Appendix S

Conceptual Integrated Landform Design for Rehabilitation and Closure

MWH

BUILDING A BETTER WORLD

REPORT

Central Eyre Iron Project

Conceptual Integrated Waste Landform Design for Rehabilitation and Closure

Iron Road Limited

October 2015

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EXECUTIVE SUMMARY

MWH Australia Pty Ltd (MWH) was commissioned by Iron Road Limited (Iron Road), to undertake a preliminary assessment of landform design and closure concepts for the integrated waste landform (IWL) at the proposed Central Eyre Iron Project (CEIP). This report presents the process and outcomes of the first stage of concept development behind the landform design, rehabilitation and closure strategy for the CEIP IWL, while giving some consideration to alternative and conceptual land uses, depending on research and trial work post project commencement. A preferred IWL design and closure concept is presented based on the findings of the investigations undertaken.

Mining of the deposit will be via drill and blast, to in-pit crushing of mine waste rock and conveying (IPCC), selected in preference to a conventional truck, shovel, load and haul mining method. Ore processing to extract magnetite is planned to be via conventional crushing, milling and magnetic/gravity separation, with a production rate of 20 million tonnes of concentrate per annum (Iron Road Limited 2014a). This method includes co-located waste rock and tailings disposal via filtered tailings stacking into the integrated waste landform. An estimated 300 tonnes per annum of co-mingled crushed waste rock and tailings, at approximately 7 to 10% moisture content with an estimated mix ratio of 2:1, will be conveyed and stacked into the IWL.

Of the proposed mining lease area of approximately 85 km^2, approximately 12.4% is mapped as native vegetation. The remaining 87.6% is predominantly cleared agricultural land. The soil types of the project area are typically characterised by undulating sand plains comprising of older consolidated carbonate sands underlying younger quartz sands. These soils comprise the surface dune/swale systems, consisting of quartz-rich aeolian sand, siliceous sand and calcareous soil and subsoil. Considerable volumes of topsoil and subsoil are considered available for rehabilitation for the final landform, which will be evaluated in detail as a component of forward work plans.

The open cut pit will mine through a mix of deeply weathered and oxidized upper surface waste materials, including sands, calcrete, and clay/saprolite approximately 40 to 70 m deep, where the highly competent unweathered gneiss ore zone commences. The Mine Waste Geochemistry Review (MWH 2015a), which included a testwork program on the upper zone oxide mine waste, indicated the presence of sulphur, along with carbonate rich waste materials. Based on the exploration drillhole database and the preliminary geochemical analysis, a conservative estimate is that approximately 80% of the overburden (oxide zone) mine waste will be non-acid generating (inert), up to 10% of the overburden mine waste may have the potential to generate acid, and at least 10% of the overburden mine waste may have acid neutralising potential.

Acid forming and sodic/unstable mine waste materials within this upper oxide zone are adjacent to considerable zones of acid consuming material in the pit profile. This circumstance lends itself to the selective handling, crushing and co-mingling prior to stacked/placement within a controlled environment

in the IWL, as described in the Acid Mine Drainage (AMD) Management Plan (MWH 2015b), providing a successful mine waste management and landform design solution that can be demonstrated with a combination of encapsulation and co-disposal. In addition, confirmatory work was conducted on the tailings produced during metallurgical testing, from which the sandy silty tailings were found to be relatively free draining, saline and non-acid forming, with low concentrations of total metals present.

The preferred conceptual landform design and the rehabilitation and closure strategy presented in this report provides the basis for development of specific landform design parameters and rehabilitation prescriptions for ongoing closure planning. Landform management, rehabilitation and closure planning will be refined as current knowledge is enhanced by a forward work plan to define specific material characteristics, volumes to be managed and placement recommendations for the rehabilitation resources available.

Current specifications for the preferred IWL design include;

- Use of a circular stacker with three separate stacking machines operating from a central pivot point to develop the construction lifts;
  - the three conveyors each place a 30 m front stack, and a 15 m back stack of approximately six lifts in 15 and 30 m high benches prior to final landform shaping;
  - construction of a final landform approximately 7 x 3.5 km in size and an estimated IWL footprint of 1990 ha;
- stacker capability to stack layers of mixed ratios of rock, subsoil and topsoil for different constructed environments producing outer surface layers of specific dimensions;
- capability to create surface features for a variety of purposes, such as dust suppressing rock mulches, a capillary break layer, crest bunds, linear features such as wind breaks, and selected combinations of materials for different rehabilitation prescriptions and the final land use;
- capability to mine, co-mingle and convey identified potentially acid forming waste material with acid consuming waste for storage and neutralisation in a defined environment within the IWL;
- current volume capacity of the preferred IWL design is 1816 million m^3, based on design dimensions of an average total landform height between approximately 135 to 160 m above the natural surface, with variability due to underlying natural topography;
- a preferred conceptual slope configuration that accounts for surface water management and long-term slope stability;
  - a slope design concave in nature for the 30 m high bench, producing longer slopes with a configuration of 18 degrees to 11.3 degrees, and a linear slope of 18 degrees for the 15 m high benches with shorter slopes;
  - a final slope design for closure, to be achieved by small amounts of reshaping during progressive rehabilitation;
  - slope lengths from 50 m to 250 m with a series of backsloping berms and batters, and a crest bund around the upper flat surface;

- the back-sloped berms ensure adequate capacity to restrain large rainfall events to ensure runoff water is not held against the outer edge of the landform. In addition, crest bunds approximately 1.5 m high will be placed on the upper four lifts;
- a store release evapotranspiration cover to minimise loss of water to the deeper profile and retain water in the upper cover zones for vegetation development and sustainability. The current cover design includes a conceptual soil profile consisting of;
  - a layer of 0.15 m of topsoil, over 3 m of subsoil / waste rock mix for the largely flat upper surface and berms;
  - a layer of 0.15 m of topsoil, over a 2 m of subsoil / waste rock mix for the batter slopes at an average angle of approximately 12 to 18 degrees;
- dimensions and components of the reconstructed soil cover profiles are to be tested, trialled, and further refined to support growth of native vegetation of varied types and resilience, prior to final treatment application; and
- revegetation strategies will be designed for specific landform areas as this is the most likely way to maintain functional and sustainable revegetation outcomes through time.

The conveyor stacking construction method involves in-pit crushing, conveying, and depositing co-mingled crushed waste rock and filter press tailings into the IWL. The conveyor stacking system provides an unprecedented level of control in materials delivery, enabling targeted composition of both the waste materials stream (crushed rock and filtered tailings) and the surface cover materials stream (subsoil and potentially topsoil) in the construction of the landform.

Conveyor stacking provides the ability to strategically design the mix of surface materials for different areas, such as flat upper surfaces or slopes. The most appropriate reconstructed soil profile (depth and composition) of subsoil/waste rock or topsoil/waste rock, to support growth of native vegetation or alternative land uses, are made possible through the conveyor stacking system.

The method presents many advantages over conventional truck dumping waste landform construction and greater opportunities for integrating earlier and progressive rehabilitation. In terms of a concept for rehabilitation and closure, an integrated waste landform approach using a stacking construction method has a high potential to meet local stakeholder expectations: maximizing storage within the available footprint, and managing dust, hence limiting off-site salt impact.

The preferred landform design modelled for the IWL is based on a conservative, conceptual approach to accommodate design parameters including;

- a suitable slope configuration to ensure adequate surface material stability and surface water management for erosion control;
- appropriate buffers between the Life of Mine (LOM) IWL footprint and proposed mine lease boundaries;
- accounts for variations in the underlying natural topography;
- material volumes, densities and characteristics of the combined tailings / waste rock mix;

- will contain all PAF mined in a manner that alleviates any risk of acid drainage and in combination contains saline material in a manner that prevents distribution of salts beyond the outer upper surfaces of the landform;
- an outer surface soil cover profile for rehabilitation; and
- a capacity to adapt and to retain flexibility if total LOM waste material volumes, waste material characteristics and rehabilitation prescriptions change during the ongoing optimisation process.

The preferred landform design is considered to be a robust and conservative solution with very low erosion rates over the long term. It is anticipated that the preferred landform design will be further developed through the forward work plan and optimised during laboratory and field studies within research centres and at the mine site. A continuing process of testing and refinement, via the forward work plan, will then inform the next stage of closure and rehabilitation design in preparation for commencement of construction, and progressive rehabilitation of the IWL. Results will be incorporated into specific rehabilitation and management strategies, in order to achieve successful rehabilitation and closure. Aspects requiring further investigation include mitigation of wind erosion, vegetation establishment, salt migration, and management of any surface water and groundwater influences.

Further development of the conceptual rehabilitation and closure strategy for the IWL will be conducted within the forward work plan into material characteristics, optimisation and the appropriate use and scheduling of soil resources for areas requiring rehabilitation, and advancements in knowledge via progressive rehabilitation trials. Currently the conceptual rehabilitation and closure strategy developed for the IWL allows for consideration of a range of potential final land use options as part of the forward work plan into rehabilitation and closure. Primary considerations for determining the final and most beneficial land use for the IWL, include consideration of the following;

- visual amenity and minimal impact from dust;
- proximity to the town of Warramboo and the local community;
- reference to the surrounding landscape, ecosystems and topographical features;
- possibilities for multiple or mixed use for added value to the community;
- stakeholder engagement; and
- conservation potential for enhancing local ecosystems.

Alternative final land uses may include agricultural production (cropping and grazing), agroforestry (multiple land use), a native woodland ecosystem for conservation or mixed use vegetation. Consideration of these alternative final land use options will incorporate an understanding of climatic influences and climate change upon long term productivity and sustainability, particularly for options such as cropping or agroforestry. Increasing aridity is predicted in the bulk of southern Australia and factors such as declining rainfall and higher evaporation rates are predicted to gradually change the nature of local land use. The validity of alternative land use options, in terms of achieving stakeholder expectations and the primary objectives of a stable, rehabilitated landform are all to be considered by investigation and research, as part of the forward work plan during the investigation, construction and operational stages of the CEIP.

Iron Road Limited

Conceptual Integrated Waste Landform Design for Rehabilitation and Closure

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ACRONYMS AND ABBREVIATIONS

Acronym or abbreviation	Definition
ANC	Acid Neutralising Capacity
AHD	Australian Height Datum
ASRIS	Australian Soil Resource Information System
BLD	Boo Loo – Dolphin deposit
BOM	Bureau of Meterology
CEIP	Central Eyre Iron Project
DFS	Definitive Feasibility Study
DSD	Department of State Development
EC	Electrical Conductivity
EIL	Ecological Investigation Level
ESP	Exchangeable Sodium Percentage
FC	Field capacity of a soil, referring to water content
GARD	Global Acid Rock Drainage
INAP	The International Network for Acid Prevention
IPCC	In-pit crushing and conveying
Iron Road	Iron Road Limited
IWL	Integrated Waste Landform
LOM	Life of Mine
mbgl	Metres below ground level
ML	Mining Lease
MLP	Mining Lease Proposal
MSRR	Murphy South – Rob Roy deposit
MWH	MWH Australia Pty Ltd
NAG	Net Acid Generation
NAF	Non-Acid Forming
NAPP	Net Acid Production Potential
PAF	Potentially Acid Forming
PSD	Particle Size Distribution
TSF	Tailings Storage Facility
WHC	Water holding capacity
WRD	Waste Rock Dump

1 INTRODUCTION

1.1 Background

MWH Australia Pty Ltd (MWH) was commissioned by Jacobs on behalf of Iron Road Limited (Iron Road), to undertake a preliminary assessment of landform design and closure concepts for the integrated waste landform (IWL) at the Warramboo Project Area (the Project Area) of the proposed Central Eyre Iron Project (CEIP) mine. The IWL is planned to accommodate all processed tailings and mine waste rock materials generated during the mine life of the CEIP. Closure and rehabilitation concepts for the IWL are required to assist with the preparation of closure and rehabilitation planning for approval submissions and subsequent stakeholder communication.

The concept of an IWL was described for the Challenger Mine in South Australia, who adopted the approach of combining waste rock and tailings material within one structure and went on to describe this facility as an 'Integrated Waste Landform' (IWL) (Sperring and Lacy 2001). A more advanced definition, relevant to the CEIP, was defined for the IWL at the Prominent Hill mine site as a landform that 'integrates, in immediate proximity, different waste materials generated by a mining operation within multiple facilities in a single structure' (Landform Solutions 2006, Outback Ecology 2006). An integrated waste landform differs from a traditional approach of separating processed tailings waste into a designated tailings storage facility (TSF) and other mine waste materials into separate waste rock landforms (Lacy and Lane 2007).

The initial aim of the work programme was to provide three to four conceptual closure design options, with each concept meeting the overarching objectives for the CEIP IWL. With input resulting from several meetings between Iron Road, Jacobs, MWH and government representatives from the Department of State Development (DSD), the project evolved to focus on the development of a 'base case' or preferred scenario for the conceptual IWL design for rehabilitation and closure. This report presents the process and outcomes of the concept development for the landform design, rehabilitation and closure strategy for the CEIP IWL. The closure concept has been developed in parallel with the Definitive Feasibility Study (DFS) in support of submission of a Mining Lease Proposal (MLP).

1.2 Project description

The CEIP is a proposed long life magnetite project located at Warramboo in the Eyre Peninsula region of South Australia, approximately 200 kilometres (km) north of Port Lincoln and 240 km southwest of Port Augusta. The CEIP lies 28 km southeast of the regional centre of Wudinna, and includes the Warramboo, Kopi and Hambidge Project Areas (**Figure 1-1**). The project will include large scale, open pit mining with an expected mine life of at least 25 years and ore processing with rail and concentrate export facilities (Iron Road Limited 2014a) (**Figure 1-2**). A utilities corridor containing rail, water and power is proposed between the mine site and the proposed port at Cape Hardy, seven kilometres south of Port Neill. The Warramboo resource has a strike length of over six kilometres, including the Murphy South – Rob Roy (MSRR) and Boo Loo – Dolphin (BLD) deposits.

For the purpose of this report, the 'Study Area' is defined as the proposed mining lease (ML) boundary for the Warramboo Project Area depicted in **Figure 1-2**.

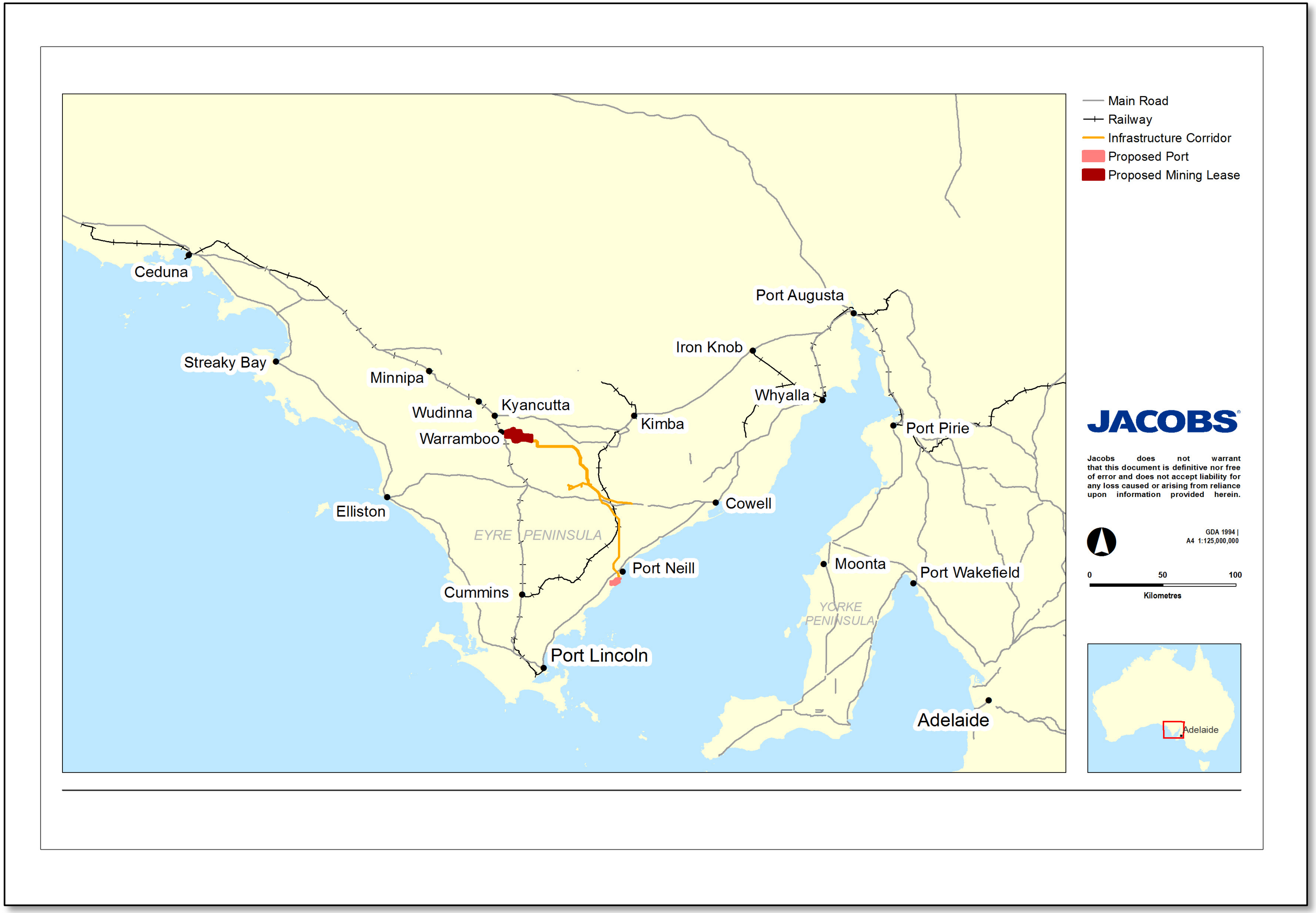


Figure 1-1: Regional location of the Central Eyre Iron Project (sourced from Jacobs)

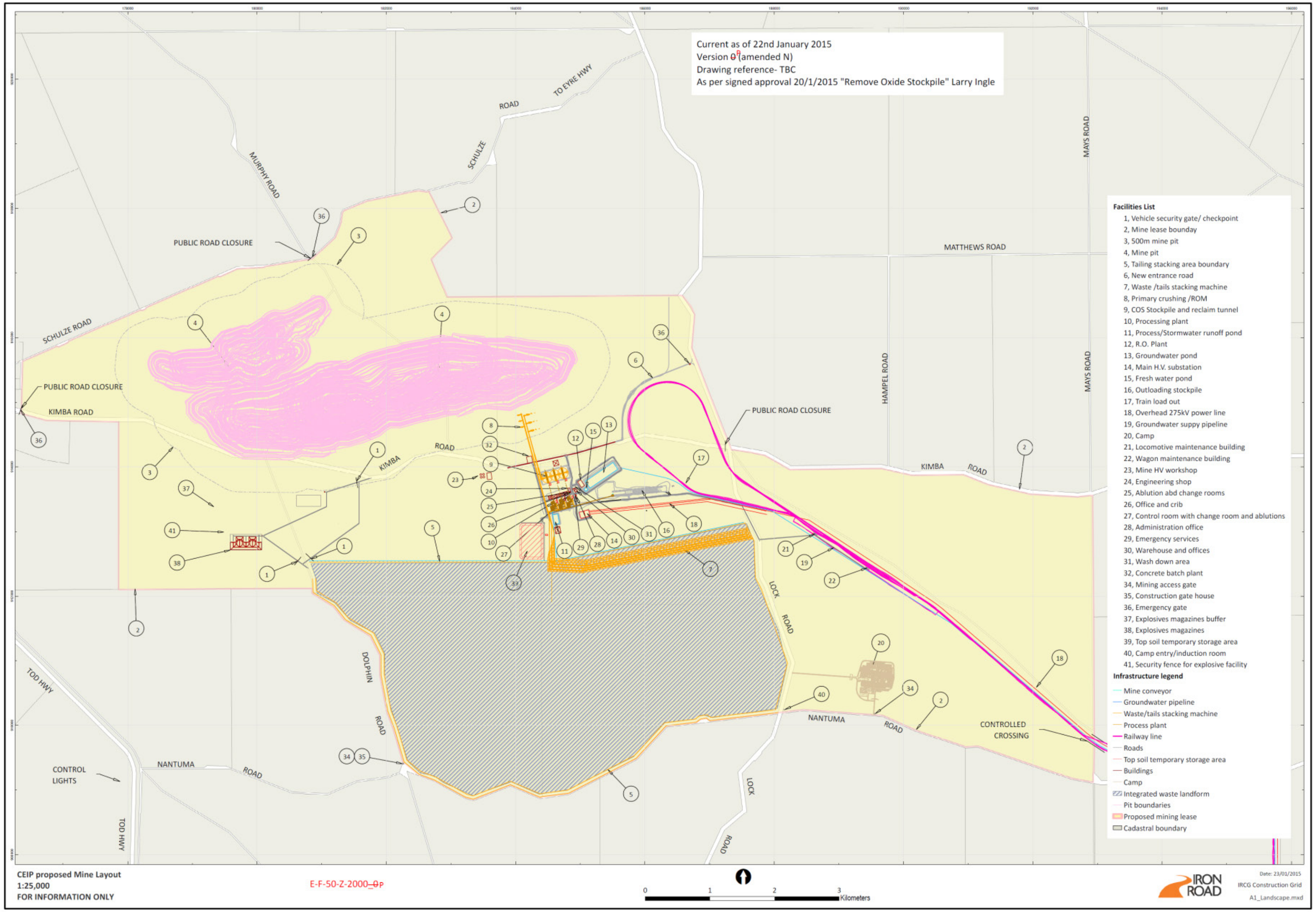


Figure 1-2: Mine layout of the Central Eyre Iron Project (sourced from Iron Road Limited, current January 2015)

Ore processing is planned to be conducted via conventional crushing, milling and magnetic/gravity separation, with a peak production rate of 21.5 million tonnes of concentrate per annum (Iron Road Limited 2014a). In-pit crushing and conveying (IPCC) was selected in preference to a conventional truck, shovel, load and haul mining method, which provides advantages in terms of reducing dust emissions and the logistics of maintaining and operating a large truck fleet. The IPCC method includes co-located waste rock and tailings disposal via filtered tailings stacking into an IWL. The waste material balance for the CEIP is detailed in **Figure 1-3**. Belt filters receive coarse and fine tailings from the process facility, where the filter process reduces the retained moisture content to approximately 10%. The filtered tailings, with the consistency of wet sand, is then delivered, or co-disposed, together with waste rock to the IWL by conveyor and dispersed using mobile stackers.

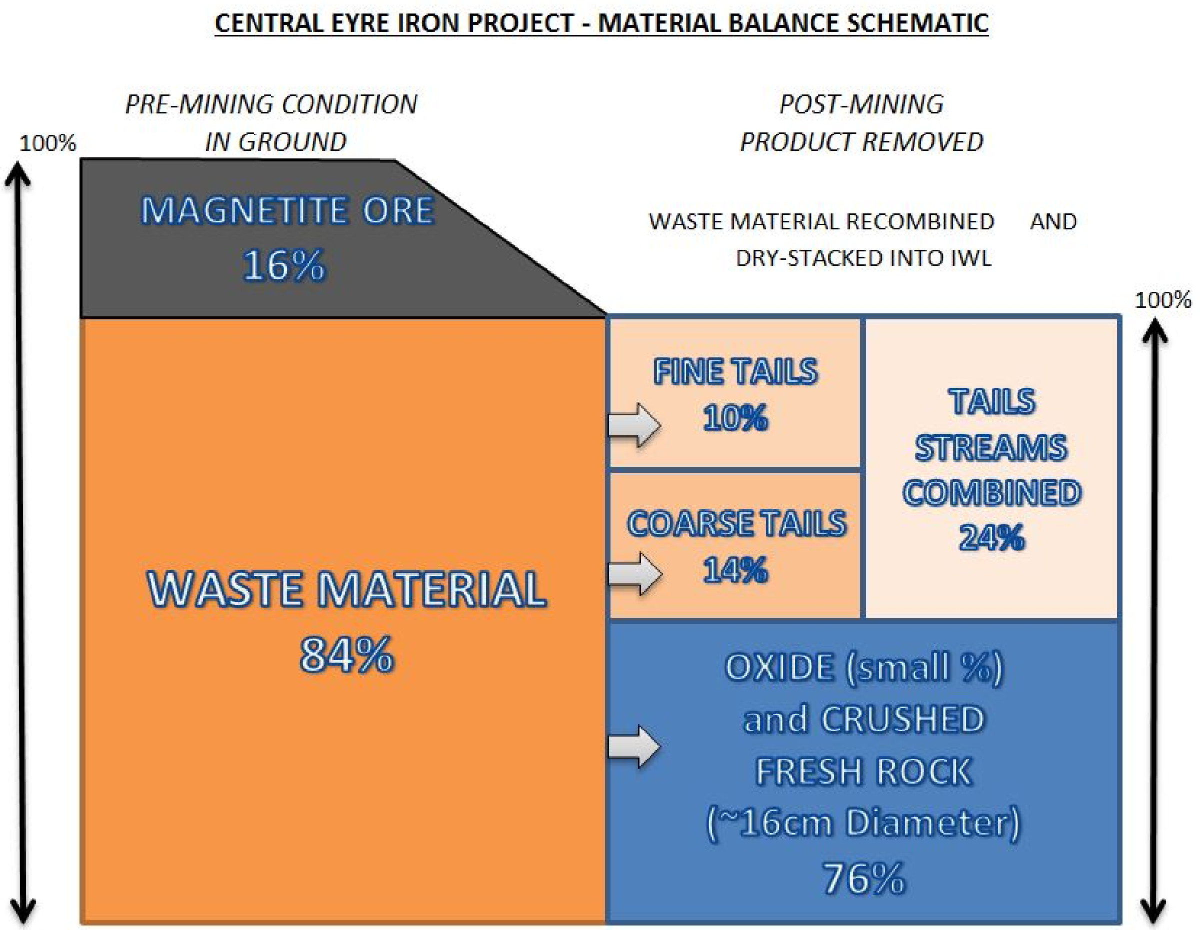


Figure 1-3: Materials balance schematic for the CEIP

The advantages of this method include a smaller waste landform footprint, recycling entrained process water, reduction of seepage, reduced dust emissions and allowing for the progressive rehabilitation of completed sections of the IWL (Iron Road Limited 2014a). The advantages of the IWL concept and the stacking construction method for rehabilitation and closure are discussed further in **Section 3.1**.

Current specifications for using the mobile stacker to construct the planned IWL include;

- use of a circular stacker with three separate stacking machines operating from a central pivot point, developing the construction lifts, with the three conveyors each placing a 30 m front stack, and a 15 m back stack, of approximately six lifts in 15 m and 30 m high benches prior to final landform shaping, with a final landform approximately 7 x 3.5 km in size and an estimated IWL footprint of 1990 ha (**Figure 1-4**);
- capability to stack layers of mixed ratios of rock, subsoil and topsoil for different constructed environments producing outer surface layers of specific dimensions; and
- capability to create surface features for a variety of purposes, such as dust suppressing rock mulches, capillary break layers, crest bunds, linear features as wind breaks and selected combinations of materials for different rehabilitation prescriptions and the final land use.

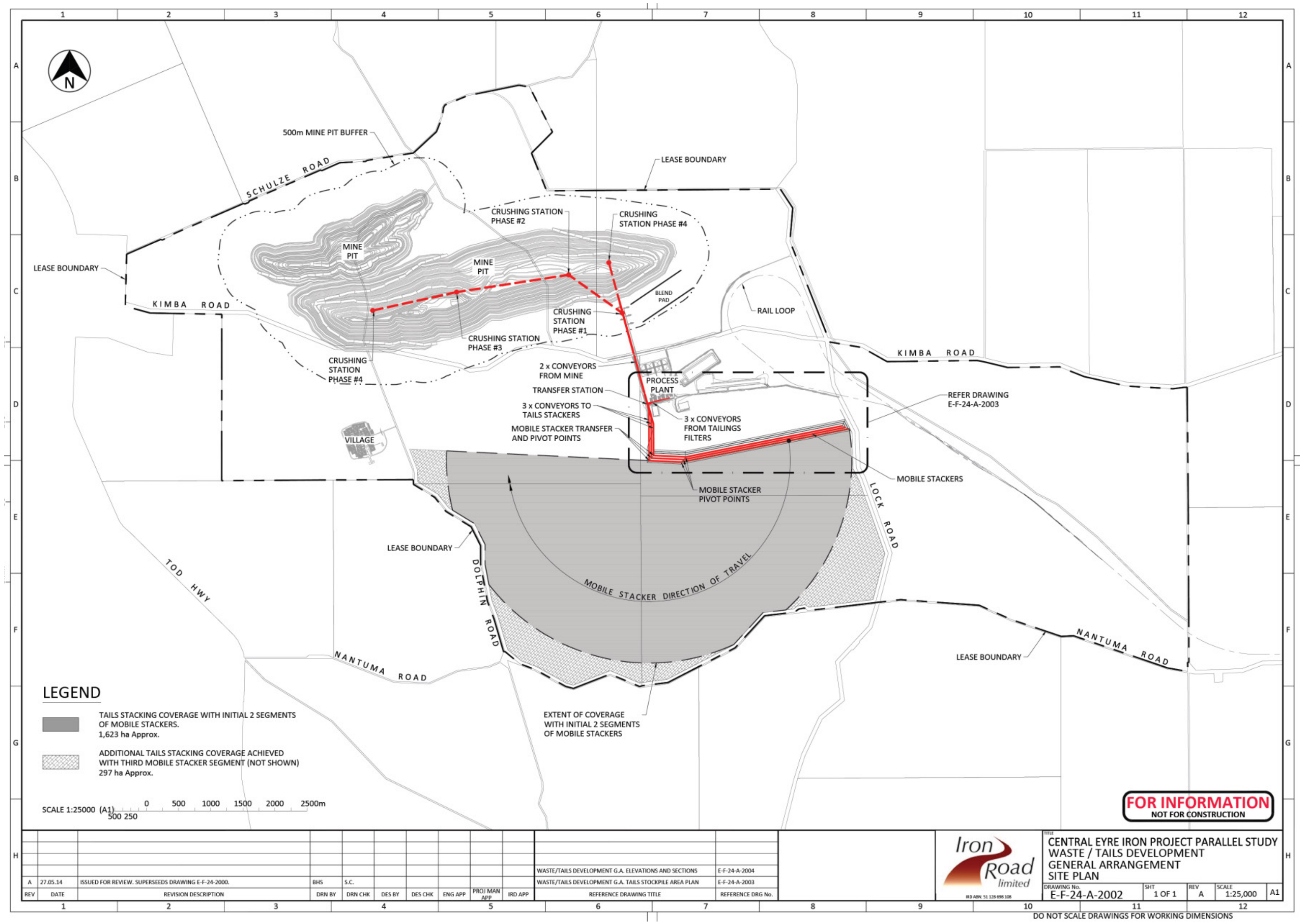


Figure 1-4: Waste rock and tailings development general arrangement (sourced from Iron Road Limited)

1.3 Objectives

Development of rehabilitation and closure concepts for the IWL necessitates investigations into the overall landform shape for integration into the landscape, slope design parameters, planning for soil / waste rock and tailings disposal, water balance studies and capability to support potential land uses. The broad objectives of the investigations performed included identification of the following:

- storage capacity requirements for combined Life Of Mine (LOM) tailings and mine waste volumes;
- a recommended overarching strategy for the landform's preferred design and visual appearance;
- overarching geotechnical landform stability and inherent surface stability to achieve a stable landform with minimal erosion potential;
- current and proposed landform footprint details;
- identification (based on the current knowledge base), placement and suitable management of any potentially problematic waste materials;
- broad recommendations for the selection and placement of 'near-surface' and surface rehabilitation / growth medium materials suitable for the conceptual end land uses and landform outcome;
- a review and inventory of soil and waste materials and characteristics;
- recommendations for the handling and placement of suitable soil and waste materials as a surface cover;
- selection of suitable strategies for water management in alignment with materials and local climatic factors, and subsequent recommendations for surface and internal drainage designs;
- suitable slope design parameters for the soil and waste materials present;
- review of the rehabilitation and closure concept in line with the International Network for Acid Prevention (INAP) Global Acid Rock Drainage (GARD) guidelines for Potentially Acid Forming wastes;
- identification of areas of risk and where current information is inadequate for accurate prediction and / or assessment of risk;
- identification of knowledge gaps that require further work post the lodgement of the approvals documents, to inform a forward work programme;
- beneficial uses of the landform designed with consideration of;
  - minimal offsite impact (e.g. dust generation from wind);
  - visual amenity (e.g. town of Warramboo, local community);
  - stakeholder engagement;
  - conservation potential; and
  - potential for 'added value' through multiple or mixed use.

As part of the process of this investigation, MWH participated in a risk-based workshop with key stakeholders (Iron Road and the Department of State Development (DSD)) to identify and assess the most relevant areas of uncertainty, impact and risk associated with the 'base case' IWL design and closure scenario. This report presents the preferred closure and rehabilitation concept developed through this risk-based process, details the process undertaken to develop the design and closure concept, and includes a summary of the supporting information. Outcomes of the high level risk review have been considered by the relevant technical aspects and are discussed in corresponding technical chapters of the MLP. All impacts and risks associated with the IWL and mine closure are summarised in the Impact and Risk register which is an appendix to the MLP.

2 INFORMATION REVIEW

2.1 Local and regional environment

2.1.1 Climate

The arid climate of the Project Area typically experiences winter dominant rainfall and relatively dry summer months characterised by warm to hot temperatures (Jacobs 2014). The Project Area receives seasonally distributed rainfall with an annual average of 314.1 mm, the majority of which falls between May to September (**Figure 2-1**). Mean annual evaporation for the Project Area is 1407 mm (Kyancutta 18044 SILO Station Pan Evaporation, in RPS 2013), far exceeding annual rainfall, and is highest during the summer period (BOM 2014). Hot summers and mild winters are typically experienced with average maximum daily temperatures ranging from 17ºC in July to 33ºC in January (BOM 2014).

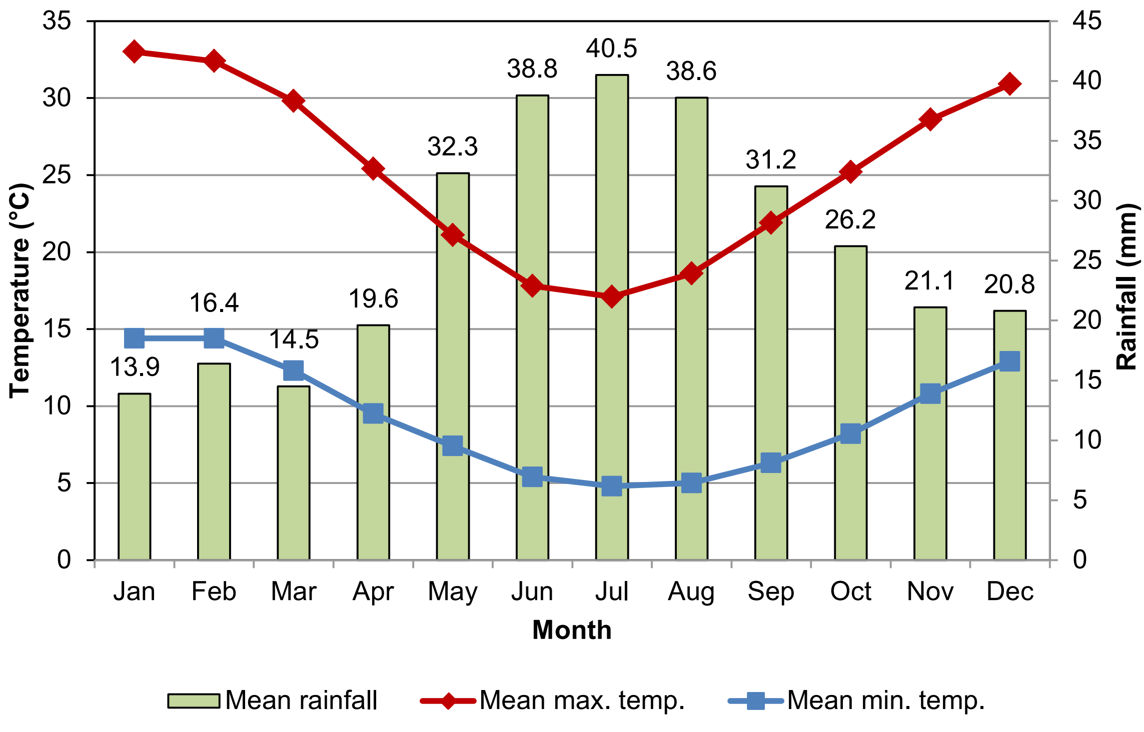


Figure 2-1: Temperature and rainfall data for Kyancutta (BOM station number 018044, approximately 12.5 km from Warramboo) for the period 1930 to 2014 (BOM data accessed 29/10/2014)

2.1.2 Geology

2.1.2.1 Regional geology

The oldest rocks of the Eyre Peninsula are the Achaean Sleaford Complex, comprising ortho and para-gneisses, granite, granodiorite, felsic volcanics, phyllite and marble (Iron Road Limited 2014b). Regionally these form the basement of the Gawler Craton. The sequence was metamorphosed to upper amphibolite/granulite facies during the Sleafordian Orogeny. This metamorphism had the effect of coarsening the mineral grain size within the gneissic textures of the local rock assemblages. The para-gneisses are a quartz, biotite feldspar, garnet gneiss with accessory sillimanite, zircon and spinel. Isolated pods of biotite-garnet and cordiorite-sillimanite quartz-feldspar gneisses also occur. The area was again subject to metamorphism during the Kimban Orogeny. The effect of the Kimban event in the Central Eyre area was slight retrograde metamorphism evidenced by mineral assemblages that include chlorite and sericite. The Sleaford Complex has very limited exposure and is almost entirely covered by younger Pleistocene-Holocene sediments (**Figure 2-2**).

The major crustal structures which separate east and west Eyre Peninsula have been recognised in regional geophysical investigations (Popkov 2000 *in* Iron Road Limited 2014b). The transition from Achaean rocks in the west of the peninsula to Proterozoic rocks in the east includes the north-south trending Kalinjala shear zone (Howard *et al*. 2006 *in* Iron Road Limited 2014b). There is evidence that Achaean rocks also form the basement below eastern Eyre Peninsula (Fraser *et al*. 2008 *in* Iron Road Limited 2014b). The Warramboo project area is located within the Sleaford Complex rocks near the eastern edge of their known extent.

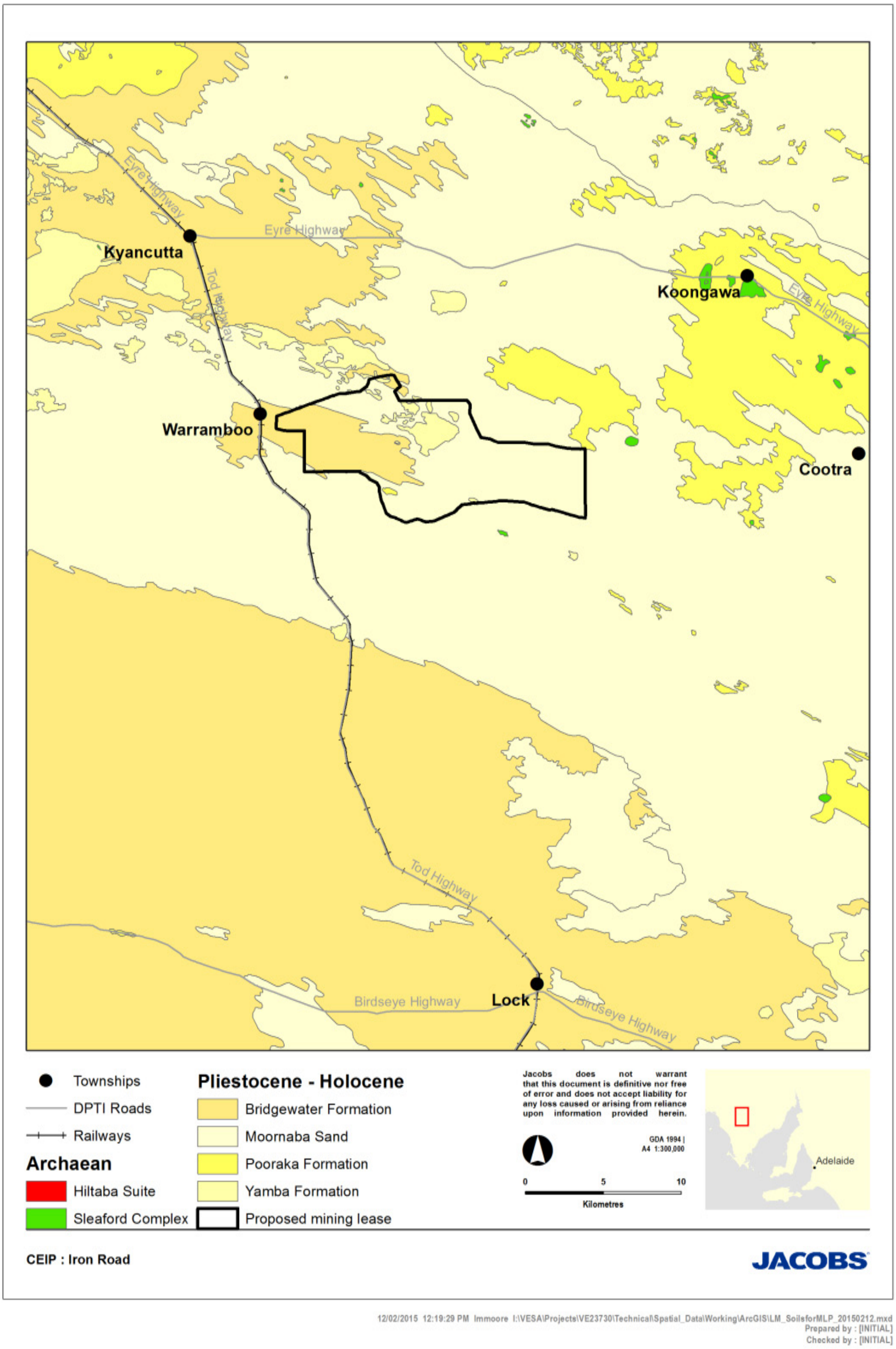


Figure 2-2: Surface geology of the CEIP (sourced from Jacobs)

2.1.2.2 Local geology

The Warramboo mineralisation is considered to be part of the Coulta Subdomain, which is a prominent and complex east-west aeromagnetic anomaly comprising a sequence of intensely folded, high grade metamorphic gneiss rocks (Iron Road Limited 2014b). The mineralisation is evidenced by extensive prominent linear magnetic anomalies with a cumulative strike length in excess of 95 kilometres. Exploration drilling has returned thick intervals >100 m of magnetite mineralisation.

The magnetite mineralisation is characterised by two main rock types, a disseminated magnetite-gneiss and a banded magnetite gneiss comprising layers of both disseminated and coarse-grained magnetite. The mineralisation is in the form of magnetite in the fresh rock. In the oxidation profile, the magnetite has been altered to martite (hematite) maghemite (hematite and magnetite) and goethite. The iron mineralisation is considered to be a remnant iron-rich pelite. Petrological examination of drill chips and core shows the magnetite gneiss to be an irregularly layered, granulose metamorphic rock which may be called a microgneiss with an incipiently hornfelsic texture.

Non-mineralised host gneiss includes quartz-feldspar-biotite and amphibole-feldsparpyroxene lithologies. Minor calcite marble has also been documented. Mineralogically the magnetite gneiss consists predominantly of quartz-feldspar-magnetite with subordinate amounts of hematite, garnet, biotite, sericite, chlorite, cordierite and sillimanite. Small accessory grains of apatite and zircon are widespread. The contained iron oxides form an integral part of the host metamorphic rock. The two main rock types that occur in the MSRR and BLD deposits include;

- a quartz-feldspar-biotite gneiss (“barren gneiss”) that envelops the magnetite bearing gneiss; and
- the magnetite bearing gneiss that consists mainly of quartz-feldspar-magnetite-garnet-biotite (“magnetite gneiss”).

Thin dolerite late stage intrusives are also observed in the drill core at the MSRR deposit. Minor lithologies at BLD include calcite marble and amphibole/bearing gneiss, with relatively rare, thin dolerite dykes traversing the area.

2.1.3 Regolith

The entire prospect area has been subjected to surface oxidation resulting in a weathering profile of saprolite through to fresh rock. A zone of weathered bedrock and thin sedimentary cover are superimposed on the basement gneiss, including unconsolidated Aeolian sands and calcrete (Iron Road Limited 2014b).

Surficial sediments include aeolian sand and thin sheets of unconsolidated silcretised alluvium. A zone of up to two metres of calcrete has developed either at or within one metre of the surface.

The aeolian sand dunes reach a maximum thickness of 10 to 30 metres and occur as linear features trending at 120 degrees.

The weathered bedrock has a typical lateritic profile modified by later arid climate onset. The base of complete oxidation has been recorded at depths up to 70 metres with an average of around 40 metres. Deep in the regolith, magnetite becomes oxidised to form martite and near the surface is hydrated to limonite and goethite.

Stratigraphic units occurring within the weathered regolith profile have been defined as hydrostratigraphic units by SKM (2014a and 2014b) during hydrogeological studies of the Study Area. These units are summarised in **Table 2-1** and **Figure 2-3**, and are described by the following;

- Quaternary sediments;
  - unconsolidated sediments consisting of red to brown silty clays with occasional calcrete and/or ferricrete layers;
- Tertiary sediments;
  - unconsolidated grey to brown silts, sands and clays. A fine to medium grained sand was logged at the base of the unit except where basement highs are present;
- Weathered saprolite/basement (saprock);
  - clays and silty clays generally light grey to grey with high biotite content; and
- Bedrock/basement gneiss;
  - fractured and un-fractured rock consisting of quartz, feldspar and biotite.

Table 2-1: Major hydrostratigraphic units in the Study Area (SKM 2014b)

Age	Name	Approximated Thickness (m)	Description	Hydraulic conductivity (m/d)
Quaternary	Undifferentiated Quaternary	10	Predominantly arenaceous i.e. sands and calcarenite. Holocene to Pleistocene aged	0.02 to 0.004[1]
Tertiary	Upper Neogene (Miocene / Pliocene)	20	Predominantly argillaceous i.e. silts, clays with some sand/gravel	-
	Basal Neogene (Miocene / Pliocene) Tertiary sediment aquifer	10	Coarser fluvial and marine sandy facies	0.5 to 3.0[2]
	Palaeogene (Eocene - Poelpena)	20	Grey to black carbonaceous sand and silt	0.2[1]
Archaean	Upper Saprolite	20	Highly weathered gneiss consisting of grey silty clay	-
	Lower Saprolite	20	High to moderately weathered gneiss consisting of grey silty clay	-
	Saprock	10	Broken metamorphics (gneiss, including magnetite gneiss and schist)	2.25 to 0.25[2] (fractured) 0.025 to 0.001[2] (un-fractured
	Gneiss (Sleaford Complex)	550+	Metamorphics (gneiss, including magnetite gneiss and schist)	

1. [1] Data from Coffey hydrogeological investigations (E-F-16-RPT-0001_0 Groundwater Monitoring Bore Installation and Sampling Program Summary).
2. [2] SKM (2014a)

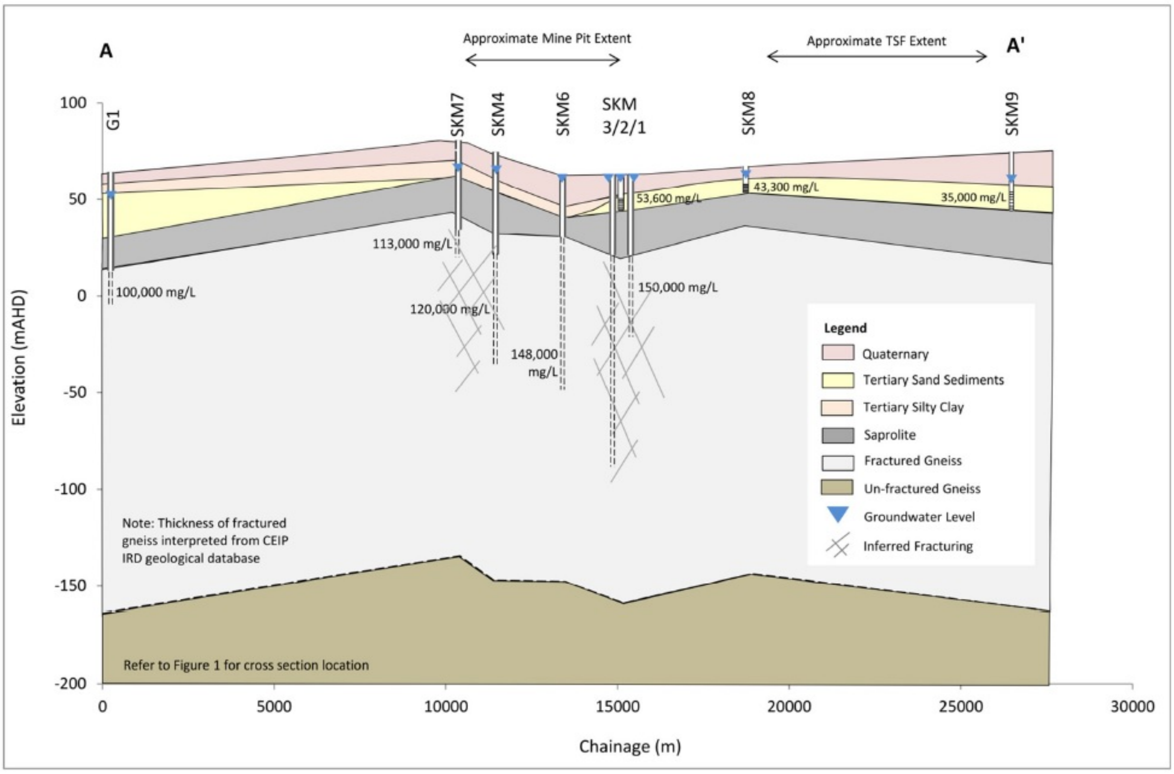


Figure 2-3: Cross section showing hydrostratigraphic units in the CEIP Study Area (SKM 2014b)

2.1.4 Soil

The soils of the Study Area are typically characterised by undulating sand plains comprising of older consolidated carbonate sands underlying younger quartz sands (Iron Road Limited 2013c). The land surface is dominated by dune/swale systems, with dunal sandy materials include quartz-rich aeolian sand, siliceous sand and calcareous soil and subsoil resulting from the Moornaba Sand strata (RPS 2013).

Regional soil and landform attribute mapping information has been compiled for the Eyre Peninsula region for the Australian Soil Resource Information System (ASRIS) by (McKenzie *et al.* 2005). Four known soil profiles are located within or in close proximity to the Study Area, providing examples of *in situ* soil types and characteristics (**Figure 2-4**, **Table 2-2**). Further information on the physical and chemical characteristics of these known soil types are presented in **Section 2.2.1**. Further information for the oxide and fresh rock mine waste materials are included in **Section 2.1.9** and **Section 2.2.2**.

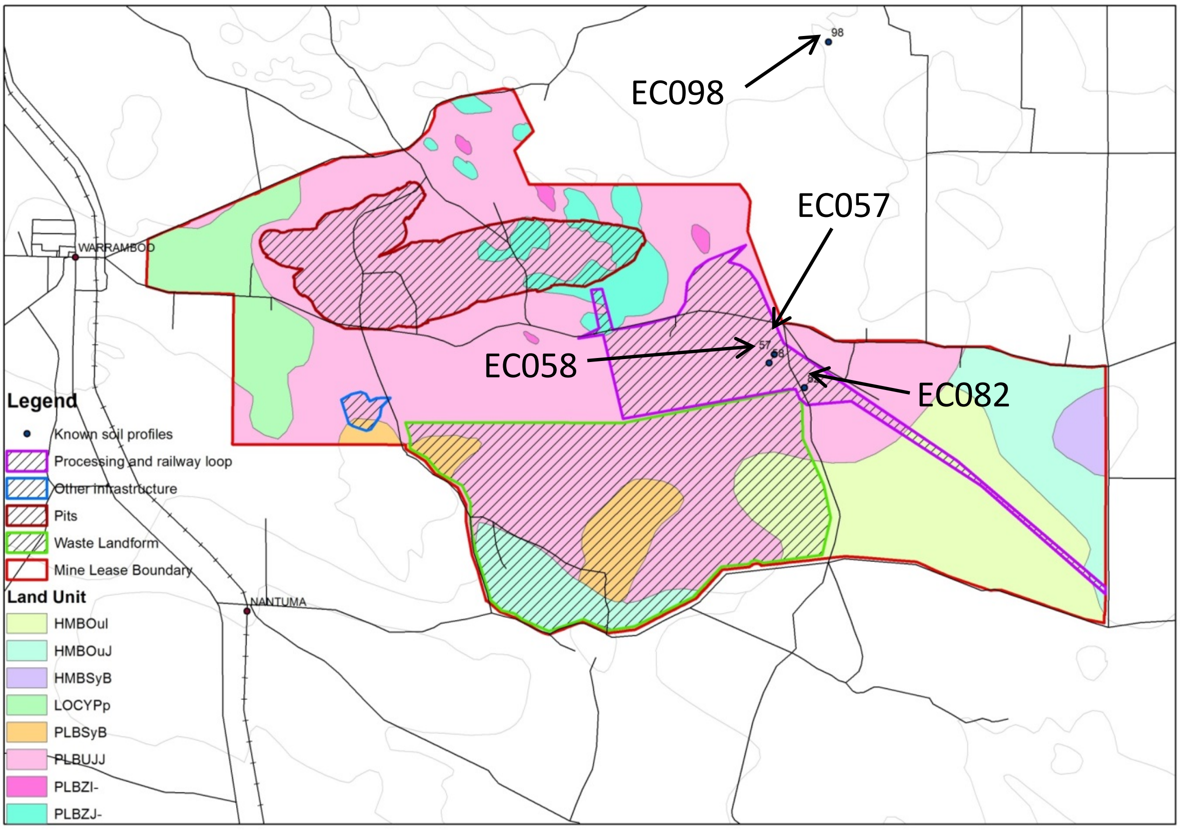


Figure 2-4: ASRIS soil landscape map units occurring within the Study Area (McKenzie *et al.* 2005)

Table 2-2: Known land units within the Study Area (McKenzie *et al.* 2005)

ASRIS Site No.	Profile photo	Description	Name	Landform	Substrate	Vegetation	Classification	Drainage	Erosion potential
EC057		Sandy loam over red clay on calcrete	Wudinna Soil	Gently undulating dunefield of low to moderate parallel sandhills	Calcrete	Mallee	Red Kandosol; medium, non-gravelly, loamy / clayey, shallow	Well drained except where there are no fractures in the calcrete	Water: Low Wind: Low
EC058		Shallow calcareous sandy loam on calcrete	Shallow Wiabuna soil	Dunefield of low to moderate parallel sandhills	Calcrete capping very highly calcareous clayey sand over Tertiary clay	Mallee	Calcarosol; medium, non-gravelly, loamy / clay loamy, shallow	Well drained except where there are no fractures in the calcrete	Water: Low Wind: Moderately low

ASRIS Site No.	Profile photo	Description	Name	Landform	Substrate	Vegetation	Classification	Drainage	Erosion potential
EC082		Shallow calcareous loam over calcrete	Shallow Wiabuna soil	Very gently undulating plain with low sandhills	Calcrete capping Hindmarsh clay	Mallee	Epihypersodic Calcarosol; medium, slightly gravelly, loamy, very shallow	Rapidly drained	Water: Low Wind: Moderately low
EC098		Deep sand	Moornaba soil	Very gentle slopes with sandhills	Windblown Molineaux sand overlying very highly calcareous Woorinen Formation deposits	Mallee	Calcarosol; very thick, non-gravelly, sandy / sandy, very deep	Rapidly drained	Water: Low Wind: Moderate

Further to the ASRIS regional data, three broad soil types occur within the Study Area, described as Calcarosols, Sodosols and Chromosols, with Calcarosols the most common (Iron Road Limited 2013a). Features of these three soil types include;

- Calcarosols;
  - widespread in pastoral districts of South Australia;
  - characterised by calcium carbonate content, ranging from 0 to 10% at the surface to 60% in subsoil, variable from soft nodules to hardened sheets (calcrete);
  - absence of a clear or abrupt textural B horizon (increase in clay content);
  - two types occur within the Study Area; calcareous earths (calcareous throughout) and shallow sands over calcrete;
- Sodosols;
  - characterised by a clear or abrupt textural B horizon (increase in clay content), with a sodic (high exchangeable sodium) subsoil;
  - distinct texture contrast from sandy surface soil to clayey subsoil, which may be impermeable;
- Chromosols;
  - characterised by a clear or abrupt textural B horizon (increase in clay content); and
  - distinct texture contrast from sandy surface soil to clayey subsoil, which may be impermeable.

These broad soil types and the regional ASRIS soil information correlate well with site specific soil descriptions obtained from geotechnical investigations within the Study Area. Soil material descriptions compiled from existing boreholes and test pits were summarised by Jacobs (2014b) within the mine pit and IWL footprints areas (**Table 2-3**). Subsoil material variability was also described in a geotechnical investigation of the IWL area by Coffey Mining (2012a), including loose silty sand topsoil (to 1.0 m), mixtures of silty sand and cemented calcrete, to cemented calcrete to depths (1.1 to 1.4 m), overlying firm sandy clays and dense clayey sands with some calcrete (to 3.0 m).

Table 2-3: Ground model soil descriptions derived from borehole and geotechnical test pit information (Jacobs 2014b)

Footprint area	Depth (mbgl)	Soil material
Mine-pits (Boo-Loo and Murphy)	0 – 0.3	Topsoil – Silty SAND, Sandy SILT
	0.3 – 3.5	Silty/Clayey SAND, SAND, Sandy SILT, some calcrete layers
	3.5 – rock [1]	Sandy/Silty CLAY, CLAY, some SAND
IWL	0 – 0.27	Topsoil – Silty/Clayey SAND, Sandy/gravelly SILT
	0.27 – 0.6	Silty/Clayey SAND, SAND, Sandy CLAY
	0.6 – 2.0 [2]	Calcrete

1. Depth to rock varies from 27 to 47 m bgl.
2. Depth to base of calcrete varies from 1.0 to 3.2 m bgl.

2.1.5 Landform and topography

The Project Area is located within the Eyre Mallee subregion of the Eyre Yorke Block (EYB) bioregion as described by the Interim Bio-regionalisation of Australia (Thackway and Cresswell 1995 in Jacobs 2014c). The Eyre Yorke Block (EYB) bioregion is characterised by Archaean basement rocks and Proterozoic sandstones overlain by undulating to occasionally hilly calcarenite and calcrete plains and areas of aeolian quartz sands, with Mallee woodlands, shrublands and heaths on calcareous earths, duplex soils and calcareous to shallow sands. The Eyre Mallee subregion consists of undulating plains with an extensive cover of dunes and sand sheets and shallow calcareous earths or deeper duplex soils typical of the plains.

Topography of the Project Area is typical of the region with a low relief swale and dune landscape orientated in a northwest to southeast direction (SKM 2014b). Local topography includes a low lying area of approximately 80 m AHD running through the Study Area in a northwest to south east direction (SKM 2014b). Topographic highs of up to 130 m AHD exist to the northeast and southwest of the low lying area.

Regional topography ranges from approximately 40 to 280 m AHD with a general uplift towards the northeast of the region towards the Gawler Ranges, approximately 80 km to the north-north-west (SKM 2014b). The highest elevations in the Gawler Ranges are associated with basement rock outcrops. There are a number of locally elevated areas surrounding the CEIP, including;

- numerous peaks in the Gawler Ranges over 400 m, including Nukey Bluff, the highest peak at 465 m (DENR 2014);
- Pinkawillinie Conservation Park to the southeast of the Gawler Ranges and approximately 40 km north-north-east of Warramboo, consists of old dune ridges which are common over much of the upper Eyre Peninsula;
- Corrobinnie Hill, at an elevation of approximately 188 m, is located in Pinkawillinie Conservation Park;
- Mount Wedge, at 248 m elevation, is approximately 40 km to the south-west;
- Darke Peak, at 247 m elevation, is approximately 60 km to the southeast within the Darke Range, with a series of ranges and hills such as Caralue Bluff and Carappee Hill. Stable vegetation communities, with a clear visual presence exist in this area; and
- the Middleback Ranges, further east at approximately 150 km distance.

2.1.6 Vegetation

A baseline flora and vegetation survey was conducted within the Study Area by Jacobs (2014c). The Study Area has predominantly been cleared for agriculture and is dominated by exotic species, as is typically found in the region. Remnant vegetation is restricted to scattered and isolated blocks of scrub of varying size on farmland and as roadside vegetation (**Figure 2-5**) (Jacobs 2014c). The proposed mining lease covers an area of approximately 85 km^2 of which approximately 12.4% is mapped as native vegetation (Native Vegetation Layer, DENR 2004 in Jacobs 2014c), with larger areas of native vegetation in the northern portion of the Study Area. The remaining 87.6% of the Study Area is predominantly cleared agricultural land.

The native vegetation present within the Study Area occurs as four vegetation types identified as common throughout the Eyre Peninsula, including;

- Red Mallee (*Eucalyptus oleosa*)/Yorrell (*E. gracilis*)/Narrow-leaved Mallee (*E. leptophylla*) low open woodland on calcareous sandy plains and low dune flanks;
- Ridge-fruited Mallee (*E. incrassata*)/Red Mallee (*E. socialis*)/Gilga (*E. brachycalyx*) low open woodland on the deeper sands of the dune crests;
- Southern Cypress Pine (*Callitris gracilis*) open woodland on sandy calcareous plains; and
- Boree (*Melaleuca pauperiflora* ssp. *mutica*) low open woodland with Brown-head Samphire (*Tetricornia indica* ssp. *leiostachya*) and Grey Samphire (*T. halocnemoides ssp. halocnemoides*) open low shrubland on saline depressions or small lakes.

Vegetation condition within the Study Area was described by Jacobs (2014c) as heavily influenced by significant clearing and the presence of agricultural practices adjacent to, and often completely surrounding, each patch of remnant native vegetation. Vegetation condition varied considerably with the size of the remnant patch. Large areas devoid of vegetation or with salt-affected vegetation were present in areas where the saline groundwater table was elevated.

Broad native vegetation associations occurring within the Study Area have also been described by Jacobs (2014d) to estimate soil seedbank type, based on the 'MVS_Name' field of the Native Vegetation Layer (DEH 2004 in Jacobs 2014c). These broad native vegetation associations include;

- Callitris forests and woodlands;
- Mallee heath and shrublands;
- Mallee with hummock grass;
- Melaleuca shrubland and open shrublands; and
- Mixed chenopod, samphire and forblands.

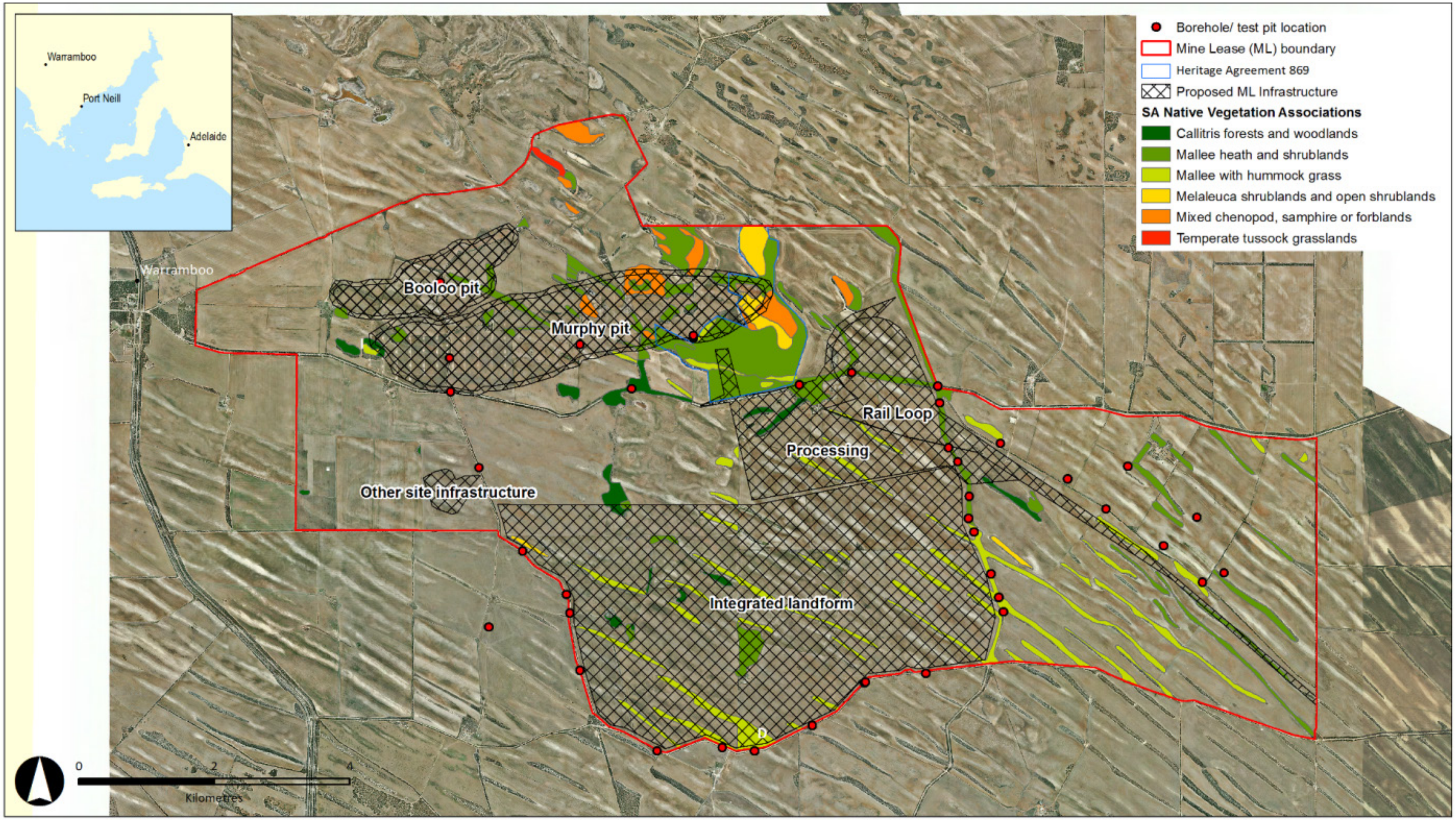


Figure 2-5: Disturbance footprints and native vegetation on the Iron Road Mine Lease (Jacobs 2014d)

2.1.7 Groundwater

The orebody is contained in gneissic bedrock which contains hypersaline groundwater in fractures (Iron Road Limited 2014d). The bedrock is overlain by 10 to 40 metres of sediments (silts, sand and clays) that yield small volumes of saline water.

Hydrogeological studies conducted within the Study Area by SKM (2014b) indicated that depth to the groundwater varies from <5 m below ground level (mbgl) near low lying salt lakes and up to 20 mbgl in elevated areas. Construction of the open pit void is expected to result in groundwater drawdown, with the pit expected to generate a pit lake and be a permanent groundwater sink post-mining, reducing the potential for groundwater to migrate off-site. The groundwater is naturally hyper-saline ranging from 35,000 to 150,000 mg/L (56 to 240 dS/m), increasing with depth. Groundwater quality information within the Study Area includes the following (SKM 2014a);

- salinity in Tertiary sediment groundwater ranging from 35,000 to 53,600 mg/L and from 113,000 to 150,000 mg/L in gneiss groundwater;
- pH reported to be acidic to slightly acidic, with Tertiary groundwater ranging from pH 3.39 to 4.7 and gneiss groundwater ranging from pH 5.67 to 6.39; and
- major ions are sodium chloride (NaCl) in type, considered to be typical in arid and semi-arid environments where high evaporation results in precipitation of calcite and gypsum in the soil, leaving sodium and chloride type water to recharge the groundwater system.

2.1.8 Surface hydrology

Local surface hydrology in the Study Area includes the presence of several low-lying depressions with no surface outlets, such as salt pans and swales, among low relief sandy dunes and some intervening plateau areas (RPS 2013). The main hydrological process on the natural land surface within the Study Area is one of rainfall-infiltration rather than rainfall-runoff, with no evidence of surface runoff processes (i.e. no network of creeks or other surface drainage channels, and no connection of ponding in low lying areas and swales) (RPS 2013). A geotechnical review by Coffey (2012b) found that near surface materials were highly variable, with predominantly permeable sand and some occurrence of low permeability clay near the surface in proximity to the salt pans.

2.1.9 Mine waste geochemistry

MWH Australia Pty Ltd (MWH) was commissioned by Jacobs to undertake a review of available mine waste geochemical data (MWH 2015a) (**Appendix E**) and develop a forward management strategy for any potential acid mine drainage (AMD) issues within an initial AMD Management report for the IWL (MWH 2015b) (**Appendix F**).

MWH undertook a review of the available oxide drillhole database following identification of some high sulphur (S) concentrations (i.e. greater than 0.2%S) within the oxide (weathered) zone intersecting with the MSRR and BLD deposits (MWH 2015a). In analysing the data individually within the drillholes, the following trends were observed;

- in nearly all cases, elevated S values are offset by neutralising CaO (interpreted as calcrete) in the upper 10 to 15 m (i.e. from the surface down to 15 m). Hence this material could be classified as NAF and is likely to contain additional acid consuming ability. This occurrence correlates with the interpreted Quaternary sediments (Jacobs 2014);
- 45 out of 140 (32%) of holes containing PAF had a concentration of PAF values at a depths between 15 to 35 m. This "upper oxide PAF zone" appears to be 10 to 15 m in thickness and correlates with the Neogene unit and the upper groundwater surface interface; and
- 85 out of 140 (60%) of holes containing PAF had a concentration of PAF values at depths between 45 to 75 m. This "lower oxide PAF zone" appears to be 25 to 35 m in thickness and correlates with the Palaeogene and Saprolite units that are located above the fractured basement.

3D geological modelling was then undertaken to determine the distribution of identified PAF and acid neutralising materials in the oxide zones of the MSRR and BLD pits (MWH 2015b) (**Appendix F**), resulting in the following observations;

- at least 90% of the oxide overburden to be stripped will be inert;
- of the PAF oxide material, the majority of this (90%) has total sulphur less than 0.5%. From the preliminary static characterisation testwork completed in January 2015, this material has a low to very low net acid producing potential (i.e. NAPP less than 20 kg / tonne H2SO4);
- PAF material with total sulphur exceeding 1% comprises approximately 0.5% of the entire overburden material. This material is considered to be a low NAPP (i.e. less than 100 kg/tonne H2SO4);
- oxide material with potential buffering capacity (mostly calcrete with CaO greater than 10%) is present within the overburden at higher volumes than PAF material greater than 1%S. The neutralising capacity of this material exceeds 100 kg/tonne H2SO4; and
- potential buffering material is likely to be excavated and placed in the IWL either prior to, or co-disposed with the PAF material.

Below the oxidised overburden zone, the fresh waste rock expected to be generated from mining has a low likelihood of being PAF due to the highly gneissic (or metamorphosed) and consistent nature of the waste rock zone. Data from magnetite concentrate data from processing testwork completed in 2014 (MWH 2015a), and geochemical testwork undertaken on the pilot tailings (**Section 2.2.2.3**) confirms this.

Further description of the oxide and fresh rock mine waste characteristics is included in **Section 2.2.2**.

2.2 Material characteristics and inventory

2.2.1 Soil resources

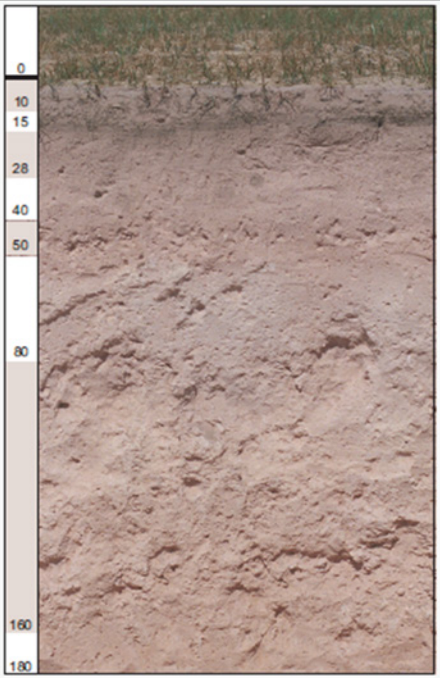
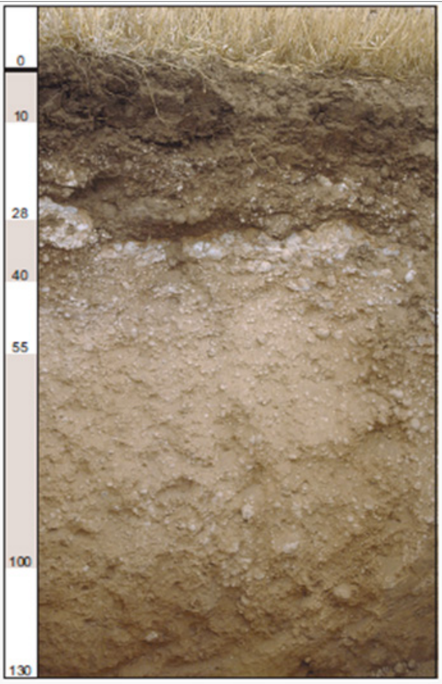
2.2.1.1 Topsoil and subsoil characteristics

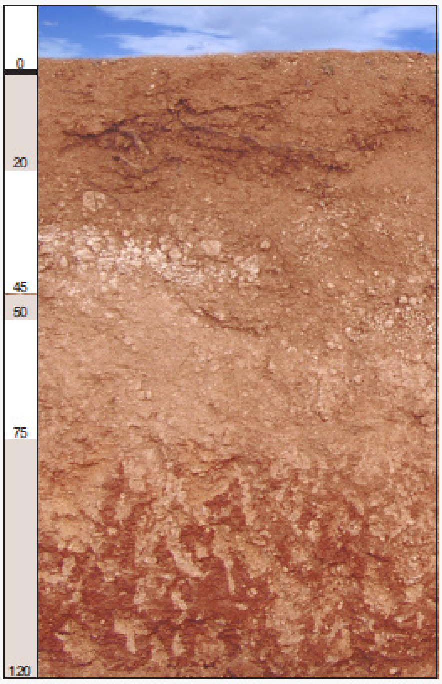
The Department of Water, Land and Biodiversity Conservation (DWLBC) database of soils within South Australia's agricultural lands forms part of the most comprehensive description of landscape units and soil characteristics available in GIS and Excel formats (DWLBC 2002). Using the regional survey data, the dominant soil profile types and their characteristics can be determined. The dominant soil profile types within the waste landform and pit areas are shown in **Table 2-4** and are described as:

- Highly calcareous sandy loam
- Deep (rubbly) calcareous loam
- Rubbly calcareous loam on clay
- Siliceous sand

These soil profiles represent over 80% of the expected soils to be found in the IWL and mine pit footprint areas. Details of the soil horizon depths to two metres and associated physical and chemical characteristics for each of the soil profiles found within the land units, as well as their proportions are detailed in the DWLBC soil database (2002).

Table 2-4: Examples of dominant soil profiles to be found within the mining tenement and proportions (%) associated with the IWL and mine pit footprints (source: DWLBC 2002)

Profile type	Proportion of mine pit and IWL area (%)	Profile description and characteristics	
Highly calcareous sandy loam	21		**Depth (cm)** – **Description** 0-10 – Dark brown very highly calcareous sandy loam with a loose single grain structure. 10-15 – Dark yellowish brown very highly calcareous massive light sandy clay loam. 15-28 – Yellowish brown very highly calcareous massive light sandy clay loam. 28-40 – Brown very highly calcareous massive light sandy clay loam. 40-50 – Strong brown very highly calcareous massive sandy loam with 20-50% hard carbonate nodules. 50-80 – Light brown very highly calcareous massive sandy loam with over 60% hard carbonate fragments and abundant fine carbonate. 80-160 – Light brown very highly calcareous massive sandy clay loam with over 60% hard carbonate fragments and abundant fine carbonate. 160-180 – Reddish yellow very highly calcareous massive sandy clay loam with abundant fine carbonate. **Classification:** Supravescent, Regolithic, Lithocalcic Calcarosol; thick, non-gravelly, loamy /loamy, moderate.
Deep (rubbly) calcareous loam	30		**Depth (cm)** – **Description** 0-10 – Dark brown highly calcareous heavy loam with weak granular structure and 2-10% hard carbonate nodules. 10-28 – Dark brown very highly calcareous massive fine sandy clay loam with 20-50% hard carbonate nodules. 28-40 – Over 60% hard carbonate fragments. 40-55 – Reddish yellow very highly calcareous massive sandy loam with over 60% hard carbonate nodules and abundant fine carbonate. 55-100 – Reddish yellow very highly calcareous massive sandy loam with 30-60% hard carbonate nodules and abundant fine carbonate. 100-130 – Reddish yellow very highly calcareous massive fine sandy light clay with 2-10% hard carbonate nodules and abundant fine carbonate. **Classification:** Endohypersodic, Regolithic, Lithocalcic Calcarosol; medium, slightly gravelly, loamy /loamy, deep.

Profile type	Proportion of mine pit and IWL area (%)	Profile description and characteristics
Rubbly calcareous loam on clay	8	 **Depth (cm)** **Description** 0-20 Dark reddish brown highly calcareous sandy clay loam with polyhedral structure and less than 2-10% hard carbonate concretions. 20-45 Dark reddish brown very highly calcareous massive sandy clay loam with over 50% hard carbonate concretions. 45-50 Over 60% hard carbonate concretions and laminae. 50-75 Yellowish red very highly calcareous massive sandy light clay with 10-20% hard carbonate concretions and abundant fine carbonate. 75-120 Dark red sandy heavy clay with prismatic structure which breaks down to subangular blocky structure and 20-50% fine carbonate segregations. **Classification:** Endohypersodic, Regolithic, Lithocalcic Calcarosol; medium, moderately gravelly, clay loamy /clay loamy, moderate.
Siliceous sand	22	 **Depth(cm)** **Description** 0-10 Reddish brown loose moderately calcareous light loamy sand. 10-45 Yellowish red loose highly calcareous light loamy sand. 45-85 Reddish yellow loose highly calcareous light loamy sand. 85-150 Yellowish red loose highly calcareous light loamy sand, with traces of fine carbonate. 150-175 Red soft highly calcareous clayey sand, with up to 10% fine carbonate segregations (Class IV carbonate). **Classification:** Ceteric, Regolithic, Calcic Calcarosol; non-gravelly, sandy /sandy, very deep.
Other	19	-

Regional ASRIS soil data provides general information on soil physical and chemical attributes for land units occurring within the Study Area (refer to **Figure 2-4**, **Section 2.1.4**). Selected soil characteristics including depth of topsoil (A horizon), subsoil (B1 horizon), texture and basic chemical properties are summarised in **Table 2-5**. While this data provides a general reference for regional soil types within the Warramboo area, site specific soil data would provide more accurate information on specific soil characteristics occurring within the Study Area. General soil features derived from the ASRIS regional data include;

- topsoil;
  - predominantly silty sands and clayey sands, loose, fine to medium grained;
  - some calcareous gravel present in some areas;
  - typically shallow, approximately 0.05 to 0.3 m depth;
  - moderate to moderately low wind erosion potential;
- subsoil;
  - predominantly silty sands, loose to moderate density;
  - found below topsoil to average depth of approximately 1.1 m bgl;
  - deeper in areas associated with dune formations; and
  - potentially sodic.

Table 2-5: ASRIS soil data within the CEIP Project area (McKenzie *et al.* 2005)

Land unit	A horizon		B_1 horizon		Salinity (EC dS/m) [2]	Subsoil sodicity (ESP %) [3]	Hydraulic conductivity (k mm/hr) [4]
	Depth (m)	Texture range[1]	Depth (m)	Texture range[1]			
PLBUJJ	0.23	30% LS 70% SL	0.4	15% LS 45% SL 40% SL+	0.17 (Non-saline)	19	109.4
HMBOuJ	0.25	35% LS 65% SL	0.36	20% LS 80% SL+	1.5 (Extremely saline)	15	213.8
HMBOul	0.32	45% LS 55% SL	0.45	25% LS 30% SL 45% SL+	1.08 (Very saline)	12	154.2
PLBSyB	0.21	15% LS 85% SL	0.41	10% LS 5% SL 85% SL+	0.17 (Non-saline)	24	147.0
HMBSyB	0.15	15% LS 85% SL	0.30	15% LS 45% SL 40% SL+	1.04 (Very saline)	21	100.7
PLBZJ-	0.13	100% SL	0.36	100% SL+	3.25 (Extremely saline)	11	62.5

1. SL: Sandy loam, LS: Loamy sand.
2. EC: Electrical conductivity.
3. ESP: Exchangeable Sodium Percentage. ESP>15% is highly sodic.
4. Hydraulic conductivity classed as moderately rapid (62.5 – 125 mm/hr) to rapid (125 – 250 mm/hr).

Physical and chemical characteristics of the three main soil types occurring within the Study Area, Calcarosols, Sodosols and Chromosols, include (Iron Road Limited 2013a);

- Calcarosols;
  - Calcareous earths;
    - surface soils are neutral to alkaline pH;
    - surface soils prone to water repellence and erosion;
    - shallow depth and effective rooting depth;
    - low water retention;
    - subsoils high in salinity, alkalinity and boron toxicity (crop dependant);
    - low plant-available nutrients and low inherent fertility;
  - Shallow sands over calcrete;
    - slightly acid to slightly alkaline pH;
    - surface soils prone to water repellence and erosion;
    - shallow depth and effective rooting depth;
    - low water retention;
    - boron in the subsoil;
    - low plant-available nutrients and low inherent fertility;
- Sodosols and chromosols;
  - surface soils may be acidic;
  - surface soils prone to water repellence and erosion;
  - low organic carbon;
  - low inherent fertility;
  - compact, slowly permeable subsoils; and
  - subsoil sodicity (Sodosols).

2.2.1.1.1 Estimations of soil water holding capacity

The estimation of the water holding capacity (WHC) of the soils associated with the waste landform and pit footprints was undertaken using expected soil profile characteristics common to each landscape unit and dominant soil type present (**Table 2-4**). Water holding characteristics have been determined by laboratory method by association with a textural soil class DWLBC (2002). This data can be used to estimate the WHC for each expected soil profile.

The WHC is described as the water content of the soil after which drainage of water from the soil profile materially ceases. This water content of the soil is considered to be field capacity (FC). Hence, for this calculation it is assumed that water holding capacity is equivalent to the water held in the soil at 10 kPa matric suction aligning with data provided by DWLBC (2002). The water holding capacity of the soil is also adjusted for the amount of coarse fragments in the soil for each soil horizon. The coarse fragments are assumed not to hold any water. The WHC for different soil horizons and soil profiles are detailed in **Table 2-6**.

Table 2-6: Horizon water holding capacities for each soil profile as described by DWLBC (2002) and proportion (%) expected across the waste landform and pit areas

Soil Profile	%	Water Holding Capacity (% vol.)		
		A horizon	B1 horizon	B2/B3 horizon
Highly calcareous sandy loam	21	30.0	26.6	17.3
Deep (rubbly) calcareous loam	30	28.6	26.3	24.3
Rubbly calcareous loam on clay	8	26.6	21.0	32.9
Siliceous sand	22	18.0	16.0	16.6
Other	19	21.5	18.2	22.8

It should also be noted that the FC points are an arbitrary representation of water contents after free drainage. In reality, the rate of 'free drainage' in the soil of the cover profile of the IWL will be dependent on the soil hydraulic characteristics of the cover profile and the underlying layer, the depth of the cover layer, and, to some extent, lateral profile drainage potential. One key parameter that influences the stability of hydraulic characteristics is the sodicity of the soil. **Table 2-7** outlines the possible sodicity levels for different horizons and soil profile as described by DWLBC (2002). Whilst the A and B1 horizons of most soil profiles are non-sodic to slightly sodic the B2-3 horizons are extremely sodic. This will need to be verified and considered as the placement of sodic soils at, or near the surface of the IWL could have significant impact on the hydraulic character and stability of the outer surface.

Table 2-7: Horizon exchangeable sodium percentage for each soil profile as described by DWLBC (2002) expected across the waste landform and pit areas

Soil Profile	Exchangeable Sodium Percentage		
	A horizon	B1 horizon	B2/B3 horizon
Highly calcareous sandy loam	2.0	9.0	39.3
Deep (rubbly) calcareous loam	1.4	18.3	46.2
Rubbly calcareous loam on clay	1.0	2.0	46.7
Siliceous sand	6.4	4.0	22.5

2.2.1.2 Soil resources inventory

The development of a soil resource inventory has been shown to be an effective method of planning for the most suitable and efficient use of available soil and mine waste resources for landform design and rehabilitation prescriptions.

High level estimates of potential soil quantities available within the mine-pit and IWL footprints were also calculated by Jacobs (2014a, 2014b), based on information from geotechnical investigations (**Table 2-8**). A net bulking factor of 1.1 was applied (accounting for bulking and compaction factors) for these volume calculations (Jacobs 2014b). Within the mine-pit footprint area, clay oxide materials comprising the bulk of the weathered regolith profile below 3.5 mbgl and above rock have been included in these calculations. Oxide overburden material characteristics and likely requirements for separate handling and stockpiling are discussed further in **Section 2.2.2**.

Topsoil resources were further characterised into soil seedbank type based on vegetation cover, including agricultural versus native vegetation cover (Jacobs 2014d) (**Table 2-9**). Agricultural topsoil resources far outweigh native vegetation topsoil and seedbank resources potentially available within disturbance footprints associated with the CEIP. Native vegetation cover was also further delineated into five broad native vegetation associations (**Table 2-10**). The majority of native topsoil seedbank volumes will be available from Mallee type vegetation associations (Jacobs 2014d).

Table 2-8: Ground model soil descriptions derived from borehole and geotechnical test pit information (Jacobs 2014a, Jacobs 2014d)

Footprint area	Area (ha)	Depth (mbgl)	Soil material	Volume (Mm^3)		
				Topsoil	Subsoil	Oxide [2]
Mine-pits (Boo-Loo and Murphy) [1]	767	0 – 0.3	Topsoil	2.5	-	-
		0.3 – 3.5	Predominantly silty sand	-	26.8	-
		3.5 – rock [2]	Predominantly clay	-	-	211.1 – 381.7
IWL[3]	1988	0 – 0.27	Topsoil	5.9	-	-
		0.27 – 0.6	Predominantly silty sand	-	13.0	-
Rail loop	297	0 - 0.21	Topsoil	0.7	-	-
Processing Infrastructure	404	0 – 0.21	Topsoil	0.9	-	-
Other Site Infrastructure	33	0.5	Topsoil	0.2	-	-
Total	**3489** [4]	**-**	**-**	**10.2**	**39.8**	**211.1 – 381.7**

1. Assumption that all material above rock across the mine pit footprints is available for collection and re-use. This material comprises the weathered regolith oxide materials.
2. Depth to rock varies from 27 to 47 m bgl.
3. Assumption that all material above 0.6 m bgl across the IWL is available for collection and re-use.
4. Footprint areas are approximate only and have subsequently been updated.

Table 2-9: Topsoil volumes categorised by native or agricultural vegetation cover (Jacobs 2014d)

Footprint area	Volume of topsoil (Mm^3) [1]	Native vegetation cover / seedbank		Agricultural vegetation cover / seedbank	
		Area (km^2)	Topsoil volume (Mm^3)	Area (km^2)	Topsoil volume (Mm^3)
Mine pits (Boo-Loo and Murphy)	2.5	1.4 (18%)	0.5	6.3 (82%)	2.1
IWL	5.9	2.0 (10%)	0.6	17.9 (90%)	5.3
Rail loop	0.7	0.4 (12%)	0.1	2.6 (88%)	0.6
Processing infrastructure	0.9	0.7 (17%)	0.12	3.4 (83%)	0.8
Other site infrastructure	0.2	0	0	0.3 (100%)	0.2
Total	**10.2**	**4.4 (13 %)**	**1.3**	**30.5 (87 %)**	**8.9**

Table 2-10: Native topsoil volumes and associated seedbank estimates categorised by broad vegetation associations (Jacobs 2014d)

Topsoil vegetation association/seedbank [1]	Mine pits (Boo-Loo and Murphy)	IWL	Rail loop	Processing infrastructure	Other site infrastructure [2]	Native topsoil volume (Mm^3)
Callitris forests and woodlands	0.009	0.042	-	0.022	*	**0.073**
Mallee heath and shrublands	0.297	0.084	0.068	0.084	*	**0.533**
Mallee with hummock grass	0.011	0.455	0.013	0.045	*	**0.524**
Melaleuca shrublands & open shrublands	0.031	0.012	-	-	*	**0.043**
Mixed chenopod, samphire or forblands	0.105	-	-	-	*	**0.105**
Total native topsoil volume (Mm^3)	**0.453**	**0.593**	**0.081**	**0.151**	**0**	**1.28**

1. Based on the 'MVS_Name' field of the Native Vegetation Layer (DEH 2004 in Jacobs 2014c).
2. * Topsoil and associated seedbank in this area is agricultural.

2.2.2 Mine waste materials

The mine waste materials expected to be mined include oxide bulk waste (overburden) and fresh bulk waste rock from both the MSRR and BLD pits (Coffey 2014). The overburden cover includes up to 30 to 40 m of oxidised gneissic materials above the 'barren gneiss' fresh waste rock, and up to 70 m of overburden cover above the 'magnetite gneiss' orebody. Oxide materials refer to the weathered regolith, or oxidised profile extending from the surface through to fresh rock, also referred to as saprolite materials. The overburden profile excludes surface topsoil and subsoil resources (to approximately 1.5 to 2 m depth).

The stratigraphy of the overburden profile comprises the surficial Quaternary through to saprolitic weathered gneiss of the lithological units described for the CEIP (Iron Road Limited 2014b and Jacobs 2014a), which include:

- Quaternary surficial deposits;
- Tertiary (Neogene) sediments;
- Tertiary (Paleogene) sediments;
- Saprolite (weathered gneiss);
- Fractured basement gneiss (waste rock and ore);
- Low-fractured basement gneiss (waste rock and ore); and
- Fresh rock gneiss (no fracturing) (waste rock and ore resource).

The tertiary sediments are also delineated as 'Clayey Tertiary' and 'Sandy Tertiary' units by Jacobs (2014a) (**Figure 2-6**).

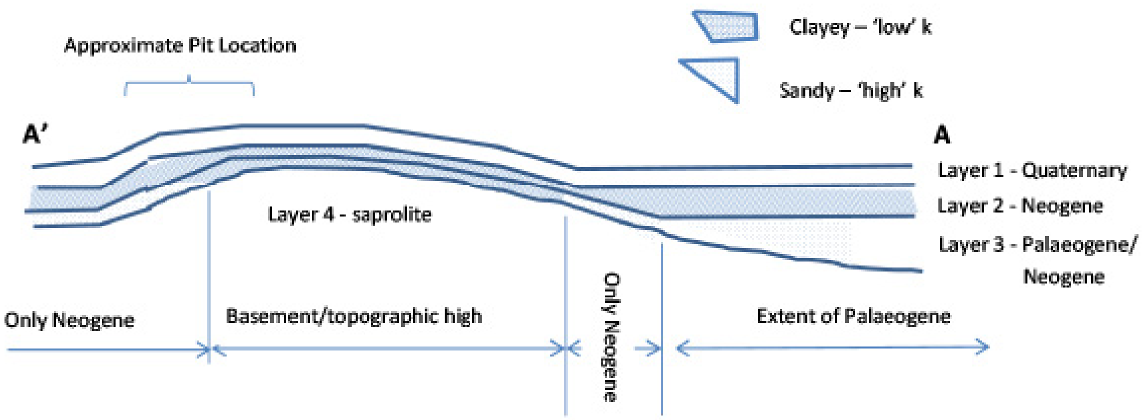


Figure 2-6: Conceptualisation of the tertiary sediment profile (sourced from Jacobs 2014a)

2.2.2.1 Oxide waste material characteristics

A review of available data from geotechnical investigations provides a snapshot of key characteristics of the oxide profile (Iron Road Limited 2013b, 2013c). A variety of oxide profile material types were described to a maximum depth of 17.5 m from a combination of test pits and boreholes by Iron Road (2014e) (**Table 2-11**). Key physical characteristics of the oxide materials include;

- particle size distribution (PSD);
  - variable ranging from 3 to 72% fines, and 0 to 72% gravel;
  - percentage of clay ranged from negligible for calcrete and silty sands to 41% for gravelly clays;
- extremely low permeability for clayey sand when compacted; and
- variable dispersion potential, non-dispersive to highly dispersive.

Table 2-11: Subsurface oxide profile material types (Iron Road 2013b)

Unit	Typical depth (mbgl)		Maximum thickness		Material type
	Test pits	Bore holes	Test pits	Bore holes	
1	0 – 0.3	0 – 0.1	0.3	0.1	Silty Sand Topsoil
2	0.05 – 1.1	0.05 – 1.4	4.0	2.0	Silty Sands
3	0.4 – 3.2	0.1 – 2.7	2.5	1.9	Calcrete
4	0.9 – 3.7	1.8 – 15.5	3.5	12.1	Clays and Sandy/Gravelly clays
5	1.4 – 3.6	1.4 – 8.1	2.2	3.9	Clayey sands
6	-	6.6 – 9.3	-	8.5	Cemented Silty sands and Sandy Silts
7	-	10.0 – 17.5	-	7.5	Extremely weathered gneiss

MWH has recently completed a preliminary AMD characterisation of the oxide zone based on Iron Road drilling information provided by Iron Road (MWH 2015). Analysis of available samples has identified that some high sulphur (S) concentrations (i.e. greater than 0.2%S) were present within the oxide (weathered) zone, and subsequently some of the mine waste materials to be encountered have a potential to generate AMD. Also identified however, was that similar volumes of mine waste materials contain significant buffering potential to neutralise AMD. Details of the findings are contained within the Oxide Zone Geochemistry Review and IWL Management Plan (MWH 2015) (**Appendix E**). Essentially based on the exploration drillhole database, and the preliminary geochemical analysis, a conservative estimate is that approximately 80% of the overburden (oxide zone) mine waste will be non-acid generating (inert), up to 10% of the overburden waste may have the potential to generate acid, and up to 10% of the overburden waste may have neutralising potential (MWH 2015).

Given that the potentially acid generating and potentially acid neutralising materials occur in close proximity, it is expected that through a combination of good planning, waste handling and management the mine waste materials can be stored in a manner such that AMD potential would be mitigated. The forward work plan involves further characterisation of the physical, chemical and geochemical characteristics of the mine waste materials (oxide, fresh rock and tailings) prior to commencement of the Project, to further quantify AMD potential and associated mitigation measures.

2.2.2.2 Fresh waste rock characteristics

Fresh waste rock material types at the CEIP are predominantly identified as either 'barren gneiss' or 'mineralised or magnetite gneiss' (**Section 2.1.2.2**). A preliminary review of information assessing the potential for AMD generation from the fresh waste rock is also included in the Geochemistry Review (MWH 2015) (**Appendix E**). In general it was considered that for the fresh rock zone immediately underlying the oxide zone, due to its highly gneissic (or metamorphosed) and consistent nature, that there is a low likelihood of this waste rock being PAF, suggested also by findings from the initial ore tailings samples (see **Section 2.2.2.3**).

2.2.2.3 Tailings characteristics

The tailings produced from processing at CEIP consist of both 'fine' and 'coarse' tailings fractions to be combined for deposition in the IWL along with mine waste materials. Preliminary geotechnical investigations by ATC Williams (Iron Road Limited 2013b) provided information on physical and chemical characteristics of the fine and coarse tailings streams, including;

- physical characteristics;
  - soil particle density (for deposition): 2.85 g/cm^3 for fine tailings and 2.82 g/cm^3 for coarse tailings;
  - plasticity (Atterburg Limits): fine tailings found to be non-plastic;
  - PSD [1];
    - fine tailings: 0% gravel, 43% fines, 31% fine sand, 26% medium sand;
    - coarse tailings: 24% gravel, 1% fines, 1% fine sand, 16% medium sand, 58% coarse sand;
  - moisture content (received dry): 0.2% for both fine and coarse tailings;
  - permeability (k):
    - 0.9 mm/hr for fine tailings
    - 244.8 to 338.4 mm/hr for the coarse tailings
  - minimum/maximum dry density:
    - 1.15 to 1.86 t/m^3 for fine tailings;
    - 1.49 to 1.79 t/m^3 for coarse tailings;
- chemical characteristics [2];
  - pH of 7.5 for the fine tailings; and

[1] Gravel % = +2.36 mm, Fines % = -75 µm.

[2] Chemical testwork performed on a slurry combining pilot tailings and seawater to replicate saline groundwater expected to be used for processing. The seawater had a pH of 7.5 and EC of 47,900 µS/cm (Iron Road Limited 2013b).

– EC of 20,900 µS/cm (fine tailings) (hypersaline).

Preliminary geochemical testwork was also undertaken for the fine and coarse fractions of the pilot tailings by Bureau Veritas (information supplied by Iron Road). Preliminary results are included in **Table 2-12**.

Table 2-12: Preliminary geochemical testwork results for the pilot tailings (Bureau Veritas, sourced from Iron Road)

Pilot tailings fraction	S%	C%	S% - sulphur digest	TIC %	MPA (kg H_2SO_4/ tonne)	NAPP (kg H_2SO_4/ tonne)	NAG (kg H_2SO_4/ tonne)	ANC (kg H_2SO_4/ tonne)
Fine	0.04	0.06	<0.05	<0.05	<0.5	<1	<0.5	12
Coarse	0.04	0.05	<0.05	<0.05	0.5	<1	<0.5	12

MWH undertook laboratory testing of a bulk sample of combined coarse and fine pilot tailings, including;

- chemical characteristics
- physical characteristics;
- geochemical characteristics; and
- bulk column testwork for capillary rise of salts and leaching of salts and metals.

Results for the preliminary laboratory testwork performed on the combined tailings are included in **Appendix A1**. Key characteristics of the tailings material are summarised below:

- physical characteristics;
  - loamy sand texture with average clay content of 3.7% clay and 23% coarse fragments (>2 mm);
  - low soil strength and hardsetting potential;
  - non-dispersive and structurally stable;
  - slow to moderately slow hydraulic conductivity, decreasing with repeated wetting and draining cycles;
  - high water holding capacity;
- chemical characteristics;
  - alkaline pH (average pH H_2O of 8.2);
  - extremely saline Electrical Conductivity (average of 1.69 dS/m);
  - predominantly low plant-available nutrient concentrations with a low Cation Exchange Capacity and extremely low organic carbon percentage;
  - sodic (average Exchangeable Sodium Percentage of 11.1%);
- geochemical characteristics and multi-element analysis;
  - classified as non-acid forming (NAF), based on static acid-base accounting results;

  - low total sulphur (average of 0.03%);negative Net Acid Production Potential (NAPP) (average of -14.7 kg H_2SO_4/t);
  - alkaline Net Acid Generation (NAG) pH;
  - high Acid Neutralisation Capacity (ANC) ratio >2 (average ratio of 17) and high ANC (average of 15.6 kg H_2SO_4/t); and
- negligible or low metal and elemental concentrations, with the exception of manganese (average of 1140 mg/kg compared to an EIL of 500 mg/kg and average crustal abundance of 950 mg/kg for manganese).

Two bulk column leach experiments were conducted using the combined coarse and fine tailings to investigate the potential for capillary rise of salts (Column Leach Experiment 1, **Appendix A**, **Section 2.1**), and the potential for leaching of salts and dissolved metals (Column Leach Experiment 2, **Appendix A**, **Section 2.2**). The results of Column Leach Experiment 1 found that capillary rise of salts did occur upon repeated wetting and drying of the tailings with accumulation of salts at the surface, while both salt and metal concentrations were found to decrease upon leaching from repeated wetting and draining in Column Leach Experiment 2. Results of the two experiments are summarised as follows;

- Column Leach Experiment 1 (capillary rise of salts);
  - substantial accumulation of salts at the surface of the tailings following repeated wetting and drying, indicating that salts have migrated upwards;
  - EC at the surface increased to 6 times that of the pre-treatment EC, with a reduction in EC in the centre and bottom of the column; and
  - no change in pH.
- Column Leach Experiment 2 (conducted in two stages);
  - Stage 1: Repeated small column leaching;
    - some water soluble metal concentrations (e.g. barium and strontium) were initially high concentrations then decreased;
    - eleven metals recorded water soluble concentrations below the lowest detectable level for all leachate samplings;
    - concentrations of water soluble aluminium remained constant over the repeated leaching cycles;
    - initial leachate EC was very high (with salts in a highly soluble form), decreasing to low at final measurement, suggesting that salt had leached with repeated wetting and draining;
  - Stage 2: Leaching of large bulk column;
    - majority of salt leached out during the first wetting and draining cycle; and
    - slight increase in pH, possibly due to the change in EC.

Salt stored within the tailings material will be bound in a low moisture environment, until incidental water from rain mobilises the solutes. Management of the tailings salt load is considered within the landform design, via a robust store release cover profile on the structure, with design features to capture runoff, and protection of the vegetation growth/storage layer via a capillary break to prevent upward movement of salt in the tailings material.

2.2.2.4 Mine waste materials inventory

An inventory of mine waste material types and the Life of Mine (LOM) volumes expected to be generated by the CEIP mine was required to determine the required storage capacity of the IWL and establish a basis for the rehabilitation and closure concept. A materials inventory establishes the basis for cataloguing different types of waste materials, expected volumes, key characteristics, and recommendations for handling and management. For example, specific mine waste materials, such as saline tailings or potentially acid-forming mine waste, are generally not suitable for use as an outer surface cover material for rehabilitation of the IWL. Problematic materials often require specific recommendations for placement or encapsulation during construction of the IWL for rehabilitation and closure planning. Consideration of the volumes of materials is therefore critical for establishing these recommendations and to inform aspects of the preliminary design for the IWL.

A preliminary mine waste material inventory for the CEIP is presented in **Table 2-13**, incorporating available information for LOM volumes of tailings and waste rock materials provided by Iron Road. Further delineation of volumes identifying the proportion of oxide waste to fresh waste rock has also been determined for the total mine waste materials destined for the IWL. Based on the current mine plans, approximately 1,040 Mm^3 (52%) of the total 1,982 Mm^3 waste rock to be mined for the CEIP will be derived from the fresh rock zone immediately underlying the oxide rock zone (MWH 2015).

Table 2-13: Preliminary mine waste materials inventory for the CEIP

Mine waste material type		Tonnage		Volume [1]	
		Annualised average (Mtpa)	LOM tonnes (Mt)	Annualised average (Mm^{3}pa)	LOM volume (Mm^3)
Waste rock	Total (oxide and fresh rock)	170	4,360	77	1,982
Tailings	Combined coarse and fine fractions	130	3,053	59	1,388
TOTAL		**300** [2]	**7,413**	**136** [2]	**3,370**

1. A consolidated stress bulk density of 2.2 t/m^3 assumed for the combined tailings/waste rock upon deposition within the IWL (information from Iron Road).
2. The annual production of waste rock and tailings to be combined within the IWL.

3 LANDFORM DESIGN AND CLOSURE CONCEPT

3.1 Concept introduction

3.1.1 IWLs and alternative construction methods

The design of the IWL will have the potential to influence the success of rehabilitation activities, the ability to achieve closure outcomes, and impacts upon the surrounding environment. Best practice concepts and design criteria, taking into account target rehabilitation outcomes, the characteristics of the waste materials and rehabilitation resources available, will ultimately be integrated into the final closure design of the IWL. The conceptual design and strategy for rehabilitation and closure of the IWL focusses on several principles to be addressed through consideration of critical design elements and objectives.

Among several advantages of an IWL, managing a single, combined mine waste material stream provides a significant opportunity for a more consolidated approach to developing a closure and rehabilitation strategy. These advantages include;

- a reduced overall final landform footprint;
  - reduced storage volume requirements for consolidated tailings stacking compared to traditional tailings slurry deposition, due to filling of voids in waste rock by tailings;
  - co-disposal of a single waste materials stream (combined tailings and mine waste materials), negating the need for a separate TSF and WRL;
- co-disposal of a single waste materials stream (including co-mingling of identified PAF and ANC mine waste materials), during the mining process, and tailings integration negating the need for separate handling; and
- a greater ability to meet local stakeholder expectations by achieving a minimal footprint, minimised dust generation and minimised salt impact.

In addition to the combined tailings and mine waste rock storage approach, the proposed stacking system is a highly managed and controlled waste material management approach compared to conventional landform construction using truck load, haul and dump mining method. Stacking via conveyors is considered to be a world-class waste management system, used extensively for material handling, such as reclaim ore-stacking, building heap leach pads, pre-stripping operations and for waste rock disposal.

The stacking method presents many advantages over conventional truck dumping landform construction and greater opportunities for integrating earlier and progressive rehabilitation. In terms of a concept for rehabilitation and closure, an integrated waste landform approach using a stacking construction method has a high potential to meet local stakeholder expectations.

Advantages of the stacking method include the following:

- improved safety with increased landform stability during construction and at closure;
  - controlled handling of consolidated materials (as opposed to a tailings slurry) and slow progressive construction builds geotechnical strength, lessening the risk of catastrophic failure, such as tailings facility wall failures;
  - constructed to be geotechnically stable to ensure the stackers and conveyors are not at risk of damage during operational conditions;
  - significant reduction in safety related traffic risks associated with using a truck fleet;
- improved efficiency during construction;
  - reduction in diesel fuel requirements with subsequent emission and greenhouse gas emissions reductions;
  - improved energy efficiency and substantially reduced energy consumption;
  - reduced water use by recycling water salvaged from recovering entrained water from the tailings prior to disposal within the IWL;
  - reduced noise from use of conveyors compared to trucks;
- reduced dust generation during construction and at closure;
  - reduced dust generation from no truck trafficking and dumping;
  - stacking of ‘wet sand’ tailings;
  - capacity to strategically control operational dust using layers of crushed competent waste rock mulch (containing no tailings);
  - rock mulches can be placed over final surfaces for as long as required to suppress dust until rehabilitation;
  - delivery of strategic material layers such as capillary breaks of crushed rock;
  - early surface stabilisation via progressive rehabilitation;
- ability to undertake progressive rehabilitation;
  - steady staged development and construction allows for experimentation and adaptive rehabilitation and management techniques, with an early capacity to test final profile closure options;
  - final height can be established at an early stage on one side of the landform to allow for a progressive rehabilitation sequence as the landform develops;
  - enhanced aesthetics and amenity with the ability to incorporate landform design features such as ridges and valleys;
  - enhanced dust and water control through early surface stabilisation;
  - negligible seepage;
  - reduced financial liability throughout the life of the project;
- design flexibility;
  - application of specific growth media layer at a depth to design;
  - application of different mixes of materials for strategic placement in specific areas;
  - single handling of growth medium materials, reducing detrimental effects of over-handling such as soil structural decline and dust generation; and

- ability to produce a final landform design compatible with the surrounding landscape, such as producing ridges and valleys instead of a conventional flat, angular, linear or rectangular landform shape.

3.1.2 Critical design elements

In addition to the specific project objectives for the CEIP IWL (**Section 1.3**), the conceptual landform design and closure strategy for the IWL should focus on achieving overall guiding principles for landform rehabilitation and closure, including the following objectives;

- the landform will be physically stable and safe;
- will contain all PAF mined in a manner that alleviates any risk of acid drainage;
- similarly will contain saline material in a manner that prevents distribution of that material beyond the outer upper surfaces of the landform;
- allows rehabilitation outcomes to be met;
  - landform design and rehabilitation will be compatible with the agreed land uses and values in the area. This may include consideration of water catchment, local industries, conservation, recreation values and ultimately access to the IWL for the local community;
  - rehabilitation will be integrated into the existing landscape;
  - rehabilitation will be resilient and sustainable (physically and biologically);
    - growth media and soils to become chemically and physically stable, with limited erosion and have adequate water holding capacity;
    - rehabilitation should exhibit sustained growth and development;
    - important biological processes such as nutrient cycling, species reproduction and recruitment need to be functioning sufficiently to ensure sustainability and continued development;
    - important attributes such as biodiversity and vegetation cover should be within expected ranges; and
    - the vegetation will be able to adequately recover from perturbations such as drought, fire and insect attack to the extent that no special management considerations will be required upon maturity.

Achieving rehabilitation and closure outcomes that conform to these principles will depend on consideration of critical design elements, developed through an understanding of the properties of soil and waste materials (as described in **Section 2.2**), and appropriate landform construction, particularly the optimal placement of materials in a soil cover profile. Critical design and rehabilitation elements considered include;

- *Characterisation, placement and management of PAF, saline and dispersive waste materials:*
  - The identification of materials deleterious to chemical and geotechnical stability are critical to the stability of any constructed landform. The design of the IWL should aim to minimise the concentration of these elements unless deemed appropriate. Wherever possible, the aim is to

isolate these elements to maximise the physical and geochemical stability of the landform. Strategies can include;

- separation of any potentially deleterious materials from the outer zones of the growth zone of the landform using competent, inert rock as capillary break material and rock mulch;
- physical separation through isolation by distance from the outer areas of the landforms; and
- leave difficult wastes in place or through backfilling mine pits, particularly within those pits that either do not intersect the water table, or those that on closure will have a large deep fairly inert and stable water cover above PAF backfill.

- *Surface water management:*

– The management of surface water flow is critical to the stability of any constructed landform. The design of the IWL should aim to minimise the concentration of surface water wherever possible, with appropriate drainage features on the upper surface, berms and bunds as applicable to prevent over-topping onto constructed slopes, and aim to maximise the infiltration of rainfall for storage within the upper soil profile for plant root access and subsequent growth;

- *Slope characteristics (shape, angle, length):*

– The steeper and longer the slope, the greater the potential for erosion. Slope angles and slope lengths should be minimised as far as practicable, bearing in mind that there is a trade-off between a reduced slope angle and length against the overall footprint of the IWL. The adoption of concave slopes, at a minimum angle possible (as dictated by IWL footprint and height), is likely to further minimise erosion, promote successful rehabilitation and enable a greater ability to blend in with the surrounding landscape.

- *Topsoil / growth medium placement:*

– Appropriate placement of suitable topsoil, subsoil and selected growth media resources, in terms landform position and depth of application, is important from a stability and vegetation growth perspective. To meet the specific design concepts and objectives for the IWL, strategic placement of available soil resources in certain parts of the final outer surface of the IWL (e.g. flat areas and lower slopes), rather than as a homogenous cover profile can be advantageous. The application of certain soil amendments may also be considered to stabilise and improve soil quality and nutrient levels.

- *Surface protection and armouring:*

– Consideration of options to enhance surface stability and protect against erosion and dust generation is of paramount importance. Strategies may include increasing the surface armouring of the soil with selected crushed rock, contour ripping of the surface following topsoil application and possibly mixing the topsoil with underlying waste rock, and direct application of benign waste rock with topsoil/subsoil.

- *Material handling and placement logistics;*
  - The separate collection, stockpiling, and re-application of potential growth medium resources, including topsoil, subsoil and mine waste materials.
  - Suitable management and potential encapsulation requirements for potentially acid forming mine waste materials (as detailed above under *Characterisation, placement and management of PAF, saline and dispersive waste materials*).

3.2 Landform design and rehabilitation options

The CEIP IWL landform is required to be stable post rehabilitation. Because of the low annual rainfall at the site, the implication is that the facility should be stable without the assistance of vegetation. Effectively, this requires that the materials used to construct the outer layers of the CEIP IWL should be as resistant to erosion as practicable.

The process adopted for the study was to consider a number of alternative design options based on both the capabilities of the equipment to be used for the construction of the IWL, and the volume of mine waste to be stored in the IWL. These options were then subjected to a desktop erosion modelling study using parameters derived from the known geotechnical properties of the soil and mine waste materials. This erosion modelling process should be seen as an initial high level assessment subject to validation through further testing of materials and refinement during the detailed design phase. However, the process is considered to be a reasonable first estimate of the likely performance of the landform based on the available knowledge base.

3.2.1 Site specific design elements

The nature of the stacking system to be used for the IWL and the available materials provides certain unique opportunities and constraints for the construction process, including;

- the capability to strategically design the mix of upper surface zone substrates and surface materials for different areas of the landform, such as across the flat upper surfaces and batter slopes;
- the opportunity to use a high proportion of waste rock (typically 160 mm in diameter) in the outer layer of the surface to minimise erosion risks;
- the potential for creating variability in the top surface through variation of the final back stacking placement; and
- the ability to consider the construction lifts, with the three conveyors each placing a 30 m front stack, and a 15 m back stack.

In considering the options, it was considered that the landform would need to include:

- application of sufficient soil cover profile depth to support growth of native shrub vegetation local to the Study Area amongst the rocky material to be placed in the outer layer;

- construction of wind breaks in the form of rocky/soil rich linear features (such as dune forms) across the upper surface structure to emulate the surrounding landscape and reduce wind erosion;
- contain all identified PAF material in a manner that alleviates any risk of acid metalliferous drainage, and similarly contains saline material in such a way as to prevent distribution of salts upward via capillary rise into the surface growth layer, and beyond the footprint of the landform;
- enhance conservation values for native flora and fauna upon final rehabilitation by providing suitable habitat and sites for local species;
- beneficial uses of the landscape designed, with consideration of;
  – minimal impact (e.g. dust generation from wind);
  – visual amenity (e.g. town of Warramboo, local community);
  – stakeholder engagement;
  – conservation potential;
  – potential for 'added value' through multiple or mixed use; and
- strategic use of native topsoil and subsoil rather than farm topsoil to avoid weed proliferation.

3.2.2 Site specific constraints and requirements

The following data has been used in the design options process;

- the tailings stacking area boundary, defining the IWL footprint area;
  – extent and location within the proposed mine lease boundary;
  – bounded to the south by the extent of the proposed mine lease boundary, defined by a public road (Nantuma Road);
  – bounded to the west by the extent of the proposed mine lease boundary, defined by a public road (Dolphin Road);
  – bounded to the east by Lock Road (public road closure within proposed mine lease boundary);
- local topographical data;
- slope parameters designed to accommodate the surface runoff expected to be generated from a 1 in 100 year hour rainfall event (which assumes no vegetation cover);
- a sediment loading based on 200 years of erosion;
- appropriate buffers between the Life of Mine (LOM) IWL footprint and proposed mine lease boundaries (e.g. 50 m minimum); and
- volume of mine waste to be stored of the order of 1,800 Mm^3, although the target volumes were uncertain early in the project and resulted in an initial target closer to 2,100 Mm^3.

3.2.3 Base case designs considered

The initial designs considered for the site include the following:

- a linear stepped design, using 20 m high lifts at 18 degrees (1 (vertical):3 (horizontal)) slope angle with 15 m wide benches between each lift (**Figure 3.1**); and

- a concave slope design using 45 m high lifts, with slopes varying from 18 degrees (1v:3h) to 9.46 degrees (1v:6h), with 40 m wide benches between each lift.

For each of the above scenarios, the benches were sized to accommodate the provisional estimate of the expected sediment accumulation over 200 years, together with the 1% Annual Exceedance Probability (AEP) rainfall at the end of 200 years. A 3D perspective view of each the two initial designs are shown in **Figure 3-2** and **Figure 3-3**.

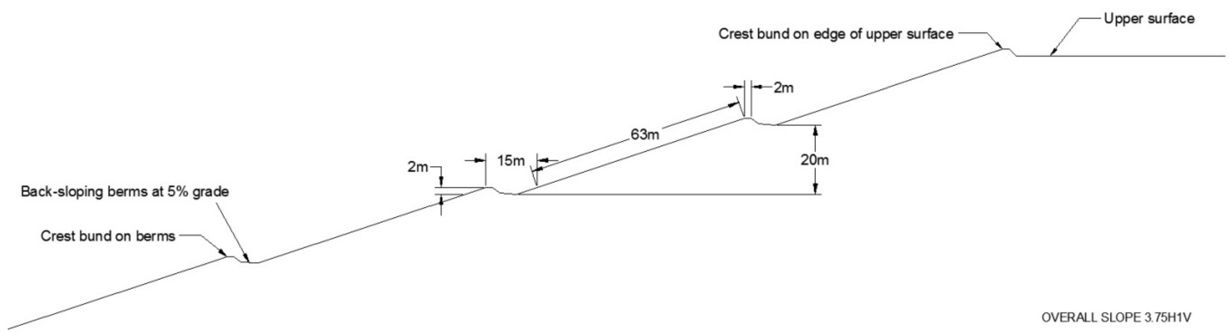


Figure 3-1: Conceptual slope configuration for the initial linear stepped design (upper batter slopes and upper surface)

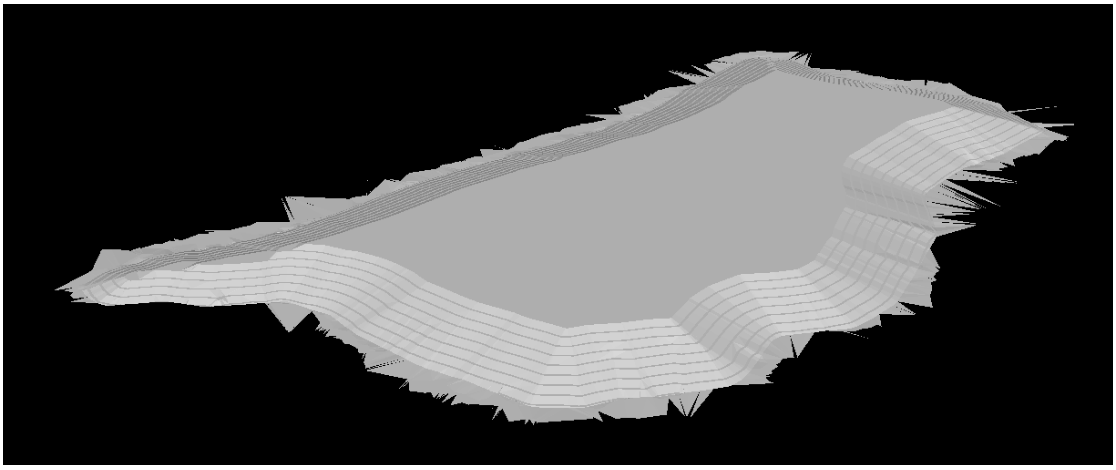


Figure 3-2: Initial linear stepped design option with 20 m high benches

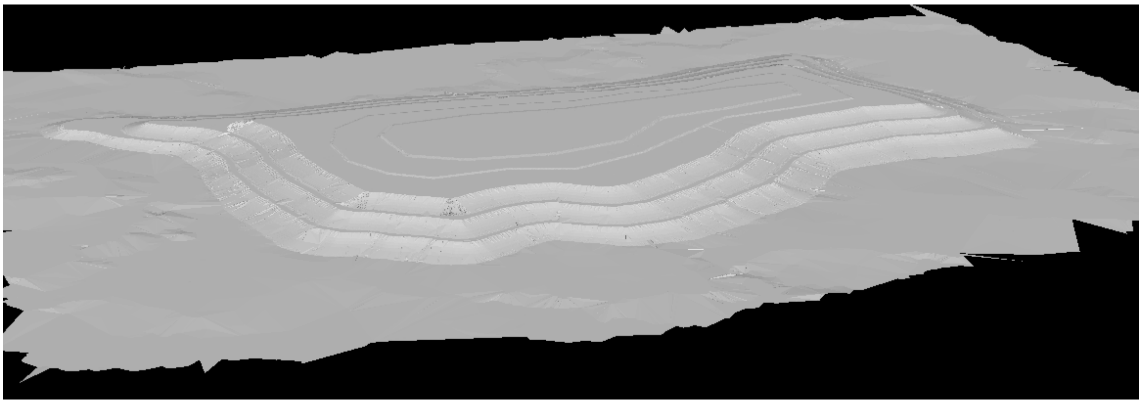


Figure 3-3: Initial concave slope design option using 45 m high lifts

For each of the initial designs, two surface material configuration scenarios were considered, namely:

- the as-built or constructed scenario prior to the placement of the outer layer, immediately after placement of a mixture of coarse tailings, fine tailings and rock; and
- the final rehabilitated scenario, with the outer layer comprising a mixture of rock, subsoil and topsoil.

A geotechnical stability assessment was undertaken for each of the two material configuration scenarios, (**Appendix C**, **Section 3.2.4**), together with a sensitivity analysis for the derived erodibility parameters, and the potential impact of variability of the proportions of soil and rock materials in the outer surface mix (**Appendix D**, **Section 3.2.5**).

3.2.4 Geotechnical stability

To assess the geotechnical capacity of the combined waste materials during construction to support the stacking machinery, a conservative assessment of the potential weakest material configuration was conducted by Jacobs (2015a) (**Appendix C**). The stability assessment assumed that the IWL is composed generally of 50% coarse and 50% fine tailings, with an angle of shearing resistance of 38°. The strength model adopted in the design does not account for strength increase with increasing depth and is therefore conservative. It is assumed that the waste material will be placed at its angle of repose (38°) during construction.

Therefore, the outer face of the IWL is expected to have a Factor of Safety (FOS) of approximately 1 during construction (angle of repose) (Jacobs 2015a). It is understood that the slope will be re-profiled in the longer term to provide a more stable long term batter slope at closure.

Furthermore the estimated factor of safety against bearing capacity failure beneath the tracks of the stacker machine for an applied pressure of 120 kPa is 3.0, with estimated settlement of 25 to

40 mm (Jacobs 2015a). The anticipated factor of safety is considered more than adequate for the transient nature of the load, and it is understood that the estimated settlements are within the tolerances of the stacker machine. The addition of rock, oxide or fresh crushed rock to the waste stack of 25% tailings, should only add further stability to a structure considered to be stable both during construction and in the longer term. Further detail of this analysis and the parameters are contained within **Appendix C**.

3.2.5 Landform evolution and erosion modelling

3.2.5.1 Initial approach for base case designs

The SIBERIA landform evolution model has been used for the erosion assessment of post-mining landforms (Hancock *et al.* 2008, Willgoose and Riley 1998) as well as natural catchments (Hancock, Willgoose and Lowry 2013, Hancock *et al.* 2010). SIBERIA has been extensively tested and validated at the Ranger Uranium Mine in Northern Territory, with simulated erosion rates compared to field measured data and similar geomorphic catchments. In addition, SIBERIA has been applied successfully as part of the landform design process on mine sites across Australia. Based on its successful track record, the SIBERIA model has been selected to model the proposed IWL designs.

Importantly, SIBERIA uses annualised erosion rates based on the long term performance of landforms. Comparative modelling of rainfall event based models such as CAESAR-Lisflood and SIBERIA (Hancock *et al.* 2014) have shown that, although the SIBERIA model doesn't include specific extreme flood events, the erosion rates and patterns generated are broadly similar to those produced by models that do include the specific flood events.

For the purposes of the study, erodibility parameters required as input to the SIBERIA model were compiled using the geotechnical properties of the materials (Jacobs 2015b) (**Appendix D**). The parameters used in the modelling are given in **Appendix D**, including values for:

- a 50:50 mix of coarse and fine tailings, considered to be a conservative input for the pre-rehabilitation landform. The performance of these materials were assessed over a 5 year period only, being a conservative assessment of the potential exposure period prior to the placement of the outer surface materials;
- various combinations of rock, subsoil and topsoil in the outer surface cover layer varying from:
  - 33% equal mix, considered to be an unlikely scenario, but used for a sensitivity analysis;
  - 50% rock, 25% subsoil and 25% topsoil, considered to be a possible outer layer mixture; and
  - 75% rock, and an equal mix of subsoil and topsoil, considered the most likely outer layer mixture at this stage.

It is important to note the preliminary nature of these assessments, and although quantitative results have been generated in the modelling process, the greater value of the modelling is in the comparative results for the different landform design options. The quantitative extent of likely future erosion will be validated during the detailed design phase. It should also be noted that for the purposes of this study, vegetation was excluded from the erosion modelling assessment as detailed in **Appendix D**.

3.2.5.2 Initial outcomes for base case designs

Examples of the initial erosion modelling outcomes are shown in **Figure 3-4** and **Figure 3-5** (short term modelling, 20 m linear stepped design, 50:50 coarse fine tailings only) and **Figure 3-6** and **Figure 3-7** (longer term modelling, concave design, 50:25:25 mix of rock, subsoil and topsoil in the outer cover layer). It was found that the two design options assessed could both perform adequately, wherein the outer slopes of the rehabilitated landform were predicted to erode at an average rate of around 10 to 20 t/ha/year over a period of 200 years, which is considered reasonable for an IWL facility, with no fatal flaws identified (Jacobs 2015b). It is important to note that the sediment remains on site due to the use of benches for both design options, and that the predicted maximum gully depth was of the order of 2 m, being within the outer capping layer.

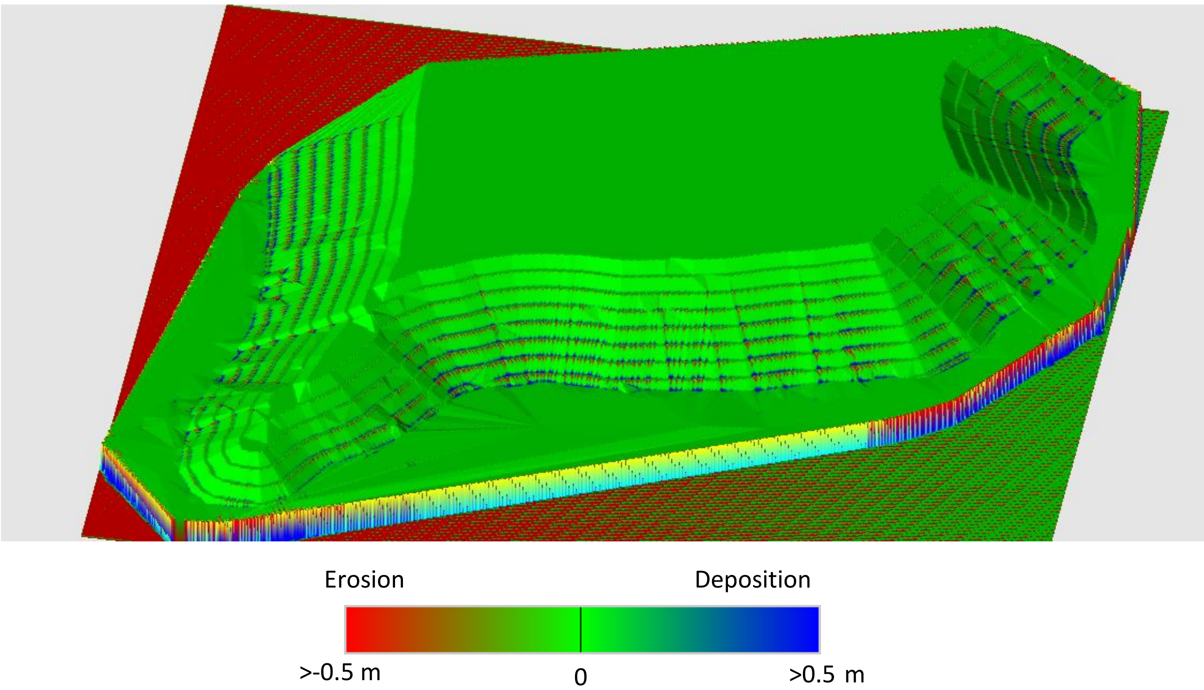


Figure 3-4: Short term modelling (5 year simulation) for the 20 m linear stepped design option assuming a 50:50 coarse and fine tailings fraction during construction (Jacobs 2015b)

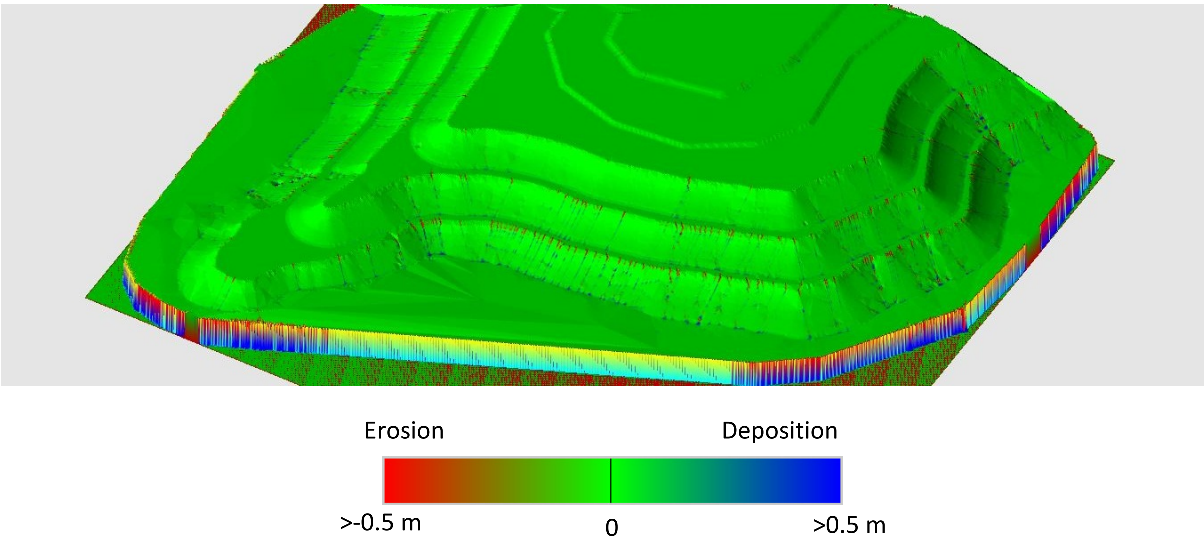


Figure 3-5: Short term modelling (5 year simulation) for the 45 m concave design option assuming a 50:50 coarse and fine tailings fraction during construction (Jacobs 2015b)

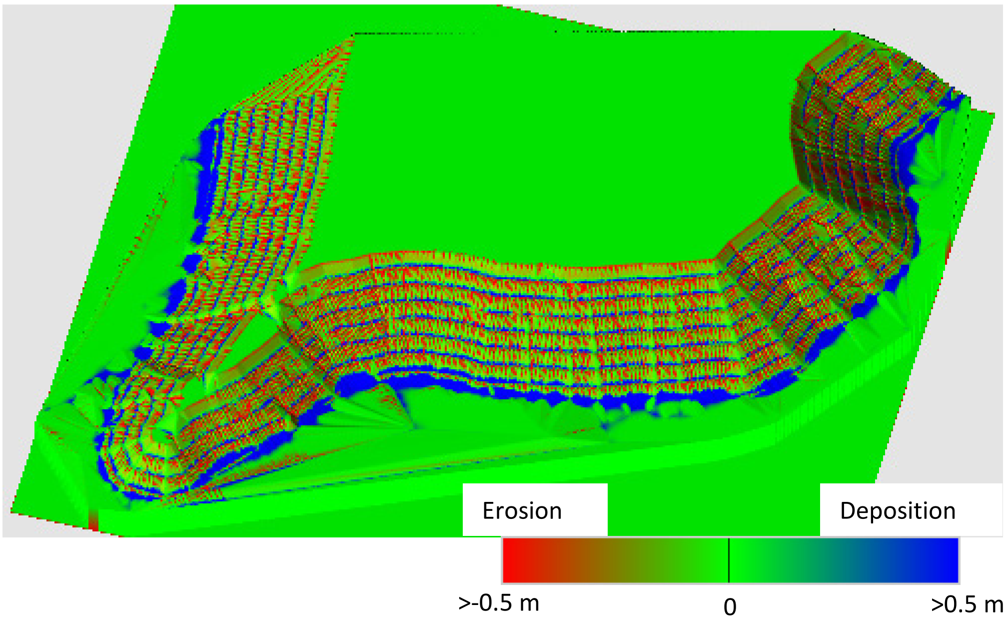


Figure 3-6: Long term modelling (200 year simulation) for the 20 m linear stepped design option, assuming a 50:25:25 waste rock, subsoil, topsoil in the outer cover layer post-rehabilitation (Jacobs 2015b)

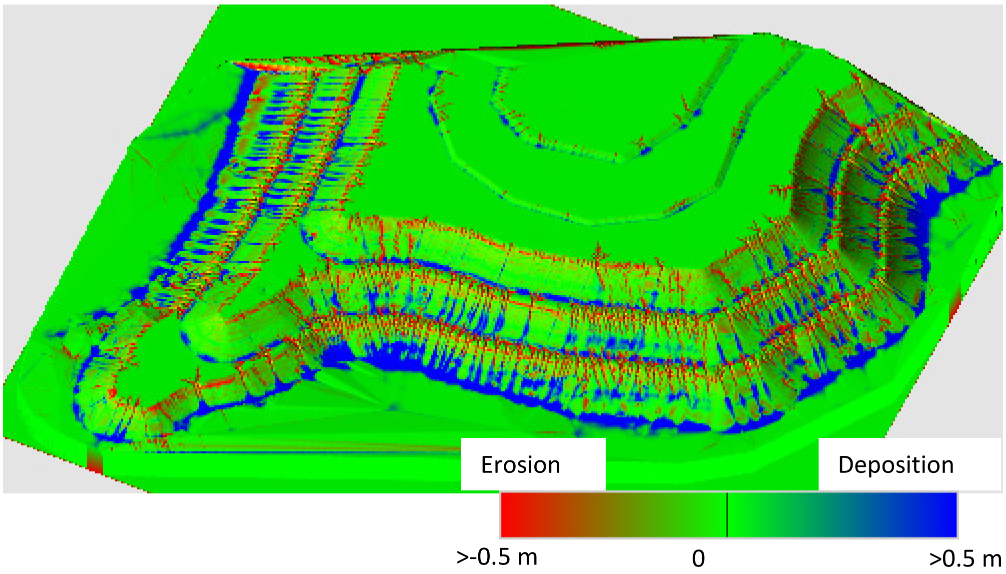


Figure 3-7: Long term modelling (200 year simulation) for the 45 m concave design option, assuming a 50:25:25 waste rock, subsoil, topsoil in the outer cover layer post-rehabilitation (Jacobs 2015b)

4 PREFERRED INTEGRATED WASTE LANDFORM DESIGN

4.1 Preferred IWL design parameters

The erosion modelling study for the base case design options identified several overarching considerations that the preferred IWL design would achieve. These included;

- slope angles that will be kept as low as practicable (<18°), taking into account footprint and logistical constraints. With the majority of slopes concave and, depending on the IWL height and resulting slope length, broken into sections between wide, back-sloping berms to encourage surface water infiltration into the store release cover;
- a store release cover that acts to limit infiltration through to the saline tailings and co-mingled PAF/ANC mine waste stored within the IWL; and
- the placement of salvaged topsoil material on the outer surface of the IWL, dependent to some degree on the final design of the IWL for closure. It may be beneficial to target specific areas of the IWL for selective placement of rehabilitation resources and develop specific rehabilitation prescriptions (e.g. soil depth, surface treatment and seed mixes) which are targeted for certain positions across the constructed landform, such as flat upper surfaces compared to batter slopes.

The conceptual landform design presented here does not detail the specific placement or scheduling of topsoil, subsoil, mine waste, or combined tailings/waste rock materials, but provides a preferred landform design upon which subsequent waste placement, optimised scheduling, and rehabilitation prescriptions can be based.

Although the initial outcomes of the erosion modelling were considered favourable, it was apparent that a number of challenges remained, including:

- minimising the risk of progressive failure should over-spilling of one of the benches occur; and
- addressing concerns around the longer term performance of the design, that is, post 200 years when the benches have potentially filled with sediment.

It was also clear that the natural analogues in the area tend to be concave from crest to the toe. However, analysis of the potential to form a completely concave outer slope indicated that it would not be practical, both in terms of the volumes that could be stored, and the construction constraints.

A preferred design was then developed incorporating the following approach:

- the front stack of each conveyor was designed as a concave slope, with typical heights of 30 m, although increasing slightly due to the back slope of the benches, as well as for the lower bench were the height can reach 50 m in places due to the variation of the Nominal Ground Level (NGL).

The slopes on the concave slopes range from 18 degrees (1v:3h) to 11.3 degrees (1v:5h) for the 30 m high lifts, but flatten further for the longer slopes, becoming 9.46 degrees (1v:6h) toward the toe of the slope;

- for the lower back stack of each conveyor, the slopes are linear with typical heights of 15 m, again increasing slightly due to the back slope of benches to close to 20 m for the bottom conveyor, these slopes being at 18 degrees (1v:3h);
- the bench widths progressively increase moving downslope, with each bench designed to be able to accommodate the full sediment loading and runoff for the design event for the full upslope catchment. The benches thus vary from 20 m on the upper bench, to 100 m for the lowest and widest bench; and
- each of the upper four back sloped benches will have design crest bund, typically 1.5 m in height, to limit the risk of overspill from the bench.

A cross-section of the preferred design is shown below in **Figure 4-1**, and site layout plan view in **Figure 4-2**. 3D perspective views of each the preferred design are shown in **Figure 4-3**, **Figure 4-4** and **Figure 4-5**.

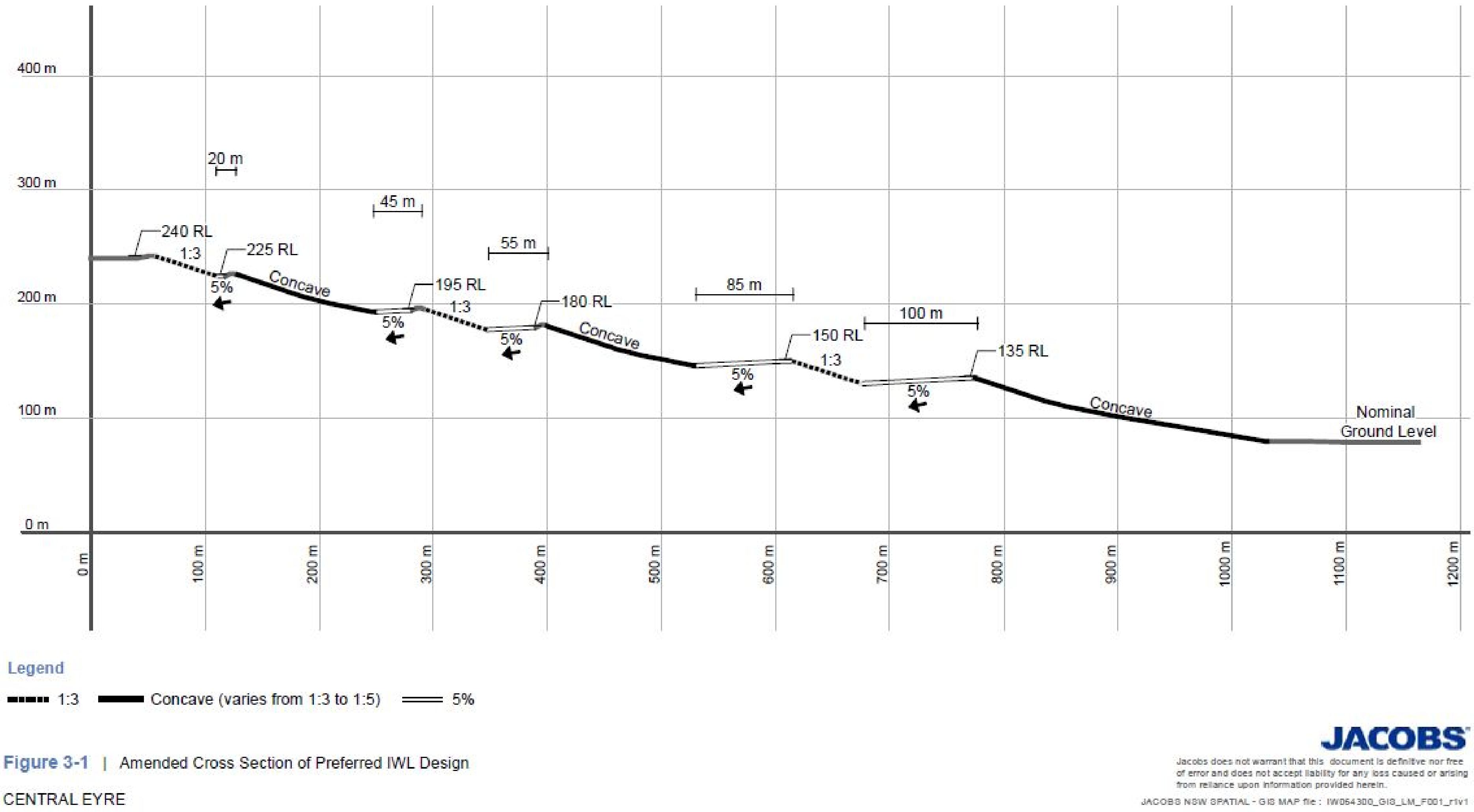


Figure 4-1: Amended cross section of the preferred IWL design (Jacobs 2015b)

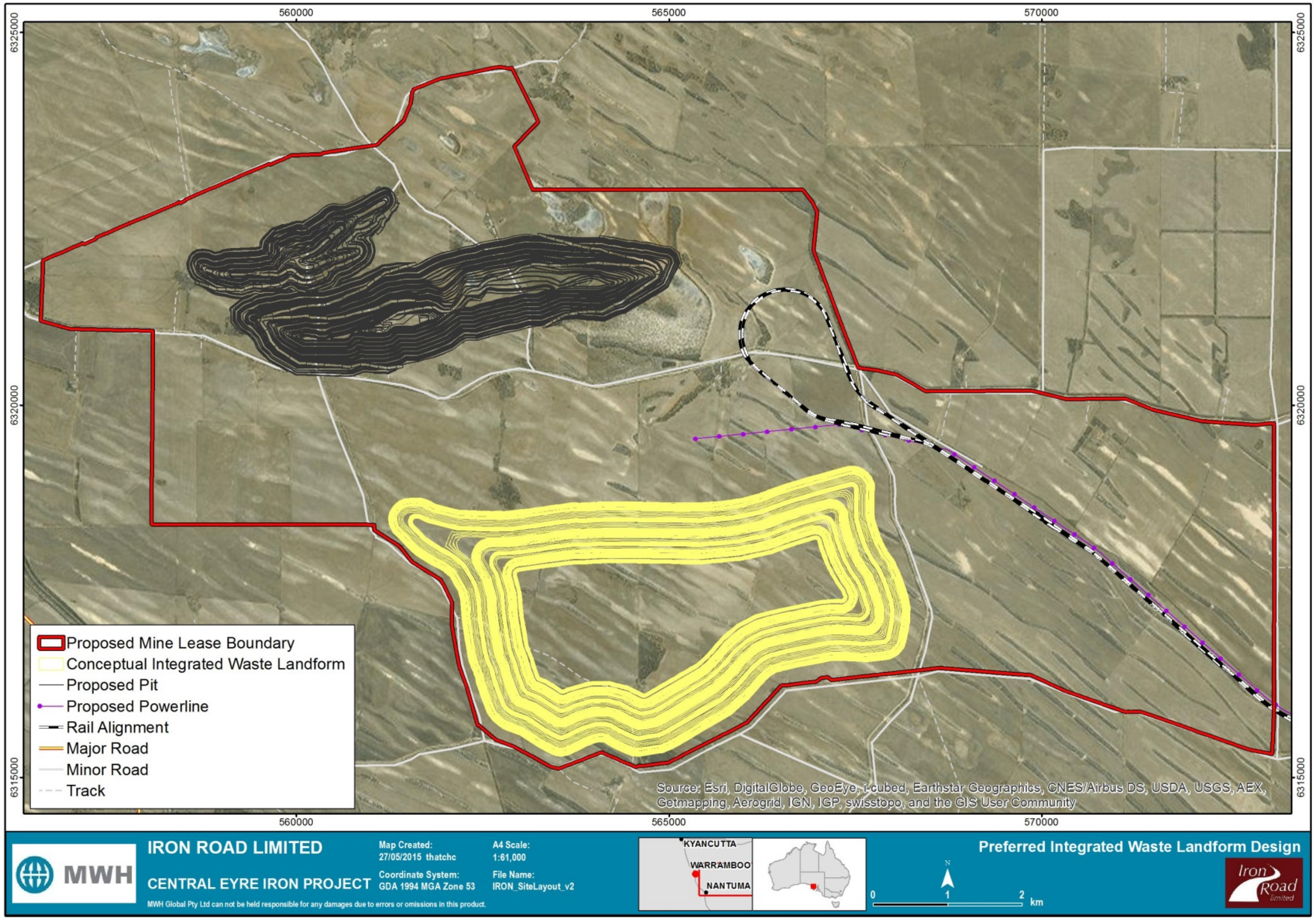


Figure 4-2: Preferred landform design for the CEIP IWL, plan view

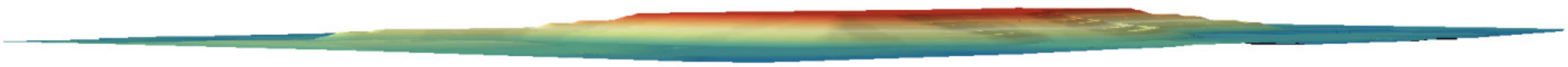


Figure 4-3: Eye-level 3D perspective view of the preferred IWL design (from south-west), shaded by elevation

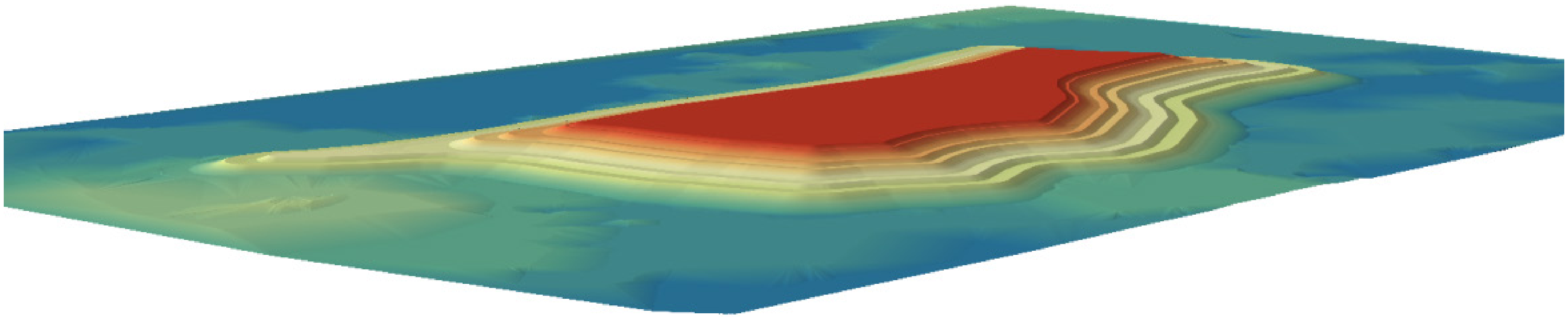


Figure 4-4: 3D perspective view of preferred IWL design (from south-west), shaded by elevation

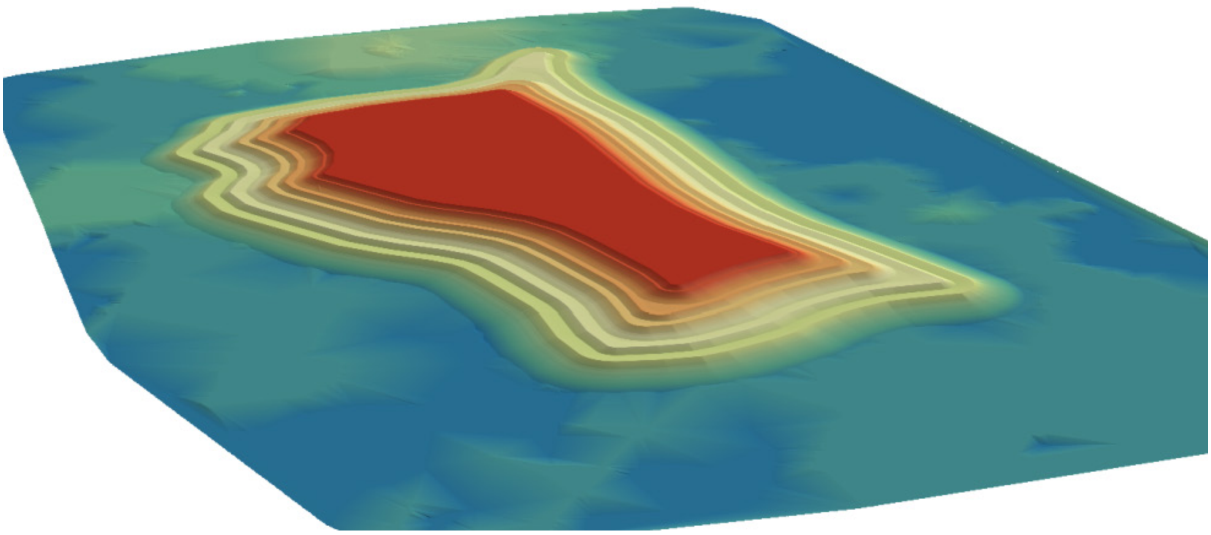


Figure 4-5: 3D perspective view of the preferred IWL design (from south-east), shaded by elevation

The benefit of the progressively wider benches is as follows:

- there is a provision to prevent progressive failure down the slope, since each bench can theoretically contain the total sediment and runoff load from the upslope catchment;
- consequently, the lower bench designs are extremely conservative for the 200 year modelling analysis should there not be overtopping from the upper benches;
- the wider benches will provide significant attenuation of any future overspills, that is, the peak flow rates of any overspill will be significantly reduced, which will further reduce the risk of erosion in the long term; and
- the overall landform has a concave appearance and thus visually should blend more with the local environment than the previous designs, but the design is still able to achieve the required volumes for the IWL.

It should also be noted that there will be a substantial crest bund placed on the upper surface crest. All the berm surfaces will be shaped to ensure water is contained and does not flow along the berm, and ponding of water against the crest bund will also be minimised by the back sloping grade of the upper berm surface, limiting the risk of piping.

4.2 Erosion modelling outcomes

The erosion modelling outcomes are shown below for the case of the constructed landform prior to placement of the outer cover layer (5 year modelling duration) (**Figure 4-6**), and the final rehabilitated landform (200 year modelling duration) (**Figure 4-7**).

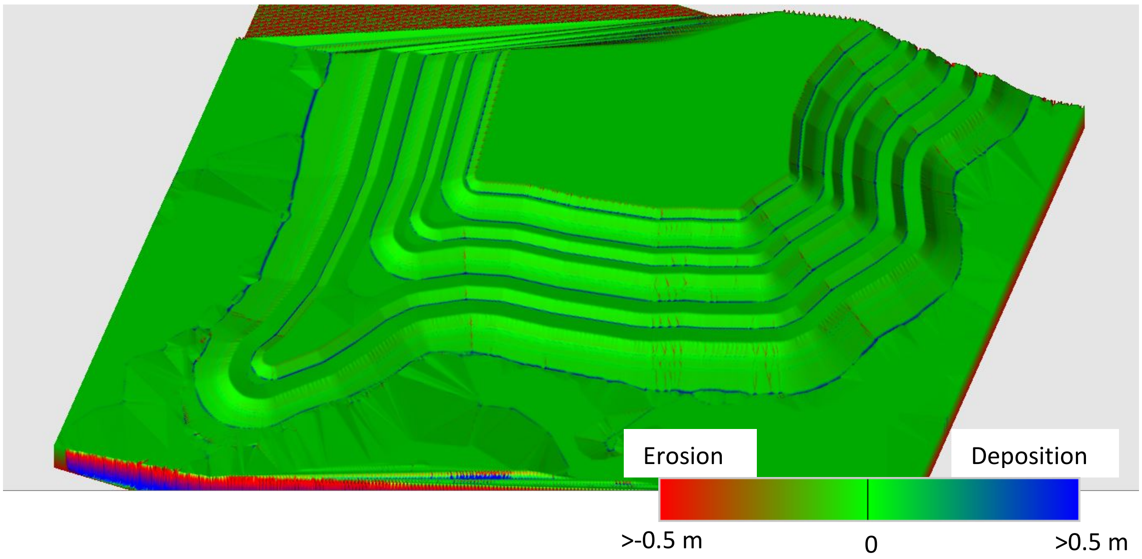


Figure 4-6: Erosion modelling of preferred landform design prior to cover placement; 5 year duration (Jacobs 2015b)

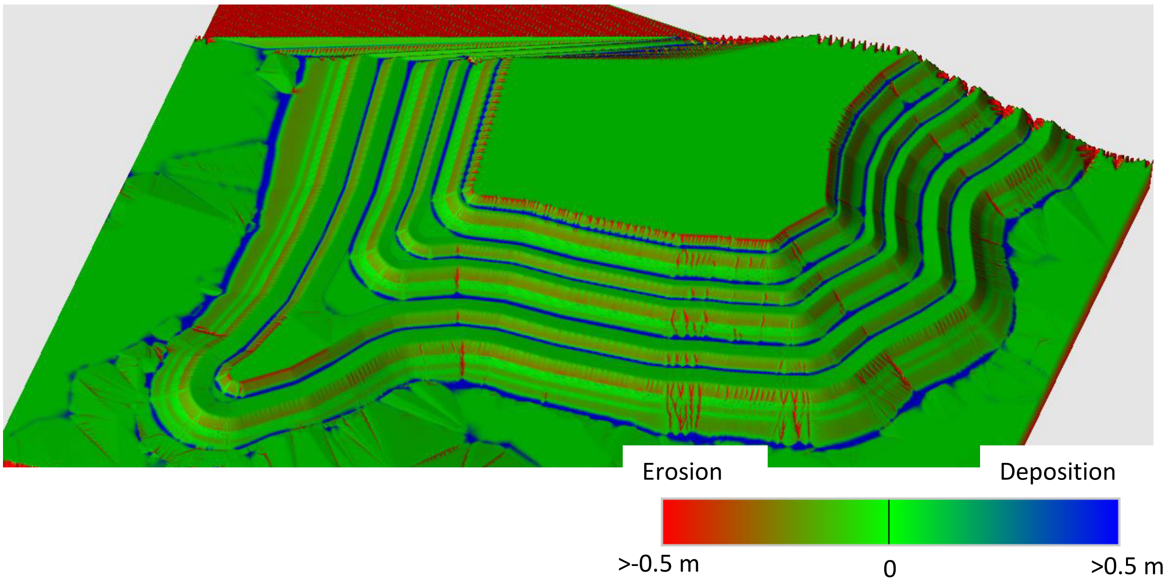


Figure 4-7: Erosion modelling of preferred landform design after cover placement; 200 year duration, based on 50% rock and equal proportions of subsoil and topsoil (Jacobs 2015b)

Important outcomes from this modelling include;

- the overall erosion rate without bunding on the benches was of the order of 5 to 10t/ha/yr, within the target erosion rate;

- sensitivity modelling with the crest bunds in place has also indicated that the lower wide benches will be able to store sediment for significantly longer periods than the original 200 year design period, currently predicted to be in excess of 500 years;
- a finer model resolution was used to assess the performance of the bunding on the benches, and they have been found to be effective in reducing the erosion rate to the lower range, typically around 5 t/ha/yr. This reduction is largely due to the removal of progressive inter bench and gullying evident in **Figure 4-7**, where overspill from an upper bench causes additional erosion on the lower slopes; and
- the benefit of attenuation of flows in reducing the impact on lower slopes once benches have filled with sediment has not been quantified to date, but is expected to be considerable in the longer term.

4.3 Sensitivity analysis

Comparison of the erodibility of the final landform for different proportions of rock was also investigated by Jacobs (2015b), and indicated the following:

- at 50% rock in the outer layer, erosion rates are currently predicted to be around 5 to10 t/ha/yr; and
- at 75% rock in the outer layer, erosion rates are predicted to decrease by around 30% compared to the 50% rock cover scenario;
- at 33% rock in the outer layer, erosion rates could increase by around 50% compared to the 50% rock coverage scenario.

As indicated previously, these values are still preliminary, but there is clearly a benefit in ensuring a rock percentage in the outer surface layer in the order of 50% or greater.

4.4 Summary of preferred landform design

Given these constraints and assumptions, outcomes of the preferred landform design for the CEIP IWL are as follows:

- current volume capacity of preferred landform design is 1,816 million m^3 [3], based on design dimensions of;
  - an average total landform height of between 135 to 160 m, with variability due to underlying natural topography (average landform height ranges from 130 m above topographical highs to 170 m above topographical lows);
  - an elevation of 240 m AHD for the upper surface of the IWL, with underlying elevation ranging from 70 to 110 m due to the natural topography (average of 80 m elevation);

[3] Equivalent to 6,048 million tonnes at an assumed consolidated stress bulk density of 2.8 t/m^3.

- footprint area of 1,970 hectares (excludes a 50 m buffer between the final rehabilitated landform toe and proposed mine lease boundary);
- a conceptual slope configuration that accounts for surface water management and long-term slope stability;
  - a slope design concave in nature for the 30 m high, longer slopes with a configuration of 18 degrees to 11.3 degrees, and a linear slope of 18 degrees for the 15 m high shorter slopes;
  - a final slope design for closure, to be achieved by small amounts of reshaping during progressive rehabilitation;
  - slope lengths from 50 m to 250 m with a series of back-sloping berms and batters, and a bund around the upper flat surface; and
  - berms are back sloped to ensure adequate capacity to restrain large rainfall events and that water is not held against the outer edge of the landform.

The preferred landform design presented for the IWL has the advantages of (Jacobs 2015b):

- incorporating both linear and concave slopes over slope heights that have been shown elsewhere to be potentially stable in arid environments;
- a built in conservatism including:
  - the use of a lower rock percentage than is expected to be achieved on the outer slope;
  - exclusion of vegetation and associated benefits in stabilising the surface of the landform; and
  - bench designs that provide for significantly greater sediment and storm capture capacity than is theoretically required, particularly on the lower benches.

The concepts within this preferred landform design, as presented, are consistent with work in progress and conducted across waste rock and integrated waste landforms in Australia over the last 20 years. Concave and linear slopes, often armoured and of varied configuration, exist at mine sites such as Wiluna Gold and Mt McClure, with two integrated waste landforms containing tailings found at the Challenger Mine IWL and at Sunrise Dam with a 30 m high concave armoured slope. Large landforms with large, stable water harvesting berms can be found at Granny Smith, Leinster Nickel and Kalgoorlie Consolidated Gold Mines. At the Jundee mine, the W10 landform, with a 30 m vertical height armoured concave slope, has 0.15 m of topsoil ripped into the armoured surface, and is somewhat analogous to the preferred landform design presented here. Many sites could be considered analogues that are successful and do relate to the IWL that is proposed at the CEIP, though it is important to note that all have unique features which make direct comparisons somewhat difficult.

The preferred design for the IWL is considered to be conservative, with a high likelihood of very stable outer batters given the underlying material will be predominantly competent rock and dry tailings, followed by a layer of competent rock of 1.5 to 2 m depth (dust control and ultimately capillary break), and then a rock/soil growth media at a ratio of at least 50% rock. The final landform design and surface cover components will be subject to further verification and validation during the early stages of mine commencement as outlined in **Section 5**. In addition, the design will incorporate water control across the upper surface, crest and batters of the IWL to restrain any erosional risk created by uncontrolled water moving across the landform.

4.4.1 Additional storage options

The preferred conceptual IWL design in **Section 3.2.1.1**, represents the 'base case' landform footprint available for construction of the IWL. This design has a storage capacity volume of 1,816 million m^3, which is below that required for storage of the total combined LOM waste rock and tailings volume of 2,648 million m^3 (**Table 4-1**). The current preferred design provides capacity for 54% of total LOM waste rock/tailings volume.

Table 4-1: Design capacity versus required for the preferred IWL design

Mine waste material type	Total LOM waste materials		Preferred IWL design		Capacity vs required [3]	
	LOM tonnes (Mt)	LOM volume (Mm^3) [2]	Tonnes (Mt)	Volume (Mm^3) [2]	Tonnes (Mt)	Volume (Mm^3) [2]
TOTAL [1]	**7,413**	**3,370**	**3,995**	**1,816**	**-3,418**	**-1,554**

1. Total combined LOM waste rock and tailings for storage within the IWL.
2. A consolidated stress bulk density of 2.2 t/m^3 assumed for the combined tailings/waste rock upon deposition within the IWL (information from Iron Road).
3. Capacity of 'base case' preliminary conceptual IWL design compared to total LOM volumes.

In consultation with Iron Road, additional options have been identified for potential waste material storage upon subsequent review of the capacity of the preferred IWL design outlined in **Section 4.4**, in comparison with likely LOM volumes for the combined waste rock and tailings materials. These additional options provide contingency for any changes in the total LOM waste material volumes to be further refined during the ongoing optimisation process (**Section 4**), and may be considered during the later stages of the mine life of the CEIP. These include;

- additional IWL storage zones within a 'new footprint' area (**Figure 4-8**);
  - expansion of the existing IWL footprint to include one extra zones to the north to increase storage capacity of the IWL design; and
  - back-filling of sections of the open pit as they become available according to the mining schedule.

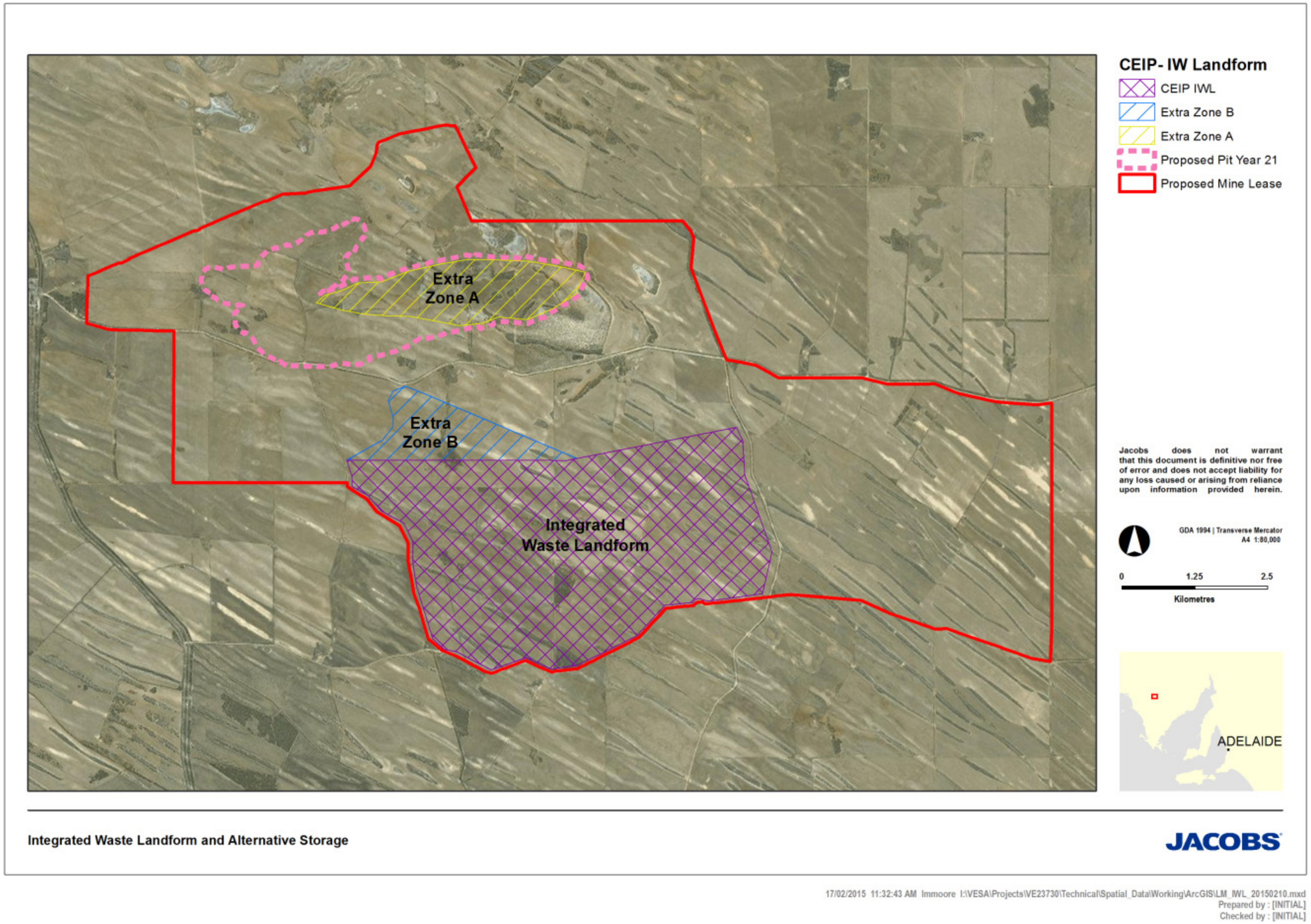


Figure 4-8: Additional waste material storage options for the IWL (sourced from Jacobs)

The preferred conceptual landform design modelled for the IWL in **Section 4.1** has a capacity to adapt if total LOM waste material volumes, waste material characteristics and rehabilitation prescriptions change. The preferred design allows for variability in design parameters, such as;

- the natural topography (detailed in **Section 3.2.2**);
- assumed characteristics of the combined waste rock/tailings materials, such as the final bulk density once deposited within the IWL;
- the thickness of the final soil cover profile required; and
- further definition of volumes of PAF and ANC as the mine progresses.

Further definition of characteristics of the combined waste rock/tailings material during ongoing investigations will aid in the next stage of development and optimisation of the preferred IWL design, from the conceptual stage to the detailed design stage. Further investigations for optimisation of the preferred IWL design are discussed further in **Section 5**.

4.5 AMD management planning

Recommendations for management of potential AMD within the landform design based on the INAP GARD Guide have been considered within the IWL Management Plan report, along with a geochemistry review of the oxide zone and summary of the GARD Guide recommendations (**Appendix E**). Currently the preferred design will implement a 'Store and Release' cover as this design is deemed appropriate as a closure and rehabilitation strategy for the IWL. The upper surface of the final IWL will be designed to encourage surface water infiltration for retention within the store release cover and to not travel down the batters of the landform. The upper surface will be broken into cells, separated by appropriately sized bunds, to encourage water to infiltrate into the cover evenly across the upper surface, alleviating any requirement to shed surface water down the sloped batters or drainage structures. It should be noted that the waste rock material, once mined and deposited in the waste landforms, will have a greater capacity for water and root penetration, and water storage, than much of the pre-mine soil profile of the current landscape, in which root exploration and water storage may be limited to cracks and weathered discontinuities in the calcrete layer and pockets of weathered regolith.

Non-acid forming waste rock would comprise the basal, upper and outer surfaces of the landform in order to minimise the potential percolation of water into potentially acid generating material (MWH 2015, **Appendix E**). Additionally, waste material stored deeper within a landform will have slower rates of oxidation than material located closer to the outer surfaces of a landform. Finally, co-disposal of AMD material with acid neutralising waste material provides buffering ability in the event of failure in cover design or in waste material planning and placement.

4.6 Soil cover profile reconstruction

4.6.1 Key soil cover design elements

Establishing an effective soil cover on the IWL is integral to the long-term success of rehabilitation and closure. Key elements of cover performance include infiltration of rain water, long-term surface stability, evapo-transpiration and soil water storage to support biological processes such as plant growth, nutrient development and retention, and soil biology. Ideally, the IWL should be rehabilitated in such a way that the natural processes of the surrounding landscape are emulated as best as possible. This will ensure that the soil and mine waste can effectively regulate the transfer and storage of water and nutrients within different areas of the landform, promote the establishment of vegetation and therefore minimise potential impacts to the surrounding environment. The extent to which this can be practically achieved will be dependent on the nature and placement of the mine waste and growth media, and the design of the IWL.

Criteria for establishing an effective soil cover are outlined below;

- Hydraulic and water storage properties
  - A critical aspect of the hydraulic properties of soil covers is the capacity of the cover to control rainfall infiltration through 'store and release', minimise through-drainage into any stored PAF mine waste materials, and to protect the growth cover from capillary rise of salts via the application of a 1.5 to 2 meter capillary break. The applied store and release cover will be designed appropriately for this task, as it has been determined that there will be minor percentages of PAF waste material storage areas within the IWL, and that salt is present in the tailings/waste rock material.
  - The performance of the soil cover in this aspect will result from a combination of both its physical properties and its overall capacity to support plant growth. The physical properties will directly influence rainfall infiltration and water storage in the profile, and will also control how effectively plant roots are able to explore and take up stored water. The volume of water that is removed by evapo-transpiration not only depends on these 'below-ground' factors, but also on the leaf area produced above ground. Productive vegetation will drive the most water use, and this productivity will in turn be strongly dependent on the chemical and biological fertility of the soil profile.
- Long-term performance
  - The long-term performance of the soil cover, and the vegetation that it supports, relies on the ability of the cover to resist erosion. This erosion risk is directly related to landform design parameters, particularly slope angle, slope length and control of surface water flow from higher zones of the landform, in combination with physical properties of the cover materials.
- Final cover sequence

- The final cover sequence of topsoil, subsoil and other resources such as oxide waste, should preferably have some commonality with natural soil profiles to enhance the ability of the seed of native species to germinate, establish and survive in the cover material. The reconstructed soil cover will likely represent the natural soil profiles, with the exception of replacing the calcrete horizon commonly found in natural soil profiles within the area. The reconstructed soil profile is therefore likely to be more favourable for root exploration than much of the natural soils in the area, depending on other potentially problematic soil properties such as salinity or sodicity. Unrestricted root exploration is important for maximising the potential productivity of vegetation. Plant productivity, is in turn correlated with leaf area and water use. Evapo-transpiration of rainfall that infiltrates into the landform surface is an important design element to minimise the potential of deep drainage through the landform and seepage.

- Physical integrity
  - Maintaining the physical integrity of the soil cover on the IWL is essential in restricting deep infiltration of incident rainfall into the waste landform. Therefore, control of surface water and prevention of erosion of the cover layers is critical. It is important that both these aspects are well understood and appropriately managed if the final cover design is to be successful. Protective surface and sub-surface rock mulch treatments can be beneficial in contributing to surface armouring and erosion resistance during rainfall events, reducing dust generation and promoting infiltration of incident rainfall into the soil profile (Jennings *et al.* 1993).

4.6.2 Construction of the soil cover profile

The conveyor/stacking system provides an unprecedented level of control in materials delivery, enabling targeted composition of both the waste materials stream (crushed rock and filtered tailings) and the surface cover materials stream (subsoil and potentially topsoil) in the construction of the CEIP IWL landform. This system can ensure that overall indicative soil requirements and their composition, such as the example presented in **Figure 4-9**, can be attained. This advantage can translate to a more diverse series of cover options specific to different landscape positions across the IWL. Those options will be selected following results of trials and investigations into final viable land use options. Indicative soil requirements for the current closure design include;

- Flat upper surface;
  - 0.15 m of topsoil;
  - 3 m of subsoil / waste rock mix (25% subsoil: 75% waste rock);
- Batter slopes;
  - 0.15 m of topsoil;
  - 2 m of subsoil / waste rock mix (25% subsoil: 75% waste rock).

Based on the above indicative soil requirements, initial soil resource estimates (**Section 2.2.1.2**) indicate that sufficient quantities of topsoil and subsoil materials are potentially available for use in construction of a soil cover across the IWL (**Table 4-2**). However, it is important to note that the quality and suitability of the available soil resources for use in rehabilitation prescriptions is yet to be determined and requires further investigation. This preliminary indication of soil resource requirements is based on the footprint area of the 'base case' preferred IWL design, which occupies an area of 1,970 hectares. The final outer surface area of the landform once constructed and reworked for rehabilitation, will be proportionally greater than the original footprint ground area of the landform. The final outer surface area of the landform will need to be determined once the final IWL design is confirmed, in order to refine soil cover requirements for rehabilitation.

Table 4-2: Initial estimates of soil resource requirements for rehabilitation of the IWL

Soil resource	Position on outer surface of landform	Indicative soil cover requirements [1, 2]		Potentially available soil volumes [3]
		Depth in reconstructed profile (m)	Volume required (Mm^3)	Volume (Mm^3) (Jacobs [3])
Topsoil	Batters and flats	0.15	2.95	
TOTAL			**2.95**	**10.2**
Subsoil	Flats	3	14.7	
	Batters	2	9.8	
TOTAL			**24.5**	**39.8**

1. Based on an original footprint area of 1970 ha for the preliminary IWL design. The final outer surface area requiring application of a soil cover for rehabilitation will be proportionally greater than the original landform footprint.
2. Preliminary subsoil/waste rock mix of 25% subsoil: 75% waste rock.
3. Based on soil volume estimates by Jacobs (2014a, 2014b) (**Table 2-6**).

CEIP has an opportunity to create multiple land use areas across the IWL once these options are verified, considered sustainable and viable, and relative to scientific, landform closure and commercial values.

Stacking provides the ability to strategically design the mix of surface materials for different areas, such as flat upper surfaces or slopes. Selected reconstructed soil profile depth and composition (ratios of subsoil/waste rock or topsoil/waste rock) to support growth of native vegetation or alternative land use are made possible through the conveyor stacking system.

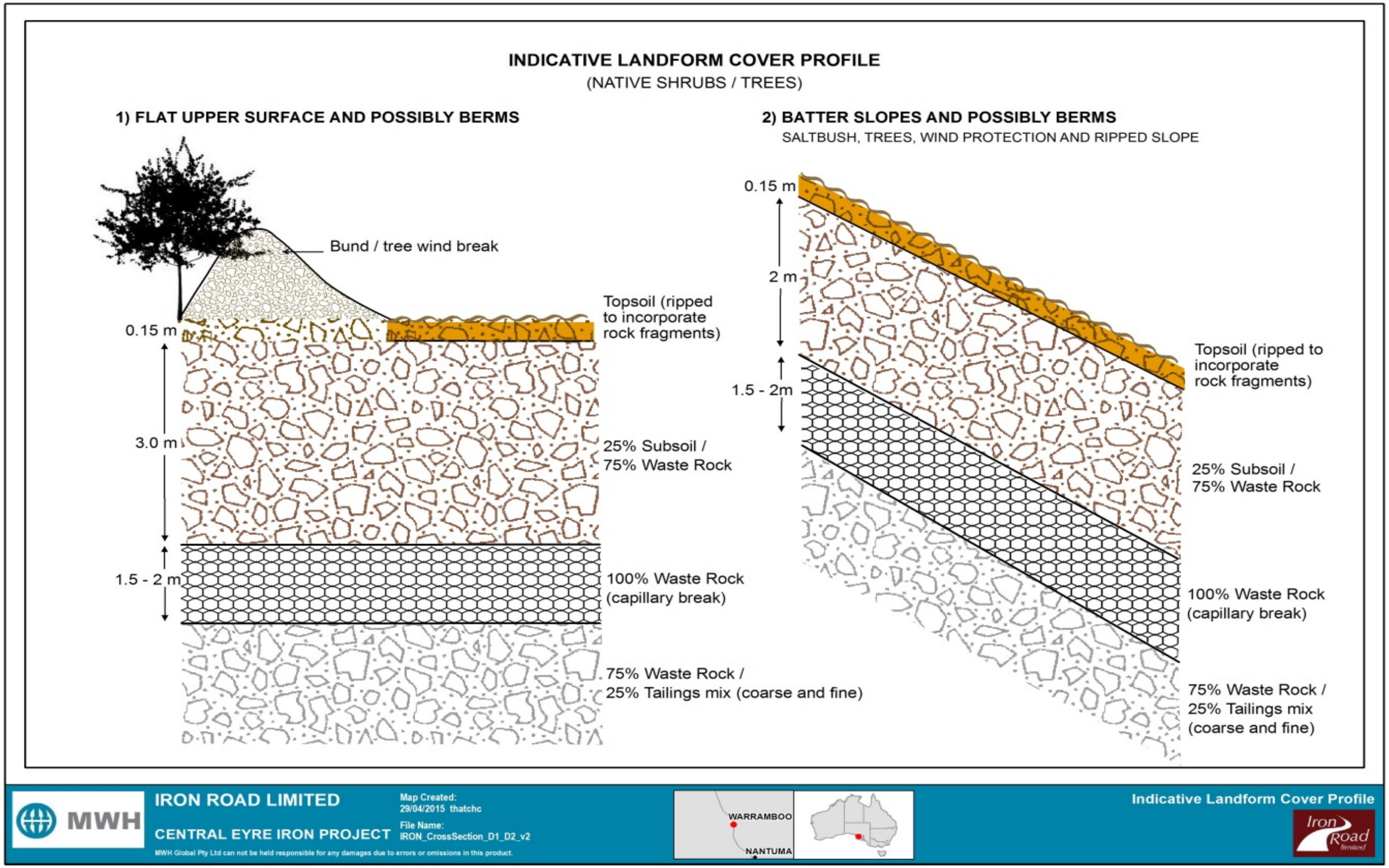


Figure 4-9: Conceptual reconstructed soil profile cross sections for the CEIP IWL base case scenario

Large volumes of upper profile soils are available within the footprints of the mine pits and the IWL for strategic collection. Quantification and classification of the soils for collection and stockpiling for immediate rehabilitation profile development during mining can commence well before mining commences. Preservation of native topsoil seedbank volumes (Jacobs 2014d) will also require consideration and strategic management, as will the use of farm topsoil to manage the potential introduction of weeds.

There is also the potential to use the coarse tailings and inert waste rock as gravel/rock mulch for temporal surface stability until final cover profiles (other than the current closure design) are researched and trials completed. Strategies for surface stability and dust mitigation are discussed further in **Section 4.6.3**.

4.6.3 Surface stability and dust mitigation

During construction, the landform will progressively move higher above the surrounding landscape, increasing exposure to the prevailing winds. As the IWL is constructed, the usual practice of operational dust management and mitigation will be applied. Conveyed stacking lends itself to providing the flexibility to have higher rock ratios in different zones to keep a more disruptive surface to this wind flow. For example, the ability to construct rocky wind barriers is available to interrupt the laminar wind flow, lessen wind speed and create more turbulence across the outer upper surface.

The landform batter slopes are likely to have considerable wind erosion potential. To reduce the potential for wind erosion and dust generation, erosion resistant subsoil/rock mixtures for stabilising the outer surface will be optimised and implemented. In the event that ripping is determined to be an appropriate management technique, contour ripping of batter and upper slopes may be used to create surface roughness for water and wind erosion control. However, due to the unusual ability of the stacking construction technique to define the rock/soil substrate mixes, these prescriptions will depend on an ongoing trial and assessment processes to determine which techniques, such as ripping, should be used.

Another distinct advantage with the stacking system is reduced dust generation compared to a conventional truck load, haul and dumping landform construction method. The high numbers of truck and tracked vehicles that generate dust during trafficking and end dumping of waste down angle-of-repose faces will be absent, aside from some smaller operational activities. The tracked stacker/conveyor is unlikely to greatly disturb the running surface of the combined rock and tailings as it moves across the landform, and the offloading chute can be controlled mechanically to reduce the fall distance of material from the conveyor. The stacked tailings will have an estimated moisture content of 7 to 10%, and will remain moist with the potential effect of dampening the waste rock and reducing dust generation.

During conveyance of the waste rock stream past the mill en-route to the IWL, the tailings will be combined on the belt with the crushed waste rock (crushed to approximately ≤ 160 mm in diameter), for all but the final placement of subsoil/topsoil/rock mixtures for the final cover layers. The tailings produced directly from the mill should maintain a moisture conditioned state as it is added to the conveyor and is then rapidly transported to the disposal point within the IWL. As the combined waste rock and tailings materials are deposited by the stackers, the void spaces between the coarse crushed waste rock will be filled with the tailings material, with an expected ratio of 60% waste rock to 40% tailings in the final product. Therefore during the bulk of IWL construction, the combined waste rock and tailings will provide stable surfaces prior to application of the reconstruction soil cover profile on the final outer surface of the IWL, as demonstrated in the erosion modelling study (Jacobs 2015b). Modelling outcomes for the preferred landform design during the construction phase indicate sufficient surface stability prior to placement of the outer surface cover (**Section 4.2**, **Appendix D**). Finally, as early stability is assured and final surfaces will be presented early in the mine life, progressive rehabilitation can commence early and will assist to control dust on final surfaces.

4.6.4 Material handling and placement

Separate collection, stockpiling and re-application of topsoil and subsoil resources will be an important component of the successful rehabilitation of target vegetation communities. Differences in soil properties and vegetation characteristics between areas constituting different habitats can often complicate the requirements for material handling. Soil stripping and handling guidelines however, must be broad enough to fit into logistical operations of earthworks and mining activities, and tailored to suit the characteristics of landforms and soils of the Study Area.

For growth medium (topsoil and subsoil) stripping:

- topsoil (native and agricultural) and subsoil horizons of the soil profiles in major disturbance areas associated with the project (e.g. mine pits, IWL, infrastructure etc) should be stripped and placed in separate stockpiles; as topsoil and subsoil respectively;
- subsoil should only be stripped to a specified depth in each area (to be determined during the forward work programme), to ensure that any potentially sodic, saline or clay-rich subsoil that may be considered unsuitable for use as a surface rehabilitation material is not collected as part of the subsoil resources;
- any coarse woody debris, surface litter, plant roots and vegetative material present within the topsoil horizon of the soil profiles is an important source of organic matter which can enhance many physical and chemical properties of the soil. This material should be collected and stockpiled with the topsoil, or directly placed onto the IWL rehabilitation areas, as the coarse organic material enhances the capacity of the soil to slow overland water flow and capture and retain water and nutrients;
- all stripped native topsoil material should be paddock-dumped into piles no greater than two metres in height. The topsoil piles should have adequate distance between them so as to create a series of mounds and troughs. This will serve to maintain the structure of the soil and will limit the potential for erosion to occur, as the runoff will be locally redistributed within the heaped piles; and

- machinery operators should minimise the frequency and intensity of disturbance so they do not compromise the structural integrity of the material (i.e. avoid dumping material from significant heights; repetitive rolling and compacting with machinery).

Soil stockpiling:

- native vegetation stockpiles should be reseeded with local, native species as soon as possible. Adequate vegetative cover will assist to maintain the structural and biological integrity of the material for when it is required as a cover material for rehabilitation purposes;
- excessive traffic and disturbance of the stockpiles should be minimised to prevent erosion. Appropriate signage should be erected at each stockpile advising site personnel and contractors of the type of material that has been stored and the activities that are permitted on or near the stockpiles;
- timing the removal of the material is important as in some areas it may result in the exposure of potentially sodic, dispersive and erodible subsoil. Therefore, soil stripping should occur as close as possible to the time when the proposed disturbance is scheduled to commence;
- separate stockpiling of sodic, clayey subsoil should occur; and
- deeper soil, sands, clay and calcrete that are suitable for the deeper growth / cover horizon may be stored in large and high stockpiles and potentially rock and vegetation mulched to stabilise the stockpiles during storage.

5 FUTURE WORK

5.1 Program for Environmental Protection and Rehabilitation (PEPR)

The development of the preferred landform design and rehabilitation and closure concept for the CEIP IWL, and review of available supporting information with ongoing stakeholder input, has enabled a level of understanding and supporting data which is commensurate with the current project phase. While this early process of concept development has naturally identified knowledge gaps for further refinement and investigation during the forward work plan, this is as would be expected for this stage of the project life-cycle (**Table 5-1**).

Following development of the preferred IWL design during the conceptual stage (as detailed in **Section 4**), it is anticipated that the preferred IWL design will be further improved via the process of validation, optimisation, investigation and ongoing data gathering as part of the PEPR implementation.

Key aspects to be included in the PEPR are:

Validation (confirming assumptions and predictions)

- Geotechnical strength parameters (field tests)
- Erosion rates (field trials, SIBERIA modelling)
- Water holding capacity / seepage rates (field trials)
- Dust emission rates from placed and rehabilitated surfaces (field monitoring)
- Salt movement in the cover sequence (field monitoring / observations)

Optimisation (gaining further knowledge to adjust design to achieve improved outcomes)

- Cover sequence material mix e.g. percentage of topsoil, sub-soil and rock (field trials)
- Cover sequence surface treatment e.g. rock mulch, straw, hydromulch, commercial products (field trials)
- Slope angles for constructability and erosion e.g. slope length and angle, berm width and any bund height (field trials)
- Weed control from the use of agricultural topsoils (field trials)
- Material movement and placement will be optimised using a commercially available mining software package (block modelling) that enables the source location (mine and other disturbance areas) to be tracked to the destination location (IWL) to ensure correct placement of PAF materials and the most efficient sequencing. ((pre-mining computer modelling)

Investigation (determining a design detail where options exist)

- Appropriate native vegetation selection for the varying areas of the landform such as the upper surface edges, upper slopes, lower slopes (local, state and national expert advice, field trials)
- Different application methods for native vegetation including direct seeding and/or seedlings and the soil preparation prior to treatment e.g. deep ripping (field trials)

- Micro-climate construction / zoning e.g. sand dune recreation, contouring, deeper profiles for specific species, landform undulations to mimic existing topography more closely (local, state and national expert advice, field trials)
- Final land use options in addition to base case which is native vegetation for top surface and slopes e.g. grain cropping, tree crops e.g. fruit, oil, biofuel, timber; or stock grazing (local, state and national expert advice, field trials)
- Potential for additional non-vegetation final land uses e.g. wing / solar power generation, recreational use (feasibility studies)

Ongoing data gathering and refinement (gaining more detailed data from which to adaptively manage)

- Additional, fine scale logging of existing soil cover sequence materials in all to be disturbed areas for use in final rehabilitation e.g. sand, clay, sodic and saline soils (field sampling)
- Additional, fine scale logging of oxide zone material during pre-strip and prior to mining (field sampling)
- Additional, fine scale logging of PAF and neutralising/buffering material in the oxide zone and fresh rock zones during mining, including further sulphide/sulphate quantification (field sampling, lab analysis)
- The block modelling of material movement will be regularly undertaken to inform other studies (field monitoring, computer model updates)
- Success of revegetation e.g. ecosystem function analysis or similar (field monitoring)
- Success of alternative final land uses e.g. commercial cropping, grazing etc. (field monitoring)

The extent of QA/QC will vary for all of the parameters listed above. Details of the QA/QC program will be established during the PEPR development process.

Table 5-1: Current understanding and knowledge gaps for the preferred landform design and rehabilitation

Mine Life Phase [1]	PFS	DFS	Project Approvals		Construction	Operation	Closure
			MLP	PEPR			
Aspirational level of understanding regarding site closure	High level only with multiple concepts considered.	One preferred closure concept.	1. Preferred design for closure/landform. 2. Understanding of site materials/wastes. 3. High level estimation of PAF/ANC materials present. 4. Closure impacts and risks understood. 5. Knowledge gaps clearly identified. 6. Draft PEPR elements.	Forward works plan to validate, optimise, investigate and gather ongoing data to ensure adaptive management is possible.	1. Refine concept design to detailed design for closure/landform. 2. Commence trials as landform develops 3. PAF material quantification, fine tune IWL Plan.	1. Landform in place. 2. Continue trials and monitoring of landform. 3. Implement IWL Plan, adaptive managemen t where required.	1. Landform well understood. 2. IWL Managemen t Plan implemente d. 3. Monitoring if required.
Current level of knowledge	Numerous concepts considered including slurry tailings and waste rock and integrated waste in a dry stack landform.	Preferred option selected: delivered by mobile stacker, integrated waste rock and tailings landform.	1. Concept for preferred option developed and documented in IWL closure concept report. 2. Geotechnically and geochemically conservative concept based on baseline understanding of materials. 3. Knowledge gaps understood and documented in IWL Closure concept report. 4. High level estimation of PAF/ANC materials undertaken. IWL management actions understood. 5. Impacts and risks associated with concept IWL understood and documented in MLP.	All impacts and risks assessed with PEPR under development. Continued discussions with stakeholders around ideas and future research.	NA	NA	NA

1. IWL= Integrated Waste Landform; PFS = Pre-feasibility Study; DFS = Definitive Feasibility Study; MLP = Mining Lease Proposal; PEPR = Program for Environmental Protection and Rehabilitation; PAF = Potentially Acid Forming; ANC = Acid Neutralising Capacity

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Appendix A Preliminary CEIP pilot tailings laboratory test work

A.1 Preliminary laboratory analysis of CEIP pilot tailings characteristics

Objective:

A bulk sample of pilot tailings from the CEIP were supplied to MWH by Iron Road to conduct preliminary laboratory test work for physical, chemical and geochemical parameters. The aim of the laboratory test work was to determine the physical, chemical and geochemical characteristics of the combined tailings product, to represent the tailings component of the combined tailings and waste rock stream to be deposited in the IWL. Previous geotechnical investigations had been conducted on the individual fine and coarse tailings streams by ATC Williams (Iron Road Limited 2013b). Samples of the fine and coarse pilot tailings streams were combined at the following ratio to represent the final combined tailings product, which is expected to comprise of;

- 55% fine tailings; and
- 45% coarse tailings.

Parameters assessed included the following;

- Physical characteristics:
  - particle size distribution (% clay, % silt and % sand) of the >2 mm fraction;
  - texture classification and coarse fragment content;
  - saturated hydraulic conductivity;
  - structural stability (Emerson Test) to determine dispersion susceptibility;
  - water holding capacity;
  - soil strength to determine susceptibility to hard-setting;
- Chemical characteristics:
  - pH, EC, organic carbon, plant-available nutrients;
  - exchangeable cations to determine cation exchange capacity (CEC) and exchangeable sodium percentage (ESP);
  - total metals and multi-element assessment; and
- Geochemical characteristics:
  - Net Acid Production potential (NAPP), Net Acid Generation (NAG), total sulphur, Acid Neutralisation Capacity (ANC).

Test work and procedures:

CSBP Soil and Plant Laboratory conducted analyses on sub-samples of the pilot tailings for plant-available ammonium and nitrate (Scarle 1984), plant-available phosphorus and potassium (Colwell 1965, Rayment and Higginson 1992), plant-available sulphur (Blair *et al*. 1991), and organic carbon (Walkley and Black 1934). Measurements of electrical conductivity (1:5 H_2O), soil pH (1:5 H_2O and 1:5 $CaCl_2$), were conducted using the methods described in Rayment and Higginson (1992). Exchangeable cations Ca^{2+}, Mg^{2+}, Na^{+} and K^{+} (Rayment and Higginson 1992) and particle size (McKenzie *et al*. 2002) was also assessed.

ALS Environmental Laboratory conducted the multi-element analysis for 26 elemental concentrations. CV/FIMS was used to analyse for Hg, while ICPAES and ICPMS was used for the other elements. In addition, total S (%) (LECO method), Net Acid Production Potential (NAPP), Net Acid Generation (NAG), Acid Neutralising Capacity (ANC), NAG pH, pH, and Maximum Potential Acidity (MPA) were analysed (Miller 1998, Miller 2000).

Soil texture was assessed by MWH using the procedure described in McDonald *et al*. (1998). A measure of soil slaking and dispersive properties (Emerson Aggregate Test) was conducted as described in McKenzie *et al*. (2002). Soil strength and the resulting tendency of each material to hardset was assessed by MWH personnel using a modified Modulus of Rupture test (Aylmore and Sills 1982, Harper and Gilkes 1994). Saturated hydraulic conductivity was assessed on columns of selected samples repacked to their respective field bulk densities, using a constant head of pressure technique as described by Hunt and Gilkes (1992). The water retention characteristics of selected samples were assessed by MWH using pressure plate apparatus, as described in McKenzie *et al*. (2002). Samples assessed using the pressure plate apparatus were packed to a bulk density likely to be experienced once the materials are disturbed and re-deposited, approximately 75% of the maximum dry bulk density.

Explanation of sulphur content and acid generating potential:

Typical ‘high risk’ trigger values for total sulphur content can be considered to be between 0.1 and 0.3% Total-S for potential acid generation. Total-S results above this range may warrant further investigation. A review of the acid-base-accounting parameters is required to characterise the relative acid forming potential of the tailings materials. NAPP and NAG results are used to determine the potentially acid forming (PAF) or non-acid forming (NAF) status of materials in static acid-base accounting, in addition to the ANC and Maximum Potential Acidity (MPA) (AMIRA 2002). While there are no definitive classification standards for acid-forming potential due to inherent material heterogeneity, **Table B1** below details the criteria that have been adopted to classify the samples and identify uncertainties within the initial screening.

Table A1-6-1: Acid rock drainage classification (AMIRA 2002)

NAG-pH	NAPP	ARD Classification
NAG-pH ≥ 4.5	NAPP ≤ 0	NAF
NAG-pH < 4.5	NAPP > 0	PAF
NAG-pH ≥ 4.5	NAPP > 0	Uncertain (UC)
NAG-pH > 4.5	NAPP ≤ 0	Uncertain (UC)

NAPP and the ratio of ANC to MPA were calculated used the following formulae (DITR 2007):

MPA = 30.6 x Total-S %

NAPP = MPA – ANC

The calculated ANC/MPA ratio refers to the inherent ability of the material to prevent acid generation. ANC/MPA ratio values of 2 or more are identified as having a high probability of retaining a near-neutral pH (DITR 2007, AMIRA 2002).

Results:

Results for the laboratory test work are presented in the following tables and figures;

- Physical characteristics: **Table A1-5-2**;
- Water retention characteristics: **Table A1-5-3** and **Figure A1-5-2**;
- Chemical characteristics: **Table A1-5-4**;
- Geochemical characteristics: **Table A1-5-5**; and acid base accounting: **Figure A1-5-2**; and
- Multi-element analysis: **Table A1-5-6**.

A Certificate of Analysis from ALS Laboratory is included in **Appendix D**.

Table A1-6-2: Physical properties of CEIP pilot tailings

Sample ID	Coarse fragments (>2 mm fraction) (% gravel)	Particle Size Distribution [1]				Texture classification (<2 mm fraction) [2]	Emerson Test Class [3]	Soil strength (Modulus of Rupture, kPa) [4]	Saturated Hydraulic Conductivity (k_{sat} mm/hr) [5]		
		Coarse sand (0.2 – 2.0 mm)	Fine sand (0.02 – 0.2 mm)	Silt (0.002 – 0.02 mm)	Clay (<0.002 mm)				1st round	2nd round	3rd round
Sub-sample 1	23.4	52.1	36.0	7.9	3.9	Loamy sand	6	14.6	10.6	6.2	4.7
Sub-sample 2	22.8	50.7	39.1	7.2	3.0	Loamy sand	6	11.6	9.3	5.6	5.4
Sub-sample 3	23.7	47.4	42.5	6.1	4.0	Loamy sand	6	11.4	11.5	6.7	5.0
Average	**23.3**	**50.1**	**39.2**	**7.1**	**3.7**	**-**	**6**	**12.5**	**10.5**	**6.2**	**5.0**
Classification	**-**	**-**	**-**	**-**	**-**	**Loamy sand**	**Stable, non-dispersive**	**Low hard-setting potential**	**Moderately slow**	**Moderately slow**	**Slow**

1. Analysed by CSBP Soil and Plant Laboratory.
2. McDonald *et al.* (1998).
3. Moore (1998).
4. Cochrane and Aylmore (1997).
5. Constant head of pressure technique (Hunt and Gilkes 1992, Hazelton and Murphy 2007, Moore 1998).

Table A1-6-3: Water retention and availability characteristics of CEIP pilot tailings

Sample ID	<2 mm soil fraction			Total material [2]	
	Upper storage limit [1] (% vol)	Lower storage limit [1] (% vol)	Plant available water (PAW) (% vol)	Upper storage limit (% vol)	Plant available water (PAW) (% vol)
Sub-sample 1	23.37	2.38	20.99	23.4	21.0
Sub-sample 2	25.74	2.55	23.20	25.7	23.2
Sub-sample 3	24.76	3.01	21.76	24.8	21.8
Average	**24.63**	**2.64**	**21.98**	**24.6**	**22.0**

1. Upper storage limit taken as 10 kPa (pF 2), Lower storage limit taken as 1500 kPa (pF 5.5).
2. Taking gravel / coarse material (>2 mm) for each material into account. This assumes water holding capacity of >2 mm coarse fraction is negligible.

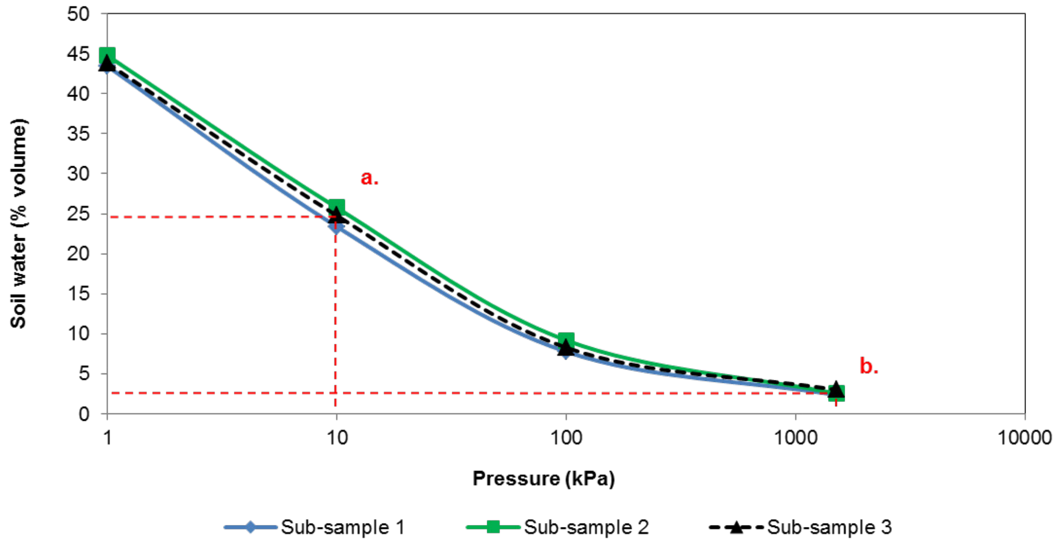

Figure A1-6-1: Water retention curves for the <2 mm fraction of CEIP pilot tailings. Note: Water content at point a. is the USL and point b. is the LSL. The difference in water content between a. and b. is the PAW

Table A1-6-4: Chemical properties of CEIP pilot tailings (CSBP Soil and Plant Laboratory)

Sample ID	pH		EC	Organic carbon (%)	Plant-available nutrients (mg/kg)					Exchangeable cations (meq/100g)				Effective Cation Exchange Capacity (eCEC meq/100g)	Exchangeable Sodium Percentage (ESP %)
	$CaCl_2$	H_2O	(dS/m)		Ammonium (NH_3)	Nitrate-Nitrogen (NO_3)	Phosphorus (P)	Potassium (K)	Sulphur (S)	Calcium (Ca)	Potassium (K)	Magnesium (Mg)	Sodium (Na)		
Sub-sample 1	7.8	8.0	1.74	0.07	1	< 1	< 2	508	181.2	1	0.1	0.23	0.14	1.47	9.5
Sub-sample 2	7.9	8.2	1.67	0.06	< 1	< 1	< 2	529	178.1	0.85	0.09	0.23	0.16	1.33	12.0
Sub-sample 3	8.2	8.5	1.66	0.07	1	< 1	< 2	561	164.8	0.76	0.08	0.21	0.14	1.19	11.8
Average	**8.0**	**8.2**	**1.69**	**0.07**	**1**	**< 1**	**< 2**	**533**	**175**	**0.87**	**0.09**	**0.22**	**0.15**	**1.33**	**11.1**
Classification	**Moderately alkaline [1]**		**Extremely saline [2]**	**Low [3]**	**-**	**-**	**Low [3]**	**High [3]**	**-**	**Low [3]**				**Low [3]**	**Sodic [3]**

1. Van Gool *et al.* (2005).
2. Based on soil texture and standard USDA and CSIRO categories.
3. Moore (1998).

Table A1-6-5: Geochemical assessment of CEIP pilot tailings [4]

Sample ID	Total S (%)	MPA [2]	NAG [3] pH 4.5 (kg H_2SO_4/t)	NAG [3] pH 7.0 (kg H_2SO_4/t)	NAG [3] NAG pH(ox)	ANC [4] as $CaCO_3$ % $CaCO_3$	ANC [4] as H_2SO_4 kg H_2SO_4/t	ANC / MPA ratio	NAPP [5] (kg H_2SO_4/t)	Acid forming potential [6]
Sub-sample 1	0.03	0.92	<0.1	<0.1	8.0	1.6	15.4	16.8	-14.5	NAF
Sub-sample 2	0.03	0.92	<0.1	<0.1	7.9	1.6	16.0	17.4	-15.1	NAF
Sub-sample 3	0.03	0.92	<0.1	<0.1	8.1	1.6	15.4	16.8	-14.5	NAF
Average	**0.03**	**0.92**	-	-	**8.0**	**1.6**	**15.6**	**17.0**	**-14.7**	-
LOR [1]	**0.01**	**0.92**	**0.1**	**0.1**	**0.1**	**0.1**	**0.5**	**16.8**	**0.5**	-

1. LOR: Limit of Reporting
2. MPA: Maximum Potential Acidity.
3. NAG pH(ox): Net Acid Generation pH after oxidation.
4. ANC: Acid Neutralisation Capacity.
5. NAPP: Net Acid Production Potential.
6. Determined as either NAF (Non-acid forming) or PAF (Potentially acid forming).

[4] NAPP and NAG results are used to determine the potentially acid forming (PAF) or non-acid forming (NAF) status of materials in static acid-base accounting, in addition to the ANC and Maximum Potential Acidity (MPA) (AMIRA 2002). The calculated ANC/MPA ratio refers to the inherent ability of the material to prevent acid generation. ANC/MPA ratio values of 2 or more are identified as having a high probability of retaining a near-neutral pH (DITR 2007, AMIRA 2002). NAPP and the ratio of ANC to MPA were calculated used the following formulae (DITR 2007):

MPA = 30.6 x Total-S %

NAPP = MPA – ANC

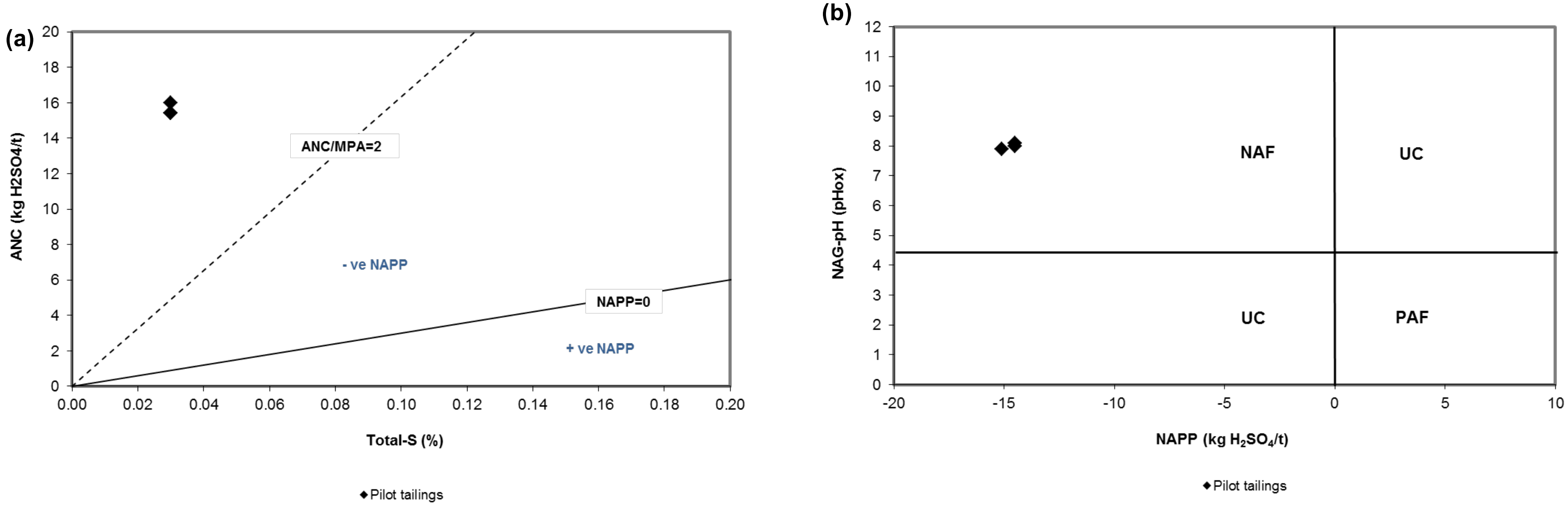

Figure A1-6-2: Static acid base accounting for pilot tailings geochemical assessment: (a) Acid Neutralisation Capacity versus Total S [1]; (b) Acid rock drainage classification (NAG-pH vs NAPP) [2]

1. **Figure B2a depicts the relationship between Total-S and ANC. The NAPP 'zero' line defines the positive and negative NAPP domains. The calculated ANC/MPA ratio refers to the inherent ability of the material to prevent acid generation. ANC/MPA ratios of ≥ 2 are identified as having a high probability of retaining a near-neutral pH (DITR 2007, AMIRA 2002).**
2. **Figure 52b: NAF: Non-acid forming; UC: Uncertain; PAF: Potentially acid forming. While there are no definitive classification standards for defining acid-forming potential, a NAG pH (pHox) ≥ 4.5 with a NAPP ≤ 0 is generally classified as non-acid forming (NAF) (AMIRA 2002).**

Table A1-6-6: Multi-element analysis of CEIP pilot tailings (mg/kg)

Sample ID	Aluminium (Al)	Antimony (Sb)	Arsenic (As)	Barium (Ba)	Beryllium (Be)	Bismuth (Bi)	Boron (B)	Cadmium (Cd)	Chromium (Cr)	Cobalt (Co)	Copper (Cu)	Iron (Fe)	Lead (Pb)	Lithium (Li)	Manganese (Mn)	Molybdenum (Mo)	Nickel (Ni)	Selenium (Se)	Silver (Ag)	Strontium (Sr)	Thallium (Tl)	Thorium (Th)	Tin (Sn)	Uranium (U)	Vanadium (V)	Zinc (Zn)
Sub-sample 1	7620	<0.1	1	49.1	0.2	<0.1	<50	<0.1	8.5	5.7	16.1	7580	1.2	7.6	1190	0.3	8.3	<1	<0.1	8	0.1	3.9	0.6	0.3	5	24.5
Sub-sample 2	6540	<0.1	0.8	45.8	0.2	<0.1	<50	<0.1	6.9	4.8	15.8	6670	1.1	6.9	1090	0.3	7.1	<1	<0.1	7.8	0.1	3.4	0.5	0.2	5	21
Sub-sample 3	6920	<0.1	2.2	45.9	0.2	<0.1	<50	<0.1	7.6	5.8	14.9	6970	1.1	7.1	1140	0.3	8.1	<1	<0.1	8.6	0.1	3.6	0.5	0.3	5	22.3
Average	**7027**	**-**	**1.3**	**46.9**	**0.2**	**-**	**-**	**-**	**7.7**	**5.4**	**15.6**	**7073**	**1.1**	**7.2**	**1140**	**0.3**	**7.8**	**-**	**-**	**8.1**	**0.1**	**3.6**	**0.5**	**0.3**	**5**	**22.6**
LOR [1]	**50**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**50**	**0.1**	**0.1**	**0.1**	**0.1**	**50**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**1**	**0.5**
EIL (mg/kg) [2]	**-**	**-**	**20**	**300**	**-**	**-**	**-**	**3**	**400 ^**	**50**	**100**	**-**	**600**	**-**	**500**	**40**	**60**	**-**	**-**	**-**	**-**	**-**	**50**	**-**	**50**	**200**
EIL (mg/kg) [3]	**-**	**-**	**80**	**-**	**-**	**-**	**-**	**-**	**270 ^ ***	**-**	**40 ***	**-**	**440**	**-**	**-**	**-**	**30 ***	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**85 ***
HIL (mg/kg) [4]	**-**	**-**	**3000**	**-**	**500**	**-**	**300000**	**900**	**3600 ^^**	**4000**	**240000**	**-**	**1500**	**-**	**60000**	**-**	**6000**	**10000**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**400000**
Average crustal abundance [5]	**82000**	**0.2**	**1.5**	**500**	**2.8**	**0.048**	**10**	**0.2**	**100**	**20**	**50**	**41000**	**14**	**20**	**950**	**1.5**	**80**	**0.05**	**0.07**	**375**	**0.45**	**12**	**2.2**	**135**	**160**	**75**

1. LOR: Limit of Reporting.
2. DEC (2010) Ecological Investigation Levels (EILs). ^ Cr III.
3. NEPM (1999) Ecological Investigation Levels (EILs). ^ Cr III, * Site-specific EIL calculated.
4. NEPM (1999) Health Investigation Levels (HILs) for Commercial/Industrial land use. ^^Cr VI
5. Average crustal abundances sourced from AIMM (2001) and Barbalace (2014).

A.2 CEIP pilot tailings salt migration bulk column leaching

Objective:

Bulk column leaching was conducted to assess the potential for salt migration in the combined (coarse and fine) CEIP pilot tailings. Two objectives were determined for the bulk column leaching test work;

1. To determine the potential for upwards salt migration via capillary rise (Column Leach Experiment 1); and
2. To determine the potential for downwards migration via leaching of salts and dissolved metals (Column Leach Experiment 2).

A.2.1 Column Leach Experiment 1: Capillary Rise

A bulk sub-sample of the combined (coarse and fine) tailings was placed in a large (110 mm diameter) column and subjected to two rounds of saturation (via wicking or capillary action) and free drainage to investigate the potential for capillary rise of salts within the column and any salt accumulation at the surface.

Test work and procedures:

- Bulk tailings sub-sample was added to a 110 mm diameter column to a depth of 430 mm (**Plate A1-1**);
- A porous material was taped to the bottom of the column, which was then placed in a bucket and suspended approximately 5 mm from the bottom of the bucket to allow for water uptake and drainage;
- After allowing 24 hrs for the tailings material to settle, 3 litres of distilled water was added to the bucket for uptake into the column;
- After 48 hours the tailings was saturated to the surface in the column and water source was removed;
- The column was then allowed to drain for 5 days under laboratory conditions;
- Saturation and drainage process was repeated again; and
- Three sub-samples of the tailings were collected from the top, middle and bottom sections of the column, and analysed for electrical conductivity (EC) and pH (analysis conducted by CSBP Soil and Plant laboratory) (**Table A1-5-7**).

Plate A1-1: Column of combined (coarse and fine) tailings

Results:

Table A1-6-7: Electrical Conductivity (EC) and pH of CEIP pilot tailings material pre and post saturation and drainage treatment

Parameter	Pre -treatment (Average)	Post-treatment sub-sample analysis		
		Top	Middle	Bottom
EC (dS/m)	1.690	10.558	0.863	0.422
pH (Ca_2Cl)	8.0	7.9	7.9	7.9
pH (H_2O)	8.2	8.3	8.6	8.7

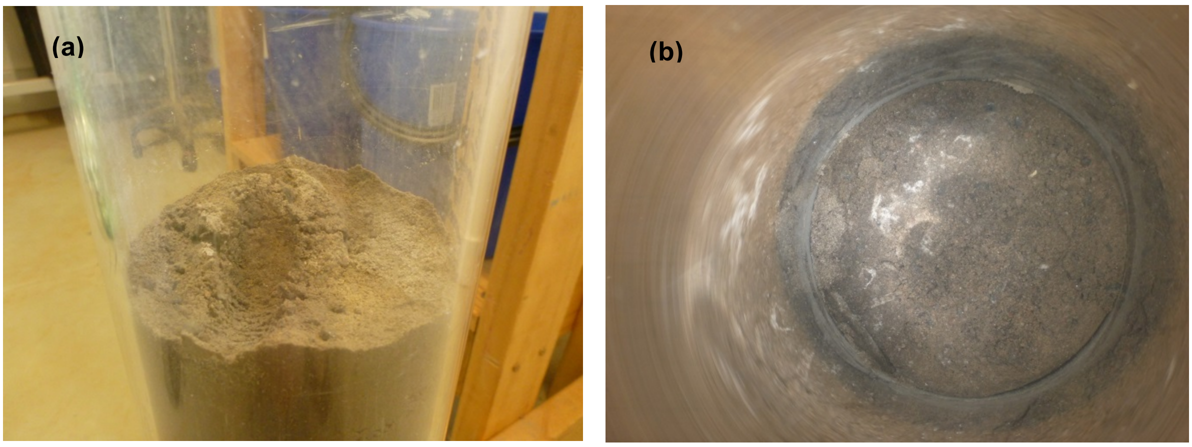

Plate A1-2: Salt efflouresence on surface of tailings column; (a) after first saturation and flush; (b) after second saturation and flush

A.2.2 Column Leach Experiment 2: Salt and dissolved metal leaching

The second column leach experiment investigating the potential for leaching of salts and dissolved metals was conducted in two stages;

1. Repeated leaching of small columns (**A.2.2.1**); and
2. Leaching of large bulk column (**A.2.2.2**).

A.2.2.1 Small column repeated leaching

Test work and procedures:

- Tailings sub-samples were placed in 50 mm diameter PVC tubes to a depth of 100 mm (3 replicates);
- Distilled water was applied to a head of 50 mm, and allowed to drain;
- Leachate was collected and sample stored in refrigerator until analysis;
- Leaching process was repeated five times to simulate repeated wetting and drying cycles over several days (Note: leachate was not collected from leaching rounds two and four); and
- Leachate was analysed by ALS Laboratory for pH, EC and total dissolved metals.

Results:

Results for the laboratory analysis of the leachate from repeated leaching rounds are presented in the following tables and figures;

- Dissolved metal concentrations: **Table A1-5-8**; and
- pH and EC: **Table A1-5-9**.

Table A1-6-8: Dissolved metal concentrations from CEIP pilot tailings in small column repeated leaching assessment

Sampling round	Sample ID	Aluminium (Al)	Antimony (Sb)	Arsenic (As)	Barium (Ba)	Beryllium (Be)	Bismuth (Bi)	Boron (B)	Cadmium (Cd)	Chromium (Cr)	Cobalt (Co)	Copper (Cu)	Iron (Fe)	Lead (Pb)	Lithium (Li)	Manganese (Mn)	Molybdenum (Mo)	Nickel (Ni)	Selenium (Se)	Silver (Ag)	Strontium (Sr)	Thallium (Tl)	Thorium (Th)	Tin (Sn)	Uranium (U)	Vanadium (V)	Zinc (Zn)
		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
1st Leach	1A	0.02	<0.001	<0.001	0.841	<0.001	<0.001	0.47	0.0001	<0.001	<0.001	0.022	<0.05	<0.001	0.044	0.652	0.015	0.001	<0.01	<0.001	3.08	<0.001	<0.001	0.002	<0.001	<0.01	0.162
	2A	0.2	<0.001	<0.001	0.85	<0.001	<0.001	0.51	0.0001	<0.001	0.001	0.025	<0.05	<0.001	0.05	0.698	0.016	0.002	<0.01	<0.001	3.17	<0.001	<0.001	0.005	<0.001	<0.01	0.151
	3A	0.08	<0.001	<0.001	0.426	<0.001	0.002	0.51	0.0001	<0.001	<0.001	0.028	<0.05	<0.001	0.05	0.707	0.016	0.002	<0.01	<0.001	3.21	<0.001	0.005	0.003	<0.001	<0.01	0.194
	AVERAGE	**0.1**	**-**	**-**	**0.706**	**-**	**0.002**	**0.50**	**0.0001**	**-**	**0.001**	**0.025**	**-**	**-**	**0.048**	**0.686**	**0.016**	**0.002**	**-**	**-**	**3.15**	**-**	**-**	**0.003**	**-**	**-**	**0.169**
3rd Leach	1B	0.18	<0.001	0.002	0.004	<0.001	<0.001	0.37	<0.0001	<0.001	<0.001	0.003	<0.05	<0.001	0.004	0.004	0.006	<0.001	<0.01	<0.001	0.009	<0.001	0.001	0.005	<0.001	<0.01	<0.005
	3B	0.12	<0.001	0.001	0.005	<0.001	<0.001	0.3	<0.0001	<0.001	<0.001	0.002	<0.05	<0.001	0.007	0.012	0.005	<0.001	<0.01	<0.001	0.019	<0.001	<0.001	0.002	<0.001	<0.01	<0.005
	AVERAGE	**0.15**	**-**	**0.002**	**0.005**	**-**	**-**	**0.34**	**-**	**-**	**-**	**0.003**	**-**	**-**	**0.006**	**0.008**	**0.006**	**-**	**-**	**-**	**0.014**	**-**	**0.001**	**0.004**	**-**	**-**	**-**
5th Leach	1C	0.1	<0.001	0.002	0.002	<0.001	<0.001	0.18	<0.0001	0.002	<0.001	0.004	<0.05	<0.001	0.003	0.007	0.004	<0.001	<0.01	<0.001	0.008	<0.001	<0.001	0.002	<0.001	<0.01	<0.005
	2C	0.08	<0.001	<0.001	0.003	<0.001	<0.001	0.17	<0.0001	0.001	<0.001	0.003	<0.05	<0.001	0.003	0.011	0.004	0.001	<0.01	<0.001	0.01	<0.001	<0.001	0.002	<0.001	<0.01	<0.005
	3C	0.07	<0.001	<0.001	0.003	<0.001	<0.001	0.19	<0.0001	0.002	<0.001	0.004	<0.05	<0.001	0.004	0.016	0.004	0.001	<0.01	<0.001	0.011	<0.001	<0.001	0.001	<0.001	<0.01	<0.005
	AVERAGE	**0.08**	**-**	**0.002**	**0.003**	**-**	**-**	**0.18**	**-**	**0.002**	**-**	**0.004**	**-**	**-**	**0.003**	**0.011**	**0.004**	**0.001**	**-**	**-**	**0.010**	**-**	**-**	**0.002**	**-**	**-**	**-**
LOR [1]		**50**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**50**	**0.1**	**0.1**	**0.1**	**0.1**	**50**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**1**	**0.5**
EIL (mg/kg) [2]		**-**	**-**	**20**	**300**	**-**	**-**	**-**	**3**	**400 ^**	**50**	**100**	**-**	**600**	**-**	**500**	**40**	**60**	**-**	**-**	**-**	**-**	**-**	**50**	**-**	**50**	**200**
EIL (mg/kg) [3]		**-**	**-**	**80**	**-**	**-**	**-**	**-**	**-**	**270 ^ ***	**-**	**40 ***	**-**	**440**	**-**	**-**	**-**	**30 ***	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**85 ***
HIL (mg/kg) [4]		**-**	**-**	**3000**	**-**	**500**	**-**	**300000**	**900**	**3600 ^^**	**4000**	**240000**	**-**	**1500**	**-**	**60000**	**-**	**6000**	**10000**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**400000**
Average crustal abundance [5]		**82000**	**0.2**	**1.5**	**500**	**2.8**	**0.048**	**10**	**0.2**	**100**	**20**	**50**	**41000**	**14**	**20**	**950**	**1.5**	**80**	**0.05**	**0.07**	**375**	**0.45**	**12**	**2.2**	**135**	**160**	**75**

1. LOR: Limit of Reporting.
2. DEC (2010) Ecological Investigation Levels (EILs). ^ Cr III.
3. NEPM (1999) Ecological Investigation Levels (EILs). ^ Cr III, * Site-specific EIL calculated.
4. NEPM (1999) Health Investigation Levels (HILs) for Commercial/Industrial land use. ^^Cr VI
5. Average crustal abundances sourced from AIMM (2001) and Barbalace (2014).

Table A1-6-9: EC and pH for CEIP pilot tailings in small column repeated leaching assessment (5th leach only)

Sampling round	Sample ID	EC		pH
		mS/cm	dS/m	(H_2O)
5th Leach	1C	242	0.242	7.99
	2C	199	0.199	7.94
	3C	208	0.208	7.96
	AVERAGE	**216**	**0.22**	**7.96**

A.2.2.2 Large bulk column leaching

A bulk sub-sample of the combined (coarse and fine) tailings was placed in a large (110 mm diameter) column and saturated (via wicking or capillary action) and drained to investigate the potential for leaching of salt.

Test work and procedures:

- Bulk tailings sub-sample was added to a 110 mm diameter column to a depth of 405 mm;
- A porous material was taped to the bottom of the column, which was then placed in a bucket and suspended approximately 5 mm from the bottom of the bucket to allow for water uptake and drainage;
- After allowing 24 hrs for the tailings material to settle, 3 litres of distilled water was added to the bucket for uptake into the column;
- The column was then drained overnight and leachate sample collected (sample L 1);
- The column was allowed to continue to drain for 48 hours, then saturation and leachate collection was repeated (sample L 2); and
- Leachate was analysed by ALS Laboratory for pH and EC (**Table A1-5-10**).

Results:

Table A1-6-10: EC and pH of leachate following leaching of CEIP pilot tailings

Parameter	Post treatment	
	Leach 1	Leach 2
EC (dS/m)	29.8	0.626
EC (mS/cm)	29800	626
pH (H_2O)	7.1	7.7

Appendix B ALS Certificate of Analysis

CERTIFICATE OF ANALYSIS

Work Order	: **EP1407037**	Page	: 1 of 4
Client	: **MWH AUSTRALIA PTY LTD**	Laboratory	: Environmental Division Perth
Contact	: MATT BAIMBRIDGE	Contact	: Scott James
Address	: 41 BISHOP ST JOLIMONT PERTH, WESTERN AUSTRALIA 6014	Address	: 10 Hod Way Malaga WA Australia 6090
E-mail	: Matt.F.Braimbridge@mwhglobal.com	E-mail	: perth.enviro.services@alsglobal.com
Telephone	: 08 9388 8799	Telephone	: +61-8-9209 7655
Facsimile	: 08 9388 8633	Facsimile	: +61-8-9209 7600
Project	: IRON-LS-14001 (83502143 050000)	QC Level	: NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Order number	: MWH 1968		
C-O-C number	: ----	Date Samples Received	: 03-SEP-2014
Sampler	: B.S.	Issue Date	: 16-SEP-2014
Site	: ----		
		No. of samples received	: 3
Quote number	: EN/059/14BQ	No. of samples analysed	: 3

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. All pages of this report have been checked and approved for release.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

NATA Accredited Laboratory 825

Accredited for compliance with ISO/IEC 17025.

WORLD RECOGNISED ACCREDITATION

Signatories

This document has been electronically signed by the authorized signatories indicated below. Electronic signing has been carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Canhuang Ke	Metals Instrument Chemist	Perth Inorganics
Efua Wilson	Metals Chemist	Perth Inorganics
Leanne Carey	Acid Sulfate Soils Supervisor	Perth ASS
Satishkumar Trivedi	2 IC Acid Sulfate Soils Supervisor	Brisbane Acid Sulphate Soils

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting

- **ASS: EA013 (ANC) Fizz Rating: 0- None; 1- Slight; 2- Moderate; 3- Strong; 4- Very Strong; 5- Lime.**

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	Sample 1	Sample 2	Sample 3	----	----
			Client sampling date / time	03-SEP-2014 15:20	03-SEP-2014 15:20	03-SEP-2014 15:20	----	----
Compound	CAS Number	LOR	Unit	EP1407037-001	EP1407037-002	EP1407037-003	----	----
EA009: Nett Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	**-14.5**	**-15.1**	**-14.5**	----	----
EA011: Net Acid Generation								
pH (OX)	----	0.1	pH Unit	**8.0**	**7.9**	**8.1**	----	----
NAG (pH 4.5)	----	0.1	kg H2SO4/t	<0.1	<0.1	<0.1	----	----
NAG (pH 7.0)	----	0.1	kg H2SO4/t	<0.1	<0.1	<0.1	----	----
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	**15.4**	**16.0**	**15.4**	----	----
ANC as CaCO3	----	0.1	% CaCO3	**1.6**	**1.6**	**1.6**	----	----
Fizz Rating	----	0	Fizz Unit	**1**	**1**	**1**	----	----
EA055: Moisture Content								
Moisture Content (dried @ 103°C)	----	1.0	%	<1.0	<1.0	<1.0	----	----
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	**0.03**	**0.03**	**0.03**	----	----
EG005T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	**7620**	**6540**	**6920**	----	----
Boron	7440-42-8	50	mg/kg	<50	<50	<50	----	----
Iron	7439-89-6	50	mg/kg	**7580**	**6670**	**6970**	----	----
EG020T: Total Metals by ICP-MS								
Arsenic	7440-38-2	0.1	mg/kg	**1.0**	**0.8**	**2.2**	----	----
Selenium	7782-49-2	1	mg/kg	<1	<1	<1	----	----
Silver	7440-22-4	0.1	mg/kg	<0.1	<0.1	<0.1	----	----
Barium	7440-39-3	0.1	mg/kg	**49.1**	**45.8**	**45.9**	----	----
Thallium	7440-28-0	0.1	mg/kg	**0.1**	**0.1**	**0.1**	----	----
Beryllium	7440-41-7	0.1	mg/kg	**0.2**	**0.2**	**0.2**	----	----
Cadmium	7440-43-9	0.1	mg/kg	<0.1	<0.1	<0.1	----	----
Bismuth	7440-69-9	0.1	mg/kg	<0.1	<0.1	<0.1	----	----
Cobalt	7440-48-4	0.1	mg/kg	**5.7**	**4.8**	**5.8**	----	----
Chromium	7440-47-3	0.1	mg/kg	**8.5**	**6.9**	**7.6**	----	----
Copper	7440-50-8	0.1	mg/kg	**16.1**	**15.8**	**14.9**	----	----
Thorium	7440-29-1	0.1	mg/kg	**3.9**	**3.4**	**3.6**	----	----
Manganese	7439-96-5	0.1	mg/kg	**1190**	**1090**	**1140**	----	----
Strontium	7440-24-6	0.1	mg/kg	**8.0**	**7.8**	**8.6**	----	----
Molybdenum	7439-98-7	0.1	mg/kg	**0.3**	**0.3**	**0.3**	----	----

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	Sample 1	Sample 2	Sample 3	----	----
			Client sampling date / time	03-SEP-2014 15:20	03-SEP-2014 15:20	03-SEP-2014 15:20	----	----
Compound	CAS Number	LOR	Unit	EP1407037-001	EP1407037-002	EP1407037-003	----	----
EG020T: Total Metals by ICP-MS - Continued								
Nickel	7440-02-0	0.1	mg/kg	8.3	7.1	8.1	----	----
Lead	7439-92-1	0.1	mg/kg	1.2	1.1	1.1	----	----
Antimony	7440-36-0	0.1	mg/kg	<0.1	<0.1	<0.1	----	----
Uranium	7440-61-1	0.1	mg/kg	0.3	0.2	0.3	----	----
Zinc	7440-66-6	0.5	mg/kg	24.5	21.0	22.3	----	----
Lithium	7439-93-2	0.1	mg/kg	7.6	6.9	7.1	----	----
Vanadium	7440-62-2	1	mg/kg	5	5	5	----	----
Tin	7440-31-5	0.1	mg/kg	0.6	0.5	0.5	----	----

CERTIFICATE OF ANALYSIS

Work Order	: **EP1408732**	Page	: 1 of 4
Client	: **MWH AUSTRALIA PTY LTD**	Laboratory	: Environmental Division Perth
Contact	: PETER FLAVEL	Contact	: Scott James
Address	: 41 BISHOP ST JOLIMONT PERTH, WESTERN AUSTRALIA 6014	Address	: 10 Hod Way Malaga WA Australia 6090
E-mail	: Peter.F.Flavel@au.mwhglobal.com	E-mail	: perth.enviro.services@alsglobal.com
Telephone	: 08 9388 8799	Telephone	: +61-8-9209 7655
Facsimile	: 08 9388 8633	Facsimile	: +61-8-9209 7600
Project	: 83502143	QC Level	: NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Order number	: MWH 2052		
C-O-C number	: ----	Date Samples Received	: 23-OCT-2014
Sampler	: ----	Issue Date	: 30-OCT-2014
Site	: ----		
		No. of samples received	: 3
Quote number	: EP/180/13	No. of samples analysed	: 3

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. All pages of this report have been checked and approved for release.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

NATA Accredited Laboratory 825

Accredited for compliance with ISO/IEC 17025.

WORLD RECOGNISED ACCREDITATION

Signatories

This document has been electronically signed by the authorized signatories indicated below. Electronic signing has been carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Daniel Fisher	Inorganics Analyst	Perth Inorganics
Efua Wilson	Metals Chemist	Perth Inorganics

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Client sample ID	1c	2c	3c	----	----
			Client sampling date / time	[23-OCT-2014]	[23-OCT-2014]	[23-OCT-2014]	----	----
Compound	CAS Number	LOR	Unit	EP1408732-001	EP1408732-002	EP1408732-003	----	----
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	**7.99**	**7.94**	**7.96**	----	----
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	**242**	**199**	**208**	----	----
EG020T: Total Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	**0.10**	**0.08**	**0.07**	----	----
Dysprosium	7429-91-6	0.001	mg/L	<0.001	<0.001	<0.001	----	----
Silver	7440-22-4	0.001	mg/L	<0.001	<0.001	<0.001	----	----
Arsenic	7440-38-2	0.001	mg/L	**0.002**	**0.001**	**0.001**	----	----
Bismuth	7440-69-9	0.001	mg/L	<0.001	<0.001	<0.001	----	----
Erbium	7440-52-0	0.001	mg/L	<0.001	<0.001	<0.001	----	----
Boron	7440-42-8	0.05	mg/L	**0.18**	**0.17**	**0.19**	----	----
Europium	7440-53-1	0.001	mg/L	<0.001	<0.001	<0.001	----	----
Strontium	7440-24-6	0.001	mg/L	**0.008**	**0.010**	**0.011**	----	----
Barium	7440-39-3	0.001	mg/L	**0.002**	**0.003**	**0.003**	----	----
Gadolinium	7440-54-2	0.001	mg/L	<0.001	<0.001	<0.001	----	----
Titanium	7440-32-6	0.01	mg/L	<0.01	<0.01	<0.01	----	----
Beryllium	7440-41-7	0.001	mg/L	<0.001	<0.001	<0.001	----	----
Gallium	7440-55-3	0.001	mg/L	<0.001	<0.001	<0.001	----	----
Cadmium	7440-43-9	0.0001	mg/L	<0.0001	<0.0001	<0.0001	----	----
Hafnium	7440-58-6	0.01	mg/L	<0.01	<0.01	<0.01	----	----
Tellurium	22541-49-7	0.005	mg/L	<0.005	<0.005	<0.005	----	----
Cobalt	7440-48-4	0.001	mg/L	<0.001	<0.001	<0.001	----	----
Holmium	7440-60-0	0.001	mg/L	<0.001	<0.001	<0.001	----	----
Uranium	7440-61-1	0.001	mg/L	<0.001	<0.001	<0.001	----	----
Caesium	7440-46-2	0.001	mg/L	<0.001	<0.001	<0.001	----	----
Chromium	7440-47-3	0.001	mg/L	**0.002**	**0.001**	**0.002**	----	----
Indium	7440-74-6	0.001	mg/L	<0.001	<0.001	<0.001	----	----
Copper	7440-50-8	0.001	mg/L	**0.004**	**0.003**	**0.004**	----	----
Lanthanum	7439-91-0	0.001	mg/L	<0.001	<0.001	<0.001	----	----
Rubidium	7440-17-7	0.001	mg/L	**0.002**	**0.003**	**0.003**	----	----
Lithium	7439-93-2	0.001	mg/L	**0.003**	**0.003**	**0.004**	----	----
Lutetium	7439-94-3	0.001	mg/L	<0.001	<0.001	<0.001	----	----
Thorium	7440-29-1	0.001	mg/L	<0.001	<0.001	<0.001	----	----
Cerium	7440-45-1	0.001	mg/L	<0.001	<0.001	<0.001	----	----

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Client sample ID	1c	2c	3c	----	----
			Client sampling date / time	[23-OCT-2014]	[23-OCT-2014]	[23-OCT-2014]	----	----
Compound	CAS Number	LOR	Unit	EP1408732-001	EP1408732-002	EP1408732-003	----	----
EG020T: Total Metals by ICP-MS - Continued								
Manganese	7439-96-5	0.001	mg/L	**0.007**	**0.011**	**0.016**	----	----
Neodymium	7440-00-8	0.001	mg/L	<0.001	<0.001	<0.001	----	----
Molybdenum	7439-98-7	0.001	mg/L	**0.004**	**0.004**	**0.004**	----	----
Praseodymium	7440-10-0	0.001	mg/L	<0.001	<0.001	<0.001	----	----
Nickel	7440-02-0	0.001	mg/L	<0.001	<0.001	<0.001	----	----
Samarium	7440-19-9	0.001	mg/L	<0.001	<0.001	<0.001	----	----
Lead	7439-92-1	0.001	mg/L	<0.001	<0.001	<0.001	----	----
Terbium	7440-27-9	0.001	mg/L	<0.001	<0.001	<0.001	----	----
Antimony	7440-36-0	0.001	mg/L	<0.001	<0.001	<0.001	----	----
Thulium	7440-30-4	0.001	mg/L	<0.001	<0.001	<0.001	----	----
Selenium	7782-49-2	0.01	mg/L	<0.01	<0.01	<0.01	----	----
Ytterbium	7440-64-4	0.001	mg/L	<0.001	<0.001	<0.001	----	----
Tin	7440-31-5	0.001	mg/L	**0.002**	**0.002**	**0.001**	----	----
Yttrium	7440-65-5	0.001	mg/L	<0.001	<0.001	<0.001	----	----
Thallium	7440-28-0	0.001	mg/L	<0.001	<0.001	<0.001	----	----
Zirconium	7440-67-7	0.005	mg/L	<0.005	<0.005	<0.005	----	----
Vanadium	7440-62-2	0.01	mg/L	<0.01	<0.01	<0.01	----	----
Zinc	7440-66-6	0.005	mg/L	<0.005	<0.005	<0.005	----	----
Iron	7439-89-6	0.05	mg/L	<0.05	<0.05	<0.05	----	----

Appendix C Integrated Waste Landform Geotechnical Stability Technical Note

Technical Note

To	Nick Bull	**Date**	26 May 2015
From	Steven Turner	**Project No**	VE23730
Copy	Stuart Cowan		
Subject	**Integrated Waste Landform – Geotechnical Stability – Iron Road Limited CEIP Project**		

1. Introduction

This technical note presents an assessment of the geotechnical stability of the proposed Integrated Waste Landform (IWL) for the Iron Road Limited (IRD) CEIP Project immediately east of Warramboo. It is understood that this assessment is to be used by IRD in seeking approval of the mine lease plan. The assessment is also needed to demonstrate that the IWL slopes remain stable during construction and they will support the proposed waste spreader and conveyor equipment.

2. General

The temporary stability of the IWL during construction has been assessed as well as the bearing capacity and anticipated settlement beneath the stacker machine tracks.

3. Geotechnical properties

The geotechnical properties of the materials likely to form the IWL were assessed assuming variable proportions of fine tailings, coarse tailing and oxide / crushed fresh rock as summarised below:

Material Description	Unit Weight (γ) kN/m^3	Cohesion (c') kN/m^2	Uniformity (D_{10}/D_{60})	Angle of shearing resistance (ø') degrees
50% coarse tailing and 50% fine tailings	17 kN/m^3	0	2.4	38°
33% coarse tailings, 33% fine tailings and 33% oxide and crushed fresh rock	19 kN/m^3	0	7.2	40°
75% oxide and crushed fresh rock and the remaining 25% of the material composed of the 50% fine and coarse tailings	19 kN/m^3	0	60	40°

Note: The unit weight adopted is based on the values provided in Table D1 of AS 4678-2002 “Earth-retaining structures” and the angle of shearing resistance was assessed using the methods presented Section D.2.2.3 of the same Standard which has been reproduced below:

3.1 Angle of shearing resistance (ø') assessment

The strength and stiffness of cohesion-less soils vary with respect to density, angularity and grading of the particles. An estimation of the characteristic peak effective internal friction angle ø' is be given by:

$$\text{ø}' = 30 + k_A + k_B + k_C$$

Where the parameters k_A, k_B and k_C relate to the angularity, grading and density of the particles. Some conservative values for these parameters are set out in the table below:

Angularity (see Note 1)		**k_A (degrees)**
	Rounded	0
	Sub-angular	2
	Angular	4
Grading of soil (see Note 2 and 3)		**K_B (degrees)**
	Uniform	0
	Moderate grading	2
	Well graded	4
N' (below 300mm) (see Note 4)		**K_C (degrees)**
	< 10	0
	20	2
	40	6
	60	9

Notes:

1. Angularity is estimated from visual description of soil.
2. Grading may be determined from grading curve by use of:
   Coefficient of uniformity = D_{60}/D_{10}

   Where D_{10} and D_{60} are particle sizes such that, in the sample, 10% of the material is finer than D_{10} and 60% finer than D_{60}.

Grading	Uniformity
Uniform	< 2
Moderate grading	2 – 6
Well graded	6

3. A step-graded soil should be treated as uniform or moderately graded soil according to the grading of the finer fraction.
4. N' from results of standard penetration test modified where necessary.
5. Intermediate values of k_A, k_B, and k_C are given by interpolation.

The grading of the fine and coarse tailings were obtained from the DFS – Tailings Storage Facility – Fine and Coarse Tailings Characteristics Report by ATC Williams (2013). While the grading for the oxide and waste rock was based on existing grading results for a Waste Rock Dumps on a mine sites with a maximum particle size of 160 mm. Composite grading curves for the anticipated materials have been included as Attachment A.

JACOBS

4. Slope stability assessment

Slope/W software which uses limit equilibrium to model stability of slopes was used to model the stability of the IWL during construction. The following modelling options were selected during the assessment:

- Mohr-Coulomb strength model.
- Slip surface search – entry and exit method.
- No groundwater was modelled.
- Analysis type - Morgenstern-Price.

4.1 Design assumptions

The following assumptions were adopted during the slope stability assessment of the IWL:

- The stability assessment assumes that the IWL is composed generally of 50% coarse and 50% fine tailings, with an angle of shearing resistance of 38° as demonstrated above. The strength model adopted in the design does not account for strength increase with increase depth and is therefore conservative.
- It is assumed that the waste material will be placed at its angle of repose (38°) during construction. Therefore, the outer face of the IWL is expected to have a Factor of Safety (FOS) of approximately 1 during construction. It is understood that the slope will be re-profiled in the longer term to provide a more stable long term batter slope at closure.
- The stability assessment was used to search for the lowest FOS daylighting below the stacker machine tracks, to confirm the machine loading on the IWL had an adequate factor of safety.
- The maximum load from the stacker machine is assumed to be 120 kPa based on information provided by Iron Road. The stacker track dimensions are assumed to be similar to those of a
- The IWL was assumed to be composed of 3 x 45 m high lifts with 40 m wide berms.
- The slope stability assessment assumes the IWL will remain free of water during construction and that adequate drainage will be provided to limit the risk of increased pore-water pressure within the landform.
- The slope stability assessment covered by this Technical Note covers the temporary stability of the IWL during construction and does not consider the long term global stability of the IWL. However, the global stability of waste dumps was considered by Coffey in the DFS Mine Pit Geotechnical Assessment Report (2014) and demonstrated stability using a conservative ground model.

4.2 Slope stability assessment results

The slope stability assessment confirmed that the first slope failure affecting the stacker machine tracks had an FOS of 1.2, when positioned 15 m from the crest of the IWL. The output from the slope/w assessment has been included as Attachment B.

The anticipated factor of safety is considered adequate for the transient nature of the load.

5. Bearing capacity and settlement assessment

Bearing capacity and settlement calculation were undertaken to assess the stability of the proposed stacker machine when working on the IWL. The Brinch Hansen method (Tomlinson 2001) was used to assess the bearing capacity while the Burland and Burbridge method (Tomlinson 2001) was used to assess the immediate settlement.

5.1 Design assumptions

The following design assumptions were adopted when calculating the allowable bearing capacity of the IWL and anticipated settlement of the stacker machine:

- The bearing capacity calculation assumes that the IWL is composed of 50% coarse and 50% fine tailings, with an angle of shearing resistance of 38° as demonstrated above.
- It is assumed that the tailings will be dry/moist and any groundwater will be beyond the depth of influence of the tracks of the stacker machine.
- The stacker track dimensions are assumed to be similar to those of a CAT D11 – 4,440 mm x 710 mm.
- The applied ground pressure from the stacker tracks is assumed to be 120 kPa based on information provided by Iron Road.

5.2 Bearing capacity and settlement results

The estimated factor of safety against bearing capacity failure beneath the tracks of the stacker machine for an applied pressure of 120 kPa is 3.0 with estimated settlement of 25 to 40 mm.

The anticipated factor of safety is considered more than adequate for the transient nature of the load. We understand that the estimated settlements are within the tolerances of the stacker machine. A typical stacker arrangement has been included as Attachment C.

6. Limitations of assessment

The following limitations should be considered when applying the results of this assessment:

- The ground model used in the stability assessment assumes a 50% fine and 50% coarse tailings to be the worst case. If the tailings processes changes as the mine is developed then different proportions or grading’s might be produced and could have an impact on the material properties.
- The grading of the oxide and fresh crushed rock waste was based on typical data from an existing waste rock dumps.

7. References

Australian Standard – AS 4678-2002 - Earth-retaining structures

Coffey Pty Ltd (2014) – DFS - Mine Pit Geotechnical Assessment – Report No.E-F-14-RPT-00200_0

ATC Williams (2013) – DFS – Tailings Storage Facility – Fine and Coarse Tailings Characteristics Report No. E-F-24-RPT-008.

Tomlins, M.J. (2001) – Foundation Design and Construction, 7th Edition.

8. Attachments

Attachment A – Composite grading curves for waste material.

Attachment B – Slope/W output.

Attachment C – Typical stacker machine.

Steven Turner
Senior Geotechnical Engineer
0421 825 591
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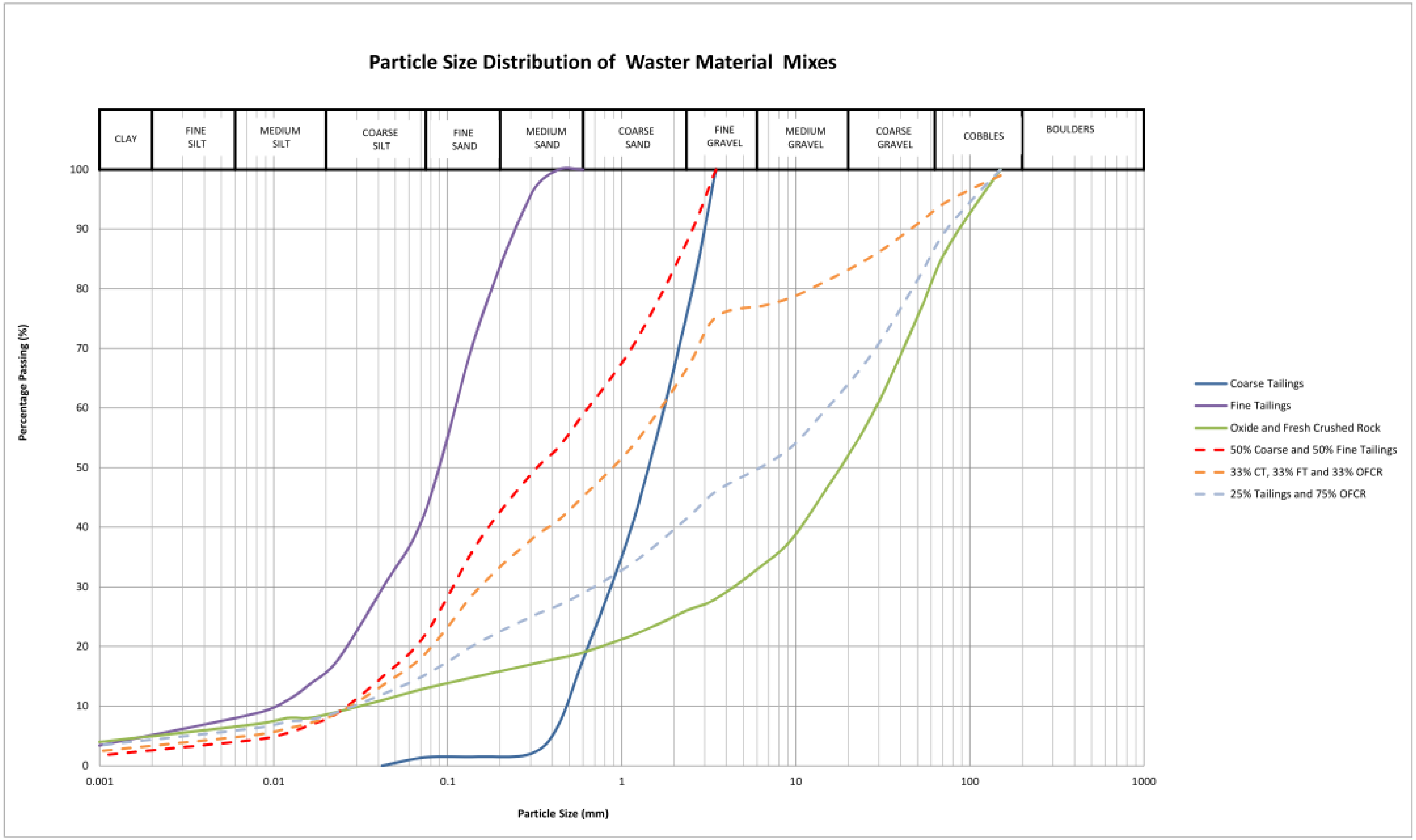
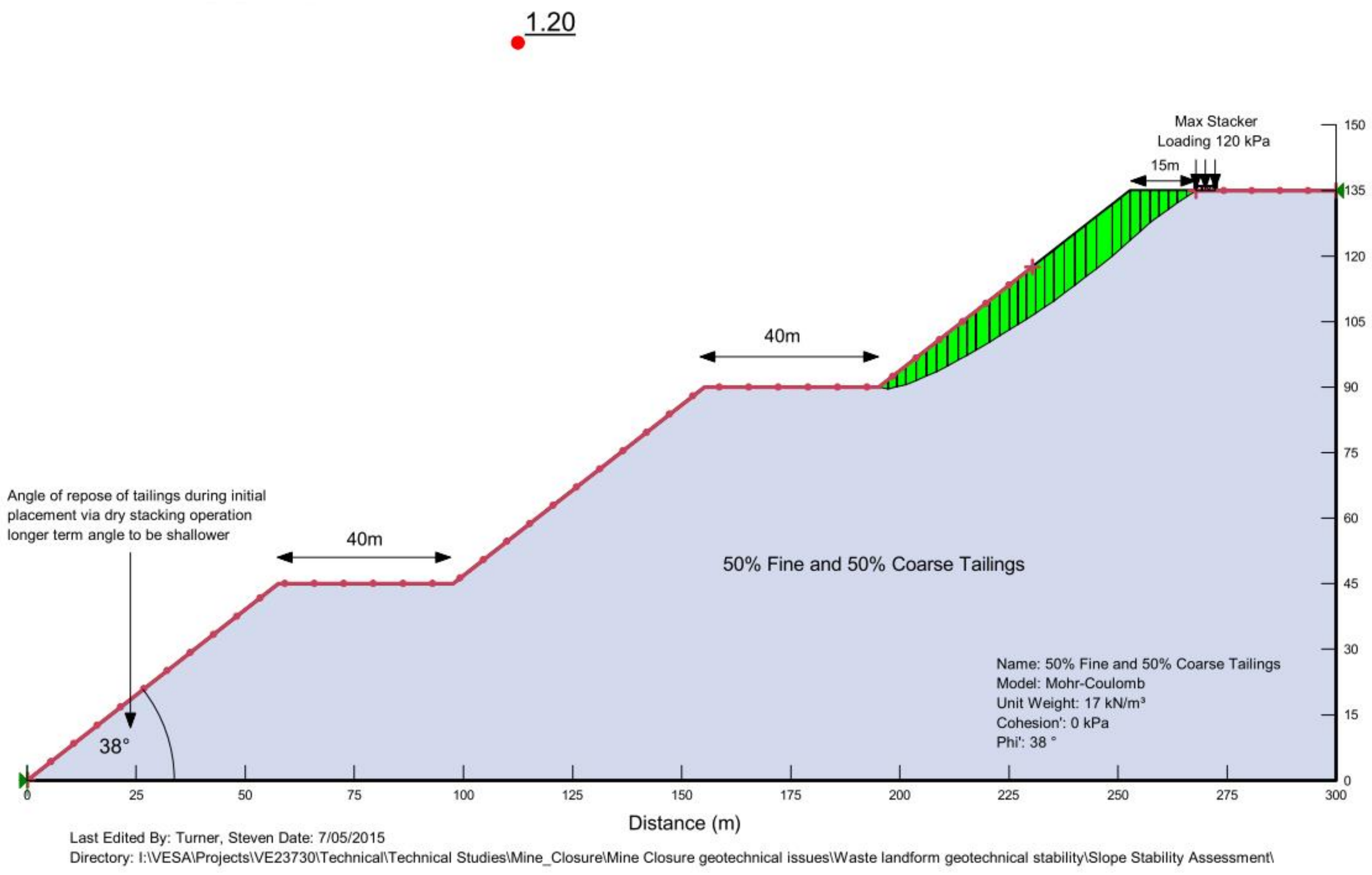
Attachment A

JACOBS



Particle Size Distribution of Waster Material Mixes
CLAY
FINE SILT
MEDIUM SILT
COARSE SILT
FINE SAND
MEDIUM SAND
COARSE SAND
FINE GRAVEL
MEDIUM GRAVEL
COARSE GRAVEL
COBBLES
BOULDERS
Percentage Passing (%)
0
10
20
30
40
50
60
70
80
90
100
0.001
0.01
0.1
1
10
100
1000
Particle Size (mm)
Coarse Tailings
Fine Tailings
Oxide and Fresh Crushed Rock
50% Coarse and 50% Fine Tailings
33% CT, 33% FT and 33% OFCR
25% Tailings and 75% OFCR

Attachment B


1.20
Max Stacker
Loading 120 kPa
15m
40m
40m
Angle of repose of tailings during initial
placement via dry stacking operation
longer term angle to be shallower
38°
50% Fine and 50% Coarse Tailings
Name: 50% Fine and 50% Coarse Tailings
Model: Mohr-Coulomb
Unit Weight: 17 kN/m³
Cohesion': 0 kPa
Phi': 38 °
150
135
120
105
90
75
60
45
30
15
0
0
25
50
75
100
125
150
175
200
225
250
275
300
Distance (m)
Last Edited By: Turner, Steven Date: 7/05/2015
Directory: I:\VESA\Projects\VE23730\Technical\Technical Studies\Mine_Closure\Mine Closure geotechnical issues\Waste landform geotechnical stability\Slope Stability Assessment\

Attachment C

Appendix D Landform Evolution Modelling Technical Note

Technical Note

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Date	26 May 2015
To	Nick Bull
From	Isaac Kelder
Subject	**Landform Evolution Modelling**

1. Introduction

The Central Eyre Iron Project (CEIP) is a proposed magnetite open pit mine at Warramboo in the Eyre Peninsula region of South Australia. An estimated 20 million tonnes per annum of co-mingled crushed waste is expected to be produced from mining operations, to be stored in an integrated waste landform (IWL), that is, a landform comprised from the co-disposal of fine tailings, coarse tailings, and rock.

This document sets out the process adopted for the conceptual design of the IWL, including details of the alternatives considered, and the outcomes of the initial desktop level erosion modelling undertaken to assess the ability of the design to withstand erosion in the long term.

1.1 Landform design and rehabilitation concepts

The CEIP IWL landform is required to be stable post rehabilitation. Because of the low annual rainfall at the site, the implication is that the facility should be stable without the assistance of a significant vegetal cover. Effectively, this requires that the materials used to construct the CEIP IWL outer layers should be stable on the slope angles and location in which they are placed.

The process adopted for this study was to consider a number of alternatives for the landform design based on the need for long term stability of the landform, the equipment to be used for the construction of the IWL and the required volumes for the facility. These alternatives were then subjected to a desktop erosion modelling study using parameters derived from the known geotechnical properties of the materials as an initial assessment of the likely performance of the landform based on the available knowledge base.

The initial outcomes then facilitated the development of a further alternative, which is now the preferred CEIP IWM landform design for the site.

1.1.1 Site Specific design elements

A unique feature of the CEIP IWL is the intention to construct it using three stacker conveyors. The system includes a central loading area where materials are placed on to the conveyor system, and consequently there are site specific opportunities and constraints for the construction process, including;

- the capability to strategically design the mix of materials for different areas of the landform, such as across the flat upper surfaces and on the side slopes;
- the opportunity to use a high proportion of rock in the outer layer of the surface to minimise the erosion risks, this being rock typically 160mm in diameter; and
- the potential for creating variability in the top surface through variation of the final back stacking placement.

Each conveyor system will place approximately 45m of material, with some variation on the lower lift due to variability of the Nominal Ground Level (NGL).

1.1.2 Site Specific Constraints and Requirements

The following data has been used in the design process;

- a defined tailings stacking area boundary, delineated by the mining boundary and various roads around the site;
- appropriate buffers between the Life of Mine (LOM) IWL footprint and proposed mine lease boundaries (e.g. 50 m minimum); and
- target volumes of the order of 1,800Mm^3, although the target volumes were uncertain early in the project and resulted in an initial target closer to 2,100 Mm^3.

In addition, design inputs were based on;

- water management based on the 1 per cent Annual Exceedance Probability (AEP) storm event, which is equivalent to the 1:100 year storm event; and
- a sediment loading based on 200 years of erosion.

It should be noted that longer erosion modelling periods were also used to assess the durability of the design for periods in excess of 200 years as well.

1.2 Base Case Designs

The initial designs considered for the site include the following:

- A linear stepped design, using 20m high lifts at 18 degrees (1 (vertical):3 (horizontal)) slope angle with 15m wide benches between each lift (refer to **Figure 1.1**).
- A concave slope design using a 45m high lift, with slopes varying from 18 degrees (1v:3h) to 9.46 degrees (1v:6h), with 40m wide benches between each lift.

For each of the above scenarios, the benches were sized to accommodate the provisional estimate of the expected sediment over 200 years, together with the 1% Annual Exceedance Probability (AEP) rainfall at the end of 200 years.

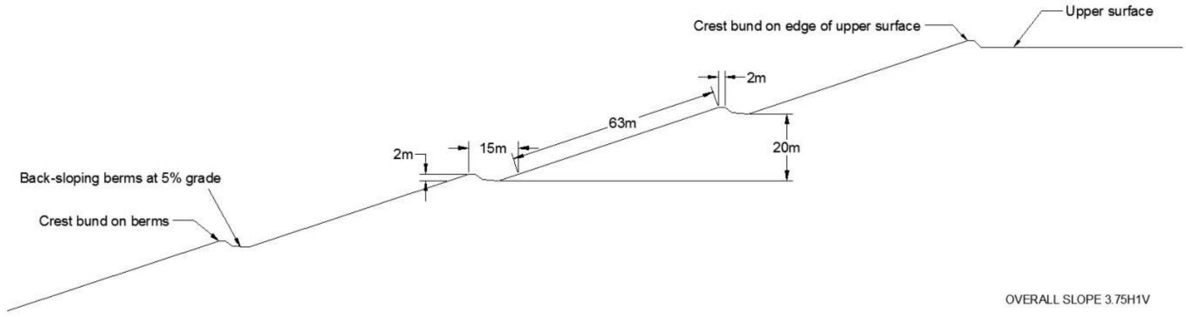


Figure 1-1: Conceptual Slope Configuration for the CEIP IWL (20m Vertical Lifts with Benching)

For each of the initial designs, two scenarios were considered, namely:

- The as built or construction scenario prior to the placement of the outer layer, that is, immediately after placement of a mixture of coarse tailings, fine tailings and rock.
- The final rehabilitated scenario, with the outer layer comprising a mixture of rock, subsoil and topsoil.

The perspective view of the two initial designs is shown in **Figure 1-2** and **Figure 1-3**.

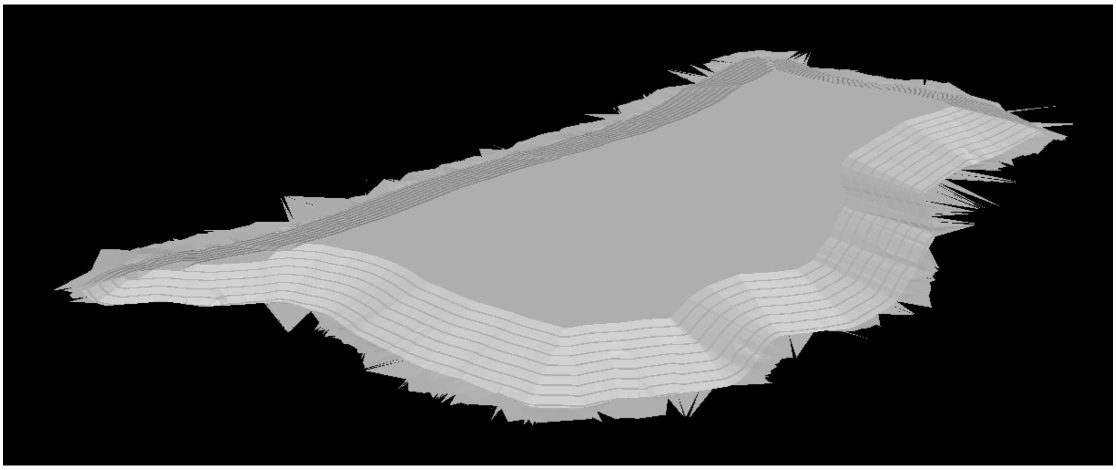


Figure 1 -2 – Initial 20m high benched option

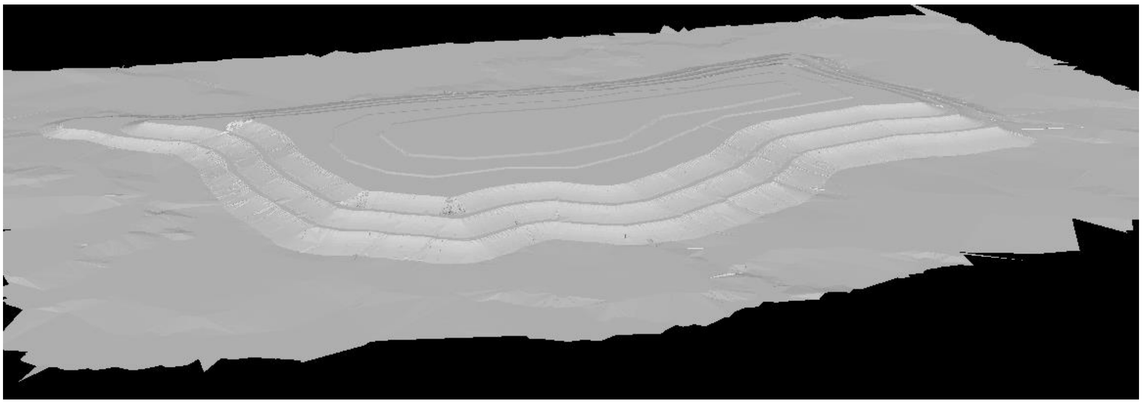


Figure 1-3 – Initial 45m high concave option

1.2.1 Geotechnical stability

To assess the geotechnical capacity of material to support the stacking machinery, a conservative assessment of the potential weakest material configuration was conducted by Jacobs 2015. The stability assessment is not detailed here, but indicated the initial designs to be geotechnically stable both during construction and in the longer term.

2. Erosion Modelling

The SIBERIA landform evolution model has been used for the erosion assessment of post-mining landforms (Hancock et al. 2008, Willgoose and Riley 1998) as well as natural catchments (Hancock, Willgoose and Lowry 2013, Hancock et al. 2010). SIBERIA has been extensively tested and validated at the Ranger Uranium Mine in Northern Territory, with simulated erosion rates compared to field measured data and similar geomorphic catchments. In addition, SIBERIA has been applied successfully as part of the landform design process on mine sites across Australia. Based on its successful track record, the SIBERIA model has been selected to model the proposed IWL designs.

Information in terms of the technical approach of SIBERIA is given in Appendix A.

Importantly, SIBERIA uses annualised erosion rates based on the long term performance of landforms. Comparative modelling of rainfall event based models such as CAESAR-Lisflood and SIBERIA (Hancock et al, 2014) have shown that, although the SIBERIA model doesn't include specific extreme rainfall events, the erosion rates and patterns generated are broadly similar to those produced by models that do include the specific flood events. This similarity in erosion patterns is because SIBERIA (once calibrated) uses average erosion rates, which are not based on average rainfall, but rather the long term average erosion including that caused by more extreme rainfall events.

For the purposes of the study, erodibility parameters required as input to the SIBERIA model were compiled using the geotechnical properties of the materials by an experienced geomorphologist (Greg Hancock). The parameters used in the modelling are given in Appendix A together with the methodology used to develop the parameters. Values have been compiled for:

- A 50:50 mix of coarse and fine tailings, considered to be a conservative input for the pre-rehabilitation landform. The performance of these materials were assessed over a 5 year period only, being a conservative assessment of the potential exposure period prior to the placement of the outer surface materials.
- Various combinations of rock, subsoils and topsoil varying from:
  - 33% equal mix, considered to be an unlikely scenario, but used for a sensitivity analysis;
  - 50% rock, 25% subsoil and 25% topsoil, considered to be a possible outer layer mixture; and
  - 75% rock, and an equal mix of subsoil and topsoil, considered the most likely outer layer mixture at this stage.

It is important to note that, although quantitative results have been generated in the modelling process, the greater value of the modelling is in the comparative results for the different landforms. The quantitative extent of future erosion will be validated once the erosion models have been calibrated.

It should also be noted that all of the analyses detailed in this evaluation are based on the landform without vegetation. This approach is motivated by the studies by Chorley (1969) in the United States that have indicated that for arid areas with rainfall below 400 to 450mm/annum, the benefit of vegetation in controlling soil erosion is limited. This limited benefit is explained as being due to the low actual surface contact cover, frequently less than 5% of the surface area. This approach to landform modelling in arid areas, that is, excluding vegetation in the modelling, has also been used widely in Australia (Landloch, 2012).

The potential benefit of vegetation for the CEIP IWL may be worth consideration at a later stage, however, based on the possibility that, if rock cover of 75% is achieved, then even a 5% basal

For the purposes of this study, vegetation has been excluded from the erosion modelling assessment.

2.1 Initial Analysis

The initial outcomes from the modelling are discussed briefly below. Note that for each of the scenarios, a sensitivity analysis was used to assess the potential impact of variability of the proportions of materials in the outer mix. However, the outcomes of the sensitivity analysis are only given for the final preferred design (refer to **Section 3**), the outcomes of the sensitivity analysis for the two options discussed here being used primarily to inform the final design.

2.1.1 Construction Phase

The stepped design and concave designs are shown in **Figures 2-1** and **2-2** for the conservative assessment of coarse and fine tailings only assuming no rock is present in the material placed.

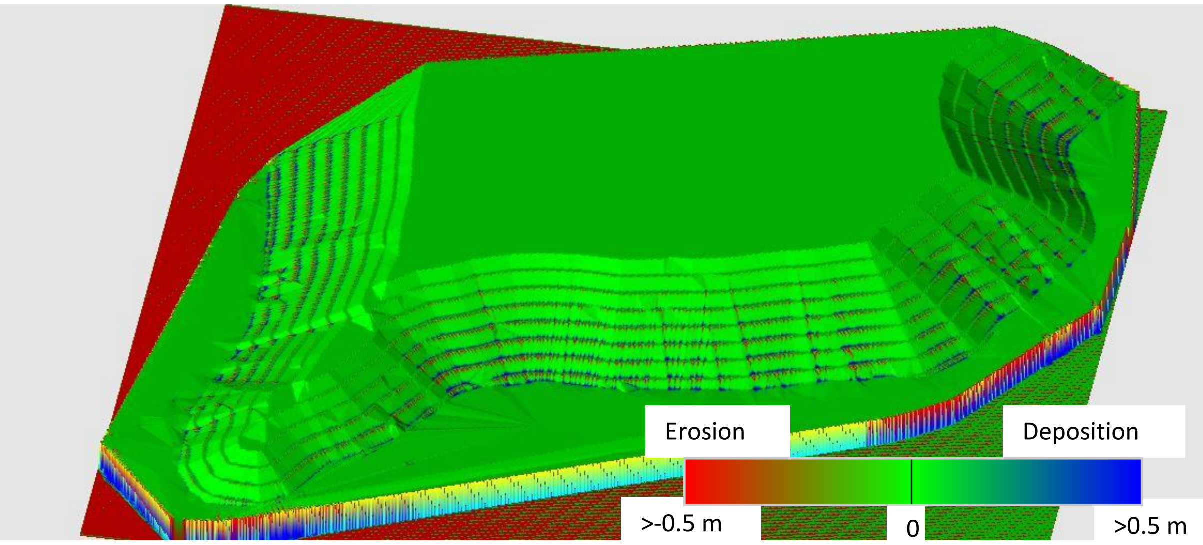


Figure 2-1: A 20m Stepped Design Assuming a 50:50 Coarse and Fine Tailings Fraction - 5 year simulation

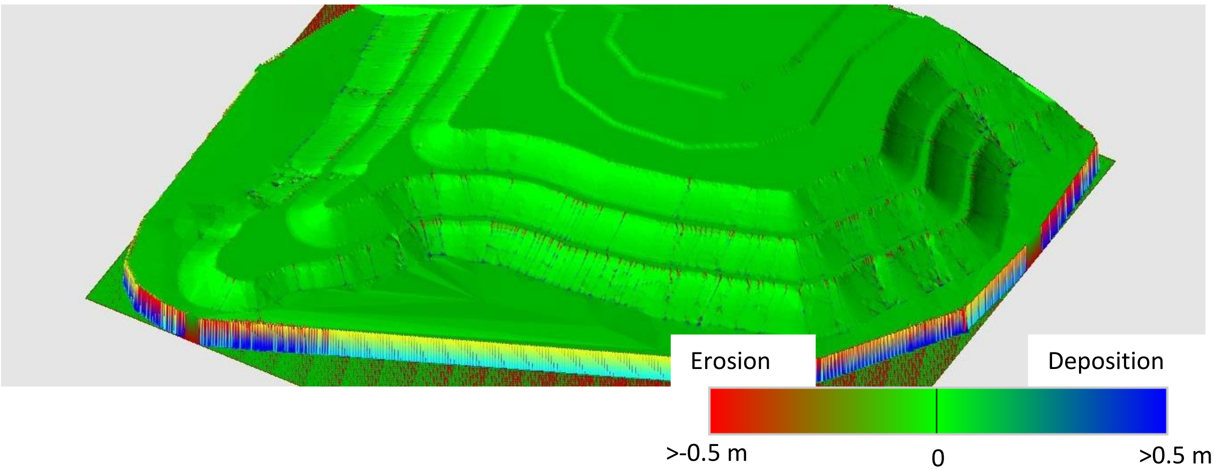


Figure 2-2: A 45m Concave Design 50:50 Coarse and Fine fraction - 5 year simulation

2.1.2 Longer Term Assessment

The stepped design and concave designs are shown in **Figures 2-3** and **2-4** for the longer term assuming a mix of rock, subsoil, and soil. The assessments shown are based on 50% rock in the outer layer, with 25% of subsoil and soil. It is important to note that the base case for the study is likely to be 75% rock in the outer layer.

The logic for assessing a lower rock percentage than that current expected in the outer layer is based on:

- The expectation that the approach to the design and construction may need to have some flexibility, so that, if a landform can be designed that meets the target for long term stability with a slightly lower rock percentage, there will be room to adjust the percentage of rock if required to address future erosion risks.

- The actual percentage rock in the outer surface achieved after placement of topsoil and deep ripping (which is the current preferred strategy for the topsoil) will need to be confirmed in the field during construction.

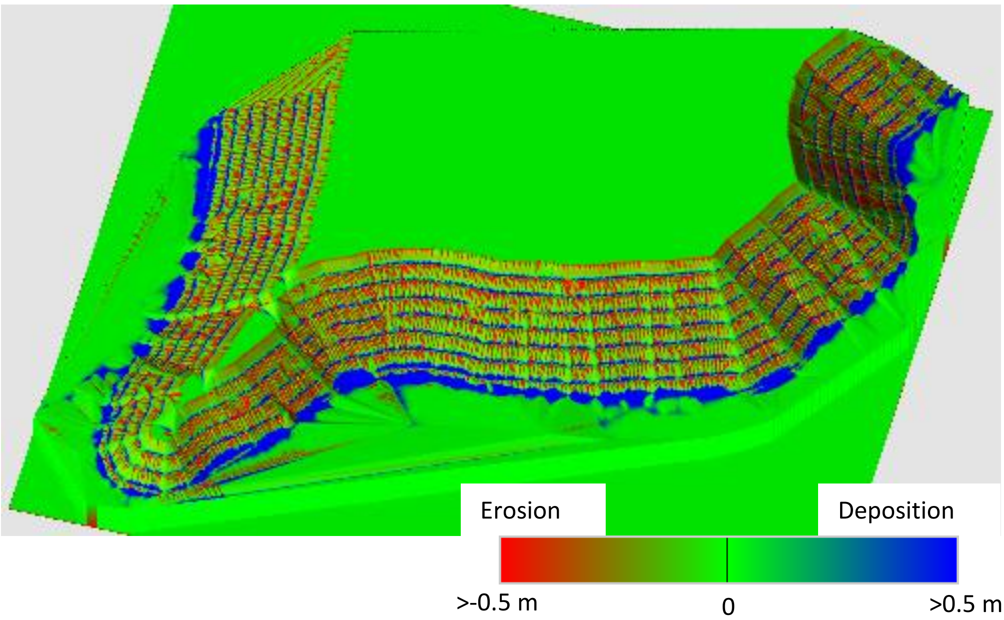


Figure 2-3: A 20m Stepped Design Assuming a 50:25:25 Rock, Soil and Subsoil mix - 200 year simulation

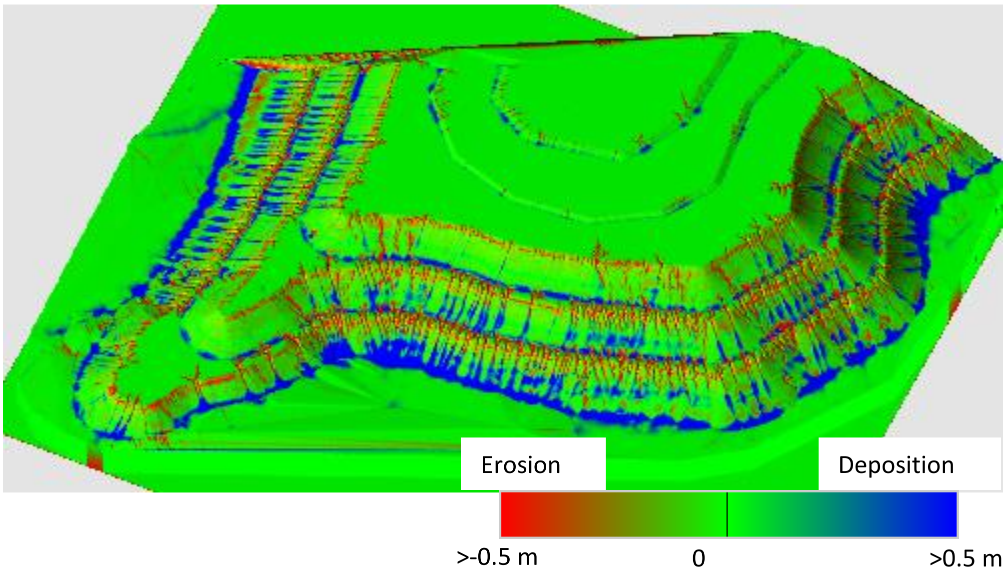


Figure 2-4: A 45m Stepped Design Assuming a 50:25:25 Rock, Soil and Subsoil mix - 200 year simulation

The predicted long term erosion rates for these designs was indicated to be in the range of 10t/ha to 20t/ha based on the parameters used.

2.1.3 Review of Initial Outcomes

For the purposes of the initial design evaluation, a target long term erosion rate of 10t/ha/year was selected. This erosion rate has not been compared to the natural erosion rate in the area, but is rather based on the expectation from published data that sites with erosion rates of the order of 5 to 10t/ha/year exhibit a low tendency for rilling and gulley formation (Landloch, 2012).

With the modelled outputs indicating average erosion rates in the range of 10 to 20t/ha/year over a period of 200 years, the initial designs are considered reasonable for an IWL facility, but slightly above the target levels for the facility.

Note that, from an environmental management perspective, the use of benches for both the benched and concave design ensures that the sediment generated remains on site for the bench design life of 200 years. In addition, the predicted typical gully depth for each of the alternatives was of the order of 0.5m, being within the outer capping layer, but with a maximum gulley depth of 2 m.

3. Preferred IWL design

Although the initial outcomes detailed in **Section 2** were considered favourable, it was apparent that a number of challenges remained, including:

- the desire to reduce the erosion rates further to preferably in the range of 5 to 10t/ha/year or less;
- the need to address concerns around the longer term performance of the design, that is, post 200years when the benches have potentially filled with sediment; and
- minimising the risk of progressive failure should overspilling of one of the benches occur.

It also became apparent during the design process that the stackers would build the 45m lifts in two stacks, namely a front stack of 30m and a back stack of 15m, which changes the optimal layout from a construction perspective with the need to limit dozing or double handling as far as is practical.

It was also clear that the natural analogues in the area tend to be concave from crest to the toe, and that developing a more concave overall appearance would be preferable from a visual perspective. However, analysis of the potential to form a completely concave outer slope indicated that it would not be practical, both in terms of the volumes that could be obtained, and the construction constraints.

An amended design was then developed incorporating the following approach:

- The front stack of each conveyor was designed as a concave slope, with typical heights of 30m. This target height increases slightly due to the back slope of benches, being up to 35m for the second concave bench. The lowest bench is also higher in places (up to 50m) due to the variation of the NGL. The concave slopes range from 18 degrees (1v:3h) to 11.3 degrees (1v:5h) for the 30m high lifts, but flattening further for the longer slopes, with the slope reducing to 9.46 degrees (1v:6h).

- For the back stack of each stacker, the slopes are linear with typical heights of 15m, again increasing slightly in height due to the back slope of benches. The slope angle for the back stacks will be 18 degrees (1v:3h). It should be noted that the concave slope template is based on having a consistent erosion risk down the slope, and that the initial slope is at 18 degrees (1v:3h) for a height of some 20m. The 15m high linear slope on the back stack at 18 degrees (1v:3h) is therefore consistent with the concave slope design.
- The benches have been made progressively wider moving downslope, with each bench designed to be able to accommodate the sediment loading and runoff for the design event for the full upslope catchment measured from each bench to the crest of the IWL, and not just the inter-bench catchment. The benches vary in width from 20m on the upper bench, to 100m for the lowest and widest bench.
- In addition to a crest bund on the upper edge of the IWL, each of the upper three benches will have crest bund, typically 1.5m in height, to further limit the risk of overspill from the bench. Note that initial erosion modelling was undertaken without the benches to assess the need for the benches.

The amended cross-section is shown in **Figure 3.1.**

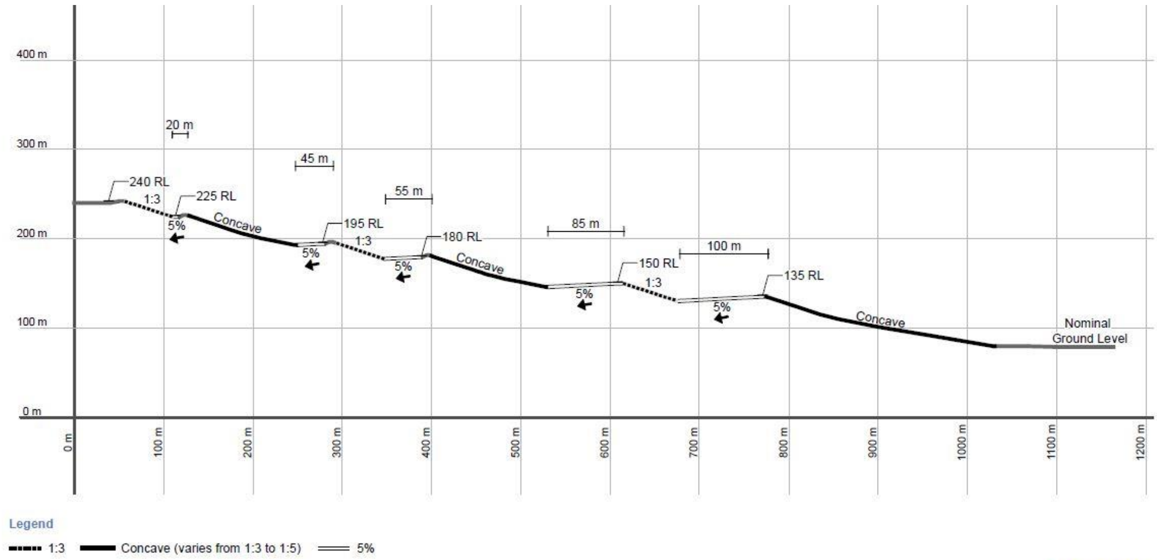


Figure 3-1 | Amended Cross Section of Preferred IWL Design

CENTRAL EYRE

Error! Reference source not found. **– Amended Cross Section of Preferred IWL Design**

The benefit of the progressively wider benches is as follows:

- There is provision to prevent progressive failure down the slope, since each bench can theoretically contain the total sediment and runoff load from the full upslope catchment.
- Consequently, the lower bench designs are extremely conservative for the 200year modelling analysis.
- The wider benches will provide significant attenuation of any future overspills, that is, the peak flow rates of any overspill will be significantly reduced, which will potentially further reduce the risk of erosion in the long term.
- The overall landform has a concave appearance and is considered to blend more with the natural environment than the previous designs. The design is still able to achieve the required volumes for the IWL.

It should also be noted that, although there is a crest bund proposed on the upper ridge line, the upper surface will be shaped to ensure water does not flow along the crest bund to reduce the erosion risk, and also does not pond against the crest bund to reduce the risk of piping. This reshaping of the upper surface on the outer edge of the IWL may result in the crest bund on the upper ridge line being only a nominal feature.

The overall layout of the preferred IWL design is shown in perspective view in **Figure 3-2**.

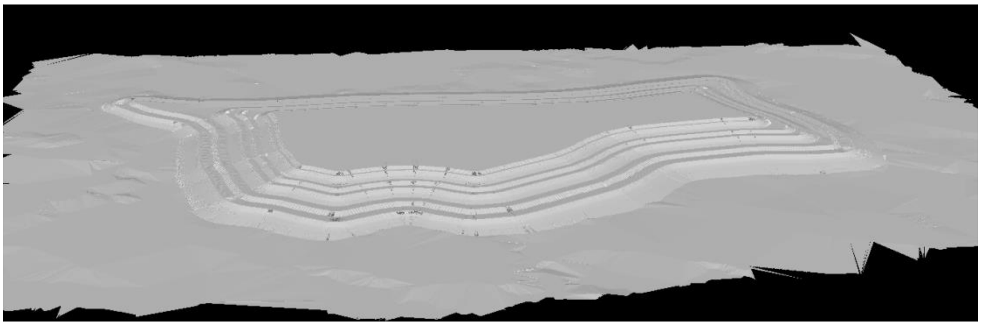


Figure 3-2: Perspective View of Preferred IWL Design

A coloured view of the landform is shown in **Figure 3-3**.

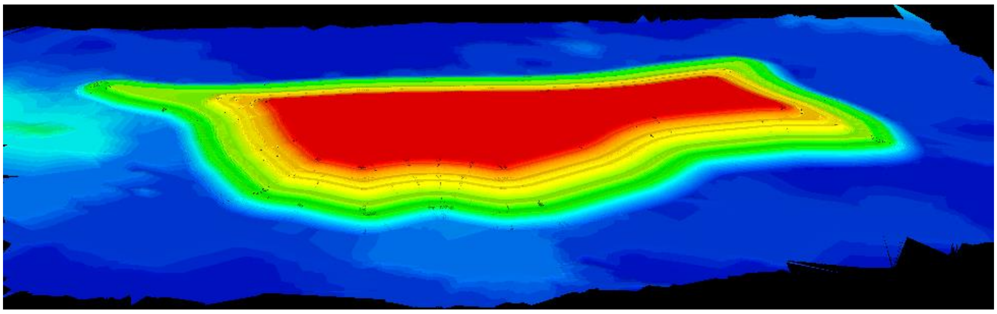


Figure 3-3: Perspective View of Preferred IWL Design Shaded by Elevation

3.1.1 Erosion Modelling Outcomes

The erosion modelling outcomes are shown in **Figure 3-4** and **3-5**, for the case of the constructed landform prior to capping (5 year modelling duration), and the final rehabilitated landform (200 year modelling duration).

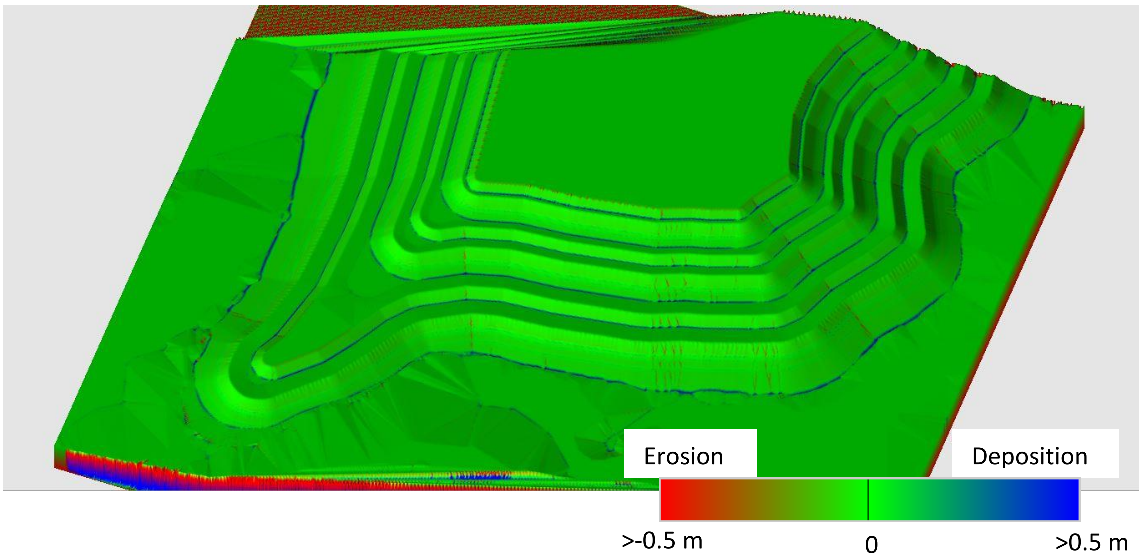


Figure 3-4: Erosion Modelling of Preferred Landform Prior to Capping; 5 year duration, without benches

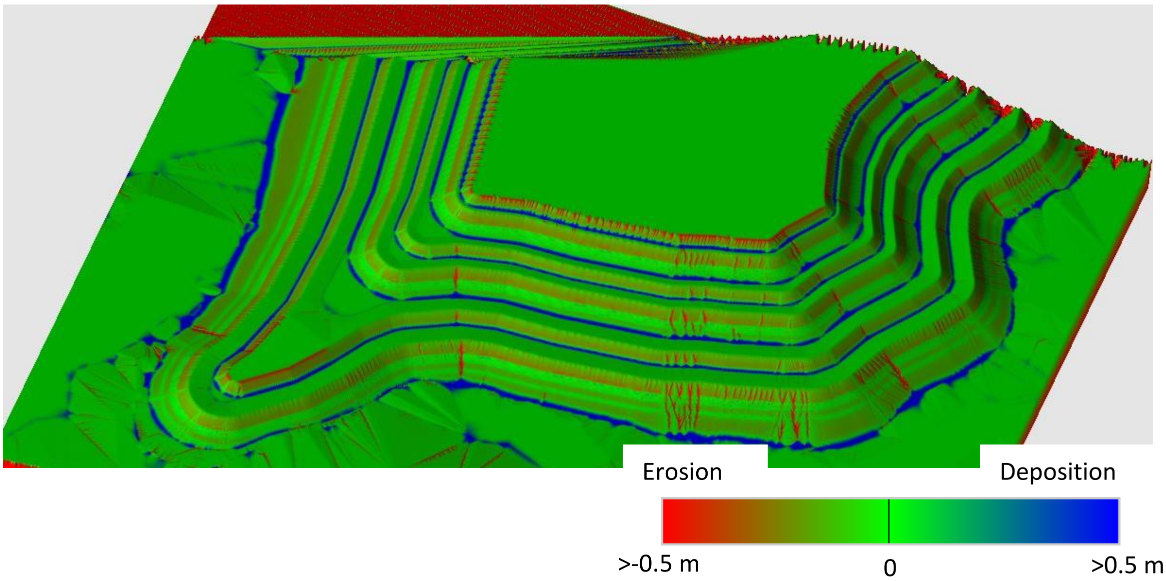


Figure 3-5: Erosion Modelling of Preferred Landform after Rehabilitation; 200 year Modelling Duration, using 50% Rock and equal proportions of subsoil and topsoil, without benches

It should be noted that:

- The overall erosion rate without bunding on the benches was of the order of 5 to 10t/ha/yr, within the target erosion rate.
- A finer model resolution was used to assess the performance of the bunding on the benches, and they have been found to be effective in reducing the erosion rate to the lower range, typically around 5 t/ha/yr. This reduction is largely due to the removal of progressive inter

bench and gullying evident in **Figure 3-5**, where overspill from an upper bench causes additional erosion on the lower slopes.

- The modelling also indicated that the lower benches will probably be able to store sediment for longer periods, potentially in excess of 500 years.
- The benefit of attenuation of flows in reducing the impact on lower slopes once benches have filled with sediment has not been quantified to date, but is expected to be considerable in the longer term.

3.1.2 Sensitivity Analysis

Comparison of the erodibility of the final landform for different proportions of rock has indicated the following:

- At 50% rock in the outer layer (shown in **Figure 3-5**), erosion rates are of the order of 5 to 10t/ha/yr on average.
- At 75% rock in the outer layer, erosion rates are predicted to reduce by around 30 per cent compared to the 50% rock coverage.
- At 33% rock in the outer layer, erosion rates could increase by around 50 per cent.

As indicated previously, these values are still preliminary, but there is clearly a benefit in ensuring a rock percentage in the outer layer of the order of 50% or greater.

3.1.3 Summary of preferred landform

Given these constraints and assumptions, outcomes of the preferred landform design for the CEIP IWL are as follows:

- current volume capacity of preferred landform design is 1,816 million m3;
- the landform dimensions are:
  - an average total landform height of between 135 to 160 m, with variability due to underlying natural topography (average landform height ranges from 130 m above topographical highs to 170 m above topographical lows);
  - an elevation of 240 m AHD for the upper surface of the IWL, with underlying elevation ranging from 70 to 110 m due to the natural topography (average of 80 m elevation); and
  - footprint area of 1,970 hectares (excludes a 50 m buffer between the final rehabilitated landform toe and proposed mine lease boundary).

The conceptual slope configuration is;

- a slope design concave in nature for the typically 30m high, longer slopes with a configuration of 18 degrees to 11.3 degrees, and a linear slope of 18 degrees for the 15 m high shorter slopes;

– a series of back sloping berms at 5 per cent grade, and bunding both on the upper four berms, as well as on the crest of the upper flat surface, although subject to optimisation at final design; and
– a high percentage of rock in the outer surface of the IWL to limit the risk of erosion, typically expected to be in the range of 50 to 75% of material with a nominal diameter of 160mm.

The landform design presented has the advantage of:

- Incorporating both linear and concave slopes over slope heights that have been shown elsewhere to be potentially stable in arid environments.
- A built in conservatism including:
  - the use of a lower rock percentage than is expected to be achieved on the outer slope;
  - exclusion of the benefit of vegetation in stabilising the landform; and
  - bench designs that provide for significantly greater sediment and storm capture capacity than is theoretically required, particularly on the lower benches.

4. Conclusion

The work undertaken has provided consideration of a number of alternatives for the CEIP IWL. The currently preferred alternative is considered to be robust solution that is expected to be easily integrated into the construction methodology.

Although based on a desktop study, it is believed that the conservative approach built into the preferred design will limit the erosion risk associated with the IWL, and will also provide the flexibility to optimise and improve the design both in the final design process, and into the construction phase.

APPENDIX A

The long-term average change in elevation of a point is determined by predicting the volume of sediment lost from and added to a node on a digital elevation model using the fluvial sediment transport equation (based on Einstein-Brown equation):

1) $\mathbf{q_{sf} = \beta_1 q^{m1} S^{n1}}$

Where q is the discharge per unit width (m^3/y), S (m/m) the slope in the steepest downslope direction; and β_1, m_1 and n_1 are calibrated parameters. SIBERIA uses a subgrid effective parameterisation to relate discharge to area draining through a point as:

2) $\mathbf{q = \beta_3 A^{m3}}$

Where β_3 is the runoff rate constant, and m_3 is the exponent of area, both of which require calibration. The input parameters of β_1, β_3, m_1, m_3 and n_1 are typically derived by fitting equation 1 & 2 to time series data of runoff and erosion. As this data is not available for CEIP, parameters are based on known material characteristics.

The β_1 parameter controls the 'rate' of erosion across the landform and controls the rate of sediment movement. The m_1 parameter controls the slope length response and the dominant erosive processes. The standard practise for situations where there is no field plot or erosion data is to assume values of m_1 = 1.5 and n_1 = 1.5. The β_3 and m_3 are often taken as 1.0 to reduce the difficulty of deriving values for the remaining parameters. The β_1 parameter was derived by relating material properties to existing data sets and calibration with the RUSLE model.

Table 1-1: Parameter set for CEIP

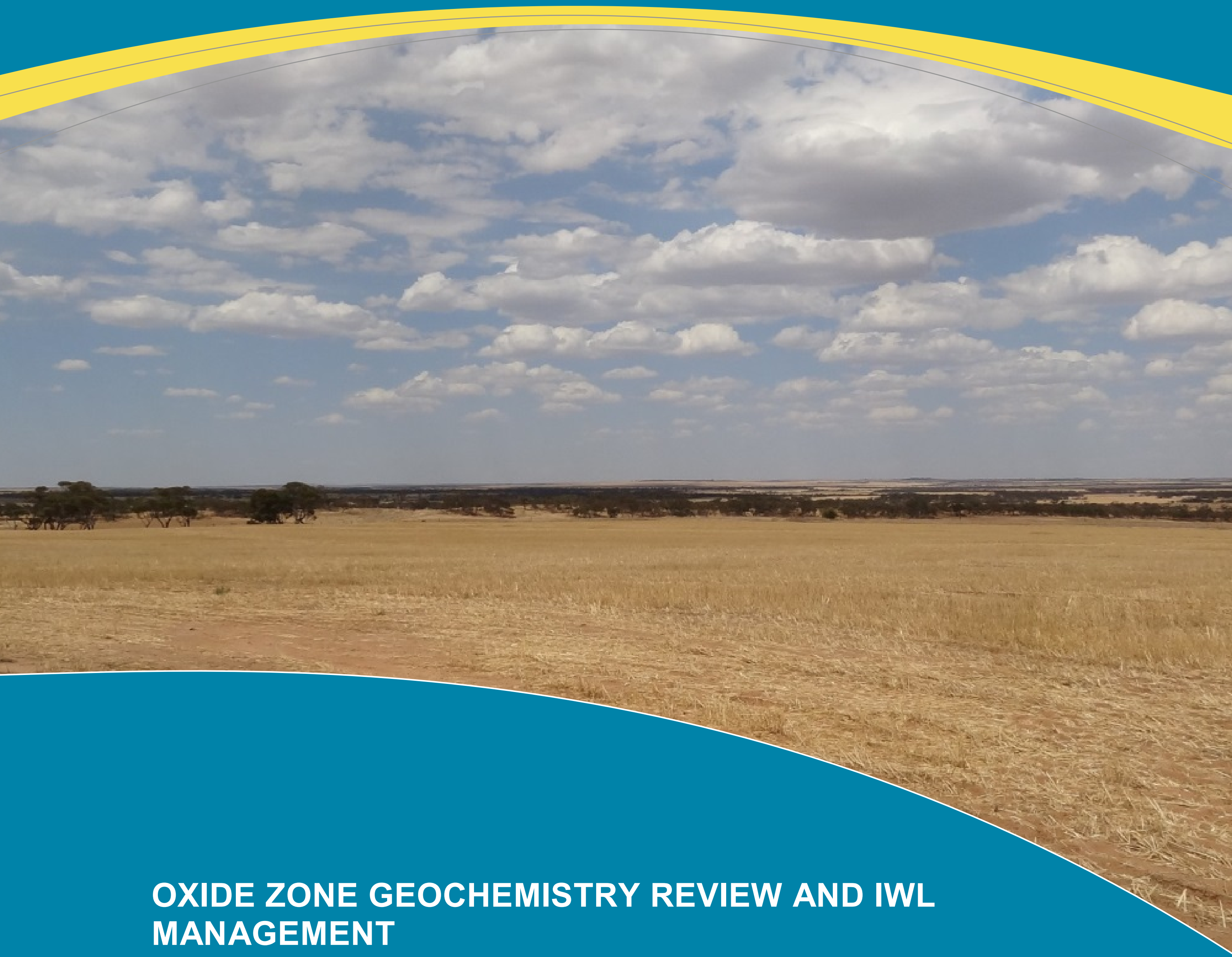
Material	β_1	m_1	n_1	β_3	M_3
50/50 Combined tailings (fine & coarse fractions)	0.00225	1.5	1.5	1.0	1.0
33/33/33 Waste rock / Fine tailings / Coarse tailings	0.00154	1.5	1.5	1.0	1.0
50/25/25 Waste rock / topsoil / subsoil	0.00293	1.5	1.5	1.0	1.0
75/12.5/12.5 Waste rock / topsoil / subsoil	0.00155	1.5	1.5	1.0	1.0

A desktop assessment was considered valid for this level of study, as detailed information on the physical and chemical characteristics of materials are not yet available. Without detailed information on material properties or erodiblity data, SIBERIA simulations must be considered as preliminary only, and will be subject to refinement as development of the mine site progresses. The desktop study allows the evolution of the landforms to be broadly understood and can indicate differences between design performances.

It is recommended that targeted flume testing and rainfall simulations are undertaken on materials prior to construction and calibrated test slopes developed as part of construction.

Appendix E CEIP Oxide Zone Geochemistry Review and IWL Management Plan

BUILDING A BETTER WORLD



OXIDE ZONE GEOCHEMISTRY REVIEW AND IWL MANAGEMENT

Central Eyre Iron Project

Prepared for Iron Road Limited

September 2015

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V3.0	28/5/15	Updated	P. Waters	B. Smedley	M. Braimbridge	M. Braimbridge
V4.0	8/9/2015	Final	P Waters	M Braimbridge	M Braimbridge	M Braimbridge

Iron Road Limited

Central Eyre Iron Project – Oxide Zone Geochemistry and IWL Management

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ACRONYMS AND ABBREVIATIONS

Acronym or abbreviation	Definition
AHD	Australian Height Datum
ANC	Acid Neutralising Capacity
AMD	Acid and Metalliferous Drainage, synonymous with acid rock drainage
ARD	Acid rock drainage, synonymous with Acid and Metalliferous Drainage
CEIP	Central Eyre Iron Project
GARDGuide	Global Acid Rock Drainage Guide
INAP	The International Network for Acid Prevention
Iron Road	Iron Road Limited
IWL	Integrated Waste Landform
ML	Mining Lease
Mtpa	Million tonnes per annum
MWH	MWH Australia Pty Ltd
NAG	Net Acid Generation
NAF	Non-Acid Forming
NAPP	Net Acid Production Potential
PAF	Potentially Acid Forming
XRF	X-Ray Fluorescence

1 OBJECTIVE

Iron Road Limited (Iron Road) is undertaking project approvals for the Central Eyre Iron Project (CEIP). The CEIP is a long life magnetite project located at Warramboo on the Eyre Peninsula region of South Australia, approximately 200 kilometres (km) north of Port Lincoln and 240 km southwest of Port Augusta. The CEIP lies 28 km southeast of the regional centre of Wudinna (**Figure 1-1**).

As per Iron Road's Environmental Policy, the project commits to managing all aspects of the operation in an environmentally responsible manner, with the objective of *"providing a net benefit for the environment and communities"* (Iron Road Limited 2015).

As part of the environmental assessment for the project, the potential for acid and metalliferous drainage (AMD, otherwise known as acid mine drainage, acid rock drainage or acid drainage) has been assessed. Despite this risk being identified as a low project risk, Iron Road is taking a precautionary approach to the management of AMD for the CEIP through the preparation and incorporation of AMD management actions into all stages of the project. A key part of the justification for this approach is illustrated in **Plate 1-1**, where the overall outcomes of the AMD assessment as detailed in this report are compared to other known AMD mining regions and individual sites. The CEIP Integrated Waste Landform (IWL) Management Plan acknowledges the framework and methodology presented in the GARD guide (INAP 2009) (**Figure 1-2**) for the management of AMD.

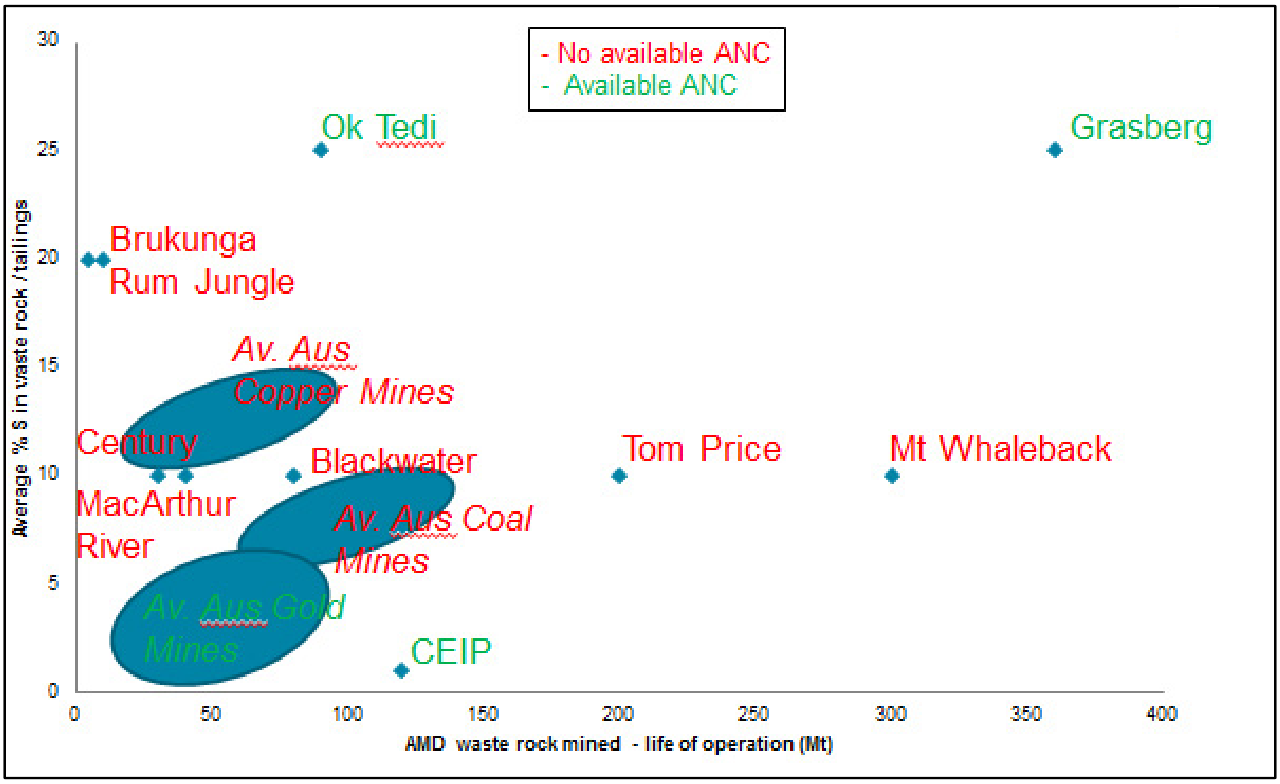

Plate 1-1: Comparison of known Australia Pacific AMD minesites

AMD assessment and management is an evolving science within the mining community. Definitions, classifications, management strategies and experiences will continue to improve over time. As such, the IWL Management Plan is intended to be updated during the life of the project as more detailed information is provided and more experience is gained. By adopting a precautionary approach, Iron Road is positioning itself to competently manage the small proportion of identified PAF material.

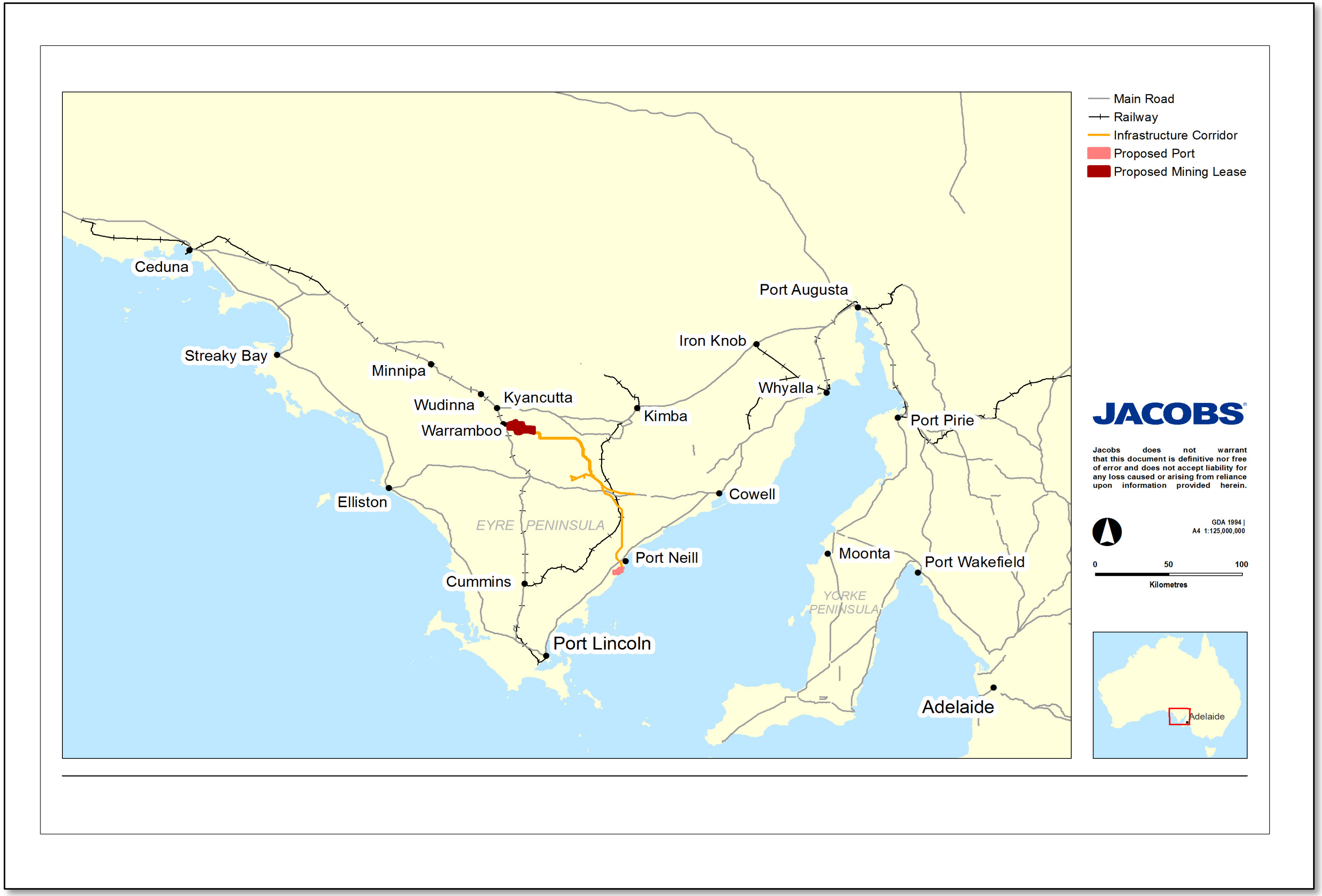

Figure 1-1: Regional location of the Central Eyre Iron Project (Source: Jacobs 2014c)

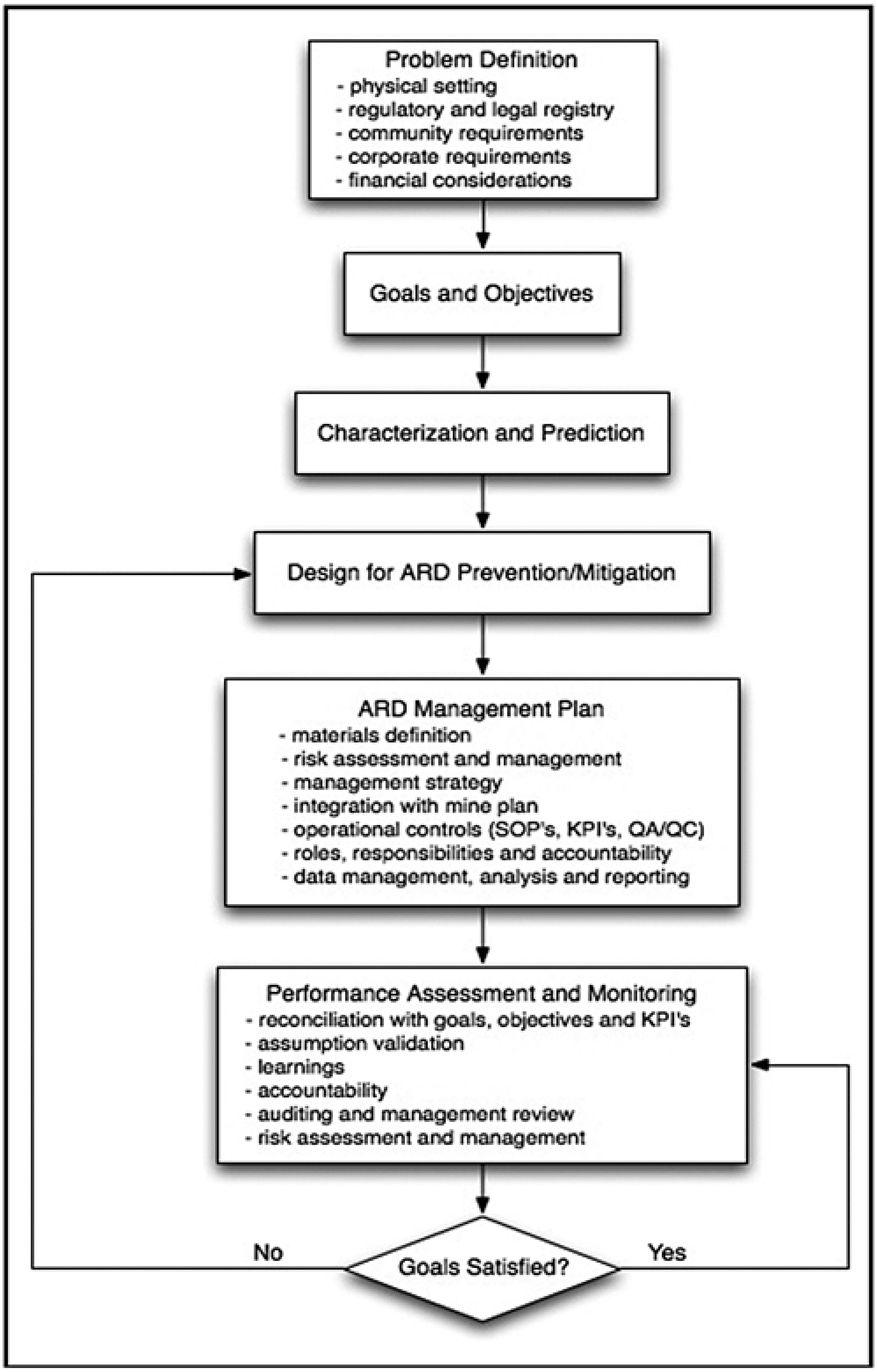

Figure 1-2: Flowchart for AMD/ARD performance assessment and management review (INAP 2009)

2 PROJECT BACKGROUND

The CEIP proposes to mine predominantly fresh (un-oxidised) magnetite rich gneiss rock located 40 to 600 metres (m) below the surface. The operation has a planned average movement of 300 Mtpa over a 25 year mine life. The project will include large scale, open pit mining and ore processing with rail and concentrate export facilities (Iron Road Limited 2014a) (**Figure 2-1**). Processing to produce a magnetite concentrate will be undertaken on site before transportation via rail to Cape Hardy for export, seven kilometres south of Port Neill. The Warramboo resource has a strike length of over six kilometres, including the Murphy South – Rob Roy (MSRR) and Boo Loo – Dolphin (BLD) deposits.

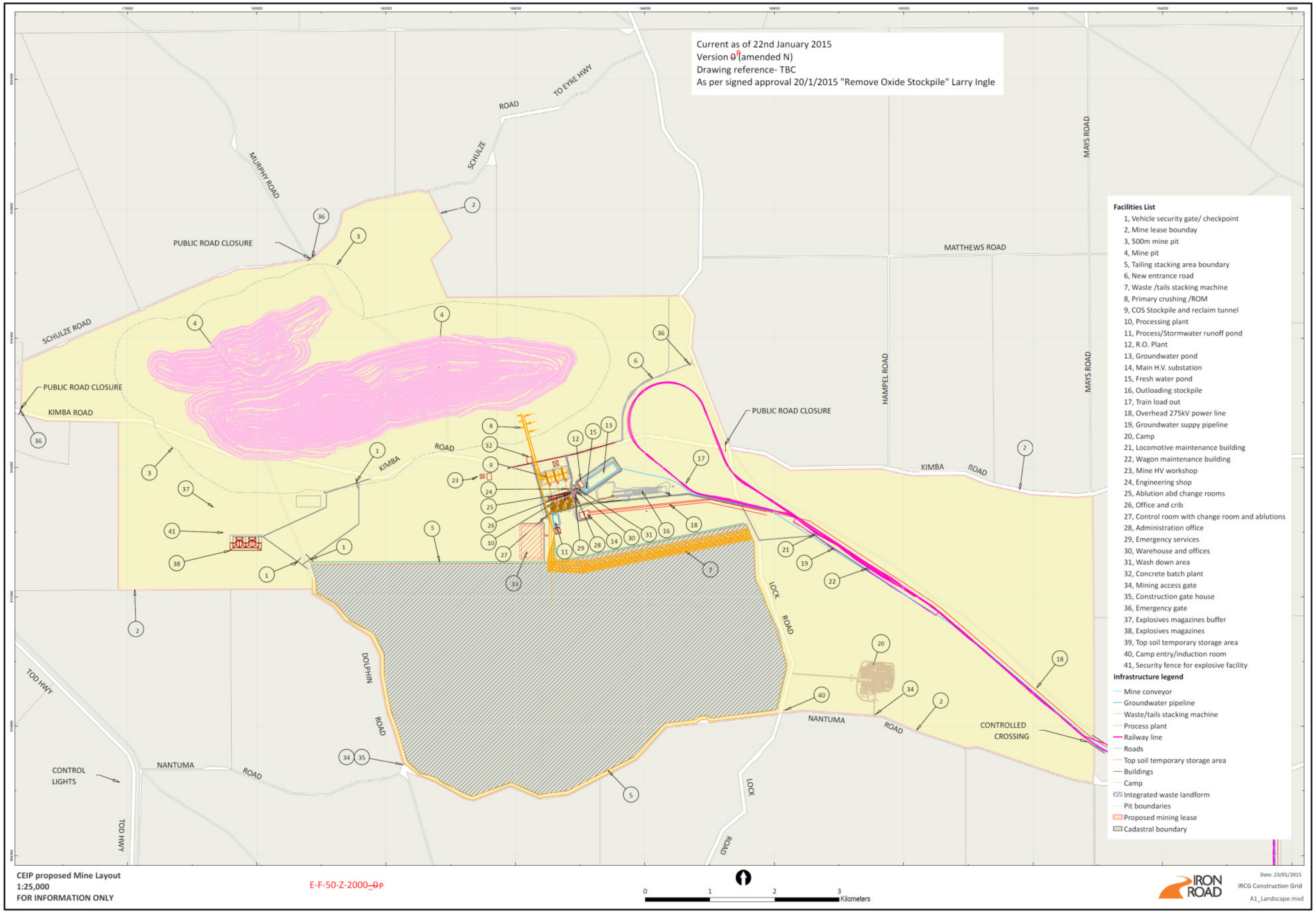

Figure 2-1: Mine layout of the Central Eyre Iron Project (Source: Iron Road Limited, current January 2015)

2.1 Geological Setting

The Eyre Yorke region is characterised by Archaean basement rocks and Proterozoic sandstones overlain by undulating to occasionally hilly calcarenite and calcrete plains and areas of aeolian quartz sands. The project area was subjected to surface oxidation resulting in a weathering profile of saprolite through to fresh rock. The weathered bedrock has a typical lateritic profile modified by later arid climate onset. The base of complete oxidation has been recorded at depths up to 70m with an average of around 40m. Published geological information (Flint and Rankin 1989) describes the project area footprint to be typically transported tertiary sediments consisting of Moornaba Sands (dune sands) overlying horizontal calcrete and clays and silts of the Bridgewater Formation. At depth the basement rock underlying these sedimentary units is Archean Granitic Gneiss.

Within the proposed mining area, the lithology of the Quaternary sediments is largely dominated by quartz sand forming dunes. Calcrete horizons are also found to varying degrees throughout the project area. These conditions are typical of the central, northern and eastern portions of the project area. Within these areas the Quaternary sediments are generally unsaturated. In low lying depressions such as around Lake Warramboo, lacustrine clay deposits are also present (Flint and Rankin 1989).

Tertiary formations consist of a Neogene (Miocene to early Pliocene) unit and older Palaeogene (mostly Eocene) unit. The lithology of the Neogene unit is predominantly argillaceous (clays and silts), however in some areas erosion and re-deposition of older Palaeogene sediments during the Neogene has resulted in a coarser fluvial and marine sand facies at the base of the Neogene (Hou et al 2003). The Palaeogene unit underlies the Neogene unit to the south and west of the project area and consists of grey to black carbonaceous sand and silt (Flint and Rankin 1989). The thickness of the Palaeogene unit is in the order of 20 m.

Saprolite within the vicinity of the project area is characterised by grey silty clay (a remnant of the original basement rock) at the top, grading down to partially weathered basement with much of the original rock fabric still remaining. Recent drilling indicates that the thickness of the saprolite is in the order of 20 to 40 m within the vicinity of the mine pit and integrated landform (SKM 2014c).

The basement material within the project area consists of the Archaean Sleaford Complex which is characterised by highly deformed and metamorphosed gneisses derived from sedimentary rocks. Due to the highly metamorphosed nature of the Sleaford Complex, it is likely that any sulphide minerals present in the original sedimentary units were subsequently mobilised out of the region as the rocks were increasingly subject to higher grades of metamorphism.

2.2 Planned Operations

The mining operation will be open pit, drill and blast, with in-pit crushing of material. Once crushed, ore will be transported by conveyor directly from the pit to the ore processing plant. Ore processing is planned to be conventional crushing, milling and magnetic/gravity separation, with a production rate of 21.5 million tonnes of concentrate per annum (Iron Road Limited 2014a). Belt filters receive coarse and fine tailings from the process facility, where the filtering process reduces the retained moisture content to approximately 10%. The dewatered tailings are then conveyed, together with crushed waste rock, to the IWL and dispersed using mobile stackers (refer to **Figure 2.2**).

Figure 2-2: Example of stacking of tailings from a conveyor (Courtesy Anglo American)

In order to access the ore, pre-stripping of the overlying oxide zone is required. The oxide zone is up to 70 m in thickness. All the overburden will be waste and will be transported from the pit area to the IWL for storage - initially by truck until the conveyor system is commissioned. Based on current dimensions of the planned pit, approximately 1,982 million cubic metres (Mm^3) of waste rock (oxide and fresh) will need to be mined over the life of the mine. The expected annual waste movement is shown in **Figure 2-3**.

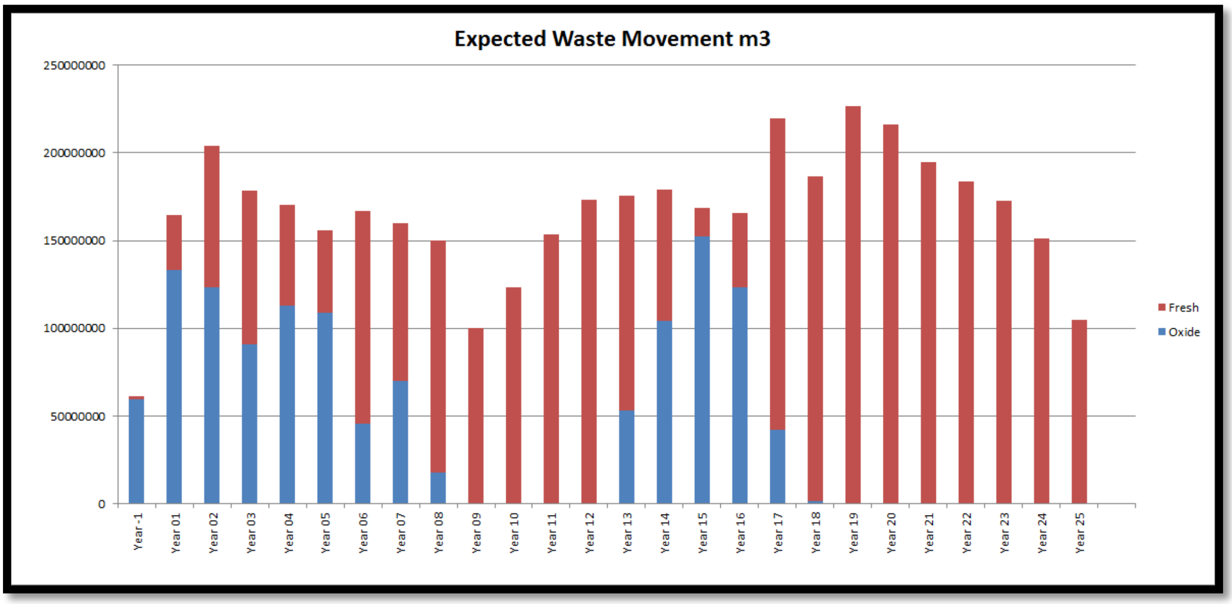

Figure 2-3: Expected waste movement volumes (m^3) per year of operation for fresh waste rock and oxide waste materials (Iron Road Limited 2014)

As only one waste landform is proposed to be created for the project, all waste rock and tailings will be co-disposed within the IWL. The IWL is designed to allow progressive rehabilitation of the landform from the early stages of construction. The integrated landform will be developed progressively by three mobile stackers that spread the waste in concurrent arcs. The IWL will be approximately 135 metres in height, constructed in three 45 metre high lifts.

A preliminary mine waste material inventory for the CEIP is presented in **Table 2-1**, incorporating available information for Life of Mine (LOM) volumes of tailings and waste rock materials provided by Iron Road.

Table 2-1: Preliminary mine waste materials inventory for the CEIP

Mine waste material type		Tonnage		Volume [1]	
		Annualised average (Mtpa)	LOM tonnes (Mt)	Annualised average (Mm^3pa)	LOM volume (Mm^3)
Waste rock	Total (oxide and fresh rock)	170	4,360	77	1,982
Tailings	Combined coarse and fine fractions	130	3,053	59	1,388
TOTAL		**300**	**7,413**	**136**	**3,370**

1. A consolidated stress bulk density of 2.2 t/m^3 assumed for the combined tailings/waste rock upon deposition within the IWL (information from Iron Road).

Progressive rehabilitation of the IWL is planned, with rehabilitation trials scheduled to commence as soon as possible after the integrated landform has reached its design height. A conceptual preliminary design for rehabilitation and closure of the IWL has been developed to provide a conservative basis for ongoing closure planning during the life of the mine. The conceptual IWL design provides a 'base case' scenario for development of specific landform design parameters and rehabilitation prescriptions, including a soil cover profile (**Figure 2-4** and **Figure 2-5**). The soil cover profile is intended to act as a store and release cover to minimise infiltration into the landform and hence any contact with any stored PAF material. In the event of any infiltration, it is expected that a lag time will occur between any recharge entering the top of the IWL and seepage reaching the water table (a distance of approximately 145 m). Assessment using a seepage model indicates the lag time may be in the order of 20 years but is significantly dependent upon vegetation cover (SKM 2014b)

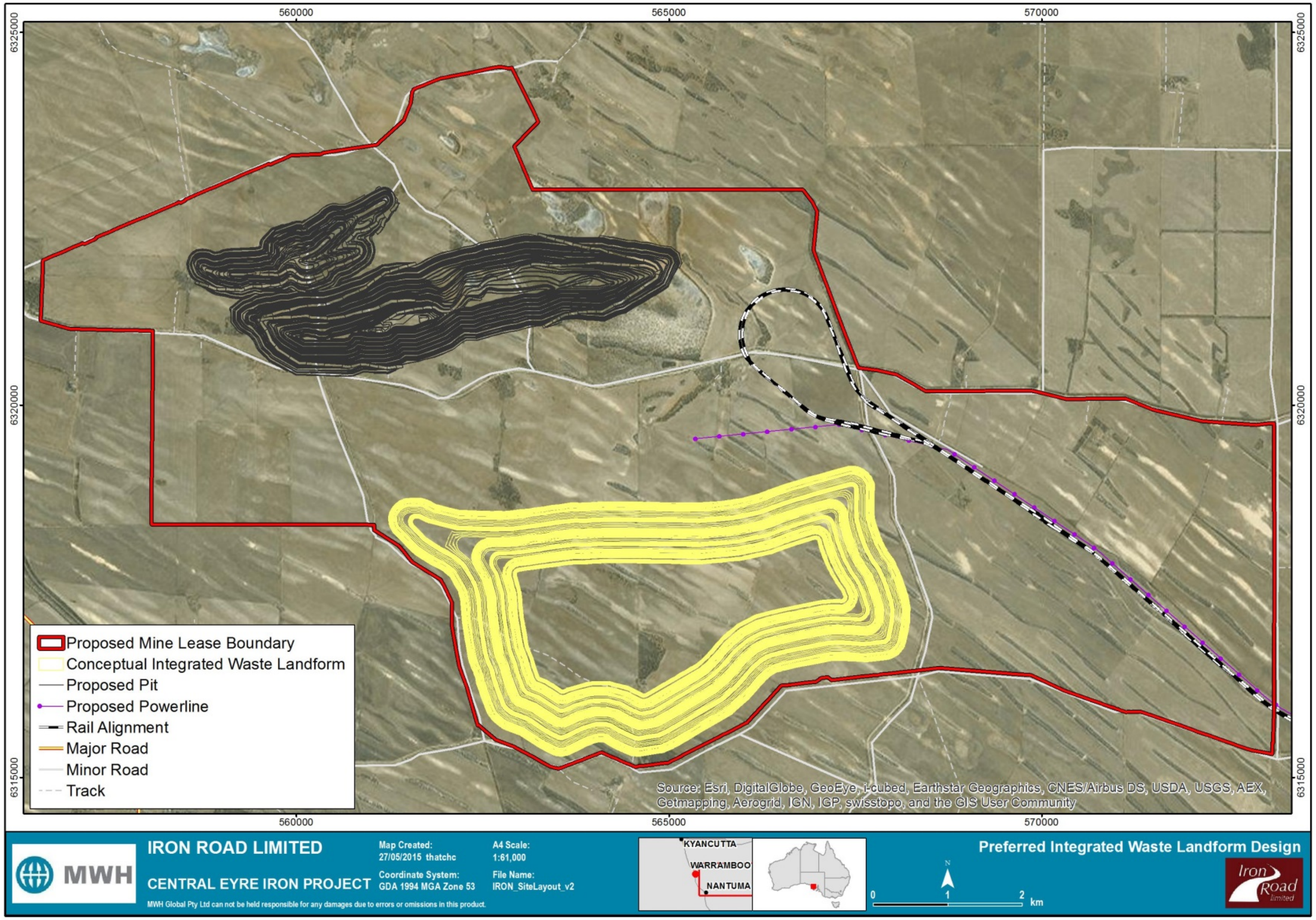

Figure 2-4: Preliminary conceptual landform design for the CEIP IWL, plan view

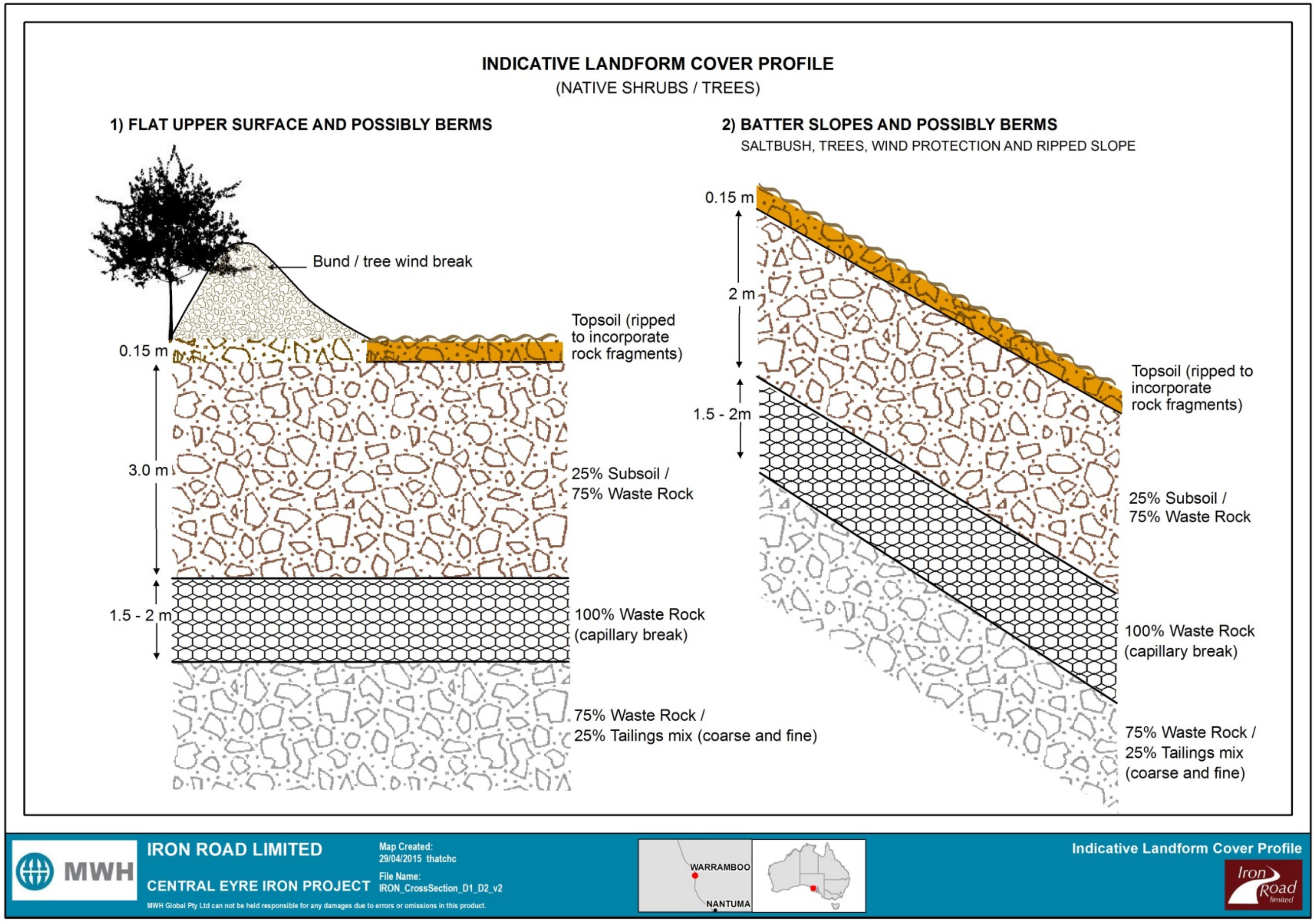

Figure 2-5: Conceptual reconstructed soil profile cross sections for the CEIP IWL base case scenario

2.3 Receiving Environment

2.3.1 Bioregional location and climate

The project area is located within the Eyre Mallee subregion of the Eyre Yorke Block (EYB) bioregion as described by the Interim Bio-regionalisation of Australia (Thackway and Cresswell 1995 in Jacobs 2014c). The Eyre Yorke Block (EYB) bioregion is characterised Mallee woodlands, shrublands and heaths on calcareous earths, duplex soils and calcareous to shallow sands. The Eyre Mallee subregion consists of undulating plains with an extensive cover of dunes and sand sheets and shallow calcareous earths or deeper duplex soils typical of the plains.

The project area typically experiences an arid climate with winter dominant rainfall and relatively dry summer months characterised by warm to hot temperatures (Jacobs 2014). The project area receives seasonally distributed rainfall with an annual average of 314.1 mm, the majority of which falls between May to September. Mean annual evaporation for the project area is 1407 mm (Kyancutta 18044 SILO Station Pan Evaporation, in RPS 2013), far exceeding annual rainfall, and is highest during the summer period (BOM 2014). Hot summers and mild winters are typically experienced with average maximum daily temperatures ranging from 17ºC in July to 33ºC in January (BOM 2014).

2.3.2 Vegetation and land use

The project area has predominantly been cleared for agriculture and is dominated by exotic species, as is typically found in the region. Remnant vegetation is restricted to scattered and isolated blocks of scrub of varying size on farmland and as roadside vegetation) (Jacobs 2014c). The proposed mining lease (ML) covers an area of approximately 85 km^2, of which approximately 12.4% is mapped as native vegetation (Native Vegetation Layer, DENR 2004 in Jacobs 2014c), with larger areas of native vegetation in the northern portion of the project area. The remaining 87.6% of the project area is predominantly cleared agricultural land.

Vegetation condition within the project area was described by Jacobs (2014c) as heavily influenced by significant clearing and the presence of agricultural practices adjacent to, and often completely surrounding, each patch of remnant native vegetation. Vegetation condition varied considerably with the size of the remnant patch. Large areas devoid of vegetation or with salt-affected vegetation were present in areas where the saline groundwater table was elevated.

2.3.3 Surface hydrology

Local surface hydrology in the project area includes the presence of several low-lying depressions with no surface outlets, such as salt pans and swales, among low relief sandy dunes and some intervening plateau areas (RPS 2013). The main hydrological process on the natural land surface within the project area is one of rainfall-infiltration rather than rainfall-runoff, with no evidence of surface runoff processes (i.e. no network of creeks or other surface drainage channels, and no connection of ponding in low lying areas and swales) (RPS 2013). A geotechnical review by Coffey (2012b) found that near surface materials were highly variable, with predominantly permeable sand and some occurrence of low permeability clay near the surface in proximity to the salt pans.

2.3.4 Groundwater

Where present within the project area, the reworked Palaeogene sediments act as an aquifer. Within the proposed ML, wells screened against these sediments (interpreted to be the coarser facies at the base of the Neogene) report salinities in excess of 35,000 mg/L and acidity of pH of 3.4 to 4.7. Aquifer thickness is in the range of 5 to 15 m with aquifer transmissivity in the range of 4 to 37 m^2/d (SKM 2014c).

Underlying the Palaeogene sediments, the saprolite is interpreted to act as an aquitard based on:

- the lithology of the unit which is dominated by clay and silt;
- permeability (slug) testing undertaken by Coffey at LS4 which calculated a hydraulic conductivity of 0.01 m/d (Coffey 2013);
- a leaky confined response to aquifer testing undertaken by SKM in the basement material (SKM 2014c);
- a salinity difference between the basement and tertiary aquifers (SKM 2014c); and
- a pressure difference between the basement and tertiary aquifers (SKM 2014c).

The basement material within the project area consists of the Archaean Sleaford Complex which is characterised by highly deformed and metamorphosed gneisses derived from sedimentary rocks. Where secondary porosity has developed in this material through fracturing and faulting, the unit acts as a fractured rock aquifer, with yields in the range of 1 to 20 L/s (SKM 2014a). Aquifer testing of this formation in support of mine dewatering studies indicates a regional transmissivity in the range of 2 to 4 m^2/day (SKM 2014a). Elsewhere in the bedrock, where secondary porosity is not as prevalent, yields are negligible. Hydrogeological investigations within the proposed ML (SKM 2014a) reported salinities in the fractured rock aquifer in excess of 100,000 mg/L.

Recharge to the basement aquifer is generally localised, irregular and occurs in areas where the basement outcrops (i.e. surface exposures). The rate of recharge is variable and is a function of the exposure, the degree of fracturing present and the composition of the rock type (Department for Water Resources 2001).

Groundwater flow in both the Tertiary sediment aquifer and fractured rock aquifer is interpreted to be in a south-westerly direction beneath the project area. Locally, groundwater is inferred to discharge to salt (playa) lakes where it is lost through evapotranspiration. This interpretation is supported by shallow groundwater levels adjacent to playa lakes and elevated groundwater salinity suggesting evapo-concentration of salts (SKM 2014a).

At the completion of mining, when the dewatering system is decommissioned, groundwater will continue to discharge into the pit and a pit lake is predicted to form. The pit lake water level is predicted to stabilise at approximately -275 m AHD approximately 1000 years post closure. This is approximately 335 m below the pre-mining groundwater level, and as such a permanent cone of depression is predicted to form around the pit. Once the pit lake level has stabilised, a new steady state groundwater flow regime will be maintained.

3 MATERIAL DEFINITION

Since the original discovery of the orebody, over 500 exploration drillholes have been drilled across the CEIP resource. Resource definition drilling is undertaken for a variety of reasons including:

- delineation of the lateral and vertical extent of the resource potential;
- estimating the concentration of the various minerals within the host rocks to determine resource potential;
- to provide a level of confidence to stakeholders about the continuity and distribution of mineralisation for the purposes of resource and reserve reporting;
- definition of surrounding rocks that would be encountered to understand mining risk (e.g. geotechnical risk, geochemical risk;
- delineation of the groundwater aquifers; and
- to satisfy industry standard reporting requirements (i.e. the Joint Ore Reserve Committee (JORC) reporting requirements.)

Exploration tenements for the CEIP were granted to Iron Road in 2008. **Table 3.1** provides a summary of the drilling and sampling completed to date on the CEIP.

Table 3-1: Summary of Drilling Undertaken across the CEIP

Year	No. of Holes	Drill Type	Sample Analysis
2008	32	RC	Lab XRF analysis
2009	27	RC and DDH	Lab XRF analysis
2010	84	RC and DDH	Lab XRF analysis
2011	72	RC and DDH	Lab XRF analysis
2012	118	RC and DDH	Lab XRF analysis
2013	191	RC and DDH	Lab XRF analysis

Reverse circulation (RC) drilling produces drill chips at the surface for geological interpretation. All RC drilling was sampled at one metre intervals, logged and a sample of each interval was submitted to a third party NATA certified laboratory for XRF analysis. Diamond Drill Hole (DDH) drilling produces core samples that are retrieved from drill holes for geological interpretation. Most DDH sampling was done at four metre intervals and half core submitted for laboratory XRF analysis. For both RC and DDH samples, the laboratory undertook a standard suite of analysis for elements: Fe, SiO_2, Al_2O_3, P, K_2O, CaO, S, Mg, Mn, Cl, As, Co, Cr, Cu, Na_2O, Ni, Pb, Sn, TiO_2 and LOI.

To date, over 44,400 individual RC and DDH samples were collected from all drill holes and submitted for full laboratory analysis of the elements described above.

3.1 Material Characterisation

As part of the ongoing assessment of the project, it was identified that some elevated sulphur (S) values (i.e. greater than 0.2% total S) were present within a small number of the samples analysed. Data from the CEIP drillhole database is summarised as follows:

- a total of 44,427 records exist for total sulphur as determined by laboratory XRF analysis;
- the average sulphur value across all records within the entire database is 0.08% total sulphur;
- 341 records (or <0.01% of the database) displayed a total sulphur value of greater than 1%; and
- approximately 75% of samples with elevated total sulphur values are located in the oxide (or weathered) zone.

In order to further quantify the geochemical characteristics of the materials present, MWH have undertaken a full review of the current exploration drillhole geochemical data and supporting information for all mine waste materials associated with the project, This review was undertaken with consideration of the requirements for mine waste geochemical characterisation as recommended by the GARD Guide (INAP 2009). This information was required to assess the potential for AMD generation and inform development of the rehabilitation and closure concept for the IWL landform design. In terms of landform design, consideration of potential AMD generation included handling and placement of the material types is further discussed in **Section 4**.

3.1.1 Oxide (Weathered) Rock Zone Geochemistry Assessment

Initially, MWH undertook a full review of the available drillhole database for the project. Laboratory XRF analysis was available for drill holes IRC001 to IRC 066 and IRD 067 to IRD 519, a total of 519 holes.. Investigations were focussed on the oxide zone geochemistry for the following reasons:

- as the laboratory analysis results for the drillhole samples are total sulphur, it is likely that the these minerals present in the oxide zone would be sulphates, not sulphides. This is common in weathered zone geochemistry, as sulphides oxidise to sulphates;
- the majority (approximately 75%) of the records above 1% total sulphur are located in the oxide zone;
- the geological setting and structural alterations encountered in the fresh rock zone are highly metamorphosed ("upper amphibolite / granulite facies" – Iron Road 2014). Hence the preservation of sulphide minerals under these conditions is highly unlikely; and
- mining will firstly occur with the stripping of oxide zone overburden in the first few years of the project (as shown in **Figure 2,3**).

Upon reviewing the geological interpretation and laboratory XRF data available for the oxide zone, the following observations were made:

- The drill grid spacing over the project area is a nominal 200 metre by 100 metre spacing.

- a total of 9,135 records were available;
- 250 sample intervals contained %S greater than 1.0% (2.7% of the total records);
- 739 sample intervals contained %S greater than 0.5% (8.1% of the total records);
- 1,940 sample intervals contained %S greater than 0.2% (21% of the total records);
- elevated sulphur values are distributed across the project area with no apparent spatial correlation or relationship with depth;
- the three highest %S values (5.2, 6.1 and 11.7%S) were located between 40 to 60 metres below ground level; and
- 875 sample intervals contained %Ca greater than 2.0% (9.6% of the total records).

Whilst some sample intervals indicated elevated total sulphur and calcium values, XRF analysis does not allow for speciation analysis to be undertaken (eg. presence of sulphides, sulphates or calcium carbonates). As such, Acid Base Accounting (ABA – otherwise known as static characterisation testwork) is routinely commissioned to determine the presence or absence of AMD potential.

In collaboration with Iron Road, it was identified that a series of diamond holes had been drilled from the surface in mid-2013, with half of the drillhole core remaining onsite and available for further analytical testwork. Use of this core had some limitations:

1. As the holes were drilled approximately 18 months ago, the core is likely to have weathered somewhat, possibly impacting on AMD assessment;
2. Core samples only remained for the oxide zone; and
3. The holes (IRD 496 to IRD 511) were all drilled within 500 metres of each other.

In order to overcome these limitations the following sample selection process was utilised;

- Samples were selected from a representative suite of geological units, in order to confirm the presence or absence of PAF / NAF / ANC for all the different units likely to be encountered by the CEIP;
- Sample intervals with higher total sulphur values were targeted. The intent of this approach was to confirm whether sulphur speciation comprised sulphides, sulphates or a combination of both. This is a deliberately conservative approach as it is targeting the intervals most likely to be PAF;
- As the samples were partially weathered, this would likely result in an over-estimation of whether a sample may be PAF (and also under-estimate ANC); as partially weathered sulphides are more mobile and some of the neutralising capacity consumed. In any event, geological units from oxidised zones that contain elevated sulphur are more likely to have elevated sulphates, as sulphide minerals oxidise over geological time; and
- Samples from similar depths and geological units, but different drillholes, were selected in order to determine spatial similarities within geological units.

By considering the potential limitations and adopting a precautionary approach, the core samples provided an effective means of preliminary AMD assessment for the oxide zone. 24 samples were selected for analysis to test for AMD and neutralising capacity with samples selected for the upper and lower sections of the oxide zone as well as varying concentrations of sulphur and calcium content. The samples were submitted to Bureau Veritas (NATA accredited) laboratories in Adelaide for the following suite of analysis:

- Total Sulphur;
- Sulphate sulphur;
- pH;
- Electrical Conductivity (EC);
- Net Acid Generation (NAG) determination at pH 4.5;
- NAG determination at pH 7.0;
- Net Acid Producing Potential (NAPP);
- Maximum Potential Acidity (MPA); and
- Acid Neutralising Capacity (ANC).

The sampling and analysis methodology undertaken is consistent with the GARDGuide framework.

Key observations arising from the preliminary AMD assessment (also refer **Plate 3-1**) of the oxide zone materials indicate that;

- the geological distribution and setting of the oxide zone is relatively simple, comprising near horizontal stratigraphic units that are well defined from the drilling programme completed to date;
- of the 24 samples submitted for AMD characterisation ("static testwork"), approximately 14 samples returned positive NAPP results. However the values were generally low (e.g. less than 100 kg H_2SO_4 per tonne) indicating a low ability to generate acid;
- NAG pH for these samples were above 4.5. Combined with a positive NAPP this equates to an "uncertain (UC)" classification (GARD Guide, INAP 2009);
- these 14 samples all returned Maximum Potential Acidity (MPA) results similar to the NAPP values, indicating that these samples contain little buffering capacity;
- of the 24 samples submitted for AMD characterisation, 10 samples returned positive ANC results. However the values were generally low (e.g. less than 100kg H_2SO_4 per tonne) indicating a low ability to neutralise acidity; and
- NAG pH for these samples were above 4.5 and NAPP values were negative. This equates to a "Non Acid Forming (NAF)" classification (GARD Guide, INAP 2009). One sample had a NAPP value less than -100 kg H_2SO_4/tonne ("acid consuming").

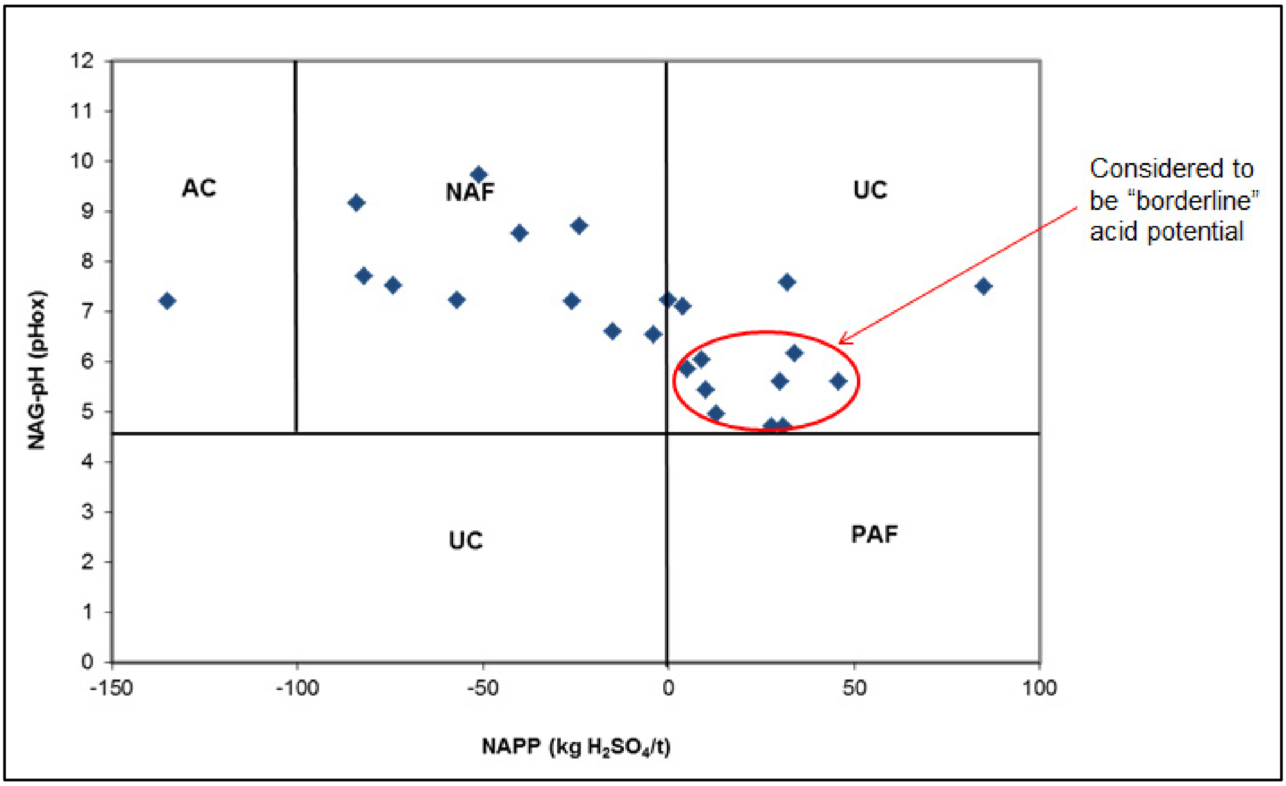

Plate 3-1: Summary of oxide zone analysis results

The static testwork confirmed that some of the overburden waste has elevated concentrations of sulphides with some potential to generate AMD. Equally, some of the overburden waste contains sufficient concentrations of buffering potential to neutralise AMD. Hence it is possible that, through a combination of good planning and waste rock management, the waste material can be stored in a manner such that AMD potential would be very unlikely.

3.1.2 Fresh Rock Zone Geochemistry Assessment

In addition to the oxide zone geochemistry, magnetite concentrate data from processing trials undertaken on the fresh rock material were reviewed (MWH 2015a). Of the 82 records available, 17 records had head grades less than 10% Fe. Of these 17 records, 6 records have %S values greater than 0.2. None of the records with head grades of greater than 10% Fe had %S values above 0.2. Further investigation of the six records with elevated total sulphur readings found that the concentration of sulphur was further elevated in the magnetic concentrate after test processing. However, the pilot tailings results reported similar levels of total sulphur to the head grade. It is likely that the sulphur mineral present within these materials has a high density and magnetic properties, indicating that the sulphur may be a sulphide mineral; possibly pyrite, pyrrhotite or arsenopyrite.

Geochemical testwork was also undertaken for the fine and coarse fractions of the pilot tailings by Bureau Veritas (information supplied by Iron Road). Results are included in **Table 3-2**.

Table 3-2: Geochemical results for the pilot tailings (Bureau Veritas, sourced from Iron Road)

Pilot tailings fraction	S%	C%	S% - sulphur digest	TIC %	MPA (kg H_2SO_4/ tonne)	NAPP (kg H_2SO_4/ tonne)	NAG (kg H_2SO_4/ tonne)	ANC (kg H_2SO_4/ tonne)
Fine	0.04	0.06	<0.05	<0.05	<0.5	<1	<0.5	12
Coarse	0.04	0.05	<0.05	<0.05	0.5	<1	<0.5	12

MWH undertook additional laboratory testing of a bulk sample of the combined coarse and fine pilot tailings (MWH 2015a), including;

- chemical characteristics;
- physical characteristics;
- geochemical characteristics; and
- bulk column testwork for capillary rise of salts and leaching of salts and metals.

The chemical characteristics of the pilot tailings are summarised as follows:

- alkaline pH (average pH H_2O of 8.2);
- extremely saline Electrical Conductivity (average of 1.69 dS/m);
- predominantly low plant-available nutrient concentrations with a low Cation Exchange Capacity and extremely low organic carbon percentage; and
- sodic (average Exchangeable Sodium Percentage of 11.1%).

The geochemical (**Table 3-3**) and multi-element analysis results from the CEIP tailings indicate that the tailings:

- can be classified as non-acid forming (NAF), based on acid-base accounting results;
- contain a very low total sulphur (average of 0.03%);
- demonstrate a negative Net Acid Production Potential (NAPP) (average of -14.7 kg H_2SO_4/t);
- possess alkaline Net Acid Generation (NAG) pH;
- possess high Acid Neutralisation Capacity (ANC) ratio >2 (average ratio of 17) and high ANC (average of 15.6 kg H_2SO_4/t); and
- possess negligible or low metal and elemental concentrations, with the exception of manganese (average of 1140 mg/kg compared to an EIL of 500 mg/kg and average crustal abundance of 950 mg/kg for manganese).

As the CEIP tailings will account for approximately 3,053Mt (or 41%) of the total volume of material stored in the IWL, this presents significant neutralising (or buffering) capacity for any possible AMD. As such this presents the CEIP with a significant opportunity to configure the IWL in such a manner (as described in Section 4) so that the potential of AMD emanating from the IWL is negligible.

Table 3-3: Geochemical assessment of CEIP pilot tailings [1]

Sample ID	Total S (%)	MPA [2]	NAG [3] pH 4.5 (kg H_2SO_4/t)	NAG [3] pH 7.0 (kg H_2SO_4/t)	NAG pH(ox)	ANC [4] % $CaCO_3$	ANC [4] kg H_2SO_4/t	ANC / MPA ratio	NAPP [5] (kg H_2SO_4/t)	Acid forming potential [6]
Sub-sample 1	0.03	0.92	<0.1	<0.1	8.0	1.6	15.4	16.8	-14.5	NAF
Sub-sample 2	0.03	0.92	<0.1	<0.1	7.9	1.6	16.0	17.4	-15.1	NAF
Sub-sample 3	0.03	0.92	<0.1	<0.1	8.1	1.6	15.4	16.8	-14.5	NAF
Average	**0.03**	**0.92**	**-**	**-**	**8.0**	**1.6**	**15.6**	**17.0**	**-14.7**	**-**
LOR [1]	**0.01**	**0.92**	**0.1**	**0.1**	**0.1**	**0.1**	**0.5**	**16.8**	**0.5**	**-**

1. LOR: Limit of Reporting
2. MPA: Maximum Potential Acidity.
3. NAG pH(ox): Net Acid Generation pH after oxidation.
4. ANC: Acid Neutralisation Capacity.
5. NAPP: Net Acid Production Potential.
6. Determined as either NAF (Non-acid forming) or PAF (Potentially acid forming).

[1] NAPP and NAG results are used to determine the potentially acid forming (PAF) or non-acid forming (NAF) status of materials in static acid-base accounting, in addition to the ANC and Maximum Potential Acidity (MPA) (AMIRA 2002). The calculated ANC/MPA ratio refers to the inherent ability of the material to prevent acid generation. ANC/MPA ratio values of 2 or more are identified as having a high probability of retaining a near-neutral pH (DITR 2007, AMIRA 2002). NAPP and the ratio of ANC to MPA were calculated used the following formulae (DITR 2007):

MPA = 30.6 x Total-S %

NAPP = MPA – ANC

The GARDGuide states that for the:

- Resource Definition Phase of a project "All samples tested for sulphur and representative samples tested for mineralogy as per ore deposit model. Static testing of at least 5 to 10 representative samples of each key material type"; and
- Pre-feasibility Phase of a project "Static testing of several hundred representative samples of high and low grade ore, waste rock and tailings, the number dependent on the complexity of the deposit geology and its host rocks. All drillhole samples analysed must include sulphur analysis and identified representative metal ions. Sampling density is dependent on complexity of ore deposit and host rock geology interval of representative drill holes but should be restricted to single rock units or lithologies - include minimums".

Samples from the fresh rock have not yet been available for AMD characterisation testwork. However some NAPP and ANC testing has been completed on pilot tailings and concentrate material. Results indicate that reject material from the processing plant (hence reporting to the IWL) contains significant buffering potential within the majority of the tailings.

The geochemical assessment of the CEIP deposit can be considered to be equivalent to the GARDGuide's "Pre-feasibility" project status as outlined in **Table 3.4.**

Table 3-4: Comparison of CEIP to the GARDGuide Requirements

GARDGuide Pre-Feasibility Requirements	Assessment
Depending on the complexity of the deposit geology, static testing of several hundred representative samples from high grade, low grade, waste rock and tailings	Over 9,000 laboratory analysis results are available for samples from the oxide zone. The geological setting of the deposit is simple, continuous and well known from greater than 500 drillholes into the deposit. Static characterisation of the lithologies likely to contain sulphides has been undertaken
All drillhole samples must include sulphur analysis	All drillholes include total sulphur analysis – total of over 44,400 records for the entire CEIP resource.
Sampling density is dependent on complexity of the ore deposit and host rock geology interval and should not be restricted to single rock units or lithologies	CEIP drilling and sampling density is across all defined lithological rock units within the CEIP resource. A 3D geochemical model has been generated for the oxide zone indicating the location and volumes of PAF and ANC materials likely to be encountered.

3.2 Volume Estimation – Oxide Zone

In order to better interrogate the entire Iron Road drill hole dataset, cut-off guidelines were developed for the oxide zone (**Table 3-5**). This guideline has been prepared specifically based on the AMD laboratory analysis results received for the CEIP, taking into account that the samples had been oxidising since mid-2013 prior to submittal for analysis. Hence the cut-off guidelines can be considered conservative.

3-D geological modelling of the various oxide zone lithologies was undertaken using LeapFrog geological modelling software. Extrapolation of geochemical results from **Section 3.1** and classifications as described in **Table 3.3** were utilised to provide a spatial distribution and volume estimate for the oxide zone.

Table 3-5: Guideline for AMD assessment of the oxide zone developed for the CEIP

%S	%CaO	Classification
< 0.2	Any value	Not Acid Forming
0.2 – 0.5	> 1.0	Not Acid Forming
0.5 – 0.8	> 2.0	Not Acid Forming
0.8 – 1.0	> 5.0	Not Acid Forming
0.2 – 0.5	< 1.0	POTENTIALLY ACID FORMING
0.5 – 0.8	< 2.0	POTENTIALLY ACID FORMING
0.8 – 1.0	< 5.0	POTENTIALLY ACID FORMING
> 1.0	Any value	POTENTIALLY ACID FORMING

Applying this methodology to the oxide drillhole database, 1671 records (18%) of the database may be classified as potentially acid forming (PAF). In analysing the data individually within the drill holes, the following trends were observed;

- for samples located within 15 metres of the pre-mining surface, elevated sulphur values in nearly all cases are offset by neutralising CaO (interpreted as calcrete). Hence this material could be classified as NAF and is likely to contain additional acid consuming ability. This occurrence correlates with the interpreted Quaternary sediments (Jacobs 2014);
- 45 out of 140 (32%) of holes containing PAF material had a concentration of PAF values at depths between 15 to 35 m. This "upper oxide PAF zone" appears to be 10 to 15 m in thickness. This zone correlates with the Neogene unit and the upper groundwater surface interface; and
- 85 out of 140 (60%) of holes containing PAF material had a concentration of PAF values at depths between 45 to 75 m. This "lower oxide PAF zone" appears to be 25 to 35 m in thickness. This zone correlates with the Palaeogene and Saprolite units that are located above the fractured basement.

Table 3-6 summarises the volumes of inert, NAF oxide, oxide with potential buffering capacity and PAF oxide materials, based on the definitive feasibility study pit shell (source: Jacobs 2014).

Table 3-6: Summary volumes of material types within the oxide zone of the planned CEIP

Location	Murphy South Deposit		Boo Loo Deposit		Total	
	Volume (m^3)	% of total	Volume (m^3)	% of total	Volume (m^3)	% of total
Inert	341,950,000	88	109,774,020	85	451,724,020	87
Buffering (CaO>10%)	14,040,000	4	655,980	1	14,695,980	3
Sub-Total NAF	**355,990,000**	**91**	**110,430,000**	**86**	**466,420,000**	**90**
0.2 – 0.5% S	30,970,053	8	14,500,227	11	45,470,280	9
0.5 – 1.0% S	1,075,778	0.3	517,697	0.4	1,593,475	0
> 1.0% S	1,840,169	0.5	3,444,076	3	5,284,245	1
Sub-total PAF	**33,886,000**	**9**	**18,462,000**	**14**	**52,348,000**	**10**
Total	389,876,000	100	128,892,000	100	518,768,000	100

The following limitation exists for the data provided in **Table 3-6**:

- for the Murphy South pit, no geochemical data was available for holes east of IRC061. This represents approximately 30% of the overburden stripping of the Murphy South pit. In discussion with IRD geologists, MWH have extrapolated the interpreted thicknesses for PAF and buffering into this area in order to provide a conservative assumption of the volume of PAF and buffering that may exist for this area of the Murphy South pit.

Plates 3-1 to **3-6** show the outputs of the 3D geological modelling, displaying the distribution of material types in the oxide zone referenced to the Boo Loo and Murphy South pits. Observations on the data presented in **Plates 3-1** to **3-6** include;

- at least 90% of the oxide overburden to be stripped will be inert and contain significant neutralising capacity;
- of the PAF oxide material, the majority of this (90%) has total sulphur less than 0.5%. From the preliminary static characterisation testwork completed in January 2015, this material has a low to very low net acid producing potential (i.e. NAPP less than 20 kg / tonne H_2SO_4);
- PAF material with total sulphur exceeding 1% comprises approximately 0.5% of the entire overburden material. This material is considered to be a low NAPP (i.e. less than 100 kg/tonne H_2SO_4);
- oxide material with potential buffering capacity (mostly calcrete with CaO greater than 10%) is present within the overburden at higher volumes than PAF material with greater than 1%S. The neutralising capacity of this material exceeds 100 kg/tonne H_2SO_4; and
- potential buffering material is likely to be excavated and placed in the IWL either prior to, or co-disposed with the PAF material.

Given the low PAF nature of the oxide overburden, the co-existence of available buffering material and the spatial distribution of the various material types, a co-disposal solution for the storage of the PAF material within the proposed IWL would be an appropriate long term storage solution for the CEIP.

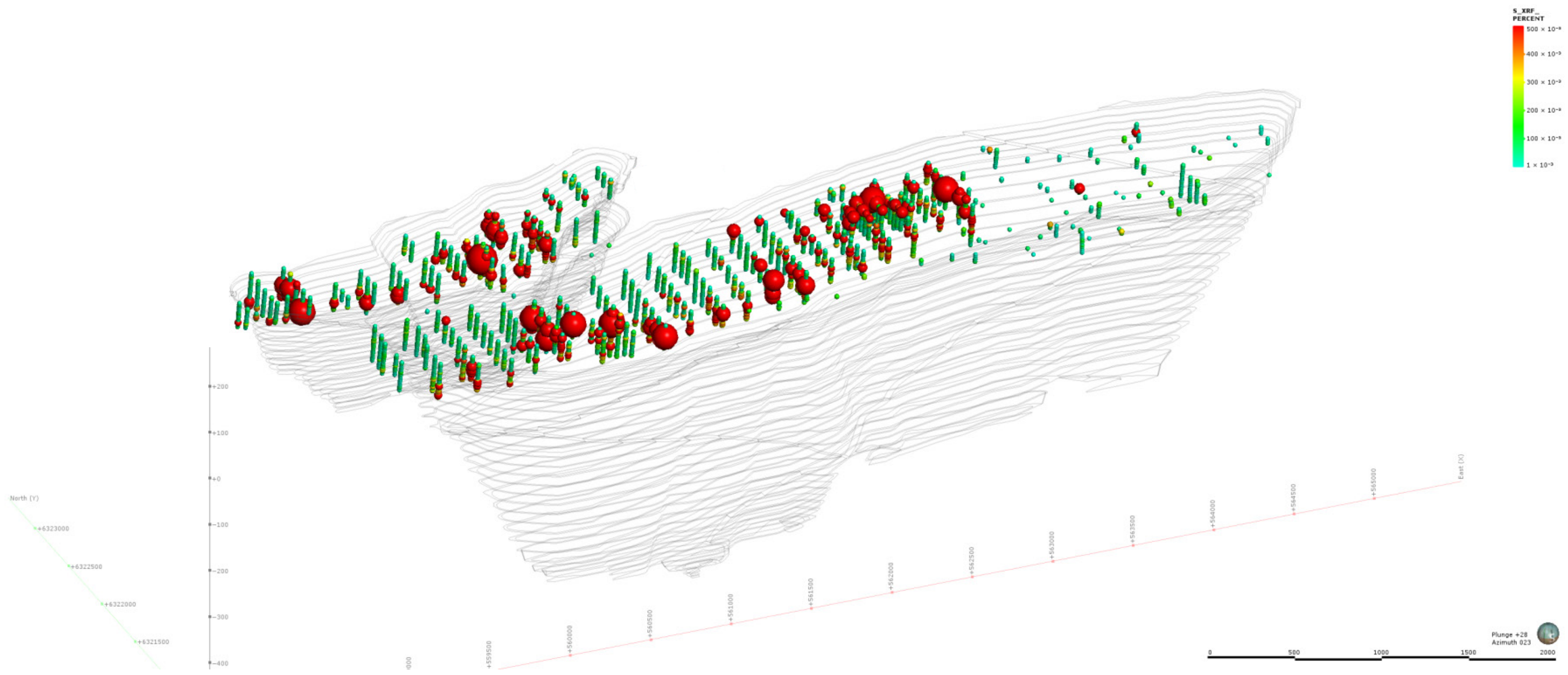

Plate 3-2: Distribution of total %S by individual drillholes for the Boo Loo and Murphy South Deposits (data as provided by Jacobs). Note that elevated %S values generally occur towards the base of the oxide zone

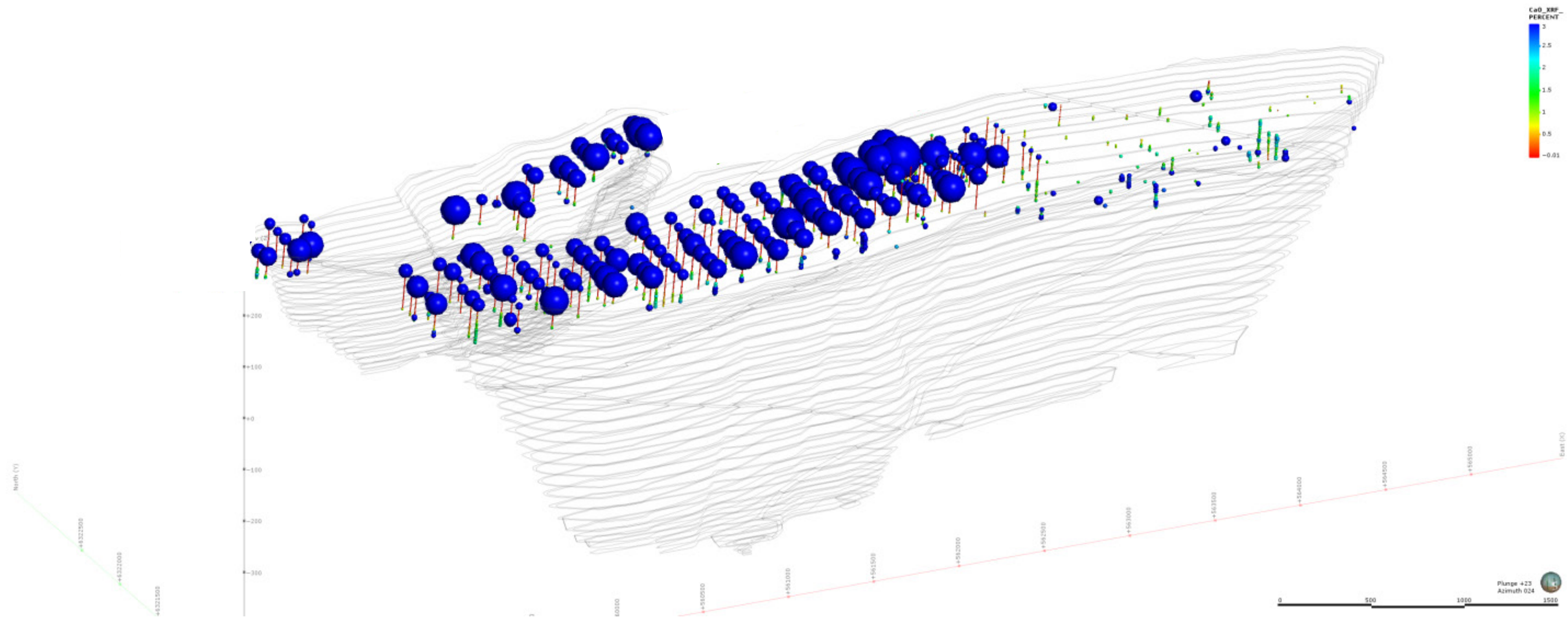

Plate 3-3: Distribution of %CaO by individual drillholes for the Boo Loo and Murphy South Deposits (data as provided by Jacobs). Note that elevated %CaO values generally occur higher in the oxide zone

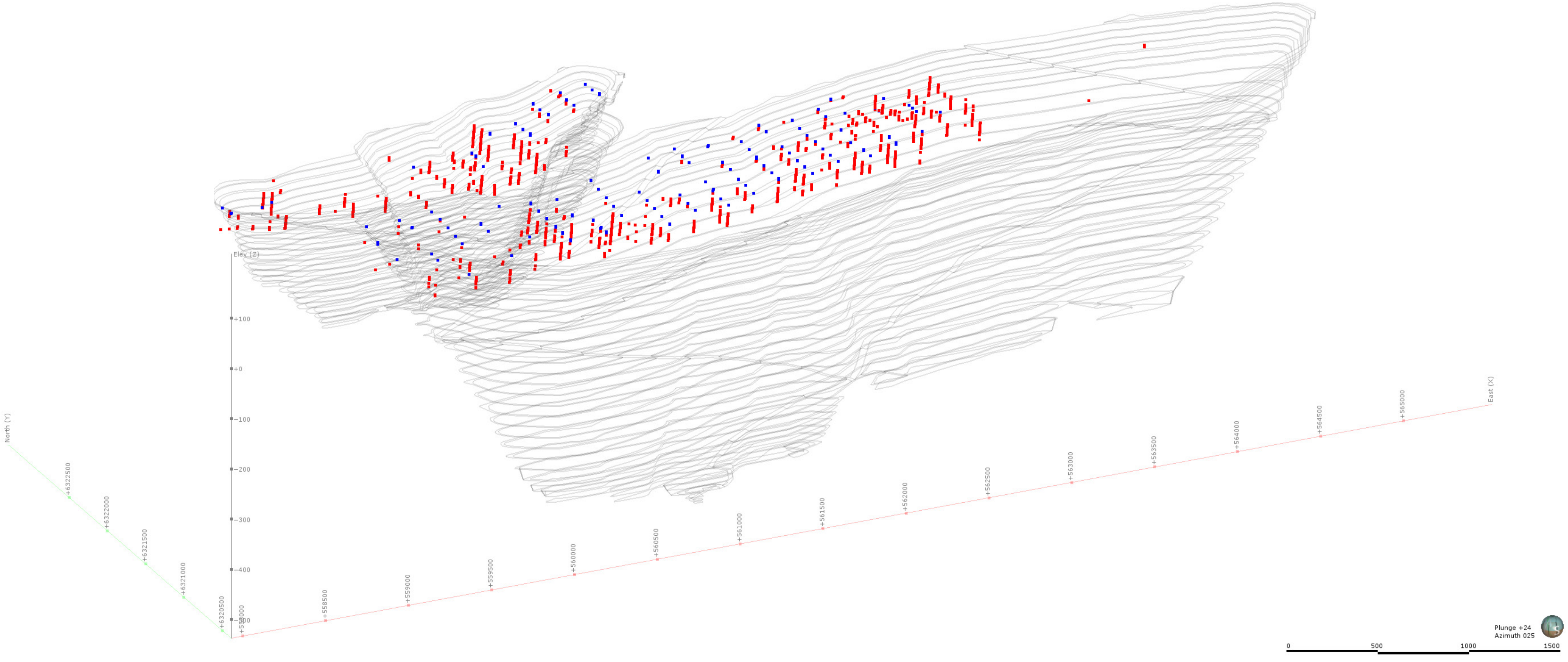

Plate 3-4: Distribution of %CaO >10% (Blue) and Potentially Acid Forming (PAF - Red) intervals by individual drillholes for the Boo Loo and Murphy South Deposits. Note that elevated PAF intervals generally occur towards the base of the oxide zone

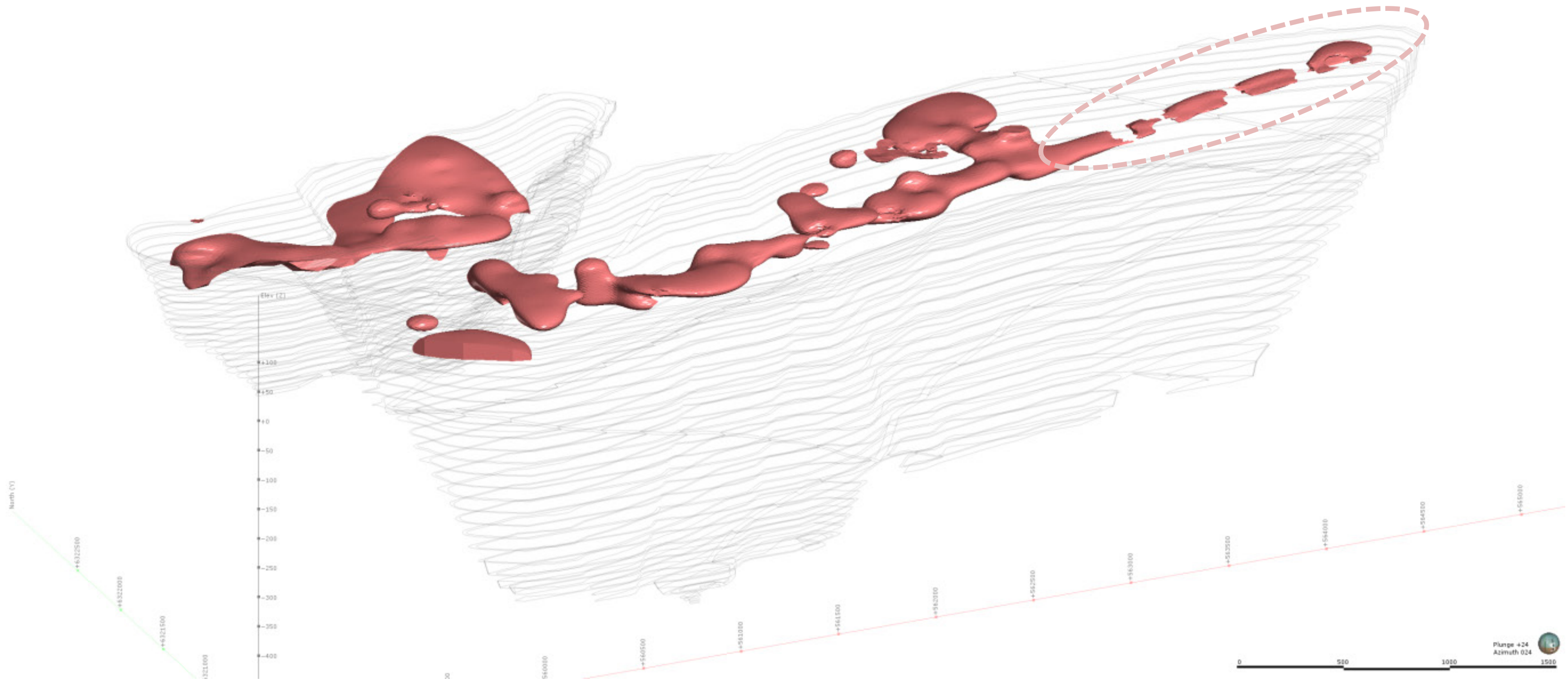

Plate 3-5: Volume envelope of PAF material calculated for the Boo Loo and Murphy South Deposits. Note that envelope has been extrapolated to the eastern limit of the Murphy South pit due to a lack of data (circled)

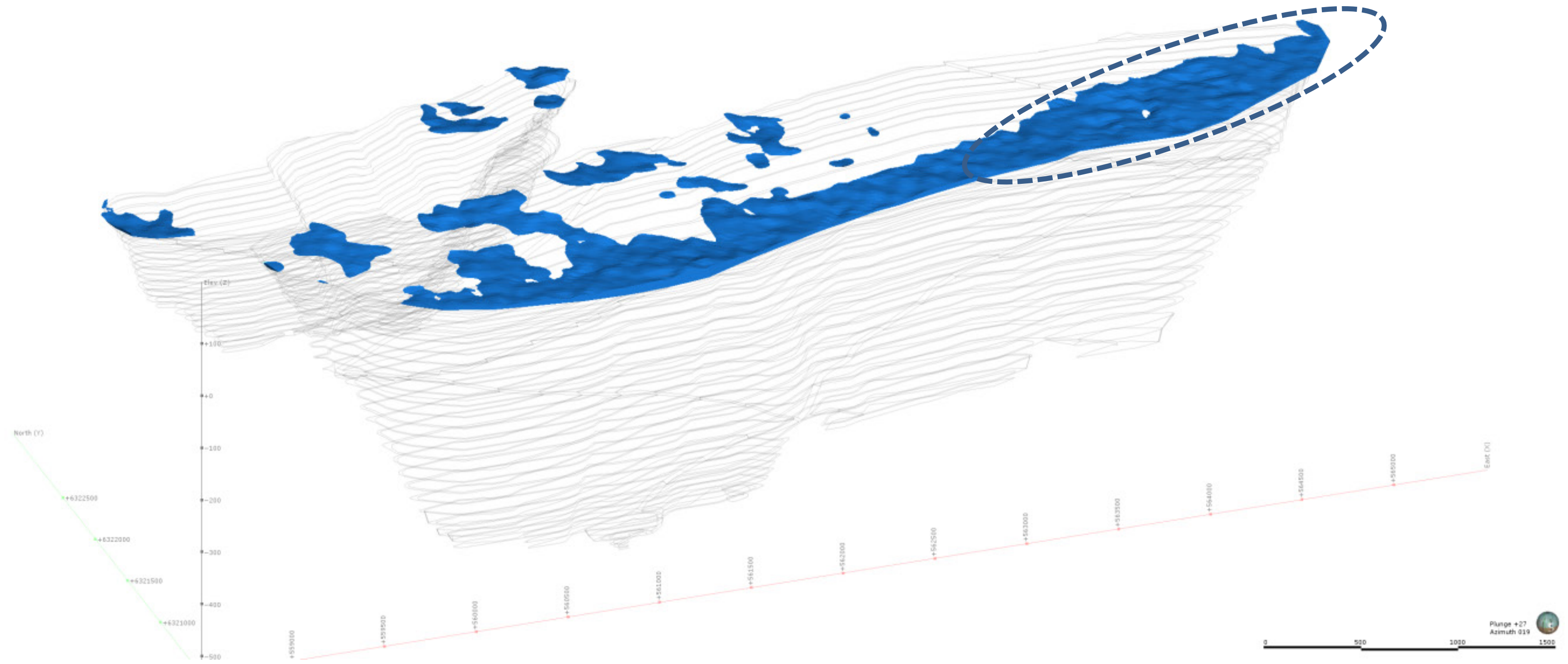

Plate 3-6: Volume envelope of %CaO >10% calculated for the Boo Loo and Murphy South Deposits. Note that envelope has been extrapolated to the eastern limit of the Murphy South pit due to a lack of data (circled)

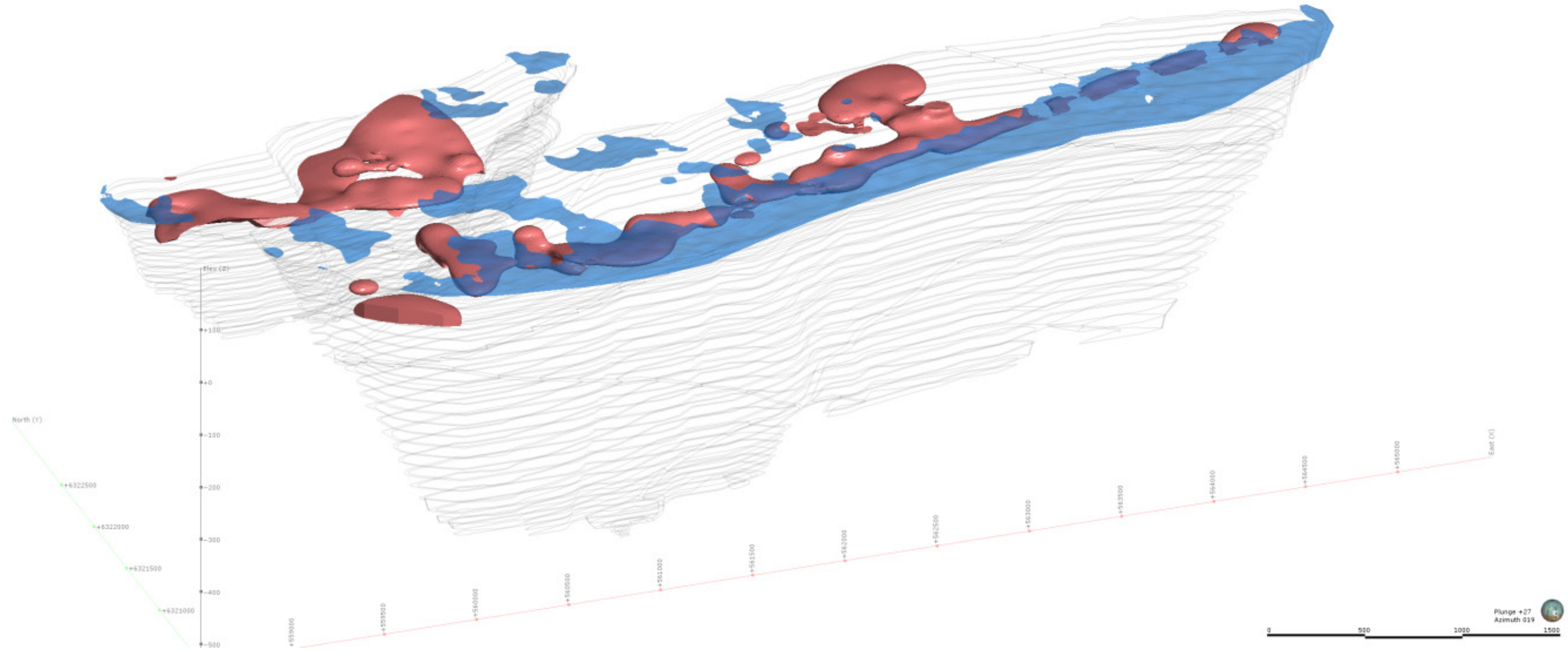

Plate 3-7: Overlay of volume envelopes for %CaO >10% calculated for the Boo Loo and Murphy South Deposits

3.3 Volume Estimations – Fresh rock zone

Based on the current mine plans approximately 1,040Mm^3 of the total 1,982Mm^3 (or 64%) waste rock to be mined for the CEIP will be derived from the fresh rock zone immediately underlying the oxide rock zone. Due to the highly gneissic (or metamorphosed) and consistent nature of the expected waste rock, there is a low likelihood of this waste rock being PAF. This is supported by the data from processing testwork completed in 2014 (as described in **Section 3.1**), along with discussion with Iron Road geologists (Heather Pearce pers comm 2014) and the review of the drillhole geological logging undertaken within the fresh rock zone.

3.4 Volume Estimations – Total CEIP

Summarising the information provided in **Sections 3.2** and **3.3**, some 1,558Mm^3 of waste rock will be mined during the life of mine for the CEIP. This total waste volume comprises:

- 518Mm^3 of oxide material (ie. weathered material); and
- 1,040Mm^3 of fresh waste rock material (ie. unoxidised).

As the PAF component of the oxide material is expected to be approximately 52Mm^3 (**Table 3.6**), this represents 3% of the total waste material to be mined. In addition, approximately 100Mm^3 (or 6%) of oxide and fresh waste rock material is predicted to be acid consuming. The expected distribution is shown in **Plate 3-8**.

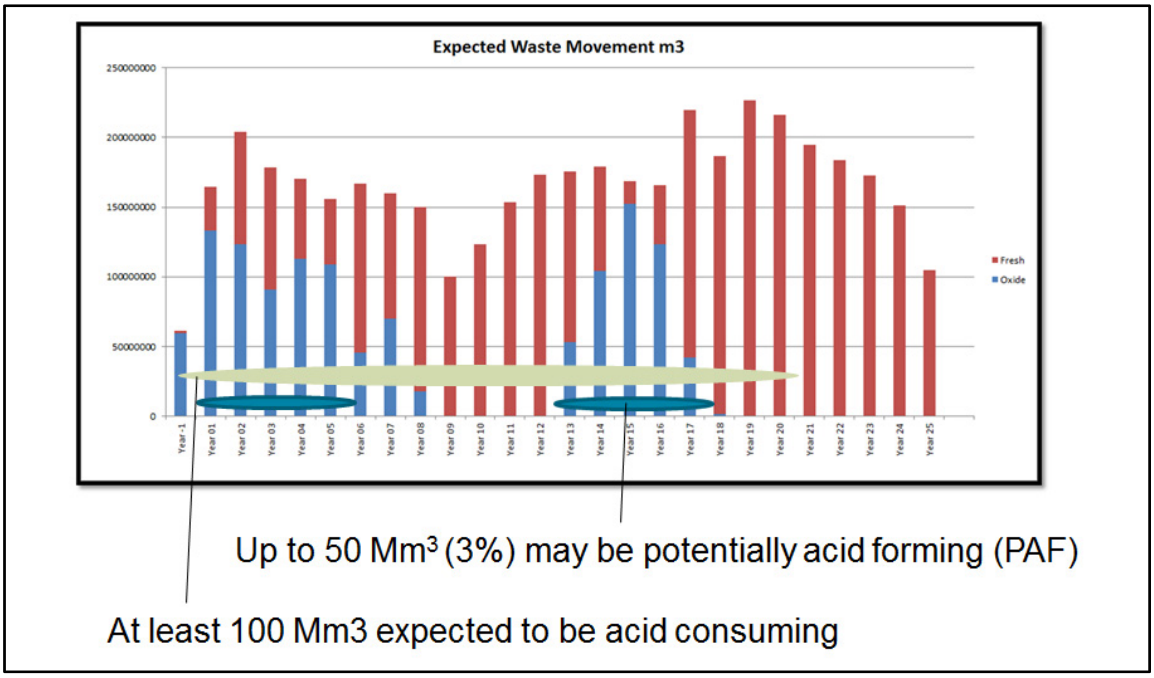

Plate 3-8: Expected distribution of PAF and acid consuming mine waste

In addition to the waste rock, the IWL will comprise 41% of tailings. As described in Section 3.1.2, testwork to date indicates that the tailings has a high Acid Neutralising Capacity (ANC), adding further to the neutralising capacity of the IWL.

4 SUMMARY OF PROPOSED IWL MANAGEMENT PLAN

In line with the GARDGuide management options, different AMD management options were evaluated. As elimination and in-pit storage options are not possible for the CEIP, PAF material will be co-disposed and stored within the IWL. Conceptually, non-acid forming waste rock would comprise the upper and outer surfaces of the landform in order to create an appropriate cover. Additionally, material stored deeper within a landform will have slower rates of oxidation than material located closer to the outer surfaces of a landform. Finally, co-disposal of AMD material with neutralising material provides for buffering ability. Based on the exploration drillhole database and the preliminary geochemical analysis, a conservative estimate is that:

- approximately 80% of the overburden waste will be non-acid generating (inert);
- up to 10% of the overburden waste may have the potential to generate acid; and
- at least 10% of the overburden waste may have neutralising potential.

As such, the IWL storage approach provides the most benefits for PAF material storage in an external landform. Tailings from the processing plant will consist predominantly of a fines fraction and laboratory analysis indicates the tailings will contain significant buffering potential; hence when co-disposed with waste rock in an IWL the pore space will be filled with this finer material. This will reduce the oxidation rate for the IWL (compared to typical waste rock landforms) and further slows the oxidation rate of the materials within the landform as well as creating neutralising conditions.

For the CEIP, a successful storage solution can be demonstrated by adopting co-disposal of PAF and NAF and ANC materials within the IWL. The aim is not to permit surface expression of PAF materials. The IWL is designed with a cover sequence (Figure 2.5) for the rapid and successful long term establishment of native vegetation. No PAF material would be used in this cover sequence i.e. in the strata above the waste rock capillary break. Erosion modelling has confirmed the long term stable nature of the structure, even without the added native vegetation on both the upper surface and the conservative slope design. **Figure 4-1** and **Figure 4-2** summarise the planned mining and storage of material types for the CEIP.

Based on greater than 85% of PAF material being <0.5%S (and hence low to very low acid generating), this material can be stored within IWL, provided it is co-disposed with surficial / calcrete / buffering material and is not within the cover sequence above the capillary break.

In order to demonstrate ongoing responsible management, a mining model of the overburden showing the different material types, volumes and planned destinations for material should be created and updated on a monthly basis (i.e. short term planning department). The mining model of the overburden can be constructed and implemented if an AMD sampling and characterisation programme is undertaken prior to the commencement of mining. This is required to determine the volume and location of PAF and buffering materials with greater accuracy. This is important for the eastern half of the Murphy South pit as there is no information currently available for this area of the deposit. As mentioned earlier, a material characterisation programme will likely result in reduced volumes of PAF, as the current PAF classification is conservative.

The next planned, pre-mining stage of characterisation and mine plan implementation will eliminate the need to undertake ongoing sampling and testwork during the mining operation although ongoing verification sampling and testwork is recommended as good practice and will be adopted.

A regular reconciliation (performed monthly / quarterly) that summarises how much material was mined during the period and destination in the IWL is recommended. Material reconciliation is a simple model to set up which will demonstrate the tracking of material types from the pit and disposal in the IWL in accordance with planning and operating procedures, to further demonstrate compliance with the Management Plan.

Key features of the IWL related to the management of AMD include:

- waste material (waste rock and tailings) stored in the IWL will be dewatered, with approximately 10% moisture retained. The 10% moisture refers to the “contained water” inherent within the material. This inherent water is contained within pore spaces and interstitially within the waste rock; hence it is not freely available to accumulate and become free flowing:
- the IWL will not be free draining. The IWL design fundamentally minimises water movement in order to conserve water, eliminate excessive seepage and promote landform geotechnical stability as compared to wet tailings systems;
- any rainfall reporting to the upper surface of the IWL will be contained and evaporated utilising the “store and release” principles of cover designs. Evaporation exceeds rainfall by a factor of 10 in the project area, ideal conditions for store and release cover designs; and
- the IWL footprint contains no drainage lines or surface water flow area.

Figure 4-1: Proposed mining configuration for CEIP ore and waste rock run-of-mine

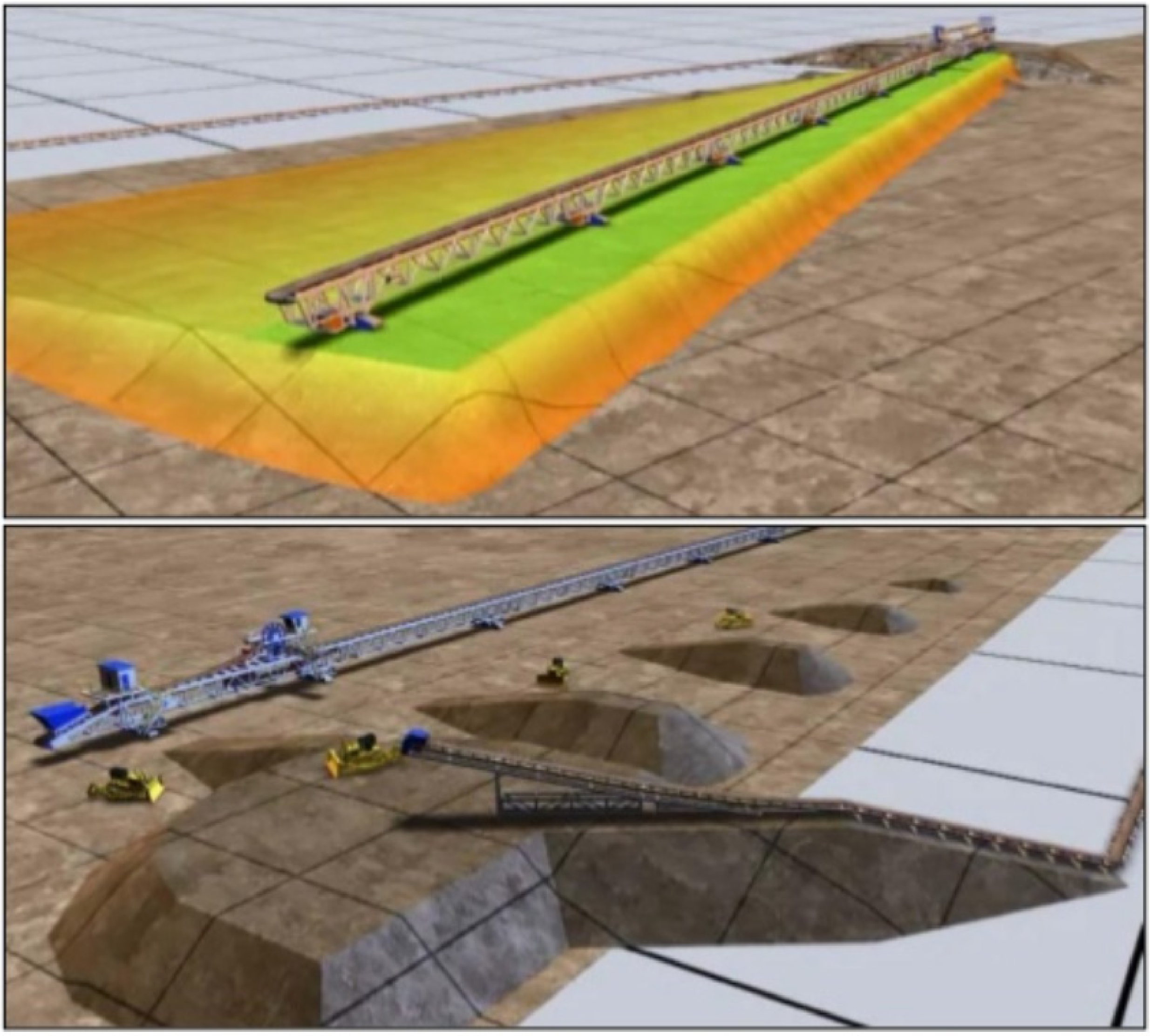

Figure 4-2: Proposed Construction of IWL using mobile stackers

5 IMPLEMENTATION OF THE IWL MANAGEMENT PLAN

5.1 Short Term Actions (now until commencement of operations)

As discussed in **Sections 3 and 4**, through a combination of good planning, waste handling and operations management, the waste material for the project can be stored in such a manner that AMD potential would be very unlikely. In order to achieve this result, development of an IWL Management Plan, inclusive of an ongoing AMD testwork programme, is recommended. Consistent with the GARDGuide, the following items are required to be addressed in the IWL Management Plan in order to demonstrate confidence:

- ongoing detail of the geological profile developed that confirms the various rock units (outlined in **Section 2**) and the potential of each of these zones to produce AMD and/or buffering potential for both the oxide and fresh rock zones; and
- a follow-up targeted and representative “AMD static characterisation programme” that samples all geological units (from both the oxide zone and fresh rock zone) within the project area and is spatially representative. This will further validate the AMD analysis and volume estimates already completed, as well further define the sulphide species that are likely to generate AMD.

A dedicated “AMD kinetic characterisation programme” that determines the rate of AMD generation over time (volume of acid per wetting/drying cycle and longevity before the acidity potential is fully exhausted), as well as the rate of neutralisation over time. The results of kinetic programme can also provide confirmation of volumes of NAF, PAF and acid consuming materials available and the sequencing of these materials ex-pit over the life of the operation.

Due to the likely conservative nature of the characterisation and volume estimates of PAF in this version of the IWL Management Plan, it is likely that further static and kinetic characterisation work will reduce the overall volume of PAF material for the CEIP.

The IWL Management Plan would become a document that can be updated throughout the life of the project as more information from ongoing testwork programmes is completed. Prior to mining, the most effective way of collecting material for characterisation is to incorporate the requirements for AMD sample collection into future drilling programmes.

5.2 Medium Term Actions (oxide zone mining)

For this initial version of the IWL Management Plan, Medium Term is defined as mining the overburden, scheduled to occur at the commencement of the operations as continue for four to five years. During this phase of the operation some of the key tasks for the operation will be:

- development of Site Operating Procedures that consider identification and classification of materials during the mining process (e.g. mining block models, blast hole or trench sampling), the tracking of material (GPS load tracking of haul trucks), placement of materials within the IWL (i.e. demarcation of no-go areas) and reporting;
- training of relevant staff and operators;
- formation of an IWL Management Committee to include the monitoring of the effectiveness of AMD storage;
- verification of the effectiveness of the IWL Management Plan;
- modification and updates to the IWL Management Plan with the outcomes from the Short Term research programmes; and
- reporting of IWL Management Plan implementation effectiveness.

The intent of this phase will be to ensure that mining operations at the CEIP are undertaken with the management of PAF material inherent to the operations. This is proven to achieve the best outcomes and be the most cost effective way of delivering good AMD management practices.

5.3 Long Term Actions (remainder of operations)

Longer term actions will be largely driven by the outcomes of the effectiveness of short and medium term actions. As the operation matures, in-pit disposal opportunities for waste material may become available and this would be a preferred disposal option from a cost perspective for all waste materials (including PAF) if this option becomes available.

6 ROLES AND RESPONSIBILITIES

To be developed prior to the commencement of mining operations but likely to include:

Geology / Environmental – Ongoing identification and characterisation of PAF, NAF and buffering lithologies. This should include the requirements for ongoing geochemical characterisation of all waste rocks to be encountered during the life of mine. Project geologists should work collaboratively with environmental experts regarding future studies and research, and closely with the mine planning teams for the geological and mining models.

Planning – Responsibility for the scheduling and short term planning of AMD and buffering material extraction, handling and storage in the IWL by Mine Planning group (nominally the Superintendent Mine Planning).

Execution – Operations to undertake extraction, handling and storage in accordance with procedures and following the planning schedules from Mine Planning.

Compliance, verification, reporting, education and future studies – co-ordinated by the Environment Group (nominally the Environmental Superintendent or similar). This role is to ensure that planning and execution roles are consistently undertaken, report and investigate and non-compliances, undertake statutory performance reporting, provide education and knowledge ongoing for CEIP and verify that AMD strategies are successful.

It is recommended that an IWL Management Committee is established to meet quarterly (or as required). Normally co-ordinated by the Environmental Department, this should be a multi-disciplinary committee comprising representatives from Mining, Planning, Environment and Geology to discuss overall effectiveness of the IWL Management Plan and identify areas for improvement. Overall responsibility for the implementation and effectiveness of the IWL Management Plan would lie with the IWL Management Committee, who should report to the Mine Manager.

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