Appendix 15.

SLR Consulting Australia (2020f) *Rum Jungle Rehabilitation – Stage 2A- Geotechnical Investigation Waste Storage Facilities and Borrow Areas*. Report to the Department of Mines and Energy, Northern Territory. PART A.

RUM JUNGLE REHABILITATION – STAGE 2A DETAILED DESIGN

Geotechnical Investigation
Waste Storage Facilities and Borrow Areas

Prepared for:

Department of Primary Industry and Resources
Darwin, NT

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BASIS OF REPORT

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

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DOCUMENT CONTROL

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680.10421.90020-R01-v1.0 Issued for Implementation	20 May 2020	Ben Tarrant	Danielle O’Toole	Danielle O'Toole

EXECUTIVE SUMMARY

SLR Consulting Australia Pty Ltd (SLR) was engaged by the Northern Territory Government Department of Primary Industry and Resources (DPIR) to undertake a geotechnical investigation to inform rehabilitation works for the former Rum Jungle Mine, located approximately 6km north of Batchelor, Northern Territory (NT). The field investigation component was carried out in two parts; the first conducted in July 2019 and the second in October 2019. The investigations were developed to fill data gaps within existing geotechnical investigation data and comprised of a test pitting program with associated sampling and in-situ testing, followed by laboratory testing, within key areas of interest as defined in the following table.

Areas of Investigation

Location	Objective
East and West Waste Storage Facilities (EWSF and WWSF)	Assessment of foundation materials within proposed WSF envelopes.
Coomalie Community Government Council Land Clay and Growth Medium Borrow Area (Borrow Area A)	Assessment and quantification of materials for use in WSF capping design and general construction fill.
Finnis River Aboriginal Land Trust (FRALT) Granular and Growth Medium Borrow Area (Borrow Area B)	Assessment and quantification of materials for use in WSF capping design and general construction fill.
Haul Road Alignment	Assessment of the subsurface conditions for paving design
Existing Waste Rock Dump (WRD) Covers	Assessment of the existing WRD cover layers, including thickness of rip rap and underlying low permeability horizons
Aldebaran Quarry	Assessment of the rock suitability as rip rap erosion protection on WSF slopes

A brief description of each area of investigation follows.

Material quality and volume requirements for the rehabilitation have been derived from works spanning several years and are as follows:

Material Type	Quality Requirements	Volume Requirements	Source of Requirement
Low permeability material for clay cover of WSFs	Clay percentage > 10% Fines percentage > 30% Gravel (4.75mm) percentage < 50% Plastic Index > 10 Ksat ≤ 1 x 10^{-9} m/s	~450,000m^3	Quality Defined by OKC [1] Volume defined by SLR.
Growth medium material for cover of WSFs and footprints of excavated waste rock dump areas	Kandosol growth medium comprising the following • 0-20 cm (SL to SCL texture – A1 horizon) • 20-60 cm (SCL to CL,S texture – A2 horizon) • 60-120 cm (CL,S to SLC texture – B21 horizon) • 120-200 cm (SLC to SLMC texture – B22 horizon).	~3.14Mm^3	SLR (part of this report)

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Material Type	Quality Requirements	Volume Requirements	Source of Requirement
Sand for bridging layer prior to Main Pit backfill	D_{50} = 1mm	~99,000m^3	SLR (report under development, March 2020)
Clean fill over waste rock in Main Pit after backfill	None specified	~156,000m^3	SLR (report under development, March 2020)
General construction material for bunds etc	General engineering fill	TBA	SLR (report under development, March 2020)
Rip rap	Durable	TBA	SLR (part of this report)

West Waste Storage Facility (WWSF) Envelope

The majority of the WWSF footprint encompasses the old ore stockpile area, which was rehabilitated in the 1980's effort. The landform is currently a terraced slope generally comprised of a cover of reworked locally sourced lateritic soils overlying run of mine ore and waste rock deposits left behind from the old stockpile. Seven test pits were performed by SLR in field investigations, four were terminated by excavator bucket refusal and three terminated due to limit reach of the excavator arm (≥4.5 m bgl).

East Waste Storage Facility (EWSF) Envelope

The proposed EWSF footprint encompasses old borrow areas and haul roads previously used in mining and rehabilitation operations. The northern and most easterly portion of the envelope generally comprises deep residual fine grain soils (clays and silts). A localised pocket within the northern portion of the envelope contains what is likely filter cake material from the Main and Intermediate water treatment operations of the 1980s. Within the mid-portion of the EWSF envelope the soils typically comprise of lateritic soils overlying natural bedrock at a depth of approximately 1.50 m bgl. The area is largely devoid of topsoil due to previous stripping for borrow materials. A region of shale/argillite bedrock dissecting the WSF envelope bedrock encountered shallow excavator refusal. Outside of the shale/argillite is deeper dolostone deposits.

The southern boundary of the EWSF envelope is marked by the northeast - southwest trending Giant's Reef Fault, where the Coomalie Dolomite abuts the granites of the Rum Jungle Complex. Groundwater was encountered within three of the five test pits proximal (<50 m) to the Giant's Reef Fault at depths between 2.8 m and 4.0 m bgl at the time of investigation and has been observed to fluctuate close to the surface (groundwater well observations) during wet seasons. The three test pits that encountered groundwater were located to the north of the fault.

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Borrow Area A (Coomalie Community Government Council Land)

Borrow Area A is located to the west of the historic Rum Jungle South mine site. The western portion of the area comprises of deep (> 5.0 m) residual fine grained (silts and clays) soils overlying dolostone bedrock. To the east previous works have left some borrow scars within the natural topography, with the soils typically comprising of a mixture of granular residual soils and deeper cohesive soils. The topsoil content within this Area is highly impacted by Gamba Grass therefore the biological properties of this topsoil may affect the use of this material in rehabilitation. This is discussed in other works by DPIR and will not be addressed within this geotechnical report. Volumetric assessment of the Borrow Area A indicates the following available quantities:

Borrow Area A Volumetric Analysis

Soil Type	Volume	Potential Use
Topsoil	228,860 m^3	Growth Medium
Lateritic Clay/Silt	1,139,490 m^3	Low Permeability Layer and Growth Medium
Laterite Granular	1,645,400 m^3	Growth Medium and General Construction
Saprolite Clay	1,611,600 m^3	Low Permeability Layer and Growth Medium
Saprolite Silt	517,950 m^3	Growth Medium
Saprolite Granular	345,300 m^3	Growth Medium and General Construction

The laterite and saprolite materials were tested for suitability as use as low permeability materials against OKC low permeability design requirements.

OKC Low Permeability Criteria

Characterisation Test	Meets Criteria	Criteria
% Clay	✓	Clay percentage > 10%
% Fines	✓	Fines percentage > 30%
% Gravel (4.75mm)	✓	Gravel (4.75mm) percentage < 50%
Atterberg Limits	✓	Plastic Index > 10
Saturated Permeability	Variable	$K_{sat} \leq 1 \times 10^{-9}$ m/s

The saturated permeability results are summarised below.

Hydraulic Conductivity Results

Material	Permeability (k_{sat})	Fines	Clay	Gravel
Laterite	7.0×10^{-10} m/s	69%	49%	2%
Laterite	2.0×10^{-8} m/s	30%	16%	40%
Laterite	7.0×10^{-9} m/s	52%	27%	19%
Laterite	2.0×10^{-9} m/s	-	-	-
Saprolite	5.0×10^{-9} m/s	-	-	-
Saprolite	2.0×10^{-10} m/s	59%	24%	5%

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The saprolite material conforms to the hydraulic requirements, however the laterite material is a more variable.

There is significant volume of saprolite and laterite available, hence prioritising areas of more suitable material (i.e. lower gravel content) should be done during borrow excavation.

Growth Medium

Growth medium requirements for the WSFs have been established by SLR based on providing a a long-term, sustainable growing medium for selected native revegetation species. It is also to provide a reduced likelihood of, equal to or better than baseline for the area, sheet, rill, and gully erosion over the proposed life of the WSFs capping. The growth material will need to provide for moderately rapid stormwater infiltration and be moderately permeable to reach field capacity but also have sufficient clay content to provide some structure, water holding capacity, and mineral exchange and nutrient adsorption capacity to support revegetation with, and long-term sustainability of, native shrubs and grasses.

Desktop review of geotechnical field logs and laboratory analytical results indicates that there is sufficient volumes of material of suitable quality to replicate the soil profile of a Kandosol to a depth of 2m over the WFSs.

The results indicate that for the most part, replication can be achieved be by targeting layers that are considered to match the required physical parameters for each horizon of the growth medium; however, there may need to be some mixing of different materials for make up any deficit, particularly for the surface (A1 and A2) horizons.

Borrow Area B (FRLAT)

The subsurface profile across proposed Borrow Area B is broadly described as topsoil overlying residual soils and shallow bedrock (≤2.0m) with localised alluvium associated with surface water channels. The underlying bedrock is shallow and comprises extremely weathered bedrock and/or competent bedrock of granite and sandstone.

Borrow Area B Volumetric Analysis

Soil Type	Volume	Use
Topsoil	379,440 m^3	Growth Medium
Sandy Gravel/Gravelly Sand	4,679,760 m^3	Growth Medium and General Construction

Borrow Area Summary

The borrow areas material can be summarised as follows:

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<table>
<tr><th>Material Type</th><th>Borrow Area</th><th>Volume Available</th><th>Volume Required</th><th>Recommendations to meet the gap (if required)</th></tr>
<tr><td>Low Permeability</td><td>Coomalie Council</td><td>2,751,000 m^3</td><td>~450,000m^3</td><td>Trial pads</td></tr>
<tr><td>Growth Medium</td><td>Coomalie Council</td><td>2,738,000 m^3</td><td rowspan="2">~3,140,000 m^3</td><td rowspan="2">Mixing to achieve replication for A1 and A2 horizons</td></tr>
<tr><td>Growth material</td><td>FRALT</td><td rowspan="4">4,679,760 m^3</td></tr>
<tr><td>Sand and capping for Main Pit</td><td>FRALT</td><td>99,000 m^3</td><td>None required</td></tr>
<tr><td>Clean cap for Main Pit</td><td>FRALT</td><td>156,000 m^3</td><td>None required</td></tr>
<tr><td>Construction fill</td><td>FRALT</td><td>TBA</td><td>-</td></tr>
</table>

Haul Road Alignment

A summary of the sub-surface conditions encountered along the haul road alignment is given below:

- Generally, all material encountered consistencies ranging from firm to very stiff or medium dense to very dense.
- Groundwater was encountered within one test pit by a river channel at 3.30 m bgl and appeared to be level with extremely weathered shale formation.
- Laboratory California Bearing Ratio (CBR) results indicated CBR% values ranging from 20% to 60% for 4-day soaked samples at 100% Standard Maximum Dry Density.

The material along the alignment is suitable for haul road use; pavements should be designed according to the CBRs identified in the various areas.

Existing Waste Rock Covers

Four shallow test pits were excavated into the side slopes of the existing Intermediate and Main Waste Rock Dump. All four excavations encountered the same strata, with little variation in thicknesses. The rock armouring was assessed as being in good condition and suitable for re-use. The following volume estimates of recoverable rock armouring have been determined (note some areas still to be determined):

Table 8 Waste Rock Dump Rock Armouring Volume Estimate

Waste Dump	Estimated Recoverable Rock Armouring Volume
Main Waste Rock Dump	14,650 to 21,975 m^3
Intermediate Waste Rock Dump	3,705 to 5,557 m^3
Dyson's Backfill	1,190 to 1,785 m^3
Dyson's Waste Rock Dump	3,535 to 5,302 m^3
Drainage lines	TBA
Total Estimated Armour Rock Volume	**23,080 to 34,620 m^3**
Required Armour Volume	**TBA**

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Aldebaran Quarry

The investigation of the Aldebaran Quarry was performed for the suitability granite deposits as rock armouring and erosion protection (rip-rap). Petrographic and geotechnical analysis suggest the granite within the Aldebaran Quarry may be suitable as an armouring material, however it is recommended further testing be conducted to confirm its suitability should additional material be required.

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1 Introduction

1.1 Overview

SLR Consulting Australia Pty Ltd (SLR) was engaged by the Northern Territory Government Department of Primary Industry and Resources (DPIR) to undertake a geotechnical investigation to inform rehabilitation works for RJM, located approximately 6km north of Batchelor, Northern Territory (NT). The field investigation component was carried out in two parts; the first conducted in July 2019 and the second in October 2019. The investigations comprised of a test pitting program with associated sampling and in-situ testing within key areas of interest as defined below in **Table 1**.

Table 1 Areas of Investigation

Location	Objective
East and West Waste Storage Facilities (WSF)	Assessment of foundation materials within proposed WSF envelopes.
Coomalie Council Land Clay and Growth Medium Borrow Area (Borrow Area A)	Assessment and quantification of materials for use in WSF capping design and general construction fill.
Finnis River Aboriginal Land Trust (FRALT) Granular and Growth Medium Borrow Area (Borrow Area B)	Assessment and quantification of materials for use in WSF capping design and general construction fill.
Haul Road Alignment	Assessment of the subsurface conditions for paving design
Existing Waste Rock Dump (WRD) Covers	Assessment of the existing WRD cover layers, including thickness of rip rap and underlying low permeability horizons
Aldebaran Quarry	Assessment of the rock suitability as rip rap erosion protection on WSF slopes

1.2 Background

DPIR proposes the rehabilitation of the former Rum Jungle Mine site (the Project). The Project's high-level objectives are two-fold and focus on environmental remediation and restoration of cultural values of the site as described below:

- Improve the environmental condition onsite and downstream of site within the East Branch Finniss River (EBFR). This includes the following key outcomes:
  - Improved surface water quality conditions within EBFR in accordance with locally derived water quality objectives (LDWQOs).
  - Achieve chemically and physically stable landforms.
  - Support self-sustaining vegetation systems within rehabilitated landforms.
  - Develop physical environmental conditions supportive of the proposed Land Use Plan.
- Improve site conditions to restore cultural values. This includes the following key outcomes:

- Restoration of the flow of the EBFR to original course as far as possible.
- Remove culturally insensitive landforms from adjacent to sacred sites and relocate ensuring a culturally safe distance from the sacred sites.
- Return living systems including endemic species to the remaining landforms.
- Preserve Aboriginal cultural heritage artefacts and places.
- Isolate sources of pollution including radiological hazards.
- Maximise opportunities for Traditional Owners to work onsite to aid reconnection to country.

To meet the above objectives, the proposed rehabilitation strategy comprises the following general tasks [2]:

- Slow down or halt the AMD production reactions from waste rock onsite by consolidating waste rock into one of three new facilities based on PAF characteristics. These facilities are:
  - Main Pit backfill zone – 1.9 Mm^3 stored volume
  - Eastern WSF – 3.8 Mm^3 stored volume
  - Western WSF – 3.2 Mm^3 stored volume
- Treat existing groundwater sources (i.e. the Main and Intermediate WRDs) that contaminate the EBFR by pumping and treating these impacted waters.
- Treat other AMD-impacted groundwater that does not contribute to the EBFR copper load (i.e. old ore stockpile area) by pumping and treating these impacted waters.
- Isolate radiological and AMD affected soils at the Rum Jungle site and Mt Burton from environmental and human receptors by relocating these soils to the new WSFs on site.
- Isolate asbestos materials at the Rum Jungle site from environmental and human receptors by removing from surface soils and relocating to the new WSFs or by another approved means offsite.
- Slow down or halt the future generation and transportation mechanisms for copper and other metals in the new WSF by adopting leading practice methodology for storage of PAF waste rock.
- Return the EBFR to its original course as far as possible.
- Restore land parcels that are poorly vegetated such as the Old Tailings Dam area and vine thicket stand.
- Revegetate new landforms to stabilise the surface and restore ecological function as far as practicable.

1.3 Objectives of Investigation

The objectives of the SLR geotechnical investigation are to:

- Determine foundation conditions across the sites proposed for the new WSFs and along the proposed haul road alignment;
- Assess material characteristics for suitability for use as low permeability cover material, growth medium or general construction fill across the proposed borrow areas and beneath the WSFs;
- Quantify the suitable materials;
- Provide commentary on excavation conditions; and
- Make recommendations on borrow area developments.

1.4 Scope of Services

To achieve the objectives described above, SLR's services comprise of the following:

- Visual inspection of site and surroundings
- Waste Storage Facilities (WSFs):
    - Excavation, logging and sampling of various soil horizons from 38 test pits within the two proposed East and West WSF footprints supplemented with Dynamic Cone Penetrometer (DCP) testing at each test pit location to establish subsurface strength profiles.
- Borrow Area A:
    - Excavation, logging and sampling of various soil horizons from 6 test pits within the proposed Borrow Area A supplemented with DCP testing at each test pit location to establish subsurface strength profiles.
- Borrow Area B:
    - Excavation, logging and sampling of various soil horizons from 7 test pits within the proposed Borrow Area B supplemented with DCP testing at each test pit location to establish subsurface strength profiles.
- Haul Road Alignment:
    - Excavation, logging and sampling of various soil horizons from 14 test pits along the proposed route supplemented with DCP testing at each test pit location to establish subsurface strength profiles, plus 7 additional DCP testing locations.
- Existing Waste Rock Dump (WRD) Cover:
    - Excavation and logging of the WRD cover layers at 4 locations (2 locations on Intermediate and 2 locations on Main WRD)
- Aldebaran Quarry:
    - Visual inspection, assessment of extent of outcrop and sampling of various rock samples from a number of surface outcrops.
- Nominate and co-ordinate soil and rock geotechnical and geochemical laboratory testing.
- Compilation of historic geotechnical data relevant to the WSF and Borrow Areas.
- Undertake analysis of field and laboratory data collated to qualify and quantify available materials for use low permeability, growth medium and/or general construction material.
- Provide recommendations on borrow area development.

2 Rehabilitation Material Requirements

Based on the rehabilitation strategy, the quality and quantity of material required have been derived as shown in Table 2. This includes the volume and quality of material required. The source of the requirement is also listed.

Table 2 Rehabilitation Material Requirements

Material Type	Quality Requirements	Volume Requirements	Source of Requirement
Low permeability material for clay cover of WSFs	Clay percentage > 10% Fines percentage > 30% Gravel (4.75mm) percentage < 50% Plastic Index > 10 Ksat ≤ 1 x 10^{-9} m/s	~450,000m^3	Defined by OKC [2]
Growth medium material for cover of WSFs and footprints of excavated waste rock dump areas	Kandosol growth medium comprising the following • 0-20 cm (SL to SCL texture – A1 horizon) • 20-60 cm (SCL to CL,S texture – A2 horizon) • 60-120 cm (CL,S to SLC texture – B21 horizon) 120-200 cm (SLC to SLMC texture – B22 horizon).	~3.14Mm^3	SLR (report under development, March 2020)
Sand for bridging layer prior to Main Pit backfill	D_{50} = 1mm	~99,000m^3	SLR (report under development, March 2020)
Clean fill over waste rock in Main Pit after backfill	None specified	~156,000m^3	SLR (report under development, March 2020)
General construction material for bunds etc	TBA	TBA	SLR (report under development, March 2020)
Rip rap	Durable	TBA	SLR (part of this report)

The background to these requirements is summarised in the following sections.

2.1 Low Permeability Materials

In 2016, O'Kane Consultants (OKC) developed a preliminary specification for the low permeability WSF capping layer [1], as shown in Table 3.

Table 3 OKC Low Permeability Material Specification

Characterisation Test	Criteria
% Clay	Clay percentage > 10%
% Fines	Fines percentage > 30%
% Gravel (4.75mm)	Gravel (4.75mm) percentage < 50%
Atterberg Limits	Plastic Index > 10
Saturated Permeability	$K_{sat} \leq 1 \times 10^{-9}$ m/s

2.2 Growth Medium

This is addressed in this report, refer Section 8.

2.3 Sand and Clean Fill for Main Pit Backfill

Refer Main Pit Investigation Report that is still under preparation.

2.4 Construction Material

TBA

2.5 Rip Rap

Durable.

3 Site Description

3.1 Site Identification

The site is separated into five proximal investigation areas all within an 8 km radius (**Figure 1** below and within site overview drawing in **Appendix A).**

- Rum Jungle – including WSFs and haul road alignments
- Clay and Growth Medium Borrow (Borrow Area A)
- Granular and Growth Medium Borrow (Borrow Area B)
- Haul Road
- Aldebaran Quarry

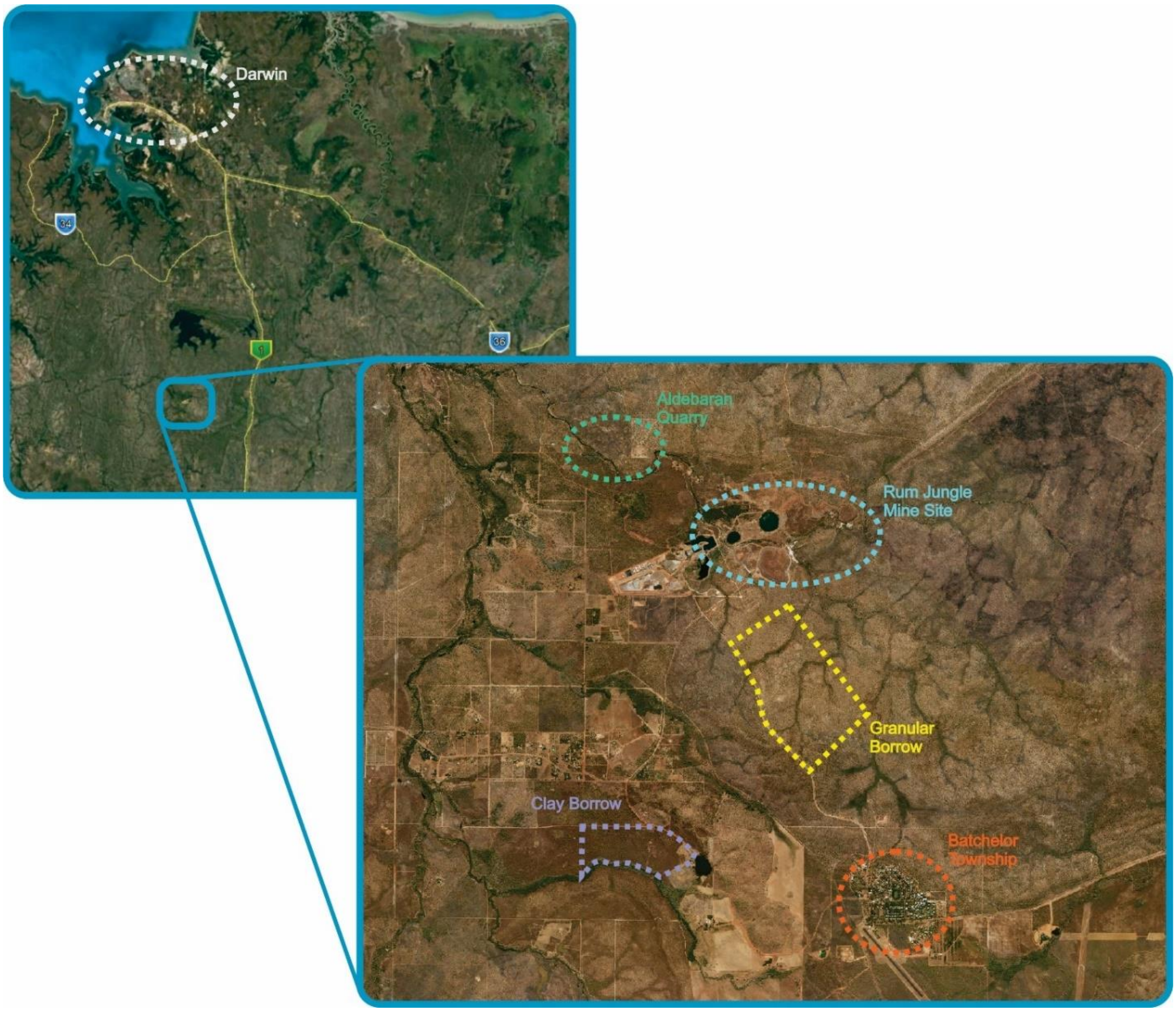


Figure 1 Investigation Areas

Figure 2 highlights the main features within each investigation area.

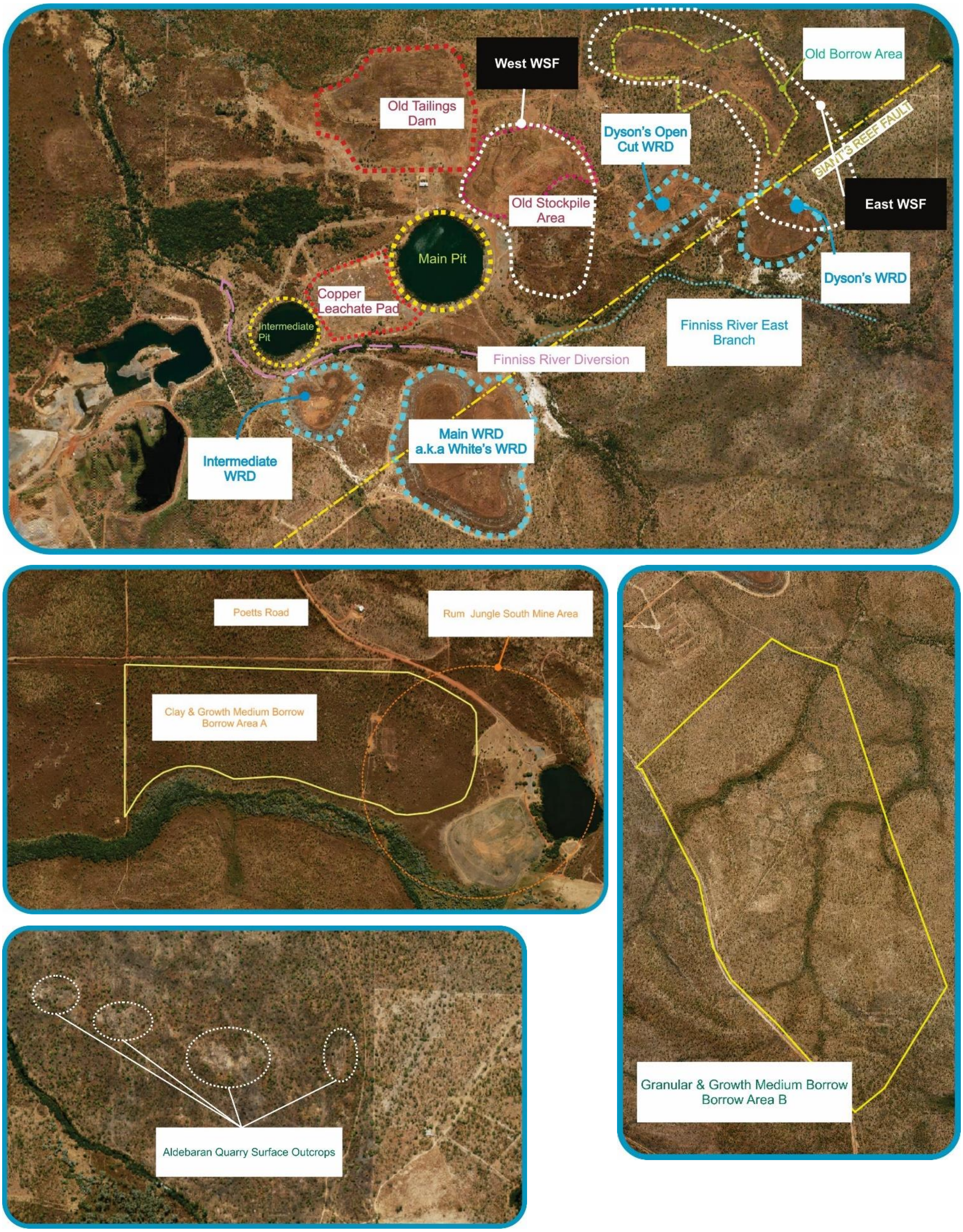


Figure 2 Investigation Area's Features

3.2 General Site Conditions and Topography

3.2.1 Rum Jungle Mine Site

RJM consists of a 655ha parcel of land contained within a Mining Lease. It is located immediately to the northeast of Rum Jungle Road and Litchfield Park Road intersection and immediately east of Browns Oxide Mine Site. The site extends approximately 2.6 km east and 2.0 km north from the Rum Jungle Road - Litchfield Park Road intersection. Access to the site is typically from the west via Rum Jungle Road or Browns Oxide Mine. An unsealed access track also exists to the north of the site allowing access.

At the time of SLR investigation (in July and October 2019), the mine site had been decommissioned for several decades, with only remnant structures, unsealed access tracks and waste rock dumps dominating the landscape. Prior to the SLR investigation a back-burning program had occurred across the site, with large tracks of land generally charred black and sparsely vegetated. Zones of dense vegetation, consisting of medium to large native trees and shrubs, were present across the site, typically found outside of old mine operation areas. Access was considered restricted in these densely vegetated areas.

Existing tracks within the site are in a reasonable to poor condition in places. Poor condition paving is present along the northern track leading to the old bridge crossing along the Brown's Oxide Mine Site boundary. The bridge is also considered to be in poor condition. Largely, all other tracks are unpaved, dirt tracks with erosion features including scours and ridges.

Four existing waste rock dumps (WRD) are present on the site:

- Dyson's WRD - founded at grade and extends to ~20m above ground level.
- Dysons Pit Overburden– former open cut pit which was backfilled with tailings during mining in the 1970s and contaminated soil from the copper extraction area placed above grade and capped.
- Main WRD (also known as White's WRD) – founded at grade and extends to ~20 m above ground level.
- Intermediate WRDs – founded at grade and extends to ~20 m above ground level.

These WRD site are capped with a growth medium material and rock armouring on their slopes. At the time of investigation, the slopes of the waste rock dumps were in good condition with no signs of slope failure or instability evident. The slope angle is typically at 30°. The rock armouring was in good condition and exhibited durability in contrast to sporadic occurrences of weathered shale which was not considered to be part of the armouring but a locally derived material. Similarly, surface rip-rap lined drainage channels across the site, were observed to be in relatively good condition, with no obvious scour or deterioration evident at observed locations.

Acid Mine Drainage (AMD) evaporative white salts were evident within drainage paths and at the toes of the WRDs. Typically, the quantity of acid salt evaporates were most prevalent proximal to the waste rock dumps and their drainage channels. A large zone of salt leachate was observed to the east of the Main WRD where the natural drainage from the WRD and the East Branch Finniss River (EBFR) would likely pool during periods of wet weather.

Other key site features include:

- Old tailings dam: Currently a low lying, low grade area subject to seasonal flooding. A rip-rap lined drainage channel directs flow westward to the boundary of the old tailings dam before turning north to reconnect with the Finniss River.

- Old Stockpile area: Currently a terraced slope dipping to the southwest, the slope consists of six benches created by both cut and fill with surface water flow bunding. A rip-rap lined drainage channel directs flow west to the old tailings dam surface water flow channel.
- Old Clay Borrow Areas: Located in the northeast portion of the site, currently they are partially vegetated areas with slightly undulating ground topography suggestive of historic stockpiling, surface water flow mitigation and earthworks. The northern old clay borrow area is known to have been used to dump water treatment waste from the Main and Intermediate Pits.
- Main and Intermediate Pits: Water filled open cut mine pits.
- EBFR: Flowing east to west the river bed was mostly dry.

The natural topography of the site has been significantly influenced by previous mining and rehabilitation activity. Some of the highest points across the site are the existing WRDs (Main WRD: RL 92 mAHD, Dyson's Open Cut RL 94 mAHD, Dyson's WRD RL 88 mAHD and Intermediate WRD RL 75 mAHD).The highest point on site is located on the natural slope north of Dyson's WRD with an elevation of RL 102m AHD. Lowest points are formed by the river channel beds of the Finniss

Across the site, between these features, the surface is variable with gentle undulating areas and localised steep gradients. The steeper gradients are normally associated with man-made features, such as the terraced old stockpile area and some sections of roads. The rim of the Main and Intermediate Pits are at approximate elevations of RL 61 mAHD and are separated by a large flat area known as the old heap leach pads.

The topographic map of Rum Jungle Mine site area is provided in **Appendix B**.

Photos taken of the general site conditions at the time of investigation are shown in **Photo 1.**

At WRTP-01 looking northwest over Old Tailings Dam

On Dyson's WRD looking northwest over Dyson's Open Cut WRD

At WRTP-09 looking north at the southern batter of Dyson's Open Cut WRD

At WRTP-05 Looking northwest down terraced slope of old stockpile area. A stack of large boulders placed in foreground.

At WRTP-03 looking south across Old Tailings dam with remanent structures in background

WRTP-08 looking southeast over Dyson's Open Cut WRD and Dyson's WRD

Photo 1 General Site Photos of Rum Jungle

3.2.2 Borrow Area A – Clay and Growth Medium Borrow

Borrow Area A consists of a 105-ha parcel of land contained within a Pastoral Lease of the Coomalie Council. The area is located to the west of Poett Road, which makes up the eastern boundary of the borrow. The southern boundary is defined by the riparian corridor created by an ephemeral creek of the Finniss River system. The northern and western boundaries are defined by an unsealed farm access road and barbed wire fence that runs part way along the northern access track. The area is largely undeveloped apart from the eastern fringe, encroaching upon the Rum Jungle South rehabilitated open cut mine area. The area at the time of investigation was heavily vegetated with ≥2.0 m tall buffel grass and sporadic trees. Some back-burning had occurred for adjacent to Poett Road.

Land use surrounding the borrow area is primarily pastoral with the decommissioned Rum Jungle Creek South mine site to the east. Several shallow ephemeral drainage gullies dissect the site, typically running north to south.

The site gently increases in elevation from west to east, ranging from RL 65 mAHD to RL 85 mAHD.

The area is located within a gently sloping topography that trends south and west towards a secondary creek that creates the southern boundary of the borrow. The creek itself makes up part of the Finniss River Catchment system and eventually joins the major river system to the north. A shallow ridgeline trending north to south exists to the east side of Poett Road and directs rainfall and surface flow westward. It is likely the area is prone to flooding within the wet season, increasing in susceptibility in a westerly direction, given the slight elevation difference across the site, volume of rainfall in wet season and nature of catchment area. The elevation within the borrow area ranges from approximately RL 96 mAHD at the eastern boundary to RL 72 mAHD along the western boundary.

Overall, the site topography comprises of relatively flat natural surfaces of less than 5% grade with minimal topographic features.

The topographic map of Clay and Growth Medium (Borrow Area A) is provided in **Appendix C**.

Photos taken of the general site conditions at the time of the investigation are shown in **Photo 2**.

NTP-08 Looking South

NTP-05 Looking North

NTP-02 Looking West

NTP-06 Looking South

Photo 2 Borrow Area A General Site Photos

3.2.3 Borrow Area B – Granular Materials and Growth Medium Borrow

Borrow Area B consists of an approximate 400 ha parcel of land, approximately 2.8 km long and 1.3 km wide, located within the Finnis River Aboriginal Land Trust (FRALT) zone. Located to the east of Rum Jungle Road and South of Rum Jungle Mine site, the area is located within the Finniss River Land Trust and generally comprises well vegetated areas of native and introduced species plants, grasses and trees. The area is dissected by several ephemeral creeks that trend northeast - southwest towards, flowing northeast to the Finniss River Eastern Branch.

Shallow rocky outcrops are evident in the south of the site as the elevation rises in a southerly direction. Elevation ranges from approximately 65 mAHD in the north to 100 mAHD in the south, with gentle undulating topography between creek channels. A powerline easement off-set by approximately 40 m runs adjacent to the Rum Jungle Road, coming from the township of Batchelor and terminating at Browns Oxide Mine site. Several access tracks also exist across the site, mostly overgrown with tight single lane vehicle access. An unsealed access road creates the eastern boundary of the borrow area.

The borrow area is located within woodland comprising generally undulating terrain created by erosional forces and incision of ephemeral streams and gullies coursing northeast towards the Finniss River East Branch. A shallow ridgeline trending northwest to southeast located to the east of Rum Jungle Road captures rainfall and runoff and directs overland flows northeast across the borrow area. Overflows are collected in secondary stream systems which eventually join at the Finniss River East Branch to the north of the borrow area. The elevation increases in a southerly direction and is characterised by undulations as streams incise into the ground. The site undulates between alluvial transition zones, ephemeral gullies and shallow plateaus away from drainage lines. Minor Anthropogenic topographic influences in old borrow areas and access track exist sporadically across the site.

The area is likely subject to localised flooding as creeks swell under wet seasonal flows with susceptibility increasing in an easterly direction and in proximity to the drainage lines. The elevation within the borrow area ranges from approximately RL 81 mAHD in the north to RL 104 mAHD in the south.

The topographic map of Granular and Growth Medium area (Borrow Area B) is provided in **Appendix D**.

The area appears to be largely undisturbed bar access tracks and powerline easements. A shed and several abandoned cars are present in the northern portion of the site.

Photos taken of the general site conditions at the time of investigation are shown in **Photo 3**.

STP-01 Looking North

STP-03 Looking South

STP-06 Looking West

STP-07 Looking North

Photo 3 Borrow Area B General Site Photos

3.2.4 Aldebaran Quarry

Aldebaran Quarry consists of an approximate 30 ha parcel of land, approximately 1.0 km by 0.5 km. Within this parcel approximately 2 ha was observed to be rock outcrops at surface. The quarry area is located approximately 2.5 km north-northwest of the Rum Jungle Mine site. Its eastern boundary is formed by the Old North Australia Railway track, southern and western boundary by the Finniss River channel and its northern boundary is defined by a small creek flowing west into the Finniss River.

Aldebaran Quarry is accessed off the Lichfield Park Road, followed by Lithgow Road which are paved and in good condition. Remaining access via White Road and the Old North Australia Railway dirt tracks are in reasonable to very poor condition, respectively. The Old North Australia Railway track comprised significant amount of scouring and overgrown vegetation.

The site is undeveloped. Shallow rock outcrops are present, forming approximate north - south trending domes up to 2 m high. Between outcrops, moderately to densely vegetated areas with significant rock debris were observed.

The topography of the quarry area generally comprises of gently sloping hills with a dominating crest aligned east - west, also in line with the most prominent rock outcrops. The gentle inclines dip towards surface water channels to the north, east and southwest. Localised undulations in the east - west direction form due to the presence of protruding rock outcrops. The highest points are located on the rock domes, up to 2 m above ground level. Elevations ranges from RL 69 mAHD to RL 71 mAHD.

Photos taken of the general site conditions at the time of investigation are shown in **Photo 4.**


Surface outcrop facing South


Surface outcrop facing East


Surface outcrop facing North


Surface outcrop facing West

Photo 4 Aldebaran Quarry General Site Photos

3.3 Climate

The climate of Rum Jungle area is considered to be ‘tropical savanna’ in accordance with the Köppen classification system used by the Bureau of Meteorology (BoM). The area receives approximately 1500 mm of annual rainfall and is marked as ‘Summer Dominant’ climate characterised by wet summers and dry winters [3]. The majority (>90%) of precipitation occurs between November to April with little rainfall seen between May and October. **Table 4** shows the monthly average rainfall and mean minimum and mean maximum temperature as recorded at the Batchelor Airport Station (014272) from 1992 to 2019.

Table 4 Average Rainfall and Temperature 1992-2019 (Batchelor Airport 014272)

Aspect	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainfall (mm)	331.7	320.6	235.8	86.8	27.3	0.4	0.8	2.1	8.1	65.0	137.5	267.5
Min Temp (°C)	24.0	23.8	23.5	21.8	19.1	17.0	16.5	17.0	20.6	23.1	24.0	24.2
Max Temp (°C)	32.7	32.5	33.1	33.8	32.8	31.6	32.0	33.4	36.0	36.8	35.6	33.9

As shown above, the lowest minimum mean temperature for Batchelor is 16.5°C (July) and highest maximum mean temperature is 36.8°C (October). The minimum mean monthly rainfall is 0.4 mm (June) and maximum is 331.7 mm (January). This is shown graphically in **Figure 3** below.

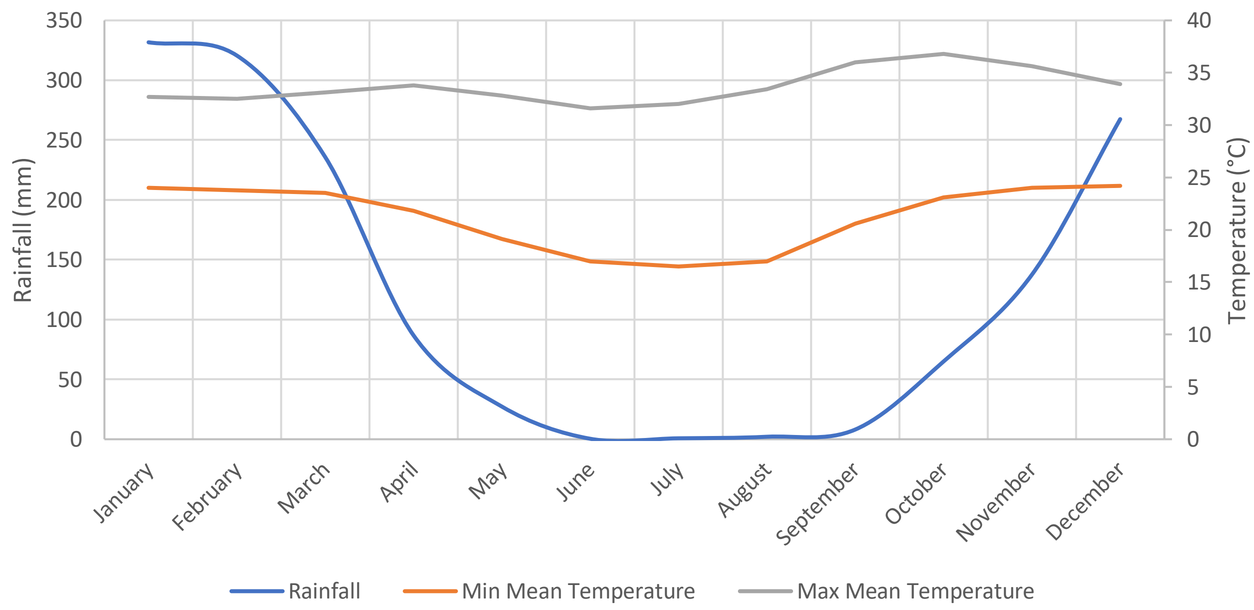


Figure 3 Climate Data Summary (1992 – 2019, Batchelor Airport Station)

3.4 Hydrology

The Rum Jungle Mine site has been studied by Robertson GeoConsultants (RGC), the following is an extract from the report 'Waste Storage Facility Investigations, Rum Jungle", June 2016. The observations made on site during the SLR 2019 investigation are in agreement with the following description of surface flows.

> *Rum Jungle Mine Site is located within the watershed of the Eastern Branch of the Finniss River, about 8.50 km upstream of its confluence with the West Branch of the Finniss Rover. Surface waters enter via the upper East Branch of the Finniss Rover and Fitch Creek. Before mining, these creeks met near the northeast corner of the Main Waste Rock Dump and flowed eastward via the East Finniss Rover. This original river course ran through the Main and Intermediate ore bodies so flow was diverted to the East Finniss Diversion Channel to allow mining operations.*
>
> *Current day, flows from the upper East Branch and Fitch Creek flow directly into the diversion channel and during high flow events into the Main Pit near the former Acid Dam.*

The Old Tailings Dam area is drained to a small ephemeral creek known as Old Tailings Creek which reports to the East Branch of the Finniss Rover about 1.5 km downstream (north) of the central mining area.

During the wet season, low-lying parts of the mine site, including the Old Tailings Dam area are subject to flooding and water ponds on the surface in some portion.

Based on SLR site observations, topography and RGC findings, the interpreted surface water flow paths of the Rum Jungle Mine site, Borrow Area A and Borrow Area B are shown in **Figure 4** to **Figure 6,** respectively. It is noted that an exaggerated vertical scale has been used in these figures.

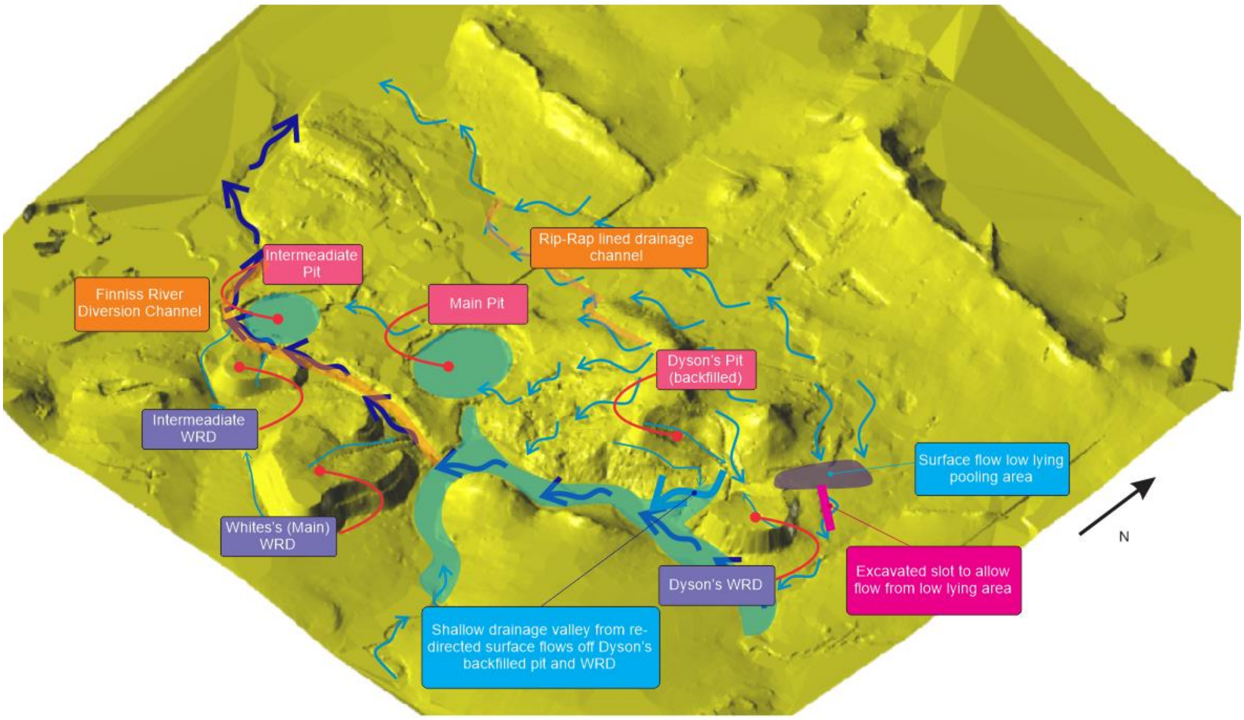


Figure 4 Interpreted Surface Water Flow Paths - Rum Jungle Mine Site

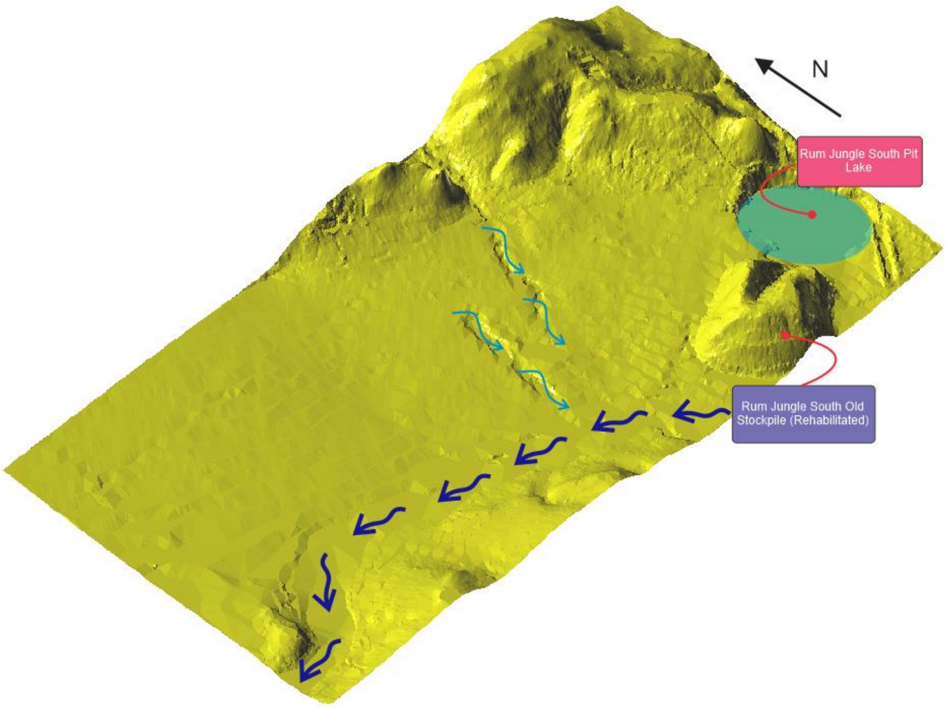


Figure 5 Interpreted Surface Water Flow Paths – Borrow Area A

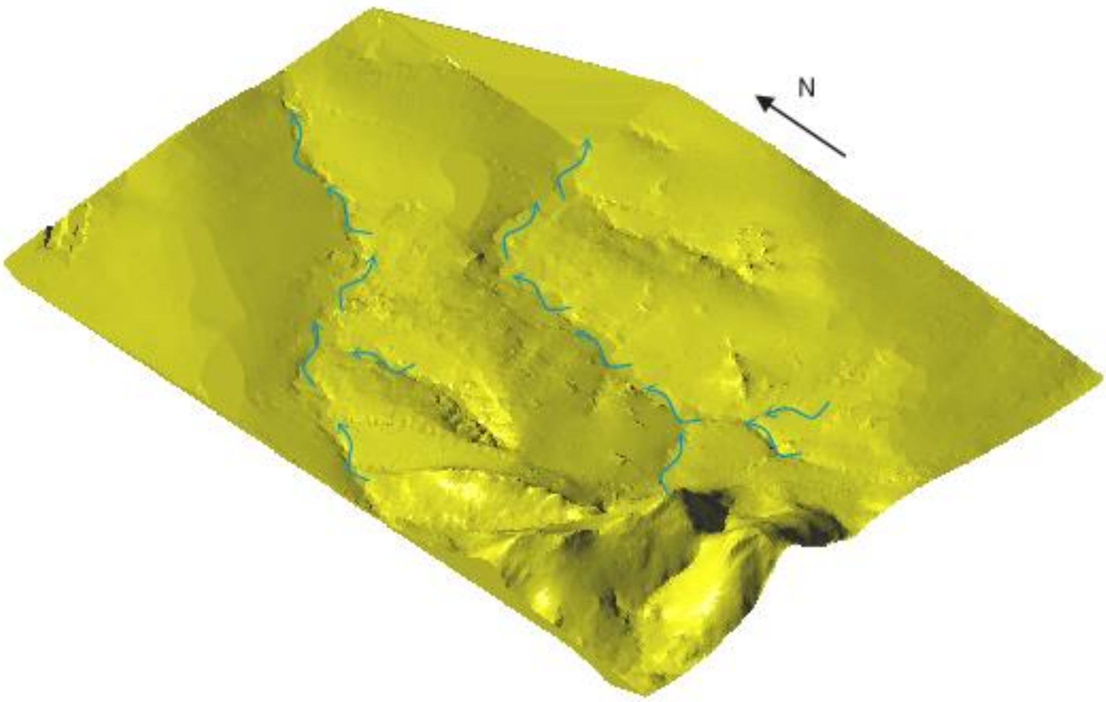


Figure 6 Interpreted Surface Water Flow Paths – Borrow Area B

3.5 Geology

3.5.1 Regional Geology

The study area is located in the Pine Creek Orogen, which is approximately 66,000 km^2 on the northern margin of the exposed Australian Craton and is approximately 2050 to 1800 Ma. The Paleoproterozoic succession is generally comprised of clastic, carbonate, and carbonaceous sedimentary and volcanic rocks that unconformably overlay Neoarchean granitic and gneissic basement. The Pine Creek Orogen is a highly productive mineral province with over 1300 known mineral occurrences, primarily of Ag-Zn, Sn-Ta, W, PGE, Ni, Co, and U [4].

The Pine Creek Orogen is typically subdivided into three domains: the Litchfield Province, the Central Domain, and the Nimbuwah Domain. RJM is located in the Central Domain, which is primarily comprised of greenschist facies Paleoproterozoic metasedimentary successions intruded by post-tectonic granite plutons and minor mafic rocks [4].

In response to subsidence of the Neoarchaean basement and rifting early Paleoproterozoic sediment deposition took place. This included the deposition of fluvial and conglomerate material (Beestones Formation), as well as supra and inter-tidal carbonates of the Manton, Namoona, and Kakadu Groups, with some localised basaltic-andesitic volcanism (Stag Creek Volcanics). The basin progressively deepens eastward resulting in sediment thickness 2 km to 18 km thick.

Within the Central Domain the Mount Partridge Group unconformably overlies the Manton and Namoona Groups. The Mount Partridge Group is comprised of the Crater Formation which is immature fluvial clastic sediments, the Coomalie and Koolpinyah Dolostones, and the Whites Formation which is comprised of carbonaceous sedimentary rocks. The Whites Formation is unconformably overlain by the South Alligator Group which is predominantly comprised of shales, chert, and volcanogenic sedimentary rocks.

Regional metamorphism and syn- to post-tectonic deformation occurred from approximately 1867-1850 Ma that resulted in the deformation, metamorphism and intrusion of the Orogen by granitoids, and mafic bodies.

Descriptions of the geological units encountered across the Rum Jungle and Borrow Area sites comprise the following:

Whites Formation Ppi

Whites Formation is part of the Mount Partridge Group and marks a distinct change in the sedimentary and environmental conditions that occurred in the Early Proterozoic. The unit overlies the Coomalie Dolostone and is described as calcareous and carbonaceous pyritic argillite, dololutite, dolarenite and rare quartzite.

Coomalie Dolomite Ppc

The Coomalie Dolostone is part of the Mount Partridge Group. The formation is described as stromatolitic, magnesite and marble, in places chloritic and tremolitic, commonly silicified or lateritised at the surface; metalutite, commonly graphitic. Subject to karstic features.

The Geolsec Formation Pyg

The Geolsec Formation unconformly overlies The Mount Partridge Group. The unit is Described as a haematitic paraquartzite breccia, milky quartz and chert breccia; haematitic mudstone, siltstone and sandstone; minor phosphatic siltstone and breccia.

Celia Dolostone Pnl

The Celia Dolostone is described as stromatolitic magnesite, dolomite, some silicified rare para-amphibolite and metapelite.

Beestons Formation Pnb

The Beestons Formation, part of the Manton Group is described as a quartz conglomerate, grit, arkose, sandstone derived from fluvial deposits.

Rum Jungle Complex Ar5, Ar6

The Rum Jungle Ar6 lithology is describes as large feldspar and coarse granites with Ar5 described as scatted outcrops of undifferentiated granite.

The local bedrock units recorded in the investigation areas are described in the sections below. Associated Drawings showing the local bedrock geology for each area are included in **Appendix B, C and D**.

A simplified stratigraphic column of the Pine Creek Orogen is shown in **Figure 7**.

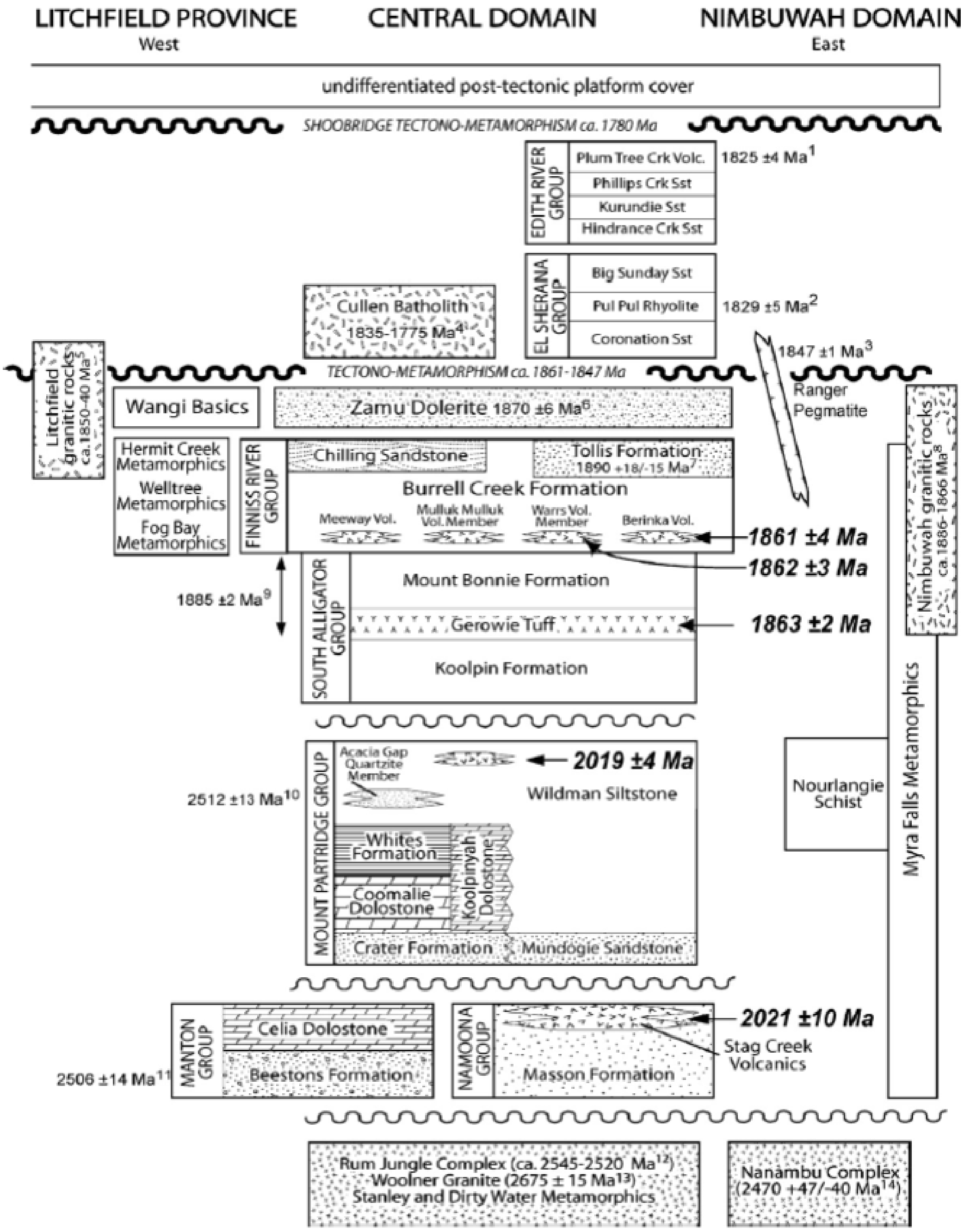


Fig. 3. Schematic and simplified stratigraphic column of the Pine Creek Orogen, with geological regional subdivisions indicated, left to right; the Litchfield Province, the Central Domain, and the Nimbuwah Domain. The major Central Domain units are depicted; historical geochronology is indicated, in small type, at the appropriate stratigraphic unit. New SHRIMP U–Pb zircon data is in italicised bold type. (1) SHRIMP zircon extrusion age (Page, 1996c); (2) SHRIMP zircon extrusion age (Jagodzinski, 1998); (3) ID-TIMS monazite intrusion age (Annesley et al., 2002); (4) SHRIMP zircon emplacement ages (Stuart-Smith et al., 1993; Page, 1996e); (5) ID-TIMS zircon and xenotime emplacement ages (Page et al., 1985); (6) SHRIMP zircon emplacement age (Page, 1996b); (7) SHRIMP zircon upper intercept deposition age (Page and Williams, 1988); (8) various ID-TIMS zircon upper intercept emplacement/metamorphic ages (Page et al., 1980); (9) ID-TIMS zircon upper intercept deposition age (Needham et al., 1988); (10 and 11) SHRIMP zircon maximum deposition ages (Cross et al., 2005); (12) SHRIMP zircon emplacement ages (Cross et al., 2005); (13) SHRIMP zircon emplacement age (McAndrew et al., 1985); (14) ID-TIMS zircon emplacement age (Page et al., 1980).

Figure 7 Simplified Stratigraphic Column of the Pine Creek Orogen [4]

3.5.2 Surficial Geology

The Rum Jungle Complex and all Proterozoic sediments and meta sediments have undergone in-situ laterization since the early Mesozoic era and Tertiary period, forming deeply weathered, well developed soil horizons. There is evidence of Quaternary soils and alluvium in select areas (largely river and creek channels) however, there is no evidence of the Permo-Carboniferous glaciation period [5].

3.5.3 Structural Geology

The relevant published geological maps (Northern Territory Geological Survey, Scale 1:100,000, Sheets 5071, 5072, 5171 and 5172 [6]) show a multitude of faults, shear zones and dykes/veins across the Rum Jungle Mine site. Details of each investigated area are discussed in the following sections.

3.5.3.1 Rum Jungle Mine Site

The Rum Jungle Mine site is situated in a triangular area of the Rum Jungle mineral field that is bounded by the dominant structural feature Giant's Reef Fault to the south and a series of east-trending ridges to the north. This triangular area of Rum Jungle mineral fields that is bounded by the Giant's Reef Fault is known as the Embayment and lies on the shallow-dipping limb of a northeast trending, southwest plunging asymmetric syncline that has been cut by northerly dipping faults. The Giant's Reef Fault has a major influence on groundwater passage within the Rum Jungle site. The fault is cut at serval locations to the north by north striking faults.

The main lithologic units in the Embayment are the Rum Jungle Complex and meta-sedimentary and subordinate meta-volcanic rocks of the Mount Partridge Group. Reference to the relevant geological maps, the Rum Jungle geology can be characterised by its location relative to Giant's Reef Fault, within primarily granites found south of the fault line and Mount Partridge Group units comprises of Geolsec Formation, Whites Formation, Coomalie Dolostone and Crater Formation [7].

3.5.3.2 Borrow Area A

Borrow Area A is situated to the immediate west of a northwest trending reverse fault. The relevant geological maps indicate that the area is divided into two main lithologic units. To the west the area is underlaid by Coomalie Dolostone and to the east by Whites Formation.

3.5.3.3 Borrow Area B

Borrow Area B is situated south of Giant's Reef Fault. The relevant geological maps indicate that the area is predominantly underlain by granites of the Rum Jungle Complex. The majority of the site in the north is underlain by large feldspar coarse granite (Unit Ar6 and Ar5).

Several uncertain age similar orientated faults exist to the south of Giant's Reef Fault. One of these faults partially dissecting Borrow Area B towards the southern extremity of the borrow area in a similar orientation to the Giant's Reef Fault. This introduces scattered outcrops of undifferentiated granite, along with earlier age Celia Dolostone and Beestons Formation of the Manton Group located in the southwest corner of the borrow area envelope.

3.5.3.4 Aldebarran Quarry

The quarry area is located to the north of the Rum Jungle Mine site and north of the Embayment northern ridges. The relevant geological maps indicated that the area is underlain by granites of the Rum Jungle Complex, specifically by unit Ar6, a large feldspar and coarse grained granite.

3.6 Hydrogeology

RJM is located along the East Branch of the Finniss River (EBFR) about 8.5 km upstream of its confluence with the West Branch of the Finniss River.

Groundwater flows from upland areas down to lower elevation areas of the EBFR and the channel in the central mining area. During wet season, groundwater discharges to creeks and tributaries of the Eastern Branch Finniss River. During the dry season groundwater generally does not discharge to surface drainage features [7].

Groundwater is generally found less than 12 m below existing ground surface, with an average depth to water of 4.0 m. Groundwater is nearer the surface (<3.0 m below the surface) proximal to Giant's Reef Fault on the northern side. Groundwater is strongly influenced by wet and dry season rainfall fluctuations, with groundwater level typically 5 m to 7 m higher during wet season periods.

Within Borrow Area B, no known groundwater studies exist, however the local topography indicates that groundwater flows in a northeasterly direction towards natural drainage channel of Eastern Branch Finniss River. The flow is likely within influenced by structural elements within the granite or deeper lying lithologies, altered by mapped faults, which are likely to act as barriers or flow paths.

Similarly, for Borrow Area A, minimal groundwater studies exist. However, based on the local topography, it is anticipated that groundwater flows in a southwesterly direction towards the tributaries of the Finniss River. Groundwater is likely influenced by seasonal variation, and in times of high rainfall it is possible that the underlying rock layer may act as a semi impervious layer resulting in a perched groundwater table at the soil/rock interface.

4 Historical Geotechnical Review

A number of investigation and assessment have been previously undertaken by the others. The following previous geotechnical investigation and option reports are considered to be relevant and have been reviewed as part of this assessment:

- Meehan Burgess & Yeates, *Rum Jungle Rehabilitation Project Engineering Report*, 1982 [8]
- Dames and Moore, *Report – Site Investigations Rehabilitation of Whites and Whites North Heaps, Rum Jungle, Northern Territory*, 1983. [9]
- Mining and Process Engineering Services, *Filter Cake Disposal Report*, 1985 [10]
- Robertson GeoConsultants (RGC), *Waste Storage Facility Investigations, Rum Jungle, Ref: 183006/2,* 2016 [11]
- GHD, *Rum Jungle Creek South Rum Jungle WRD Remediation Geotechnical Investigation Report*, 2019 [12]
- O'Kane Consultant's (O'Kane's) *Rehabilitation of the former Rum Jungle Mine: Stage 2 Works Specification*, June 2016 [1].

Based on the review of the above previous reports, a number of historical test pits and laboratory tests results are considered to be relevant to the areas in interest. The details of the relevant data are summarised in **Table 5**.

Table 5 Relevant Historical Test Pits Summary

Area	Relevant Historical Studies	Relevant Data
Waste Storage Facilities	RGC, 2016 [13]	Subsurface in this area over the depth of test pit investigations was found to be relatively uniform, generally: • Fill materials comprising of reworked laterite and saprolite materials, average thickness 0.50 m; • Saprolite materials consisting of gravels with sands and low-plasticity clays, well-cemented at least 0.90 m thick; • Weathered Geolsec bedrock underlying the saprolite deposits, typically transitioning to competent rock at less than 10 m depth. Shallow refusal of the excavations indicates that the strength increases significantly with depth and is high near surface. Also, under current conditions, there was no evidence of weak soil strata in the upper 2.5 m to 5 m below the ground surface. The tested materials are typically very dense soils with a density index above 85% (AS 1726-1993).

Area	Relevant Historical Studies	Relevant Data
	Meehan Burgess & Yeates 1982 [8]	Subsurface investigation performed in 1982 prior to development of the area. Observations would likely not reflect current day conditions. Of the test pits performed relevant to the WSF envelopes the following was reported: • 0.20 m thick topsoil deposited comprising of sand/gravel with considerable clay; • 1.30 m to 2.80 m thick gravel; initially lateritic sandy gravel transitioning to breccia clayey gravel. • 0.30 m to 1.20 m thick clay, initially lateritic and transitioning to extremely weathered rock. Lateritic clay plasticity was recorded as high and plasticity of the extremely weathered rock was recorded as medium. • Extremely weathered rock was encountered at depths of 3.00 mbgl and 2.50 mbgl. Shallow refusal and observed dense or very stiff to hard consistency indicates an increase in strength with depth. Moisture content within the soil layers above the extremely weathered rock were observed to have slightly higher moisture content.

<table>
<tr><th>Area</th><th>Relevant Historical Studies</th><th>Relevant Data</th></tr>
<tr><td></td><td>Dames and Moore 1983 [9]</td><td>
Subsurface investigation performed in 1983 builds upon Meehan Burgess & Yeates investigation and was performed prior to development of the area. Observations would likely not reflect current day conditions. Observations and results are most relevant to the proposed WSF East.
Of the test pits performed relevant to the WSF envelopes the following was reported:

0.10 m to 0.20 m thick, topsoil, comprising silty gravelly sand
0.70 m to 2.10 m thick, lateritic, gravelly sand/ gravelly clayey sand with variable quantities of clay
Occasional, 0.90m thick, lateritic, high plasticity clay with trace sand and siltstone nodules;
1.30 m to 2.40 m thick, saprolite, low to medium plasticity, silty clay/clayey silt, distinct yellow-grey, blue-grey colouring;
Extremely weathered mudstone/siltstone with clay banding encountered from 2.40 mbgl to 3.10 mbgl.

5 sets of permeability tests were performed on collected samples at 90% and 100% maximum standard dry density. Results are summarised below.
<table>
<tr><th rowspan="2">Test Pit</th><th>Depth</th><th>Relative Density</th><th>Laboratory Moisture</th><th>Coefficient of Permeability</th><th>% Fines (particle passing 75µm)</th></tr>
<tr><td>(m bgl)</td><td>(%)</td><td>(%)</td><td>(m/sec)</td><td>(%)</td></tr>
<tr><td rowspan="2">DM-503</td><td rowspan="2">1.50 – 2.00</td><td>90%</td><td>100% OMC</td><td>2×10^{-6}</td><td rowspan="2">61</td></tr>
<tr><td>100%</td><td>100% OMC</td><td>4×10^{-10}</td></tr>
<tr><td rowspan="2">DM-505</td><td rowspan="2">2.00 – 2.50</td><td>90%</td><td>100% OMC</td><td>2×10^{-7}</td><td rowspan="2">68</td></tr>
<tr><td>100%</td><td>100% OMC</td><td>7×10^{-8}</td></tr>
<tr><td rowspan="2">DM-511</td><td rowspan="2">2.00 – 2.10</td><td>90%</td><td>100% OMC</td><td>3×10^{-7}</td><td rowspan="2">88</td></tr>
<tr><td>100%</td><td>100% OMC</td><td>7×10^{-10}</td></tr>
<tr><td rowspan="2">DM-516</td><td rowspan="2">1.80 – 2.20</td><td>90%</td><td>100% OMC</td><td>1×10^{-6}</td><td rowspan="2">69</td></tr>
<tr><td>100%</td><td>100% OMC</td><td>3×10^{-9}</td></tr>
<tr><td rowspan="2">DM-518</td><td rowspan="2">2.50 – 2.80</td><td>90%</td><td>100% OMC</td><td>1×10^{-7}</td><td rowspan="2">94</td></tr>
<tr><td>100%</td><td>100% OMC</td><td>4×10^{-9}</td></tr>
</table>
</td></tr>
</table>

<table>
<tr><th>Area</th><th>Relevant Historical Studies</th><th>Relevant Data</th></tr>
<tr><td></td><td>Mining and Process Engineering Services 1985 [10]</td><td>
Subsurface investigation performed in 1985 to assess .
Of the test pits performed relevant to the WSF envelopes the following was reported:

0.50 m to 1.20 m thick, lateritic, sandy gravel, dense
>2.50 m thick, lateritic, medium to high plastic clay, friable, very stiff to hard
Areas of >3.00 m thick, saprolite, low to medium plasticity, silty clay/clayey silt, distinct yellow-grey, cream and blue-grey colouring towards the southern fringe of the investigation area.

Falling head tests of an uncased section were performed in two shallow boreholes within the area. The tests were performed in 'near surface section of very stiff to hard clay material which underlies the surface sandy gravel materials' and 'softer wetter clay'. Field permeability results returned k-values of 3.4×10^{-6} cm/sec and 7×10^{-5} cm/sec.
</td></tr>
<tr><td>Borrow Area A</td><td>GHD 2019 [12]</td><td>
GHD conducted a geotechnical investigation with the aim of assessing the suitability of materials for the Waste Storage facility cover remediation works. The field investigation, performed in May 2019, comprised of 31 test pits. The report provides a description of ground conditions encountered, comments on laboratory results and assessment of potential borrow growth medium from the overburden stockpile, western borrow and rock fill borrow areas. [12]
Overburden stockpile were limited in their depth, this because of the small size of the machinery used to do the excavation. The landform appeared structurally and erosional stable and the vegetation is reasonably well established. The material found was residual to extremely weathered and clay was the most predominant material encountered. Finally, a black sandy gravel that may be residual shale was also found. It is worth noting that a small amount of black residual material was observed in TP11, this material should be avoided and tested if it needs to be encapsulated
Western borrow stockpile area of analysis covered around 30 ha, the findings were consistent, from 0.0 to 0.10m a topsoil, from 0.0 to 2.0 m a Clayey SAND and from 2.0 to 2.5 m a Sandy Clay. It was found that this material would be appropriate as growth medium, provided amelioration as required. Even though a consistent clay layer was observed by GHD, their report did not include the assessment of suitability of clay materials from this area.
Rock Fill Borrow contained a steeply graded hill to the west of the overburden stockpile and was identified as potential source of rock fill that could be appropriate for use in the rock mulch layer.
It is important to mention that the size of the machinery used in most of the test pits was small, therefore there were several limitations such as reach of arm which was 2 m only.
Materials and estimated volumes extracted from the report are shown
<table>
<tr><th>Borrow Pit Area</th><th>Estimated Volume (m^3)</th><th>Material</th></tr>
<tr><td>Overburden Stockpile</td><td>87 000</td><td>Clay</td></tr>
<tr><td>Western Borrow Stockpile</td><td>600 000</td><td>Growth Medium</td></tr>
<tr><td>Rock Fill Borrow</td><td>40 000</td><td>Rock</td></tr>
</table>
</td></tr>
</table>

Area	Relevant Historical Studies	Relevant Data
Borrow Area B	None	-
Proposed Road Alignment	None	-

5 Ground Investigation

Geotechnical field investigations were carried out by SLR in July and October 2019 in accordance with Australian Standard *AS 1726:2017 - Geotechnical Site Investigation*. The fieldwork comprised of a series of test pits (TP) with associated sampling and in-situ Dynamic Cone Penetrometer (DCP) testing.

Laboratory testing were carried out on selected soil samples from our investigation.

5.1 Fieldworks

The following were undertaken as part of SLR fieldwork:

- 68 No. test pits across the investigation areas. The test pits were excavated using a 20-tonne excavator with 600 mm toothed bucket. It is noted that in-situ Dynamic Cone Penetration (DCP) test was undertaken in the immediate vicinity of each test pit to assess the in-situ strength profile of the subsurface strata.
- 15 No. additional in-situ DCP tests – in addition to those undertaken at each test pit location. The additional DCP tests were conducted along an existing road, north of the proposed West WSF and at bridge crossing points as part of the investigation into the proposed haul road alignment.
- Soil sampling at each test pit/ selected locations for laboratory testing.
- Logging of observed ground and groundwater at each test pit location by experienced geotechnical engineer.
- Photographic records for each test pit.

Table 6 provides a breakdown of the test pits and their associated areas and details of the supplementary historical data used in geotechnical assessment.

Table 6 Summary of SLR Test Pits and Relevant Historical Investigation Test Pits

Area	No. SLR Test Pits (naming convention)	Relevant Historical Studies	Previous Investigation Test Pits Considered
Waste Storage Facilities	20 (WRTP) 21 (WRD-SLR-TP)	• Robertson GeoConsultants (RGC), 2016 • Meehan Burgess & Yeates 1982 • Dames and Moore 1983 • Mining and Process Engineering Services 1985	29 x RGC 7 x Meehan Burges & Yeates 20 x Dames and Moore 9 x MPES
Clay Borrow	6 (NTP)	• DPIR 2019 • GHD 2018	6 x DPIR 17 x GHD
Granular Borrow	7 (STP)	None	N/A
Proposed Road Alignment	14 (HR-SLR-TP) 15 DCPs	None	N/A

Notes:
Meehan, Burgess & Yeates, Rum Jungle Rehabilitation Project, Engineering Report, Vol 2 Part 1 Results of Site Investigation, May 1982
Dames and Moore, Miscellaneous Site Investigations, Rum Jungle Rehabilitation, Stage 4.1, Report No. 13137-006-73, October 1984
Robertson GeoConsultants, Waste Storage Facility Investigations Rum Jungle, Report No. 183006/2, June 2016.
Robertson GeoConsultants Physical and Geochemical Characteristics of Waste Rock and Contaminated Materials, Report No. 183006/1, June 2016.
GHD, Rum Jungle Creek South WRD Remediation Geotechnical Investigation Report, May 2019.
Department of Primary Industry (DPIR) 2019, Borrow Area Technical Memorandum, Report No. 680.10421-M01-V0.1, Aug 2019. * Test pits performed under SLR guidance and reporting performed by SLR.

The exploratory hole and DCP test locations are provided in **Appendix B,C,** and **D** along with combined historical boreholes.

All exploratory hole records and in-situ test results are provided in **Appendix E.**

5.2 Laboratory Testing

Geotechnical and Geochemical laboratory testing were undertaken on selected soil and/or rock samples in order to assess the geotechnical and geochemical properties of the subsurface strata.

The following laboratory testing were undertaken as part of the current investigation:

- Geotechnical laboratory testing:

Table 7 Summary of Laboratory Testing Methods

Test Method	Standard	No. of SLR tests	Rationale
Moisture Content	AS 1289.2.1.1	38	Determine moisture content of recovered material to assess in-situ conditions and likely behaviour characteristics.
Particle Size Distribution	AS 1289.3.6.1	33	Characterise material and assess suitability for material re-use in cover and general construction material.
Particle Size Distribution (Hydrometer)	AS 1289.3.6.3	18	Characterise the portion of material smaller than 75µm – clay and silt fraction and assess suitability for material re-use as liner and general construction material.
Particle Density	AS 1289.3.5.1	9	Characterise material and assess suitability in construction and as hydraulic backfill
Atterberg Limits	AS 1289 3.3.1	14	Assess the liquid and plastic limit of cohesive soils (clays and silts) and assess suitability for reuse and likely behaviour characteristics with moisture changes.
Linear Shrinkage	AS 1289 3.4.1	14	Using Atterberg Limit findings, further assess the material behaviour with moisture change, i.e. its shrinkage
Emerson Class	AS 1289 3.4.1	22	Assess the materials propensity to disperse into a liquid. Used to assess susceptibility to erosion and suitability as liner material. Typically performed on granular soils (sands).
Proctor (Standard)	AS 1289.5.1.1	12	Determine the relationship between the materials moisture content and its density with compaction. Assess the compaction effort required and moisture content for materials in construction.
Triaxial (Consolidated Undrained)	AS 1289.6.4.2	3	Simulate the active mode of shear, the test provides the undrained shear strengths. Effective strength characteristics can also be determined for use in stability assessments.
Direct Shear	AS 1289.6.2.2	2	Test provides shear strengths. Effective strength characteristics can also be determined for use in stability assessments.
Permeability	AS 1289 6.7.1 & 6.7.2	7	Assess permeability of materials for reuse in liner and embankment. Falling head permeability for clay/silt and constant head for sands/gravels.
California Bearing Ratio	AS 1289.6.1.1	10	Penetration test used to assess materials suitability as subgrade and inform pavement design.
Point Load Index	AS 4133 4.1, 4.2.1	16	Assess rock/aggregate intact strength
Sodium Sulphate Soundness	AS 1141.24	2	Assess rock/aggregate resistance to weathering and degradation. Used to establish durability of a material
Petrographic Analysis	-	1	Assess rocks suitability for re-use as an engineering construction material

Test Method	Standard	No. of SLR tests	Rationale
Flume Testing	-	2	Assess soil characteristics for SIBERIA modelling parameters

Table 8 Summary of Historical Laboratory Tests Used

Laboratory Test	RGC	Meehan Burges and Yeates	Dames and Moore	GHD
Relevant Area	WSFs	WSF East	WSF East	Borrow Area A
Moisture Content	13	1	3	8
Particle Size Distribution	16	1	1	8
Atterberg Limits	13	1	3	8
Linear Shrinkage	13	1	3	8
Emerson Class		1	1	4
Proctor	-	-	5	-
Triaxial	-	-	-	-
Permeability	-	-	10	-

The available laboratory test results, along with the test methods followed are presented in **Appendix F**. Results of laboratory testing to date from samples taken at each area of interest are summarised in the below tables:

- **Table 20** Geotechnical Laboratory Testing Results - West WSF;
- **Table 21** Geotechnical Laboratory Testing Results - East WSF;
- **Table 22** Geotechnical Laboratory Testing Results - Clay Borrow;
- **Table 23** Geotechnical Laboratory Testing Results - Granular Borrow
- **Table 25** Geotechnical Laboratory Testing Results - Aldebaran Quarry

Table 9 Test Area Breakdown

Area	Number of SLR Tests Performed – Area Breakdown								
	Moisture Content	PSD (incl. hydrometer)	Atterberg Limit	Linear Shrinkage	Emerson Class	Proctor	Triaxial	Permeability	CBR
WSF East	7	8	4	4	5	3	-	3	2
WSF West	2	2	2	2	2	1	-	-	1
Borrow Area A	7	8	8	8	4	4	3	3	1
Borrow Area B	14	8	2	2	5	4	-	1	3
Haul Road	14	4	1	1	6	3	-	-	3

In addition to the breakdown presented above. Nine particle density tests were performed on samples collected from Borrow Area B, two shear box tests were performed on samples collected from Borrow Area B, two Flume tests were performed on samples collected from Borrow Area A and petrographic assessment, point load and sulphate soundness was performed on rock samples collected from Aldebaran Quarry.

Results of Investigation, detailed description of materials encountered, logs and geological cross sections from the test pitting program are presented in **Appendices E and G** respectively. Explanatory sheets on Terms and Abbreviations can be found at the end of test pit logs. Locations of the test pits are presented in **Appendix B,C and D**.

Each area of investigation areas are discussed separately in the following sections.

5.3 West Waste Storage Facility Envelope

The footprint of the West Waste Storage Facility (WSF) is shown in **Appendix B**, along with maps pertaining to the locations of test pits, the local bedrock geology and topography (**Appendix B**). Based on bedrock geology maps of the region, bedrock encountered comprised of dolostone (Coomalie Dolomite Formation), meta - pelites such as shales and slates (White's Formation) and haematite quartzite breccia (Geolsec Formation).

The majority of the West WSF encompasses the old stockpile area, which was rehabilitated in the 1980's effort to a terraced slope generally comprising a cover of reworked locally sourced lateritic soils overlying waste rock deposits left behind from the old stockpile.

Seven test pits were performed by SLR in field investigations, four were terminated by excavator bucket refusal and three terminated due to limit reach of the excavator arm (≥4.50 m bgl).

5.3.1 Generalised Soil Profile

Cover

The SLR test pit excavations describe the Cover to be primarily a CLAY with zones of clayey GRAVEL around SLR-TP-04, SLR-TP-05 and SLR-TP-06, which are located on the upper portion of the slope. The layer is described as hard clays or dense to very dense gravels, medium to high plasticity clay, fine to medium, sub rounded to sub angular gravel, red brown and orange brown colouring, with trace roots and some fine to medium grained sand. Cover was found to be thickest on the lower terraces of the slope (>0.80 m thick), thinning towards the ridgeline.

Waste Rock

Encountered waste rock was generally described as, gravelly cobbles, sub-rounded to sub-angular, poor to well graded, greeny grey and pale grey with red orange staining and occasion pyrite mineralisation on well preserved samples. Fine to coarse grained sand present with occasional medium to high plasticity clay deposits. The waste rock was generally encountered in most test pits located on the terraced slope, increasing in thickness with progression down the slope. On test pit SLR-TP-01 performed on the second to last terrace bench, base of waste rock was not encountered due to excavator arm reach limit. Lower terraces benches contain the thickest and most unweathered waste rock due in part to the thick clay cover material.

Laterite

Encountered laterite was described as a clayey GRAVEL and/or gravelly/sandy CLAY with zones of COBBLES/BOULDERS. The layer is generally described as dense to very dense, fine to coarse, sub-rounded to sub-angular gravels or hard, medium to high plasticity clays with fine to coarse grained sand, red brown and orange brown with occasional white quartzite inclusions. Cobbles, <200mm, rounded to sub-angular.

Observation during the site investigation generally showed the laterite soil transition to cobbles/boulders within 1.00m of being encountered, which in turn readily transitions to extremely weathered underlying bedrock. Laterite thickness was typically found deepest on the lower elevations and thinnest towards the ridgeline.

Saprolite

Saprolite soils were encountered in within the Old Tailings Dam area (TP-SLR-03) to the west of terraced slope toe. The soil was generally described as very dense, fine to coarse, angular to sub-angular, orange brown and yellow brown mixture of COBBLES/BOULDERS and gravelly sandy CLAY/clayey GRAVEL. The residual soil was found to readily transition to extremely weathered bedrock with depth.

Extremely Weathered

Extremely weathered bedrock materials were found to be very dense, fine to coarse, sub-angular to angular, breccia or dolostone, red brown and orange brown; cobbles 50 mm to 150 mm, matrix progressing to self-supported with depth.

Bedrock

Bedrock was found to comprise of either quartzite haematite breccia or dolostone. Breccia was predominantly found on the sloping topography and was described as a fine to coarse, red brown, moderately weathered of low to moderate strength. Dolostone was encountered on the Old Tailings Dam and was described highly weathered, fine grained with quartz veins throughout.

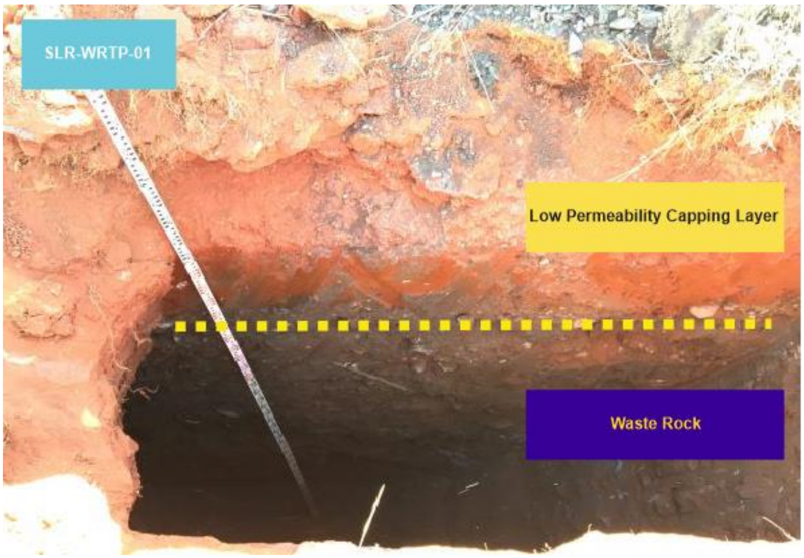
The subsurface profile across the proposed West WSF envelope is briefly summarised in **Table 10**.

Table 10 Strata Encountered - West WSF

Deposit	Dominant Material Type	Depth to top (m bgl)	Thickness (m)
Cover (Fill)	Gravelly CLAY/clayey GRAVEL w/ SAND Sandy CLAY/Silty Sandy CLAY	0.00	0.40 to 0.60
Waste Rock	Sandy Gravel and gravelly COBBLES & BOULDERS	0.40 - 1.20	0.20 to >4.50
Laterite	Clayey GRAVEL Clayey SAND Mixture of COBBLES/BOULDERS and clayey SAND/GRAVEL	0.00 - 1.10	1.20 to 2.60m
Saprolite	Mixture of COBBLES/BOULDERS and Clayey GRAVEL/gravelly CLAY	4.10 - 4.30	0.70m - >1.50m
Extremely Weathered	Mixture of Breccia COBBLES/BOULDERS and Clayey GRAVEL	1.20 - 1.80	0.10 - 0.80
Bedrock	Quartzite Haematite Breccia Dolostone	1.30 - >5.50	Base Not Encountered

The area has been rehabilitated to a terraced slope created by cut, waste rock fill and cover. The upper slope and most easterly portion of the envelope typically comprises of a thin locally sourced lateritic soil cover (≤0.50m thick) overlying remnant waste rock deposits (≤0.50 m thick) overlying natural weathered granular lateritic soils transitioning to breccia bedrock with depth (>2.00 m). The lower slope and most westerly portion of the envelope comprises of thick cover (≥1.00 m thick) overlying remnant waste rock deposits generally increasing in thickness from ≥1.00 m at the mid-slope to ≥4.00 m thick on the benches located at the slope toe.

Figure 8 Capping Over Waste Rock, Old Stockpile Area – West WSF



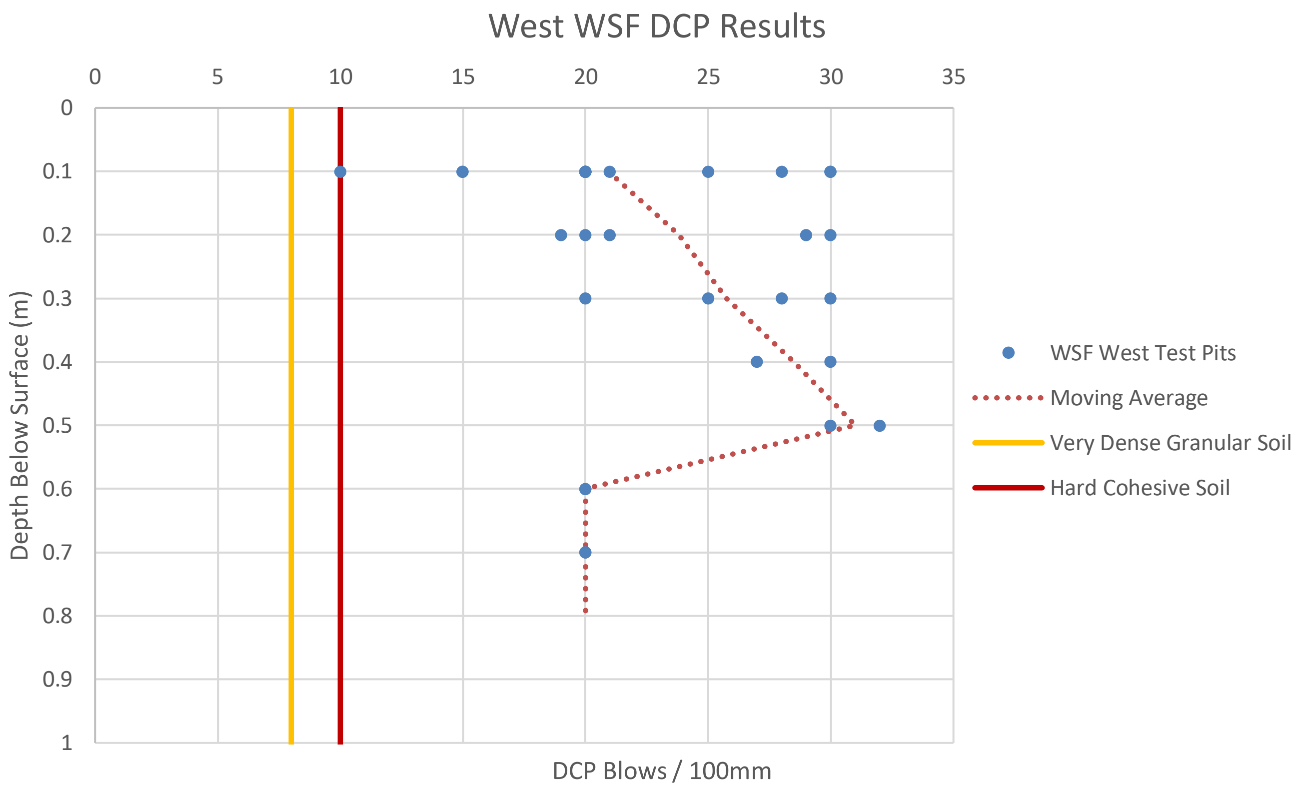
The northwest portion of the WSF envelope encroaches on the Old Tailings Dam and generally comprises of thin cover (≤0.50 m thick) overlying a thin layer of tailings (≤0.30 m thick) overlying residual lateritic soils transitioning to saprolite soils (≥4.00 m below ground level) with depth.

5.3.2 In-Situ DCP Testing

Compilation of all DCP test results (SLR and Historic Investigations) from the West WSF area are shown in **Figure 9** below. The plot the number of blows per 100mm increment.

From approximately 0.70 m bgl the spread of results is reduced, and the moving average also reduced to between 8 and 20 blows. Overall, the soil strength profile gradually increases from 0.70 m bgl and all results fell within very dense to very stiff soils. The improving strength profile is consistent with observed subsurface conditions.

Figure 9 Compiled DCP Results - West WSF



Compiled DCP Test Results include both granular and cohesive material results.

5.4 East Waste Storage Facility Envelope

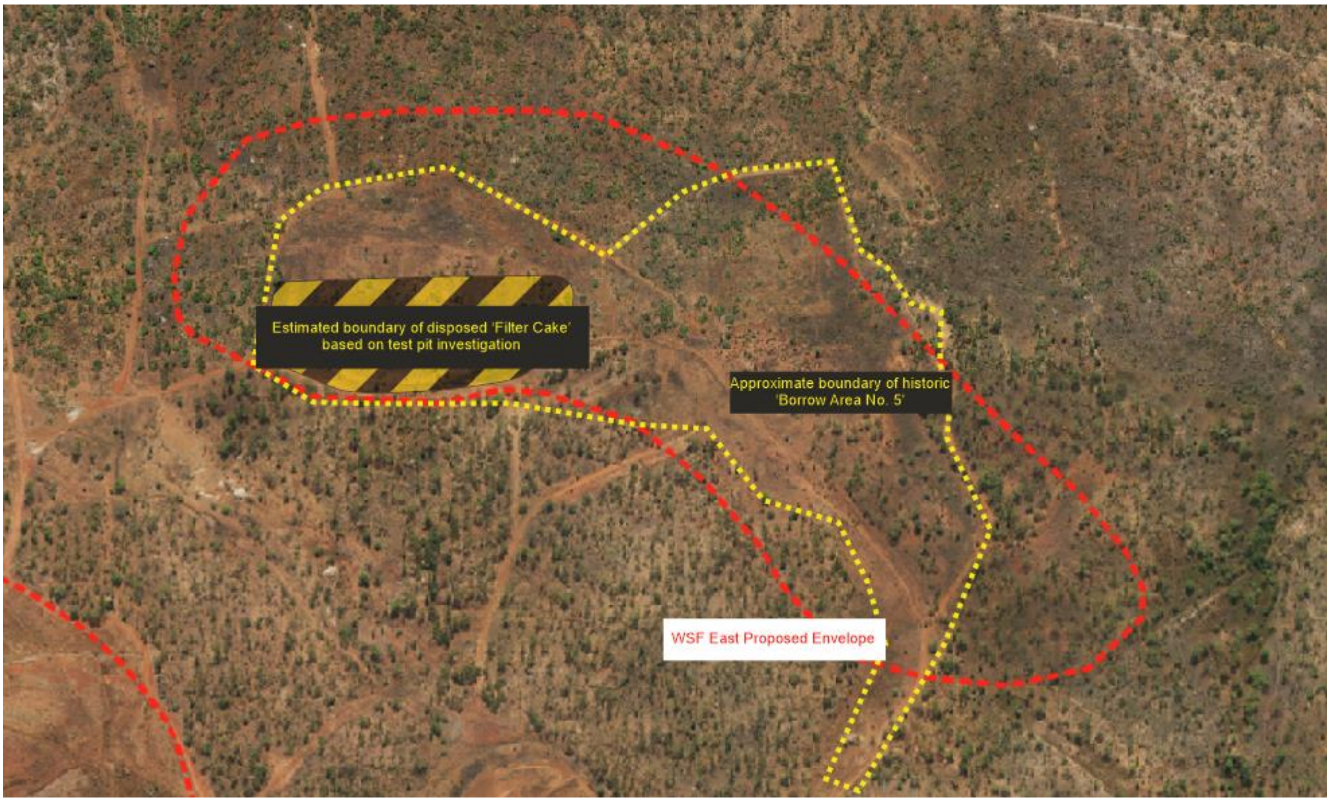
The proposed East WSF envelope encompasses old borrow areas and haul roads previously used previously in mining and rehabilitation operations. The northern and most easterly portion of the envelope generally comprises of deep residual fine grain soils (Clays and silts). A localised pocket within the northern portion of the envelope contains, what is likely filter cake material as inferred from Mining and Process Engineering Pty. Ltd. *Filter Cake Disposal Report* [14] from the copper leachate operations. Within the mid-portion of the WSF envelope the soils typically comprise of lateritic soils overlying natural bedrock at a depth of approximately 1.50m below surface level. The area is largely devoid of topsoil deposits due to previous stripping for borrow materials. A region of shale/argillite bedrock dissecting the WSF envelope bedrock proves shallow excavator refusal. Outside of the shale/argillite is deeper dolostone deposits.

The soils encountered across the WSF East envelope are subject to anthropological influences resultant of waste disposal and borrow activities. A generalised summary along with site map is provided below:

- Area Filter Cake: The area is understood to be an old clay borrow area used in the 1980 rehabilitation. The clay borrow area was subsequently backfilled with filter cake material used to treat the water within the Main Pit during the rehabilitation works. Approximately 76,000 m^3 Filter Cake was placed in the then described 'Borrow Area 5' [14]. Limited information exists as to the extent of the Filter Cake emplacement, however the SLR 2019 test pit program proved the extremities of material at discrete locations, with an approximation boundary based on historical data and recent test pitting provided in **Figure 10** below.
- Northern East WSF Envelope: Outside the filter cake area, the area is generally classified as a medium to high plastic clay saprolite and lateritic clayey soil.

- Middle and Southern East WSF Envelope: This area is understood to have once been a borrow area for lateritic low permeability soils and growth medium. The batters located western and eastern fringes of the area suggest material was extracted down to weathered rock level, leaving behind shallow residual granular deposits of gravels and cobbles weathered out from the underlying brecciated bedrock.

Figure 10 East WSF Envelope with Estimated Borrow Area and Filter Cake Boundaries



The southern portion of the East WSF envelope approaches the Giants Reef Fault. Shallow groundwater was encountered in test pits proximal to the fault as the fault appears to act as a sub-surface barrier to south trending groundwater flows.

The footprint of the East WSF is shown in **Appendices A and B**, along with the locations of test pits, local bedrock geology and topography. Based on bedrock geology maps of the region rock encountered comprised of dolostone (Coomalie Dolomite Formation), meta - pelites such as shales and slates (White's Formation), haematite quartzite breccia (Geolsec Formation) and granite (Rum Jungle Complex).

Twenty-nine test pits were undertaken within the East WSF, with three test pits (WRD-SLR-TP06B, 6C and 6D were undertaken to establish the extend of water treatment waste (filter cake) placed in the historically identified 'Borrow area 5' [14].

The maximum depth of excavation of the twenty-nine test pits performed by SLR within the East WSF region are as follows:

- Three terminated by excavator bucket refusal on bedrock;
- Seven terminated by slow digging (practical refusal);
- Two terminated due to instabilities and collapsing of test pit from groundwater infiltration;

- Three terminated once presence of filter cake had been determined; and
- Fourteen terminated due to limit reach of the excavator arm (≥4.50 m bgl).

5.4.1 Generalised Soil Profiles

Topsoil

The SLR test pit excavations observed topsoil from surface as a sandy SILT to silty/clayey SAND with minor amounts of gravel and rootlets. The maximum basal depth of 0.80 m bgl was recorded in WRD-SLR-TP11. Topsoil was encountered in a large number of test pits, generally in areas which have remained undisturbed by mining activities. The layer is described as dry, medium dense to dense granular deposits or firm to very stiff clays which are desiccated.

Roadbase

Roadbase materials were only encountered in test pits located on access roads (WRTP-15 and WRTP-20). The material is described as a sandy GRAVEL with clay/silt comprising of fine to medium, sub-rounded to sub-angular gravel, well graded, orange brown, with fine to coarse grained sand. The roadbase was generally thin, ranging from 0.10 m to 0.50 m thickness.

Reworked Material and Possibly Reworked Material

Reworked and underlying suspected reworked material comprised fine grained lateritic deposits with lesser granular material. They were encountered throughout a prominent, circular, rehabilitation feature within the old borrow area 5 in the northern region of East WSF envelope. These materials are recorded form surface to a maximum of 5.20m bgl (base of the excavation). Deposits were described as a range of materials including CLAY, SILT, SAND, GRAVEL with variable minor constituents. The thickest deposits tended to be silty/sandy GRAVEL of siltstone found at depth in WRD-SLR-TP06A, 06B, 06C and 06D and were described as medium dense to dense making their excavation less difficult than in-situ deposits. These deposits are thought to have originated from the weathering of dolostone.

In the south central region of the WSF footprint reworked silty/gravelly SAND deposits are recorded with gravel of quartz, meta - sediment and shale present indicating a different source, considered to be from more local shale and breccia deposits from the White’s and Geolsec Formations, respectively. Deposits are encountered from surface to a maximum of 2.80 m bgl, overlying their respective in-situ residual soil deposits.

Fill

Filter cake, a by-product from the water treatment of the Main and Intermediate Open Cut pits, is known to have been deposited in old borrow area 5. It was encountered in four test pits (WRD-SLR-TP03, 04, 05 and 08) between depths of 0.20 m and 3.5 m bgl with a maximum deposit thickness of 2.80 m. The material is described as dark brown to grey and black, firm to very stiff, clayey/sandy SILT.

Alluvium

Alluvium was only encountered in test pits within the eastern portion of the East WSF envelop (WRTP-13, 14 and 16) proximal to natural drainage channels. The alluvium was generally described as a dense sandy/clayey GRAVEL to clayey SAND with trace organic material present. Alluvium was encountered between depths of 0.10 m to 0.60 m bgl with a maximum thickness of 0.50 m.

Laterite

Encountered laterite deposits included granular and fine-grained beds which are described as CLAY, SILT, SAND and GRAVEL with zones of COBBLES/BOULDERS. Generally, in the northern and south-eastern regions of the WSF a layered and sometimes interbedded record of CLAY, SILT and GRAVEL deposits was encountered, with variable amounts of minor constituents. Densities range from medium dense to very dense and consistencies from firm to very stiff. Clays are generally described as medium to high plasticity, rarely low. Gravel includes siltstone, ironstone, mudstone and quartz which is indicative of the original bedrock, considered to be Coomalie Dolostone. These deposits are found from 0.15 m bgl and extend beyond the base of some excavations (>5.20 m bgl). CLAY beds range from 0.50 m to >4.60 m thick (WRD-SLR-TP10 and WRTP-16, respectively) and granular beds range from 0.50 m to 1.40 m thick (WRD-SLR-TP07 and WRD-SLR-TP02, respectively).

Within the south-central region laterite deposits are dominated by clayey SAND, gravelly SAND, SAND & GRAVEL (rare CLAY interbeds) and clayey GRAVEL, described as dense to very dense material. This granular laterite beds were encountered between 1.00 m and >4.00 m bgl with a maximum bed thickness of 0.80 m. They comprise gravel of shale, slate, quartzite and siltstone which is considered representative of the underlying bedrocks of the White's Formation and the Geolsec breccia formation.

Saprolite

Granular saprolite deposits were encountered in WRTP-17 and WRD-SLR-TP05, 07 and 10 between depths of 1.40 m and >5.50 m bgl with thicknesses recorded as 2.20 m to > 3.60 m (WRD-SLR-TP07). The unit recorded in WRTP-17 is described as very dense sandy GRAVEL with cobbles and boulders, including quartzite, haematite and sandstone. This is considered representative of the weathered Geolsec breccia.

Descriptions from WRD-SLR-TP05, 07 and 10 ranged from dense to very dense clayey GRAVEL to sandy GRAVEL with gravel and cobbles of siltstone, mudstone, ironstone and quartz. This is considered representative of the weathered Coomalie Dolomite.

Extremely Weathered Bedrock

Extremely weathered bedrock materials were encountered in test pits located within the south-central region and south-east of the Giant's Reef Fault. Units encountered include shale, quartzite haematite breccia and granite from the White's Formation, Geolsec Formation and Rum Jungle Complex, respectively.

Extremely weathered shale was encountered in the south-central region of the WSF from surface (WRD-SLR-TP12) to a maximum depth of 3.30 m bgl in WRTP-14 with a maximum encountered unit thickness of 1.90 m. It was recovered as very dense SAND & GRAVEL with occasional lenses of clay. With depth increasing amounts of cobbles and boulders are recorded. Gravel, cobbles and boulders comprised extremely low strength, foliated shale and slate.

Breccia was predominantly found on the sloping topography along the south-eastern edge of the White's Formation outcrop. Encountered at 4.30 m bgl in WRTP-17 the unit is described as very dense clayey GRAVEL with cobbles and boulders of sandstone, haematite and quartzite.

Extremely weathered granite in WRD-SLR-TP18 is described as very dense SAND & GRAVEL with trace clay and silt and cobbles, encountered from 0.30 m to 1.90 m bgl. Gravel and cobbles comprised granite and quartz.

Bedrock

Bedrock was found to comprise of quartzite haematite breccia, shale and granite from the Geolsec Formation, White's Formation and Rum Jungle Complex, respectively. Shale was encountered in the south-central region of the WSF from 2.50 m to 3.30 m bgl, extending beyond the maximum depth of excavation and with overlying extremely weathered bedrock, laterite or reworked deposits. Shale is described as a fine grained, foliated, red brown and dark grey, moderately weathered of low to moderate strength. Bedrock unit boundaries were generally in accordance with available geological maps.

The subsurface profile across the proposed East WSF envelope is briefly summarised in **Table 11**.

Table 11 Strata Encountered - East WSF

Deposit	Origin	Depth Encountered (m bgl)	Thickness (m)
Topsoil	Mixed	0.00	0.10 to 0.80
Roadbase	Mixed	0.00 to 0.50	0.10 to 0.50
Reworked and Possibly Reworked Material (residual soils)	Coomalie Dolomite Formation Haematite Quartzite Breccia & White's Formation	0.00	0.70 to >5.20
Alluvium	Mixed	0.10 to 0.60	0.20 to 0.50
Filter Cake	Water Treatment By-product	0.30 to 3.50	0.60 to 2.80
Clay Laterite	Coomalie Dolomite Formation White's Formation Geolsec Formation	0.20 to 1.80	0.30 to >4.40
Silt Laterite	Coomalie Dolomite Formation	2.10 to 4.30	0.90 to >2.30
Granular Laterite	Coomalie Dolomite Formation White's Formation Geolsec Formation	0.00 to 3.30	0.50 to 1.50
Granular Saprolite	Coomalie Dolomite Formation Geolsec Formation	1.40 to 2.90	2.60 to >3.60
Extremely weathered bedrock	White's Formation Geolsec Formation Rum Jungle Complex	0.00 to 4.30	0.30 to 1.90
Bedrock	White's Formation	2.50 to 3.30	Base Not Encountered

A summary of the subsurface conditions encountered at the East WSF envelop is given below:

- Large circular feature evident in satellite imagery in the northern area of East WSF. Also known as a flora revegetation trial site carried out by EcOz on behalf of the Department of Mines and Energy [15]. Likely rehabilitated old Borrow Area 5 feature comprised of reworked lateritic deposits (majority gravelly and sandy SILT) and filter cake fill deposited in the southern portion;
- West and south of the old borrow area 5 feature in the north of the East WSF largely fine grained lateritic deposits from the Coomalie Dolomite Formation are encountered, extending beyond the maximum depth of excavation, with minor granular laterite beds;
- North and north-east of the old borrow 5 feature thick deposits (> 2.00m) of saprolitic granular soils, originating from dolostone bedrock, were encountered extending beyond the base of excavations with minor interbedding of clay deposits;
- North central region comprises an east – west trending band of thick clay-rich lateritic deposits from Dolomite bedrock, which extends past 5.00 m bgl, and occasional granular beds at shallow depths;
- South central region of the East WSF is dominated by shallow outcropping weathered shale bedrock of the White's Formation (approximately trending northeast – southwest) which is frequently overlain by laterite deposits or reworked largely granular laterite deposits from the previous rehabilitation works in the area;
- A northeast – southwest trending wedge of the Geolsec Formation was encountered along the southeastern edge of the outcropping White's Formation and comprised thick granular laterite and saprolite deposits of haematite sandstone and quartzite breccia, becoming extremely to moderately weathered bedrock from 4.20 m bgl in WRTP17 or overlying shale laterite deposits in WRD-SLR-TP17;
- Underlying the southeastern area of the East WSF deposits of interbedded clay, silt and granular laterites, with bed thicknesses of 1.00 m to > 4.00 m, originating from dolostone bedrock;
- The southeastern boundary of the WSF is marked by the northeast - southwest trending Giant's Reef Fault, where the Coomalie Dolomite abuts the granites of the Rum Jungle Complex, with residual soil deposits overlying competent granite bedrock generally < 2.00 m bgl; and,
- Groundwater was encountered within test pits proximal to the Giant's Reef Fault at depths between 2.80 m and 4.00 m bgl.

Figure 11 WSF East Soil Zones

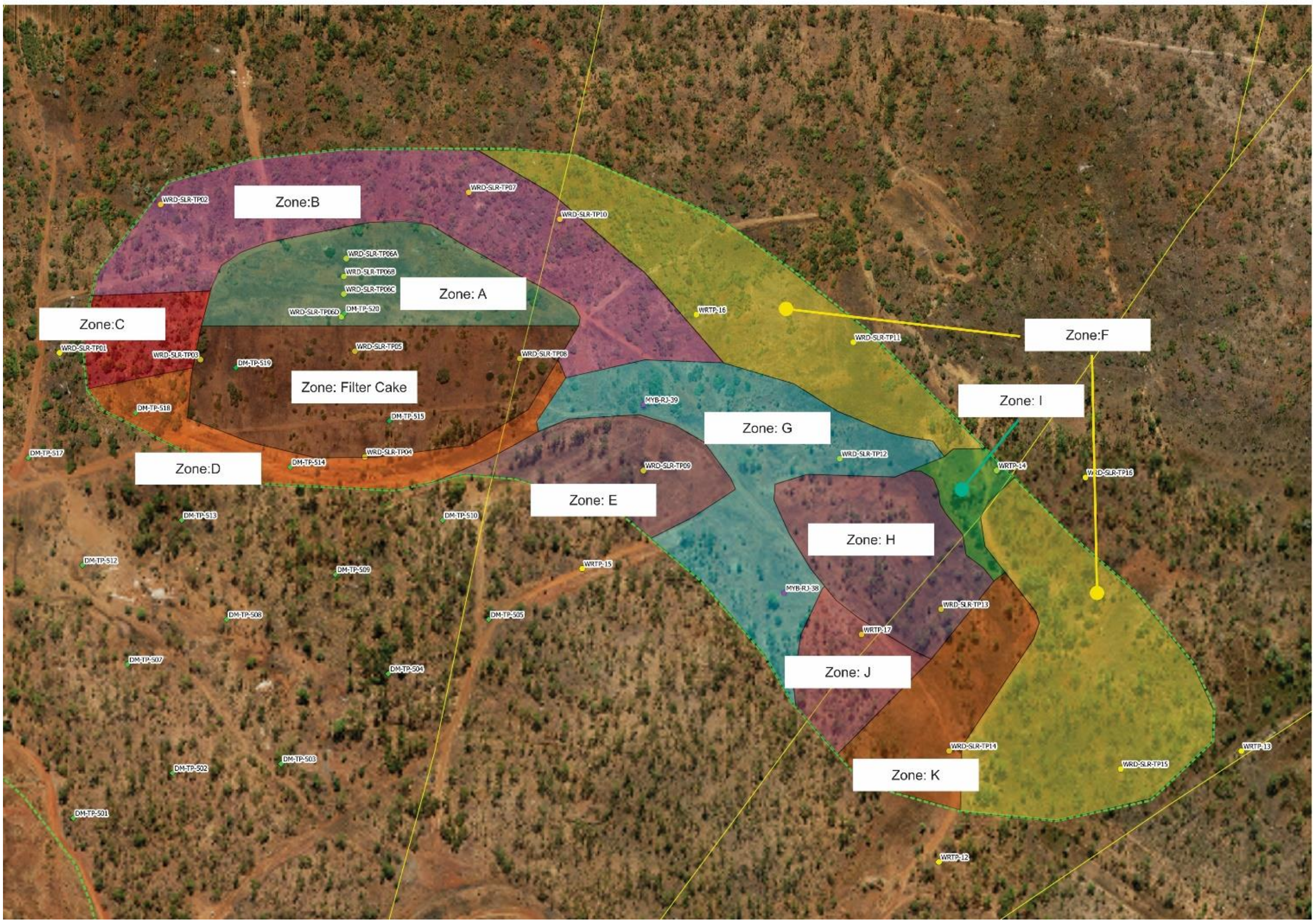


Table 12 WSF East Soil Zone Excavated Volumetric Breakdown

Zone	Description	Generalised Soil Type	Depth	Volume
FC	Filter Cake Disposal Area Approximate Area = 30,900 m^2 (Not excavated)	Cover Filtercake Laterite Sands/Clays	0.00 m – 0.70 m 0.70 m – 3.00 m 3.00 m – >5.00m	Not Excavated
A	Lateritic fill overlaying granular saprolite. Approximate Area = 21,100 m^2 (Not excavated)	Fill Saprolite Cobble/Gravels	0.00 m - 0.80 m 0.80 m - >5.00m	Not Excavated
B	Lateritic sands overlying lateritic clay overlaying saprolite sands/gravels. Approximate Area = 40,050 m^2	Topsoil Lateritic Gravel Lateritic Clay Saprolite Gravel	0.00 m - 0.20 m 0.20 m - 0.90 m 0.90 m - 1.50 m 1.50 m - 3.10m	8,383 m^3 29,341 m^3 25,150 m^3 67,066 m^3

Zone	Description	Generalised Soil Type	Depth	Volume
C	Deep lateritic clay deposit. Approximate Area = 7,225 m^2	Topsoil Lateritic Sands Lateritic Clay	0.00 m - 0.20 m 0.20 m - 0.40 m 0.40 m – 3.80 m	1,079 m^3 1,079 m^3 24,014 m^3
D	Laterite Sites overlaying Saprolite Clays and Silts. Approximate Area = 12,425 m^2 (Not excavated)	Topsoil Lateritic Sands Saprolite Clay Saprolite Silt	0.00 m - 0.20 m 0.20 m - 0.70 m 0.70 m - 1.60 m 1.60 m - >5.00m	Not Excavated
E	Reworked lateritic fill overlaying saprolite clays. Approximate Area = 13,300 m^2 (Not excavated)	Fill (reworked lateritic sands) Saprolite Clay	0.00 m - 2.00 m 2.00 m - >5.00m	Not Excavated
F. North	Lateritic sands overlaying saprolite clays and silts. Approximate Area = 29,150m^2 (north) + 37,350m^2 (south)	Topsoil Lateritic Sands/Gravels Saprolite Clay Saprolite Clay Saprolite Silt	0.00 m - 0.20 m 0.20 m - 1.30 m 1.30 m - 2.50 m 2.50 m - 3.00 m 3.00 m ->5.00 m	5,692 m^3 31,310 m^3 34,157 m^3 Not Excavated Not Excavated
F. South	Lateritic sands overlaying saprolite clays and silts. Approximate Area = 29,150m^2 (north) + 37,350m^2 (south)	Topsoil Lateritic Sands/Gravels Saprolite Clay Saprolite Clay Saprolite Silt	0.00 m - 0.20 m 0.20 m - 1.30 m 1.30 m - 1.40 m 1.40 m - 3.00 m 3.00 m - >5.00m	7,448 m^3 40,966 m^3 3,724 m^3 Not Excavated Not Excavated
G	Shallow shale bedrock. Approximate Area = 31,100m^2 (Not excavated)	Shale	0.00 m - >5.00m	Not Excavated
H	Reworked lateritic fill overlaying saprolite gravels and shale. Approximate Area = 18,642 m^2	Fill (reworked) Saprolite Gravel Shale	0.00 m - 2.80 m 2.80 m - 4.10 m 4.10 m - 5.72 m	24,043 m^3 Not Excavated Not Excavated
I	Saprolite deposits overlaying shale. Approximate Area = 4,055 m^2	Topsoil Saprolite Sand Saprolite Silt Saprolite Silt Shale	0.00 m - 0.10 m 0.10 m - 0.60 m 0.60 m - 2.40 m 2.40 m - 2.70 m 2.70 m - 5.42 m	267 m^3 1,339 m^3 4,820 m^3 Not Excavated Not Excavated
J	Lateritic Sands/Gravels overlaying weathered breccia. Approximate Area = 10,372 m^2	Lateritic Sands/Gravel Weathered Breccia	0.00 m - 1.40 m 1.40 m - 3.20 m	14,621 m^3 18,798 m^3
K	Reworked lateritic fill overlaying saprolite deposits. Approximate Area = 14,397 m^2	Lateritic Fill (sands/gravels) Saprolite Sands/Gravel Saprolite Clay Saprolite Sands/Gravel	0.00 m - 1.00 m 1.00 m - 1.70 m 1.70 m - 3.20 m 3.20 m – 3.66 m	14,593 m^3 10,215 m^3 Not Excavated Not Excavated

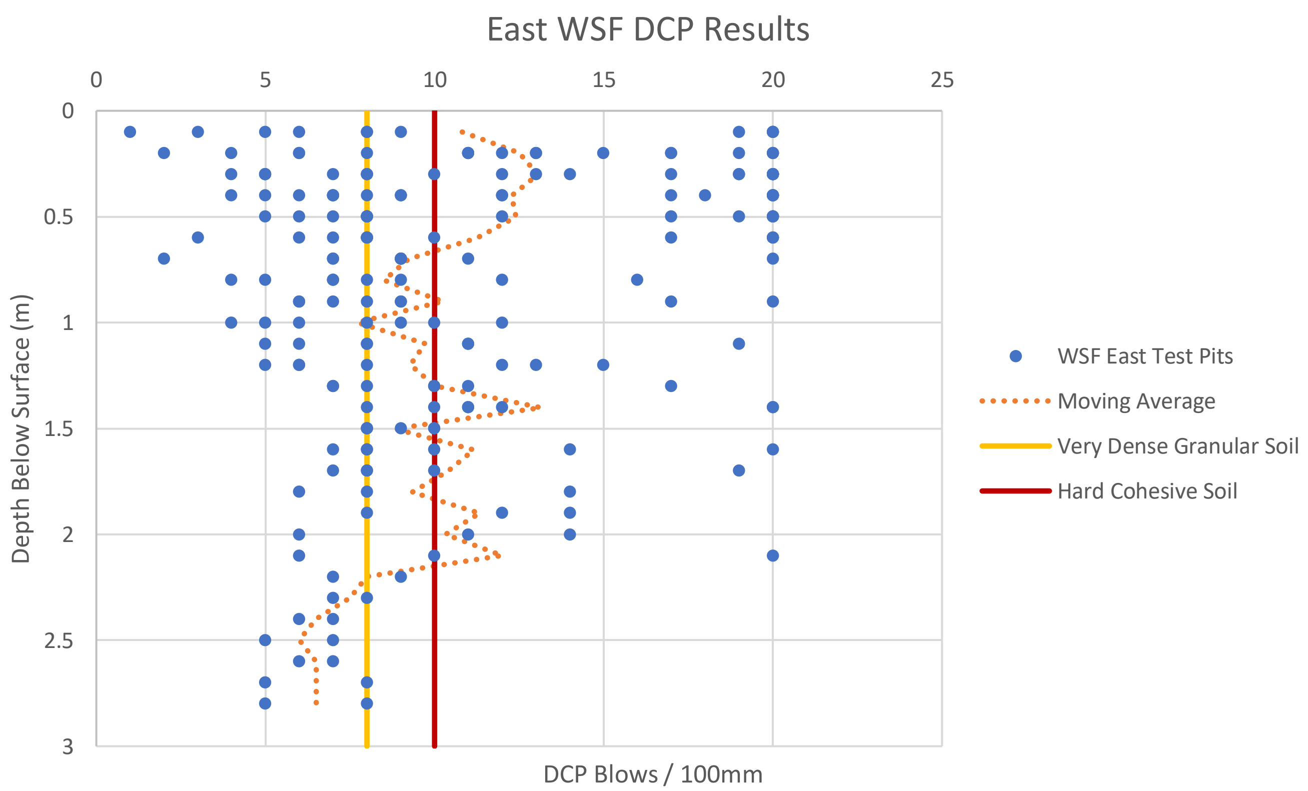
5.4.2 In-Situ DCP Testing

DCP tests were started from surface or up to 0.40 m bgl within East WSF area. The deepest tests were terminated at 2.90 m bgl in WRD-SLR-TP01 and 02 due to the limited number of rods and as such, these DCP tests did not achieve refusal.

Assessment of all DCP test results from East WSF area produces the plot shown in **Figure 12**. The plot indicates a range of low and high strength materials are encountered from surface, with several locations refusing on the first 100 mm increment. This is considered to be a consequence of dry and highly desiccated upper horizons.

From approximately 0.70 m bgl the spread of results is reduced, and the moving average also reduced to between 8 and 10 blows. Overall, the soil strength profile gradually increases from 0.70 m bgl until approximately 2.10 m bgl when it sharply decreases to approximately 6 or 7 blows. The improving strength profile is consistent with observed subsurface conditions however the decrease in strength is a feature of the two deepest DCP tests which do not achieve refusal. These are located on the northwest of the WSF footprint boundary in very stiff lateritic sandy CLAY and sandy SILT deposits.

Figure 12 Compiled DCP Results - East WSF



Compiled DCP Test Results include both granular and cohesive material results.

5.5 Borrow Area A

The Clay and Growth Borrow area (Borrow Area A) is located to the west of the historic Rum Jungle South mine and north of an ephemeral, east west trending drainage path. The western portion of the area is largely free of anthropological influences and comprises of deep (> 5.00m) residual fine grained (silts and clays) soils overlying dolostone bedrock. To the East, previous works presumably from the Rum Jungle South project, has left some borrow scares within the natural topography, with the soils typically comprising of a mixture of granular residual soils and deeper cohesive soils.

Of the test pits performed, two encountered shallow termination due to practical refusal/slow digging on bedrock, the remaining were continued to limit of excavator machine reach.

5.5.1 Generalised Soil Profile

Topsoil

Topsoil was encountered in all test pits performed within the borrow area. Topsoil was generally found to be a silty/clayey SAND or silty sandy GRAVEL. The sand is described as medium dense to dense, fine to medium grained sand, grey, red brown and brown with medium to high plasticity clay, fine to medium gravel and trace roots.

Laterite

Encountered laterite soils were described as a clayey GRAVEL and/or gravelly/sandy CLAY with zones of COBBLES/BOULDERS. The layer is generally described as dense to very dense, fine to coarse, sub-rounded to sub-angular gravels/sands or hard, medium to high plasticity clays with fine to coarse grained sand, red brown and orange brown with occasional white quartzite inclusions. Cobbles, <200mm, rounded to sub-angular.

Saprolite

Encountered saprolite soils were generally described as silty/sandy CLAYS of medium to high plasticity, pale grey, green grey and orange brown with fine to medium grained sand and fine to coarse grained gravels. The Saprolites tended to transition of cobbles/boulder matrix supported soil with depth as the strata tended towards the underlying bedrock.

The subsurface profile across the proposed Borrow Area B is briefly summarised in **Table 13**.

Table 13 Strata Encountered – Borrow Area B

Deposit	Dominant Material Type	Depth to top (m bgl)	Thickness (m)
Topsoil	Silty SAND clayey SAND silty sandy GRAVEL	0.00	0.10 to 0.20
Laterite	Sandy CLAY Clayey GRAVEL Gravelly CLAY COBBLES & BOULDERS w/ clayey GRAVEL	0.10 - 0.20	2.80 to 3.80

Deposit	Dominant Material Type	Depth to top (m bgl)	Thickness (m)
Saprolite	Silty CLAY Sandy CLAY COBBLES & BOULDERS w/ Silty CLAY	3.00 - 4.00	0.50 to 1.50
Extremely Weathered	Dolostone as COBBLES Argillite as clayey GRAVEL	3.60 - 4.90	0.50 - 0.60
Bedrock	Dolostone Argillite	4.10 - 4.50	Base Not Encountered

The subsurface conditions encounter in the test pits generally correlated with the expected geology. The soil profile comprised of thin topsoil cover overlying lateritic soils which in turn overlay saprolite.

Figure 13 Clay and Growth Borrow Soil Zones

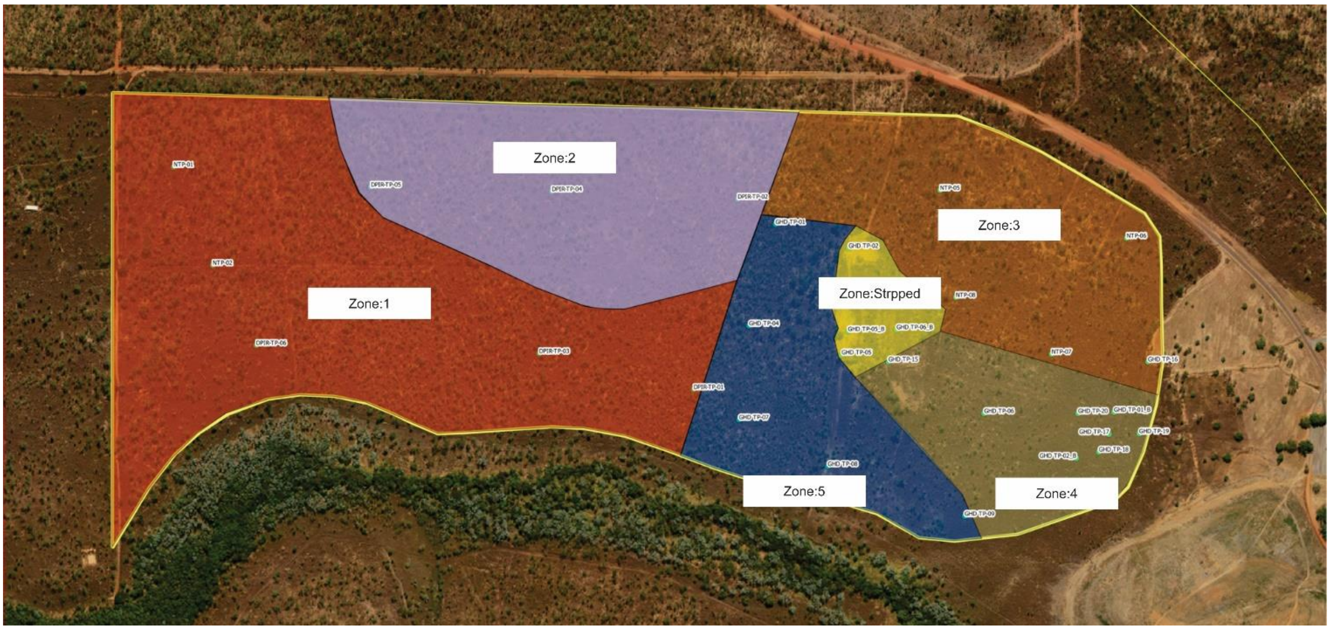


Table 14 Borrow Area A Zones

Zone	Description	Generalised Soil Type	Depth	Volume
1	Predominantly Clay. Approximate Area: 345,300m²	Topsoil Lateritic Clay Saprolite Silt Saprolite Granular	0.00m - 0.20m 0.20m - 3.50m 3.50m - 5.00m 5.00 m - >6.00m	69,060m³ 1,139,490m³ 517,950m³ 345,300m³
2	Sand Overlying Clay. Approximate Area: 176,400m²	Topsoil Clayey/Gravelly Sand Saprolite Clay	0.00m - 0.20m 0.20m - 2.50m 2.50m - >5.00m	86,000m³ 989,000m³ >1,075,000m³

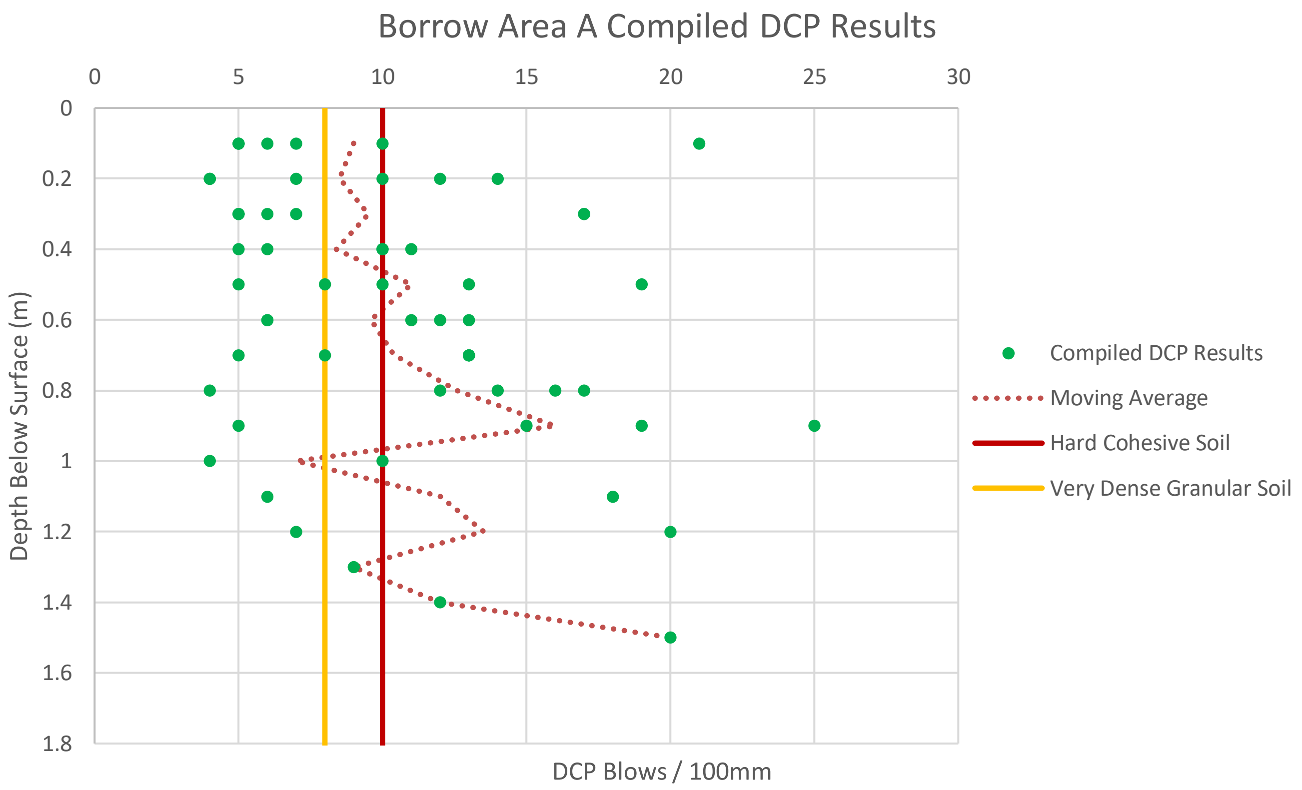
Zone	Description	Generalised Soil Type	Depth	Volume
3	Granular laterite overlaying saprolite clay. Approximate Area: 163,000m^2	Topsoil Lateritic Sands/Gravel Saprolite Clay	0.00 m - 0.20 m 0.20 m - 3.20 m 3.20 m - >5.00m	32,600 m^3 489,000 m^3 293,400 m^3
4	Granular lateritic deposits overlaying saprolite clays overlaying saprolite granular. Approximate Area: 93,000m^2	Topsoil Lateritic Granular Saprolite Clays Saprolite Granular	0.00m - 0.20 m 0.20 m - 2.00 m 2.00 m - 3.40 m 3.40 m - >5.00m	18,600 m^3 167,400 m^3 130,200 m^3 148,800 m^3
5	Sand Overlying Deep Clay. Approximate Area: 113,000m^2	Topsoil Saprolite Sand Saprolite Clay	0.00m - 0.20m 0.20m - 4.00m 4.00m - >5.00m	22,600m^3 429,400m^3 >113,000m^3
4	Stripped Area. Approximate Area: 24,700m^2	Sand/Gravel	0.00m - >3.70m	>91,390m^3

5.5.2 In-Situ DCP Testing

DCP tests were commenced from surface with the deepest test terminated at 1.50 m bgl in NTP-05.

Assessment of all DCP test results from Borrow Area A area produces the plot shown in **Figure 14**. The plot indicates a range of low and high strength materials are encountered from surface, with a general increasing number of blows with depth trend. From approximately 1.0 m depth most DCP blow counts equate to very dense to very stiff soils.

Figure 14 Compiled DCP Results – Borrow Area A



Compiled DCP Test Results include both granular and cohesive material results.

5.6 Borrow Area B

The Granular and Growth Borrow area (Borrow Area B) is located to the south of the Rum Jungle Site and adjacent to Rum Jungle Road. The area is largely free of anthropological influences and located on Finniss River Land Trust, with several north east trending ephemeral drainage paths dissecting the area. The subsurface profile across the proposed Granular and Growth Borrow is broadly described as topsoil overlying residual soils with localised alluvium associated with surface water channels. The underlying bedrock is shallow and comprises extremely weathered bedrock and/or competent bedrock of granite and sandstone from the Rum Jungle Complex and White's Formation, respectively.

Of the nine test pits undertaken within and proximal to the area, seven were terminated by excavator bucket refusal and two terminated due to practical refusal/slow digging.

5.6.1 Generalised Subsurface Profile

Topsoil

Topsoil was encountered in all test pits performed within the borrow area. Topsoil was generally found to be a gravelly SAND. The sand is described as medium dense to dense, fine to coarse grained sand, pale grey and grey with fine to medium, sub rounded to sub angular gravel with trace roots.

Alluvium

Alluvium was generally found in test pits proximal to surface water drainage channels. The material is broadly described as, sandy GRAVEL or gravelly SAND comprising medium dense to dense, fine to medium grained sands and gravels, yellow brown and grey with infrequent clayey horizons. Alluvium was encountered in test pits SLR-STP-02, 03, 05 and 07.

Residual

Encountered residual soils were described as clayey SAND, gravelly SAND or sandy GRAVEL. The layer was found to be dense to very dense comprising fine to coarse sand and fine to coarse, sub-rounded to sub-angular gravel, red brown, grey and orange brown with occasional pale grey quartzite inclusions and granite derived cobbles.

Observations during the site investigation generally showed the residual soil transition to cobbles/boulders within 1.00m of being encountered, which in turn was observed to readily transition to extremely weathered underlying granite bedrock.

Extremely Weathered

Extremely weathered granite bedrock was found in most test pits and comprised relatively thin thickness (<0.50 m). The material was found to be in-situ as a clayey SAND, fine to coarse grained, pale grey and red brown, of extremely low strength.

Bedrock

In the north of the site, bedrock was found to comprise fine to medium grained, pale grey and red brown granite.

Towards the south/southwest of the borrow, bedrock is encountered at shallower depths and described as Sandstone in STP-04, 06 and 07. Based on the local geology, these are likely to form part of the White's Formation which comprises a range of calcareous/meta sedimentary units.

Excavator bucket refusal was typically met shortly after bedrock was encountered.

The subsurface profile across the proposed Clay Borrow is briefly summarised in **Table 15**.

Table 15 Strata Encountered – Borrow Area B

Deposition Environment	Dominant Material Type	Depth to top (m bgl)	Thickness (m)
Topsoil	SAND Gravelly SAND Silty SAND	0.00	0.10 to 0.20
Alluvium	Sandy GRAVEL Gravelly SAND Clayey SAND	0.10 - 0.20	0.40 to 0.70
Residual	Gravelly SAND Sandy GRAVEL Clayey SAND	0.10 - 0.60	0.20 to 3.70m
Extremely Weathered	Granite as Sandy GRAVEL Sandstone as Sandy GRAVEL	0.50 - 1.60	0.40 - 0.70
Bedrock	GRANITE SANDSTONE	1.00 - 4.30	Base Not Encountered

The subsurface profile across proposed Borrow Area B is broadly described as topsoil overlying residual soils and shallow bedrock (≤2.0m) overlying shallow bedrock of extremely weathered granite and sandstone. Volumetric assessment using the ground model profile of 0.20m thick topsoil overlying 2.00m thick sandy gravel/gravelly sand produces the following volumes.

Table 16 Borrow Area B Volumetric Analysis

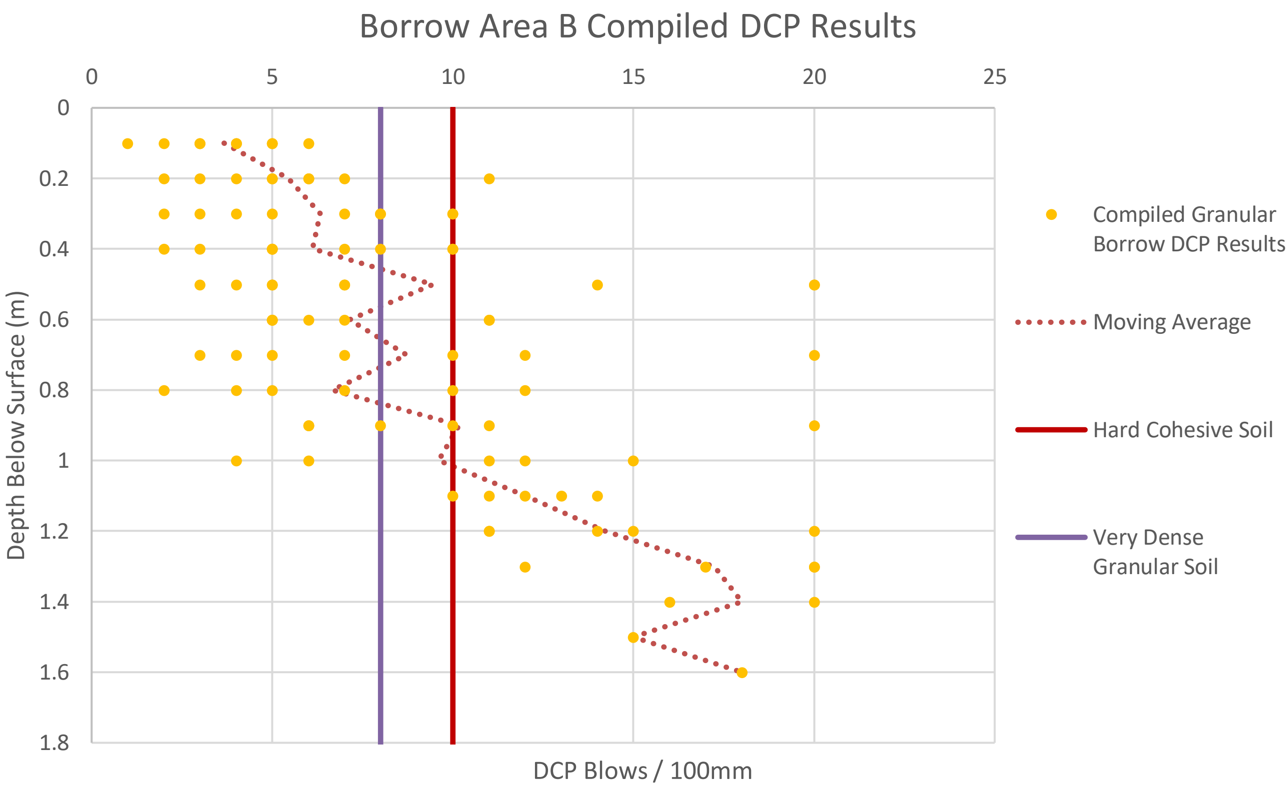
Soil Type	Volume	Use
Topsoil	379,440 m^3	Growth Medium
Sandy Gravel/Gravelly Sand	4,679,760 m^3	Growth Medium and General Construction

5.6.2 In-Situ DCP Testing

DCP tests were commenced from surface with the deepest test terminated at 1.60 m bgl in STP-07.

Compilation of all DCP test results from Granular and Growth Borrow area are shown in **Figure 15**. The plot indicates an increasing in-situ soil density with depth.

Figure 15 Compiled DCP Results – Borrow Area B



Compiled DCP Test Results include both granular and cohesive material results.

5.7 Haul Road Alignment

Fourteen test pits with corresponding DCP tests plus seven individual DCP tests were performed along the proposed haul road alignment. Eight additional DCP test were conducted at proposed bridge crossing locations.

The depth of excavation of the fourteen test pits performed by SLR along the haul road alignment are as follows:

- one terminated by excavator bucket refusal (HR-SLR-TP11);
- one terminated due to instabilities and collapsing of test pit from groundwater infiltration (HR-SLR-TP09A);
- nine terminated at target depth of 2.00 m bgl; and
- three terminated due to limit reach of the excavator arm (≥ 4.50 m bgl).

5.7.1 Generalised Soil Profiles

Topsoil

Eight test pits observed topsoil from surface to a maximum depth of 0.65 m bgl. The topsoil encountered from surface was generally described as a sandy SILT to gravelly SAND with minor constituents of silt, sand, gravel and rootlets. Topsoil was encountered in areas which have remained undisturbed by mining activities. The layer is described as dry, medium dense to dense granular deposits or stiff to very stiff silty deposits.

Roadbase

Roadbase materials were encountered in test pits located on existing access roads (HR-SLR-TP03 and HR-SLR-TP09A). The material was described as medium dense to very dense gravelly SAND and sandy GRAVEL with /silt, comprising of gravels of weathered granite and breccia from the local area (HR-SLR-TP03) and/or from underlying granite and shale, schist and meta-sediment of the White's Formation (HR-SLR-TP09A). The roadbase was generally thin, recorded as 0.40 m thickness.

Fill

Fill comprised of re-worked site won soils were encountered in HR-SLR-TP07 in the area of a former Heap Leach Pad. Fill extended beyond the base of the excavation (> 2.10 m bgl) and comprised an upper horizon of very dense gravelly SAND with cobbles with an underlying very stiff gravelly CLAY with rare boulders of granite present. The upper section of the soil profile was bleached with soils becoming brown and grey with depth.

Alluvium

Alluvium was present in areas proximal to surface water channels (HR-SLR-TP01) and at bridge crossing locations (HR-SLR-TP06A, 06B, 09A and 09B). Alluvium in HR-SLR-TP01 was found to be relatively thin layer, 0.20 m to 1.0 m bgl and described as very dense silty SAND. Deeper alluvium deposits were recorded by the larger river channels at proposed bridge crossing points. HR-SLR-TP06A and 06B encountered deep alluvium from surface to base (> 4.80m bgl) and were described as a granular material (medium dense to very dense silty SAND to sandy GRAVEL) in HR-SLR-TP06A and as cohesive material (firm to very stiff gravelly CLAY to clayey SILT) in HR-SLR-TP06B. At HR-SLR-TP09A and 09B a road and bridge are still present and were found to comprise of roadbase overlying alluvium deposits. Deposits were generally described medium dense to very dense silty SAND and sandy GRAVEL, with only one horizon in HR-SLR-TP09B described as a very stiff gravelly CLAY encountered between 2.00 m and 3.80 m bgl.

In HR-SLR-TP09B alluvium extends past the base of the pit (5.00 m bgl). In HR-SLR-TP09A, groundwater was encountered at 3.30 m bgl and observed to be perched above the underlying extremely weathered shale bedrock.

Laterite

Lateritic clay and granular deposits derived from underlying granite was encountered in HR-SLR-TP03. An upper clay horizon was recorded from 0.40 m bgl to 1.00 m bgl and described as very stiff gravelly CLAY. From 1.00 m to the base of the pit (2.00 m bgl) very dense gravelly SAND and sandy GRAVEL deposits were present with occasional CLAY lenses.

At HR-SLR-TP08 a very stiff gravelly CLAY laterite was encountered at 0.40 m to 1.30 m bgl, derived from the underlying extremely weathered Coomlie Dolomite.

Saprolite

Granular saprolite deposits derived from the Rum Jungle Complex granites were encountered in HR-SLR-TP01, 02, 04 and 12 between depths of 0.20 m to > 2.20 m bgl (maximum test pit depth). The unit is recorded as very dense sandy GRAVEL with silt and cobbles of weathered granite.

Log description from HR-SLR-TP05 included very dense gravelly SAND to sandy GRAVEL. Gravel comprised siltstone, mudstone, ironstone and quartz which is considered representative of the weathered Coomalie Dolomite.

Extremely Weathered Bedrock

Extremely weathered bedrock materials were encountered in test pits located on the western site boundary and within the centre of the site, north and east of the Main Pit. Units encountered include dolostone, shale, quartzite haematite breccia and granite from the Coomalie Formation, White's Formation, Geolsec Formation and Rum Jungle Complex, respectively. At HR-SLR-TP10 extremely weathered breccia is found to overly extremely weathered shale.

The Coomalie Dolomite was encountered at 1.30 m bgl in HR-SLR-TP08 with overlying laterite. It is described as extremely weathered extremely low to moderate strength fine grained meta-sediments with occasional quartz veins. It was recovered as very dense sandy GRAVEL with occasional cobbles and boulders of dolostone, siltstone, meta-sediment and quartz. The excavation was completed at 2.10 m bgl without encountering competent rock.

Extremely weathered shale was encountered in the base of the pits in HR-SLR-TP09A and HR-SLR-TP10 with overlying alluvium deposits and extremely weathered breccia, respectively. In HR-SLR-TP09A shale is encountered at 3.30 m bgl alongside a groundwater strike at the same depth. Due to the water strike recovered material was limited and highly disturbed. In HR-SLR-TP10 shale is encountered at 1.10 m bgl, extending past the base of the test pit at 2.40 m bgl. The shale is described as extremely low strength foliated and brown mottled grey and were recovered as very dense silty SAND to SAND & GRAVEL with cobbles of shale.

Breccia was east of the Main Pit in HR-SLR-TP10 and HR-SLR-TP11. Within HR-SLR-TP10, bedrock was encountered underlying topsoil and overlying the White's Formations, between 0.30 m and 1.1 m bgl. It is described as extremely low to low strength sandstone and quartzite (recovered as very dense sandy GRAVEL with cobbles). In HR-SLR-TP11 breccia is encountered from surface and bucket refusal occurred at 1.00 m bgl, indicating competent rock at shallow depths. It is described as low to highly strength quartzite and sandstone and recovered as very dense gravelly SAND with cobbles and boulders, including sandstone, haematite and quartzite.

Extremely weathered granite of the Rum Jungle Complex was encountered in HR-SLR-TP12 at 1.90 m bgl. It is described highly weathered with low to moderate strength.

Bedrock

Bedrock was encountered in HR-SLR-TP11 at 0.90 m bgl, comprising of quartzite haematite breccia from the Geolsec Formation. It is described as moderately weathered and high strength.

The subsurface profile across the proposed haul road alignment is briefly summarised in **Table 17**.

Table 17 Strata Encountered - Haul Road Alignment

Deposit	Origin	Depth Encountered (m bgl)	Thickness (m)
Topsoil	Mixed	0.00	0.10 to 0.65
Roadbase	Mixed	0.00 to 0.40	0.40
Fill (Heap Leach Pad)	Mixed	0.00	> 2.10 (Base Not Encountered)
Alluvium	Mixed	0.00 to 1.00	0.80 to > 4.80
Clay Laterite	Coomalie Dolomite Formation Rum Jungle Complex	0.40	0.60 to 0.90
Granular Laterite	Rum Jungle Complex	1.00	> 1.00 (Base Not Encountered)
Granular Saprolite	Rum Jungle Complex	0.20 to 1.00	> 1.80 (Base Not Encountered)
Extremely weathered bedrock	Coomalie Dolomite Formation White's Formation Geolsec Formation Rum Jungle Complex	0.00 to 3.30	0.30 to 1.90
Bedrock	Geolsec Formation	0.9	Base Not Encountered

A summary of the sub-surface conditions encountered along the haul road alignment is given below:

- The western leg of the alignment (including proposed main site access and access to the granular borrow area is underlain by very dense saprolitic gravels with competent granite source present at shallow depths (approximately 2.00 m bgl);

- The north - south trending section between the intermediate and main WRD and the intermediate and main pits comprises a mixture of deposits (engineered fill, superficial alluvium deposits and lateritic and saprolitic deposits derived from the Coomalie Dolostone, with shallow bedrock encountered in HR-SLR-TP08;
- Thick alluvium deposits (bother granular and cohesive) were recorded at the two bridge crossings (HR-SLR-TP06A, 06B, 09A and 09B)
- The eastern leg of the alignment which heads south from the Main Pit encountered shallow bedrock (<1.00 m bgl) comprising breccia and shale.
- Generally, all material encountered consistencies ranging from firm to very stiff or medium dense to very dense.
- Groundwater was encountered within one test pit by a river channel, HR-SLR-TP09A, at 3.30 m bgl and appeared to be level with extremely weather shale formation.

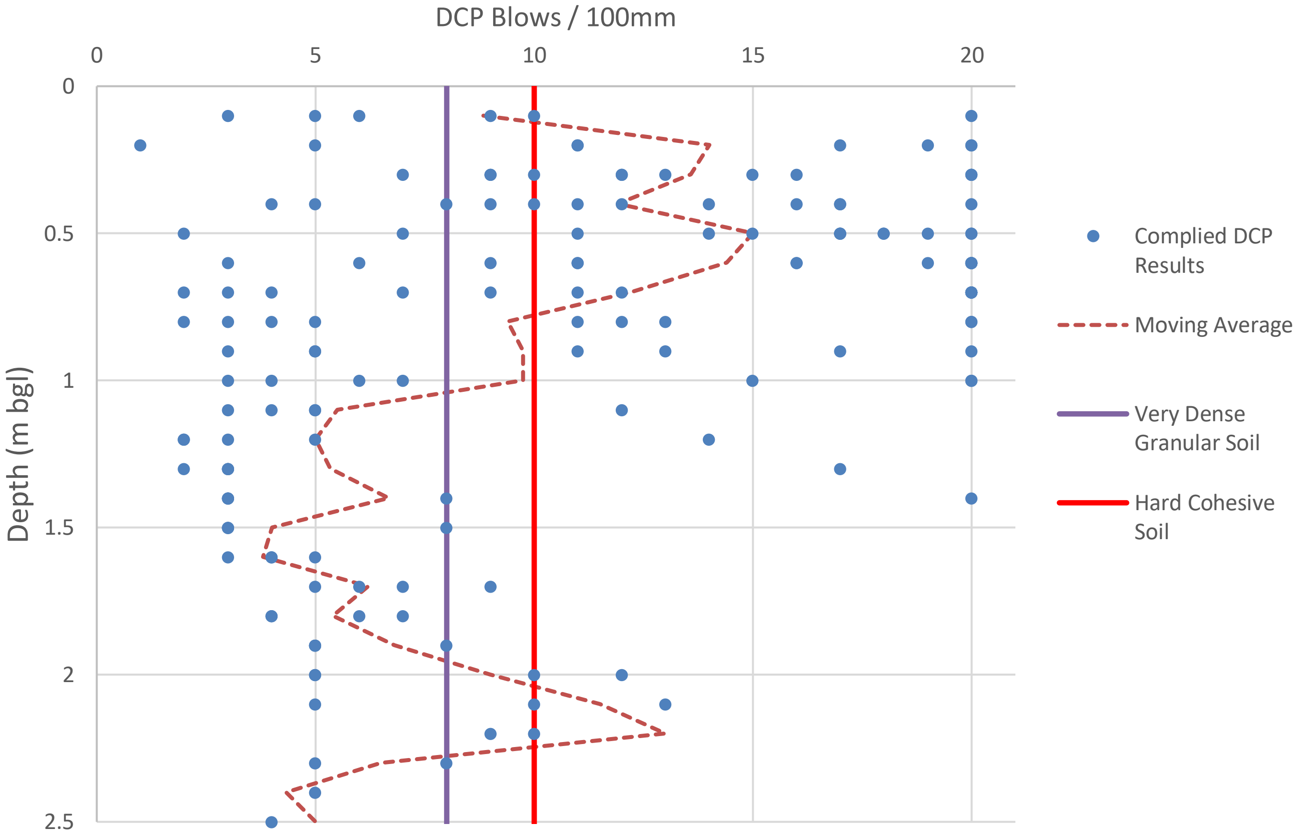
5.7.2 In-Situ DCP Testing

DCP tests were started from surface or down to 0.70 m bgl across the haul road alignment. The deepest test was terminated at 2.50 m bgl in HR-SLR-TP12 and 02 due to the limited number of rods.

Assessment of all DCP test resulted from across the haul road alignment produces the plot shown in **Figure 16**. The plot indicates a large range of low and high strength materials encountered from surface, with several locations refusing on the first 100 mm increment. This is considered to be a consequence of dry and highly desiccated upper horizons.

From approximately 1.00 m bgl the spread of results is reduced, and the moving average also reduced to between 4 and >10 blows. Overall, the soil strength profile gradually increases from 0.70 m bgl until approximately 2.10 m bgl when it sharply decreases to approximately 6 or 7 blows. The improving strength profile is consistent with observed sub-surface conditions however the decrease in strength is a feature of the two deepest DCP tests which do not achieve refusal. These are located on the northwest of the WSF footprint boundary in very stiff lateritic sandy CLAY and sandy SILT deposits.

Figure 16 Compiled DCP Results - Haul Road Alignment



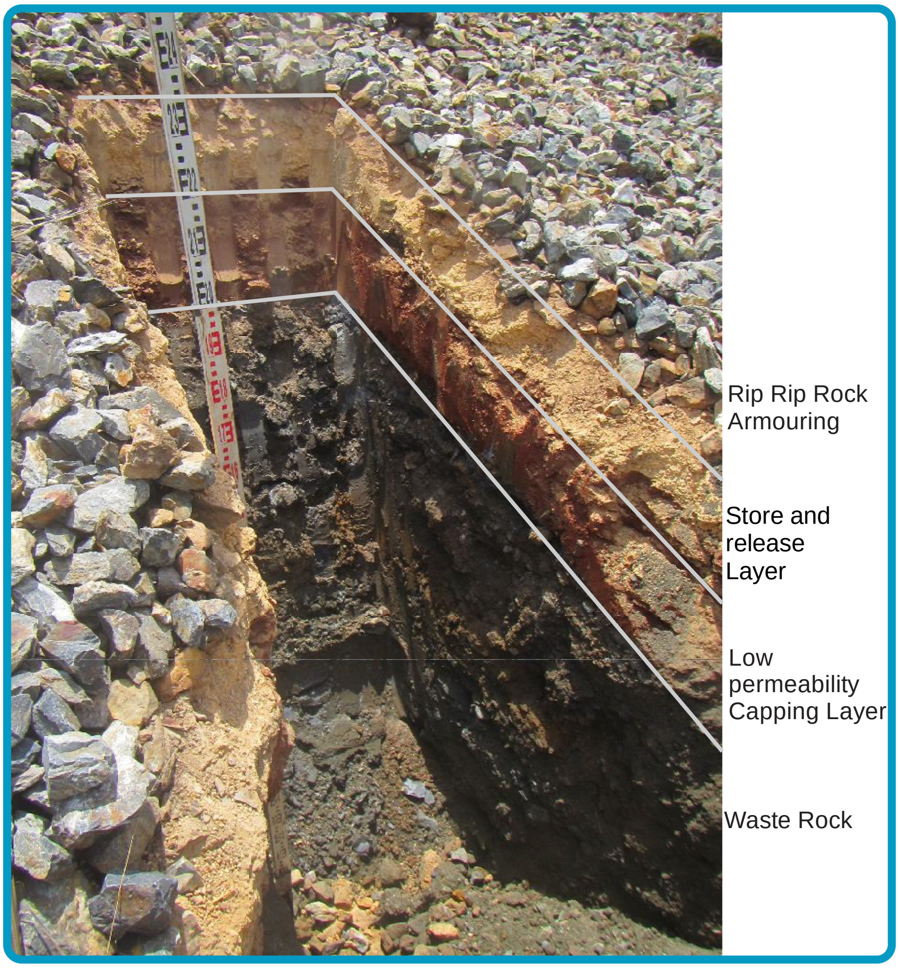
5.8 Existing Waste Rock Dump Covers

Four shallow test pits (WRD-SLR-TP19 to 22) were excavated in to the side slopes of the existing Intermediate and Main Waste Rock Dump to assess the thickness of the side slope rock armouring. All four excavations encountered the same strata, with little variation in thicknesses. The strata is summarised in the **Table 18** and **Figure 17** shows the general profile, below.

Table 18 Intermediate and Main Waste Rock Dump Cover Layer

Strata Type	Description	Thickness
Rip Rap	GRAVEL with cobbles comprising strong and durable igneous rock, quartzite and meta-sediments	0.10 to 0.15 m
Store and Release Layer	Very gravelly SAND	0.10 to 0.35 m
Low Permeability Capping	Stiff CLAY with sand trace gravel	0.20 to 0.40 m
Waste Rock	Very gravelly SAND with silt	Base not encountered

Figure 17 Waste Rock Typical Armouring Cover Profile



No test pitting was performed on the batters of Dyson's Main Pit, which has a similar rock armouring cover. However, forensic investigation into the Rum Jungle cover systems in 2003 performed by the Australian Centre for Mining Environmental Research [16] suggests that approximately 40,000m^3 of dolomitic rock removed from the south-west corner of Intermediate WRD was used in construction of rock blanket on the backfilled pit. It is assumed some of this material was also used in the batter erosion rock armouring.

Observations taken during SLR test pit investigations shows the dolomitic rock armouring to be in good condition, with little evidence of breakdown since placement. Comparison is afforded with the occasional inclusion of shale in the covering, which shows signs of significant breakdown through weathering.

Deterioration of shale within dolomitic rock armouring

Close up of deteriorated shale within dolomitic rock armouring on Dyson's Open Cut

Photo 5 Dyson's Open Cut WRD Rock Armouring

Volumetric estimate of available rock armouring based on available survey data and the assumption of a batter placement thickness of 100 mm to 150 mm is provided in **Table 19** below.

Table 19 Waste Rock Dump Rock Armouring Volume Estimate

Waste Dump	Estimated Volume (m^3)
Main Waste Rock Dump	14,650 to 21,975
Intermediate Waste Rock Dump	3,705 to 5,557
Dyson's Open Cut Waste Rock Dump	1,190 to 1,785
Dyson's Waste Rock Dump	3,535 to 5,302
Total Estimated Armour Rock Volume	**23,080 to 34,620**

5.9 Aldebaran Quarry

A site a walkover assessment was undertaken in October 2019 to inspect surface outcrops of a known disused granite quarry to assess the rock as a potential rip-rap and rock armouring source. Grab samples from dislodged boulder/cobbles were collected for geotechnical and geochemical laboratory testing.

5.9.1 Walkover and Inspection

Outcrops and loose rock debris were inspected across the area and described as a fine to medium grained granite with frequent phenocrysts, primarily consisting of quartz, k-feldspar and plagioclase feldspar with lesser amounts of biotite and muscovite. The weathered surface of the outcrop was occasionally heavily stained black with quartz and feldspar phenocrysts prominent. The granite was estimated to have very high strength based on scratch tests and hammer blows. Photos of the rock outcrops encountered are shown previously in **Photo 4.**

The outcrops form a series of roughly north - south trending domes, up to 2.00 m above the surface in places. Some jointing was present. In between the outcrops, the surface is vegetated with significant cobble and boulder cover from the in-situ granite. Hammer strikes and scratching with rock pick on outcrops suggested high to very high strength rock.

Several grab samples were chipped off the surface for submission to laboratories. As the outcrops were generally similar there was little variation in samples except on the weathered surface or in the amount of phenocrysts present.

6 Laboratory Analysis

Geotechnical laboratory testing on soil and rock samples was undertaken by NATA accredited Douglas Partners laboratories. Geochemical Testing on soil samples for growth medium potential assessment was performed by NATA accredited ALS Laboratories and consisted of testing detailed in another report. Flume Testing was undertaken by the University of Newcastle and Petrographic analysis was performed by NATA accredited Geochempet Laboratories.

Please note laboratory testing is still ongoing at this time and this report represents an interim summary of available laboratory testing results. The available laboratory test results, along with the test methods followed are presented in **Appendix F**. Results of laboratory testing to date from samples taken at each area of interest are summarised in the below tables:

- **Table 20** Geotechnical Laboratory Testing Results - West WSF;
- **Table 21** Geotechnical Laboratory Testing Results - East WSF;
- **Table 22** Geotechnical Laboratory Testing Results - Clay Borrow;
- **Table 23** Geotechnical Laboratory Testing Results - Granular Borrow
- **Table 24** Geotechnical Laboratory Testing Results – Haul Road Alignment
- **Table 25** Geotechnical Laboratory Testing Results - Aldebaran Quarry

Table 20 Geotechnical Laboratory Testing Results - West WSF

Location	Depth (m bgl)	Gravel (%)	Coarse Grained Sand (%)	Medium Grained Sand (%)	Fine Grained Sand (%)	Silt (%)	Clay (%)	LL (%)	PL (%)	PI (%)	LS (%)	Emerson Class	CBR (%)	MC (%)
WRTP-06	0.70 - 1.00	48	9	11	11	21		-	-	-	-	6 (non-dispersive)	45	6.1
WRTP-08	0.40 – 1.10	53	12	2	11	22		-	-	-	-	6 (non-dispersive)	-	9.6

Table 21 Geotechnical Laboratory Testing Results - East WSF

Location	Depth (m bgl)	Gravel (%)	Coarse Grained Sand (%)	Medium Grained Sand (%)	Fine Grained Sand (%)	Silt (%)	Clay (%)	LL (%)	PL (%)	PI (%)	LS (%)	Emerson Class	CBR (%)	MC (%)
WRTP-13	1.00 - 1.40	-	-	-	-	-	-	-	-	-	-	-	-	18.4
WRTP-14	1.70 - 2.00	5	4	11	30	26	24	34	18	16	9	-	-	12.7
WRTP-16	0.60 - 1.40	-	-	-	-	-	-	67	24	43	6.0	4 (non-dispersive with gypsum/calcite)	-	-
WRTP-17	0.80 - 1.20	21	10	10	25	23	11	-	-	-	-	6 (non-dispersive)	60	7.4
WRTP-17	3.10 - 3.20	44	12	9	13	22		-	-	-	-	-	20	7.0
WRD-SLR-TP01	2.00 - 3.00	11	6	10	9	27	37	39	21	18	10.0	6 (non-dispersive)	-	-

Location	Depth (m bgl)	Gravel (%)	Coarse Grained Sand (%)	Medium Grained Sand (%)	Fine Grained Sand (%)	Silt (%)	Clay (%)	LL (%)	PL (%)	PI (%)	LS (%)	Emerson Class	CBR (%)	MC (%)
WRD-SLR-TP09	4.00 – 4.40	21	7	5	15	27	32	62	23	39	14	5 (non-dispersive)	-	20.1
WRD-SLR-TP11	2.00 – 2.20	9	6	5	8	31	41	-	-	-	-	-	-	-
WRD-SLR-TP15	1.30 – 1.50	12	5	6	9	33	35	55	23	32	12	4 (non-dispersive with gypsum/calcite)	-	14.9
WRD-SLR-TP16	1.90 - 2.10	1	1	3	23	31	41	47	22	25	8.0	6 (non-dispersive)	-	-

Table 22 Geotechnical Laboratory Testing Results - Clay Borrow

Location	Depth (m bgl)	Gravel (%)	Coarse Grained Sand (%)	Medium Grained Sand (%)	Fine Grained Sand (%)	Silt (%)	Clay (%)	LL (%)	PL (%)	PI (%)	LS (%)	Emerson Class	CBR (%)	MC (%)
NTP-01	0.40 - 0.80	-	-	-	-	-	-	-	-	-	-	6 (non-dispersive)	-	-
NTP-01	5.20 - 5.40	-	-	-	-	-	-	-	-	-	-	6 (non-dispersive)	-	-
NTP-01	4.00 – 4.30	0	1	1	3	65	30	42	24	18	8.0	-	-	18.4
NTP-02	0.80 - 1.10	2	5	15	9	20	49	58	31	27	10.5	-	-	15.2
NTP-02	4.40 - 4.60	10	6	9	5	47	23	64	33	31	11.5	-	-	30.1

Location	Depth (m bgl)	Gravel (%)	Coarse Grained Sand (%)	Medium Grained Sand (%)	Fine Grained Sand (%)	Silt (%)	Clay (%)	LL (%)	PL (%)	PI (%)	LS (%)	Emerson Class	CBR (%)	MC (%)
NTP-06	1.80 - 2.00	40	13	9	8	14	16	32	15	17	8.5	4 (non-dispersive)	35	8.7
NTP-06	4.20 - 4.60	11	6	3	2	39	39	61	27	34	11	-	-	21.2
NTP-07	1.10 - 1.70	19	10	8	11	25	27	34	13	21	9.0	-	-	14.7
NTP-07	3.70 - 4.00	3	2	2	1	59	33	55	18	37	11	4 (non-dispersive)	-	24.1
NTP-08	3.10 - 3.30	5	3	6	2	38	46	63	29	34	10.5	-	-	23.2
DPIR-TP01	4.40 - 4.60	2	7	8	10	43	32	73	31	42	14	5 (non-dispersive)	-	36.5
DPIR-TP03	1.00 - 1.20	15	11	13	9	52		-	-	-	-	4 (non-dispersive)	-	17.9
DPIR-TP04	2.80 - 3.00	3	5	5	5	32	50	59	21	38	14	ND2 (completely erosion resistant)	-	17.1
DPIR-TP05	0.80 - 1.00	18	17	15	15	19	16	44	20	24	11	6 (non-dispersive)	-	17.5
DPIR-TP06	3.80 - 4.00	18	12	10	9	22	29	72	34	38	14.5	4 (non-dispersive)	-	25.0

Table 23 Geotechnical Laboratory Testing Results - Granular Borrow

Location	Depth (m bgl)	Gravel (%)	Coarse Grained Sand (%)	Medium Grained Sand (%)	Fine Grained Sand (%)	Silt (%)	Clay (%)	LL (%)	PL (%)	PI (%)	LS (%)	Emerson Class	CBR (%)	MC (%)
STP-01	0.70 - 1.00	33	26	11	8	22		34	22	12	6.0	6 (non-dispersive)	30	7.4
STP-02	0.30 - 0.60	37	16	12	10	10	15	-	-	-	-	4 (non-dispersive)	-	4.1
STP-02	1.40 - 1.60	40	16	14	13	17		-	-	-	-	6 (non-dispersive)	-	4.8
STP-03	1.00 - 1.20	30	18	13	4	15	20	36	17	19	7.0	6 (non-dispersive)	-	7.7
STP-04	0.30 - 0.60	56	19	9	5	11		-	-	-	-	-	-	2.9
STP-05	0.60 - 1.00	-	-	-	-	-	-	-	-	-	-	-	-	7.1
STP-06	0.70 - 1.00	34	8	18	18	22		-	-	-	-	-	40	4.4
STP-07	1.60 - 1.90	13	21	16	18	11	21	-	-	-	-	6 (non-dispersive)	20	9.8

Table 24 Geotechnical Laboratory Testing Results – Haul Road Alignment

Location	Depth (m bgl)	Gravel (%)	Coarse Grained Sand (%)	Medium Grained Sand (%)	Fine Grained Sand (%)	Silt (%)	Clay (%)	LL (%)	PL (%)	PI (%)	LS (%)	Emerson Class	CBR (%)	MC (%)
HR-SLR-TP01	0.10 - 0.20	26	25	18	9	13	9	-	-	-	-	5 (non-dispersive)	-	16.6

Location	Depth (m bgl)	Gravel (%)	Coarse Grained Sand (%)	Medium Grained Sand (%)	Fine Grained Sand (%)	Silt (%)	Clay (%)	LL (%)	PL (%)	PI (%)	LS (%)	Emerson Class	CBR (%)	MC (%)
HR-SLR-TP01	0.50 - 0.60	26	23	17	9	9	16	-	-	-	-	6 (non-dispersive)	-	11.2
HR-SLR-TP01	2.00 - 2.20	26	18	14	9	13	20	-	-	-	-	6 (non-dispersive)	-	6.2
HR-SLR-TP02	0.10 - 0.20	41	19	15	7	9	9	-	-	-	-	5 (non-dispersive)	-	10.0
HR-SLR-TP02	0.60 - 0.70	36	18	14	6	9	17	-	-	-	-	6 (non-dispersive)	-	12.3
HR-SLR-TP02	0.80 - 1.30	40	15	13	9	23		-	-	-	-	-	-	
HR-SLR-TP02	2.00 - 2.10	30	19	15	7	14	15	-	-	-	-	6 (non-dispersive)	-	9.5
HR-SLR-TP04	0.60 - 0.80	55	12	7	12	14		-	-	-	-	-	40	4.5
HR-SLR-TP6B	2.00 - 2.20	20	9	6	29	36		27	21	6	-	-	25	11.9
HR-SLR-TP9A	1.40 - 1.80	1	1	10	44	44		-	-	-	-	-	40	6.8

Table 25 Geotechnical Laboratory Testing Results - Aldebaran Quarry

Location	Sample Type	Point Load Index, $Is_{(50)}$ (MPa)	Interpreted Rock Strength	Sodium Sulphate Soundness – Total Weighted Loss (%) (AS1141.24)
Q-SLR-GS02	Rock grab sample - lump	3.61, 3.17 8.26, 3.05	Very high	-
Q-SLR-GS03	Rock grab sample - lump	5.12, 6.46 2.72, 4.51	High to very high	50.1 13.4
Q-SLR-GS04	Rock grab sample - lump	3.63, 5.58 2.21, 6.40	High to very high	-
Q-SLR-GS05	Rock grab sample - lump	5.97, 7.20 6.69, 8.15	Very high	0.5

7 Material Characterisation

The following sections present the geotechnical laboratory test results and provides a summary of their suitability for various aspects of the Rum Jungle Mine Rehabilitation project. Each area of investigation is discussed separately in the following sections.

The characterisation has been based primarily on the 2019 SLR investigations and is supplemented by the historical data from the desk top review.

7.1 West Waste Storage Facility (WWSF) Envelope

7.1.1 Particle Size Distribution

Compilation of Particle Size Distributions curves relevant to the WWSF are provided below in **Figure 18**. Statistical assessment of compiled PSD results is shown in **Table 26**. The majority samples tended to plot within the coarse granular (sandy gravel) material as shown in the curves and statistical breakdown below.

Table 26 Particle Size Distribution - West WSF

Analyte	% Sand	% Gravel	% Fines
Count	10 Samples (2 x SLR + 1 x MBY, 8 x Robertson GeoConsultants)		
Mean	33	45	22
Maximum	43	64	51
Minimum	25	7	9
Standard Deviation	5.3	14.6	12.0

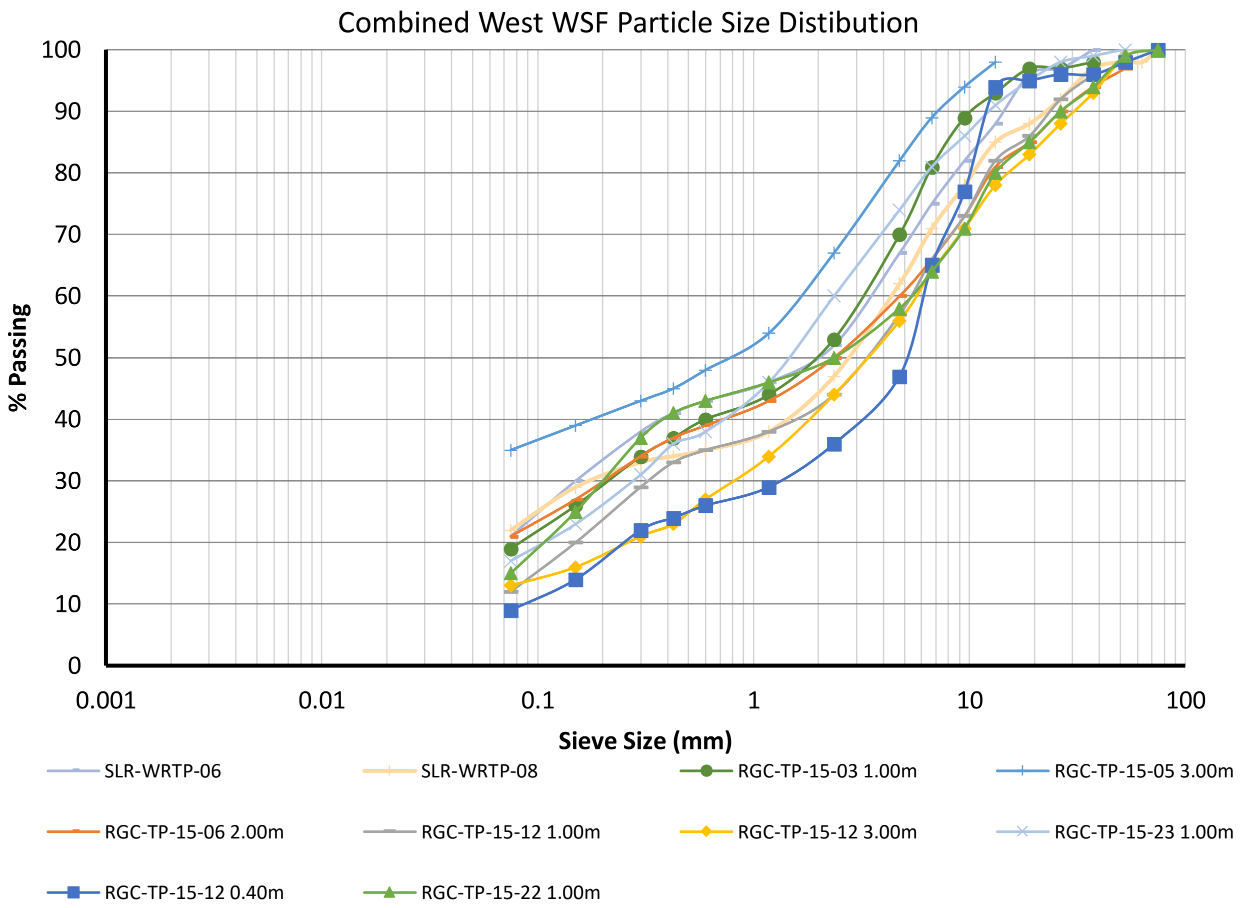
MBY: Meehan Burgess & Yeates 1982 [8],
RGC: Robertson GeoConsultants, 2014 [13]

The sandy gravel characterisation is considered representative of the natural, in-situ materials encountered across the WSF West footprint and aligns with the visual and tactile observations in the field. Observations found the material to be residual in nature, derived from the underlying brecciated bedrock, which typically became more granular and larger in particle size (cobbles and boulders) with depth as the soil transitioned to extremely weathered bedrock.

Based on field observations, the samples are representative of natural soil materials, and are envisioned to be readily encountered within the eastern portion of WWSF envelope within the upper slopes. However, as was encountered in the field test pit programs, the westerly portion of the WWSF footprint intersects the Old Stockpile Area, in which an engineered terraced slope comprising of ~1.0 m thick low permeable clay cover overlying varying thickness of waste rock that has been keyed into the natural topography as part of the 1980 remediation efforts. The thickness of the capping layer and waste rock tapers towards the ridgeline of the slope in an easterly direction.

Based on the general soil characterisation, the natural soils would be suitable as a general fill material and have potential as a road construction material. However, given the previous land use of the area of the Western WSF, it is likely any soils within the area are contaminated, precluding their use in construction.

Figure 18 Compiled PSD Curves - West WSF



7.1.2 California Bearing Ratio

One California Bearing Ratio (CBR) was performed on a sample from WRTP-06, representative of a residual sandy GRAVEL material. The soil recorded a CBR value of 45%, optimum moisture content of 6.5% and 0% swell. The material is considered representative of encountered residual soils derived from the breccia (GEOLSEC) bedrock.

7.1.3 Emerson Class

Two samples, WRTP-06, and WRTP-08 were submitted for Emerson Class analysis to assess erosion resistance. The results were compiled with historic results from the Meehan Burgess and Yeates assessment [8]. The soil materials returned an Emerson Class of 5 to 6, indicating the soil to be non-dispersive within and proximal to the WSF West envelope.

7.2 East Waste Storage Facility (EWSF) Envelope

7.2.1 Particle Size Distribution

Statistical assessment of the PSDs is provided below in **Table 27**. Compiled PSD curves shown in **Figure 19**. The material is shown to be highly variable across the Eastern WSF envelope, ranging from silty clays to sandy gravels as shown in the curves and statistical breakdown below.

Table 27 Particle Size Distribution - East WSF

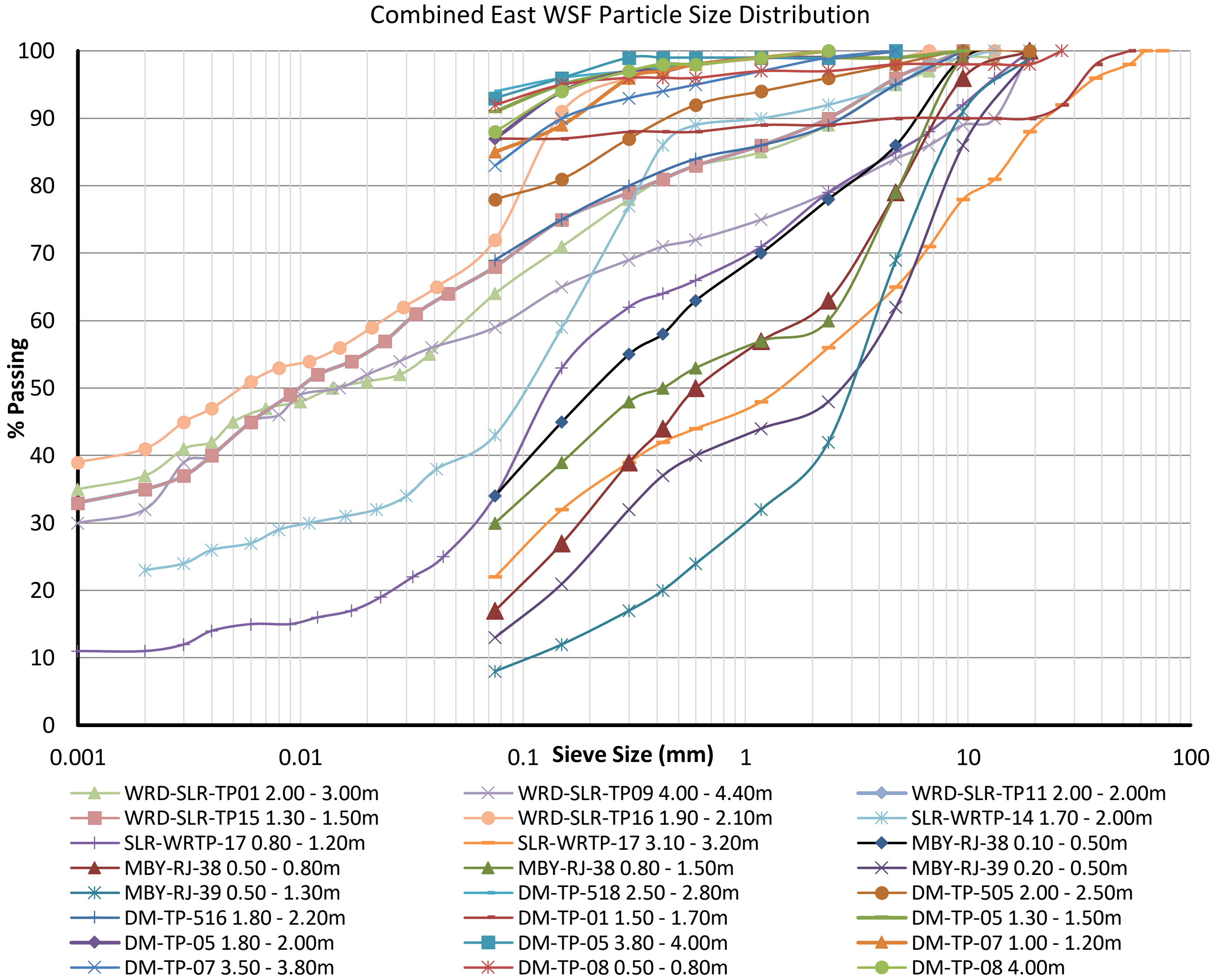
Analyte	% Gravel	% Sand	% Fines
Count	32 Samples (8 x SLR, 5 x MBY, 3 x DM, 8 x MPES, 8 x RGC)		
Mean	23	25	53
Maximum	72	46	94
Minimum	0	2	8
Standard Deviation	22.5	12.2	30.5

MBY: Meehan Burgess & Yeates 1982 [8],
DM: Dames and Moore, 1983 [17],
MPES: Mining and Process Engineering Services, 1985 [14]
RGC: Robertson GeoConsultants, 2014 [13]

A PSD and hydrometer performed on a sample from SLR-WRTP-14 at 1.70 - 2.00m bgl, described as sandy CLAY with trace gravel recorded 5% gravel, 36% sand (primarily fine grained), 35% silt and 24% clay. This suggests a very sandy clayey SILT/CLAY material. This material grading was found to be generally representative of material found within the northern portion and eastern boundary of WSF East envelope and is supported by the Mining and Process Engineering 1985 [14] results procured from test pits performed proximal to the SLR-WRTP-14 location, which reported percentage fines ranging between 83% to 93% by weight and are shown by the cluster of upper curves in **Figure 19**.

Within SLR-WRTP-17 two samples, granular laterite deposit described as clayey SAND with gravel from 0.80 - 1.20 m bgl and granular laterite described as sandy GRAVEL with cobbles from 3.10 - 3.20 m bgl, underwent PSD analysis. The laterite recorded 21% gravel, 45% sand, 23% silt and 11% clay, suggesting a silty SAND with gravel, and the lateritic sample recorded 12% cobbles, 32% gravel, 34% sand and 22% fines, suggesting sandy GRAVEL with silt/clay and cobbles. These results are generally in line with field observations taken from the mid to southern and mid-west of the WSF East Envelope, which was observed during field investigation to be likely an old stripped borrow area, generally devoid of topsoil and cut down to granular lateritic/saprolite soils that transition readily to extremely weathered bedrock deposits. The observations are further supported by review of the Meehan Burges and Yeates and Dames and Moore reports which shows the demarcation of “Borrow Area No. 5”, a borrow used for the supply of construction materials used in the 1980 rehabilitation program proximal SLR-WRTP-17. Review of recent satellite imagery shows scaring of the landscape and has been inferred as the likely boundary of the old Borrow Area No. 5 (**Figure 20**).

Figure 19 Compiled PSD Curves - East WSF



A ternary plot has been created to illustrate the distribution of particle sizes in individual samples taken from EWSF (**Figure 21**) as a means of assessing the materials suitability as a low permeability layer. A ternary plot is useful for illustrating fines and gravel content against requirements for material acceptable as a low permeability layer. Suitable cohesive soils were found in the north and eastern fringes of the proposed EWSF as shown by the green shading, with the boundary of the cohesive likely extending eastward beyond the demarcated zone.

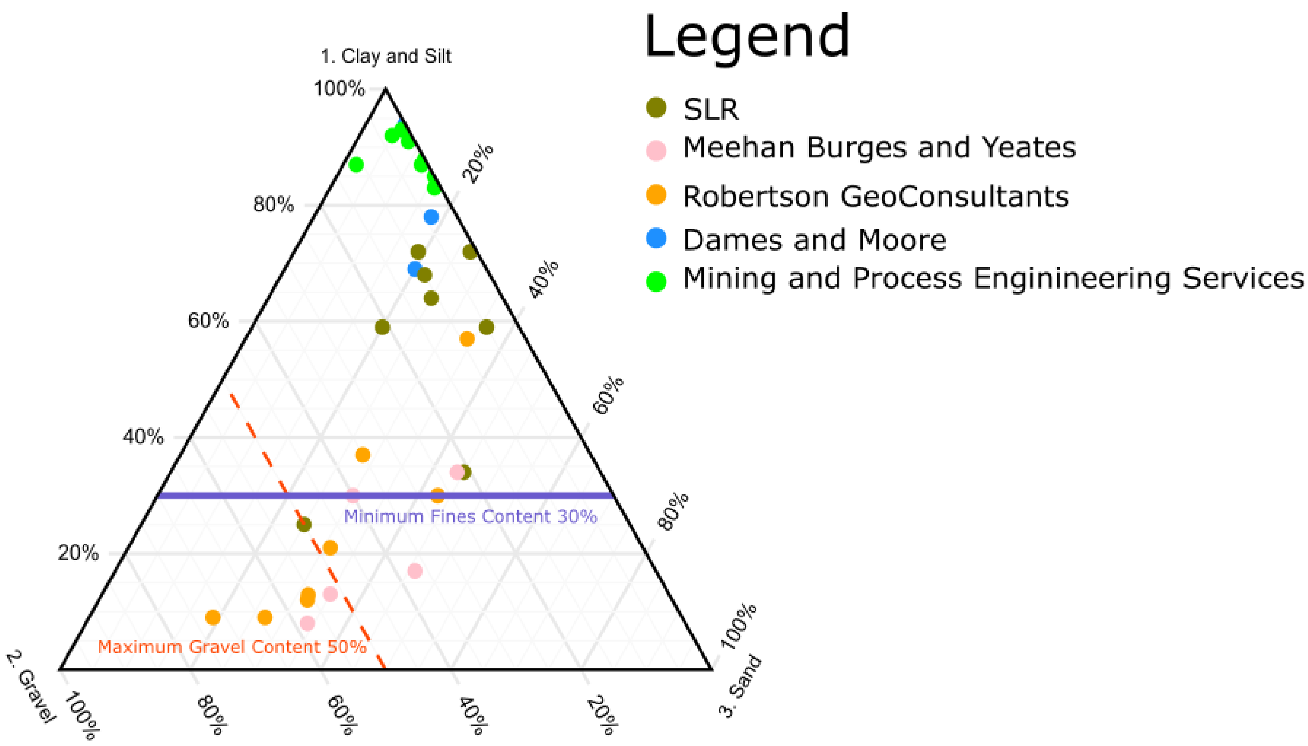
Review of the Filter cake disposal report [14] recommended the disposal of the 1980 water treatment filter cake by-product material within the Borrow Area No. 5. The SLR investigation in October 2019 performed test pits within the likely area of placement to confirm the presence of the filter-cake material. Based on the findings of the October 2019 investigation, an inferred boundary of filter cake combined with boundary of stripped material likely removed from Borrow No. 5 activities as shown by the black and grey zone overlays the zone of suitable low permeability material. The black and grey zone has been considerably influenced by historic works, reducing the likelihood of usable and suitable low permeability material.

Soil samples collected within the green zone (**Figure 20**) generally contained greater than the 30% fines and less than 50% gravel materials. Material with at least 30% fines (<0.075mm) are typically suitable for constructing a low permeability layer.

Figure 20 Old Borrow Area No. 5 Inferred Boundary and Zones of Suitable Low Permeability Materials

At gravel contents greater than 50% there may be insufficient fines to fill the voids between the gravel particles. Gravel contents greater than 50% generally result in an increase in hydraulic conductivity or segregation during placement, which can lead to pockets of higher gravel content. Samples collected outside of the green zone exhibited such qualities and would not be suitable for low permeability purposes.

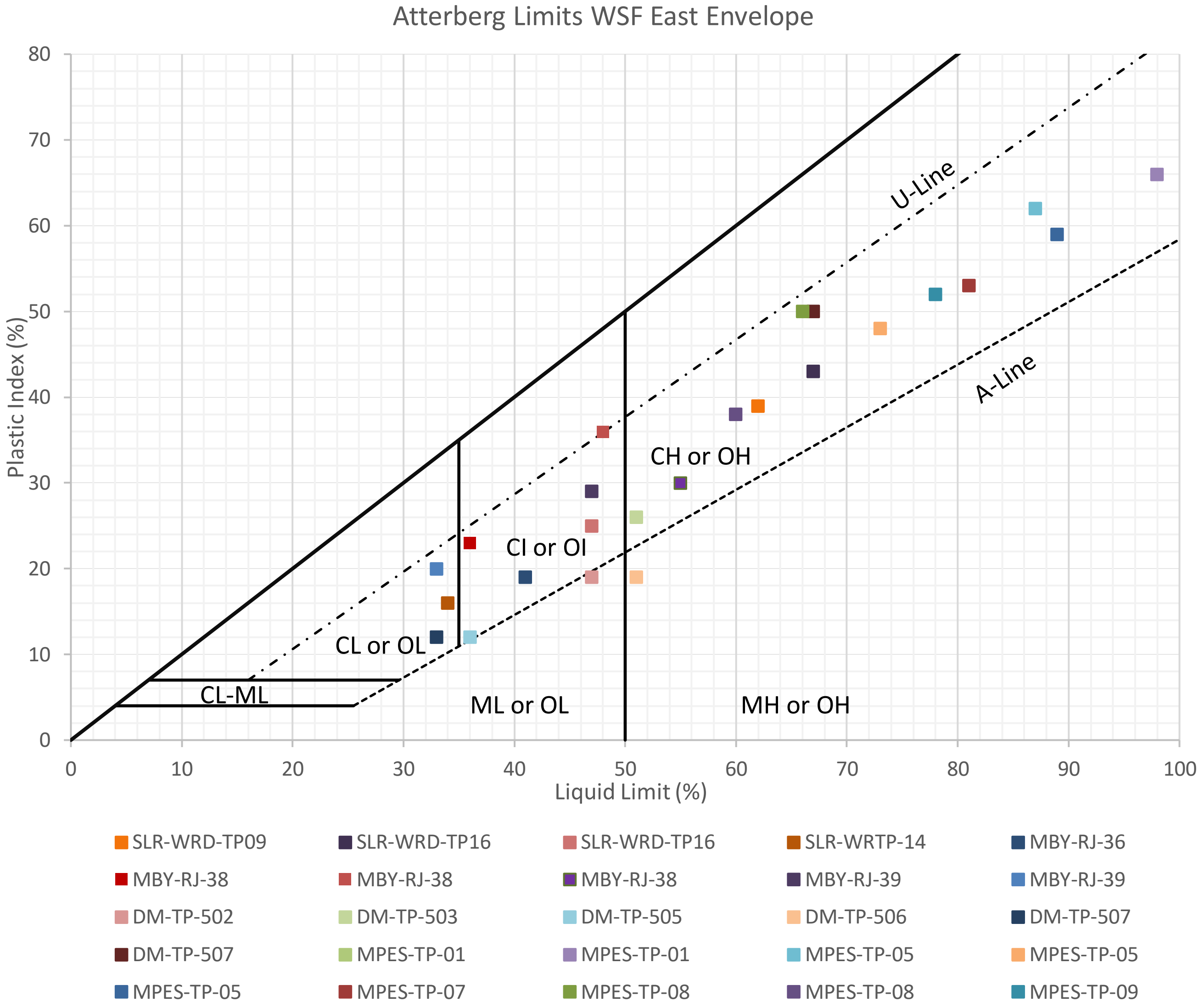
Figure 21 Ternary Plot of East WSF Sampled Material



7.2.2 Atterberg Limits

Four samples from SLR investigation were submitted for Atterberg Limit analyses and proximal results from historical investigations including; six results from the Meehan Burgess and Yeates 1982 investigation [8], twenty-one results from the Dames and Moore 1983 investigation [17], nine from the Mining and Process Engineering Services 1985 [10] investigation and ten from the Robertson GeoConsultants 2014 investigation [13], were used with the Atterberg Limit plot of shown in **Figure 22**. The Dames and Moore results record low to intermediate clay behaviour for samples described as clayey GRAVEL and clayey SAND. Results which plot below the A-line indicated silt-like behaviour and range from intermediate to high plasticity. This is in line with recent field observations.

Figure 22 Atterberg Limit Plot Graph - East WSF



Notes: CL-ML: Low plastic Clay or Silt, CL: Low plastic clays; sandy and silty clays, CI: Medium Plastic Clays, CH: High plastic clays, ML: Medium plastic silts

The activity of samples ranged between 0.67 to 1.22, indicative of the presence of active clay minerals and in adequate amounts suitable for a low permeability layer.

7.2.3 Linear Shrinkage

Linear shrinkage was compiled for recent and historic investigations. Results show for soils with a minor granular component (> 30% by weight) recorded linear shrinkages ranging from 6% to 10%. These values indicate a low volume change potential. The larger the cohesive soil component, the greater the volume change potential, with soils having less than 15% granular soil exhibiting linear shrinkages between 13% and 19%, indicating moderate to high susceptibility to volume change with moisture change. The predominantly cohesive soils with low granular contents and high-volume change potential were typically found in the eastern portion of the WSF East envelope.

Table 28 Linear Shrinkage – WSF East

Analyte	WSF East	'Green Zone' WSF East
Count	48 Samples (3 x SLR, 6 x MBY, 16 x DM, 9 x MPES, 10 x RGC)	30 Samples (3 x SLR, 5 x MBY, 14 x DM, 9 x MPES)
Mean	10.8 %	11.9 %
Maximum	18.5 %	18.5 %
Minimum	1.0 %	6.0 %
Standard Deviation	3.9	3.5

MBY: Meehan Burgess & Yeates 1982 [8],

DM: Dames and Moore, 1983 [17],

MPES: Mining and Process Engineering Services, 1985 [14]

RGC: Robertson GeoConsultants, 2014 [13]

7.2.4 Hydraulic Material Characterisation

Three samples taken from within the East WSF envelope was assessed for hydraulic conductivity using falling head test (AS 1289 6.7.2). The historic investigation of Dames and Moore also performed hydraulic conductivity tests on samples collected within and proximal to WSF East as part of the borrow material suitability assessment. The SLR laboratory results along with the Dames and Moore [17] borrow investigation results are presented in **Table 29**. It is noted, the O'Kane's Consultants permeability specification requirement for low permeability layers and starter bunds is $k_{sat} < 1 \times 10^{-9}$ m/s.

Table 29 Hydraulic Conductivity Results at standard MDD - East WSF

Sample ID	Depth (m bgl)	MDD (t/m³)	+/- OMC (%)	Remoulded Density	Permeability (m/s)	% Fines	% Gravel
SLR-WRD-TP08	3.40 - 3.70	1.71	+0.5	100% SDD	2×10^{-9}		
SLR-WRD-TP14	3.00 - 3.20	2.13	0.0	95% SDD	5×10^{-9}		
SLR-WRTP-14	1.70 - 2.00	1.87	+1.0	100% SDD	2.0×10^{-10}	59 (24% Clay)	5
DM-TP-503	1.50 – 2.00	1.86	0.0	90% SDD	2.0×10^{-6}	61	14
			0.0	100% SDD	4.0×10^{-10}		
DM-TP-505	2.00 – 2.50	1.82	0.0	90% SDD	2.0×10^{-7}	78	4
			0.0	100% SDD	7.0×10^{-8}		
DM-TP-511	2.00 – 2.10	1.65	0.0	90% SDD	3.0×10^{-7}	88	2
			0.0	100% SDD	7.0×10^{-10}		
DM-TP-516	1.80 – 2.20	1.69	0.0	90% SDD	1.0×10^{-6}	69	11
			0.0	100% SDD	3.0×10^{-9}		
DM-TP-518	2.50 – 2.80	1.35	0.0	90% SDD	1.0×10^{-7}	94	0
			0.0	100% SDD	4.0×10^{-9}		

Further to the laboratory test results presented in **Table 29**, field permeability tests were performed as part of the Mining and Process Engineering Services - Filter Cake Disposal investigation [10] within the 'Borrow Area 5'. Limited details on the test methodology are provided, however, with the information available, the tests appeared to be conducted as falling head tests of an uncased section within a shallow borehole. The tests were performed in 'near surface section of very stiff to hard clay material which underlies the surface sandy gravel materials' and 'softer wetter clay'. Field permeability results returned k-values of 3.4 x 10^{-6} cm/sec and 7 x 10^{-5} cm/sec. It is noted, the tests were performed in 1985, with the k-values derived from two water level readings spaced 207 seconds (test 1) and 4500 seconds (test 2) apart respectively.

7.2.5 Emerson Class

Six samples from the East WSF were submitted for Emerson Class analysis. Five samples returned a result of Class 6, non-dispersive material. One sample returned Class 4 which is also generally non dispersive, however contains minor elements (such as gypsum) which are susceptible to erosion. Overall, the material recovered from this area of the site is still considered to have a low risk of dispersive soils.

7.2.6 California Bearing Ratio

California Bearing Ratios (CBRs) were performed on two samples from WRTP-17 at 0.80m to 1.20m and 3.10m to 3.20m depths. The purpose of the test was to assess the re-use potential of the granular soils within the WSF East envelope. CBR tests were performed at 95% Standard Compaction. Results are presented below.

Table 30 WSF East CBR Results

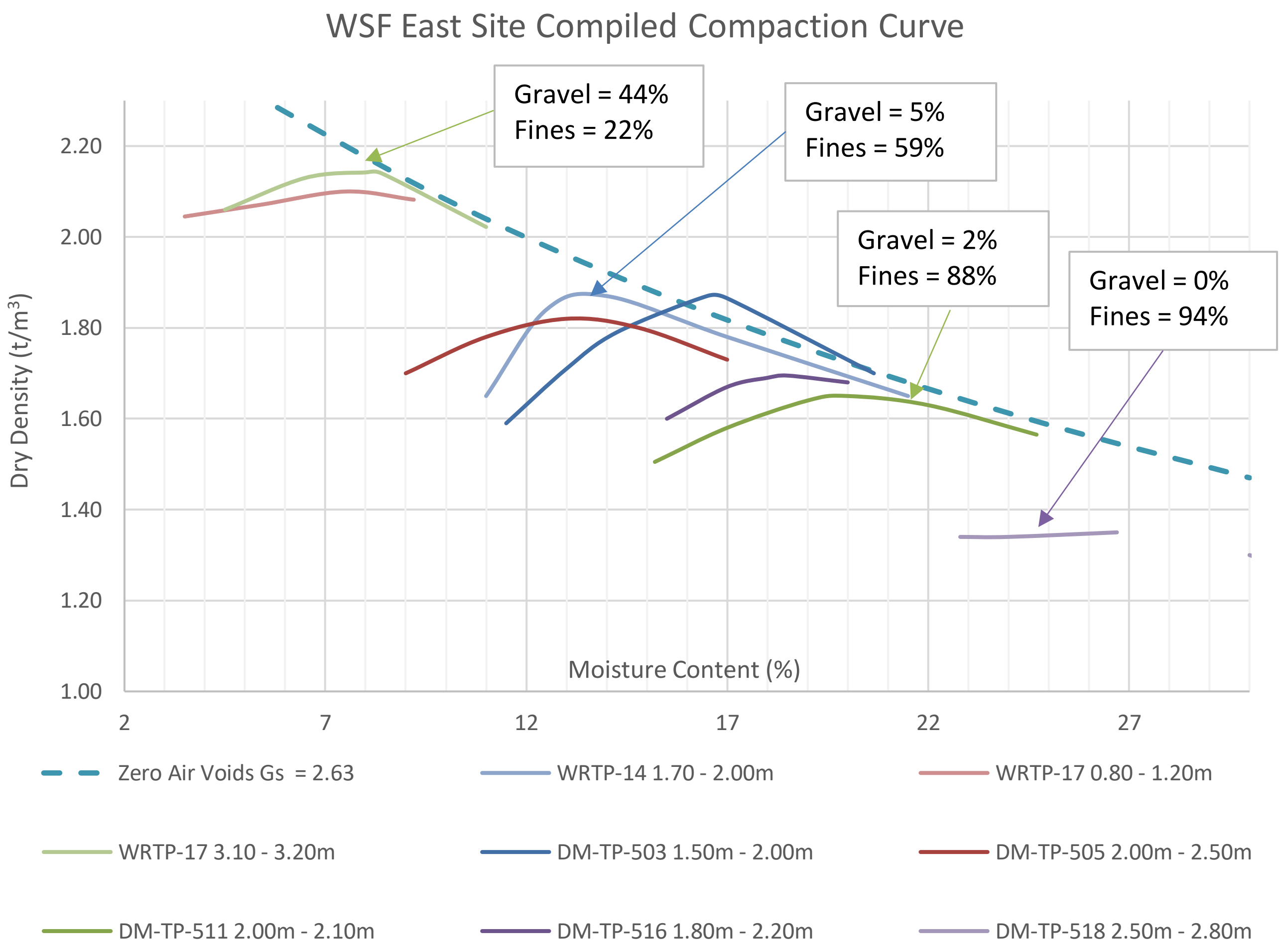
Test Pit	Depth	CBR (%)	Swell (%)	Material	Gravel/Sand/Fines
WRTP-17	0.80m – 1.20m	60	0.0	Lateritic Clayey Sand with Gravel	21%/45%/34%
WRTP-17	3.10m – 3.20m	20	0.0	Lateritic Sandy Silt with Clay	5%/36%/59%

7.2.7 Standard Compaction

Three samples from WSF East were submitted for proctor compaction testing. The results are compiled against the Dames and Moore 1983 proctor curves for samples collected proximal to WSF East along with sample percentages for gravel and clay. In general the laboratory measured field moisture contents were found to be within -4.30 % to +1.3 % of Optimum Moisture Contents (OMC). Generally, the more granular the sample, the closer the material was to Optimum Moisture Content.

For the sample driest of OMC (-4.3%), approximately 90L per cubic meter would be required to bring the sample to OMC. However, based on the laboratory results, for materials to be re-used and placed at OMC, it is anticipated that minimal water addition would be required for construction so long as excavated soils were managed correctly and prevented from drying out. If soil is stockpiled for a prolonged period, particularly in the dry season, additional water may be required.

Figure 23 WSF East Compiled Compaction Curves



7.2.8 Chemical Material Characterisation

Chemical material characterisation was completed on agronomy samples by ALS Laboratories. Agronomy samples were collected from four of the SLR geotechnical test pits (WRTP-12, WRTP-14 and WRTP-15). Sample depths ranged from 0.1 m to 0.60 m below ground surface and comprised of 0.1 m to 0.20 m intervals per sample. Sample depths only contained one soil horizon. Detailed assessment of the environment chemistry are provided in the **Growth Material for Waste Rock Capping** in **Section 8.**

Soil Salinity Classification

Soil salinity classification provides insight into the erodibility of a soil. The classifications are normal, saline, sodic and saline-sodic. Classification is based on electrical conductivity (EC), exchangeable sodium percentage (ESP) and pH. Below are the classifications as per the Natural Resources Conservation Services (NRCS) (adapted from Horneck 2007 [18]):

Table 31 Soil Salinity Classification Limits (NRCS)

Class	EC (µS/cm)	pH	ESP	Soil Structural condition
Normal	< 4000	< 8.5	< 15	Flocculated
Saline	> 4000	< 8.5	< 15	Flocculated
Sodic	< 4000	> 8.5	> 15	Dispersed
Saline – Sodic	> 4000	< 8.5	> 15	Flocculated

Normal as well as saline and saline-sodic tend to have a flocculated structure while sodic soils have a dispersive structure which leads to increased erodibility. Normal soils are preferred as they are non-dispersive. Maximum values for EC, pH and ESP for the tested samples were: 5µS/cm, 6.2 and 1.2. All of the samples tested were classified as "Normal" and considered non-sodic.

7.2.9 WSF East Material Characterisation Summary

The characterisation program performed within the WSF East has demonstrated that some low permeability clays are available within and proximal to the proposed excavation footprint (green shaded area **Figure 20**) suitable for use in low permeability layers for Rum Jungle Rehabilitation works in accordance with O'Kane's material specification.

Low permeability specification requirements are outlined in **Table 32** below.

Table 32 Low Permeability and Starter Bunds Criteria (O'Kane's and Industry)

Characterisation Test	Meets Criteria	Criteria
O'Kane's Material Specification		
% Clay	✓	Clay percentage > 10%
% Fines	✓	Fines percentage > 30%
% Gravel (4.75mm)	✓	Gravel (4.75mm) percentage < 50%
Atterberg Limits	✓	Plastic Index > 10
Saturated Permeability	✓*	$K_{sat} \leq 1 \times 10^{-9}$ m/s
Industry Recommendations for Low Permeability Layers		
Activity	✓	Activity > 0.5
Dispersivity	✓	Emerson ≥ 4 Pin Hole dispersion less dispersive or equal to ND2.

Characterisation Test	Meets Criteria	Criteria
CEC	✓	CEC > 10 meq/100g

Notes: [*] Generally achieved for clay borrow materials placed at 100% SDD, however high granular contents correspond to increased permeability. Screening and placement of material wet of optimum likely required to reduce and homogenise permeability.

The soils encountered within the green zone (**Figure 20**) of the northern portion of the WSF East Envelope are generally found to comprise of predominantly highly plastic and moderately reactive (to moisture change) clays. These clays, have been shown through laboratory testing to be generally suitable for low permeability layers if placed wet of optimum moisture content (+1% to + 3% Optimum Moisture Content) and at 100% standard compaction. Minimisation of exposure for long periods of time and/or periodic wetting down is recommended to mitigate against desiccation cracking. Such placement compactions and moisture should also be checked in scaled field trials. It is noted, upon wetting, the soils are anticipated to be difficult to work with due to the low granular contents. Addition of granular materials to improve workability should be used tentatively as the clays are already at the higher end of permeability requirements, with the addition of granular material potentially increasing permeability beyond desired limits.

Towards the south of the green zone (**Figure 20**), the soils tend to increase in silt content, particularly within saprolite deposits at depths below 2.00 m. While these soils have potential as a low permeability layer, upon wetting, but will be difficult to work with without the addition of granular material, potentially limiting their effectiveness as a low permeability layer. As above, field trials assessing the in-situ permeability and workability is recommended prior to full scale application.

7.3 Borrow Area A

The following sections assess the geotechnical testing that was performed on samples taken from the proposed Borrow Area A (Clay Borrow) and provides a summary of the material from within the borrow area suitability for various aspects of the Rum Jungle Rehabilitation project.

Test pit and associated laboratory testing has been compiled from the following investigations:

- 2019 SLR Rum Jungle Test Pit Borrow Investigation;
- 2019 DPIR Rum Jungle Preliminary Test Pit Preliminary Investigation (performed under guidance from SLR);
- 2019 GHD Rum Jungle Creek South Test Pit Investigation (Ref: **Table 5**).

7.3.1 Particle Size Distribution

Statistical assessment of compiled particle size distribution (PSD) of samples taken within Borrow Area Aare provided below in **Table 33** and compiled PSD curves shown in **Figure 24**. The majority of samples tended to plot within cohesive (sandy/gravelly clay/silt) material as shown in the curves and statistical breakdown below.

Table 33 Particle Size Distribution –Borrow Area A

Analyte	% Sand	% Gravel	% Fines
Count	22 Samples (9 x SLR + 5 x DPIR Investigation + 8 GHD)		
Mean	26	17	56
Maximum	62	57	95
Minimum	5	0	16
Standard Deviation	15.4	14.8	23.8

GHD: GHD Rum Jungle South, 2019 [12],

DPIR: Investigation performed by DPIR under SLR guidance, 2019,

Borrow Area A has been characterised into zones (**Figure 25**) considered representative of the general soil types encountered. The material was typically found to comprise of a topsoil layer overlying residual soils of lateritic description overlying saprolite. Saprolite soils typically comprised of larger slit contents, becoming more granular and larger in particle size (cobbles and boulders) with depth as the soil transitioned to extremely weathered bedrock.

The thickest deposits of cohesive materials were generally found towards the western portion of the site.

Figure 24 Compiled PSD Curves - Borrow Area A

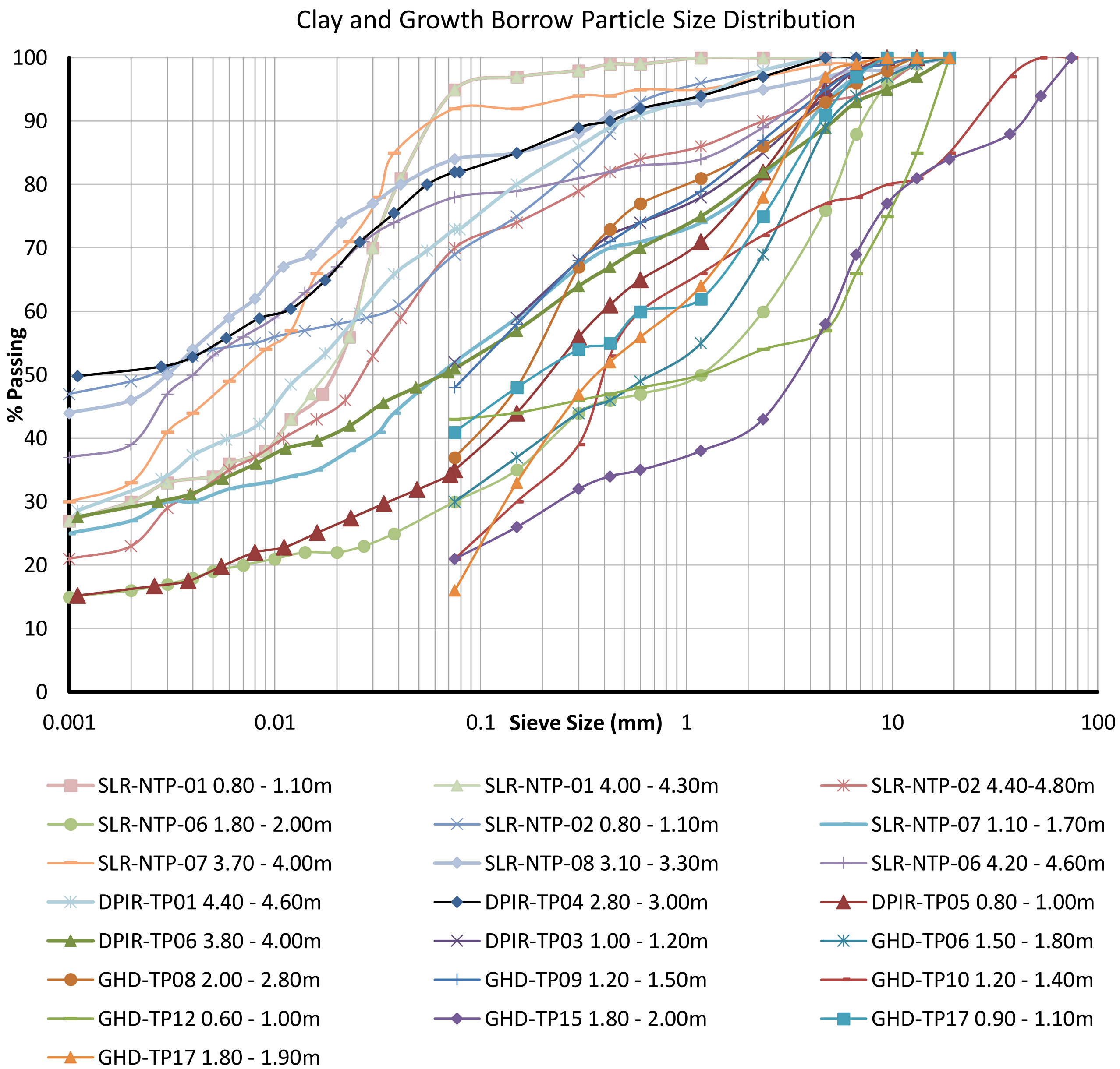


Figure 25 Borrow Area A - Soil Zones

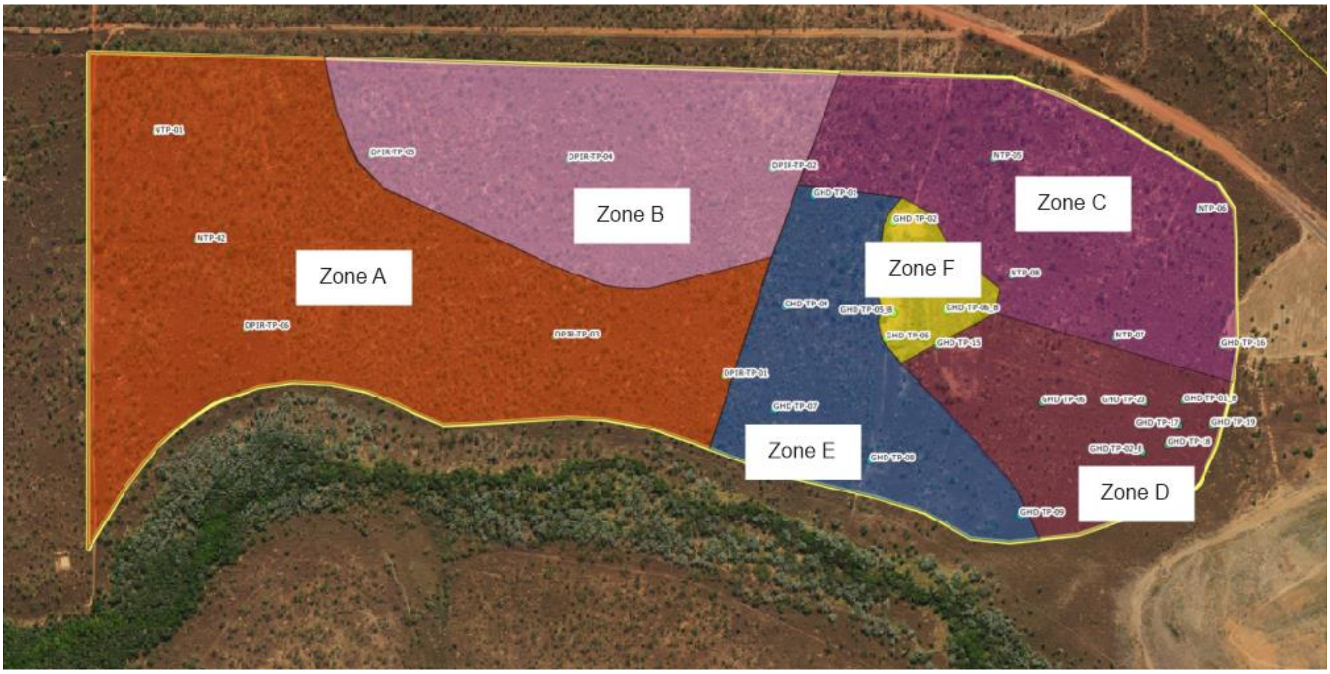


Table 34 Summary of Borrow Area A Soil Zones

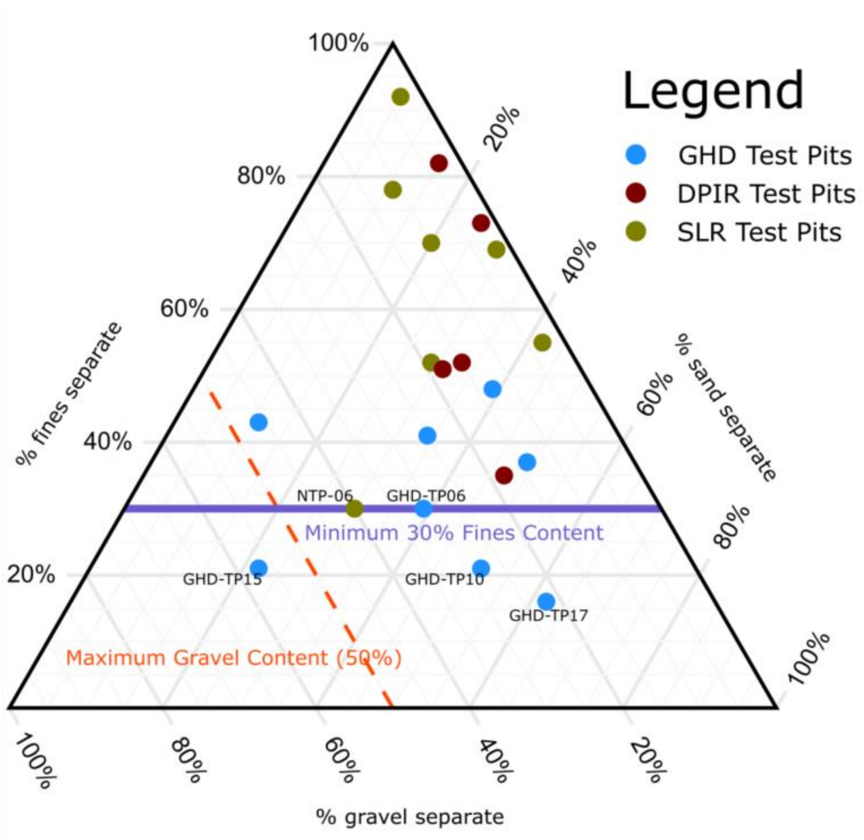
Zone	Description	Generalised Soil Type	Depth	Volume
A	Predominantly Clay and Silt Approximate Area: 344,500m^2	Topsoil Lateritic Clay Saprolite Silt	0.00 m - 0.20 m 0.20 m - 3.50 m 3.50 m - >5.00 m	67,200 m^3 1,108,800 m^3 >504,000 m^3
B	Sand Overlying Clay Approximate Area: 180,350m^2	Topsoil Lateritic Gravel/Sand Saprolite Clay	0.00 m - 0.20 m 0.20 m - 3.00 m 3.00 m - >5.00 m	36,070 m^3 504,980 m^3 >360,700 m^3
C	Sand Overlying Clay/Silt Approximate Area: 164,500m^2	Topsoil Lateritic Sands/gravels Saprolite Clays/Silt	0.00 m - 0.20 m 0.20 m - 3.20 m 3.20 m - >5.00 m	32,900 m^3 493,500 m^3 >296,100 m^3
D	Sand Overlaying Clay Overlying Gravels/Cobbles Approximate Area: 93,720m^2	Topsoil Lateritic Sands Saprolite Clay Saprolite Gravel/Cobbles	0.00 m - 0.10 m 0.10 m - 2.00 m 2.00 m - 4.00 m 4.00 m - >5.00m	9,372 m^3 178,068 m^3 187,440 m^3 >93,720 m^3
E	Gravel/Sand Approximate Area: 115,500m^2	Topsoil Lateritic Sand Lateritic Gravel	0.00 m - 0.10 m 0.10 m - 0.80 m 0.80 m - >2.80 m	11,550 m^3 80,850 m^3 >231,000 m^3
F	Stripped Area Approximate Area: 24,500m^2	Sands and Gravels	0.00 m - >2.30 m	56,350 m^3

Only One of the twenty samples tested had greater than 50% gravel separate (>2.0 mm). A value of less than 50% is considered a criteria for a low permeability compacted clay (i.e. $\leq 1 \times 10^{-9}$ m/s).

A ternary plot of the distribution of particle sizes in individual samples taken from Borrow Area A is shown in **Figure 26**. A ternary plot is useful for illustrating fines and gravel content against requirements for material acceptable as a low permeability layer. Results demonstrated that samples generally contained more than the 30% fines and less than 50% gravel materials, characteristics suitable for low permeability layers [19]. At gravel contents greater than 50% there may be insufficient fines to fill the voids between the gravel particles. Gravel contents greater than 50% generally result in an increase in hydraulic conductivity. Preliminary relationships drawn between laboratory tested permeability and gravel percentage suggest gravel percentages <10% are favourable in achieving permeabilities $<1 \times 10^{-9}$ m/sec.

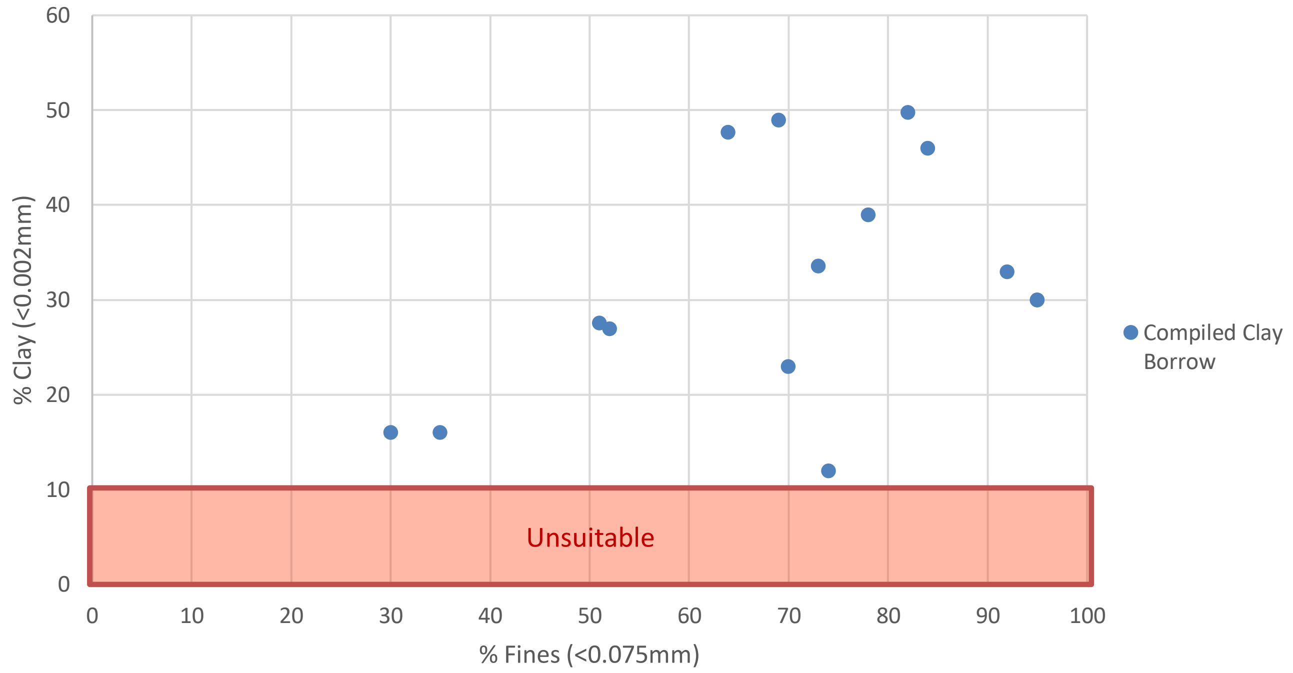
While there is no minimum gravel limit, lower percentages are favourable in compacted clay layers due to its contribution to strength and bearing capacity.

Figure 26 Ternary Plot – Borrow Area A



Clay content is not necessarily proportional to fines content as shown in **Figure 27**. The plot shows the relationship of fines and clay percentage from samples collected Borrow Area A. The figure shows that, in general, percent fines can be used as an indicator for clay criteria (i.e. clay separate >10%) for soils containing greater than 30% fine materials.

Figure 27 Relationship Between Clay and Fines from Borrow Area A Samples

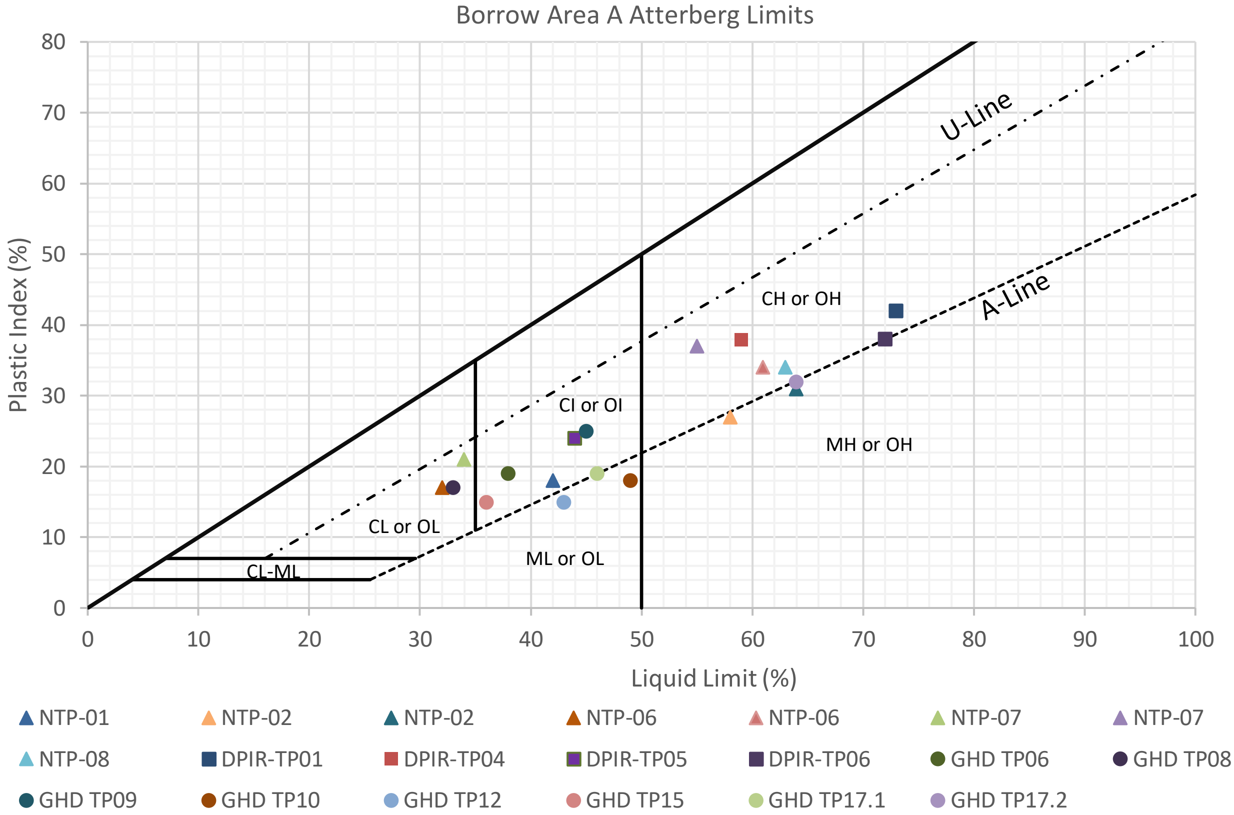


7.3.2 Atterberg Limits

A total of 17 (6 x SLR (2019), 3 x DPIR (2019) and 8 x GHD (2018)) Atterberg limits tests were performed on samples collected. The combined Atterberg limit results are plotted on the A-Line Graph in **Figure 28**.

Based on the Unified Soils Classification System (USCS) acceptable material would include inorganic clays of low to medium plasticity (CL) and inorganic clays of high plasticity (CH).

Figure 28 Combined Atterberg Limit Graph – Borrow Area A

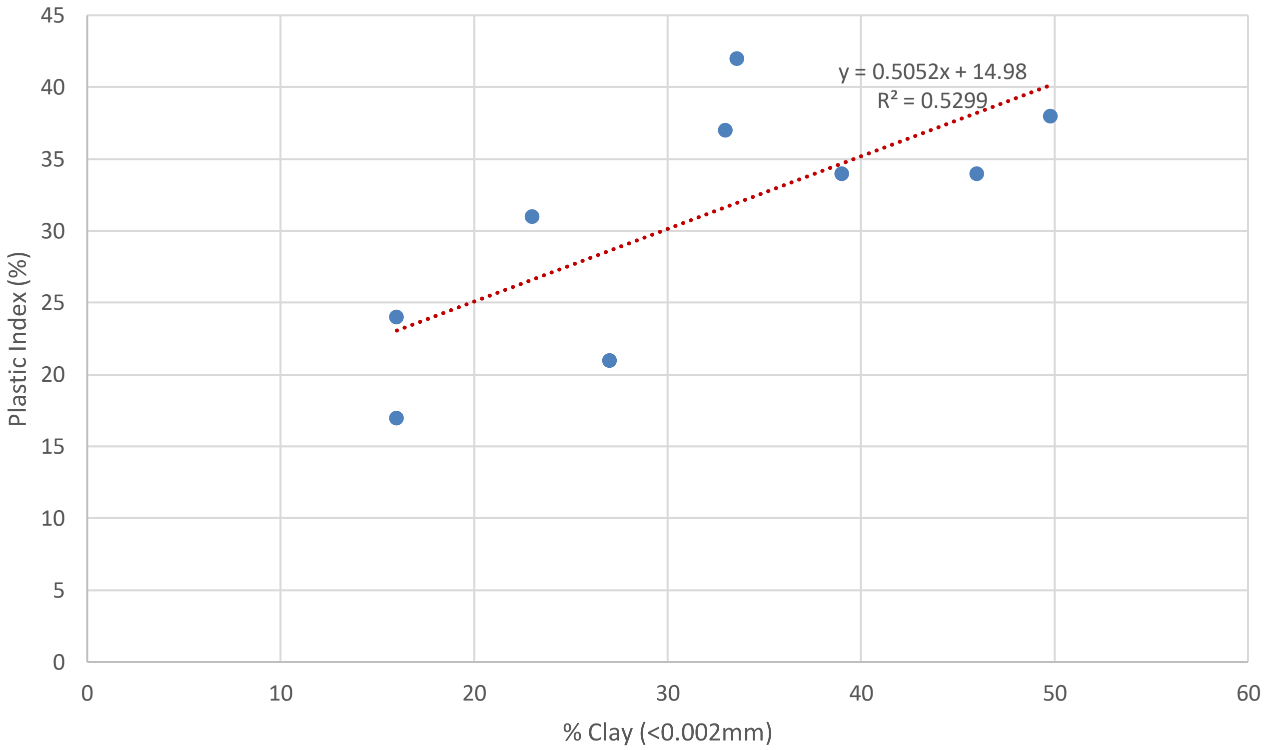


Notes: CL-ML: Low plastic Clay or Silt, CL: Low plastic clays; sandy and silty clays, CI: Medium Plastic Clays, CH: High plastic clays, ML: Medium plastic silts

The activity of samples in which the clay fraction (<0.002 mm) was measured ranged from 0.60 to 1.50. Activity between 0.5 to 1.0 is generally desirable for low permeability layers. Of the derived activity results, five out of nine results returned activities greater than 1.00 and were observed to have silt contents greater than that of the clay.

The Plastic Index (PI) of the compiled samples have been compared to percent clay (<0.002 mm particle size) as shown in **Figure 29**. The samples demonstrated a 'moderate' (0.25< R^2 <0.49) [20] trend of increasing PI with percent clay.

Figure 29 Plastic Index and % Clay from Compiled Samples – Borrow Area A



7.3.3 Shrinkage

Table 35 Atterberg Limits, Linear Shrinkage

Analyte	% Linear Shrinkage	% Liquid Limit	% Plastic Limit	% Field MC	% OMC (average)
Count	20 Samples (8 x SLR + 4 x DPIR Investigation + 8 x GHD)				
Mean	10.0	50.6	24.5	18.2	16.3%
Maximum	15.5	73.0	34.0	36.5	
Minimum	6.0	32.0	13.0	8.7	
Std. Deviation	2.8	12.8	6.4	6.0	

Linear shrinkage is described as the decrease in length of a wet sample to a dry sample as a percentage of the original length. Kleppe and Olson (1985) [21] determined that a volumetric strain of 4% can lead to the development of desiccation cracks in compacted slabs. While linear shrinkage does not directly relate to volumetric strain, is does provide a proxy as to the potential reactivity of the material.

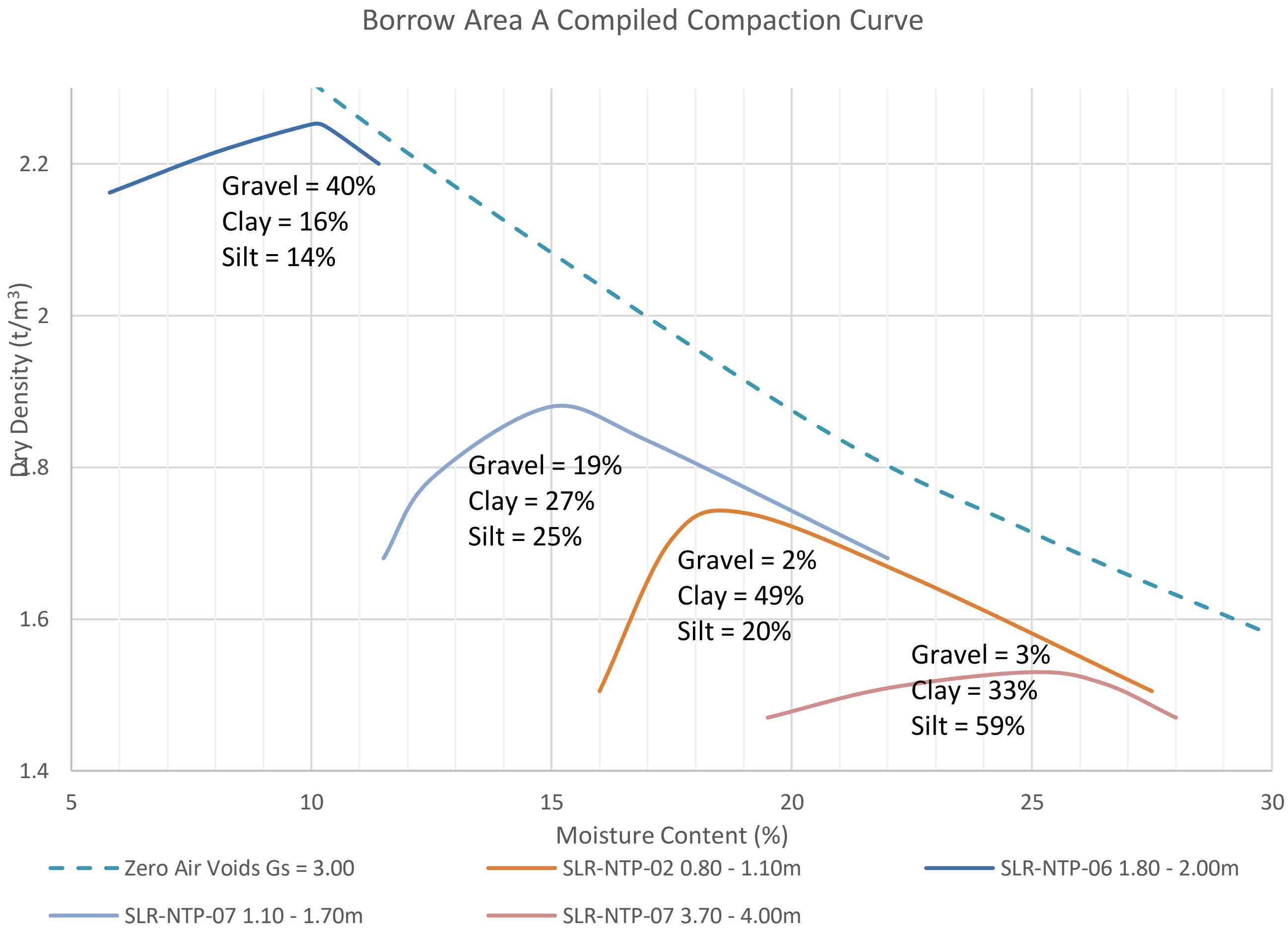
7.3.4 Standard Compaction

Samples submitted for Proctor testing are summarised in terms of Maximum Dry Density (MDD), Optimum Moisture Content (OMC) and natural water content.

Table 36 Proctor Tests

Location ID	Depth (m)	Maximum Dry Density (t/m^3)	OMC (%)	% Field Moisture
NTP-02	0.80 - 1.10	1.74	19	21.2
NTP-06	1.80 - 2.00	2.25	10	12.4
NTP-07	1.10 - 1.70	1.88	15	14.1
NTP-07	3.70 - 4.00	1.53	25	19.7
Average		1.85	17.25	16.85

Figure 30 Compiled Compaction Curves Clay and Growth Borrow



Samples tested had a field moisture content at optimum or within the -5% to +3% of OMC threshold. For low permeability layers, it is recommended to place the material wet of optimum to minimise permeability. Little if any additional water would be required for placement so long as excavated soils were managed to mitigate drying out. If soil is stockpiled for a prolonged period of time, particularly in the dry season, additional water may be required to bring the moisture content to +2-3% OMC.

Given the natural water content measured in laboratory tests and the required moulding water content at compaction (2 to 3% wet of OMC) for low permeability, it is estimated that gravimetric water contents would need to be increased approximately 0% to 5% for driest soils. In terms of water volumes, approximately 30-40L per cubic meter on average would be required for water conditioning.

7.3.5 Shear Strength

Consolidated undrained triaxial shear strength testing (CU) was completed on samples SLR-NTP-02, SLR-NTP-04 and SLR-NTP-07 at standard compaction densities. Shear strength testing was conducted to provide information regarding bearing capacity and slope stability strength parameters. Tests were completed on samples remoulded at +0.2% to 0% of optimum moisture content and confining pressures of 550 kPa, 600 kPa and 700 kPa. The samples were selected as they were considered representative of in-situ materials likely to be encountered within the clay and growth borrow. Results are presented in **Appendix F**.

Table 37 Summary of triaxial results

Sample ID	MDD	+/- OMC	Remoulded Density (% of proctor)	Cohesion (c′)	Friction Angle (ϕ′)	% Fines	% Clay
NTP-06 1.80 m - 2.00 m Laterite	2.25 t/m^3	+0.2%	99% SDD	18 kPa	42	30%	16%
NTP-07 1.10 m - 1.70 m Laterite	1.88 t/m^3	-0.1%	100% SDD	11 kPa	35	52%	27%
NTP-07 3.70 m - 4.00 m Laterite	1.53 t/m^3	0.0%	100% SDD	7 kPa	24	92%	33%

It should be noted the presented results are representative of a 'best case scenario' for the shear strength properties of the soil. Good construction practice for placement of low permeability layers is to compact at moisture contents +2% to +3% wet of optimum. Increasing moisture content has a reducing effect on the shear strength properties of the soil.

7.3.6 Hydraulic Material Characterisation

Table 38 Hydraulic Conductivity Results

Sample ID	MDD	+/- OMC	Remoulded Density (% of proctor)	Permeability (k_{sat})	Fines	Clay	Gravel
NTP-02 0.80 m - 1.10 m Laterite	1.74 t/m^3	0.0 %	100% SDD	7.0×10^{-10} m/s	69%	49%	2%
NTP-06 1.80 m - 2.00 m Laterite	2.25 t/m^3	-1.0%	100% SDD	2.0×10^{-8} m/s	30%	16%	40%

Sample ID	MDD	+/- OMC	Remoulded Density (% of proctor)	Permeability (k_{sat})	Fines	Clay	Gravel
NTP-07 1.10 m - 1.70 m Laterite	1.88 t/m^3	-1.0%	100% SDD	7.0×10^{-9} m/s	52%	27%	19%

Tested materials returned results ranging on either side of the O'Kane's design specification permeability of $K_{sat}<1 \times 10^{-9}$ m/s. The most permeable result observed from NTP-06 sample coincides with the highest gravel (> 2.0mm) content and lowest clay content.

The result from NTP-07 is slightly more permeable than design requires, however it is envisioned placement wet of optimum moisture content is likely to reduce permeability. The hydraulic conductivity of a material is highly influenced by its moulding water content. It is well documented that material compacted wet of optimum water content typically achieves lower hydraulic conductivities [22], [23].

The result of NTP-07 may be used as guidance for the upper bound gravel content needed to achieve design permeability.

7.3.7 California Bearing Ratio

One sample collected by SLR as tested for California Bearing Ratio (CBR) using 4-day soak CBR test AS12896.1.1 compacted to 95% Standard Density. The result is summarised **Table 44** below.

Table 39 Borrow Area A California Bearing Ratio

Test Pit	Depth (m bgl)	CBR (%)	Swell (%)	Material
Clay and Growth Borrow Area				
SLR-NTP-06	1.80 – 2.00	35	0.0	Clayey Gravel; Laterite

7.3.8 Emerson Class

Twelve samples were submitted for Emerson Class analysis and one sample for pin-hole dispersion. The samples generally comprised of materials with a cohesive content greater than 30%. Most samples returned a non-dispersive Emerson Class value (5 or 6) and the pin-hole dispersion returned an ND2 (non-dispersive) result. Of the samples tested, two fell into Class 4 which is also generally non dispersive, however contains minor elements (such as gypsum) which are susceptible to erosion. Overall, the material recovered from this area of the site is still considered to have a low risk of dispersive soils.

7.3.9 Chemical Material Characterisation

Chemical material characterisation was completed on agronomy samples by ALS Laboratories. Agronomy samples were collected from four of the SLR geotechnical test pits (NTP-01, NTP-05 and NTP-07). Sample depths ranged from 0.6 m to 5.40 m below ground surface and comprised of 0.1 m to 0.20 m intervals per sample. Sample depths only contained one soil horizon. Detailed assessment of the environment chemistry are provided in the **Growth Material for Waste Rock Capping** in **Section 8**.

Soil Salinity Classification

Maximum values for EC, pH and ESP for samples tested were: 36µS/cm, 7.4 and 0.5 respectively. All of the samples tested were classified as "Normal" and considered non-sodic (**See Table 31**).

Cation Exchange Capacity

The cation exchange capacity (CEC) ranges from 37.9 to 3.6 meq/100g with an average of 15.7 meq/100g. As CEC increases, soils tend to become more structurally resilient in terms of aggregate development. Low CEC values suggest poor shrink-swell potential and high CEC values indicate good potential. In general, CEC values less than 20 meq/100g indicate soil will have poor shrink-swell potential and are more susceptible to erosion. CEC values between 20 and 40 meq/100g suggest soil has moderate shrink-swell potential and are more resistant.

For landfill design, clay with a CEC > 10 meq/100g is recommended for low permeability liner material [19]. The materials found across the Rum Jungle Clay Borrow Area is considered generally suitable.

7.3.10 Borrow Area A Material Characterisation Summary

The characterisation program performed has demonstrated that low permeability clays are available within the borrow area suitable for use in the Rum Jungle Rehabilitation works in accordance with O'Kane's material specification.

Table 40 Low Permeability and Starter Bunds Criteria (O'Kane's and Industry)

Characterisation Test	Meets Criteria	O'Kane's Material Specification
O'Kane's Material Specification		
% Clay	✓	Clay percentage > 10%
% Fines	✓	Fines percentage > 30%
% Gravel (4.75mm)	✓	Gravel (4.75mm) percentage < 50%
Atterberg Limits	✓	Plastic Index > 10
Saturated Permeability	✓*	$K_{sat} \leq 1 \times 10^{-9}$ m/s
Industry Recommendations for Low Permeability Layers		**Industry Recommendation for Low Permeability Liner Material**
Activity	✓	Activity > 0.5
Dispersivity	✓	Emerson ≥ 4 Pin Hole dispersion less dispersive or equal to ND2.
CEC	✓	CEC > 10 meq/100g

Notes: [*] Generally achieved for clay borrow materials placed at 100% SDD, however high granular contents correspond to increased permeability. Screening and placement of material wet of optimum likely required to reduce and homogenise permeability. The Author notes, permeabilities derived from laboratory tests are under values derived under ideal conditions and may not be reproducible in the field. Caution should be exercised in assuming laboratory values translate to placement permeabilities with scale field trials of low permeability layers advised.

7.4 Borrow Area B

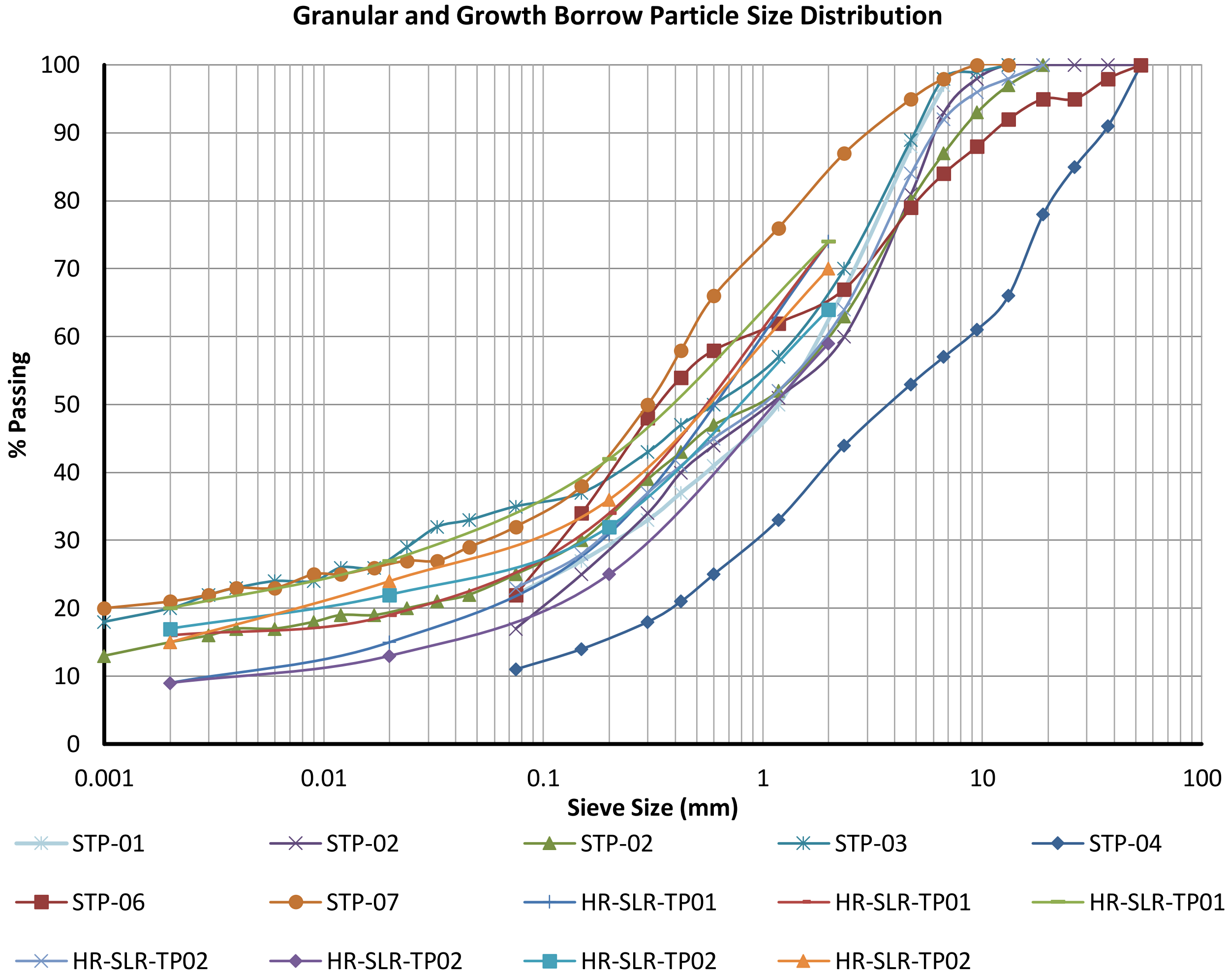
7.4.1 Particle Size Distribution

Compilation of PSDs relevant to the Granular and Growth Borrow from available data are provided below in **Table 41**, with compiled PSD curves shown in **Figure 31**. All samples tended to plot within the sandy GRAVEL to gravelly SAND brackets as shown in the curves and statistical breakdown below.

Table 41 Particle Size Distribution - Granular Borrow

Analyte	% Gravel	% Sand	% Fines
Count	14 Samples (14 x SLR)		
Mean	33	43	24
Maximum	56	55	35
Minimum	13	33	11
Standard Deviation	9.8	6.2	6.6

Figure 31 Compiled PSD Curves - Granular and Growth Borrow



7.4.2 Atterberg Limits

Two samples, SLR-TP-01 and SLR-TP-03 were tested for Atterberg Limits. Results indicate the fine materials within the soil matrix to have a low to medium plasticity.

7.4.3 Emerson Class

11 samples from the within and proximal to the Granular and Growth Borrow were submitted for Emerson Class analysis. Of the samples tested, eight returned Class 6, non-dispersive, two returned Class 5 non-dispersive material and one returned Class 4 which is also generally non dispersive, however contains minor elements (such as gypsum) which are susceptible to erosion. Overall, the material recovered from this area of the site is considered to have a low risk of dispersive soils.

7.4.4 Particle Density

Nine Particle density tests were performed on un-sieved material, and three tests were performed on samples passing 2.36 mm. Results of the Particle Density tests are provided below.

Table 42 Particle Density Test

Analyte	Particle Density (g/cm^3)		
Count	**7**	**3**	**1**
Mean	2.58	2.61	2.64
Maximum	2.68	2.63	-
Minimum	2.41	2.59	-
Standard Deviation	0.09	0.02	-

7.4.5 Hydraulic Material Characterisation

One falling head permeability test was performed in accordance with AS1289.6.7.1 on sample taken from SLR-STP-02.

Table 43 Hydraulic Conductivity Results

Sample ID	MDD	+/- OMC	Remoulded Density (% of proctor)	Permeability	Fines	Gravel
STP-02 1.40 m - 1.60 m	1.92 t/m^3	-1.0 %	98% SDD	4.0 x 10^{-7} m/s	17%	40%

7.4.6 Shear Characteristics

Direct shear box tests were performed on sample collected from Haul Road test pit SLR-HR-TP02. The test pit is proximal to the Granular and Growth Medium Borrow area and is considered representative of the material within the borrow. Material was sheared in its loose and saturated state for assessment as a bedding layer within the Main Pit. The sample was screened and tested at a maximum particle size of 3.15 mm and 1.18 mm. Peak friction angle returned a value of 40° to 43° and ultimate of 37° to 40° for -1.18 mm and 3.15 mm respectively. Further detail on the result is provided in the Haul Road Section 7.5.3.

7.4.7 California Bearing Ratio

Three samples collected by SLR were tested for California Bearing Ratio (CBR) using 4-day soak CBR test AS12896.1.1 compacted to 95% Standard Density. Compiled CBR results from the Granular Borrow are shown in **Table 44** below.

Table 44 Granular and Growth Borrow Area California Bearing Ratio

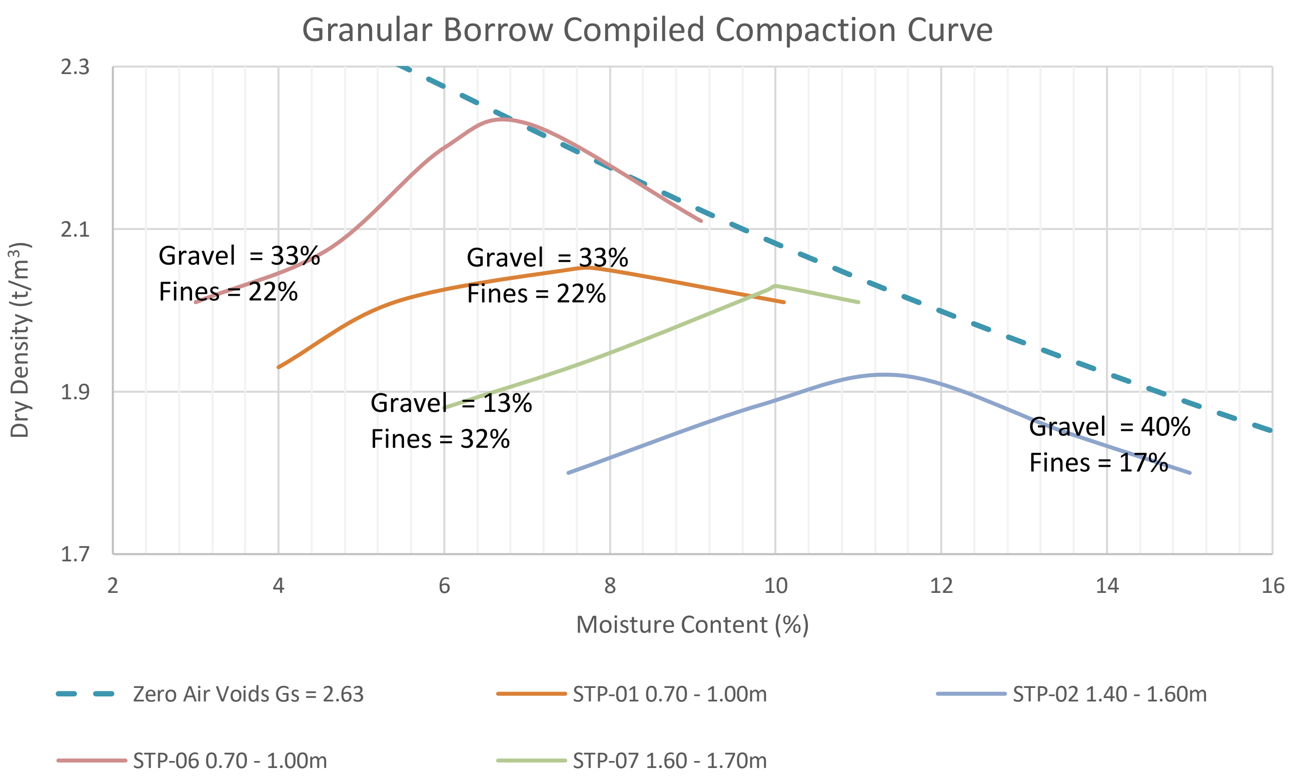
Test Pit	Depth (m bgl)	CBR (%)	Swell (%)	Material
Granular and Growth Borrow Area				
SLR-STP-01	0.70 – 1.00	30	0.5	Clayey Gravelly Sand; Residual
SLR-STP-06	0.70 – 1.00	40	0.0	Clayey Gravelly Sand; Residual
SLR-STP-07	1.60 – 1.90	20	0.0	Clayey Sand; Residual

7.4.8 Standard Compaction

Four samples from Granular Borrow area were submitted for proctor compaction testing. The results are presented in along with sample percentages for gravel and clay. In general the laboratory measured field moisture contents were found to be within -6.70 % to -0.1 % of Optimum Moisture Contents (OMC). Generally, the more granular the sample, the closer the material was to Optimum Moisture Content.

For the sample driest of OMC (-6.7%), approximately 200L per cubic meter is required to bring the sample to OMC. However, based on the laboratory results, for materials to be re-used and placed at OMC, it is anticipated that only a small water addition would be required for construction so long as excavated soils were managed correctly and prevented from drying out. If soil is stockpiled for a prolonged period, particularly in the dry season, additional water may be required.

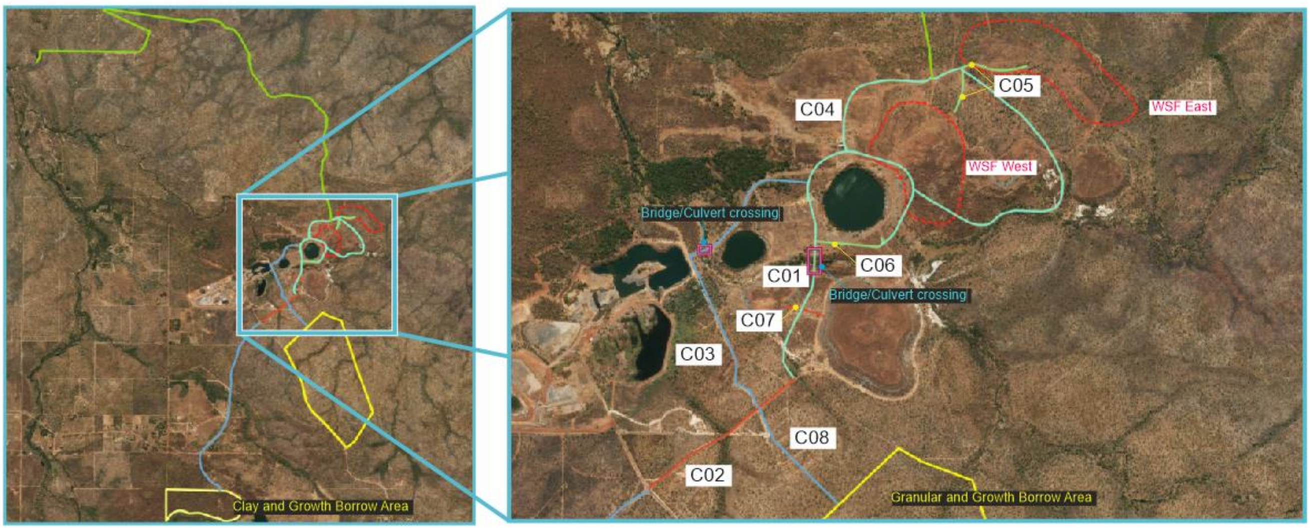
Figure 32 Granular and Growth Borrow Area Compaction Curve



7.5 Haul Road Alignment

At the time of writing, the haul road alignment was preliminary in design with the final alignment to be optimised pending final Waste Storage Facility alignment and ancillary infrastructure placement. For the purpose of assessment, test pits were performed along the preliminary alignment to serve as guidance for the final design.

Figure 33 Preliminary Haul Road Alignment



Given the geospatial expanse of the proposed haul road alignment, several test pits performed for borrow areas and WSF storage can also be used to inform road design.

7.5.1 Particle Size Distribution

Four samples collected by SLR specific to the road alignment were analysed for particle size distribution (PSD). One from road section C01 (**Figure 33**) (HR-SLR-TP04), two from proposed bridge crossings on C01 (HR-SLR-TP06B) and C03 (HR-SLR-TP09A) and one from the Granular Borrow haul road C08 (HR-SLR-TP02).

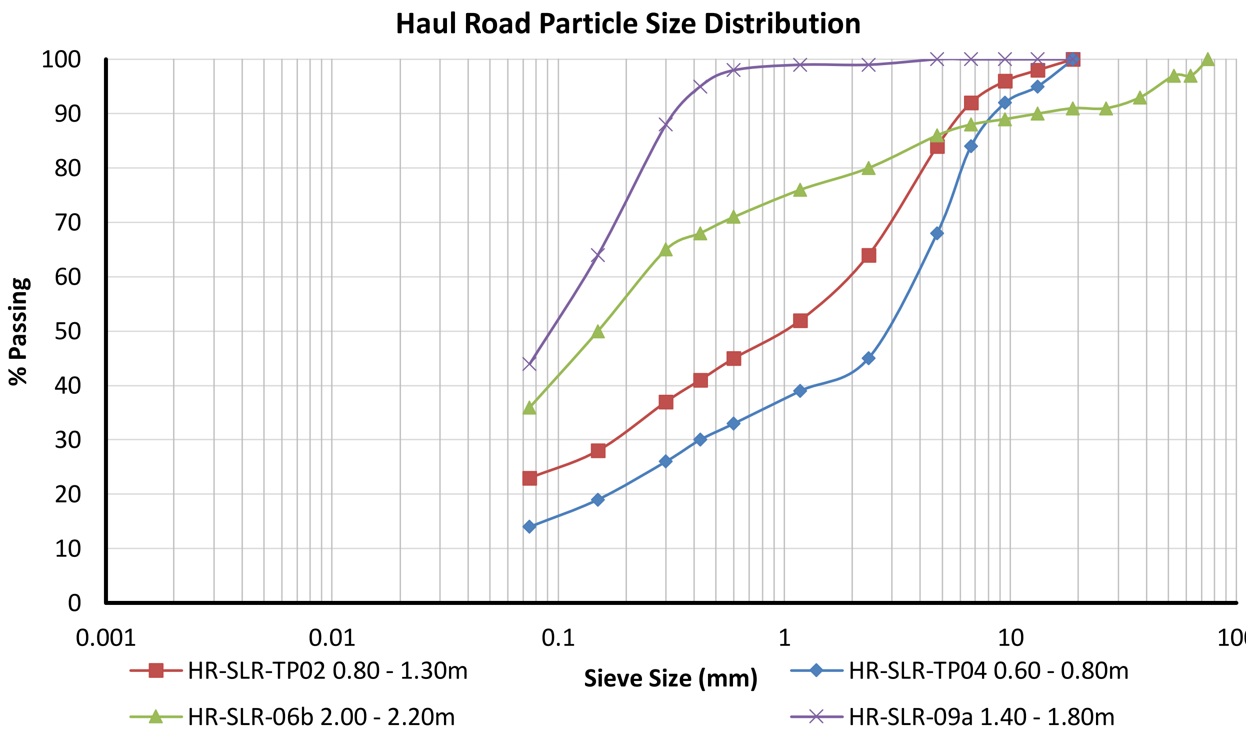
Statistical assessment of the PSDs is provided below in **Table 45** below. Compiled PSD curves are shown in **Figure 34**.

Table 45 Particle Size Distribution - Haul Road Alignment

Analyte	% Gravel	% Sand	% Fines
Count	**9 Samples**		
Mean	20	46	33
Maximum	55	55	44
Minimum	1	31	14
Standard Deviation	38.4	21.8	16.7

Test pits performed at proposed bridge/culvert crossings (HR-SLR-TP06B and 09A) generally encountered thick alluvium deposits. PSD results indicate the analysed samples to comprise of gravel between 20% and 1% sand between 44% and 55% and 36% to 44% fines, respectively. This is consistent with silty SAND to sandy CLAY field descriptions given.

Figure 34 Compiled PSD Curves - Haul Road Alignment



Based on the O'Kane's haul road material requirements, generally, site won granular materials from the Haul Road and Borrow Area B would be suitable as a base course and sub-base course. For wearing course, generally some minor blending volumes (>10% by weight) of larger particles (>25mm) and screening of fine sized particles would be required to bring site won material from the Rum Jungle site and Borrow Area B up to material requirements.

7.5.2 Atterberg Limits

One sample taken from the Haul Road test pits was submitted for Atterberg Limits analysis. HR-SLR-TP06B retuned a liquid limit of 26% and Plastic Index of 6%. Unified Soils Classification System (USCS) classifies the material as a low plasticity clay or silt (CL and ML). This is in line with recent field observations.

7.5.3 Shear Strength

One sample (HR-SLR-TP02) was tested for shear strength properties using the direct shear box method. The same sample was tested twice for material passing 3.00mm particle size and 1.00mm particle size. Each test was confined at 50kPa, 75kPa and 150kPa. Each sample was tested in its loose state as poured into the shear box and sheared in a saturated state. Given the test pit location, the sample is considered representative of material within the Granular and Growth medium Borrow area.

Table 46 Shear Box Results

Sample ID	Dry Density	Cohesion (c’)	Friction Angle -Peak (ϕ’)	Friction Angle – Ultimate (ϕ’)	% Fines	Maximum Sieve Size Material Passing
HR-SLR-TP02 0.80 m - 1.30 m	1.30 t/m^3	0 kPa	43°	43°	23%	3.15 mm
HR-SLR-TP02 0.80 m - 1.30 m	1.14 t/m^3	0 kPa	40°	37°	23%	1.18 mm

7.5.4 California Bearing Ratio

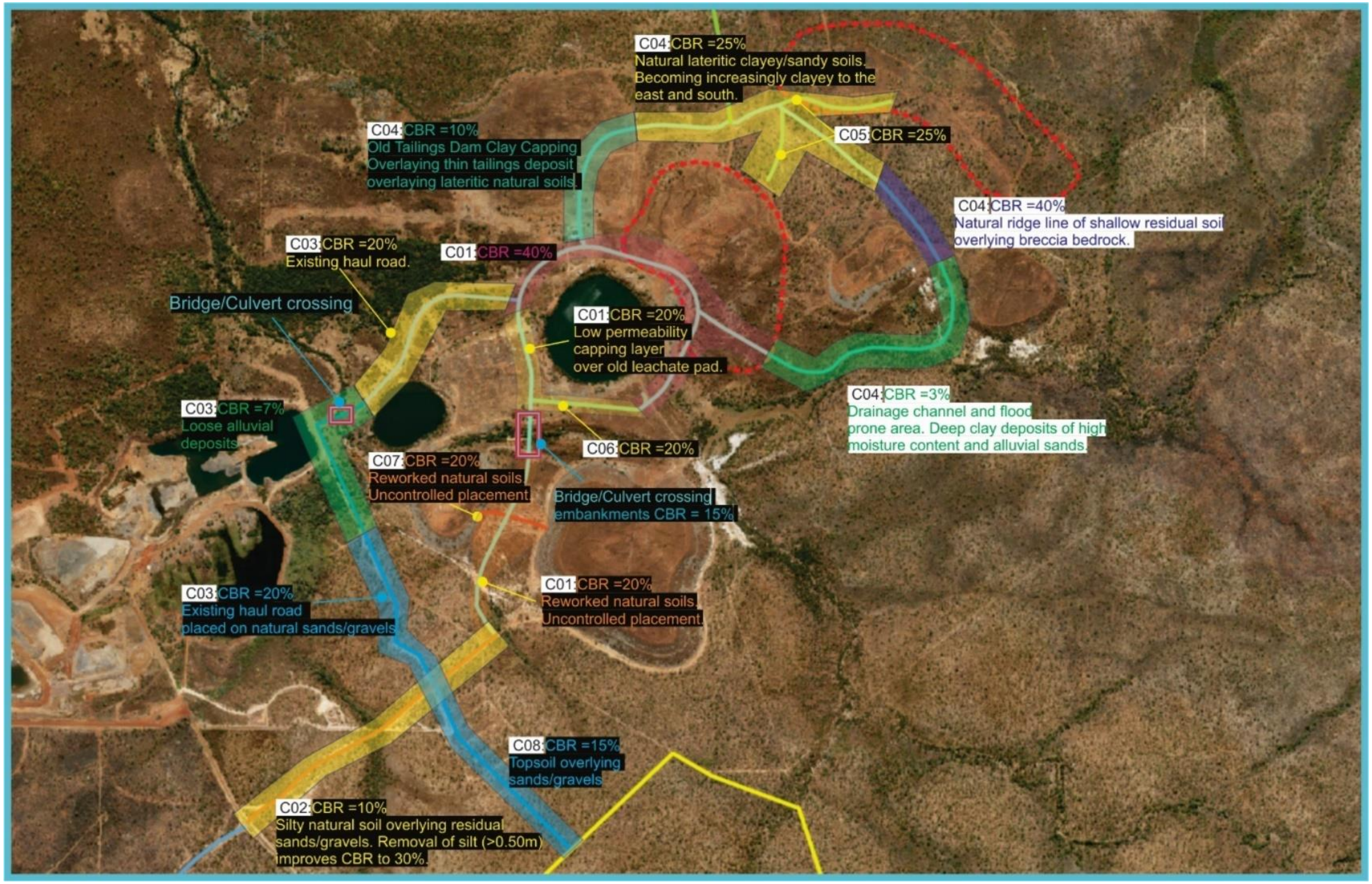
Three samples along the haul road alignment collected by SLR (HR-SLR-TP04, 06B and 09A) were tested for California Bearing Ratio (CBR) using 4-day soak CBR test AS12896.1.1 compacted to 95% Standard Density. For the purpose of comparison, compiled CBR results from the Rum Jungle site, Granular Borrow and Clay Borrow are also included in **Table 47** below.

Table 47 Compiled Laboratory California Bearing Ratio 4-Day Soak

Test Pit	Depth (m bgl)	CBR (%)	Swell (%)	Material
Haul Road				
HR-SLR-TP04	0.60 – 0.80	40	0.0	Sandy Gravel with Clay; Fill
HR-SLR-TP06b	2.00 – 2.20	25	0.0	Clayey Sand; Alluvium
HR-SLR-TP09a	1.40 – 1.80	40	0.0	Silty Sand; Alluvium
Rum Jungle Site				
SLR-WRTP-06	0.70 – 1.00	45	0.0	Clayey Sandy Gravel; Laterite
SLR-WRTP-17	0.80 – 1.20	60	0.0	Silty Gravelly Sand; Laterite
SLR-WRTP-17	3.10 – 3.20	20	0.0	Silty Sandy Gravel; Laterite
Granular and Growth Borrow Area				
SLR-STP-01	0.70 – 1.00	30	0.5	Clayey Gravelly Sand; Residual
SLR-STP-06	0.70 – 1.00	40	0.0	Clayey Gravelly Sand; Residual
SLR-STP-07	1.60 – 1.90	20	0.0	Clayey Sand; Residual
Clay and Growth Borrow Area				
SLR-NTP-01	1.80 – 2.00	35	0.0	Sandy Clay w Gravel; Laterite

Utilising the in-situ Dynamic Cone Penetration Results (**Section 5.7.2**) along with the compiled laboratory results for reference, an interpreted CBR map has been created for the preliminary haul road alignment. The CBR values provided are based on lower bound values obtained from in-situ DCP testing and derived using the US Army Corps empirical correlation between DCP and CBR values as determined by Webster [24]. The CBR values stated in **Figure 35** are provided on the assumption undesirable material such as topsoil, organic matter and silts are removed.

Figure 35 In-situ CBR Map



7.6 Aldebaran Quarry

As part of the Aldebaran Quarry site walkover assessment, surface grab samples of representative rock were submitted for petrographic assessment, point load testing and sodium sulphate soundness testing. The results are discussed below.

7.6.1 Petrographic Assessment

One sample, Q-SLR-GS04, was sent for petrographic analysis to confirm the rock type and composition and assess its suitability as a rock armour material. The sample was identified as a hard, strong, porphyritic micro-granite. Its composition was quartz, orthoclase feldspar and plagioclase feldspar in approximately equal proportions with 8% minor constituents including biotite, muscovite, chlorite, limonite, epidote and oxides.

Figure 36 Q-SLR-GS04 Sample

Crystal grains ranged from 0.1 mm to 0.5 mm with phenocrysts between 1mm to 2 mm. Quartz phenocrysts indicate metamorphism as they are formed of aggregates of finer crystals.

Approximately 9% of the composition is weak or non-durable secondary minerals. The Northern Territory Standard Specification for Road Maintenance (DIPL) recommends a maximum 25% content of secondary material for aggregate.

The petrographic report published by Geochempet Services is presented in **Appendix F**.

7.6.2 Point Load Testing

Four samples were sent for point load testing to determine the rock strength. Four irregular lump samples (approximately fist size) collected from outcrops recorded point load strength ($Is_{(50)}$) values between 2.72 MPa and 14.26 MPa which correlates to Unconfined Compressive Strength (UCS) of 65 MPa and 342MPa respectively. The point load strengths categorise the rock as high to very high strength. The highest and lowest values were recorded on the same sample, Q-SLR-GS03.

7.6.3 Sodium Sulphate Soundness

Three samples, Q-SLR-GS03 and 04, were submitted for sodium sulphate soundness testing. Q-SLR-GS04 recorded 0.5% weight loss which is considered very low degradation. Sample Q-SLR-GS03 recorded 50.1% weight loss after analysis. A second test was performed on Q-SLR-GS03 to confirm the result, with a returned value of 13.1% weight loss.

7.6.4 Aldebaran Quarry Rock Durability Assessment

Reference to applicable guidelines for rock armouring, including, AS2758.6:2019 '*Guidelines for the Specification of Armourstone', NSW Roads and Maritime Services Specification Guide R44* granite rock is generally considered a durable material and suitable as an erosion protection amour. It is noted, as part of AS2758 guidelines, a point load strength of >8 MPa is recommended, however consideration to the application must be given, AS2758 is orientated towards sea breakwalls and is considered overly conservative for the Rum Jungle application. A point load strength of $Is_{(50)}$ >8 MPa is considered "excellent". Other authorities provide alternate strength recommendations, example is the NSW Roads and Maritime requirement of $Is_{(50)}$> 1 MPa point load strength and engineering application such as the Noosa Scour Protection rock armouring specification requirement of $Is_{(50)}$ > 3.5 MPa. The petrographic and geotechnical analysis suggest the granite within the Aldebaran Quarry may be suitable as an armouring material, however it is recommended further testing be conducted to confirm its suitability.

Table 48 Aldebaran Quarry Rock Suitability Assessment

Parameter	Recommendation	Aldebaran Quarry Granite
Point Load Strength ($Is_{50)}$)	> 3 MPa	2.21 MPa to 8.26 MPa (average = 5.2 MPa)
Sulfate Loss	< 6%	0.5% – 50.1%
Dry Density	> 2.6 t/m3	Not tested
Water Absorption	< 1.5%	Not tested

8 Growth Material for Waste Rock Capping

The purpose of this section of the report is to develop a purpose-designed growth material to cover the new WSFs. The growth material is to provide a long-term, sustainable growing medium for selected native revegetation species. It is also to provide a reduced likelihood of, equal to or better than baseline for the area, sheet, rill, and gully erosion over the proposed life of the WSFs capping. The growth material will need to provide for moderately rapid stormwater infiltration and be moderately permeable to reach field capacity but also have sufficient clay content to provide some structure, water holding capacity, and mineral exchange and nutrient adsorption capacity to support revegetation with, and long-term sustainability of, native shrubs and grasses.

8.1 Historical Soil and Land Resource Information

8.1.1 Land Systems of the Northern Part of the Northern Territory

The *Land Systems of the Northern Part of the Northern Territory* [25] is an amalgamation of some 16 existing land system surveys covering the northern portion of the Northern Territory. The land system approach provides a broad-scale representation of the main features of the landscape, which are based on detailed information collected at specific field sites.

The Project site and specific areas are located across the land systems described in **Table 49** and shown on **Figure 37.**

These land systems provide an indication of the geology, terrain, soils and vegetation characteristics and associations that may guide design and characterization of the WSFs capping growth material.

8.1.2 Soil and Land Information Soil Profile Descriptions

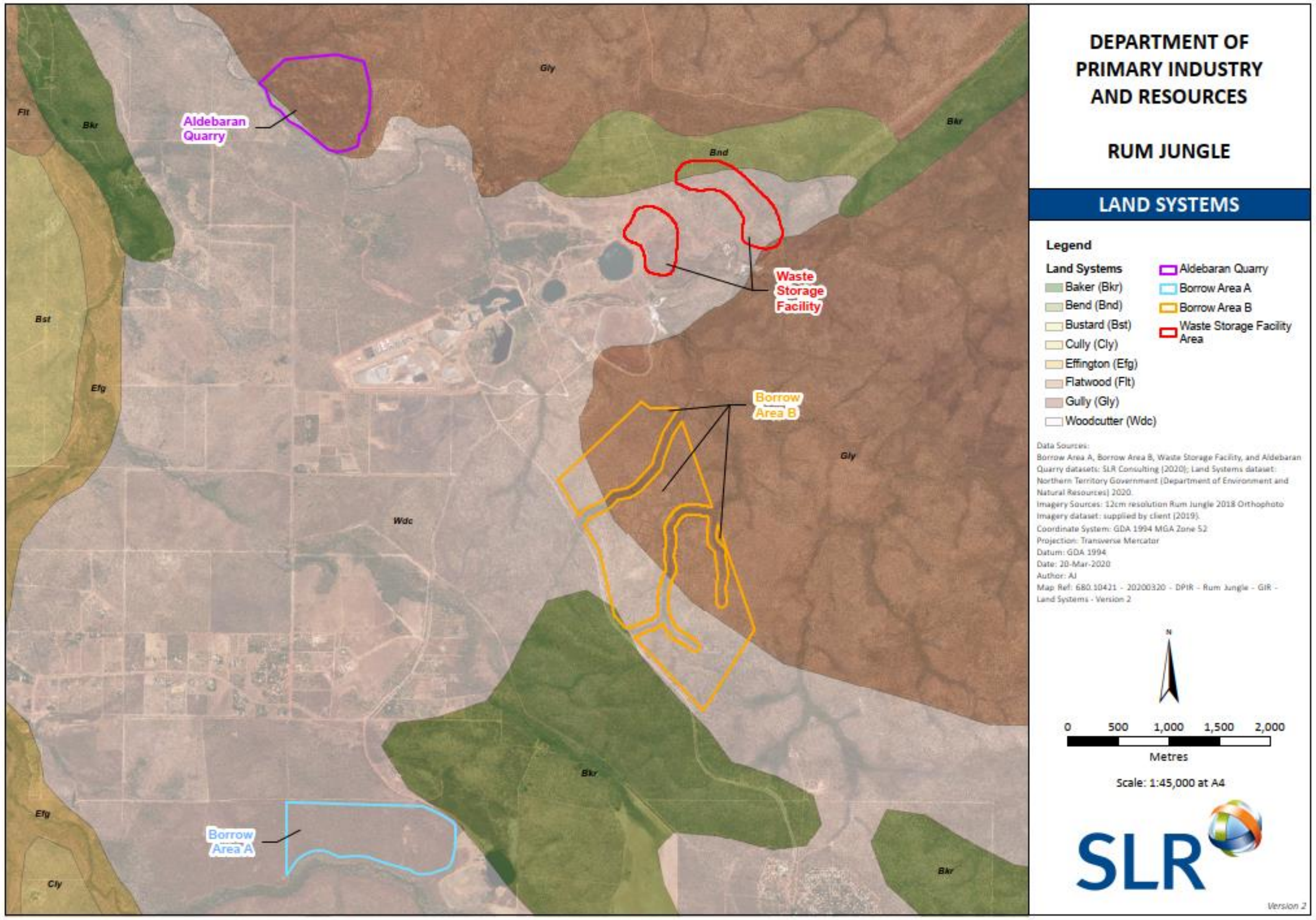
The Northern Territory Department of Environment and Natural Resources maintains a database of soil profile information from all soil surveys, which is referred to as the Soil and Land Information (SALI) database. Accessing this database provided representative soil profile descriptions within and immediately surrounding the Project site in the dominant land systems described in **Table 49** and shown on **Figure 37** that the Project site is primarily located in. These being Woodcutter (Wdc) and Gully (Gly) land systems.

Table 49 Land Systems of Project Site

Land System	Geological Zone	Landscape Class	Landscape Class Description	Landform Description	Original Soil Description	Australian Soil Classification	Vegetation Description	Specific Areas
Baker (Bkr)	Pine Creek	Sandstone hills	Low hills, hills and stony plateaux on sandstone, siltstone, quartzite and conglomerate (deeply weathered in places); outcrop with shallow stony soils	Rugged hills and strike ridges with intervening narrow valleys and short lower slopes on folded Burrels Creek greywacke, sandstone and siltstone	Skeletal soils and outcrop with minor sandy red and yellow gradational soils	Leptic Rudosols, shallow Yellow and Brown Kandosols	Mid-high woodland of C. dichromophloia, E. miniata, C. bleeseri, E. tectifica and C. terminalis over Sorghum spp, Themeda triandra and Chrysopogon spp	Very thin margin of southwestern edge of Borrow Area B. Very thin margin of northeastern edge of Borrow Area A.
Bend (Bnd)	Pine Creek	Sandstone plains and rises	Plains, rises and plateaux on mostly on sandstone, siltstone, claystone, shale and some limestone; commonly shallow soils with surface stone and rock outcrop	Undulating low strike ridges and rises on folded Burrels Creek greywacke, sandstone and siltstone	Skeletal soils and shallow gravelly loams	Shallow Yellow and Brown Kandosols and Leptic Rudosols	Mid-high woodland of *C. latifolia*, *C. foelscheana*, *E. polysciadia*, *E. tectifica*, *Erythrophleum chlorostachys* over tropical tall grass (*Sorghum* spp, *Heteropogon* spp, *Chrysopogon* spp)	Northwestern portion of Eastern WSF
Gully (Gly)	Pine Creek	Granite plains and rises	Gently undulating to undulating plains with rises and low hills on granite, schist, gneiss (deeply weathered in places); coarse grained sandy, earthy and texture contrast soils	Undulating terrain developed on granite, schist, and gneiss	Red massive earths and mottled yellow duplex soils	Red Kandosols and Yellow Chromosols	Woodland of C. confertiflora, C. foelscheana, Erythrophleum chlorostachys, Terminalia canescens, Petalostigma spp over perennial grasses (Heteropogon triticeus, Themeda australis, Sorghum plumosum)	Northeastern half of Borrow Area B. Far southeastern portion of Eastern WSF

Land System	Geological Zone	Landscape Class	Landscape Class Description	Landform Description	Original Soil Description	Australian Soil Classification	Vegetation Description	Specific Areas
Woodcutter (Wdc)	Pine Creek	Sandstone plains and rises	Plains, rises and plateaux on mostly on sandstone, siltstone, claystone, shale and some limestone; commonly shallow soils with surface stone and rock outcrop	Very gently upland surface; probably developed on Tertiary sediments overlying carbonate-rich Lower Proterozoic rocks	Deep red massive earths and yellow massive earths	Deep Red and Yellow Kandosols	Mid-high woodland of Erythrophleum chlorostachys, E. miniata, C. confertiflora, C. papuana, Petalostigma spp over perennial grasses (Heteropogon triticeus, Chrysopogon latifolius, Imperata cylindricus)	Majority of Eastern WSF All of Western WSF Most of southwestern half of Borrow Area B. Majority of Borrow Area A.

Figure 37 Land Systems of the Project Site



The dominant soils across these land systems appear to be Kandosols that tend to occur on very gently undulating plains, rises and plateaus. The final landforms proposed for the WSFs should be consistent with these landforms and, therefore, these soils should be most suitable to replicate for the growing medium over the capping on the WSFs. Representative profile examples of Kandosols from the surrounding landscape are shown in **Appendix H** with available historical laboratory data shown in **Appendix I.**

Aside from being dominant soils in the general landscape, Kandosols are considered a suitable growth medium for the following reasons:

- They tend to be deeply weathered profiles, which are suitable for the tropics
- They have a sandier texture and good humus content in the surface horizon that provide for moderately rapid stormwater infiltration due to lack of surface crusting or hard setting properties
- They have gradually increasing clay contents that provide for good water retention and cation exchange capacity
- They have deep, less consolidated (massive to weak structure) profiles suitable for deep root penetration by grasses and shrubs (but not so deep as to penetrate a clay capping) and are moderately permeable
- They have moderately high humus and organic carbon levels as a result of good vegetation growth that in turn improves surface horizon texture and structure.

Should replication of the Kandosol soil prove problematic, the preference would be to replicate a Dermosol soil, which has a fraction more clay throughout the profile and a structure that is weak to moderate.

8.2 Characteristics of Landforms

Landforms surrounding the Project site are strongly influenced by surface geology, faulting and folding, and climate (typically, a monsoonal wet season from November to March and dry season from May to September). Based on the land systems and SALI database information, landforms surrounding the Project site appear to largely comprise:

- Plateaus with relatively flat (<9 m relief, 0-1% slopes) to gently undulating (<30 m relief, 1-3% slopes) surfaces that abruptly downslope become either short, cliffed (>300%), precipitous (100-200%) and/or very steep (56-100%) slopes, usually rocky, or steep (32-56%) and/or moderately inclined (10-32%) slopes, that grade to gently inclined (3-10%) followed by very gently inclined (1-3%) slopes that level off on flat (0-1%) to very gently undulating (1-3%) plains. Slopes are intersected by shallow and relatively level drainage depressions on the plateaus that become steep gullies, as they drop off the plateaus, that gradually flatten with the concave landform to become streams, creeks and rivers meandering through the landscape.
- Ridges with cliffed (>300%), precipitous (100-200%) and/or very steep (56-100%) slopes, usually rocky, concavely grading to steep (32-56%) and/or moderately inclined (10-32%) slopes, that grade to gently inclined (3-10%) followed by very gently inclined (1-3%) slopes that level off on flat (0-1%) to very gently undulating (1-3%) plains. Slopes are intersected by steep gullies from ridges that gradually flatten with the concave landform to become streams, creeks and rivers meandering through the landscape.
- Gently undulating to rolling low hills (<30 m relief, <10% slopes) with crests that are smoothly convex, flat (0-1% slopes) to very gently inclined (1-3% slopes) convexly grading into gently inclined (3-10%) slopes and terminating on the bank of a drainage feature.

Based on the above, the preferred landform for the new WSFs would be a plateau to low hill with relatively flat (0-1%) grading to gently inclined (1-3%) slopes (convex crest) that relatively rapidly increases to a moderately inclined (10-32%) slope that grades to gently inclined (3-10%) followed by very gently inclined (1-3%) slopes (concave slope) as it grades into natural ground landform conditions.

Drainage off the preferred landform would be sheet flow as much as is practicably possible to minimise concentrated flows creating rills and gullies.

8.3 Characteristics of Kandosols

In accordance with the *Australian Soil Classification* (ASC) (Isbell & NCST, 2016), Kandosols are soils that lack strong texture contrast, have massive or only weakly structured B horizons, and are not calcareous throughout. More specifically, these soils have all of the following characteristics:

- B2 horizons in which the major part is massive or has only weak grade of structure
- A maximum clay content in some part of the B2 horizon which exceeds 15% (i.e. heavy sandy loam, SL+)
- Do not have a tenic B horizon
- Do not have a clear or abrupt textural B horizon
- Are not calcareous throughout the solum, or below the A1 or Ap horizon or a depth of 0.2 m if the A1 horizon is only weakly developed.

Based on the representative profile examples of Kandosols from the surrounding landscape, as shown in **Appendix H**, and the available historical laboratory data, as shown in **Appendix I**, the general characteristics of a Kandosol for the growth material should be similar to those detailed in **Table 50**.

Table 50 Generalised Characteristics of Kandosol Soil Profile

Attribute	Description
Slope:	<2% (but can be considerably steeper depending on specific surface texture, depth, vegetative cover and other factors)
Runoff:	Slow to moderate
Permeability:	Moderately to highly permeable
Drainage:	Imperfectly to well-drained
Surface rock:	0%
Horizon:	A1
Depth:	From 0 to 0.1-0.2 m
Texture:	Sandy loam to sandy clay loam (refer to NCST, 2009, pp164-166)
Colour:	Dark brown (may tend reddish or yellowish)
Fabric:	Earthy
Pedality:	Massive
pH:	Range from 4.5 to 5.5
EC:	At least 10 µS/cm
Chloride:	<10 mg/kg
CEC:	At least 5.0 cmol+/kg
Exch. Sodium % (ESP):	Non-sodic
Ca:Mg ratio:	>1
Total P:	At least 50 mg/kg
Bicarb Extr. P:	At least 20-40 mg/kg

Attribute	Description
Total Kjeldahl N:	At least 150-250 mg/kg
Total Organic Carbon:	At least 1.5-2.5%
Sulfur:	<10 mg/kg
Horizon:	A2
Depth:	From 0.1-0.2 to 0.2-0.6 m
Texture:	Loam to clay loam, sandy (refer to NCST, 2009, pp164-166)
Colour:	Brown (may tend reddish or yellowish)
Fabric:	Earthy
Pedality:	Massive
pH:	Range from 5.0 to 6.0
EC:	At least 10 µS/cm
Chloride:	<10 mg/kg
CEC:	At least 5.0 cmol+/kg
Exch. Sodium % (ESP):	Non-sodic
Ca:Mg ratio:	>1
Total P:	At least 50 mg/kg
Bicarb Extr. P:	At least 20-40 mg/kg
Total Kjeldahl N:	At least 150-250 mg/kg
Total Organic Carbon:	At least 1.5-2.5%
Sulfur:	<10 mg/kg
Horizon:	B21
Depth:	From 0.2-0.6 to 0.4-1.0 m
Texture:	Sandy clay loam to light clay (refer to NCST, 2009, pp164-166)
Colour:	Strong brown (may tend red or yellow)
Fabric:	Earthy
Pedality:	Massive to weak
pH:	Range from 5.0 to 6.0
EC:	At least 2 µS/cm
Chloride:	<20 mg/kg
CEC:	At least 5.0 cmol+/kg
Exch. Sodium % (ESP):	Non-sodic
Ca:Mg ratio:	>1
Horizon:	B22
Depth:	From 0.4-1.0 to 0.8-1.6 m
Texture:	Clay loam, sandy to light medium clay (refer to NCST, 2009, pp164-166)
Colour:	Strong brown (may tend dark red or yellow)
Fabric:	Earthy
Pedality:	Massive to moderate
pH:	Range from 5.0 to 6.0
EC:	At least 5 µS/cm
Chloride:	<50 mg/kg
CEC:	At least 5.0 cmol+/kg
Exch. Sodium % (ESP):	Non-sodic
Ca:Mg ratio:	>1

8.4 Identification of Suitable Materials for the Growth Material

Although a Kandosol replication is proposed for the growth material, the soil profile will be classified as an Anthroposol, in accordance with the ASC (Isbell & NCST, 2016). Anthroposols are described under the ASC as soils that result from human activities that have caused a profound modification, mixing, truncation or burial of the original soil horizons, or the creation of new soil parent materials.

The intent of the design is to utilize naturally occurring layers of material that are inherently suitable for specific horizons of the growth material. Where this is not possible to source in the first instance to the maximum volume required, the deficit may be made up by combining appropriate proportions of other naturally occurring layers of material to meet the desired horizon texture specifications.

Geotechnical field logs within the Borrow Areas A and B were referenced to identify the potentially most suitable layers to form the growth material. Laboratory analytical results for selected samples collected from representative test pits were also referenced to further inform the identification of suitable layers. As the geotechnical field logs were based on the Unified Soil Classification System (USCS) for classifying the proportions of clay, silt, sand and gravel present in each pit layer, interpretation of the data was approximated to the Australian field texture classes described in the *Australian Soil and Land Survey Field Handbook* (NCST, 2009) based on clay, silt and sand fractions only and excluding the gravel fraction. These approximate interpretations were supported by the physical laboratory analytical results for the selected samples that were analysed for most of the following agronomical parameters for each sample:

- pH $_{(1:5\ water)}$ and pH $_{(CaCl2)}$
- Electrical conductivity
- Chloride
- Acid neutralizing capacity
- Cation exchange capacity, exchangeable cations and acidity, calcium: magnesium ratio and exchangeable sodium percentage (ESP)
- Emerson aggregate test
- Particle size distribution
- Bicarbonate extractable potassium
- Sulfur
- Silicon
- Boron
- Extractable metals (Cu, Fe, Mn, Zn)
- Trace metals (arsenic, barium, beryllium, boron, cadmium, chromium, cobalt, copper, lead, manganese, nickel, selenium, vanadium and zinc)
- Mercury
- Hexavalent chromium
- Cyanide
- Nitrogen (ammonia, nitrite, nitrate, total Kjeldahl and total)

- Phosphorus (total and bicarb. extract.)
- Total carbon, total organic carbon and organic matter
- Carbon: nitrogen ratio.

The chemical laboratory analytical results for the selected samples provided for determining whether there were likely to be any highly unsuitable materials to be avoided as specific layers within the growth material. Generally, it appears through this random selection of samples from a range of test pits that the majority of the soil materials with suitable texture classes will not have unsuitable chemical compositions for creating a Kandosol-equivalent soil. The laboratory analytical results are presented in **Appendix J**.

Although the soil materials will not likely have unsuitable chemical compositions, this does not mean that they will not be deficient in certain nutrients and minerals to support vegetative growth. Ameliorants will be required, applied either during stockpiling and blending of suitable materials for the specific horizons of the Kandosol-equivalent growth medium or following placement of each horizon of the Kandosol-equivalent soil material.

8.5 Suggested Soil Sources to Create Kandosol-Equivalent (Anthroposol) Growth Material

It appears from this desktop review of geotechnical field logs and laboratory analytical results that there should be sufficient volumes of material of suitable quality to replicate the soil profile of a Kandosol to a depth of 2m over the WFSs.

Appendix K presents a table of available horizon volumes from the borrow areas against the required volumes for the growth medium capping based for various depths and slope areas (note, slope areas are still under investigation at the time of reporting as part of SLRs erosion assessment).

The results indicate that for the most part, replication can be achieved be by targeting layers that are considered to match the required physical parameters for each horizon of the growth medium; however, there may need to be some mixing of different materials for make up any deficit, particularly for the surface (A1 and A2) horizons. The calculations of potential available volumes of materials is on the basis of assuming the material available within each layer of each geotechnical bore hole is representative for a nominal area around each geotechnical bore hole. As such there is potential for an inherently large error in these calculations; however, given there appears to be substantially more material available than required overall, the potential error should be offset.

Based on the above characteristics of a Kandosol soil, it is suggested that the most appropriate soil materials listed in **Table 51** be used at the depths specified, or adjacent depth, to create the Kandosol-equivalent (Anthroposol) growth material for the WSFs capping. Note the potential sources are not listed in any priority order for each layer, rather they should be further field assessed on site at the time of excavation as to their actual suitability. Advice is provided on how to undertake this in **Section 8.7**.

The suggested sources are indicative for the Kandosol-equivalent growth material depth. These will need to be modified should a Dermosol-equivalent growth material be developed instead. Actual source and depth of placement should be dictated by increasing proportion of clay with depth based on soil texture classification and commensurate increase in plasticity to no more than medium plasticity, preferably low plasticity at 100-200 cm. This means potential sources could be moved one layer up or down where multiple sources in one layer demonstrate slightly higher or lower clay content and plasticity, where appropriate, such that they can provide the gradual increase in soil texture classification throughout the Kandosol-equivalent growth material. Where possible, gravel content is to be limited to the greatest extent practicable, in particular rocky material regarded as cobbles (60-200 mm) or greater and especially in the surface horizons (A1 and A2).

Table 51 Suggested Soil Sources to Create Kandosol Growth Material

Kandosol Growth Material Layers by Depth from Surface (cm)	Potential Soil Sources			Soil Texture Classification	
	Borrow Area	Site	Source Depth (cm)	Approximate USCS	NCST (2009) (Preferred, Excluding Gravel)
0-20 (A1 horizon) and 20-60 (A2 horizon)	A	NTP-05	0-10	Clayey Silty Sand to Silty Clayey Sand, Non-Plastic	Sandy Loam (SL), Sandy Clay Loam (SCL) to Clay Loam, Sandy (CL,S)
		NTP-07	0-20		
		DPIR-TP-01	0-20		
		DPIR-TP-03	0-20		
		DPIR-TP-04	0-20		
		DPIR-TP-06	0-10		
		DPIR-TP-06	350-480		
		GHD TP-01	0-15		
		GHD TP-01_B	0-10		
		GHD TP-02_B	0-10		
		GHD TP-04	0-10		
		GHD TP-05	0-5		
		GHD TP-05_B	0-5		
		GHD TP-06	0-10		
		GHD TP-07	0-10		
		GHD TP-08	0-10		
		GHD TP-09	0-20		
		GHD TP-16	0-15		
		GHD TP-17	0-10		
		GHD TP-18	0-10		
		GHD TP-19	0-10		
		GHD TP-20	0-20		
	B	SLR-TP-05	0-20		
		SLR-TP-06	0-20		
60-120 (B21 horizon)	A	NTP-01	0-20	Clayey Sandy Silt to Sandy Clayey Silt, Very Low to Low Plasticity	Clay Loam, Sandy (CL,S) to Sandy Light Clay (SLC)
		NTP-02	0-20		
		NTP-06	280-310		
		DPIR-TP-01	20-40		
		DPIR-TP-01	200-400		

Kandosol Growth Material Layers by Depth from Surface (cm)	Potential Soil Sources			Soil Texture Classification	
	Borrow Area	Site	Source Depth (cm)	Approximate USCS	NCST (2009) (Preferred, Excluding Gravel)
		DPIR-TP-02	20-60		
		DPIR-TP-04	20-210		
		DPIR-TP-04	420-500		
		DPIR-TP-05	250-450		
		DPIR-TP-06	10-350		
		GHD TP-01	15-95		
		GHD TP-01	95-210		
		GHD TP-01_B	10-220		
		GHD TP-02	120-220		
		GHD TP-02_B	10-200		
		GHD TP-02_B	340-440		
		GHD TP-04	10-230		
		GHD TP-05	5-60		
		GHD TP-05	60-190		
		GHD TP-06	10-210		
		GHD TP-07	10-250		
		GHD TP-08	10-280		
		GHD TP-09	20-260		
		GHD TP-16	15-210		
		GHD TP-17	10-155		
		GHD TP-18	10-170		
		GHD TP-19	10-220		
		GHD TP-20	20-40		
	B	SLR-TP-01	60-430		
		SLR-TP-02	60-200		
		SLR-TP-03	60-330		
		SLR-TP-05	20-160		
		SLR-TP-07	80-290		
120-200 (B22 horizon)	A	NTP-05	10-100	Silty Sandy Clay to Sandy Silty Clay, Low to Medium Plasticity	Sandy Light Clay (SLC) to Sandy Light Medium Clay (SLMC)
		NTP-06	310-400		
		NTP-07	80-100		
		DPIR-TP-01	40-200		
		DPIR-TP-02	60-500		
		DPIR-TP-03	20-310		
		GHD TP-01_B	220-480		
		GHD TP-02_B	200-340		
		GHD TP-06	210-250		
		GHD TP-06_B	140-170		
		GHD TP-15	200-220		
		GHD TP-16	210-250		

Kandosol Growth Material Layers by Depth from Surface (cm)	Potential Soil Sources			Soil Texture Classification	
	Borrow Area	Site	Source Depth (cm)	Approximate USCS	NCST (2009) (Preferred, Excluding Gravel)
		GHD TP-17	155-190		
		GHD TP-18	170-250		
		GHD TP-19	220-280		
		GHD TP-20	40-280		

8.6 Stockpile Establishment

It is suggested that suitably sized stockpile areas be designated for each of the horizon categories. Each stockpile area is to be clearly designated and separated from the other stockpile areas. The preference is for the stockpiles to be established in the following way to prevent cross-contamination of stockpiles where excellent quality materials have been sourced for upper layers and lesser quality materials for lower layers:

- 0-20 cm (SL to SCL texture – A1 horizon) soil material placed at the highest location in the general landscape
- 20-60 cm (SCL to CL, S texture – A2 horizon) soil material placed either downslope of the A1 horizon (0-20 cm) stockpile or adjacent to the A1 horizon stockpile where the A2 horizon stockpile will not impact on the A1 horizon stockpile because both will drain immediately downslope away from each other
- 60-120 cm (CL, S to SLC texture – B21 horizon) soil material placed downslope of the A2 horizon (20-60 cm) stockpile or adjacent to the A2 horizon stockpile where the B21 horizon stockpile will not impact on the A1 or A2 horizon stockpiles because all three will drain immediately downslope away from each other
- 120-200 cm (SLC to SLMC texture – B22 horizon) soil material placed at the lowest location in the general landscape or adjacent to the B21 horizon stockpile where the B22 horizon stockpile will not impact on the A1, A2 or B21 horizon stockpiles because all four will drain immediately downslope away from each other.

8.7 Field Selection of Appropriate Horizon Materials

In the first instance, material with minimal gravel content is to be selected for all horizons, although this is most important for the A1 and A2 horizons and progressively less important for the B21 and then the B22 horizons. In all instances, where there is gravel, it is not to be associated with poorly developed soil material that is more consistent with weathered parent material (i.e. B/C or C horizons) rather than recognisably developed B horizon material.

Prior to each layer of the natural soil profiles being excavated, their pH and electrical conductivity (EC) be tested using a field pH/electrical conductivity kit/meter and soil field texture be confirmed, without the coarse fragments (gravel (>2 mm)), to more effectively grade them in accordance with the *Australian Soil and Land Survey Field Handbook* (NCST, 2009). Reference is to be made to the pH and EC ranges provided in **Table 50** and Recommended Scale (top scale on page 162), figure 16 on page 163 and the field texture grades on page 164-166 of the *Australian Soil and Land Survey Field Handbook* (NCST, 2009), to confirm each layer's suitability in accordance with the soil texture classifications in column 5 of **Table 51**.

For the 0-20 (sandy loam to sandy clay loam texture – A1 horizon) and 20-60 (sandy clay loam to clay loam, sandy texture – A2 horizon) soil materials, preference is to be given to sources at or close to the soil surface. This is to include existing humus, leaf, twig and bark, microbial and seed material to the greatest extent practicable thereby retaining some biologically active organic content in the surface materials. This will likely improve the potential for rapid successful regeneration of vegetation/ pasture and lowering the risk of failure.

Additionally, for the 60-120 (clay loam, sandy to sandy light clay – B21 horizon) and 120-200 (sandy light clay to light medium clay – B22 horizon) soil materials, preference is to be given to sources between the surface and 2 m, where practicable, to minimise the likelihood of unfavourable physical and chemical properties, including gleyed colouring.

The suitably classified and appropriately selected materials can then be excavated and transported to the applicable horizon category stockpile area.

All excavations of materials should be supervised by an appropriately qualified and experienced soil scientist alongside the site geotechnical engineer to ensure greatest possible success with identifying and confirming suitable soil layer materials and ensuring grading and stockpiling are performed as required. All growth material works should be governed by a detailed Planning Construction Soil (Growth Material) Management Plan for the construction and revegetation establishment phases. An overview of growth material management practices is provided in **Section 8.8**.

8.8 Overview of Growth Material Management Practices

8.8.1 Stockpile Management

8.8.1.1 Hydroseeding of Growth Material Stockpiles

Where soil material for any growth material horizon is to be stockpiled for >3 months and/or there is a high likelihood of rain, the stockpile should be hydroseeded with a suitable seed mix (e.g. Japanese millet, annual couch and/or annual and/or perennial native grasses) and watered as needed to ensure vigorous and lush growth. This will form a protective layer of vegetation as soon as possible to prevent any immediate possibility of erosion and loss of this material. Depending on the storage period for the stockpile, the perennial native species will progressively replace the annual species thereby ensuring continued protection of the stockpile surface from erosion. All grasses will also enhance any inherent chemical and biological properties by mulching down and being incorporated into the growth medium by microbes in preparation for final placement. Should the grasses also reach maturity and successfully set seed, they will start to establish a seed bank in preparation for continued protection of the stockpile or establishing a vegetative cover on the WSFs.

8.8.1.2 Weed Control on Growth Material Stockpiles

Weeds have the potential to interfere with successful revegetation of the growth material once placed on the WSF capping material. Where weeds are identified on the stockpiles, they are to be prevented from flowering by appropriate control methods for the weed species identified and to minimise any effects on the hydroseeded grass species. This may mean sufficiently regular inspections and treatment at a rate commensurate with the shortest growth cycle weed species present, ego potentially weekly. Where weeds are not adequately controlled and establish seed banks from successfully flowering and seeding, the stockpiled soil material may have to be scalped to remove the weed seed bank and this material disposed of, potentially wasting a limited resource required for the success of growth material and revegetation establishment on the WSF capping.

8.8.1.3 Inspections and Monitoring of Growth Material Stockpiles

Regular inspections should be made of all the growth material stockpiles to monitor the stockpiles for erosion effects from wind or water, vegetative coverage to ensure it is more than adequate, and weed infestations, and to ensure they are being controlled and prevented from flowering.

Inspections should be immediately following rainfall events, where possible, and at regular intervals sufficient to ensure any erosion is addressed as soon as possible, hydroseeded grass species are establishing and maintaining a high foliage cover, and the fastest growing and maturing weed species are unable to flower and seed between inspections and/or treatments.

8.8.1.4 SL to SCL Texture (0-20 cm) A1 Horizon Soil Material

The A1 horizon (0-20 cm (SL to SCL texture)) soil material is to be stockpiled no greater than 2 m high with batters no steeper than the material's natural dry angle of repose without vegetation. This is to preserve any inherent organic content and, where stored for >3 month, ensure maximum surface area for hydroseeding to generate as much additional organic material for incorporation ahead of final placement whilst providing for the most stable form to minimise erosion potential. Final placement of this material will be on top of the A2 horizon (20-60 cm) Kandosol-equivalent growth material as a topsoil (A1 horizon).

8.8.1.5 SCL to CL, S (20-60 cm) A2 Horizon Soil Material

The 20-60 cm (SCL to CL, S texture) soil material is to be stockpiled no greater than 2 m high with batters no steeper than the material's natural dry angle of repose without vegetation. This is to preserve any inherent organic content and, where stored for >3 month, ensure maximum surface area for hydroseeding to generate as much additional organic material for incorporation ahead of final placement whilst providing for the most stable form to minimise erosion potential. Final placement of this material will be on top of the B21 horizon (60 -120 cm) Kandosol-equivalent growth material as a sub-topsoil (A2 horizon).

8.8.1.6 CL, S to SLC (60-120 cm) B21 Horizon Soil Material

The B21 horizon (60-120 cm (CL, S to SLC texture)) soil material can be stockpiled up to 3 m high with batters no steeper than the material's natural dry angle of repose without vegetation. Final placement of this material will be on top of the B22 horizon (120-200 cm) Kandosol-equivalent growth material as the upper subsoil (B21 horizon).

8.8.1.7 SLC to SLMC (120-200 cm) B22 Horizon Soil Material

The B22 horizon (120-200 cm (SLC to SLMC texture)) soil material can be stockpiled up to 3 m high with batters no steeper than the material's natural dry angle of repose without vegetation. Final placement of this material will be on top of the clay capping as the lower subsoil (B22 horizon).

8.8.2 Growth Material Mixing and Sampling Prior to Placement and Revegetation

Excavation and placement of the respective materials at each stockpile location should ensure maximum mixing without excessive overworking of the soil materials, which would degrade the soil structure, where there is reasonable structure. This is to ensure adequate mixing of the materials for each horizon of the Kandosol-equivalent soil ahead of spreading over the clay capping on the WSFs.

As sufficient volume for each stockpile is being approached or use of the material is impending as capping progresses, a representative number of samples are to be collected, bulked and submitted to a laboratory that is NATA-accredited for undertaking most of the analyses required to understand the physical and chemical properties of the respective horizon material.

For sampling of the topsoil stockpiles, samples are not to be taken directly from the surface as this will give a skewed interpretation of the quality of the topsoil, given it may have a cover crop incorporating organic material into it. The surface material represents a small fraction of the overall stockpile so will largely disappear once mixed, so a sample should be taken >200 mm beneath the surface, preferably quite deep as this will be most representative. Also, should the protective cover crop have been poorly managed and is full of weeds, the surface layer of the topsoil stockpile may have to be scalped and discarded to get rid of the weed seed bank, so samples should not to be collected from the surface.

A sufficient number of samples are to be collected from around each stockpile and then bulked together. Each stockpile should have its own bulked sample to be analysed. The number should be representative of the size of the stockpile, i.e. for small stockpiles only 3-4 samples may be required, however, for large to really large stockpiles, anywhere from 6-10 or more samples will be required and bulked together.

8.8.3 Growth Material Testing and Treatment Prior to Placement and Revegetation

Following sampling, bulking and submission of samples for each growth material horizon stockpile, the bulked samples are to be analysed for the parameters outlined in **Table 52**.

Table 52 Laboratory Testing of Growth Material Layers Following Placement

Parameter	Layers			
	0-20 cm (SL-SCL) (A1 horizon)	20-60 cm (SCL-CL, S) (A2 horizon)	60-120 cm (CL, S-SLC) (B21 horizon)	120-200 cm (SLC-SLMC) (B22 horizon)
pH $_{(1:5\ water)}$ and pH $_{(CaCl2)}$	✓	✓	✓	✓
Electrical conductivity	✓	✓	✓	✓
Chloride	✓	✓	✓	✓
Acid neutralizing capacity	✓	✓	✓	✓
Cation exchange capacity, exchangeable cations and acidity, calcium: magnesium ratio and exchangeable sodium percentage (ESP)	✓	✓	✓	✓
Particle size distribution (by sieve and hydrometer) for the following fractions: clay (<2 µm), silt (0.002 (2 µm)-0.02 mm), fine sand (0.02-0.2 mm), coarse sand (0.2-2 mm) and gravel (>2 mm)	✓	✓	✓	✓
Emerson aggregate test	✓	✓	✓	✓
Bicarbonate extractable potassium	✓	✓		
Sulfur	✓	✓		
Boron	✓	✓		
Extractable metals (Cu, Fe, Mn, Zn)	✓	✓		

Parameter	Layers			
	0-20 cm (SL-SCL) (A1 horizon)	20-60 cm (SCL-CL, S) (A2 horizon)	60-120 cm (CL, S-SLC) (B21 horizon)	120-200 cm (SLC-SLMC) (B22 horizon)
Nitrogen (ammonia, nitrite, nitrate, total Kjeldahl and total)	✓	✓		
Phosphorus (total and bicarb. extract.)	✓	✓		
Total carbon, total organic carbon and organic matter	✓	✓		
Carbon: nitrogen ratio	✓	✓		

Following analysis for each layer, the results are to be used to determine whether any specific physical, chemical and/or biological treatments are required to ensure the growth material meets the indicative growth material success criteria (refer to **Section 8.8.4**).

The results of the particle size distribution analysis on the bulked samples are to be categorised according to the recommended scale in NCST (2009), page 162. The scale is to be grouped as follows, disregarding the gravel fraction post analysis (except that the gravel content should not dominate the other fractions), to confirm the texture, in accordance with NCST (2009), figure 16, page 163 and the field texture grades on pages 164-166:

- Clay: <2 µm
- Silt: 0.002 (2 µm)-0.02 mm
- Fine sand: 0.02-0.2 mm
- Coarse sand: 0.2-2 mm.

This will confirm the stockpiled soil material has a suitable texture for the Kandosol-equivalent growth material horizon that the respective stockpile is designated for.

Where the above particle size distribution does not meet the texture specifications for the particular Kandosol-equivalent horizon, additional soil material of the appropriate particle size(s) is to be sourced in sufficient volume to make up the desired texture. On completion of adding and mixing the additional material, the stockpile is to be re-tested for particle size distribution to confirm it meets the texture specification. This process is to be repeated until the texture specification is met for all stockpiles.

Where particular stockpiles of materials do not quite meet the physical, chemical and/or biological specifications (refer to **Section 8.8.4**), a range of ameliorants may be considered, including, but not limited to:

- Gypsum – to maintain existing pH, increase cation exchange capacity, increase calcium to magnesium ratio, reduce sodicity, improve soil structure
- Lime – to raise pH, increase cation exchange capacity, increase calcium to magnesium ratio, reduce sodicity, improve soil structure
- Humus – to increase organic matter content, improve structure, increase nutrient content, improve water holding capacity
- Fertiliser – to increase nutrient content
- Liquid sulfur – to lower soil pH, increase sulfur availability, increase nitrogen utilisation.

These ameliorants are to be applied to the respective stockpile prior to placement of the growth material onto the growth material area and spread to further mix the combined source materials for that horizon and incorporate the ameliorants.

8.8.4 Establishment Phase Growth Material Monitoring

The growth material should be monitored bi-annually for the revegetation establishment phase. Monitoring should be towards the end of the dry season and at the end of the wet season to compare soil physical and chemical changes that result from annual and seasonal climate variations and on-going revegetation management practices.

Monitoring should include full soil profile (down to the clay capping but not into the clay capping) description and sampling using a hand auger or push tube at all revegetation monitoring sites with laboratory analysis for comparison against growth material design and success criteria, previous growth medium soil profile monitoring results, and revegetation monitoring data.

Indicative growth material design and success criteria are provided in **Table 53**. Where adjustments are made to the growth material design due to availability of materials, e.g. depths of horizons or growth material more in line with a Dermosol texture profile, etc, these design and success criteria will need to be adjusted accordingly.

Table 53 Growth Material Design and Success Criteria

Attribute	Description
Slope:	Consistent with final design gradients
Runoff:	Very slow to moderately rapid (refer to NCST, 2009, pp144-145)
Permeability:	Slowly to moderately permeable (refer to NCST, 2009, pp200-202)
Drainage:	Moderately to well-drained (refer to NCST, 2009, pp202-204)
Surface rock:	<1%
Horizon:	A1
Depth:	From 0 to 0.2 m
Texture:	Sandy loam to sandy clay loam (refer to NCST, 2009, pp164-166)
Colour:	Dark brown (may tend reddish or yellowish) (refer to Munsell colour charts)
Fabric:	Earthy (refer to NCST, 2009, pp181-182)
Pedality:	Massive (refer to NCST, 2009, pp171-180)
pH $_{(1:5\ soil:water)}$:	Range from 4.5 to 5.5
EC:	At least 10 µS/cm
Salinity:	Very low to low
Chloride:	<10 mg/kg
CEC:	At least 5.0 cmol+/kg
Exch. Sodium % (ESP):	Non-sodic
Ca:Mg ratio:	>1
Total P:	At least 50 mg/kg
Bicarb Extr. P:	At least moderate (>20-40 mg/kg)
Total Kjeldahl N:	At least moderate (>150-250 mg/kg)
Total Organic Carbon:	At least moderate (>1.5-2.5%)
Sulfur:	<10 mg/kg
Horizon:	A2
Depth:	From 0.2 to 0.6 m
Texture:	Sandy clay loam to clay loam, sandy (refer to NCST, 2009, pp164-166)
Colour:	Brown (may tend reddish or yellowish) (refer to Munsell colour charts)

Attribute	Description
Fabric:	Earthy (refer to NCST, 2009, pp181-182)
Pedality:	Massive (refer to NCST, 2009, pp171-180)
pH:	Range from 5.0 to 6.0
EC:	At least 10 µS/cm
Salinity:	Low to medium
Chloride:	<10 mg/kg
CEC:	At least 5.0 cmol+/kg
Exch. Sodium % (ESP):	Non-sodic
Ca:Mg ratio:	>1
Total P:	At least 50 mg/kg
Bicarb Extr. P:	At least moderate (>20-40 mg/kg)
Total Kjeldahl N:	At least moderate (>150-250 mg/kg)
Total Organic Carbon:	At least moderate (>1.5-2.5%)
Sulfur:	<10 mg/kg
Horizon:	B21
Depth:	From 0.6 to 1.2 m
Texture:	Clay loam, sandy, to light clay (refer to NCST, 2009, pp164-166)
Colour:	Strong brown (may tend red or yellow) (refer to Munsell colour charts)
Fabric:	Earthy (refer to NCST, 2009, pp181-182)
Pedality:	Massive to weak (refer to NCST, 2009, pp171-180)
pH:	Range from 5.0 to 6.0
EC:	At least 2 µS/cm
Salinity:	Low to high
Chloride:	<20 mg/kg
CEC:	At least 5.0 cmol+/kg
Exch. Sodium % (ESP):	Non-sodic
Ca:Mg ratio:	>1
Horizon:	B22
Depth:	From 1.2 to 2.0 m
Texture:	Sandy light clay to sandy light medium clay (refer to NCST, 2009, pp164-166)
Colour:	Strong brown (may tend dark red or yellow) (refer to Munsell colour charts)
Fabric:	Earthy (refer to NCST, 2009, pp181-182)
Pedality:	Massive to moderate (refer to NCST, 2009, pp171-180)
pH:	Range from 5.0 to 6.0
EC:	At least 5 µS/cm
Salinity:	Low to high
Chloride:	<50 mg/kg
CEC:	At least 5.0 cmol+/kg
Exch. Sodium % (ESP):	Non-sodic
Ca:Mg ratio:	>1

8.8.5 Post-Establishment Phase Growth Material Monitoring

The growth material should continue to be monitored bi-annually biennially for the next 10 years, post-establishment phase, and thereafter biannually every 5 years. Monitoring should be towards the end of the dry season and at the end of the wet season to compare soil physical and chemical changes that result from annual and seasonal climate variations and on-going vegetation management practices.

Monitoring should include full soil profile (down to the clay capping but not into the clay capping) description and sampling using a hand auger or push tube at all revegetation monitoring sites with laboratory analysis for comparison against growth material design and success criteria, previous growth medium soil profile monitoring results, and revegetation monitoring data.

Indicative growth material design and success criteria are provided in **Table 53**. Where adjustments are made to the growth material design due to availability of materials, e.g. depths of horizons or growth material more in line with a Dermosol texture profile, etc, these design and success criteria will need to be adjusted accordingly.

8.9 Conclusion/Summary

The ideal growth material for the WSF would be a soil profile similar to the Kandosols that naturally occur and are dominant throughout the surrounding landscape. The preferred Kandosol growth medium would consist of the following soil horizons (layers) at these preferred depths, although these may be varied to accommodate the volumes of available materials:

- 0-20 cm (SL to SCL texture – A1 horizon)
- 20-60 cm (SCL to CL,S texture – A2 horizon)
- 60-120 cm (CL,S to SLC texture – B21 horizon)
- 120-200 cm (SLC to SLMC texture – B22 horizon).

The quantity of available soil materials from the available borrow areas appears to not provide sufficient material of the exact textures required for the A1 and A2 horizons of the Kandosol. There appears, however, to be sufficient separate materials to be able to manufacture sufficient volumes of soil materials to create the desired A1 and A2 textures.

The quantity of available soil materials from the available borrow areas appears to provide well and truly sufficient material for the B21 and B22 horizons.

The quality of the soil materials available from the borrow areas appears, in the main, to be suitable for the Kandosol soil profile. There were limited instances of unsuitable materials displaying very strongly acidic, marginally sodic, etc chemical properties; however, should these materials be harvested the dilution factor with the significantly larger volumes of good material would likely nullify their effects and/or they could be treated with small volumes of readily available ameliorants, such as lime and gypsum.

Should it not be practicable to construct the Kandosol growth medium from the available materials, the alternative would be a Dermosol soil. A Dermosol soil has slightly more clay than a Kandosol, particularly in the surface horizons making it more uniformly clay rather than distinctly graduated. The preferred Dermosol growth medium would consist of the following soil horizons (layers) at these preferred depths, although these may be varied to accommodate the volumes of available materials:

- 0-20 cm (SCL to CL, S texture – A1 horizon)
- 20-60 cm (CL,S to SLC texture – A2 to B21 horizon)
- 60-120 cm (SLC to SLMC texture – B21 to B22 horizon)
- 120-200 cm (SLMC to SMC texture – B22 to B23 horizon).

The quantity of available soil materials from the available borrow areas appears likely to provide sufficient material for all horizons of the Dermosol, although some mixing may be required to create additional material sufficient for the upper horizons.

Similar to the Kandosol, the quality of the soil materials available from the borrow areas appears, in the main, to be suitable given the likely dilution factor with the significantly larger volumes of good material nullifying the effects of the poor materials and/or they could be treated with small volumes of readily available ameliorants, such as lime and gypsum.

For either the Kandosol or Dermosol growth material profile, field and laboratory testing at the time of harvesting (during construction) by suitably qualified field and laboratory soil scientists would be sufficient to identify appropriate materials for stockpiling and amelioration ahead of placement on the WSF. A detailed Planning Construction Soil (Growth Material) Management Plan would be advisable to provide detailed instruction to the construction contractor at the time of tendering.

9 Summary and Conclusions

SLR Consulting Australia Pty Ltd (SLR) was engaged by the Northern Territory Government Department of Primary Industry and Resources (DPIR) to undertake a geotechnical investigation to inform rehabilitation works for the former Rum Jungle Mine, located approximately 6km north of Batchelor, Northern Territory (NT). The field investigation component was carried out in two parts; the first conducted in July 2019 and the second in October 2019. The investigations were developed to fill data gaps within existing geotechnical investigation data and comprised of a test pitting program with associated sampling and in-situ testing, followed by laboratory testing, within key areas of interest as defined in the following table.

Table 54 Areas of Investigation

Location	Objective
East and West Waste Storage Facilities (EWSF and WWSF)	Assessment of foundation materials within proposed WSF envelopes.
Coomalie Community Government Council Land Clay and Growth Medium Borrow Area (Borrow Area A)	Assessment and quantification of materials for use in WSF capping design and general construction fill.
Finnis River Aboriginal Land Trust (FRALT) Granular and Growth Medium Borrow Area (Borrow Area B)	Assessment and quantification of materials for use in WSF capping design and general construction fill.
Haul Road Alignment	Assessment of the subsurface conditions for paving design
Existing Waste Rock Dump (WRD) Covers	Assessment of the existing WRD cover layers, including thickness of rip rap and underlying low permeability horizons
Aldebaran Quarry	Assessment of the rock suitability as rip rap erosion protection on WSF slopes

A brief description of each area of investigation follows.

9.1 West Waste Storage Facility (WWSF) Envelope

The majority of the WWSF footprint encompasses the old ore stockpile area, which was rehabilitated in the 1980’s effort. The landform is currently a terraced slope generally comprised of a cover of reworked locally sourced lateritic soils overlying run of mine ore and waste rock deposits left behind from the old stockpile. Seven test pits were performed by SLR in field investigations, four were terminated by excavator bucket refusal and three terminated due to limit reach of the excavator arm (≥4.5 m bgl).

9.2 East Waste Storage Facility (EWSF) Envelope

The proposed EWSF footprint encompasses old borrow areas and haul roads previously used in mining and rehabilitation operations. The northern and most easterly portion of the envelope generally comprises deep residual fine grain soils (clays and silts). A localised pocket within the northern portion of the envelope contains what is likely filter cake material from the Main and Intermediate water treatment operations of the 1980s. Within the mid-portion of the EWSF envelope the soils typically comprise of lateritic soils overlying natural bedrock at a depth of approximately 1.50 m bgl. The area is largely devoid of topsoil due to previous stripping for borrow materials. A region of shale/argillite bedrock dissecting the WSF envelope bedrock encountered shallow excavator refusal. Outside of the shale/argillite is deeper dolostone deposits.

The southern boundary of the EWSF envelope is marked by the northeast - southwest trending Giant's Reef Fault, where the Coomalie Dolomite abuts the granites of the Rum Jungle Complex. Groundwater was encountered within three of the five test pits proximal (<50 m) to the Giant's Reef Fault at depths between 2.8 m and 4.0 m bgl at the time of investigation and has been observed to fluctuate close to the surface (groundwater well observations) during wet seasons. The three test pits that encountered groundwater were located to the north of the fault.

9.3 Borrow Area A (Coomalie Community Government Council Land)

Borrow Area A is located to the west of the historic Rum Jungle South mine site. The western portion of the area comprises of deep (> 5.0 m) residual fine grained (silts and clays) soils overlying dolostone bedrock. To the east previous works have left some borrow scars within the natural topography, with the soils typically comprising of a mixture of granular residual soils and deeper cohesive soils. The topsoil content within this Area is highly impacted by Gamba Grass therefore the biological properties of this topsoil may affect the use of this material in rehabilitation. This is discussed in other works by DPIR and will not be addressed within this geotechnical report. Volumetric assessment of the Borrow Area A indicates the following available quantities:

Table 55 Borrow Area A Volumetric Analysis

Soil Type	Volume	Potential Use
Topsoil	228,860 m^3	Growth Medium
Lateritic Clay/Silt	1,139,490 m^3	Low Permeability Layer and Growth Medium
Laterite Granular	1,645,400 m^3	Growth Medium and General Construction
Saprolite Clay	1,611,600 m^3	Low Permeability Layer and Growth Medium
Saprolite Silt	517,950 m^3	Growth Medium
Saprolite Granular	345,300 m^3	Growth Medium and General Construction

The laterite and saprolite materials were tested for suitability as use as low permeability materials against OKC low permeability design requirements.

Table 56 OKC Low Permeability Criteria

Characterisation Test	Meets Criteria	Criteria
% Clay	✓	Clay percentage > 10%
% Fines	✓	Fines percentage > 30%
% Gravel (4.75mm)	✓	Gravel (4.75mm) percentage < 50%
Atterberg Limits	✓	Plastic Index > 10
Saturated Permeability	Variable	$K_{sat} \leq 1 \times 10^{-9}$ m/s

The saturated permeability results are summarised below.

Table 57 Hydraulic Conductivity Results

Material	Permeability (k_{sat})	Fines	Clay	Gravel
Laterite (SLR-NTP-02)	7.0×10^{-10} m/s	69%	49%	2%
Laterite (SLR-NTP-06)	2.0×10^{-8} m/s	30%	16%	40%

Material	Permeability (k_{sat})	Fines	Clay	Gravel
Laterite (SLR-NTP-07)	7.0 x 10^{-9} m/s	52%	27%	19%
Laterite (WRD-SLR-TP08)	2.0 x 10^{-9} m/s	-	-	-
Saprolite (WRD-SLR-TP14)	5.0 x 10^{-9} m/s	-	-	-
Saprolite (WRTP-14)	2.0 x 10^{-10} m/s	59%	24%	5%

The saprolite material conforms to the hydraulic requirements, however the laterite material is a more variable.

There is significant volume of saprolite and laterite available, hence prioritising areas of more suitable material (i.e. lower gravel content) should be done during borrow excavation.

9.4 Growth Medium

Growth medium requirements for the WSFs have been established by SLR based on providing a a long-term, sustainable growing medium for selected native revegetation species. It is also to provide a reduced likelihood of, equal to or better than baseline for the area, sheet, rill, and gully erosion over the proposed life of the WSFs capping. The growth material will need to provide for moderately rapid stormwater infiltration and be moderately permeable to reach field capacity but also have sufficient clay content to provide some structure, water holding capacity, and mineral exchange and nutrient adsorption capacity to support revegetation with, and long-term sustainability of, native shrubs and grasses.

Desktop review of geotechnical field logs and laboratory analytical results indicates that there is sufficient volumes of material of suitable quality to replicate the soil profile of a Kandosol to a depth of 2m over the WFSs.

The results indicate that for the most part, replication can be achieved be by targeting layers that are considered to match the required physical parameters for each horizon of the growth medium; however, there may need to be some mixing of different materials for make up any deficit, particularly for the surface (A1 and A2) horizons.

9.5 Borrow Area B (FRLAT)

The subsurface profile across proposed Borrow Area B is broadly described as topsoil overlying residual soils and shallow bedrock (≤2.0m) with localised alluvium associated with surface water channels. The underlying bedrock is shallow and comprises extremely weathered bedrock and/or competent bedrock of granite and sandstone.

Table 58 Borrow Area B Volumetric Analysis

Soil Type	Volume	Use
Topsoil	379,440 m^3	Growth Medium
Sandy Gravel/Gravelly Sand	4,679,760 m^3	Growth Medium and General Construction

9.6 Borrow Area Summary

The borrow areas material can be summarised as follows:

Material Type	Borrow Area	Volume Available	Volume Required	Recommendations to meet the gap (if required)
Low Permeability	Coomalie Council	2,751,000 m^3	~450,000m^3	Trial pads

<table>
<tr><th>Material Type</th><th>Borrow Area</th><th>Volume Available</th><th>Volume Required</th><th>Recommendations to meet the gap (if required)</th></tr>
<tr><td>Growth Medium</td><td>Coomalie Council</td><td>2,738,000 m³</td><td rowspan="2">~3,140,000 m³</td><td rowspan="2">Mixing to achieve replication for A1 and A2 horizons</td></tr>
<tr><td>Growth material</td><td>FRALT</td><td rowspan="4">4,679,760 m³</td></tr>
<tr><td>Sand and capping for Main Pit</td><td>FRALT</td><td>99,000 m³</td><td>None required</td></tr>
<tr><td>Clean cap for Main Pit</td><td>FRALT</td><td>156,000 m³</td><td>None required</td></tr>
<tr><td>Construction fill</td><td>FRALT</td><td>TBA</td><td>-</td></tr>
</table>

9.7 Haul Road Alignment

A summary of the sub-surface conditions encountered along the haul road alignment is given below:

- Generally, all material encountered consistencies ranging from firm to very stiff or medium dense to very dense.
- Groundwater was encountered within one test pit by a river channel at 3.30 m bgl and appeared to be level with extremely weathered shale formation.
- Laboratory California Bearing Ratio (CBR) results indicated CBR% values ranging from 20% to 60% for 4-day soaked samples at 100% Standard Maximum Dry Density.

The material along the alignment is suitable for haul road use; pavements should be designed according to the CBRs identified in the various areas.

9.8 Existing Waste Rock Covers

Four shallow test pits were excavated into the side slopes of the existing Intermediate and Main Waste Rock Dump. All four excavations encountered the same strata, with little variation in thicknesses. The rock armouring was assessed as being in good condition and suitable for re-use. The following volume estimates of recoverable rock armouring have been determined (note some areas still to be determined):

Table 8 Waste Rock Dump Rock Armouring Volume Estimate

Waste Dump	Estimated Recoverable Rock Armouring Volume
Main Waste Rock Dump	14,650 to 21,975 m³
Intermediate Waste Rock Dump	3,705 to 5,557 m³
Dyson's Backfill	1,190 to 1,785 m³
Dyson's Waste Rock Dump	3,535 to 5,302 m³
Drainage lines	TBA
Total Estimated Armour Rock Volume	**23,080 to 34,620 m³**
Required Armour Volume	**TBA**

9.9 Aldebaran Quarry

The investigation of the Aldebaran Quarry was performed for the suitability granite deposits as rock armouring and erosion protection (rip-rap). Petrographic and geotechnical analysis suggest the granite within the Aldebaran Quarry may be suitable as an armouring material, however it is recommended further testing be conducted to confirm its suitability should additional material be required.

10 Closure

We are more than happy to discuss any aspect of this report and provide further services to assist you with your project.

Please refer to our standard limitation text below. The statements presented are intended to advise you of what your realistic expectations of this report should be. Our limitations are not intended to reduce the level of responsibility accepted by SLR, but rather to ensure that all parties who may rely on this report are aware of the responsibilities each assumes in so doing.

11 Limitations

SLR has performed investigation and consulting services for this project in general accordance with current professional and industry standards. The extent of testing was limited to discrete test locations and variations in ground conditions are likely to occur between test locations that are difficult to infer or predict.

A geotechnical consultant should always provide inspections during construction to confirm assumed conditions in the design. SLR would be happy to assist in provide construction support to confirm ground conditions assumed in this assessment. If subsurface conditions encountered during construction differ from those indicated in this report, geotechnical advice should be sought immediately, and we would be happy to provide further advice.

SLR, or any other reputable consultant, are unable provide unqualified warranties nor do we assume any liability for the site conditions not observed or accessible during the investigation. We also note that site conditions may change subsequent to the investigations and assessment due to ongoing use and/or deterioration.

This document is produced by SLR solely for the benefit and use by DPIR in accordance with the terms of the engagement. SLR does not and shall not assume any responsibility or liability whatsoever to any third party arising out of any use or reliance by any third party on the content of this document

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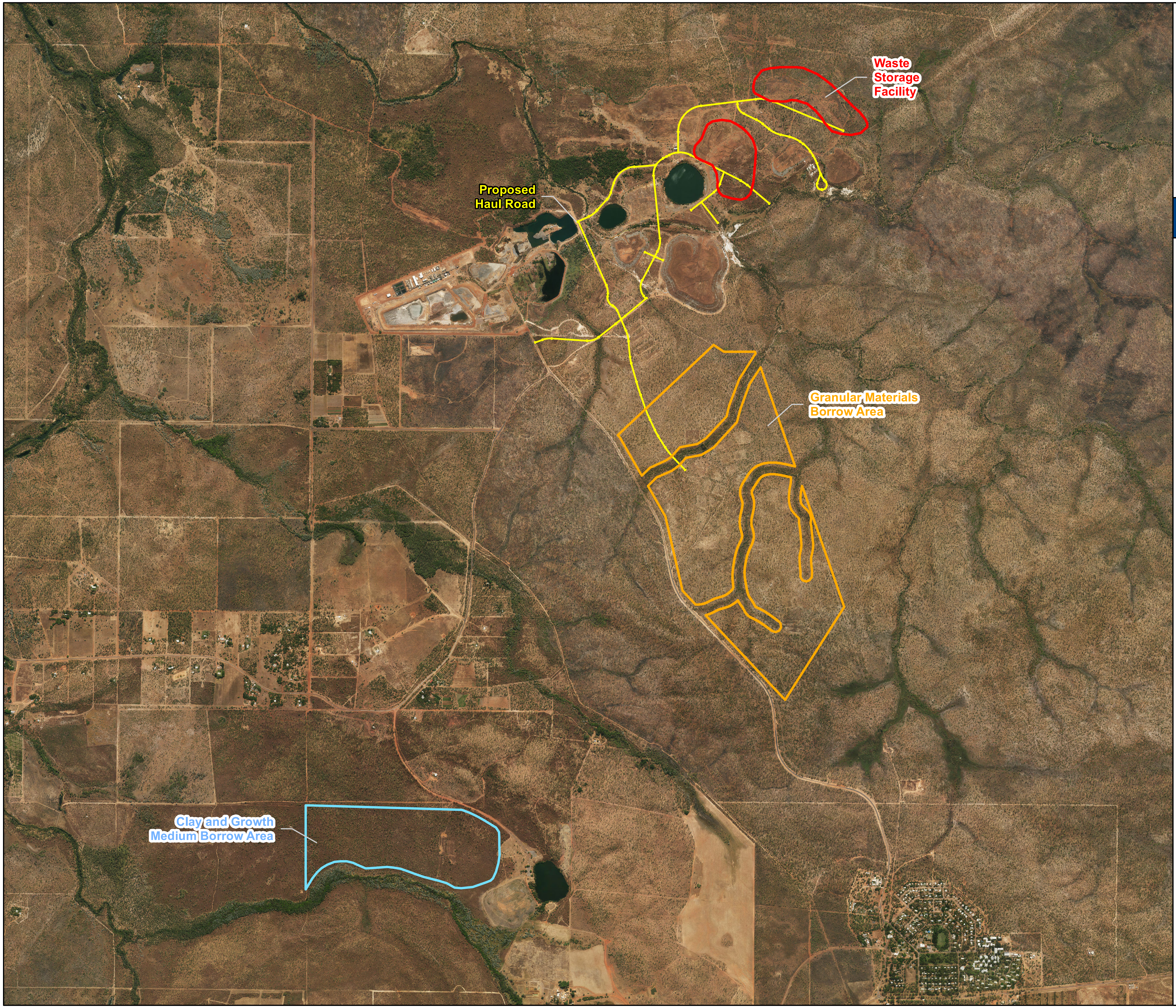
APPENDIX A

Site Overview



DEPARTMENT OF PRIMARY INDUSTRY AND RESOURCES

RUM JUNGLE

SITE OVERVIEW

Legend

- Proposed Haul Road
- Borrow Area A - Clay and Growth Medium
- Rum Jungle Waste Storage Facility Area
- Borrow Area B - Granular Materials and Growth Medium

Data Sources:
Proposed Haul Road, Clay and Growth Medium Borrow Area, Waste Storage Facility, and Granular Materials Borrow Area datasets: SLR Consulting (2019).
Imagery Sources: 12cm resolution Rum Jungle 2018 Orthophoto Imagery dataset: supplied by client (2019).
Coordinate System: GDA 1994 MGA Zone 52
Projection: Transverse Mercator
Datum: GDA 1994
Date: 20-Nov-2019
Author: SLR Consulting
Map Ref: 680.10421 - DPIR - Rum Jungle - GIR - Site Overview - v2

N

0 400 800 1,200 1,600
Metres

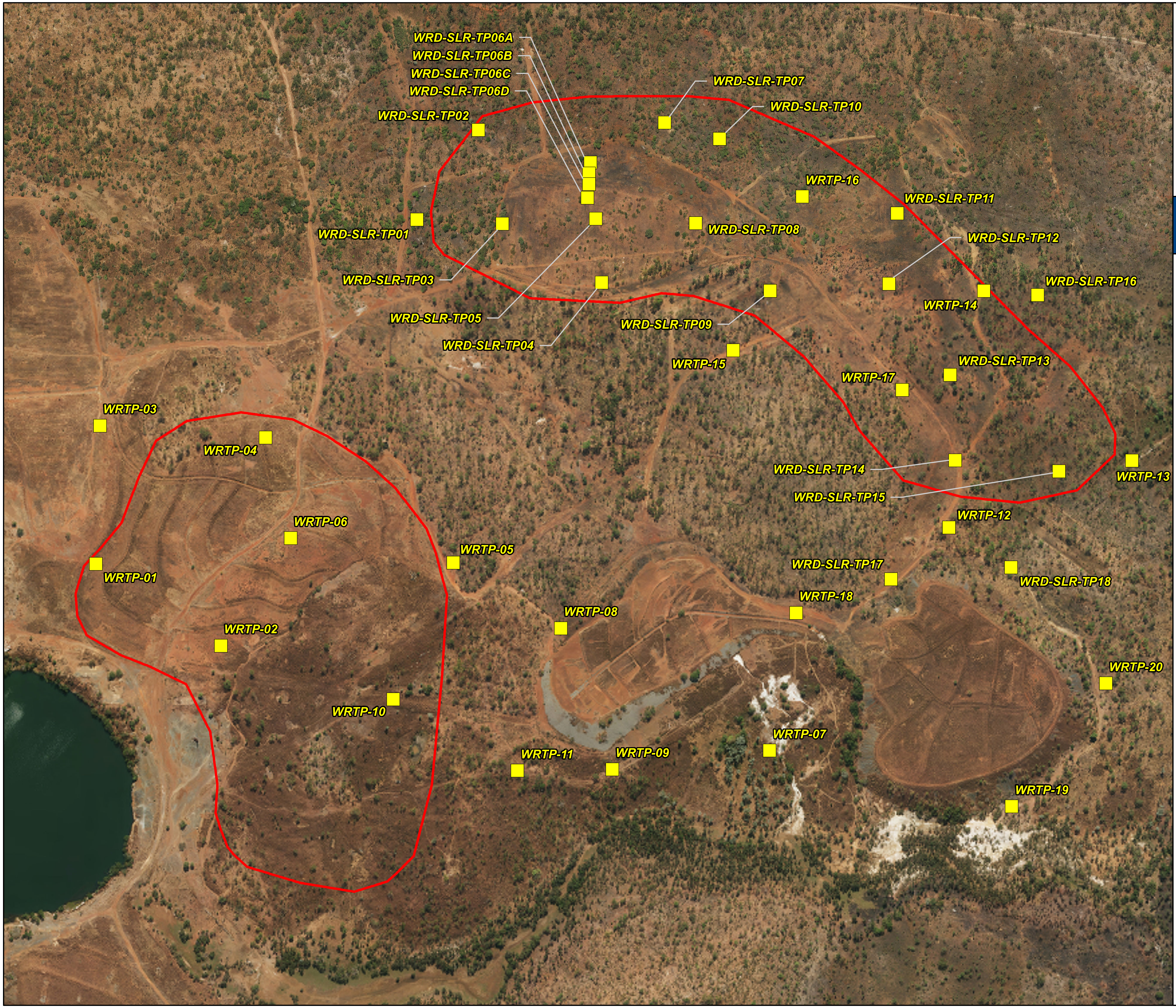
Scale: 1:30,000 at A3

SLR

Version 2

APPENDIX B

Rum Jungle Mine Site Maps



DEPARTMENT OF PRIMARY INDUSTRY AND RESOURCES

RUM JUNGLE

WASTE STORAGE FACILITY SITE OVERVIEW

Legend

SLR WSF Test Pit

Waste Storage Facility Area

Data Sources:
SLR WSF Test Pit, and Proposed Waste Storage Facility datasets: SLR Consulting (2019).
Imagery Sources: 12cm resolution Rum Jungle 2018 Orthophoto Imagery dataset: supplied by client (2019).
Coordinate System: GDA 1994 MGA Zone 52
Projection: Transverse Mercator
Datum: GDA 1994
Date: 21-Nov-2019
Author: AJ
Map Ref: 680.10421 - DPIR - Rum Jungle - GIR - Waste Storage Facility - Site Overview - v2

N

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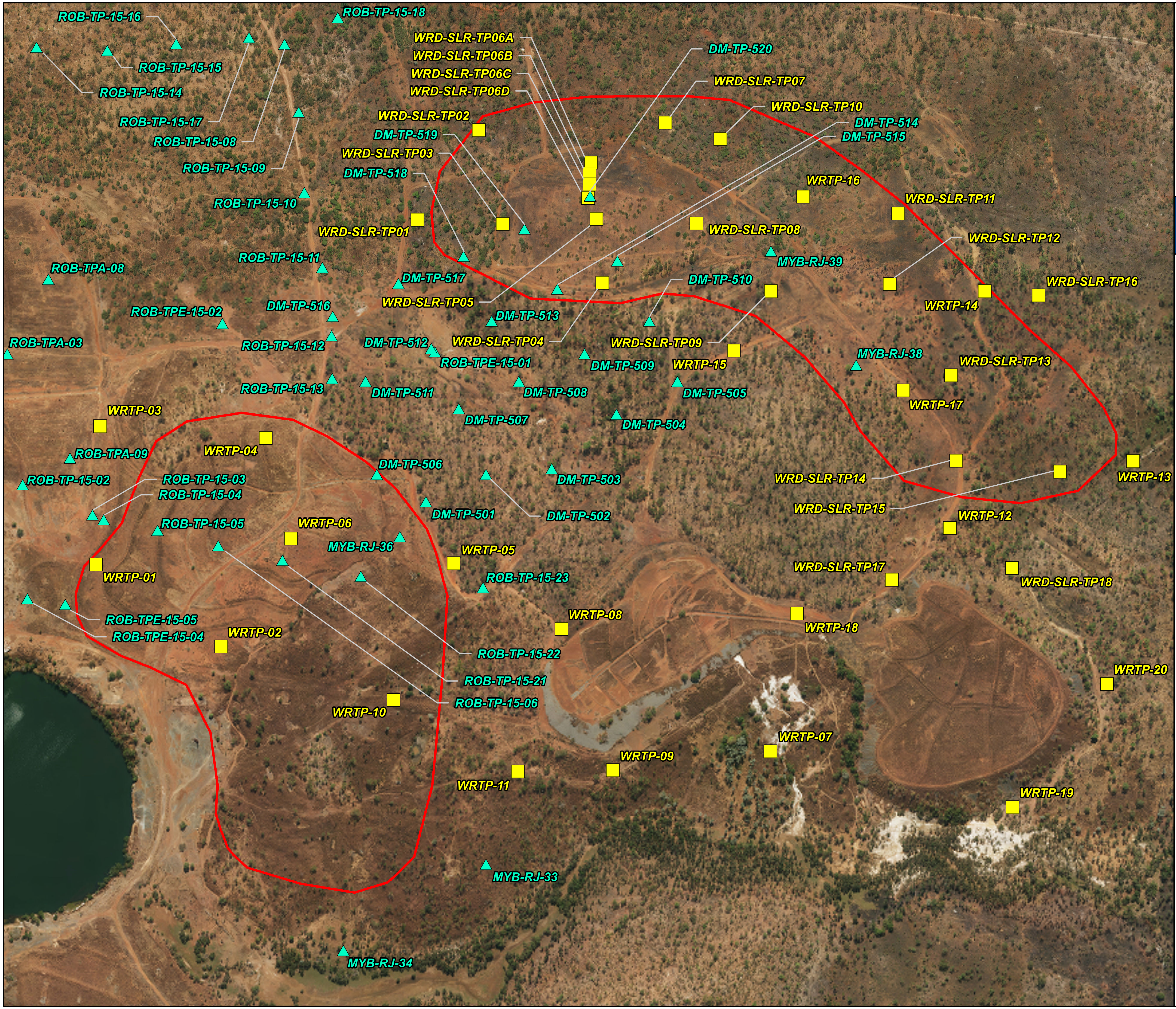
Metres

Scale: 1:5,000 at A3

SLR

Version 2



DEPARTMENT OF PRIMARY INDUSTRY AND RESOURCES

RUM JUNGLE

WASTE STORAGE FACILITY COMBINED TEST PITS

Legend

- SLR WSF Test Pit
- Combined WSF Test Pit
- Waste Storage Facility Area

Data Sources:
SLR WSF Test Pit, Combined WSF Test Pit, and Proposed Waste Storage Facility datasets: SLR Consulting (2019).
Imagery Sources: 12cm resolution Rum Jungle 2018 Orthophoto Imagery dataset: supplied by client (2019).
Coordinate System: GDA 1994 MGA Zone 52
Projection: Transverse Mercator
Datum: GDA 1994
Date: 21-Nov-2019
Author: AJ
Map Ref: 680.10421 - DPIR - Rum Jungle - GIR - Waste Storage Facility - Site Overview - v2

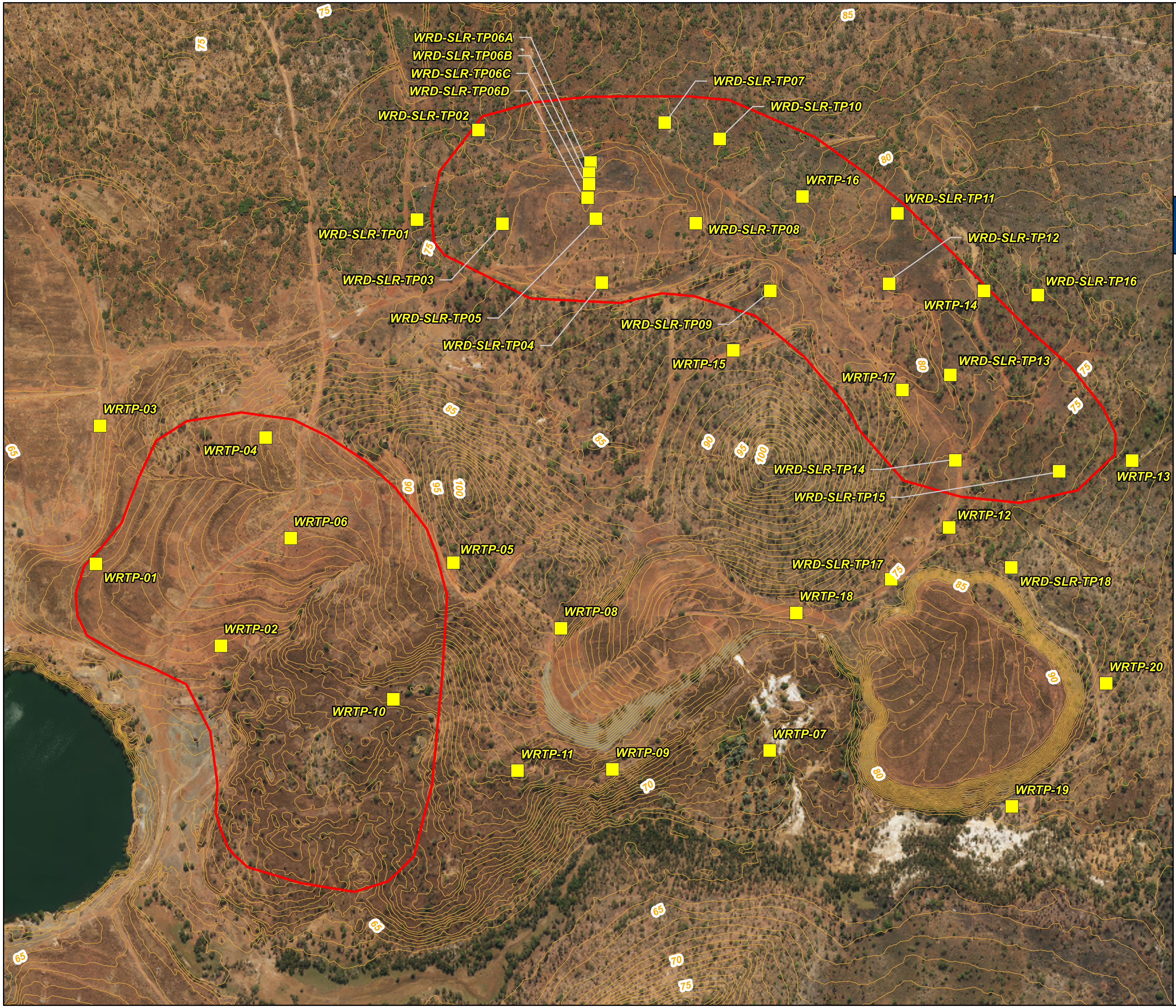
N

0 50 100 150 200
Metres

Scale: 1:5,000 at A3

SLR

Version 2



DEPARTMENT OF PRIMARY INDUSTRY AND RESOURCES

RUM JUNGLE

WASTE STORAGE FACILITY SITE TOPOGRAPHY

Legend

- SLR WSF Test Pit
- Contour (mAHD)
- Waste Storage Facility Area

Data Sources:
SLR WSF Test Pit, 1 metre Contour (mAHD), and Proposed Waste Storage Facility datasets: SLR Consulting (2019).
Imagery Sources: 12cm resolution Rum Jungle 2018 Orthophoto Imagery dataset: supplied by client (2019).
Coordinate System: GDA 1994 MGA Zone 52
Projection: Transverse Mercator
Datum: GDA 1994
Date: 21-Nov-2019
Author: AJ
Map Ref: 680.10421 - DPIR - Rum Jungle - GIR - Waste Storage Facility - Site Topography - v2

N

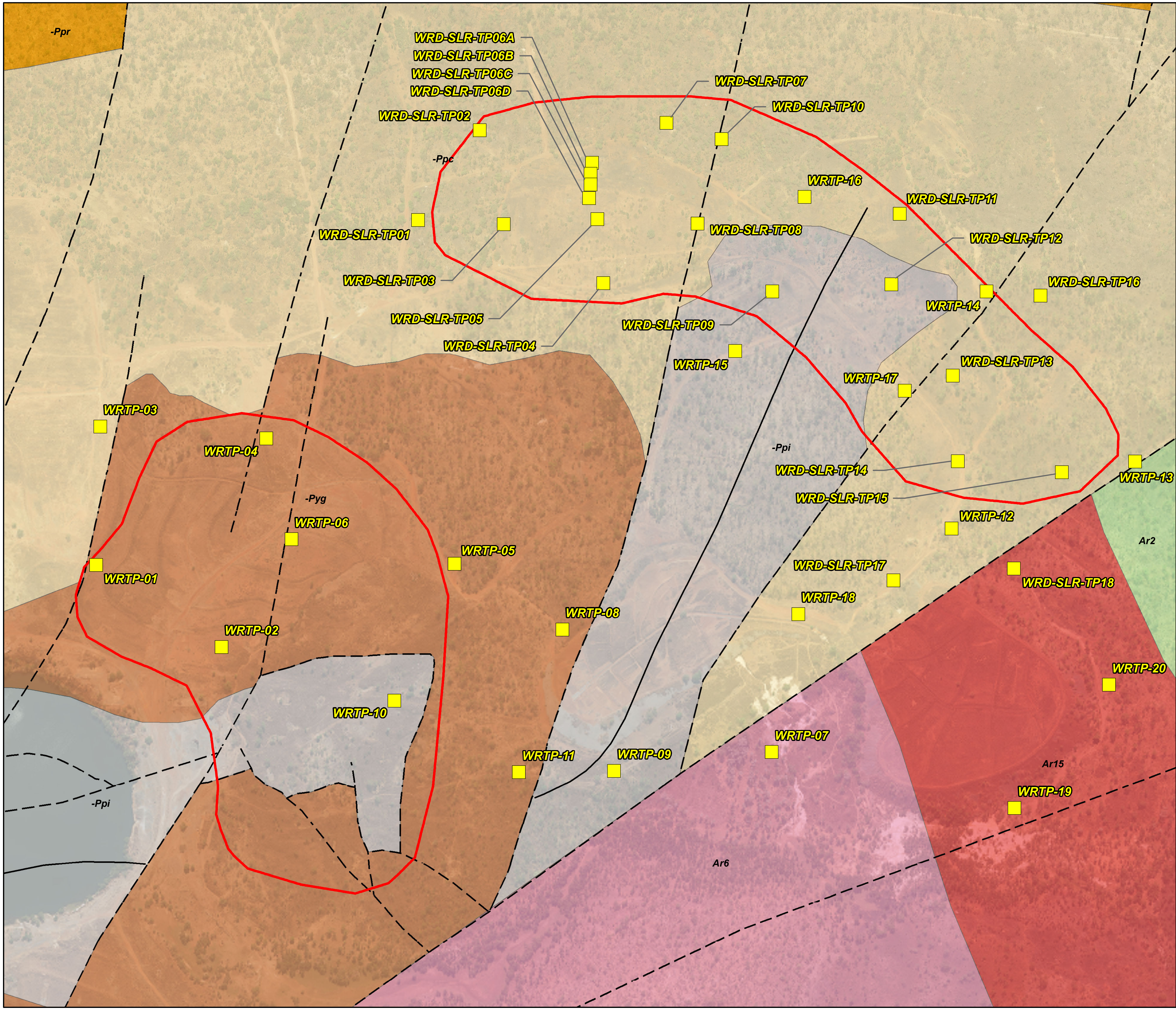
0 50 100 150 200

Metres

Scale: 1:5,000 at A3

SLR

Version 2



DEPARTMENT OF PRIMARY INDUSTRY AND RESOURCES

RUM JUNGLE

WASTE STORAGE FACILITY GEOLOGY

Legend

- SLR WSF Test Pit
- Waste Storage Facility Area
- Geological Fault
- Geological Fold

Lithology Summary (1:100K)

- Stromatolitic magnesite, dolostone, some silicified, para-amphibolite, metapelite (Ppc)
- Calcareous & carbonaceous pyritic argillite, dololutite & dolarenite, rare quartzite (Ppi)
- Quartz-pebble arkose, poorly sorted BIF-quartz pebble-boulder conglomerate, sandstone, siltstone, shale (Ppr)
- Haematitic paraquartzite breccia, milky quartz & chert breccia; haematitic mudstone, siltstone and sandstone; minor phosphatic siltstone and breccia (Pyg)
- Leucocratic granite (Ar15)
- Granite gneiss (Ar2)
- Large-feldspar and coarse granite (Ar6)

Data Sources:
SLR WSF Test Pit, and Proposed Waste Storage Facility datasets: SLR Consulting (2019); Rum Jungle Mineral Field - NT - Interpreted Geology 1:100K 2003 dataset: © Northern Territory of Australia (Northern Territory Geological Survey) 2019.
Imagery Sources: 12cm resolution Rum Jungle 2018 Orthophoto Imagery dataset: supplied by client (2019).
Coordinate System: GDA 1994 MGA Zone 52
Projection: Transverse Mercator
Datum: GDA 1994
Date: 21-Nov-2019
Author: AJ
Map Ref: 680.10421 - DPIR - Rum Jungle - GIR - Waste Storage Facility - Geology - v2

N

0 50 100 150 200
Metres

Scale: 1:5,000 at A3

SLR

Version 2