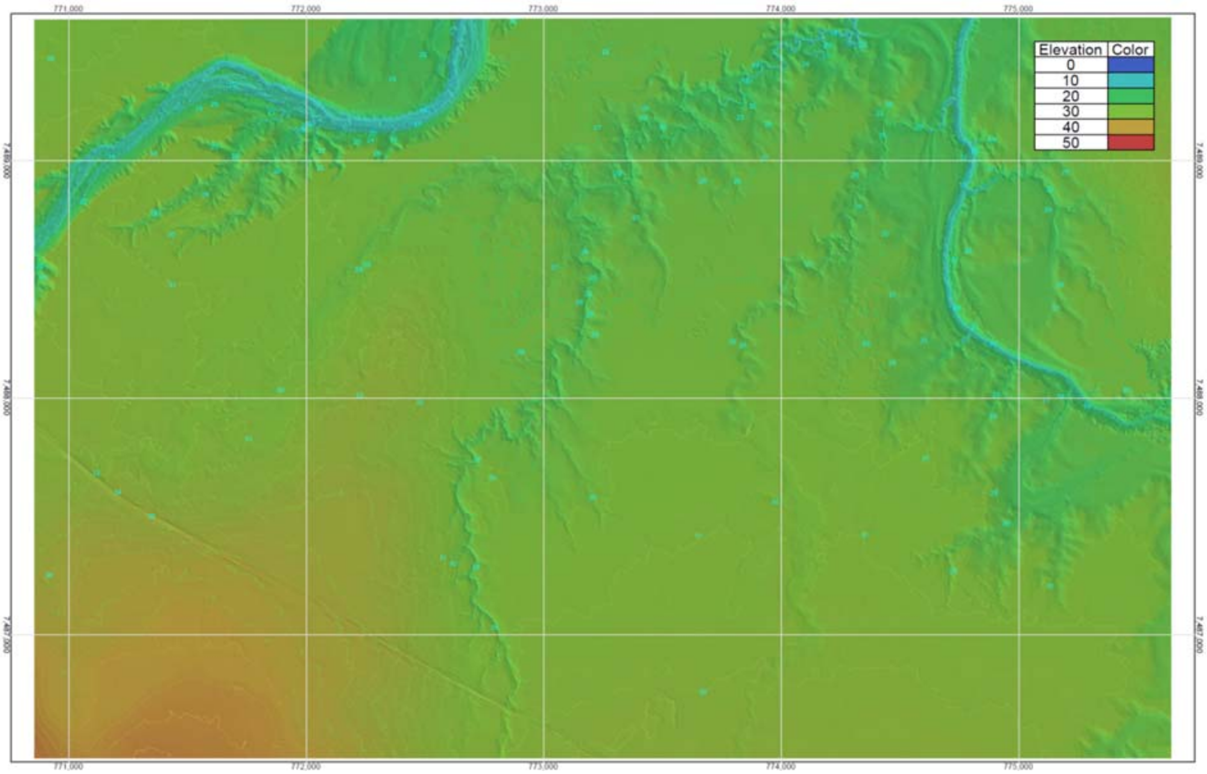


Figure 4-1: Site baseline topography

Figure 4-2: Site topography and vegetation cover

4.3 Geology

The earliest geological investigations in the Styx River area were undertaken to assist in coal prospecting and mapped in detail at the time by T.W.E. David in about 1890 (Malone, 1965 in HydroAlgorithmics, 2020). In 1892, a map of the Styx River Coalfield was prepared by Geological Survey of Qld (Rands, 1892, in HydroAlgorithmics, 2020).

The CQC Project area within the Styx Basin, as a small, Early Cretaceas, intracratonic sag basin which covers an area of about 300 km^2 onshore and 500 km^2 offshore (AMEC, 2017). The coal bearing strata are known as the Styx Coal Measures and consist of quartzose, calcareous lithic and pebbly conglomerate, sandstone, siltstone, mudstone, carbonaceous shale and coal seams (AMEC, 2017). The depositional environment of the CQC Project deposit was freshwater, deltaic to paludal, with occasional marine incursions (AMEC, 2017). The Styx Coal Measures occur as basin infill in a half graben geometry which has a plunge to the north (AMEC, 2017). The deposit has north and east dipping components and the full sequence of coal is about 6 m occurring within a sequence of about 120 m of coal bearing strata (AMEC, 2017).

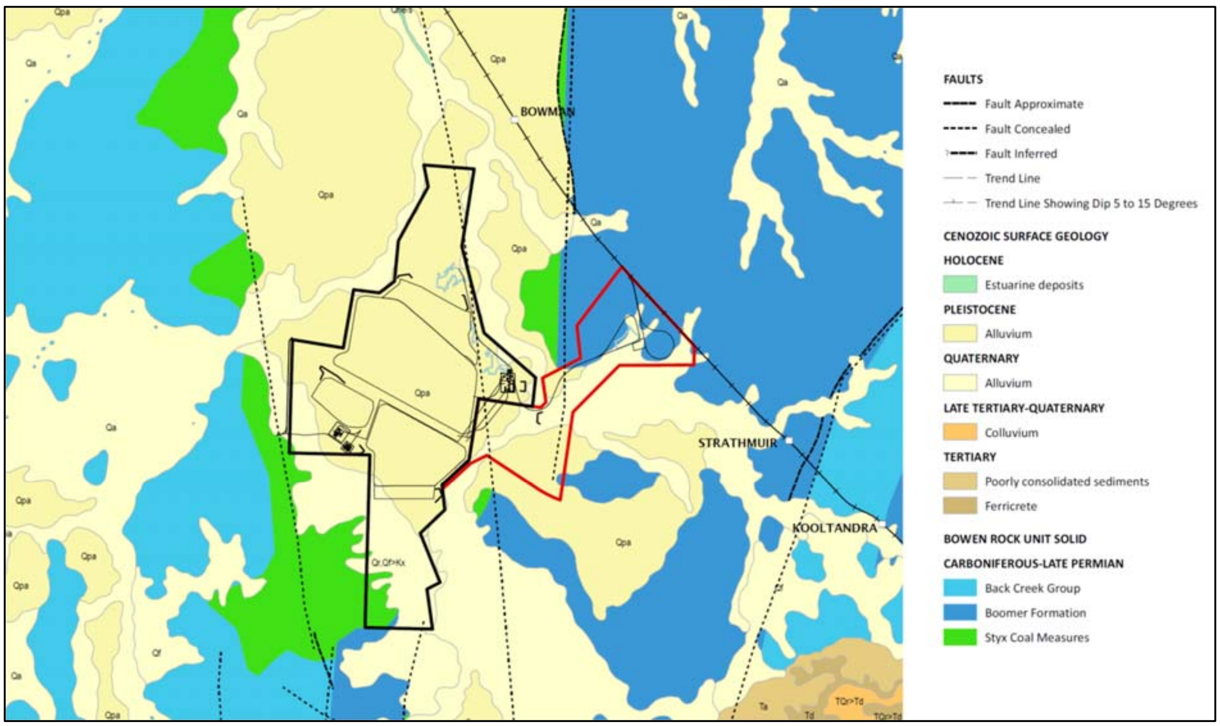


Figure 4-3: Surface geological strata

4.3.1 Geological logging

The CQC project has an extensive geological database including detailed geological logs that verify the proposed open cut pit geology is dominated by siltstone, mudstone and sandstone (Figure 4-4**).** Although conglomerate is referred to regionally there is no conglomerate in the proposed open pits (CQC, pers. comm 29-04-2020, AMEC, 2017, Cardno, 2018, and Cardno, 2020).

4.3.2 Stratigraphy and structure

The Styx Coal Measures comprise multiple coal seams which are interbedded with sandstone, siltstone and mudstone. Bedding thickness varies. Partings are present along bedding planes. Lensing of coal seams also occurs. Bedding is uniform with an average dip of 3°. Maximum dip is about 7°. Partings occur along bedding planes. Jointing is widely spaced. To date no significant faults or dykes have been encountered during geological investigations (AMEC, 2017, Cardno, 2018, and Cardno, 2020).

4.3.3 Geotechnical assessment and numerical modelling

There is a detailed geological model (Version: Geological Block Model 06.02.12) that has the potential to support geoenvironmental block modelling during development of the PRCP (to be developed after Project approval).

Geotechnical assessment of pit floor, low wall and high wall stability, and construction materials have been completed by AMEC, 2017, Cardno, 2018, and Cardno, 2020. The open cut pit on the north eastern side of the Bruce Highway has been positioned to be a minimum of 500 m away from the Bruce Highway for the next 10 years. In the long-term mining is proposed on both sides of the Bruce Highway (Cardno, 2020).

A conceptual mining section (distances in mm) and plaxis model of the two open pits in relation to the Bruce Highway is provided in **Figure 4-4** and **Figure 4-5**.

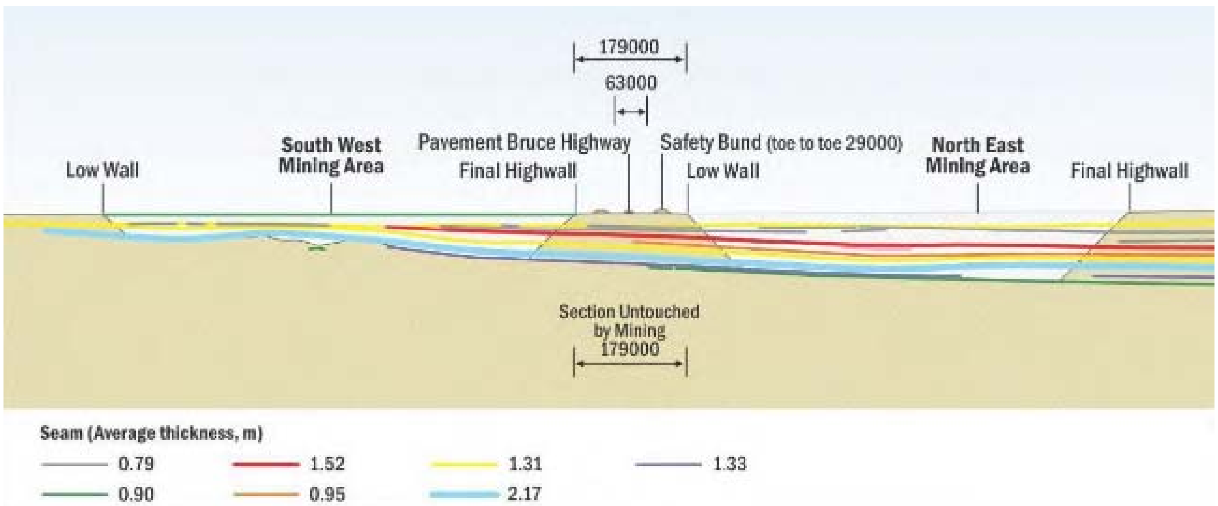


Figure 4-4: Conceptual mining section inclusive of the Bruce Highway (Cardno, 2018)

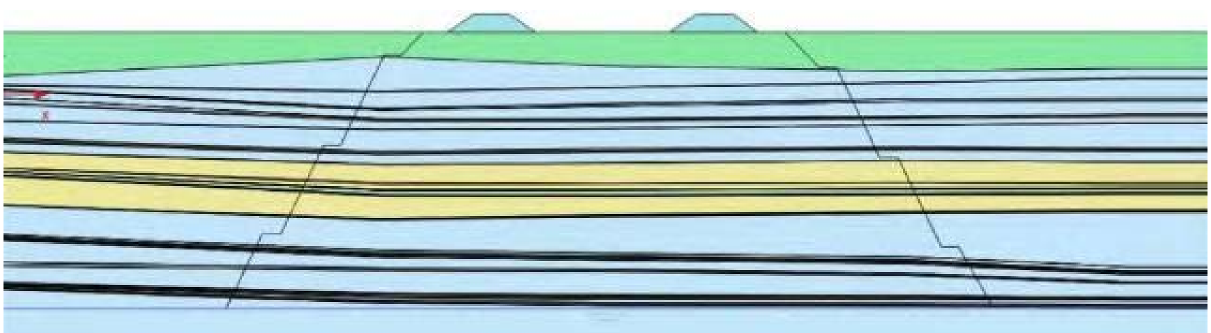


Figure 4-5: Plaxis Model section used to model high wall stability adjacent to the Bruce Highway (Cardno, 2018)

4.4 Mine material assessment

A total of 487 geochemical analyses of representative samples of waste rock (overburden and interburden) and potential coal reject have been analysed for the CQC Project (RGS, 2020a).

Representative samples were identified and collected as drill core from the 2012 exploration drilling program samples (RGS, 2020a). A total of 174 waste rock and potential coal reject samples were collected from 15 drill holes at the Project samples (RGS, 2020a). A further 21 fine reject samples were collected and tested in 2018 (CDM, 2018), making a total of 195 waste rock and coal reject samples (RGS, 2020a).

In addition, total sulfur data was available for a further 292 coal samples from the Project and included in the assessment program samples (RGS, 2020a).

4.4.1 Mine waste: coarse and fine rejects

When coal seam material is processed at the Coal Handling and Preparation Plant (CHPP), some of the material is rejected and comprises low-grade coal and particulates that can vary in size from small (fine reject)) to large (coarse reject). These coal reject materials will be dewatered before leaving the CHPP for disposal within waste rock materials, and typically make up a small fraction of total waste materials. Rejects will be initially emplaced into out-of-pit waste rock dumps until the capacity exists to backfill rejects and tailings to the mined pits over the remainder of the life of mine.

A total of 48 samples of fine coal reject and potential coal reject have been analysed.

4.4.1.1 Acid drainage potential

Total sulfur concentration in the potential coal reject samples ranges from 0.01 to 1.30 %S (median (0.13 %S). The Maximum Potential Acidity (MPA) of the 48 samples ranges from 0.2 kg H_2SO_4/t to 39.8 kg H_2SO_4/t and has a low median value of 3.2 kg H_2SO_4/t). The Acid Neutralising Capacity (ANC) of the 48 samples ranges from 10.0 to 349.0 kg H_2SO_4/t and has a median value of 33.1 kg H_2SO_4/t, which is an order of magnitude greater than the MPA. The NAPP value for the 48 samples ranges from -322.7 to 4.2 kg H_2SO_4/t and has a negative median value of -27.4 kg H_2SO_4/t.

The overwhelming majority of the potential coal reject materials have low sulfide content, excess ANC, are classified as Non-Acid Forming (NAF) and have a very low risk of acid generation and a high factor of safety with respect to potential for generation of acidity (RGS, 2020a). Coal reject from the CHPP is also expected to have relatively low sulfide content and excess ANC and as a bulk mixed material, it is expected that coal reject will be classified as NAF and have a relatively low risk of generating acidic drainage (RGS, 2020a).

4.4.1.2 Saline drainage potential

Saline drainage may be sourced from sodium chloride, or sodium bi-carbonate present within the groundwater and is also sourced from the oxidation of sulfur bearing minerals.

Initial and ongoing surface runoff and seepage from coal reject materials is expected to be mildly alkaline and have a low level of salinity (and low level of dissolved solids) (RGS, 2020a).

The salinity and sodicity results are similar for the mine waste samples and therefore have the potential to be sodic due to the presence of entrained sodium chloride or sodium bi-carbonate salts within the bedrock and regolith.

4.4.1.3 Metalliferous drainage potential

There is no significant metal/metalloid enrichment in coal reject materials compared to median crustal abundance in unmineralised soils (RGS, 2020a).

Most metals/metalloids are sparingly soluble at the alkaline pH of leachate expected from bulk NAF potential coal reject materials. Dissolved metal/metalloid concentrations in surface runoff and leachate from bulk NAF potential coal reject materials are expected to be low and unlikely to pose a significant risk to the quality of surface and groundwater resources at relevant storage facilities (RGS, 2020a).

4.4.2 Interburden and overburden

Interburden and overburden will be backfilled to the mined open pits over the life of mine. The exception to this will be in two external out of pit areas where the mined materials will be emplaced.

4.4.2.1 Acid drainage potential

Acid Base Account (ABA) results for 147 waste rock samples from the Project are presented in RGS (2020a). The total sulfur concentration in the waste rock samples ranges from below the limit of reporting (LoR) (0.01 %S) to 8.18 %S. The total sulfur concentrations are generally low with a median value of 0.04 %S, below the global median crustal abundance of sulfur in unmineralised soils (0.07%) (INAP, 2009). The Maximum MPA that could be generated through sulfide oxidation from the 147 samples ranges from 0.2 kg H_2SO_4/t to 233.4 kg H_2SO_4/t and has a median value of 0.9 kg H_2SO_4/t). The ANC value for the 147 waste rock samples ranges from 5.3 to 390.0 kg H_2SO_4/t and has a median value of 39.8 kg H_2SO_4/t, which is almost two orders of magnitude greater than the MPA The NAPP is the balance between the capacity of a sample to generate acidity (MPA) minus its capacity to neutralise acidity (ANC). The NAPP value for the 147 waste rock samples ranges from -389.7 to 197.2 kg H_2SO_4/t and has a negative median value of -38.2 kg H_2SO_4/t.

ABA testing indicates that less than 1 % of the overburden and interburden samples obtained from within the planned open pit area are PAF, although as a bulk material, waste rock is expected to have a significant excess of ANC.

4.4.2.2 Saline drainage potential

The waste rock salinity is likely to be low to moderate but some materials may be sodic due to the presence of entrained sodium chloride or sodium bi-carbonate salts within the bedrock and regolith. The presence of sulfur in the deposit may contribute to sulfate in the mine impacted water.

4.4.2.3 Metalliferous drainage potential

Based on the geochemical characterisation results including the negligible potential for acid drainage the potential for metalliferous drainage in mine impacted water is very low.

4.4.2.4 Physical properties

Geotechnical testing of drill core samples provides quantitative measurements of rock hardness and has been undertaken on three occasions (AMEC, 2017, Cardno, 2018, and Cardno, 2020) using direct shear analysis (AS 1289.6.2.2), unixal compressive strength (AS 4133.1.1.1: 4.2.2 (2013), triaxial assessment (D7012-14 Method A; D4543), slake durability (AS 4133.3.4), and Atterberg Limits. The physical data verifies that the rock units within the deposit will be suitable for progressive rehabilitation and construction requirements.

The rock strength is logged as very low strength or low strength (Figure 4-4), but moderate strength rock logged in STX145C at 80 m bgl (Figure 4-4). In 2020, there was a geotechnical investigation to evaluate rock properties of the final pit walls (Cardno, 2020) that followed work by AMEC (2018) and Cardno (2018). The 2020 work included sampling from two fully cored holes (STX1903G and STX1904G) drilled adjacent to the Bruce Highway. A third hole (STX1902A) has been drilled to provide supplementary stratigraphic data. All geotechnical logs and core photographs are in Appendix 1 (Cardno, 2020).

The STX1903G drill hole samples (n=125) collected from 27 m to 147 m bgl and STX1904G samples (n=50) collected from 22 m to 100 m bgl were subjected to diametral and axial point load testing: results varied from extremely low to very high. This available data verifies that there is very high strength rock in the deposit.

Quantifying the hardness and durability of the rocks in the deposit will be important in understanding and quantifying land stability. Further work is planned to be undertaken prior to the commencement of mining operations to assist in refining the final landform design to ensure its long-term stability.

Rock strength and durability data is necessary to define and build on (i) the understanding of whether mined waste will retain a particle size distribution (PSD) dominated by cobble to boulder or cobble to sand size fractions and (ii) determine if the cobble to boulder sized material is durable and will resist chemical and physical weathering for years, decades or millennia. The as-mined PSD also has a significant effect on soil: water functions within the landform.

4.4.3 Regolith

The regolith in the project area is defined as the material above the base of weathering that occurs at about 25 m bgl. The regolith includes topsoil and subsoil underlain by extremely weathered strata that includes sand, and clay lenses, and weathered claystone, siltstone, and sandstone. The presence of up to 25 m of weathered to extremely weathered strata and sand clay lenses makes it probable that the material balance for rehabilitation can be increased.

The geotechnical analyses (AMEC, 2017, Cardno, 2018, and Cardno, 2020) verify that weathered profile is deep and dominated by fines. The regolith is variable in structure, texture and composition. For example:

- STX00505 has a lens of sand from 1 m bgl below the logged soil to 28.5 m bgl
- STX050C is moderately weathered claystone from surface to 18.9 m bgl
- STX120 has clay from surface to 6 m bgl underlain by sand from 6 m to 19 m bgl
- STX124 has 2 m of soil, underlain by silt from 7 m to 11 m bgl, sand from 11 m to 17 m bgl and clay from 17 m to 23.06 m bgl.

4.4.3.1 Regolith fertility and geochemical properties

The geochemical properties of the regolith samples were determined on 19 samples (RGS, 2020a) and found to be NAF (one sample returned a total sulfur value of 8.18% and EC of 2,780 µS/cm and was classified as PAF). This sample was sourced from a depth interval of 20.35 m to 20.60 m approximately 6m below the base of weathering in the stratigraphic profile at Drill Hole STX136C in the northern part of the proposed open pit area. The sample was logged as sandstone, but contains some carbonaceous mudstone, which is likely to be the source of the elevated sulfur content and potential acidity.

The low to moderate $EC_{1:5}$ of the regolith samples should make them suitable as a growth medium to supplement existing topsoil and subsoil reserves.

4.4.3.2 Physical properties

The geotechnical logs undertaken by AMEC (2018), Cardno (2018) and Cardno (2020) and the extensive database of geological logs can be used to quantify the depth of the regolith units within the pit shells. Slake durability testing on four samples (Cardno, 2020) verified that the regolith samples from 10.76 m to 21.1 m bgl will degrade to a fine dominated matrix and thus could have potential use in rehabilitation work. The fine-grained nature of the regolith units would make them suitable to retain soil moisture is the root zone of rehabilitated soil profiles.

4.4.4 Soil

The soil survey for the SEIS made 145 soil observations, 54 with full profile descriptions and laboratory analysis and 105 check and exclusion sites (HESSE, 2020). The Project area contains Vertosols, Sodosols, Kandosols and Rudosols (HESSE, 2020). The soil properties and land support capabilities are outlined in Chapter 5 –

Land. The soil mapping units defined by HESSE 2020 include the following (refer HESSE, 2020 for additional information).

- Soil map unit 1 — Red and Brown Gravelly Earths (Kandosols), soils on rises
- Soil map unit 2 — Non-gravelly Rudosols, flood plain soils
- Soil map unit 3 — Gravelly Rudosols & Tenosols, flood plain soils
- Soil map unit 4 — Sodic Vertosols, alluvial plain soils
- Soil map unit 5 — Sodosols, alluvial terrace soils

The maximum recommended stripping depths provided by HESSE (2020) of primary media and secondary media are shown in **Table 4-1**. Subsoil sodicity and chloride content was a constraint to suitability for subsoil stripping and reuse. The volume of primary media (topsoil) available across the CQC Project area was estimated at 1.6 M cubic metres and secondary media (subsoil) at 7.0 M cubic metres. When a handling loss of 10% is allowed, volumes are reduced to 1.4 M cubic metres and 6.3 M cubic metres, primary media and secondary media respectively. (**Table 4-1**).

HESSE (2020) estimated 1.4 M m^3 of topsoil material is suited for use as primary growth media to re-establish vegetation on rehabilitated mine land. Low soil fertility, particularly available phosphorous, is a limitation to topsoil fertility. Subsoil sodicity below 0.2 to 0.3 m is a general constraint to topsoil stripping depth.

HESSE (2020) estimated 6.3M m^3 of subsoil material is suited for use as secondary growth media that can be placed on overburden. The secondary media estimate is based on the root zone depth below the topsoil stripping depths identified from soil profile descriptions. Sodicity, salinity and dispersive behaviour of this material constrains its use at the land surface as a growth media. Its use as a primary growth medium could be considered following gypsum and fertiliser amendment, and the addition of organic matter. Ideally the secondary growth media would be reinstated below the primary growth media in the rehabilitation program.

Table 4-1: Soil stripping depths and material balance

SOIL MAP UNIT	TOPSOIL DEPTH (m)	SUBSOIL DEPTH (m)	LAND CLASS	AREA	SUBSOIL VOLUME	TOPSOIL VOLUME
				(m^2)	(m^3)	(m^3)
Alluvial Soils Gravelly sandy alluvial soils (Rudosols)						
UNITS 2, 3	0.3	1	D	205,029	205,029	61,509
Earthy Soils – Kandosols Gravelly red and brown earths sandy to loamy over clay loam						
UNIT 1	0.3	0.6	C2	366,517	219,910	109,955
Sodic Texture-contrast Soils – Sodosols Gravelly grey and brown texture contrast soil clay loam over highly sodic cracking clay subsoil (Sodosol)						
UNIT 5	0.1	0.5	C2	12,549,063	6,274,532	1,254,906
Cracking Clay Soils – Vertosols Non-gravelly grey and brown cracking clays with highly sodic subsoils soils (Vertosols)						
UNIT 4	0.3	0.5	C1	610,101	305,050	183,030
TOTAL					**7.0Mm³**	**1.6Mm³**

4.4.4.1 Soil fertility and chemistry

The soil chemical data provide baseline measurements of soil fertility that varies spatially with soil type and depth within the profile. There are unlikely to be any constraints to using the soil for rehabilitation.

4.4.4.2 Management of Sodic or Dispersive Soils

The HESSE (2020) soil map units (SMU) indicate that SMU 4 and 5 are naturally saline and sodic. Despite the potential for saline and sodic soil, the existing soil fertility in the project area supports improved and native pasture.

Although sodicity is caused by a chemical problem—too much sodium—its effects are largely physical. Sodicity changes the structure of the soil by preventing the soil particles from forming clumps that allow the water to flow between cracks and pores. Instead, particles in a sodic soil disperse and form sheets into which water cannot penetrate. In wet conditions, sodic soils can be slippery on top and dry underneath, as water can't infiltrate deeper into the soil profile. In dry conditions, these slippery soils can dry as hard as concrete. Sodic soils lead to increased erosion and runoff. As rainwater can't penetrate the soil, it runs along the top, gaining speed as it goes. The faster water erodes deeper and deeper into the soil, creating furrows called rills and gullies, and causing the water flow to speed up even more. In other situations where only the subsoil is sodic, subsurface water flowing over this sodic layer will create tunnels, leaving cavities that eventually collapse to form gullies.

The runoff water often carries fine clay particles into dams and waterways. This is called entrainment and causes turbidity or cloudiness within waterways. The removal of turbidity is very costly for industrial and domestic water users. It also causes environmental problems in rivers and wetlands as it prevents light from reaching plants that need it and impedes some animals' ability to hunt for their food. In addition, run-off from sodic soils is more likely to carry higher levels of nitrogen and phosphate into waterways and reservoirs, which can contribute to algal blooms.

Physical analyses of the topsoil and subsoil include aggregate stability measurements, that verify chemical assessments that the soil will be dispersive and susceptible to erosion. A broader suite of tests are required for detailed design after environmental approvals are obtained to verify how the proposed soil covers for rehabilitation will perform in the short to long term, including mineralogy to quantify clay mineralogy, particle size distribution, soil water characteristic curve analysis, permeability. These tests are primarily aimed at quantifying the soil and water balance to verify how much rain reports as runoff, how much water is stored in the root zone or is lost as evapotranspiration and how much water ultimately reports as seepage to groundwater.

HESSE (2020) state that treatment of stockpiled material with gypsum at 5 T/Ha/yr will flocculate the exposed soil and ameliorate the dispersive properties.

The soil data suggest that soil on rises (elevated above alluvial and flood plains that include SMU 1) has lower electrical conductivity and sodicity, that is associated with the leaching of salts from the elevated soil profile. This finding has practical implications for soil stripping, stockpiling and reuse for rehabilitation because elevating saline and sodic soil in stockpiles is likely to lead to leaching of sodium and chloride from the stockpiles over time decreasing sodic potential.

4.4.4.3 Erosion

Soil loss estimates were computed by HESSE (2020) to enable effective erosion and sediment control measures to be put in place during project development and to aid mitigation measures designed to reduce the erosion potential in post-mining landforms. Final constructed landforms are proposed to be low relief with flat crests, and gently to moderately inclined slope lengths at a maximum of 7 degrees. Figure 4-6 provides a plan-view of the proposed final constructed landform and indicative section locations. Figure 4-7 shows the representative final landform sections.

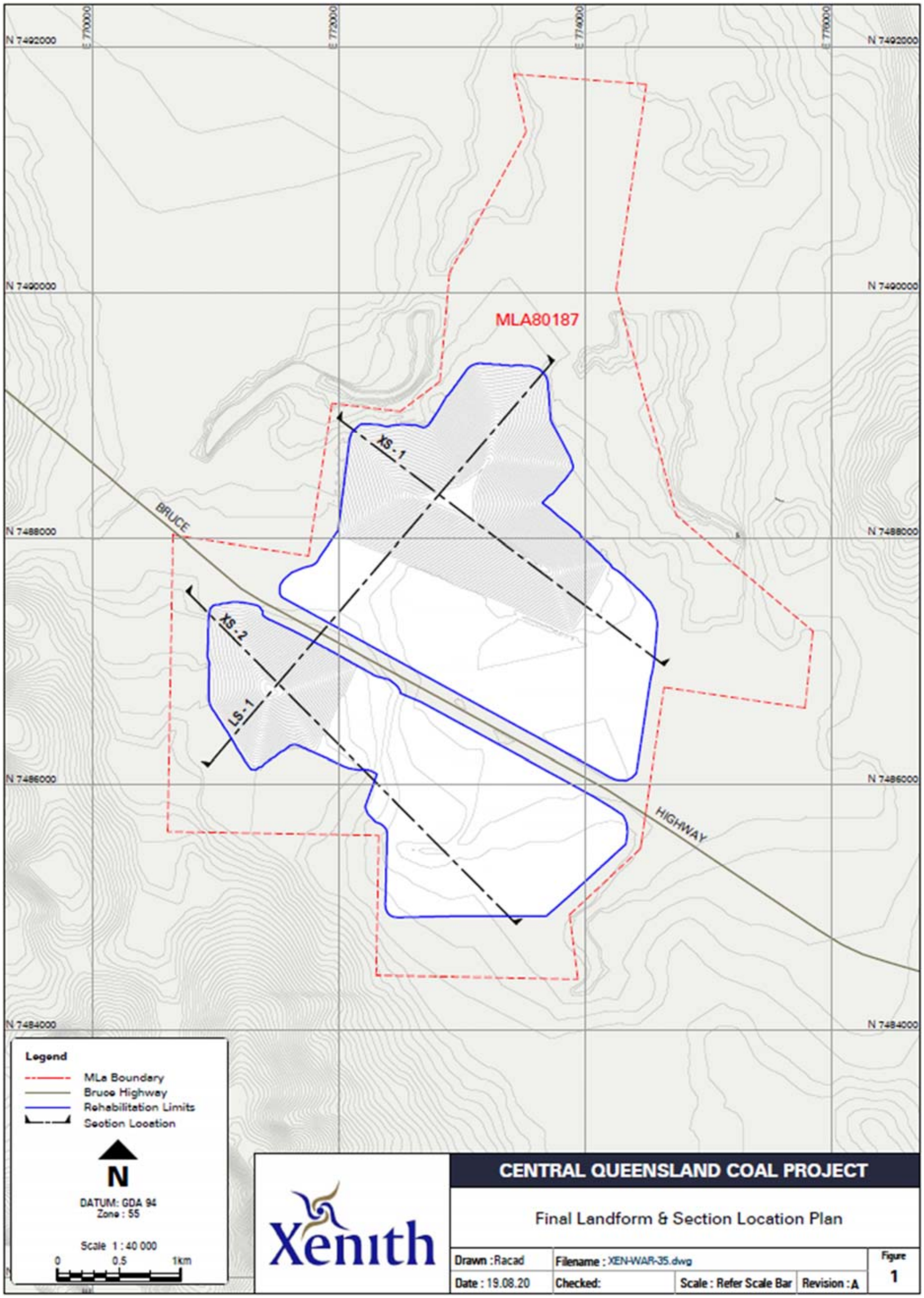


Figure 4-6 Final Constructed Landform with Section

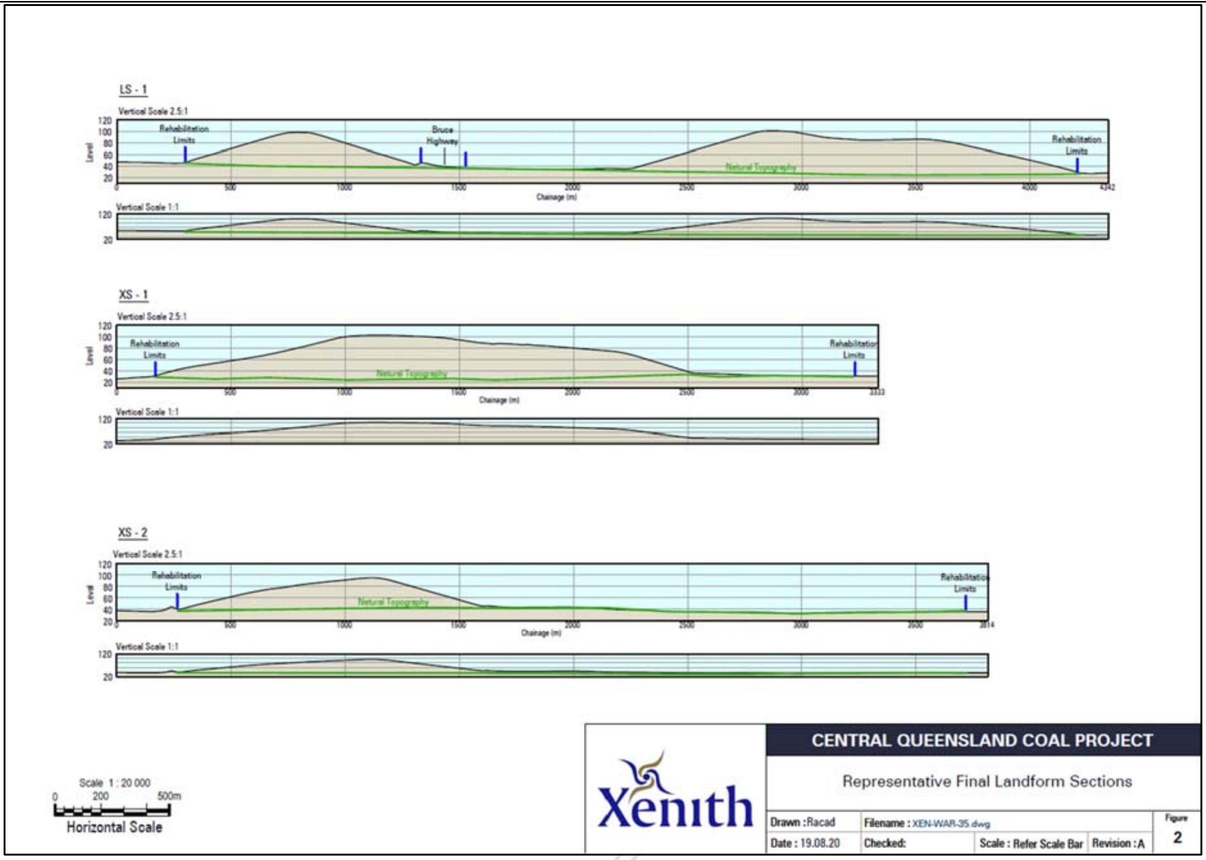


Figure 4-7 Final Constructed Landforms Sections

Estimated soil loss rates were calculated by HESSE (2020) for primary and secondary soil media. The erosion rates of bare soil comprising primary media were 167 tonnes/ha/yr on flat land and 698 tonnes/Ha/yr on sloping land. Secondary media erosion rates of 167 to 335 tonnes/ Ha /yr and 698 to 1397 tonnes/ Ha /yr were calculated for flat and sloping landforms', respectively. Erosion rates were calculated to be 21 tonnes/ha/yr for primary soil media with > 80 % cover.

4.5 Proposed land use

Rehabilitation works (including temporary rehabilitation) will occur progressively through mining operations as areas become practicably available for rehabilitation activities. Final reshaping, rehabilitation and mine closure activities are conceptually scheduled to occur from Project Year 15.

CQC intend to manage its operations and conduct decommissioning and rehabilitation activities to ensure that the land disturbed is returned to land suitable for low intensity cattle grazing activities following the completion of mining operations. Land held by the applicant which neighbours the mining areas which will remain undisturbed throughout the proposed mining activities will be rehabilitated and managed to naturally regenerate to meet conservation objectives.

Since the release of the EIS, CQC has committed to no final voids remaining in the landscape at mine closure and committed to destocking the majority of the Mamelon Property to enable natural regeneration of the non-mining areas such as the riparian zones of Deep Creek and Tooloombah Creek. The destocking is to also enable land management activities to be consistent with desired biodiversity management outcomes that will be developed through the Projects offset planning.

Overarching performance indicators and completion criteria have been updated from those in the EIS, SEIS and SEISv3 and are presented in Chapter 11. The criteria have been updated to reflect the intended post-mining land uses for each site domain and to include further detail to address regulatory comments.

These performance criteria will be used as the basis for preparing the PRCP and will be further refined and developed based on the monitoring and testing of progressive rehabilitation completed throughout the life of the Project. The performance indicators and the completion criteria will be reviewed as part of the PRCP process every three to five years.

5 Landform stability assessment

This landform stability assessment addresses the final waste rock dumps that will exist above pre-mine topography at closure.

The operational aspects of the management of the waste rock dumps is addressed through implementation of the soil, water and sediment and erosion control management strategies.

The landform stability assessment includes two components. The first is the stability of the as-placed mine materials within the waste rock dump, and the second relates to the stability of the reinstated soil cover system.

5.1 Mine planning and rehabilitation schedule

This open cut coal mine is a truck and shovel mining operation with a 19-year mine life and an allowance for 24 years inclusive of final rehabilitation.

5.1.1 Design goals, design objectives, design criteria and performance targets

A complete list of rehabilitation goals, design objectives, design criteria and performance targets are in Chapter 11 of the SEIS

5.1.2 Mine domains

A summary of the approximate area of the mine domains and additional information relating to the mine plan for the CQC project is in Chapters 1 and 11 of the SEIS.

5.1.3 Mining sequence

The general mining sequence, sequential mining sequence and final rehabilitated landform is in **Attachment 9.1**.

5.1.4 Mining schedule

There is an annual mining and mine placement schedule for the project to specify material movement (Table 5-1). The cumulative volume of excavated waste from open cut activities is expected to include approximately 743 million bank cubic metres (Mbcm) consisting of waste rock, subsoils (i.e. those subsoils which are not suitable for mine rehabilitation) and coarse and fine (i.e. dry filter press tailings) reject materials from the CHPPs. Approximately 140 Mbcm of waste rock materials to be stored within the waste rock stockpiles during operations will ultimately be used for the final backfilling of the mining area to ensure that no final voids remain at closure.

Waste materials generated during the mining operations will be emplaced within either: the waste rock stockpiles (particularly during the initial development of the open cut pits) or backfilled within the completed mining areas.

The waste rock stockpiles to be developed during the initial open cut activities will be temporarily rehabilitated (including the installation of appropriate water management structures) to assist with the management of erosion. At the completion of mining operations, materials temporarily stored within these waste rock stockpiles will be used to fill the completed mining areas. At this time, the remaining materials within the waste rock stockpiles will be reshaped, covered with sub soil and topsoil and rehabilitated to achieve the final landform design.

Reject materials (including both coarse reject and fine dry filter press tailings) generated during the processing of ROM coal will be transported and co-disposed with waste rock materials within the waste rock stockpiles and within the pit. These materials will be disposed in locations well below the elevation of the final landform design.

Table 5-1: Proposed mining schedule by period.

Year	Volume (Mbcm)	Accumulative Volume (Mbcm)	In-Pit Dump (Mlcm)*	Ex-Pit Dump (Mlcm)*	In-Pit Pit-2 (Mlcm)*	In-Pit Pit-1 (Mlcm)*	Ex-Pit Pit-2 (Mlcm)*	Ex-Pit Pit-1 (Mlcm)*	CHPP Total Reject	CHPP-1 (Mlcm)*	CHPP-2 (Mlcm)*
P1	17.81	17.81	3.65	18.07	3.65		18.07		0.16	0.00	0.16
P2	22.03	39.83	14.27	12.60	14.27		12.60		0.32	0.00	0.32
P3	21.60	61.43	22.94	3.41	22.94		3.41		0.30	0.00	0.30
P4	23.15	84.59	28.25	0.00	28.25				0.31	0.00	0.31
P5	45.20	129.79	55.15	0.00	55.15				0.65	0.00	0.65
P6	40.87	170.66	47.21	2.66	47.21		2.66		0.65	0.00	0.65
P7	49.07	219.73	59.86	0.00	59.86				0.65	0.00	0.65
P8	51.22	270.95	57.19	5.30	57.19		5.30		0.66	0.00	0.66
P9	51.13	322.08	57.72	4.66	57.72		4.66		0.62	0.00	0.62
P10	54.28	375.08	53.86	12.36	53.86			12.36	0.59	0.07	0.52
P11	86.61	462.86	76.20	29.47	54.71	21.49		29.47	0.92	0.39	0.53
P12	108.48	571.43	108.22	24.13	80.96	27.26		24.13	1.01	0.40	0.60
P13	48.55	618.45	59.23	0.00	59.23				0.59	0.00	0.59
P14	42.75	655.43	52.16	0.00	37.58	14.58			0.62	0.16	0.46
P15	13.54	676.09	6.93	9.58		6.93		9.58	0.33	0.33	0.00
P16	24.54	695.01	29.94	0.00		29.94			0.32	0.32	0.00
P17	19.09	719.26	23.29	0.00		23.29			0.31	0.31	0.00
P18	21.72	739.63	26.50	0.00		26.50			0.31	0.31	0.00
P19	0.78	742.44	0.95	0.00		0.95			0.02	0.02	0.00
Total	742.4	742.4	783.5	122.3	632.6	151.0	46.7	75.5	9.3	2.3	7.0

5.1.5 Rehabilitation schedule

The HESSE (2020) soil study calculated stripping depths and material balances that allow for 1.4 Mlcm of topsoil and 6.3 Mlcm of subsoil. The available volume from the proposed strip depth fulfills the projected material requirement for rehabilitation. Further detail on the soil balance and rehabilitation works is provided in Chapter 5 – Land and Chapter 11 – Rehabilitation.

5.2 Temporary landform design

It is estimated that approximately 743 Mbcm will report to the two ex-pit waste rock stockpiles and two open cut pits throughout the mine life. The area occupied by Waste Rock Stockpile 2 (WRS2, servicing Open Cut 2) and Waste Rock Stockpile 1 (WRS1, servicing Open Cut 1) will be 76 ha and 153 ha respectively.

WRS1 will initially be developed up to RL 150 m and be reformed to a maximum final landform height of RL 100 m upon the completion of mining operations.

WRS2 will initially be developed up to a maximum landform height of RL 135 m and will be reformed to a landform height of approximately RL 100 m at mine closure i.e. 70 m in height assuming the pre-mine elevation is approximately 30 m RL.

The final landform design of WRS1 and WRS2 will be refined throughout the mine life to ensure that the landform established will be stable, safe and support the intended final land use (i.e. low intensity cattle grazing) for the Project area.

5.2.1 Backfilling open pits

The Project no longer proposes to retain open cut pits (or voids) in the final landform at the time of mine closure. The waste rock and overburden materials which are temporarily stored within the 'in pit' and 'out of pit' waste rock stockpiles will be available to backfill the completed open cut pits to the final landform design Chapter 11 of the SEIS).

Geotechnical stability associated with the open pit low wall, high walls, pit floor and stability of the slopes associated with the Bruce Highway area addressed by Cardno (2018 and 2020).

Backfilling open pits is consistent with best industry practice and negates significant environmental issues associated with the presence of final voids and the development of pit lakes.

Backfilling of the open pits will proceed progressively over the life of mine. Backfill material will include overburden, interburden and coal rejects and tailings. The physical properties of these materials and their distribution through the backfill will influence and in some instances control the overall stability of the structure. The CQC open pits are shallow (relative to other coal open pits) and the geotechnical issues associated with slumping or failure of the in-pit end tipped slopes will be managed using standard industry practices.

The geochemical analyses of the mine materials including coarse and fine rejects have determined that the environmental risk of the samples is low (RGS, 2020a). The environmental aspects of backfilling mine materials to the open pits over the mine life are the effects related to the potential oxidation, weathering and leaching of salts and metals/metalloids from the mine materials to the toe of the tip head and into in-pit sumps. During mining operations, the in-pit water will be pumped into the mine water dams. As the backfilling process proceeds the backfilled material will be subjected to loading and settlement that will consolidate the backfill materials.

In cases where backfilling into mined pits is followed by reshaping and rehabilitation, settlement at the surface can lead to the formation of depressions in the contour drain (**Figure 5-1**) that subsequently lead to ponding and then overtopping of the drain during rainfall events which potentially may lead to scouring and erosion (**Figure 5-2**).

Landform stability issues associated with backfilling mine waste to the mined open pits will not occur on the CQC stockpiles (or will be significantly reduced) as the schedule (**Table 5-1**) allows for years of loading, and settlement of the backfill material prior to reshaping to final landform design.

Figure 5-1: Example from the Bowen Basin settlement in a contour drain leading to ponding and development of low points in the contour drain embankment

Figure 5-2: Example from the Bowen Basin of minor gully erosion from a contour drain due to settlement of the landform and overtopping

5.2.2 Temporary landforms

Other than the area that can be shaped to final landform design on the western face of the WRS2 developed in Year 3 (**Section 9.1**), the external faces of the WRS1 and WRS2 will be built at angle of repose (Chapter 11 of the SEIS). Slope angles and lengths associated with landforms such as this are managed through standard mining construction methods and therefore the risk of slope failure will be low.

At the completion of mining operations, materials temporarily stored within these waste rock stockpiles will be used to fill the completed mining areas. At this time, the remaining materials within the waste rock stockpiles will be reshaped, covered with subsoil and topsoil and revegetated to achieve the final landform rehabilitation objectives (**Section 5.1.1**).

5.2.3 Reactive material

Identifying and selectively utilising waste rock materials with low sodicity will be important for the temporary and final shaping and rehabilitation of the waste rock stockpiles. Materials characterised and validated as non-dispersive and non-sodic will be used for the outer slopes of waste rock stockpiles to limit the potential for dispersion and erosion, with identified sodic materials disposed of within the central (inner) zones (i.e. below the final landform design) of waste rock stockpiles.

Waste rock materials that are sodic (or have other geochemical constraints) will be selectively handled and disposed deep within the mining area or within the core of the waste rock stockpiles (i.e. in locations which are well below the final landform design).

Dried coarse rejects and filter pressed fine rejects will be mixed with overburden waste and strategically placed within both the waste rock stockpiles and in the open cut mine void. Co-mingling of coarse and fine reject materials within waste rock stockpiles is an effective management strategy if the geochemical attributes are suitable as it reduces the potential for point sources associated with “cells” to contribute to long term water quality issues. The geochemical attributes of the overburden and interburden coupled with the attributes of the rejects and tailings would support co-mingling over the life of the mine. The coarse and fine reject materials will be sampled and analysed for pH, EC, sulfur species and ANC (initially monthly) until geochemical trends have been established. Sampling and analysis will then continue to be undertaken on an annual basis.

PAF or sodic material will not be placed near the surface of the temporary (or designed final landform surface) of the waste rock stockpiles. If any such material is identified, the material will be picked up and end tipped to the open pit otherwise the area will be capped with geochemically and physically inert material prior to top soiling and seeding.

The potential for the placement of PAF waste into temporary waste rock stockpiles or within 5 m of the final landform surface will be avoided with detailed mining and rehabilitation scheduling.

As discussed above, the impact of reactive material (e.g. saline or sodic material) would be the leaching of salts through the backfilled material into the mined void and then to the deepest mined surface (pit floor) and pit sumps.

The adverse effects of the placement of reactive mine materials into the pits will be low (i) because the geochemical analyses indicate the geochemical risk of the samples is low and (ii) the groundwater quality within most areas of the mine pits is moderately or highly saline.

5.2.4 Beneficial use of non-reactive material

As the project evolves and detailed designs are developed, it will be possible to define the surface extent of the final landform surfaces. With this knowledge, it may be possible to selectively place geochemically low risk (non-sodic) regolith materials in these zones i.e. construct zones within the temporary landform design to final design. This will have the added benefit of building extensive areas of the stockpiles to conform with the natural soil and regolith profile.

5.2.5 Surface armouring

The temporary waste rock stockpiles to be developed during the initial open cut activities will be temporarily stabilised (including the installation of appropriate water management structures) to assist with the management of erosion. The process to achieve temporary landform stability (limiting erosion) will be to armour the external stockpile faces and the temporary upper landform terraces of areas that may be susceptible to erosion with competent and durable rock (Engeny, 2020). Rock armouring is routinely used on landforms and as a component of hydraulic designs to achieve landform stability.

The capacity to implement this armouring process will be dependent on the ability to source adequate volumes of suitable material over the life of the mine. The physical sampling and analysis completed to date (AMEC, 2017, Cardno, 2018 and Cardno, 2020) verify that there is competent and durable rock within the overburden and interburden units available for this construction use (**Section 4.4.2.4** and **Section 4.4.3.2**).

5.3 Final landform design

5.3.1 Stakeholder expectations

Increasingly, stakeholders and regulators are requiring objective assessments of landform stability over longer time periods. Given the financial and environmental liability that is associated with constructed landforms, such assessments are in the best interests of both regulators and the mining industry.

The Queensland Government approach to addressing these financial, and environmental issues is for projects to develop a PRCP. CQC has the geological information and mine planning principles in place to develop a PRCP that will meet the requirements of DES.

5.3.2 Principles of landform design[1]

The following principles of landform design are consistent with the values being developed for the CQC Project and conform to leading industry practice..

1. **Begin with the end in mind.** Create a shared vision for the reclaimed land among the mine, its stakeholders and work together to earn each other's trust.
2. **Establish governance**. Assemble a multidisciplinary design team and appoint a lead designer.
3. **Set clear land-use targets, goals, design objectives, and design criteria** in a Design Basis Memorandum. Support the vision. Anticipate the land will evolve over time — physically, chemically, ecologically, and socially. Design and maintain the land to adapt to these changes, including those driven by an ever-changing climate.

[1] Sourced from Canadian Landform Institute. http://landformdesign.com/about.html

4. **Work collaboratively in every endeavour**. Build the reclaimed landscape *with* (not *for*) the land's users.
5. **Work all spatial scales** — regional, landscape, landform internal and external), element — simultaneously.
6. **Design for construction and operations**. Landforms and landscapes should be easy to build and reclaim using available technology that is fit for purpose. Control the source of contaminants. Avoid producing soft tailings.
7. **Use a risk-based approach**. Design for the most reliable or most likely case. Embrace the observational method and true adaptive management. Enact predetermined contingencies as needed to allow the evolving land to perform as intended.
8. **Follow every drop of water through the landscape**. Water is both a key to life and a great agent of disruption.
9. **Know your materials**. Cover and revegetate all mine waste. Ensure adequate borrow. Conserve soils.
10. **Favour progressive reclamation**. Learn by doing and document achievements. Ensure timely access to reclaimed land. Collaborate for progressive signoff. Minimize the work required after the last tonne of ore is mined and the mill shuts down.
11. **Acknowledge the land will revert to the local community** and support their duty of stewardship. Reclaim every square metre. Avoid unnecessary long-term care but anticipate where it will be required. Provide full financial assurance for all phases of mine life.

5.3.3 Typical failure modes

Constructed mine landform designs for waste rock dumps can range from linear slopes and hard engineering approaches using berms, and batters and drop structures through to the application of curvilinear / concave profiles and in some cases complex geomorphic design principles that strive to conform with local landscape geomorphology.

Major risk factors for degradation or failure of constructed landforms are extended slope length, high slope angle (including uniform or convex slopes), upslope catchment, ponding of water, permanent erosion control structures, high clay, silt, and fine sand contents, sodicity, dispersion, and a low or non-resilient fragmental content (Emerton et al., 2018). Where failure is present on these material types, it appears as poor or patchy plant cover, capillary rise of salts, piping, sheet and gully erosion, and failure of designed erosion control structures (Emerton et al., 2018).

Erosion is the end point of failed land stability. The potential for erosion to occur can be evaluated through geochemical and physical sampling and analytical programs (GaPSaAP) to quantify the properties of the materials and subsequently (i) the use of the samples in field trials to measure erosion or (ii) the application of the measured data using numerical modelling methods to infer erosion potential.

Landform design evaluation methods using numerical modelling have advanced considerably over the last 10 years. It is now possible to use various runoff/erosion models to develop site and material specific landform designs that are demonstrably stable in the medium to long term, and to consider a wider range of rehabilitation goals. However, these modelling methods (e.g. CAESAR, SIBERIA, WEPP, RUSLE) are constrained to the evaluation of erosion from the surface material. While these landform modelling tools provide an estimate of landform evolution, using field measured data to determine if the design objectives are being met is preferred.

Constructed slopes designed with traditional planar cross sections are encountered in most land development, including highway cut and fill sections, constructed embankments, and reclaimed mine lands. However, planar landscape profiles are seldom encountered in nature. Curvilinear slopes with concave shapes usually arise as the result of evolutionary processes in fluvial systems and hillslopes (**Figure 5-3**).

5.3.4 Landform design considerations

Landform design approaches such as the geomorphic reclamation of mine lands (Toy and Chuse, 2005) include the construction of concave shapes in both the transverse (cross-slope) and longitudinal (downslope) directions to create natural self-sustainable ecosystems (Martín-Duque et al. 2010) with improved erosion resistance (Schor and Gray 2007). Hancock et al. (2003) studied a series of linear and concave landforms on mine spoil in northwest Western Australia. His study demonstrated that over the range of slopes and slope lengths examined, concave slopes can reduce sediment loss by up to five times that of linear slopes.

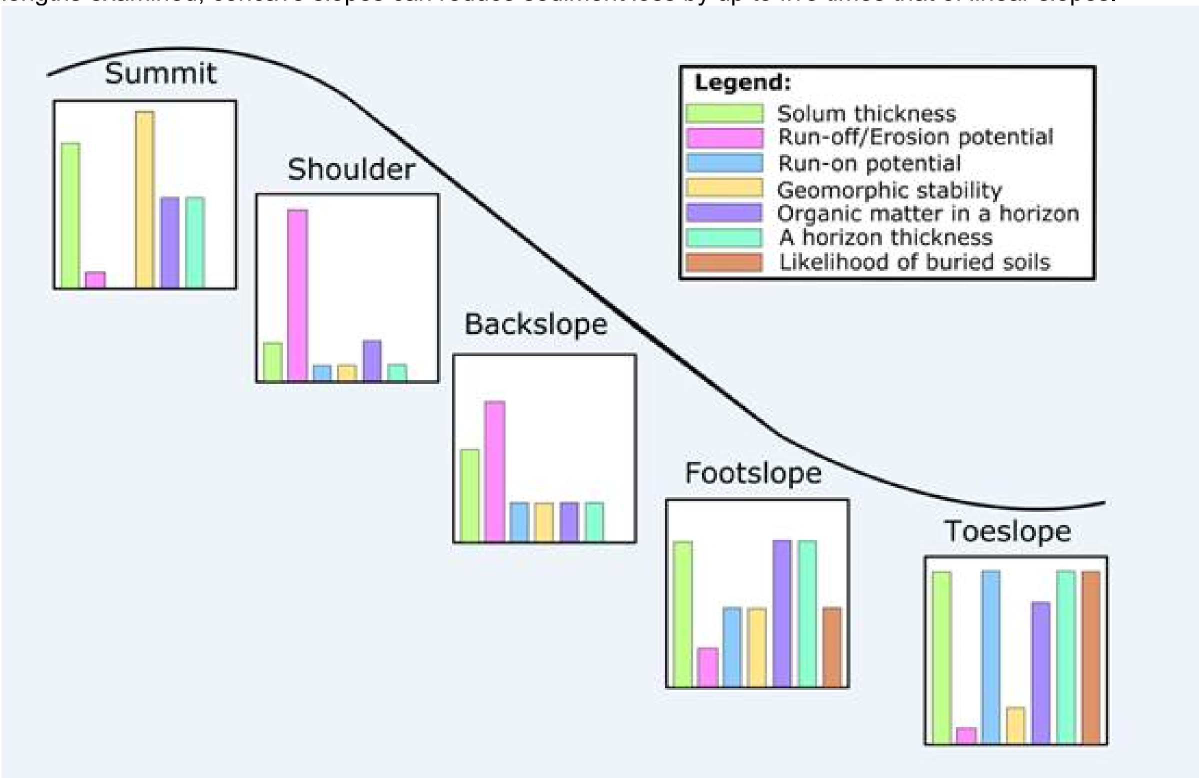


Figure 5-3: Effects of hillslope position on soil properties in a humid climate. (After Schaetzl (2013).)

Although there is evidence to verify that concave slopes yield less sediment from erosion than planar slopes (Hancock, 2003, Priyashantha et al., 2009 and Jeldes et al., 2016) not all concave shapes are mechanically stable. For example, Howard et al. (2011) point out the risk associated with the practice of shaping slopes to reflect natural regional landforms without appropriate material characterisation (Emerton *et al*., 2018) and stability and erosion analyses and without accounting for the limited precision of the construction equipment employed to build concave profiles can lead to erosion and slope failure. The outcome of the extensive bodies of work related to landform design and landform stability are that each site should be evaluated on its own merits and standard approaches should be avoided.

CQC have included an area within the site that will be profiled to final landform design by Year 3. This commitment will enable CQC to evaluate a range of landform design profile and surface treatments that can be applied to the later stages of project development. The development of site-specific landform design principles are consistent with authors including Howard et al (2011) and Emerton et al (2018).

Detailed landform designs integrated with the mining schedule will enable the projected final landform surface to be defined. Throughout the mine life, material can be placed on the contact of the final landform surface to attain final landform design principles i.e. deep layers of regolith units could be placed on this contact so what when the temporary material placed above it is pushed down or moved the exposed material will be suitable as the basal layer of the final rehabilitation layer.

Building on this material placement approach, and acknowledging that the long term landform evolution process is likely to lead to a curvilinear slope with concave shapes, the placement of the "regolith" units could be done so that a greater depth of material is placed on the shoulder, backslope and foot slope e.g.,

- 2 m of regolith material could be placed on the summit,
- 5 m of regolith material could be placed on the shoulder,
- 10 m of regolith material could be placed on the backslope

- 2 m of regolith material could be placed on the foot slope
- 1 m of regolith material could be placed on the toe slope as material eroding from higher on the slope with aggrade in this zone.

The geotechnical drilling by AMEC, 2017, Cardno, 2018 and Cardno, 2020 all verify that the regolith profile in the project area (although it is variable in material types) is nevertheless deep (in the order of 20 to 25 m in depth) and consistently dominated by clay, silt and sand size fractions. These findings verify there will be the potential to construct deep regolith profiles as a component of the final landform design.

5.3.5 Landform profiling to final design

Substantial movement of temporary landforms is not scheduled to occur until Project Year 15. This provides a beneficial outcome for the project related to landform stability as there will be long periods of loading, settlement and consolidation that will ensure that the final landform surface will be stable and therefore less prone to subsidence that might affect surface water drainage structures.

The reshaping process and movement of stockpiled material placed above the final landform surface will lead to surface disturbance including uprooting of opportunistic vegetation. The mobilisation of material during this process may lead to erosion that can be adequately managed and contained within the surface water dams.

At the end of mining operation, the as-built temporary waste rock stockpiles will be reshaped to achieve the final landform design criteria, with overall slopes of up 8% to 12%. Maximum slope lengths will be in the order of 700 m. The proposed slope angles are low and provide the maximum potential possible to establish slopes with a low potential for erosion.

General landform design considerations from Hawley and Cunning (2018), being incorporated into the final landform design (**Table 5-2**) are that the as-built final geometry should resemble a mature landform, which involves measures such as the following:

- designing the final landform using natural analogues
- avoiding benches, terraces, contour banks and abrupt changes in topography
- avoiding man made materials (e.g. gabions)
- using a spur end shape in plan view with a concave-convex profile if feasible
- providing appropriate distribution and quantity of drainage features (that are a function of climate, soils and slope)
- situating watercourses in valleys as opposed to banks
- establishing vegetation progressively.

Table 5-2 Summary of Design Criteria

Key Design Constraints	Acceptance Criteria
Landform Height	Ex-Pit Dump 1 70m (RL100m); Ex-Pit Dump 2 62m (RL98m)
Slope	Maximum overall slope of 7 degrees
Geotechnical Stability	Factor of safety to be >1.5
Water Management	Landform appropriately designed to ensure it is free draining to neighbouring environment (i.e. no ponding) Contour drains and water containment will be required for all stages of the mine plan
Void Areas	No final voids to remain; In-pits filled to existing/marginally higher than pre-mining landform elevations

Where possible, waste rock dumping should be planned to minimise material rehandling, controlling closure costs. The top surface should be sloped and minimised to reduce the potential for ponding and the accumulation of water that has to be removed without causing erosion.

The proposed final landform design adheres to industry leading practice with maximum backfilling of final voids and no open final voids that could become pit lakes, very low slopes, and no large flat areas on the top of the constructed mine landforms.

Detailed landform design process will verify how the temporary landforms will progress to a final landform design. Assumptions relating to how this can be managed are in **Section 5.2.2**.

5.3.5.1 Soil stripping, stockpiling and reclamation

The topsoil and subsoil and the deeper regolith to about 25 m bgl within the open pit footprints ranges from having low to high salinity and sodic potential (AMEC, 2017, Cardno, 2018 and Cardno, 2020, HESSE, 2020 and RGS, 2020a).

Based on stripping depths by HESSE, 2020, the available material balance of topsoil and subsoil is sufficient for landform rehabilitation. Maximising the stripping depth wherever possible should be encouraged to increase the available material balance.

Stripping and stockpiling of soil prior to its use in rehabilitation programs inevitably leads to soil loss and soil degradation over the mine life: a 10% soil loss was accounted for by HESSE, 2020 and in the rehabilitation schedule. Soil removed early in the mine life will need to be stockpiled for 15 to 20 years, whereas the soil stripped in the last year of mining may well be used immediately.

The stockpiling of topsoil and subsoil has beneficial outcomes for the project because elevated stockpiling will lead to leaching of soluble sodium and chloride from the soil over time. The stripping and stockpiling process can be supplemented with the addition of gypsum.

Reclaiming sodic soils is primarily achieved by leaching sodium chloride from the soil to decrease the soluble and exchangeable sodium percentage (ESP), typically with mineral supplements such as powdered dolomite that contains calcium and magnesium or powdered calcium carbonate. But this approach may oversimplify the facts and limits the reclamation process to one aspect without considering hydraulic and biological aspects. For example, Dieleman (1963) and Leffelaar and Sharma (1977) reported that an amendment may not be needed for reclamation of saline soils having high sodium adsorption ratio (SAR). They found that the decision to use a chemical amendment for the reclamation of saline soils having excess neutral soluble salts and a high SAR of soil solution (the so called saline-sodic soils) would depend on soil infiltration characteristics and the electrolyte level of the irrigation water. Light textured soils and those having a favourable infiltration rate are not likely to respond to gypsum application: light textured soil with a high silt and sand content are a probable feature of the material that will be present below the final subsoil and topsoil. In heavy textured soils, and where such soils are leached with low electrolyte water, application of an amendment is desirable to hasten reclamation.

5.3.6 Re-establishing the soil profile

The reconstructed landform profile includes five components:

- Foundation material (natural ground or deepest mined surface)
- Basement material (overburden, interburden (claystone, siltstone, and sandstone)) and coarse and fine rejects
- Regolith (sand, sandy clay, clay units)
- Subsoil (B and C horizons)
- Topsoil (A and B horizons)

The constructed soil profile will be built on the basement material e.g. emplaced overburden and interburden comprising claystone, siltstone, and sandstone.

The physical attributes of the basement material have been quantified and found to range from low to high rock strength using point load and uniaxial analytical methods (AMEC, 2017, Cardno, 2018 and Cardno, 2020). The physical attributes from the measured data can be applied to the strata within the CQC geological database to construct a detailed geological model (and in time material balances for units such as competent sandstone to be used for rock armouring). When this work is done as a component of the PRCP in a detailed mine schedule this will then enable the location, volume, and probable performance of the strata in the stockpiles to be determined. The outcome of this analysis will be that competent durable strata will be able to be identified and segregated for specific applications such as armouring temporary end tipped stockpiles faces.

The geological and modelling information outlined above (and the information discussed in **Section 5.3.4**) will make it possible to place regolith strata (or other specific strata recovered during mining) on what will become the final landform surface contact so that when the temporarily stockpiled overburden and interburden material is removed the basement unit on the final landform (the regolith strata) is already in place. There is a substantial volume of regolith strata available for this purpose verified by geotechnical drilling and logging by AMEC, 2017, Cardno, 2018 and Cardno, 2020.

When the final landform basement material (that may comprise recovered regolith strata or as mined waste) is uncovered and profiled to conform to the final landform design criteria, the secondary media (subsoil) material will be placed over the basement unit. The material balance estimate for the secondary media (subsoil) is based on the root zone depth below the topsoil stripping depths identified from soil profile descriptions by HESSE (2020). Sodicity, salinity and dispersive behaviour of this material may constrain its use, however soil remediation using leaching and or gypsum will reduce any adverse effects related to sodicity. Under the proposed rehabilitation process subsoil will be placed below topsoil thereby reinstating baseline soil profile conditions to enable sustainable growth of vegetation.

The upper component of the soil profile will be primary soil media (topsoil). Low soil fertility, particularly available phosphorous, was defined as a limitation to topsoil fertility (HESSE, 2020), however the measured values are nonetheless known to support the existing vegetation and land use so the measured values representing baseline conditions should not be a constraint, unless the stockpiled soil lose carbon and nutrient content during stockpiling. If the loss of carbon and nutrient content does occur these impacts can be overcome during the rehabilitation process.

The soil material balance specifies that there is the capacity to spread approximately 100 mm of topsoil and 500 mm of subsoil on the reshaped waste rock stockpile slopes. It is assumed that the subsoil will be hauled from the stockpiles to the top of the dumps and will be pushed down the slopes using graders or dozers and that the topsoil will be placed over the subsoil.

Deep ripping through the topsoil and subsoil along contour can be evaluated as a method to slow and intercept surface runoff and reduce overland flow.

Soil development is intimately tied to the slopes on which soils form. Soils across and down slopes are connected, process-wise, like links in a chain: this analogy has led to the concept of a “catena” – a term for a series of soils on a slope (Schaetzl, 2013). Inclusion of these processes are important to consider in the rehabilitation process because fluxes of sediment, commonly facilitated by water, vary predictably as a function of position on the slope, leading to soils that may be thinner or thicker than expected on steep slope segments where runoff is accentuated (**Figure 5-3**). Conversely, soils on lower, flatter slope segments may be overthickened from many years of slow but episodic sediment accumulations from upslope; when sediment accumulations are particularly fast or large, soils here can become buried.

Soil texture and infiltration capacities dramatically impact these processes; on slopes composed of coarse, more permeable materials, catenary position is less important because there is less runoff, and thus, even on the steepest slope segments, much of the water infiltrates vertically. Water tables, commonly deepest on the steepest slope segments, vary predictably as a function of position on the slope. Shallow water tables can dramatically affect internal soil processes, as well as weathering and related phenomena, although it is noted that groundwater is typically greater than 10 m below ground level (refer to Chapter 10 of the SEIS).

5.3.7 Re-vegetation and final land use

Revegetation methods are described in Chapter 11 of the SEIS. RGS support the use of a cover crop to stimulate the accumulation of carbon, organic matter and nutrients in the topsoil and subsoil horizons as this this assist in improving soil texture and structure and reduce the effects of sodicity.

A carefully managed grazing land use is likely to have significant benefits for the long-term stability of the constructed mine landform that could include recycling nutrients through the soil profile.

5.3.8 Surface water management of the final landform

Much of the mine waste will be contained within the backfilled voids. This is a beneficial outcome of the landform design because it will lead to almost all of the soluble major ions and metal(loids) percolating through the mine waste into the backfilled voids, rather than as seepage from the toe of the dumps onto the natural (un-mined land) land which subsequently runs off into the two adjoining creeks.

One of the failure modes that leads to erosion is the ability of a rehabilitated landform to manage surface water during rainfall events. Typical landform design options include linear slopes or linear slopes with (temporary or permanent) contour drains that direct runoff to drop structures. Alternative designs can include building slopes that are more like natural slopes i.e. curvilinear / concave slopes.

There are three key failure mechanisms that can occur to engineered water drains (i) the drain fails due to a structural flaw or poor implementation of the design and / or (ii) the materials used to construct the drain weather in an unexpected way affecting their integrity and /or (iii) settlement of the landform occurs rendering the design objective obsolete i.e. the land settles and a contour drain sinks, pooling water instead of draining the water from the slope, leading to overtopping of the pool across the top of the contour berm, followed by erosion, breaching and failure that in most cases leads to gully erosion. Development of the final landform and drainage structures will take into account and design to avoid these potential failure mechanisms.

Contour grooving, channel linings, surface armour and drop structures will be constructed on the outer slopes to prevent long watercourse runs and minimise slope erosion (SEIS Chapter 11 and Engeny, 2020).

The proposed mine water management system has been designed to contain runoff from mining disturbance within the site (WRM, 2020). During wet climatic conditions, releases from the mine water management system to Deep Creek are proposed to occur. These releases are expected to result in negligible impacts on downstream water quality and are to remain within the range of natural variability (WRM, 2020).

5.3.9 Groundwater management of the final landform

Over the mine life flood water has a low potential to enter the site and inundate the external waste rock dumps, open pits and backfilled pits. Surface water inundation will be managed with flood levees in place during mining operations. Subsurface flow could occur through the regolith during flood events, but because of the low incidence of these events the actual flow rates would be quite low.

From a long-term closure perspective, the backfilled voids will store a substantial amount of water. The water will saturate the backfilled spoil including the rejects and tailings. The presence of carbon and sulfur in the mine waste will lead to anoxic and reducing conditions leading to the immobilisation of sulfate and most metal(loids). Therefore, the effects on groundwater quality should remain within pre-mine baseline conditions.

6 Forward works and recommendations

The technical work for this project will continue during the subsequent stages of project development. The ongoing work will fill existing technical gaps and be used to develop the mine to a detailed design stage that can be subsequently compiled into a PRCP for the project.

RGS recommend that CQC implement the following staged sequence of work.

- Undertake a detailed gap-analysis of the geological data to identify any data shortfalls and develop a geochemical, physical and analytical sampling program (GaPSaAP) to address these shortfalls
- Utilise CQC's existing geological model and geological logs to identify the major strata including the soil and regolith and overburden and the interburden e.g. topsoil, subsoil horizons, alluvial or colluvial lenses, regolith, extremely weathered to weathered rock units in the overburden and the subsequent fresh rock units in the interburden. Refine the geological model to include these major geological strata.
- Use the geological and GaPSaAP data to develop a combined geo-environmental block model (GBM)
- Use the GBM to verify the material balance that is available for each of the major geological units in the deposit and use this information to verify key landform design criteria.
- Build the GBM into a detailed landform haulage schedule (LHS) that can be used to compile a complete and detailed life of mine plan.
- Use the GBM and LHS to optimise the construction and rehabilitation sequence.

6.1 Progressive mining and rehabilitation

This section of the document describes the rehabilitation strategy for CQC that will be incorporated into a PRCP which is a regulatory requirement in Queensland.

The overall intent of a PRCP is to ensure that the materials that will be mined over the life of mine will be available when they are required, to:

- build constructed mine landforms (CML) that might include an open pit, water dam, tailings and waste rock storage facility or underground void;
- manage chemically or physically reactive mine waste so the CML is non-polluting, safe and stable;
- attain self-sustaining ecological development and land use; and,
- minimise adverse impacts to the receiving environment.

CQC will develop a PRCP for the Project following obtaining the relevant environmental approvals for the Project. A PRCP requires:

- **planning** information in **Section 3-1** to **Section 3-5** of the PRCP Guideline and most of this background information is obtained from the technical studies completed for the EIS submission, and,
- **scheduling** information in **Section 3-6** to **Section 3-8** and **Section 4** of the PRCP Guideline that aims to quantify the types of material that will be mined and produced, the characteristics and classification of the material types, material balances and landform haulage schedule (referred to in the guideline as a block model) that enable the environmental aspects of constructed mined landform designs to be evaluated.

The outcome of the planning and scheduling components lead to a determination of whether the project is likely to meet its compliance requirements, have a tolerable level of environmental harm on the receiving environment (residual risk) and achieve surrender of the mining lease (**Section 5** of the PRCP Guideline). The approach to develop the PRCP will be to implement a series of tasks as outlined in **Figure 6-1** that starts within the outlined red circle that shows a requirement for a geochemical and physical sampling and analysis plan (GaPSaAP). The general workflow associated with the GaPSaAP is in **Figure 6-2**.

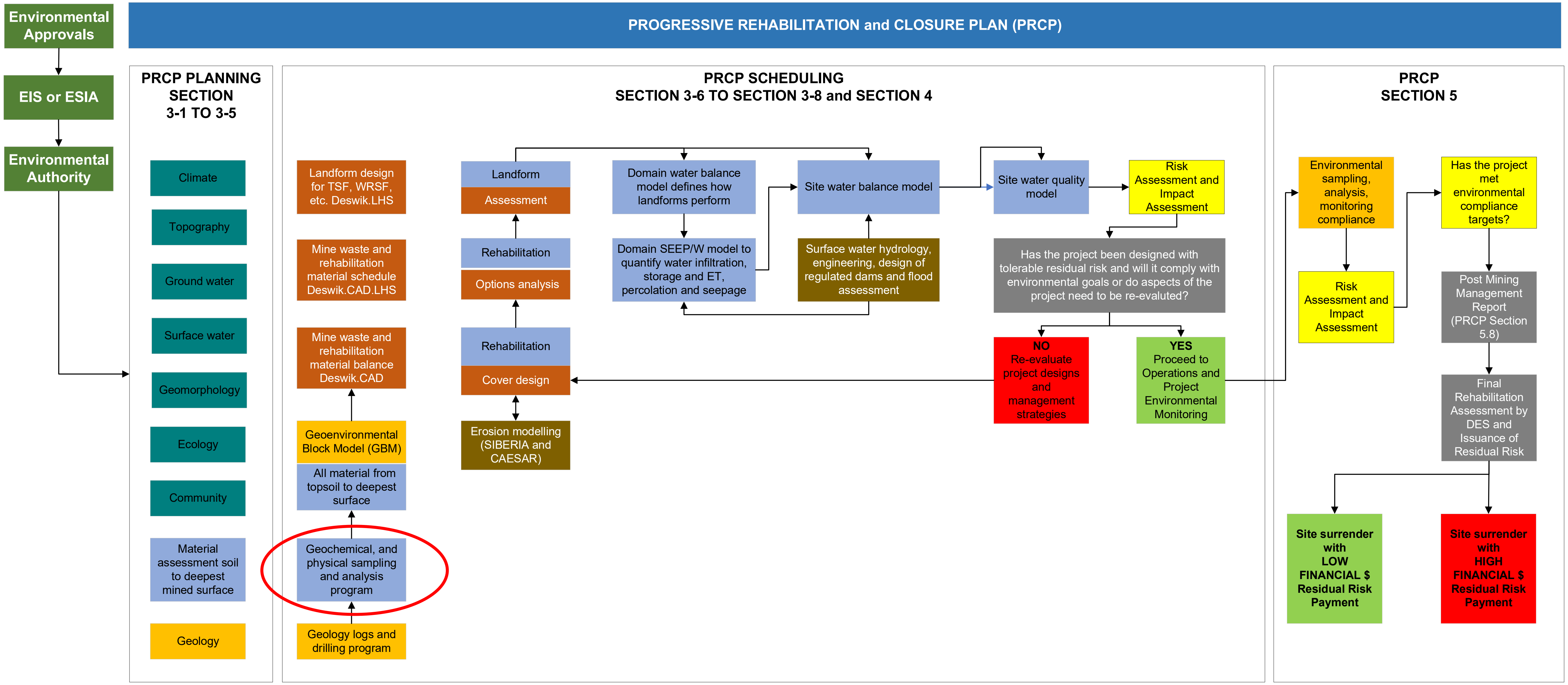


Figure 6-1: Summary of the environmental approvals and PRCP process including the GaPSaAP (red circle) detailed in Table 6-2

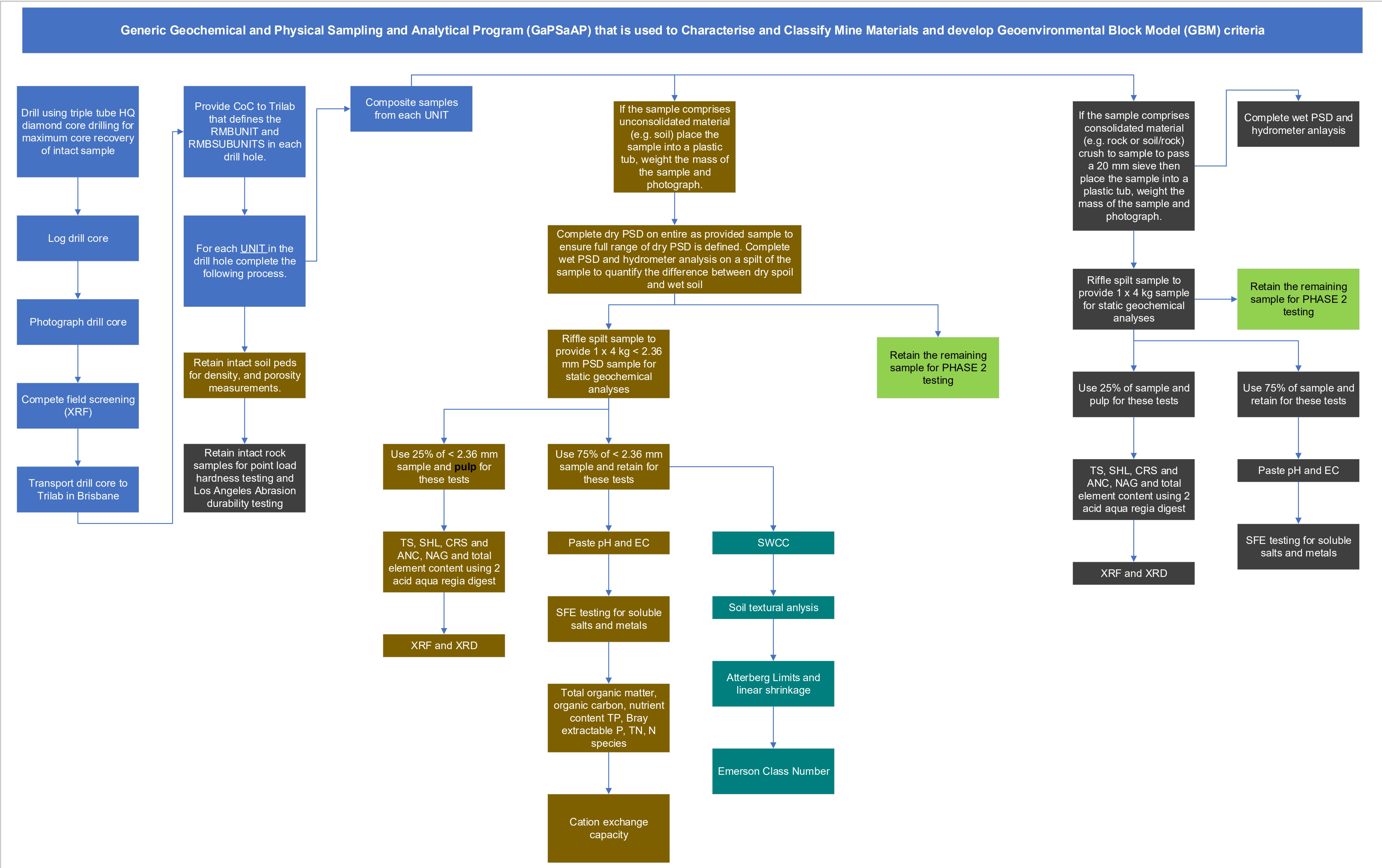


Figure 6-2: GaPSaAP flow chart defining the analytical processes to be undertaken

6.2 Geochemical and physical sampling and analytical program

The geochemical sampling program undertaken in 2012 is fit for the purpose of the SEIS. Additional soil fertility, geochemical and physical characterisation work is recommended as the project moves from its current stage of development into subsequent stages (i.e. following receipt of the necessary environmental approvals).

To address any data gaps related to the geochemical and physical characterisation of the material that will be mined and backfilled the program of work outlined below is recommended by RGS. This will be amended as required by the detailed gap analysis once the initial GBM is developed using existing information, to better target follow up works.

The source of the samples for this program would come from deep trenches to sample the soil and regolith and diamond core drill holes to sample overburden and interburden.

RGS recommends the following sampling program to supplement existing data.

- Developing 18 deep trenches to 6 m bgl (6 trenches in each of the three major soil units)
- Drilling six PQ diameter diamond core holes (three in each pit).

The total number of samples would be in the order of 120 samples from the trenches and 120 samples from the diamond core drilling program.

Each sample would be in the order of 50 kg which is sufficient to undertake a broad range of soil fertility, geochemical and physical analyses.

One of the data gaps related to chemical stability are the processes related to the changes that will occur to groundwater from the backfilling process.

Kinetic leach testing is recommended to quantify how the porewater within the backfilled spoil may evolve over time as it transitions from oxic to anoxic and reducing conditions.

The broad suite of analyses that would be undertaken are included in **Table 6-1.**

Table 6-1: Nominal soil fertility, geochemical and physical analytical program

Soil fertility analyses	**ALS Code**
Exchangeable Cations (Ca, Mg, Na, K) plus ECEC & ESP with pre-treatment on Soils (pH <7.3 and EC >300µm) NOTE: If pH < 6.0 ECEC includes ED005 - Exchange Acidity (includes Exchangeable	ED008
AG-3 - AG2 + Chloride (1:5), pH ($CaCl_2$) Colwell P and K, DTPA extractable Fe, Cu, Zn and Mn, Organic Matter and Organic Carbon by Walkley Black	AG1 (EK055, EK057G, EK058G, EK059G, EK061G)
Static geochemical analyses	**ALS Code**
pH plus EC (1:5)	EA02 and EA010
NAPP (includes ANC, Total S)	ASS1
Chromium Reducible Sulfur (22B)	EA026
Major, minor and trace elemental analysis (Total) (48 elements)	ME-MS41
Shale Flask Extraction 1:3 and 16 hr leach for water soluble elements	**ALS Code**
Leach method	EN35
pH plus EC (1:5)	EA02 and EA010
Alkalinity: including Bicarbonate, Carbonate, Hydroxide & Total as CaCO3	ED037
Acidity as CaCO3	ED038
Cations - Dissolved: Calcium, Magnesium, Sodium, Potassium + Anions: Major (Cl, SO_4, Alkalinity), Fluoride	NT-1 & NT-2
Trace metals by ICP/MS (including digestion)	EG020F (ME-02)
Reactive Phosphorus as P by discrete analyser	EK071G
Mercury	EG035F
Kinetic Leach Cell Testing	

Free draining leach cells	RGS Method to quantify free draining and saturated materials
Physical Parameter (Trilab Brisbane)	
Sample Preparation	AS 1289.1.2.1-1998
Grading - Coarse (75mm to 0.075mm)	AS 1141.11 - 1996
Grading with Hydrometer (includes Particle Density)	AS 1289.3.6.3, 3.5.1, 5.2.1 – 2003
Atterberg Limits - Standard Oven Preparation	ASTM D4318
Maximum Dry Density - A Mould Standard - 1 litre	AS 1289.5.4.2 - 2007
Permeability (constant or falling head)	AS 1289.6.7.3 - 2016
Soil Water Characteristic Curve (10 Point)	Chin et al. (2010)
Emerson Class No.	AS 1289 3.8.1 - 2006
Point Load - Either axial, diametral or irregular lump	AS 4133.4.1 - 2007
Los Angeles Abrasion (LAA) value (Strength and durability of rock)	ASTM C131
Aggregate soundness (sodium sulfate)	AS 1141.24 - 2018
California Bearing Ratio	AS 3706.4 - 2012

6.3 Geo-environmental block model

CQC has a coal resource model and a detailed groundwater geological model has been developed. These models can be supplemented with the soil observation / test pit excavations and geotechnical drilling across the site to quantify the recoverable soil depth (i.e. for rehabilitation).

CQC does not currently have a geology model for the overburden (that includes regolith comprising soil and subsoil units and fresh rock) and interburden that is mostly associated with fresh rock. CQC have the necessary information in their geological database to produce a robust geological model of these strata.

The purpose of developing a geo-environmental stratigraphic block model (GBM) is to (primarily) identify beneficial mine waste units so they can be mined, hauled, and placed into the most appropriate place to achieve maximum beneficial outcomes for progressive rehabilitation. The GBM includes chemical and physical attributes.

Key chemical attributes to quantify and include in the GBM are the determination of high sodic material, and to mitigate this, identify mine materials with high calcium/magnesium content.

Key physical attributes in the model are related to rock strength, and more importantly in sedimentary unit rock durability to determine if the rock has the potential for long term structural stability. Having the ability to identify, classify and then model where each of the major units will be taken from them placed into a waste rock stockpile will enable parameters such as the particle size distribution to be determined i.e. will the end-tipped face of a landform by comprised of fines or coarse stable rock and will this improve design outcomes?

After the overburden model is constructed it used by the short, medium, and long term mine planners to optimise the mining, haulage, and placement of the materials into ex-pit and in-pit waste dumps.

The general process is to

- Identify the major strata in the deposit to include:
  - soil inclusive of topsoil and subsoil horizons within the three soil types in the project area
  - regolith units that include extremely weathered regolith and alluvium
  - transition units including claystone, siltstone, and sandstone and
  - fresh rock units including claystone, siltstone, and sandstone
- Align the detailed geological logs into the simplified major strata (**Figure 6-3**).

- Compile the simplified strata into a geological model. Cross sections of an overburden model are shown in **Figure 6-4** for reference purposes.

The model can then be used to verify where each major unit will be hauled from and then emplaced to. This can be used to determine (for example) if the external face of the temporary landform will be unconsolidated fines with a high potential for erosion, or coarse competent rock that will be non-erosive.

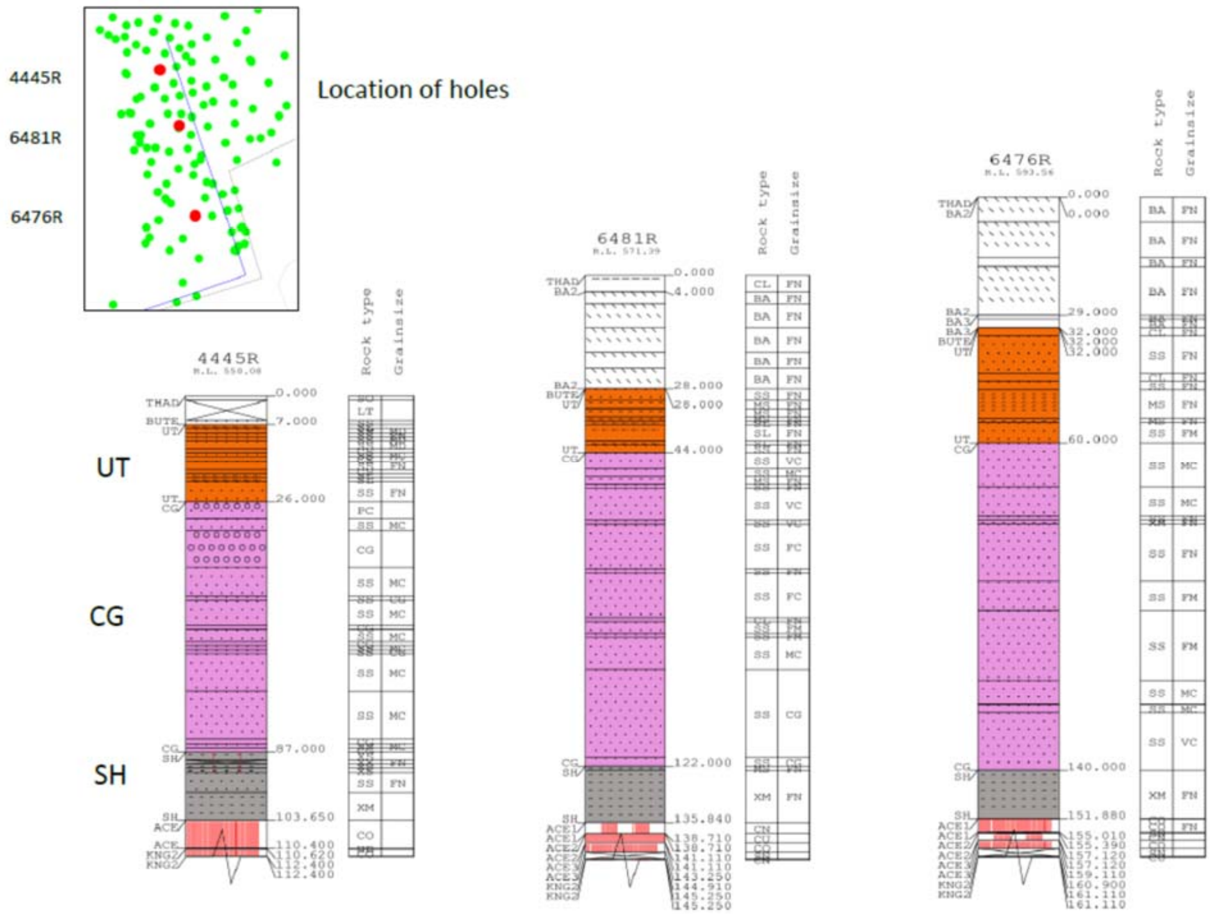
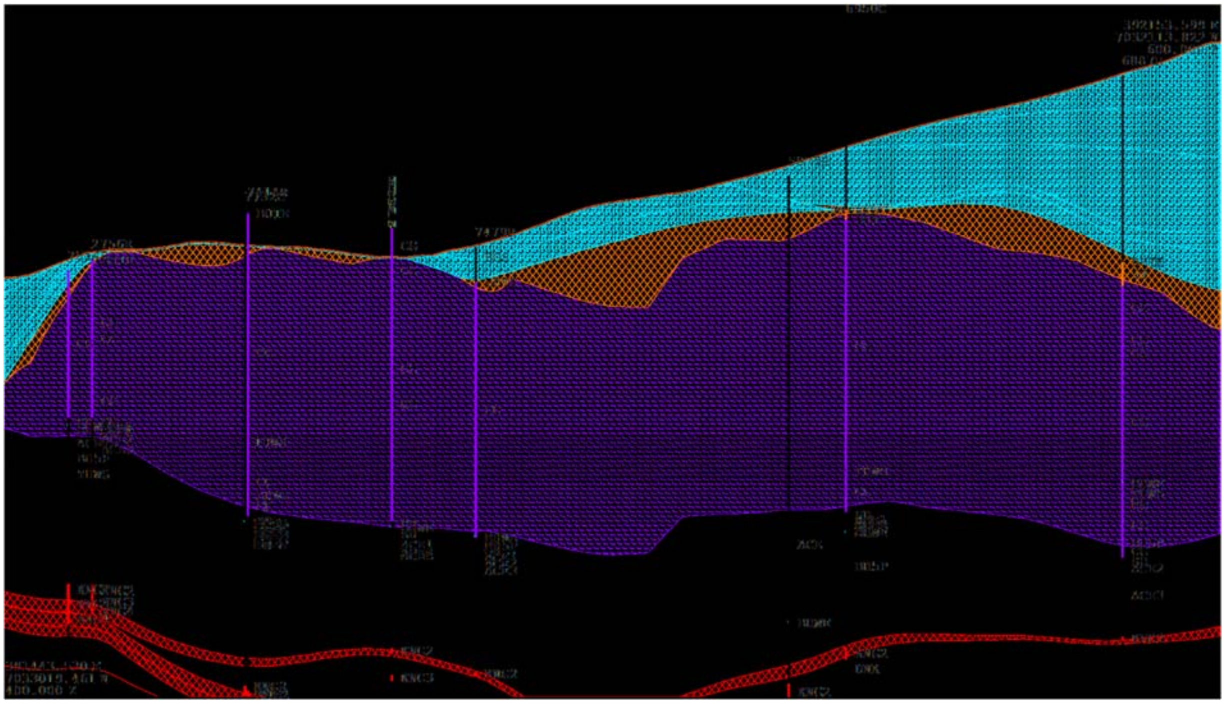


Figure 6-3: Development of simplified major material types from detailed geologicl logs (for reference purposes only)



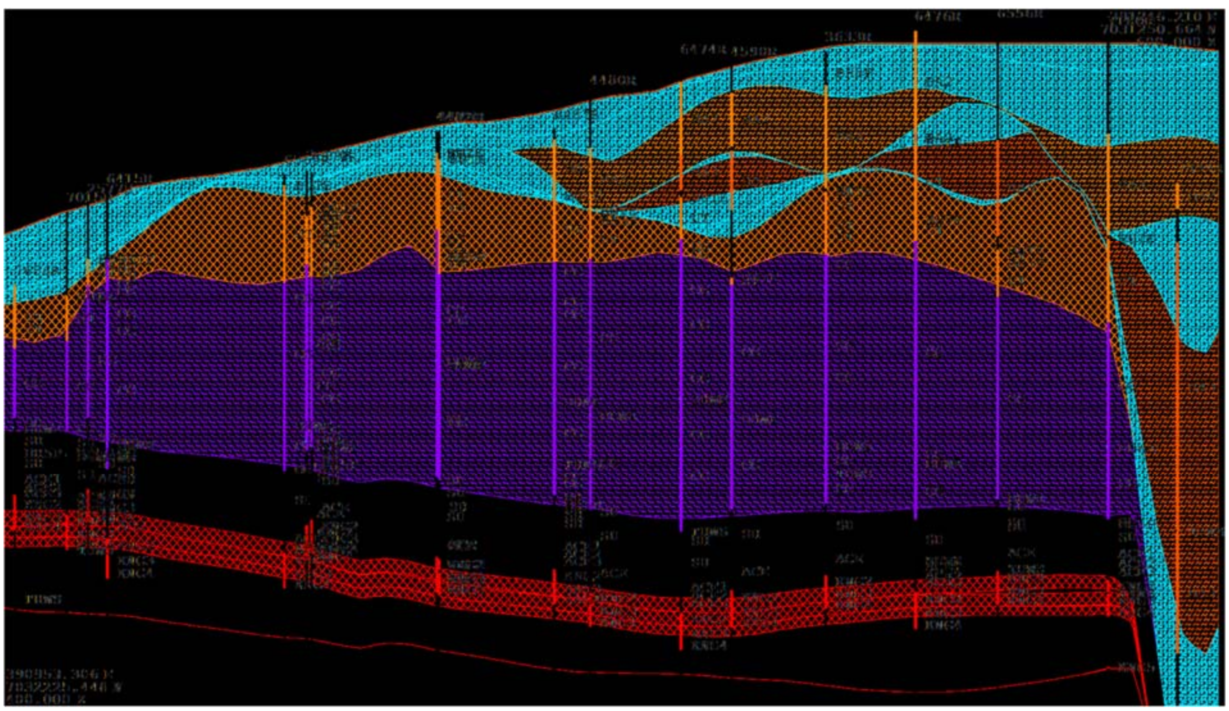


Figure 6-4: Geoenvironmental model showing cross section of major strata from a 3D geological model (for reference purposes only)

7 Recommendations

RGS recommend the following be undertaken for the Project:

- Soil reclamation methods should be evaluated in site specific trials and refined as early as possible to inform large-scale reclamation, the need for application of amendments and their quantities.
- The final landform will have been in place for up to 20 years in some areas, but as little as 1 year in other areas. Settlement and consolidation of the foundation materials in the backfilled pits will therefore be variable. Settlement of the landform may affect surface drainage features and an allowance should be made to reinstate or repair drainage features until surface stability is attained.
- A detailed hydro-geo-chemical conceptual model should be developed for the backfilled pits to depict how the landform design will lead to the aforementioned outcomes.
- Evaluate the proposed final land use methods as early as possible in the mine life to verify that early rehabilitation areas are fit for purpose.
- Reclaim the topsoil and sodic soils as they are stripped and stockpiled over the life of the mine so that when it is replaced over the final waste rock dump landform, they have significantly improved chemical and physical properties (Section 5.4.1).
- Ensure the reinstated soil profile include at least 0.1 m of topsoil, 0.5 m of subsoil and a further 2.4 m of material that is dominated by fine drained (< 2 mm PSD) material where reinstatement of 3m depth or more is required. This additional unit in the reinstated soil profile may be unconsolidated clay, silt and sand from run of mine waste, or stockpiled regolith.
- Understanding of long-term landform evolution should be considered in the design i.e. soil depth may need to be deeper in the middle of the linear slope as this area of the slope will undergo the most erosion over time as the landform moves from a linear to concave slope.

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9 Attachments

9.1 Attachment A: Mining Sequence and Rehabilitation Schedule

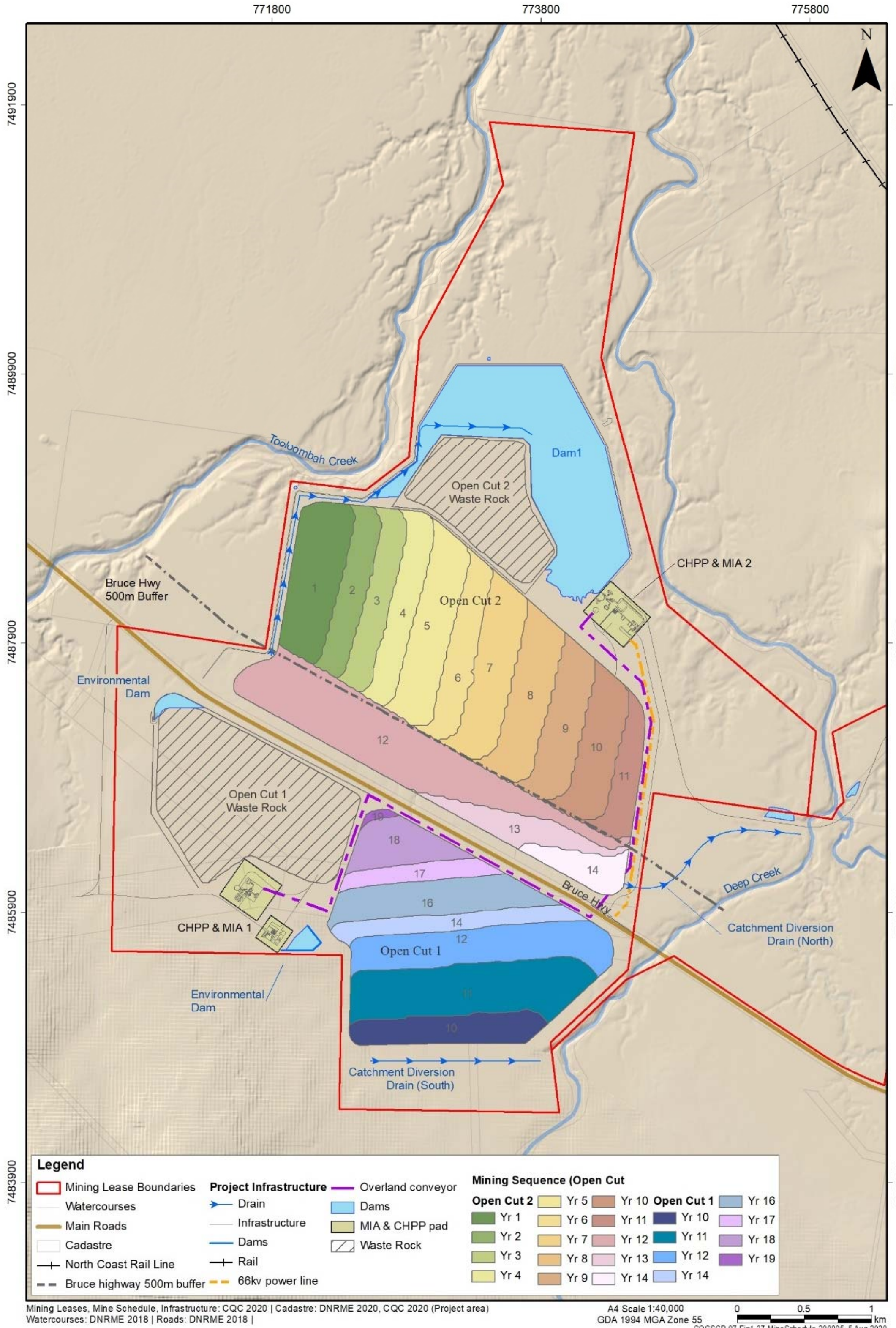

Figure 9.1.1 General Mining Sequence

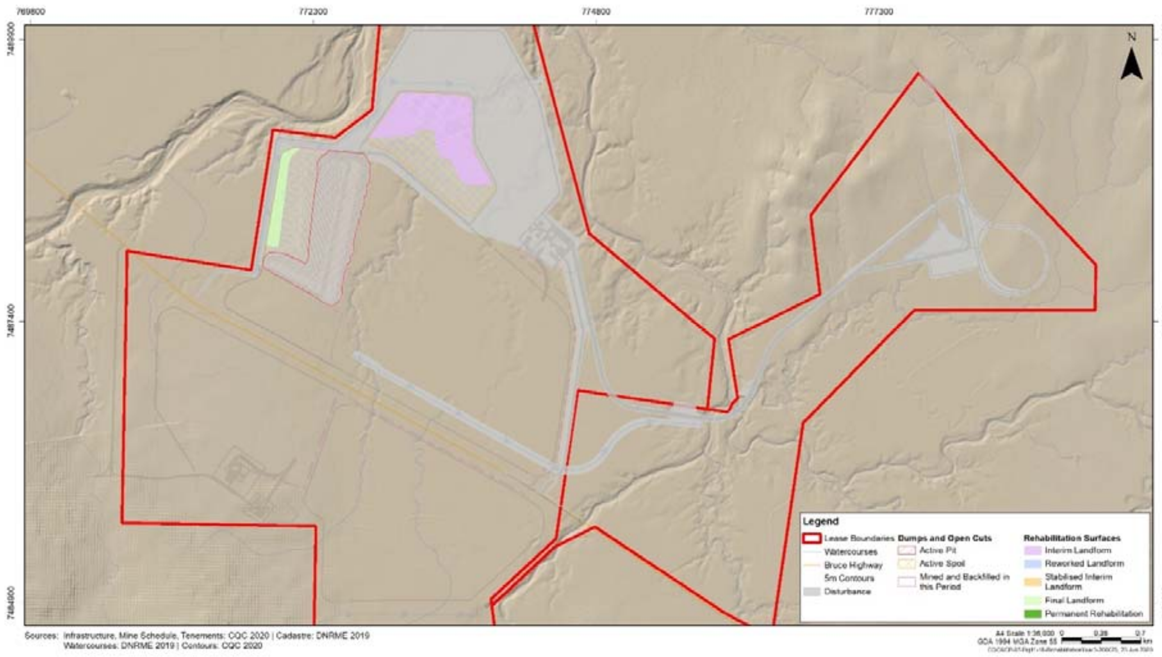

Figure 9.1.2 Mine / Rehabilitation Schedule – Year 3

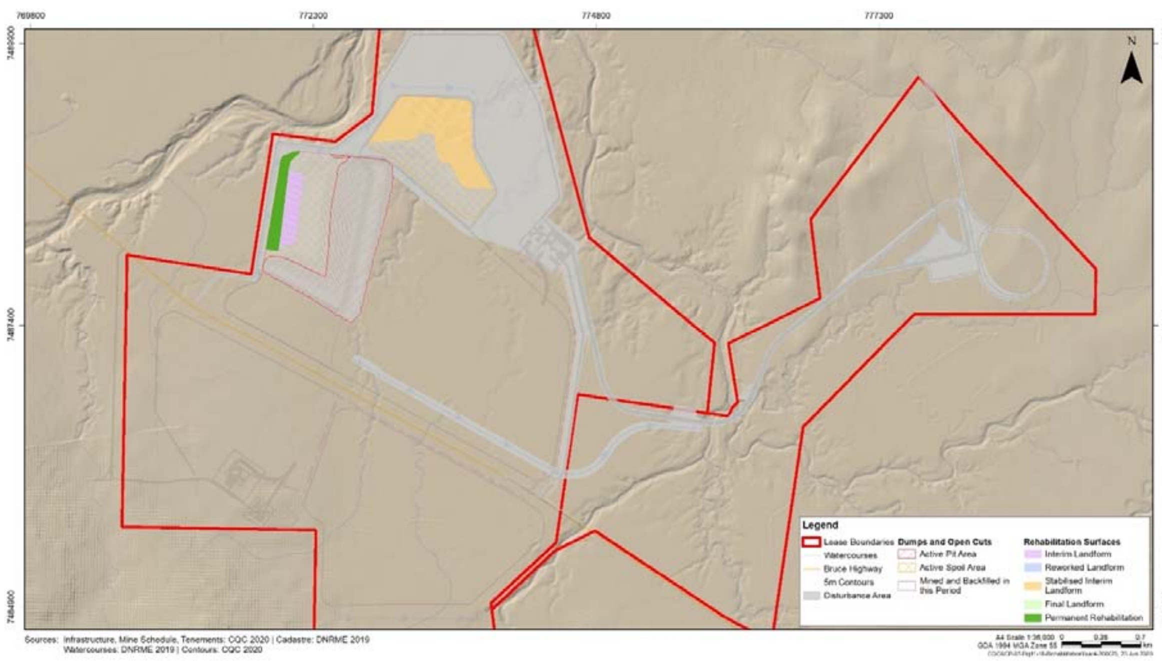

Figure 9.1.3 Mine / Rehabilitation Schedule – Year 4

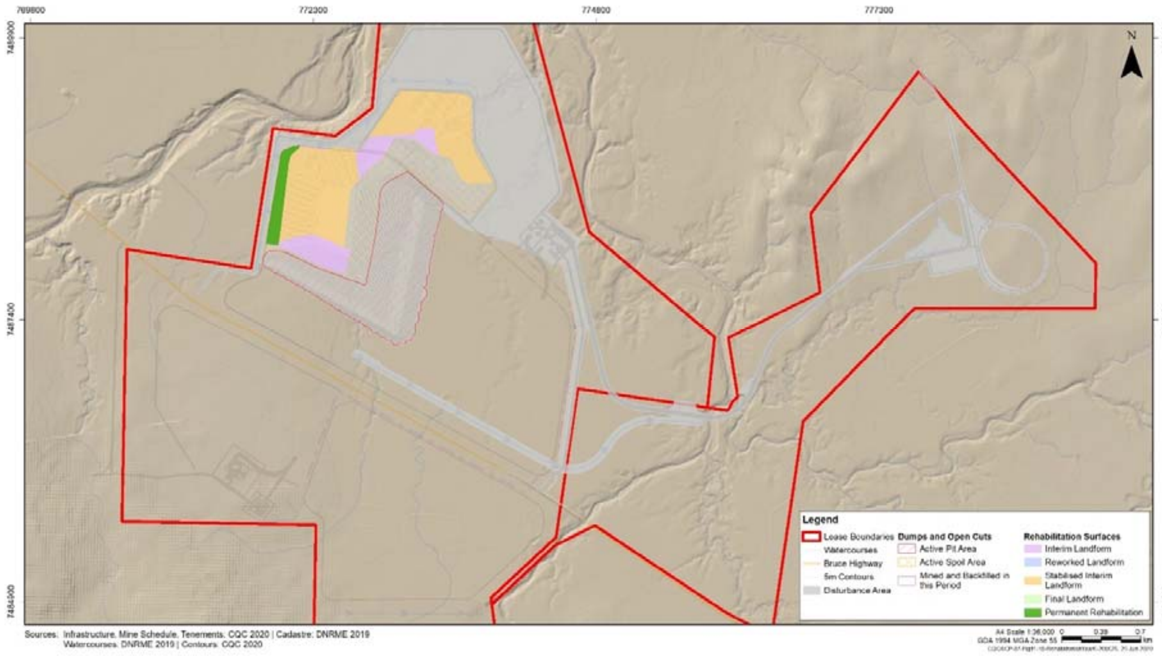

Figure 9.1.4 Mine / Rehabilitation Schedule – Year 6

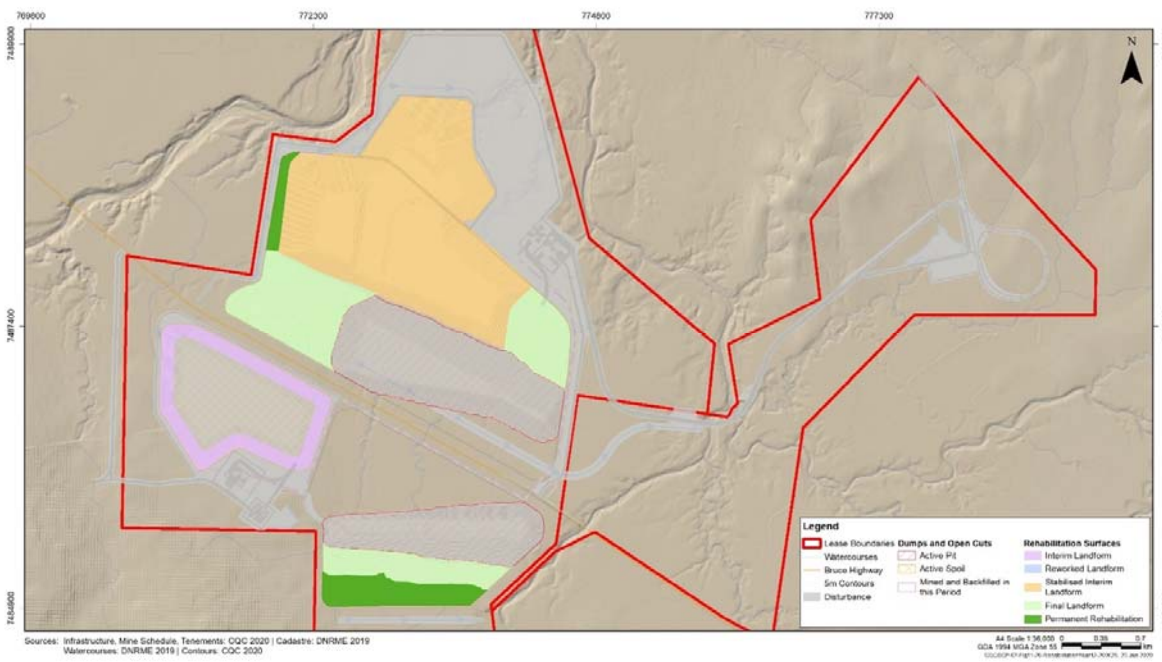

Figure 9.1.5 Mine / Rehabilitation Schedule – Year 12

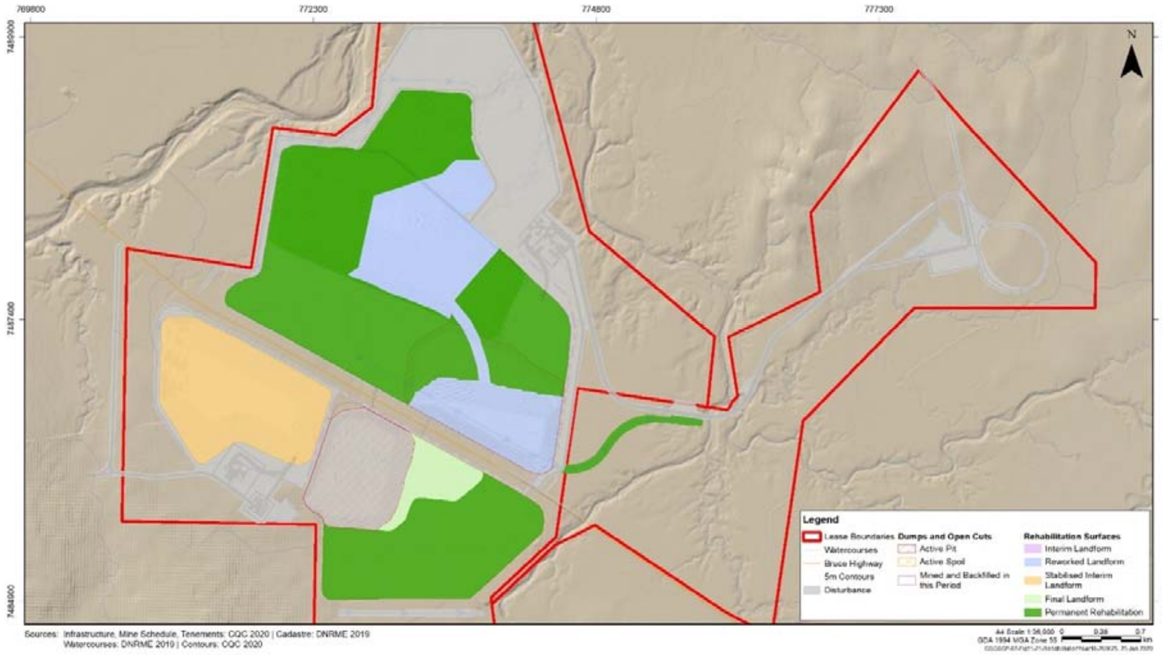

Figure 9.1.6 Mine / Rehabilitation Schedule – Year 18

Figure 9.1.7 Mine / Rehabilitation Schedule – Final Rehabilitation

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