I Soils, Topography and Land Disturbance

HANCOCK GALILEE PTY LTD

FINAL

Soil and Land Suitability Assessment

Kevin's Corner

August 2011

URS03-012

GSS ENVIRONMENTAL
Environmental, Land and Project Management Consultants

URS Australia

Kevin's Corner Project Environmental Impact Statement

Soil & Land Suitability Assessment

Prepared for **URS Australia**

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Issue	Date	Description	Authors	QA/QC
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2	5th April 2011	EIS Draft V2 Doc	Matt Hemingway &	
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EXECUTIVE SUMMARY

GSS Environmental (GSSE) was commissioned by URS Australia (URS) to prepare a soil and land suitability assessment for the proposed Kevin's Corner Project (the Project). The Project is located within the Galilee Basin approximately 65 km north of Alpha, 110 km west-south-west of the township of Clermont and approximately 340 km south-west of Mackay in Central Queensland. The Study Area covers a total of 37,379ha, which has been divided into four areas for the purpose of impact assessment, which are based on the proposed level of disturbance: nil disturbance (36.5%), Subsidence (53.2%), Infrastructure (2.1%), Open cut & tailings dam (8.2%).

The preparation of a soil and land suitability assessment for the Project was undertaken using a two phased process as outlined below:

Phase 1 involved an initial reconnaissance level investigation and communications with the Department of Environment and Resource Management (DERM) to provide a suitable Phase 2 approach outside the DERM guidelines. In December 2010 DERM responded with an agreement for a suitable scope for Phase 2. A preliminary EIS report was submitted in April 2011, which outlined results from Phase 1 and details of the proposed assessment process to be undertaken in Phase 2.

Phase 2 involved a targeted survey at a 1:100,000 scale assessing 86 test pits, and was undertaken in May 2011, following significant delays due to wet weather and inaccessible conditions.

An initial broad scale reconnaissance soil map for the Study Area was developed using the Desert Upland Land Resource Assessment (Lorimer 2005) and a reconnaissance level field investigation undertaken in late 2010. The Study Area consisted of 5 Landscapes, 8 Land Systems and 23 Land units as described on Lorimer (2005) and outlined in **Section 3.2** of this report. The phase 2 investigations distinguished 26 representative soil types for the land units previously mapped, using field and laboratory analysis.

The project area is dominated by Sodosols (26%) and Kandosols (23%), with Rudosols (16%), Chromosols (15%) and Dermosols (15%) also present throughout the project area. Small areas of Tenosols (4%) are located along creeklines, and very small pockets of Vertosols (1%) are also present.

The agricultural land assessment was undertaken following phase 2 of the soil field investigation program and consisted of a land suitability, agricultural land class, good quality agricultural land (GQAL) and a preliminary strategic cropping land (SCL) assessment. Initial consultation with Agricultural Land Class Maps and SCL Draft Trigger Maps C3 and C5, indicated that the Study Area does not contain cropping land or lie within a potential SCL area. Field observations and laboratory analysis confirmed the unlikely existence of potential cropping land. Given these results the land suitability assessment focussed on beef cattle grazing and ranked each land unit and soil type for this use. The majority of the pre mining land consists of land suitability for beef cattle grazing Class 3 with areas along creeklines and small patches in the east of the project site being Class 4, and minor steep rocky country in the far west being Class 5. The post mining land suitability continues to be dominated by Class 3 land, however the overburden emplacement slopes will be Class 4 land and final voids, tailings dam, freshwater dams and the rail loop are expected to be Class 5.

Preliminary soil management recommendations have been made in this report including soil stripping and handling techniques for the open cut and other high disturbance areas, erosion and sediment control strategies, and topsoil respreading and seedbed preparation methods. Detailed soil specific management techniques are provided in **Section 3.2**.

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1.0 INTRODUCTION

1.1 Project Background

GSS Environmental (GSSE) was commissioned by URS Australia (URS) on behalf of Hancock Galilee Pty Ltd (HGPL), to prepare a soil and land suitability assessment for the proposed Kevin's Corner Project (the Project). This is to form part of an Environmental Impact Statement (EIS) to support the development application for the Project, which is located within the Galilee Basin approximately 65 km north of Alpha, 110 km west-south-west of the township of Clermont and approximately 340 km south-west of Mackay in Central Queensland as shown in the locality map (**Figure 1**).

The Project will be a 30 Mtpa thermal coal mine, comprising of both open-cut and underground operations. The coal will be treated by a coal preparation plant (CPP) and conveyed to a rail load out facility within the Study Area. The Project will involve the development of a rail spur connecting the mine to the proposed HCPL Alpha Coal Project railway.

The Project deposit is a well-known coal deposit within the Galilee Basin. Exploration began in the vicinity of the Project area in the 1970s. HGPL is the holder of MDL 333 and resource drilling is continuing. Initially all product coal is planned for export, however domestic use will be explored. The Project has an expected mine life of 30 plus years, with sufficient Joint Ore Reserves Committee (JORC) compliant resources to significantly extend the Project life beyond 30 years.

1.2 Study Area

The Study Area for the Soil and Land Suitability Assessment covers a total of 37,379.1ha, which has been divided into four areas for the purpose of this impact assessment, that are based on the proposed level of disturbance and as shown on **Figure 2.** The four disturbance areas are described as follows:

- **Nil Disturbance** (Buffer Land): This area consists of 13,671.0 ha or 36.5% of the Study Area and includes buffer areas, which are currently not designated for any mining related disturbance.

- **Subsidence Disturbance** (Subsided land from underground mining): This area consists of 19,863.6 ha or 53.2% of the Study Area and includes land to be subsided by longwall mining up to 3 m. No soil stripping will occur on this land, however given the predicted subsidence profiles, drainage and erosion issues are considered.

- **Infrastructure Disturbance** (Rail loop, accommodation village, conveyors, workshop, light industrial area, freshwater dams, detention basins, etc.): This area consists of 797.4 ha or 2.1% of the Study Area and includes land to be used for the construction of infrastructure as listed above. Soil stripping may occur on this land, and drainage/erosion issues are considered.

- **Open Cut & Tailings Dam Disturbance** (Open Cut mining & Tailings Dam): This area consists of 3,047.0 ha or 8.2% of the Study Area and includes open cut pits, overburden dumps and tailings dams. The disturbance level for these activities includes impact on the soil profile and potential stripping of topsoil for re-use in rehabilitation post mining.

1.3 Study Objectives

The major objectives of the Soil and Land Suitability Assessment were to:

1 Classify and determine the soil types for the Study Area at a 1:100,000 survey scale;

2 Assess the pre-mining and post-mining Land Suitability (LS) classes within the Study Area;

3 Assess the pre-mining and post-mining Agricultural Land Classes (ALC) including highlighting

any Good Quality Agricultural Land (GQAL) within the Study Area;

4. Assess the pre-mining Strategic Cropping Land (SCL) within the Study Area;
5. Calculate and discuss potential erosion rates for a variety of disturbance levels;
6. Assess the suitability of the current topsoil for future rehabilitation including the identification of unfavourable materials in the Study Area; and
7. Provide soil management recommendations for the topsoil management.

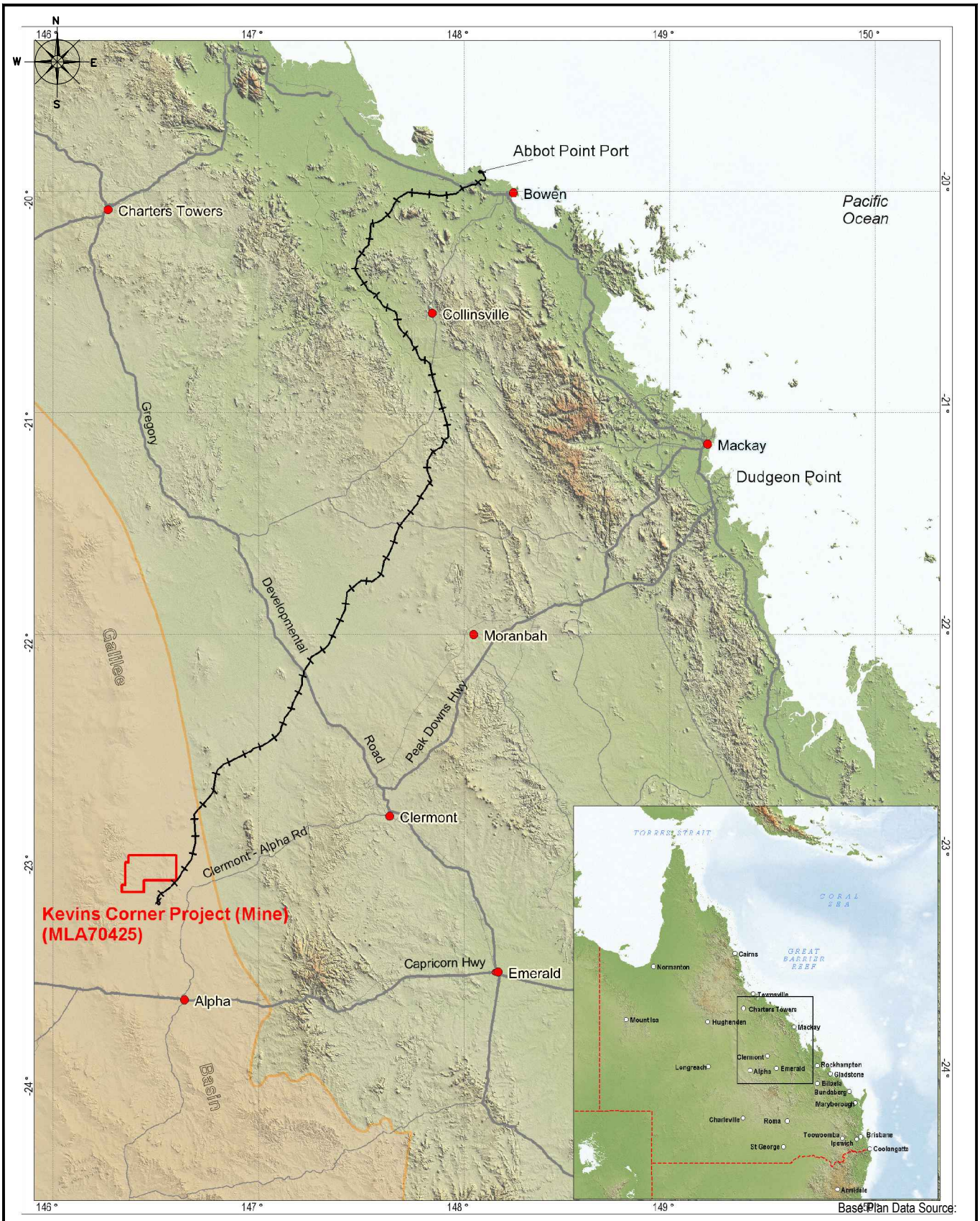
1.4 Status of Reporting

The preparation of a soil and land suitability assessment for the proposed Kevin's Corner Project is being undertaken in a two phased process. This was agreed by GSSE and URS due to the size of the site.

Phase 1 involved an initial reconnaissance level investigation and communications with the Department of Environment and Resource Management (DERM) to provide a suitable Phase 2 approach outside the DERM guidelines. In December 2010 DERM responded with an agreement for a suitable scope for Phase 2. A preliminary EIS report was submitted in April 2011, which outlined results from Phase 1 and details of the proposed assessment process to be undertaken in Phase 2.

Phase 2 involved a targeted survey at a 1:100,000 scale assessing 73 test pits, and was undertaken in May 2011, following significant delays due to wet weather and inaccessible conditions.

This Supplementary Report to the EIS presents the full soils and land suitability assessment for the Project.



LEGEND	FIGURE 1	Project: Soil and Land Capability Assessment Kevins Corner (2010)
Not to Scale	Location Plan	Client: URS (Brisbane)

Version	Date:	Author:	Checked:	Approved:
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2.0 EXISTING ENVIRONMENT

2.1 Climate

Data from the nearest Bureau of Meteorology weather station, located approximately 120km north-east of the Project at Clermont, shows the Study Area experiences a semi-arid climate, with a highly variable, summer-dominant average rainfall. The majority of rainfall occurs between December and February, with the least falling between July and September. Mean annual rainfall recorded at this station is 801 millimetres (mm), based on data collected from 1870 to present.

The region lies between two major pressure systems that affect Australia's climate. This means that it is too far north to receive reliable winter rainfall, and too far south to get many of the monsoonal 'wets' of northern Australia. This leaves it prone to frequent droughts.

The annual mean maximum temperature in the region is 29.7 degrees Celsius (°C) with an annual mean minimum temperature of 15°C. The highest temperatures were recorded in December with average maximum temperature of 34.9°C.

2.2 Geology and Soils

The Project deposit lies in the Galilee Basin within the late Permian Colinlea and Bandanna formations. The coal bearing strata sub-crop in a linear, north-south trending belt are in the central portion of the basin and are essentially flat lying. No major regional scale fold and fault structures have been identified in regional mapping of the Project area.

Within the Study Area there are four major coal seams that dip gently from east to west varying in thickness from 5 m to 8 m. The Project has significant resources of thermal coal which is thought to be within a premium location of the Galilee Basin.

The Project area is located within the Desert Uplands Bioregion of Central Queensland. This bioregion is divided into 4 sub regions, of which the Study Area falls within the Jericho Plains subregion. This subregion is dominated by deep sandy deposits, which include Tertiary sand plains and Quaternary alluvial fans. Clay plains and sandy alluvial terraces are predominant in the valley bottoms. The gently dipping, Mesozoic sandstones outcrop to form an escarpment with a north-south alignment, giving rise to sandy red Kandosols of variable depth. The much older, strongly folded, Palaeozoic sediments (Permian) outcropping to form a ridge in the southeast are, in fact, part of the Brigalow Belt bioregion, but have been included in this study because property boundaries extend beyond bioregional boundaries. Gently dipping, Mesozoic shales and mudstones underlie the clay plains in the south and southwest.

The Project is located to the east of the eastern boundary of the Great Artesian Basin (GAB). The basal unit of the geological GAB is the Rewan Formation/ Dunda Beds, which outcrop to the west of the Project lease area. The Project will be developed within sediments of the Permian Bandanna Formation and Colinlea Sandstone.

2.3 Hydrology and Topography

The Mine area is located on a gently undulating landscape with a typical elevation of approximately 320 m above sea level. There are six creek-lines within the Project tenement: Sandy Creek, Rocky Creek, Well Creek, Middle Creek, Little Sandy Creek and a small section of Greentree Creek. These creeks are tributaries of the Belyando River, which flows in a northerly direction and eventually meets up the Burdekin River. The Belyando catchment is approximately 35,411 km^2 and is one of the main sub catchments in the Burdekin Basin. A number of small ephemeral drainages also exist on the Study Area.

2.4 Land Use

Large sections of the Study Area have been cleared of vegetation for the purposes of low intensity cattle grazing. Several isolated areas have been cropped for fodder species to supplement grazing on native and introduced pastures. Other areas are comprised of uncleared or partially cleared open woodland. The DERM Environmentally Sensitive Areas map did not identify any Category A Environmentally Sensitive Areas on the Study Area. However, a number of pockets of Category B Environmentally Sensitive Areas were identified that are listed as Endangered Regional Ecosystem (Biodiversity Status) in the Environmental Protection Regulation 1998.

3.0 SOIL SURVEY

This soil survey provides an analysis of the main soil types located within the Study Area. This section outlines the methodology and results framework for the field and laboratory assessment.

3.1 Soil Survey Methodology

3.1.1 Background Reference Information

An initial broad scale reconnaissance soil map for the Study Area was developed using the following background information, resources and techniques:

- Aerial photographs and topographic maps;

  Aerial photo and topographic map interpretation was used as a remote sensing technique allowing detailed analysis of the landscape, and mapping of features expected to be related to the distribution of soils within the Study Area.

- Reference information;

  Source materials were used to obtain correlations between pattern elements and soil properties that may be observable in the field. These materials included cadastral data, prior and current physiographic, geological, vegetation and water resources studies.

  The key source used for reference, which detail previous soil and landscape mapping for the Study Area and its surrounds was the Desert Uplands Strategic Land Resource Assessment, as outlined below:

  Desert Upland Land Resource Assessment – This study was undertaken within the Desert Uplands Bioregion which included the Kevin's Corner Study Area. Information obtained in this report includes landscapes and land systems, which detail specific soil types likely to be present within the area and management implications for these soil types.

3.1.2 Field Survey Methodology

GSSE used a qualitative integrated free survey for the Project assessment. An integrated survey assumes that many land characteristics are interdependent and tend to occur in correlated sets (McKenzie & Grundy, 2008). Background reference information derived from sources cited in Section 3.1.1 (including observable air photography) were used to predict the distribution of soil attributes in the field. Characteristics evaluated include geology, landform and vegetation. A free survey is a conventional form of integrated survey and its strength lies in its ability to assess soil and land at medium to detailed-scales (Hewitt et al., 2008). Survey points are located irregularly, according to the survey teams' expertise and judgement to enable the delineation of soil boundaries.

The soil mapping was initially undertaken at a reconnaissance level following initial field investigations (Phase 1), and was then undertaken at a medium intensity survey scale of 1:100,000 as proposed by DERM in letter dated 3rd December 2010 (Phase 2). This survey scale offered an adequate dataset of soil types within the Study Area and appropriate detail to assess the potential impact on these soils following the proposed underground and open-cut mining. To satisfy the terms of reference (ToR), this scale is in accordance with the *Guidelines for Surveying Soil and Land Resources* (2008), with the number of observations per unit area required being 1 observation per 100 ha which equates to 374 observations for the 37,381 ha study area. Whilst the majority of these observations were considered 'minor' observations, such as exposed cuttings, 0.30 m auger holes and rock outcrops, a total of 73 detailed full profile descriptions were made in the field.

The soil profiles were assessed in accordance with the Australian Soil and Land Survey Field Handbook soil classification procedures. Detailed soil profile descriptions were logged using soil data sheets and the information recorded consisted of the following parameters as specified in **Table 1**. Photographs and GPS locations were taken at each site and all soil test pits were be backfilled immediately following field assessment.

Table 1– Detailed Profile Description Parameters

Descriptor	Application
Horizon Depth	Weathering characteristics, soil development
Field Colour	Permeability, susceptibility to dispersion /erosion
Field Texture Grade	Erodibility, hydraulic conductivity, moisture retention, root penetration
Boundary Distinctness and Shape	Erosional / dispositional status, textural grade
Consistence Force	Structural stability, dispersion, ped formation
Structure Pedality Grade	Soil structure, root penetration, permeability, aeration
Structure Ped & Size	Soil structure, root penetration, permeability, aeration
Stones – Amount & Size	Water holding capacity, weathering status, erosional / depositional character
Roots – Amount & Size	Effective rooting depth, vegetative sustainability
Ants, Termites, Worms etc	Biological mixing depth

Soil layers at each profile site were also assessed according to a procedure devised by Elliot and Veness (1981) for the recognition of suitable topdressing material. This procedure assesses soils based on grading, texture, structure, consistence, mottling and root presence. A more detailed explanation of the Elliot and Veness procedure is presented in **Section 4** of this report.

3.1.3 Laboratory Soil Assessment

Soil samples from 41 soil profiles across the study area were utilised in the laboratory testing program and were analysed at the NATA accredited ALS Lab (Brisbane QLD & Newcastle NSW), and Scone Research Centre (NSW), for the following parameters:

Every sample
- EC, pH and Chloride

Every major soil horizon
- Exchangeable Cations
- Cation Exchange Capacity
- Exchange acidity
- Particle size
- Total phosphorus, Potassium, Sulphur

Surface soil horizon
- Micronutrients
- Aluminium
- Free and total iron
- Sulphate
- Total Nitrogen
- Organic Carbon
- Replaceable Potassium

Some samples were also analysed for the following parameters in order to satisfy other components of the TOR's:

- Gravimetric Water Content
- K-factor

3.1.4 Soil Classification

The Study Area was firstly divided into five Landscapes and within those five Landscapes, eight Land Systems were described according to the Desert Uplands Land Resource Assessment. Each of these land systems is described as an overview in section 3.2, ahead of individual land unit descriptions within each land system. GSSE adopted the Australian Soil Classification system nomenclature to identify and label soil types found within land unit boundaries within the Study Area, as required by the ToR's. The ASC standard is routinely used as the soil classification system in Australia and forms the key descriptor throughout this report. In this system soil layers are termed horizons and for the solum these include the A and B horizons. The ASC classifications have also been cross-referenced to the land unit descriptions from The Land Resource Assessment of the Desert Uplands bioregion.

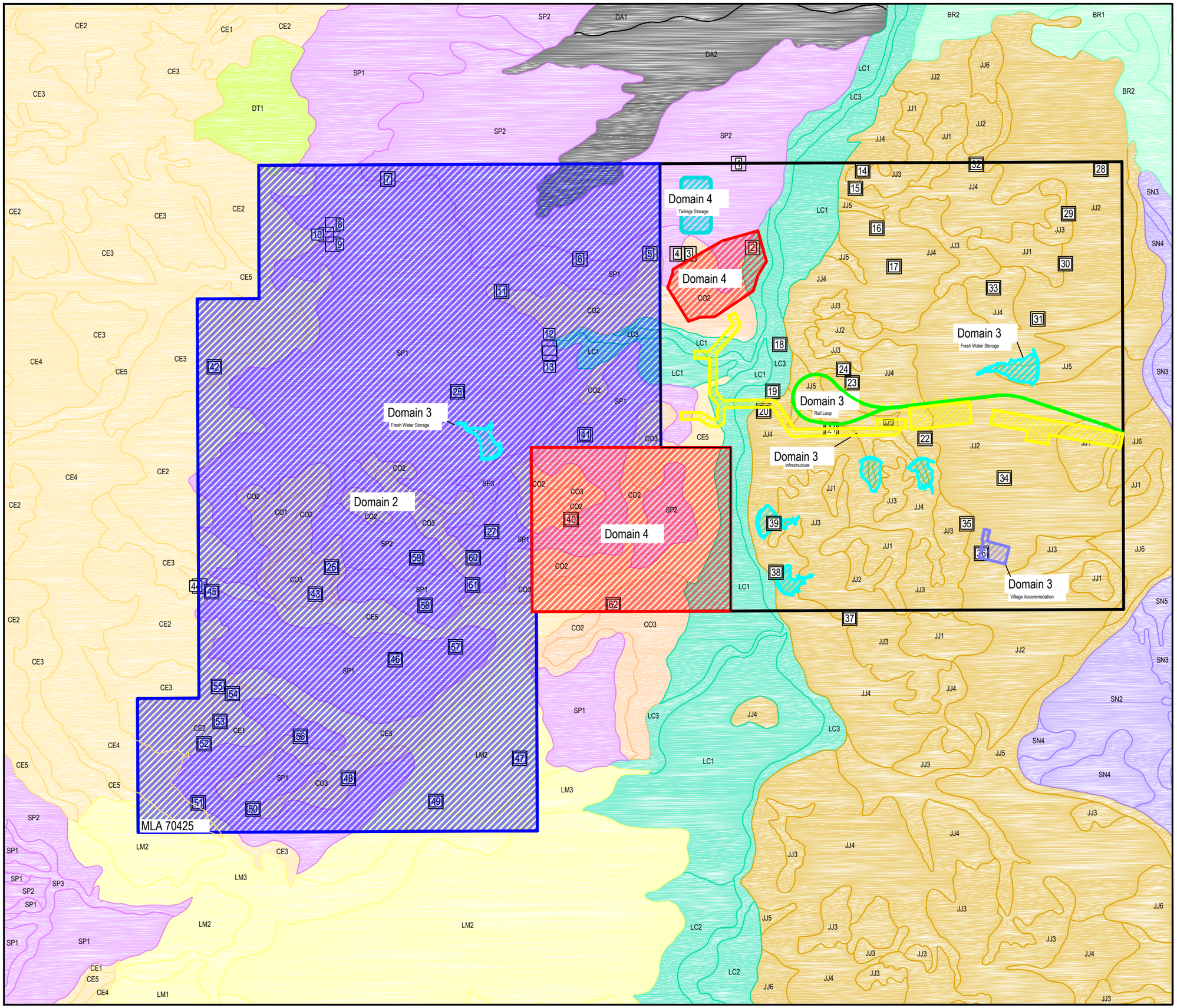
3.2 SOIL SURVEY RESULTS

3.2.1 Land Systems Overview

Land Systems are defined as being an area or group of areas that have a reoccurring pattern of topography, soils and vegetation that can be recognised. Within the Project area there are 8 land systems comprised of 23 land units and 26 soil types. Descriptions of the land systems, land units and soil types follow.

Table 2 – Land Systems and Land units within the Study Area

Landscapes	Land System	Land Unit Number	Land Unit Code	Representative Soil Type (ASC)	Area	
					ha	%
Lateritic	1. Cudmore	1	CE1	Brown Sodosol	173.43	0.5
		2	CE2	Petroferic Rudosol	1,068.00	2.9
		3	CE3	Brown Sodosol	724.36	1.9
		4	CE4	Brown Vertosol	239.16	0.6
		5	CE5	Stratic Rudosol	1,932.25	5.2
	2. Colorado	6	CO1	Red Kandosol	120.36	0.3
		7	CO2	Red Kandosol	2,204.91	5.9
		8	CO3	Lithic Rudosol	1,567.92	4.2
Sandstone	3. Southern Plateau	9	SP1a	Red Dermosol	10,528.61	28.2
		9	SP1b	Yellow Kandosol		
		9	SP1c	Yellow Sodosol		
		10	SP2a	Red Sodosol	2,860.07	7.7
		10	SP2b	Brown Dermosol		
		11	SP3	Red Sodic Dermosol	323.14	0.9
	4. Joe Joe	12	JJ1	Red Kandosol	860.87	2.3
		13	JJ2	Grey Sodosol	4,433.21	11.9
		14	JJ3	Grey Chromosol	1,836.81	4.9
		15	JJ4	Brown Chromosol	3,642.66	9.7
		16	JJ5	Tenosol	713.63	1.9
		17	JJ6	Stratic Rudosol	104.84	0.3
Alluvial Fans	5. Lambton Meadows	18	LM2	Stratic Rudosol	1249	3.3
		19	LM3	Stratic Tenosol	257.35	0.7
	6. Degula	20	DA2	Red Chromosol	200.4	0.5
Alluvial Plains	7. Lagoon Creek	21	LC1	Yellow Kandosol	1,681.5	4.5
		22	LC3	Stratic Tenosol	646.15	1.7
Sand Plain	8. Desert	23	DT1	Red Kandosol	11.17	0.0
				Total	**37,379.8**	**100.0**



LEGEND

- MLA Boundary
- XX - GSSE Reconnaissance Soil Observations
- Arterial Roads
- Domain 1- Nil (Undisturbed) 13671 ha
- Domain 2 (Underground) 19863.6 ha
- Domain 3 (Infrastructure) 484 ha
- Domain 3 (Rail Loop) 27.4 ha
- Domain 3 (Accommodation Village) 41.1 ha
- Domain 3 (Fresh Water Storage) 245 ha
- Domain 4 (Open Cut) 2917 ha
- Domain 4 (Tailings Storage) 130 ha
- Joe Joe Land System
- Lagoon Creek Land System
- Cudmore Land System
- Colorado Land System
- Degula Land System
- Desert Land System
- Lambton Meadows Land System
- Southern Plateau Land System

0 1.0 2.0 3.0 4.0 5.0 km

FIGURE 2

Kevins Corner Land Systems

Project:
Soil and Land Capability Assessment
Kevins Corner (2011)

Client:
URS (Brisbane)

File:
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Projection:
MGA94 Zone 55

Version:	Date:	Author:	Checked:	Approved:
1	19/04/11	LH	CR	JL
2	20/04/11	LH	CR	JL
3	04/08/11	LH	CR	JL
4	09/09/11	LH	CR	JL

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3.2.2 Cudmore Land System

The Cudmore land system contains some of the most rugged, inaccessible country in the Desert Uplands bioregion (Plate 1). The soil-vegetation associations are quite diverse with dense heathlands of slender wattle, fringe myrtle and desert tea-tree on shallow uniform sands over an ironstone hardpan (CE1), dense woodlands of lancewood on steep scarps with exposed ferricrete and gradational soils of variable depth (CE2), and complex woodlands of lancewood, narrow-leaved ironbark and bloodwood on moderate - steep slopes derived from sandstone with texture contrast soils with shallow topsoils covered with a mantle of silcrete (CE3). On the gentle lower slopes a complex of reddish-brown gradational and texture-contrast profiles plus some brown uniform clay soils support tall woodlands of silver-leaved ironbark and poplar box with some lemon-scented gum and Gympie messmate, and mid-high woodlands of brigalow, respectively (CE4). A tall woodland of river red gum predominates on the alluvial silty loam profiles of the stream banks and adjacent alluvial areas (CE5).

Plate 1: Cudmore Land System (CE2)

CE1

This land unit represents the very edge of the plateau, immediately adjacent to the steep scarp described in land unit CE2. The soils are predominantly sandy loam Lithic Rudosols (shallow, uniform-textured profiles) with abundant ironstone gravel. The nutrient status is very low and an ironstone hardpan underlies the whole unit, with exposures at the soil surface common.

CE2

This land unit represents the steep slopes and laterite cliffs of the scarp. Reddish-brown gradational soil profiles. Red Kandosols are most common, however erosion on the steep rocky slopes is also common and the topsoils, if present, are very thin. Considerable variation in soil depth, rockiness and slope occurs between sites.

CE3

This land unit represents the rises and steeply dissected areas of sandstone bedrock exposed by erosion and advance of the scarp into the Desert Uplands plateau. Sites with detailed soil and vegetation information are not available and poor access has prevented a proper relationship between soil, vegetation and slope position from being established. Reddish-brown gradational soil profiles Kandosols are most

common but there are also texture contrast soils with shallow topsoils (Sodosols covered with a mantle of siltcrete).

CE4

This land unit represents the lower slopes between the steep scarp slopes (CE2 and CE3) and the narrow alluvial terraces of the drainage depressions (CE5). The soils are a complex of Red Kandosols (reddish-brown gradational-texture profiles), Brown Chromosols (texture-contrast profiles) and Brown Vertosols (uniform cracking-clay soils) formed in situ on the underlying bedrock and on colluvial material from the adjacent steep slopes.

CE 5

This land unit represents the drainage depressions and the narrow alluvial floodplain associated with most creeks in the Cudmore land system. The narrow alluvial terraces often have a 'recent' layer of alluvium sitting on top of an older soil profile Stratic Rudosols.

An overview of the representative soil types for each of these units is provided below.

CE1 – Brown Sodosol (Site 69)

Soil Description; The Brown Sodosol observed at Site 69 is a texture contrast soil that generally consists of brown loamy sand overlying reddish brown clay loam to clay. A bleached A2 horizon lies between the topsoil and the subsoil. These well drained topsoils and poorly drained subsoils have a neutral pH, are non saline with low fertility characteristics. The subsoil is strongly sodic. Structure is moderate with 5 to 15mm sub angular blocky peds through to strong 2 to 20mm smooth faced angular blocky structure down the profile. The analytical information of the representative site is presented in **Figure CE1 - A** and **Table 3** below.

Management; Generally the topsoil does not display any specific management risk related to potential disturbance during stripping. The topsoil layer exhibits structure and chemical characteristics that would be suitable as surface cover in rehabilitation. The subsoil not recommended for stripping given it is strongly sodic and would require erosion control structures to be implemented if disturbed. The recommended stripping depth of this soil is 0.25 m.

Plate 1.1: CE1 - Brown Sodosol

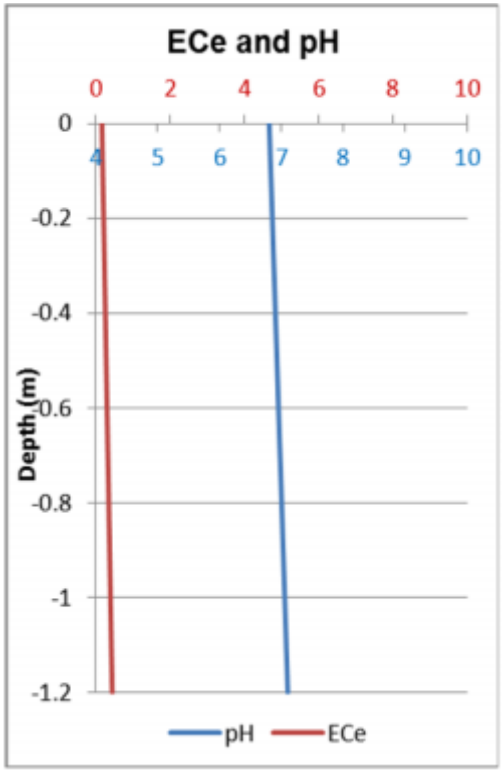


Figure CE1 - A: ECe and pH

Table 3: Laboratory Analysis (CE1)

Depth	Colour	pH		ECe		CEC		ESP	
cm		#	Rate	%	Rate	#	Rate	%	Rate
0 - 15	Strong brown	6.8	Neutral	0.16	Non-saline	2.3	Very low	4.35	Non-sodic
30 - 50	Reddish brown	7.1	Neutral	0.44	Non-saline	11.4	Low	17.5	Strongly sodic

Figure CE1 - B shows the soil texture throughout the profile, and **Figure CE1 - C** shows the trend of exchangeable cations with depth. The full suite of analytical results for this soil type can be found in **Appendix 3**.

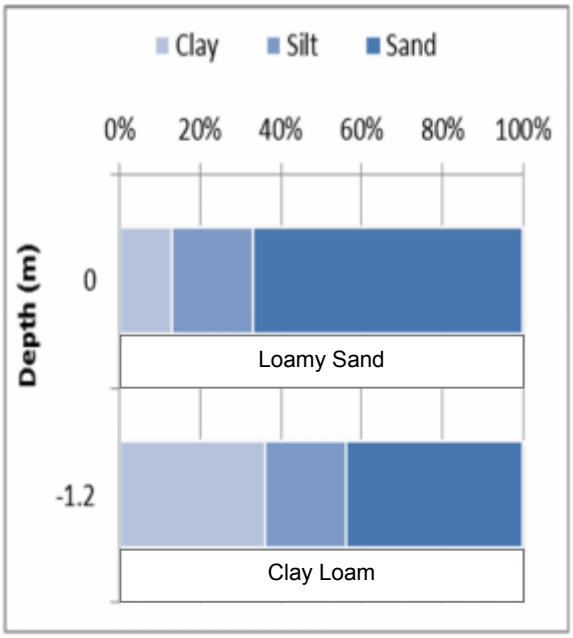


Figure CE1 - B: Particle Size Analysis

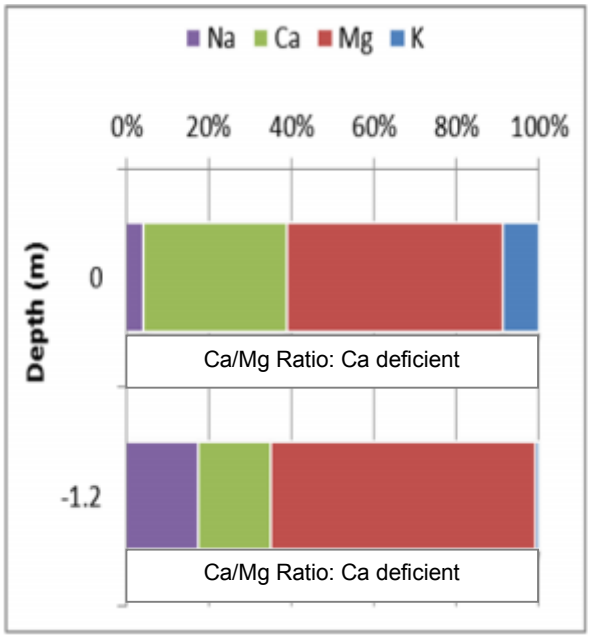


Figure CE1 - C: Exchangeable Cations

CE2 – Petroferic Rudosol (Site 62)

Soil Description; There is no soil profile information or lab analysis for this land unit given the rocky nature of the surface and restricted access during fieldwork, however the following information applies to the land unit: The steep, rocky nature of this land unit and the very high susceptibility to erosion, restrict the options for alternative land use and limit the level of productivity. The soils are shallow, droughty and of low fertility. The land surface is subject to high runoff. The ground cover has a low productivity and is vulnerable to overgrazing and degradation and it is difficult to regenerate. Laboratory analysis was not undertaken for this soil type. The above description is based on field observations.

Management; Generally this soil is unsuitable for use in rehabilitation due to its rocky nature.

Plate 1.2: CE2 - Petroferic Rudosol

CE3 – Brown Sodosol (Site 71)

Soil Description; The Brown Sodosol observed at Site 71 is a texture contrast soil that generally consists of light brown sandy loam overlying reddish brown clay. These moderately drained topsoils and poorly drained soils have moderate structure with 5 to 15mm platy peds through to moderate 20 to 50mm rough faced angular blocky structure down the profile. Laboratory analysis was not undertaken for this soil type. The above description is based on field observations, however the following information applies to the land unit: Erosion is a natural process and quite active in this land unit, however, increased grazing pressure is likely to reduce the sparse ground cover even further and increase the rate of erosion. The soils are shallow, droughty and of low fertility. The land surface is subject to high runoff. The ground cover has a low productivity and is vulnerable to overgrazing and degradation, which is difficult to regenerate.

Management; Generally the topsoil does not display any specific management risk related to potential disturbance during stripping. The topsoil layer exhibits structural characteristics that would be suitable as surface cover in rehabilitation. The subsoil appears sodic and would require erosion control structures to be implemented if disturbed. The recommended stripping depth of this soil is 0.15 m.

Plate 1.3: CE3 - Browns Sodosol

CE4 – Brown Vertosol (Site 61)

Soil Description; The Brown Vertosol observed at Site 61 is a uniform textured soil that generally consists of brown to reddish brown silty clay throughout the profile. These poorly drained soils have a neutral pH, are highly saline below 0.05m with high fertility characteristics. The soil below 0.05m is strongly sodic. Structure is moderate to strong throughout the profile. The analytical information of the representative site is presented in **Figure CE4 - A** and **Table 4** below.

Management; Generally these soils are not suitable for stripping due to the high salinity and strong sodicity below 0.05m. The top 0.05m may be salvaged and blended with sandy material to create a suitable medium for the re-establishment of vegetation. Therefore if required this soil may be stripped to 0.05m however the exposed soil would require erosion control structures to be implemented. The recommended stripping depth of this soil is 0.05 m if treated.

Plate 1.4: CE4 – Brown Vertosol

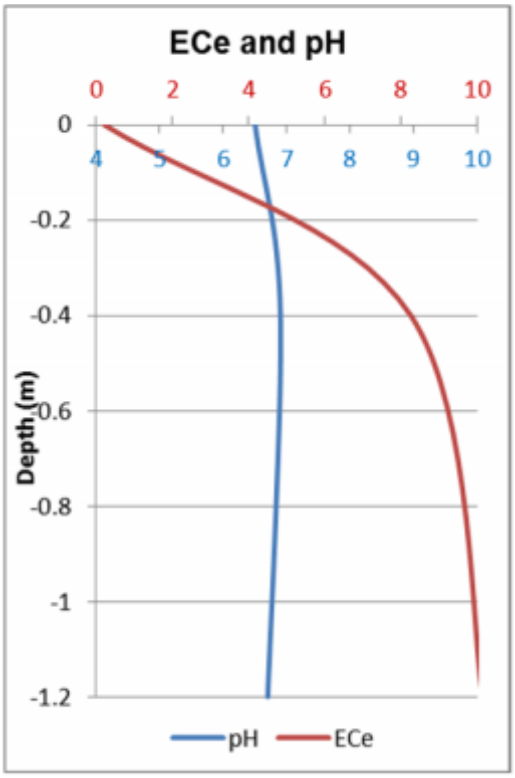


Figure CE4 - A: ECe and pH

Table 4: Laboratory Analysis (CE4)

Depth	Colour	pH		ECe		CEC		ESP	
cm		#	Rate	%	Rate	#	Rate	%	Rate
0 - 5	Light brown	6.5	Slightly acid	0.22	Non-saline	15.6	Moderate	4.49	Non-sodic
5 - 40	brown	6.9	Neutral	8.26	Highly saline	31.4	High	27.7	Strongly sodic
40 - 70	Reddish brown	6.7	Neutral	10.15	Highly saline	32.3	High	33.1	Strongly sodic

Figure CE4 - B shows the soil texture throughout the profile, and **Figure CE4 - C** shows the trend of exchangeable cations with depth. The full suite of analytical results for this soil type can be found in **Appendix 3**.

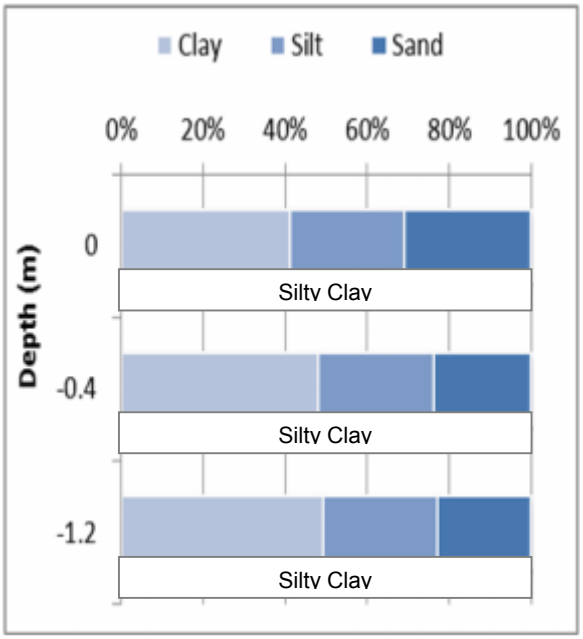


Figure CE4 - B: Particle Size Analysis

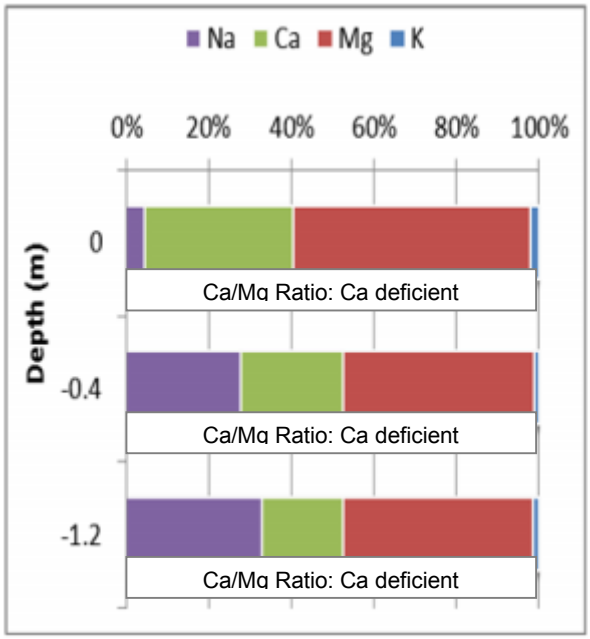


Figure CE4 - C: Exchangeable Cations

CE5 – Rudosol (Site 4)

Soil Description; The Rudosol observed at Site 4 is a uniform textured soil that generally consists of light brown to reddish brown loamy sand to sand throughout the profile. These well drained soils are mildly alkaline, non saline with very low fertility characteristics. The soil is non sodic and structure is weak throughout the profile. The analytical information of the representative site is presented in **Figure CE5 - A** and **Table 5** below.

Management; Generally the soil does not display any specific management risk related to potential disturbance during stripping. The soil is marginally suitable for use in rehabilitation and would benefit by blending with a clay material to improve the water holding capacity. The recommended stripping depth of this soil is 1.2 m, providing it is blended with clay material.

Plate 1.5: CE5 – Rudosol

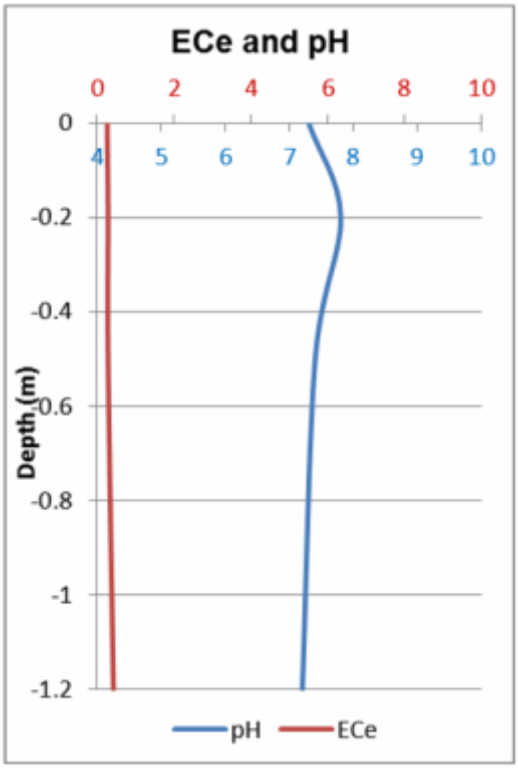


Figure CE5 - A: ECe and pH

Table 5: Laboratory Analysis (CE5)

Depth	Colour	pH		ECe		CEC		ESP	
cm		#	Rate	%	Rate	#	Rate	%	Rate
0 - 10	Light brown	7.3	Neutral	0.253	Non-saline	2.7	Very low	2	Non-sodic
10 - 20	Reddish brown	7.8	Mildly alkaline	0.276	Non-saline	1.2	Very low	4	Non-sodic
40 - 50	Reddish brown	7.4	Mildly alkaline	0.276	Non-saline	1.2	Very low	4	Non-sodic
90 - 120	Reddish brown	7.2	Neutral	0.414	Non-saline	1.0	Very low	5	Non-sodic

Figure CE5 - B shows the soil texture throughout the profile, and **Figure CE5 - C** shows the trend of exchangeable cations with depth. The full suite of analytical results for this soil type can be found in **Appendix 3**.

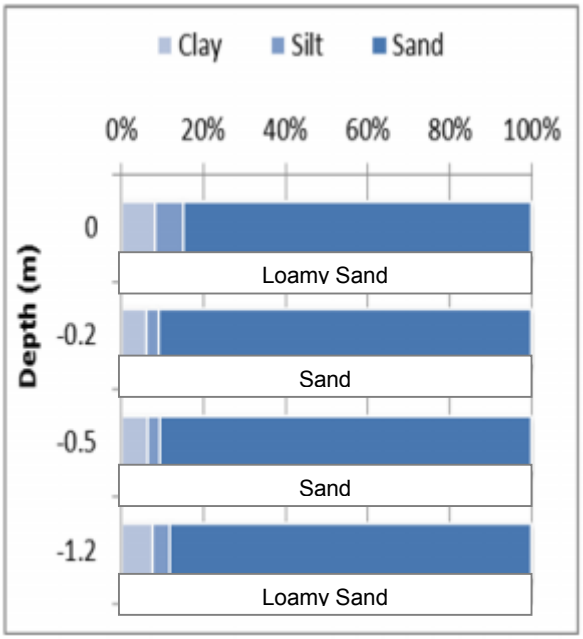


Figure CE5 - B: Particle Size Analysis

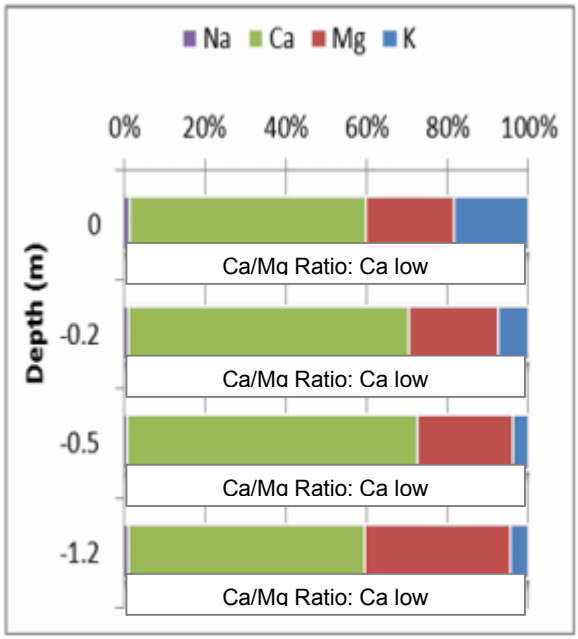


Figure CE5 - C: Exchangeable Cations

3.2.3 Colorado Land System

The Colorado land system represents an extensive area of steeply dissected country in the western half of the Study Area. The plateau margin (CO1) with sandy gradational soils overlying an ironstone hardpan, sometimes exposed at the surface, supports a shrubland with isolated Normanton box, ghost gum and bloodwood. The scarp (CO2) of exposed ferricrete has variable steepness and soil depth, but lancewood and bendee dominate the vegetation. The footslopes (CO3) have open woodlands of silver-leaved ironbark, poplar box and ghost gum with diverse shrub and ground cover layers on deep texture-contrast soil profiles.

Plate 2: Colorado Land System (CO2)

CO1

This land unit represents the margins of the Desert Uplands plateau. An ironstone hardpan occurs throughout, with exposures of ferricrete common along the edge of the scarp. The soils are predominantly shallow, sandy Kandosols (gradational-textured profiles) with abundant ironstone gravel. Shallow, sandy Lithic Rudosols (uniform-textured profiles with no horizon development) are also common. No further details on the soil profile are available for this land unit, given the small size of the area within the Study Area and the rocky, hard pan nature of the material.

CO2

This land unit represents a scarp position in the landscape, which may be precipitous and rocky. Shallow, Red Kandosols (reddish-brown gradational profiles) and Brown Chromosols (texture-contrast soils) are most common, although pockets of deeper soils can be found overlying the ferricrete or ferruginised sandstone.

CO3

This land unit represents a diverse combination of soil-vegetation associations. With increasing distance from the adjacent scarp the slope decreases and the soil depth increases. Shallow Lithic Rudosols (uniform sands) and Kandosols (gradational profiles) with an ironstone hardpan change with increasing distance from the scarp to deep Chromosols (texture-contrast profiles) with reddish-brown clay subsoils. Very deep texture contrast and uniform clay profiles with mottled subsoils, and Vertosols may be present further out.

C02 – Brown Kandosol (Site 23)

Soil Description; The Brown Kandosol observed at Site 23 is a gradational textured soil that generally consists of brown to reddish brown silty loam to silty clay loam down the profile. These moderately drained soils have a slightly acidic to neutral pH, are non saline, non sodic with very low fertility characteristics. Structure is moderate platy to sub angular blocky down the profile. The analytical information of the representative site is presented in **Figure CO2 - A** and **Table 6** below.

Management; Generally these soils do not display any specific management risk related to potential disturbance during stripping. The soil exhibits structure and chemical characteristics that would be suitable as surface cover in rehabilitation. The recommended stripping depth of this soil is 1.2 m.

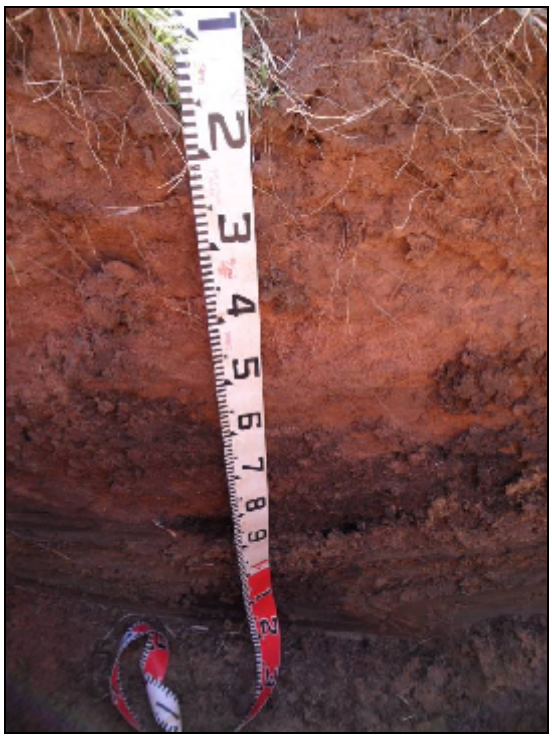


Plate 2.1: C02 – Brown Kandosol

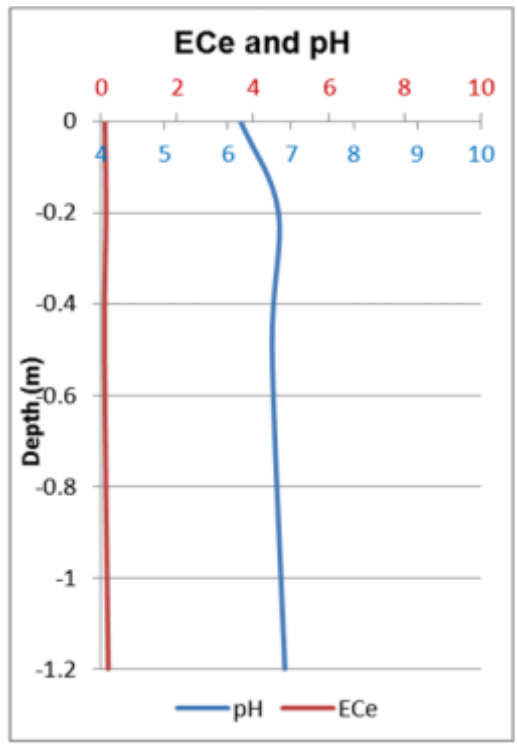


Figure C02 - A: ECe and pH

Table 6: Laboratory Analysis (CO2)

Depth	Colour	pH		ECe		CEC		ESP	
cm		#	Rate	%	Rate	#	Rate	%	Rate
0 -10	Light brown	6.2	Slightly acid	0.10	Non-saline	3.2	Very low	1.56	Non-sodic
10 - 20	Reddish brown	6.8	Neutral	0.12	Non-saline	4.1	Very low	1.22	Non-sodic
40 - 50	Reddish brown	6.7	Neutral	0.09	Non-saline	5.5	Very low	0.91	Non-sodic
90 - 120	Dark greyish brown	6.9	Neutral	0.181	Non-saline	8.9	Low	1.12	Non-sodic

Figure CO2 - B shows the soil texture throughout the profile, and **Figure CO2 - C** shows the trend of exchangeable cations with depth. The full suite of analytical results for this soil type can be found in **Appendix 3**.

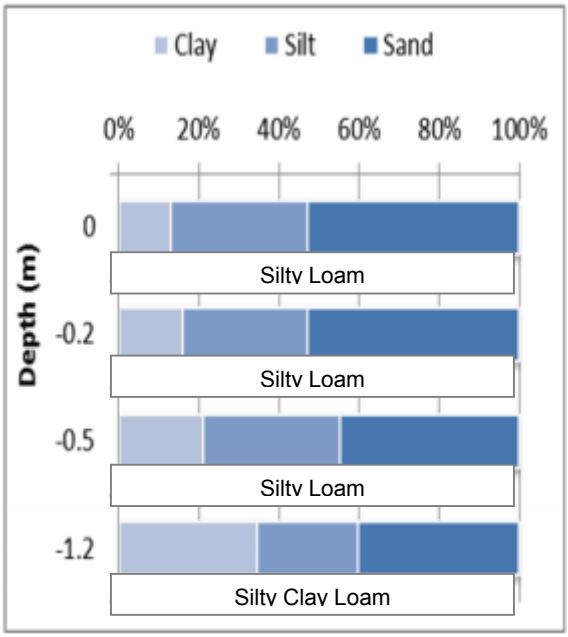


Figure C02 - B: Particle Size Analysis

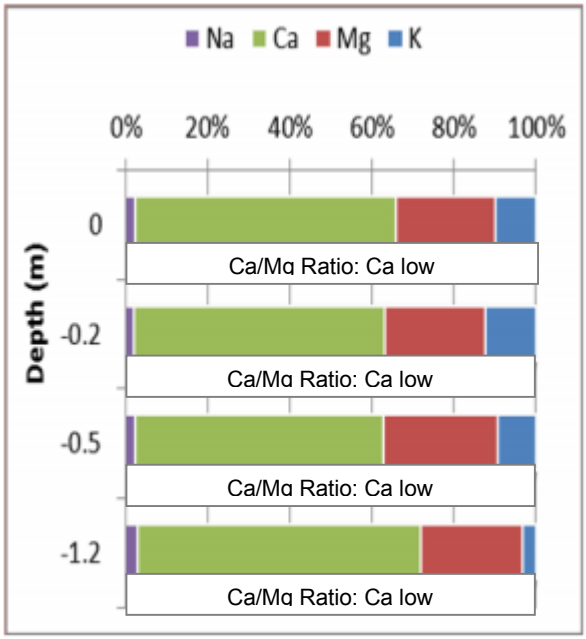


Figure C02 - C: Exchangeable Cations

C03 – Rudosol (Site 8)

Soil Description; The Rudosol observed at Site 8 is a uniform textured soil that generally consists of grey brown to red loamy sand throughout the profile. These well drained soils are slightly acidic, non saline, non sodic with very low fertility characteristics. Structure is weak throughout the profile. The analytical information of the representative site is presented in **Figure CO3 - A** and **Table 7** below.

Management; Generally the soil does not display any specific management risk related to potential disturbance during stripping. The soil is marginally suitable for use in rehabilitation and would benefit by blending with a clay material to improve the water holding capacity. The recommended stripping depth of this soil is 1.2 m, providing it is mixed with clay material.

Plate 2.2: C03 – Rudosol

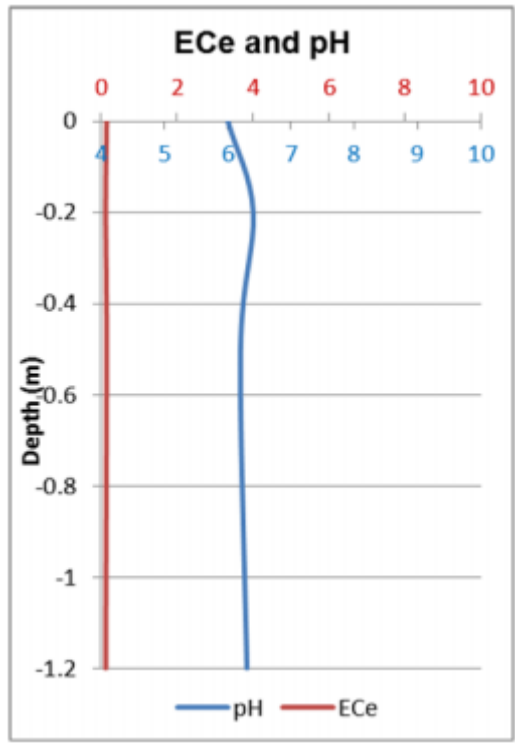


Figure CO3 - A: ECe and pH

Table 7: Laboratory Analysis (CO3)

Depth	Colour	pH		ECe		CEC		ESP	
cm		#	Rate	%	Rate	#	Rate	%	Rate
0 - 10	Light brown	6	Moderately acid	0.138	Non-saline	1.9	Very low	3	Non-sodic
10 - 20	brown	6.4	Slightly acid	0.115	Non-saline	2.3	Very low	2	Non-sodic
40 - 50	Reddish brown	6.2	Slightly acid	0.138	Non-saline	2.1	Very low	2	Non-sodic
90 - 120	Red	6.3	Slightly acid	0.115	Non-saline	1.6	Very low	3	Non-sodic

Figure CO3 - B shows the soil texture throughout the profile, and **Figure CO3 - C** shows the trend of exchangeable cations with depth. The full suite of analytical results for this soil type can be found in **Appendix 3**.

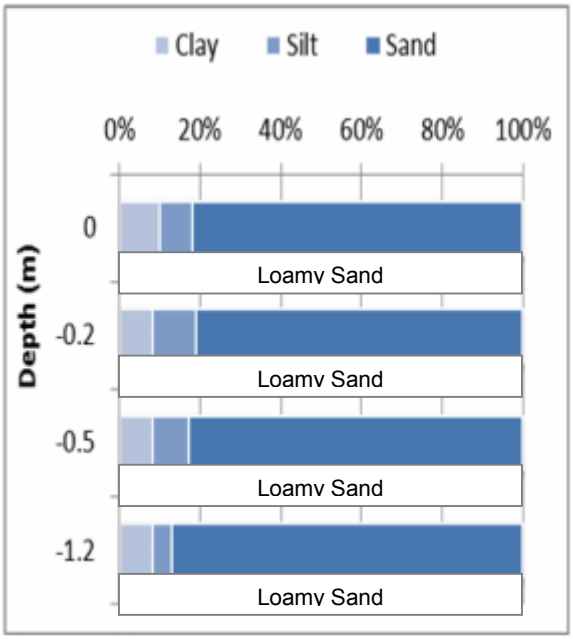


Figure CO3 - B: Particle Size Analysis

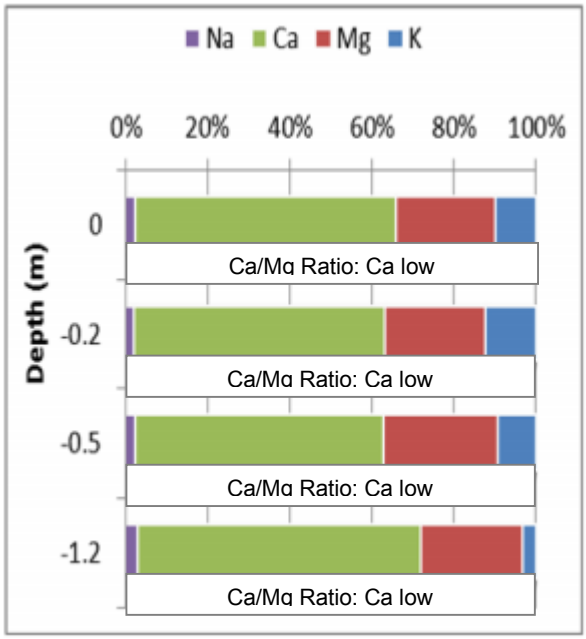


Figure CO3 - C: Exchangeable Cations

3.2.4 Southern Plateau Land System

The Southern Plateau land system represents an extensive landscape of undulating rises to the east of the lateritic Cudmore LS. An ironstone hardpan underlies most of the area and has a profound influence on the vegetation of the crests and upper slopes (SP1), where sparse woodlands of silver-leaved ironbark and ghost gum, together with occasional applejack and bush-house paperbark exist on shallow uniform sands and sandy loams. White cypress pine and poplar box are not uncommon, but represent small areas with deeper soil profiles. On the lower slopes (SP2) deep texture-contrast soil profiles predominate with thick sandy loam topsoils and reddish brown clay subsoils. Tall sparse woodlands consist of silver-leaved ironbark and ghost gum with a mid stratum of ironwood, false sandalwood, prickly pine, quinine tree and dead finish. Gummy spinifex dominates the ground layer. The drainage depressions with young sandy soils of variable depth and river red gum have been combined with closed depressions, which have grey uniform clay soils and coolabah-gidgee vegetation, to form land unit SP3. These areas are minor in extent but have important conservation values as riparian corridors and ephemeral wetlands.

Plate 3: Southern Plateau Land System (SP1)

SP1

This land unit represents the crests and upper slopes in a landscape of undulating rises. The soils are predominantly sandy loam Rudosols (uniform-textured profiles) overlying a ferricrete hardpan at 0.5 m or less. The vegetation is much more variable, as small differences in depth or texture of the soil result in different proportions within the community and different species assuming dominance. The most common community is a tall sparse woodland of Eucalyptus melanophloia (silver-leaved ironbark), E. populnea (poplar box) and Corymbia dallachiana (ghost gum), with an occasional C. setosa (applejack) or C. plena (large-fruited bloodwood). Very shallow soils with ironstone close to, or at, the surface often have Melaleuca tamariscina (bush-house paperbark) and M. uncinata (mallee broombush), whereas pockets of Callitris glaucophylla (white cypress pine) occur in areas with deeper sand profiles. A sparse shrub layer includes Carissa ovata (currant bush), Grevillea parallela (silver oak) and Acacia coriacea (desert oak) while the ground layer is dominated by Triodia pungens (gummy spinifex), Aristida holathera (erect kerosene grass) and Chrysopogon fallax (golden beard grass). Because of the proximity of the Grant (GT) land system it is not unusual to have outliers of those characteristic heath-wattle communities within this land unit.

SP2

This land unit represents the middle and lower slopes in a landscape of an undulating plain. Red Chromosols (reddish brown texture-contrast profiles) are dominant. Topsoil depth and subsoil colour vary according to position in the landscape and hydromorphic conditions respectively. However, most common are Red Chromosols with thick, reddish brown sandy loam topsoils over very deep, red clayey subsoils. An ironstone hardpan may be present below 1.5 m.

SP3

This land unit represents the drainage depressions and shallow closed depressions. Young, sandy Stratic Tenosols and Kandosols (uniform and gradational-textured profiles, respectively) of variable depth are predominant in the drainage depressions and interfluves with Eucalyptus camaldulensis (river red gum) on the stream banks and E. populnea (poplar box) on the current floodplain. In the shallow closed depressions the soils are typically deep and clayey. Grey Vertosols (uniform cracking-clays) predominate although some depressions are saline and devoid of vegetation. E. coolabah (coolabah) and Acacia cambagei (gidgee) are common, together with Myoporum acuminatum (waterbush) and Eremophila mitchelli (false sandalwood).

An overview of the representative soil types for each of these units in provided below, and due to the widespread distribution of the units SP1 and SP2 throughout the Study Area, there are multiple representative soil types elected to represent these areas (SP1a, b & c, SP2 a & b).

SP1a – Red Dermosol (Site 97)

Soil Description; The Red Dermosol observed at Site 97 is a uniform textured soil that generally consists of red brown to red silty clay loam throughout the profile. These well drained soils are strongly acidic, non saline, non sodic with very low fertility characteristics. Structure is strong in the topsoil and weak in the subsoil. The analytical information of the representative site is presented in **Figure SP1a - A** and **Table 8** below.

Management; Although the soil is strongly acidic, lime can be applied to ensure there is minimal management risks related to potential disturbance during stripping. The soil is marginal to not suitable given the poor structure and high acidity, as a surface cover in rehabilitation, and acid tolerant species may be required.

Plate 3.1: SP1a – Red Dermosol

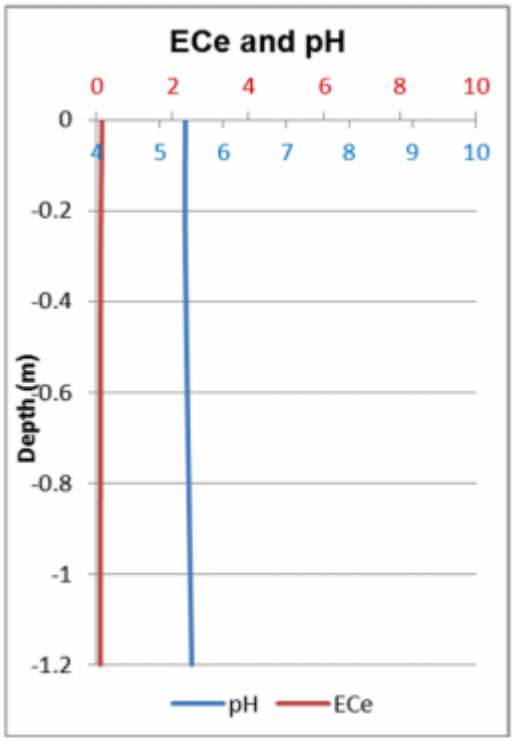


Figure SP1a - A: ECe and pH

Table 8: Laboratory Analysis (SP1a)

Depth	Colour	pH		ECe		CEC		ESP	
cm		#	Rate	%	Rate	#	Rate	%	Rate
0 - 10	Reddy brown	5.4	Strongly acid	0.14	Non-saline	3.3	Very low	2	Non-sodic
10 - 30	Red	5.4	Strongly acid	0.10	Non-saline	2.8	Very low	2	Non-sodic
70 - 80	Red	5.5	Strongly acid	0.09	Non-saline	2.6	Very low	8	Marginally sodic

Figure SP1a - B shows the soil texture throughout the profile, and **Figure SP1a - B** shows the trend of exchangeable cations with depth. The full suite of analytical results for this soil type can be found in **Appendix 3**.

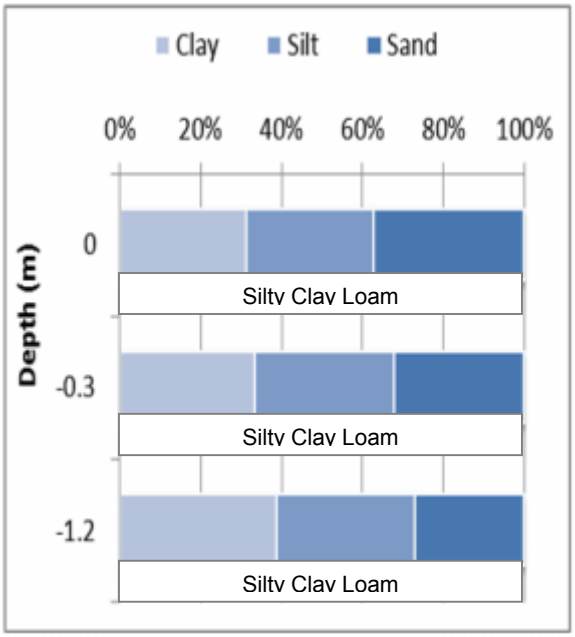


Figure SP1a - B: Particle Size Analysis

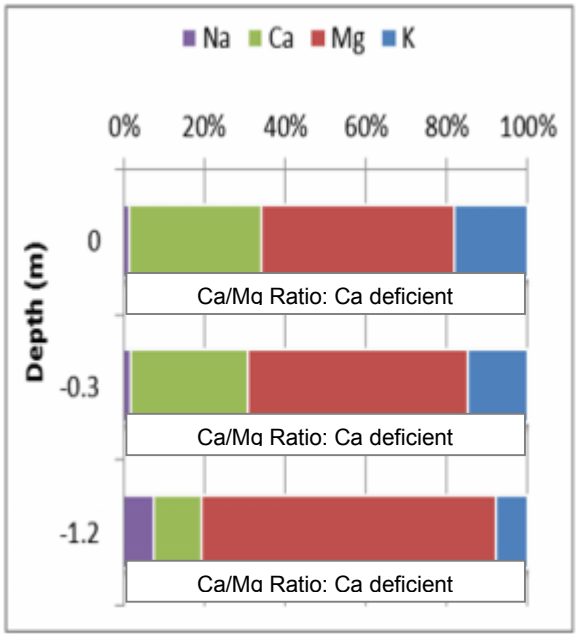


Figure SP1a - C: Exchangeable Cations

SP1b – Yellow Kandosol (Site 1)

Soil Description; The Yellow Kandosol observed at Site 1 is a gradational textured soil that generally consists of brown to pale yellow loam to bright yellow clay loam down the profile. These moderate to poorly drained soils are moderate to slightly acidic, non saline, non sodic with very low fertility characteristics. Structure is moderate platy to sub angular blocky down the profile. The analytical information of the representative site is presented in **Figure SP1b - A** and **Table 9** below.

Management; Generally these soils do not display any specific management risk related to potential disturbance during stripping. The soil exhibits structure and chemical characteristics that would be suitable as surface cover in rehabilitation. The recommended stripping depth of this soil is 1.2 m.

Plate 3.2: SP1b – Yellow Kandosol

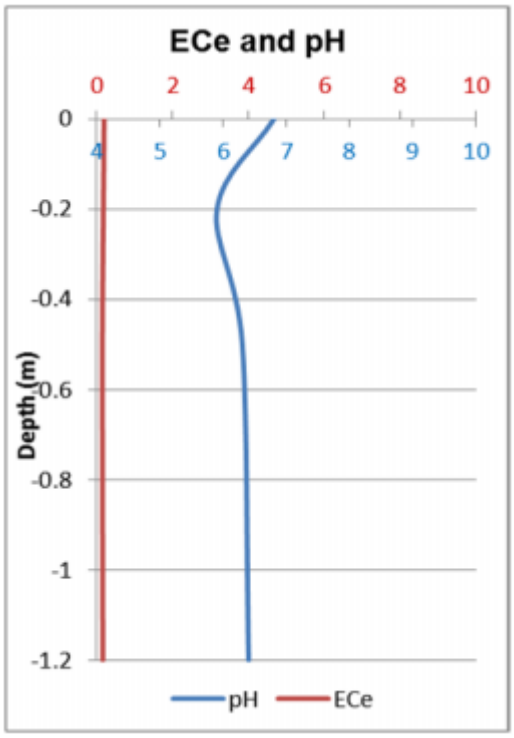


Figure SP1b - A: ECe and pH

Table 9: Laboratory Analysis (SP1b)

Depth	Colour	pH		ECe		CEC		ESP	
cm		#	Rate	%	Rate	#	Rate	%	Rate
0 - 10	Strong brown	6.8	Neutral	0.19	Non-saline	4.1	Very low	1.22	Non-sodic
10 - 20	Pale yellow	5.9	Moderately acid	0.17	Non-saline	3.7	Very low	1.35	Non-sodic
40 - 50	Yellow	6.3	Slightly acid	0.15	Non-saline	4.3	Very low	1.16	Non-sodic
90 - 120	Yellow	6.4	Slightly acid	0.155	Non-saline	5.2	Very low	0.96	Non-sodic

Figure SP1b - B shows the soil texture throughout the profile, and **Figure SP1b - C** shows the trend of exchangeable cations with depth. The full suite of analytical results for this soil type can be found in **Appendix 3**.

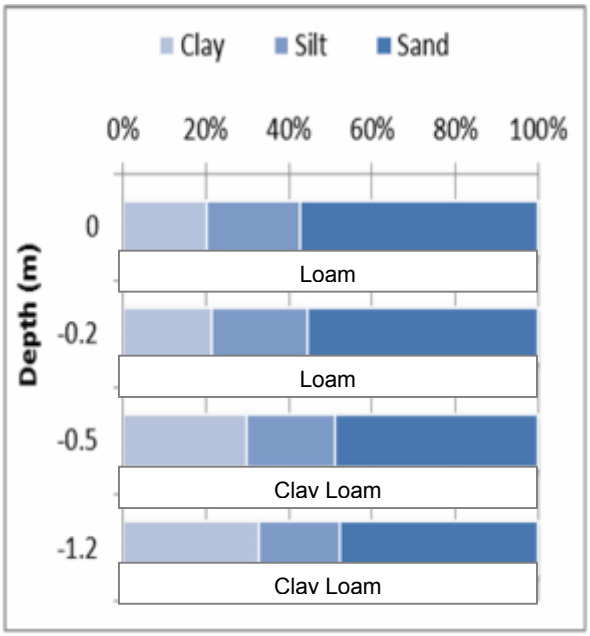


Figure SP1b - B: Particle Size Analysis

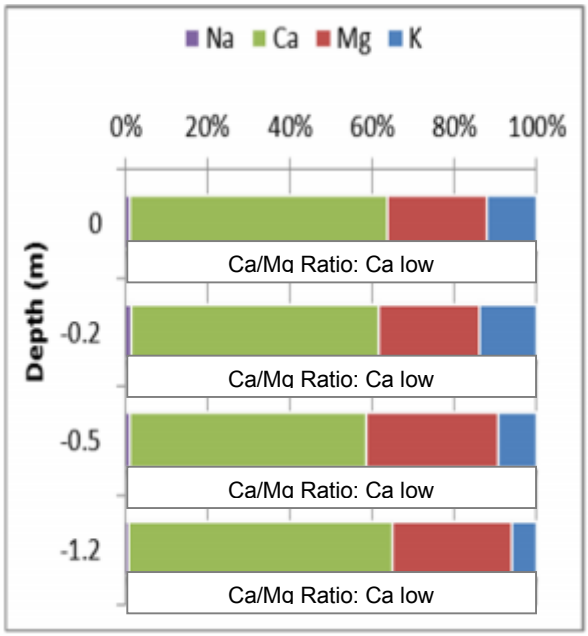


Figure SP1b – C: Exchangeable Cations

SP1c – Yellow Sodosol (Site 3)

Soil Description; The Yellow Sodosol observed at Site 3 is a texture contrast soil that generally consists of grey brown to yellow loam overlying yellow clay. These moderately drained topsoils have weak to moderate structure, are moderately acidic, non saline, non sodic with very low fertility characteristics. The poorly drained subsoils have weak to massive structure, are slightly alkaline, non saline, strongly sodic and have low fertility characteristics. The analytical information of the representative site is presented in **Figure SP1c - A** and **Table 10** below.

Management; Generally the topsoil does not display any specific management risk related to potential disturbance during stripping. The topsoil layer exhibits structural characteristics that would be suitable as surface cover in rehabilitation. The subsoil is sodic and would require erosion control structures to be implemented if disturbed. The recommended stripping depth of this soil is 0.6 m.

Plate 3.3: SP1c – Yellow Sodosol

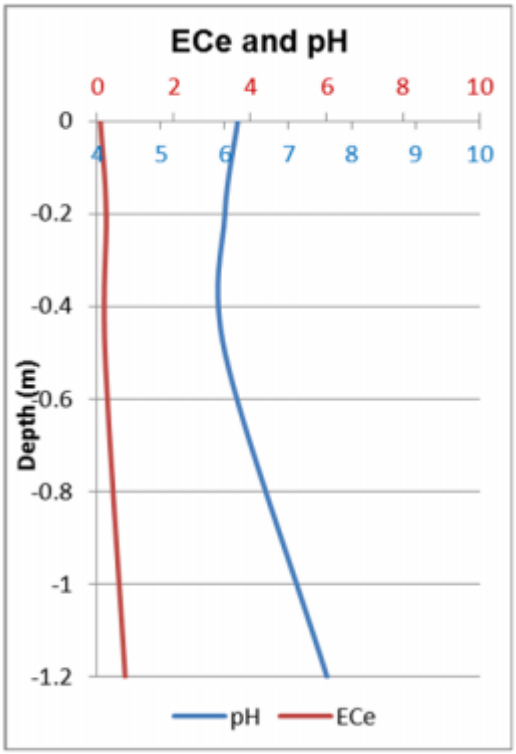


Figure SP1c - A: ECe and pH

Table 10: Laboratory Analysis (SP1c)

Depth	Colour	pH		ECe		CEC		ESP	
cm		#	Rate	%	Rate	#	Rate	%	Rate
0 - 10	Greyish brown	6.2	Slightly acid	0.08	Non-saline	3.0	Very low	1.67	Non-sodic
10 - 20	Yellow	6.0	Moderately acid	0.23	Non-saline	2.8	Very low	1.79	Non-sodic
40 - 50	Yellow	6.0	Moderately acid	0.20	Non-saline	2.5	Very low	2	Non-sodic
90 - 120	Light Yellow	7.6	Slightly alkaline	0.722	Non-saline	10.2	Low	18.6	Strongly sodic

Figure SP1c - B shows the soil texture throughout the profile, and **SP1c - C** shows the trend of exchangeable cations with depth. The full suite of analytical results for this soil type can be found in **Appendix 3**.

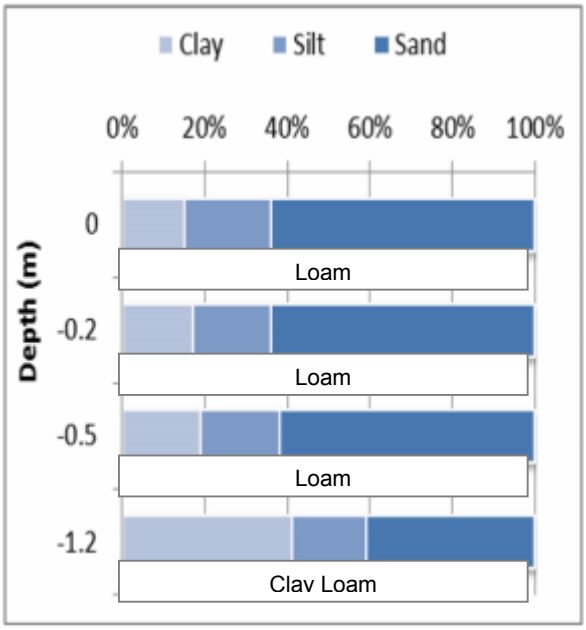


Figure SP1c - B: Particle Size Analysis

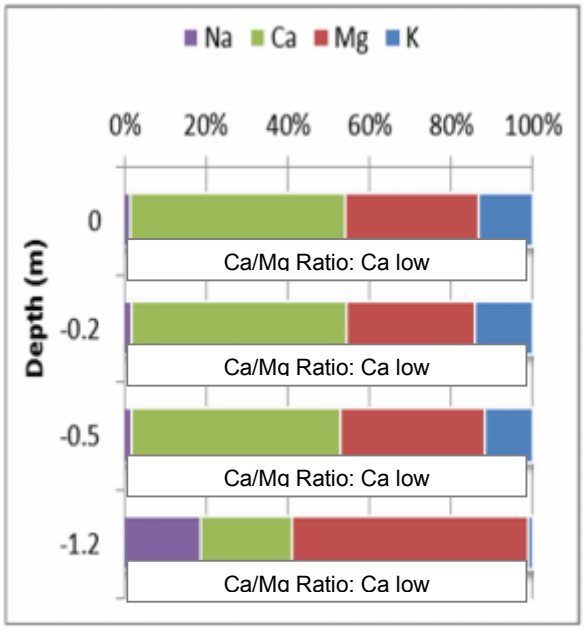


Figure SP1c - C: Exchangeable Cations

SP2a – Red Sodosol (Site 30)

Soil Description; The Red Sodosol observed at Site 30 is a texture contrast soil that generally consists of brown silty loam overlying red silty clay loam. These well drained topsoils have moderate structure, neutral pH, are non saline, non sodic with very low fertility characteristics. The poorly drained subsoils have moderate structure, are moderate to strongly alkaline, moderate to highly saline, strongly sodic and have moderate fertility characteristics. The analytical information of the representative site is presented in **Figure SP2a - A** and **Table 11** below.

Management; Generally the topsoil does not display any specific management risk related to potential disturbance during stripping. The topsoil layer exhibits structural characteristics that would be suitable as surface cover in rehabilitation. The subsoil is strongly sodic and saline and would require erosion control structures to be implemented if disturbed. The recommended stripping depth of this soil is 0.3 m.

Plate 3.4: SP2a – Red Sodosol

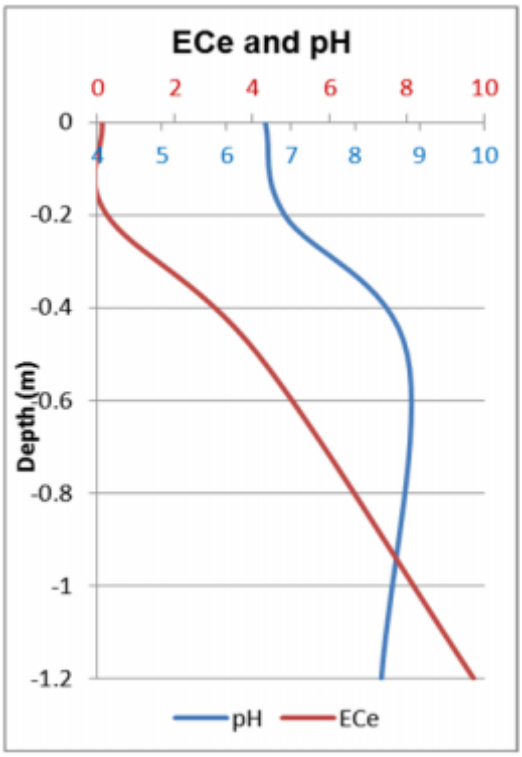


Figure SP2a - A: ECe and pH

Table 11: Laboratory Analysis (SP2a)

Depth	Colour	pH		ECe		CEC		ESP	
cm		#	Rate	%	Rate	#	Rate	%	Rate
0 - 10	Mid brown	6.6	Neutral	0.11	Non-saline	5.9	Very low	3.39	Non-sodic
10 - 20	Mid brown	6.9	Neutral	0.24	Non-saline	5.1	Very low	5.88	Non-sodic
40 - 50	Brownish red	8.8	Strongly alkaline	4.14	Moderately saline	17.8	Moderate	25.3	Strongly sodic
90 - 120	Brownish red	8.4	Moderately alkaline	9.718	Highly saline	18.4	Moderate	47.8	Strongly sodic

Figure SP2a - B shows the soil texture throughout the profile, and **Figure SP2a - C** shows the trend of exchangeable cations with depth. The full suite of analytical results for this soil type can be found in **Appendix 3**.

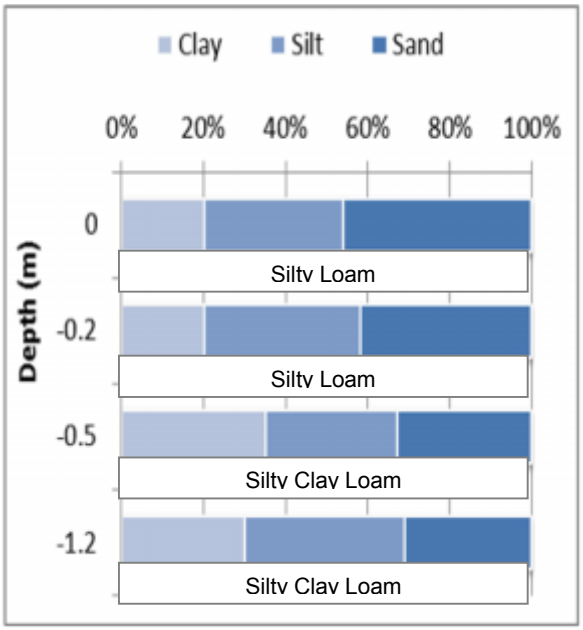


Figure SP2a - B: Particle Size Analysis

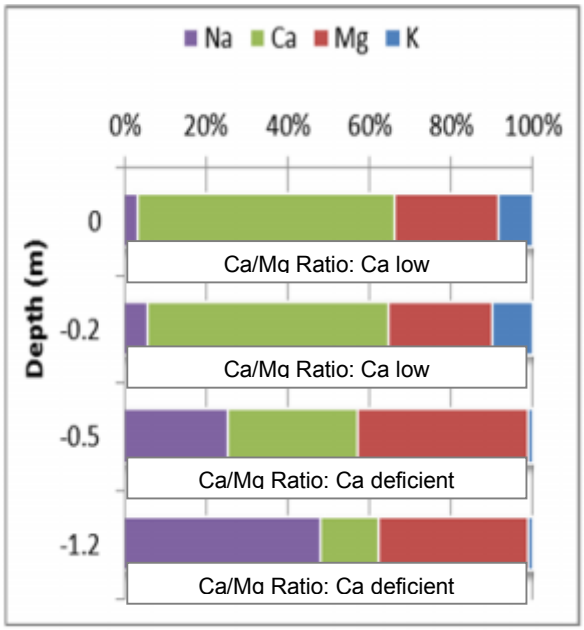


Figure SP2a - C: Exchangeable Cations

SP2b – Brown Dermosol (Site 21)

Soil Description; The Brown Dermosol observed at Site 21 is a uniform textured soil that generally consists of brown to red brown loam through to yellow brown silty loam down the profile. These well drained soils are slightly acidic to neutral, non saline, non sodic with low fertility characteristics. Structure is moderate to weak in the top layers, through to strong in the subsoil. The analytical information of the representative site is presented in **Figure SP2b - A** and **Table 12** below.

Management; Generally these soils do not display any specific management risk related to potential disturbance during stripping. The soil exhibits structure and chemical characteristics that would be suitable as surface cover in rehabilitation. The recommended stripping depth of this soil is 1.2 m.

Plate 3.5: SP2b – Brown Dermosol

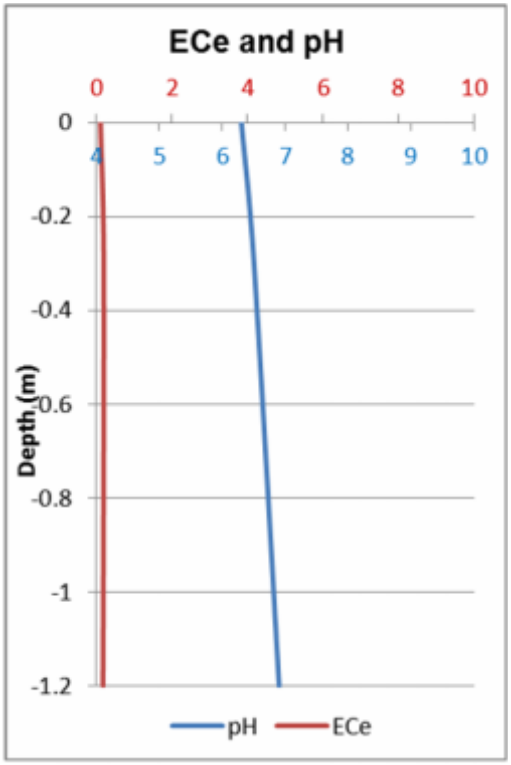


Figure SP2b - A: ECe and pH

Table 12: Laboratory Analysis (SP2b)

Depth	Colour	pH		ECe		CEC		ESP	
cm		#	Rate	%	Rate	#	Rate	%	Rate
0 - 10	Strong brown	6.3	Slightly acid	0.10	Non-saline	4.8	Very low	1.04	Non-sodic
20 - 30	Reddish brown	6.5	Slightly acid	0.19	Non-saline	4.2	Very low	1.19	Non-sodic
70 - 80	Yellowish brown	6.9	Neutral	0.17	Non-saline	4.1	Very low	2.44	Non-sodic

Figure SP2b - B shows the soil texture throughout the profile, and **Figure SP2b - C** shows the trend of exchangeable cations with depth. The full suite of analytical results for this soil type can be found in **Appendix 3**.

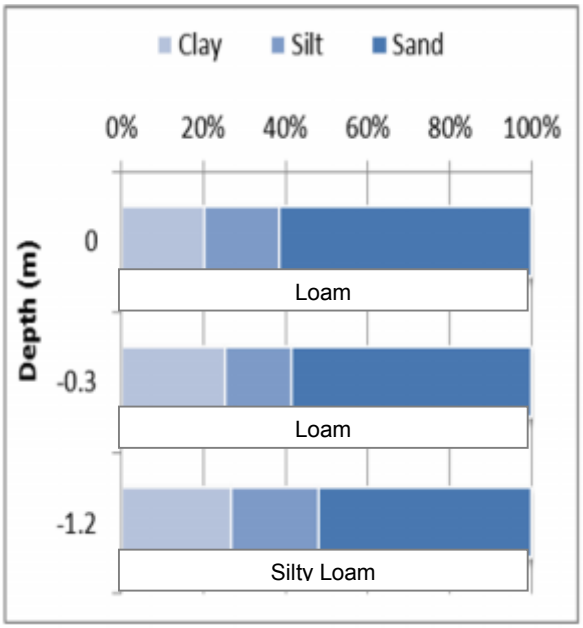


Figure SP2b - B: Particle Size Analysis

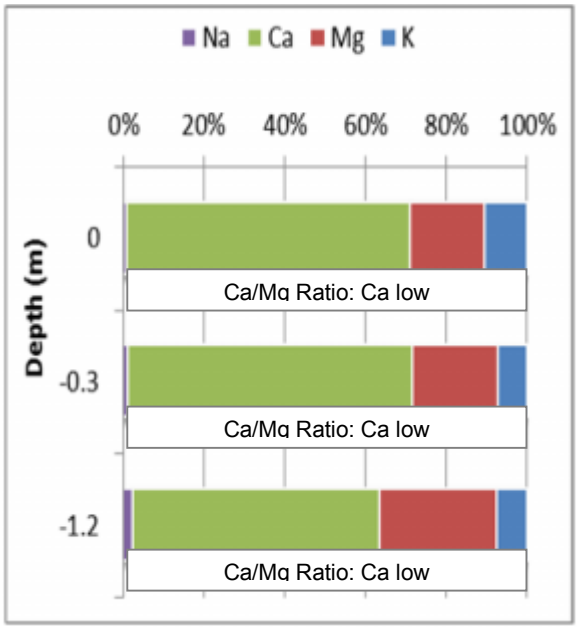


Figure SP2b - C: Exchangeable Cations

SP3 – Red Sodic Dermosol (Site 16)

Soil Description; The Red Sodic Dermosol observed at Site 16 is a gradational textured soil that generally consists of reddish brown to red silty loam through to mottled yellow clay loam down the profile. These well drained soils are slightly neutral to moderately alkaline, non saline, non sodic to strongly sodic in the lower layer, with very low to low fertility characteristics. Structure is strong to moderate down the profile. The analytical information of the representative site is presented in **Figure SP3 - A** and **Table 13** below.

Management; Generally the topsoil does not display any specific management risk related to potential disturbance during stripping. The topsoil layer exhibits structural characteristics that would be suitable as surface cover in rehabilitation. The subsoil is strongly sodic and would require erosion control structures to be implemented if disturbed. The recommended stripping depth of this soil is 0.3 m.

Plate 3.6: SP3 – Red Sodic Dermosol

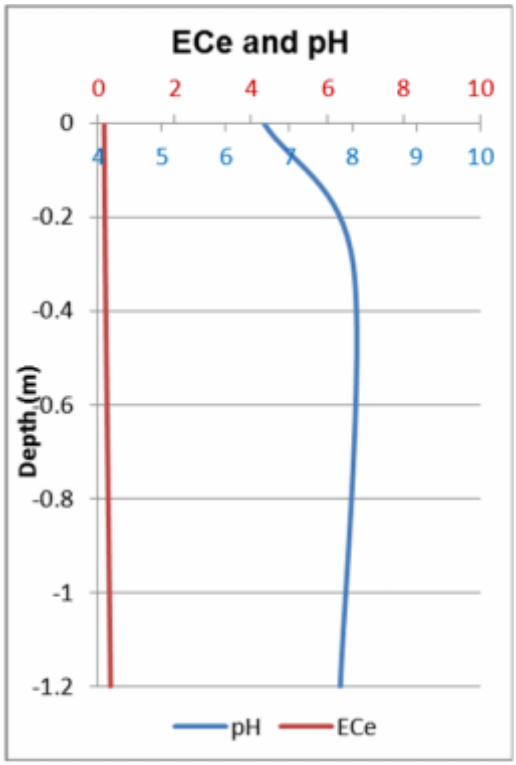


Figure SP3 - A: ECe and pH

Table 13: Laboratory Analysis (SP3)

Depth	Colour	pH		ECe		CEC		ESP	
cm		#	Rate	%	Rate	#	Rate	%	Rate
0 - 10	Red brown	6.6	Neutral	0.15	Non-saline	4.8	Very low	1.04	Non-sodic
25 - 30	Red	8.0	Moderately alkaline	0.18	Non-saline	5.3	Very low	3.77	Non-sodic
30 - 100	Yellow	7.8	Slightly alkaline	0.32	Non-saline	7.3	Low	16.4	Strongly sodic

Figure SP3 - B shows the soil texture throughout the profile, and **Figure SP3 - C** shows the trend of exchangeable cations with depth. The full suite of analytical results for this soil type can be found in **Appendix 3**.

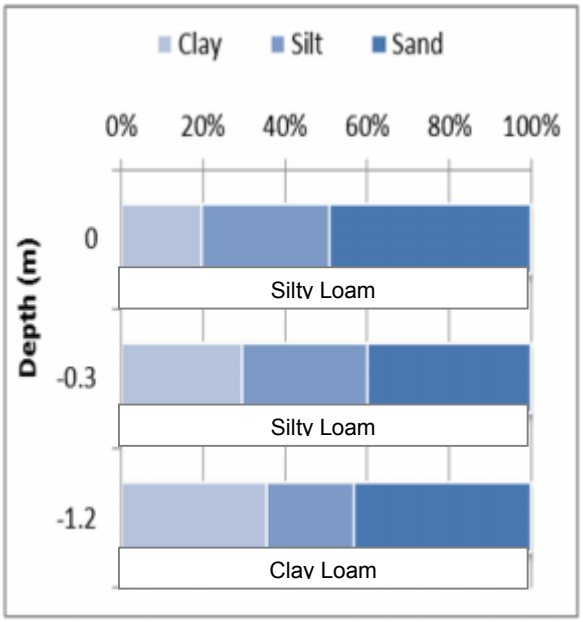


Figure SP3 - B: Particle Size Analysis

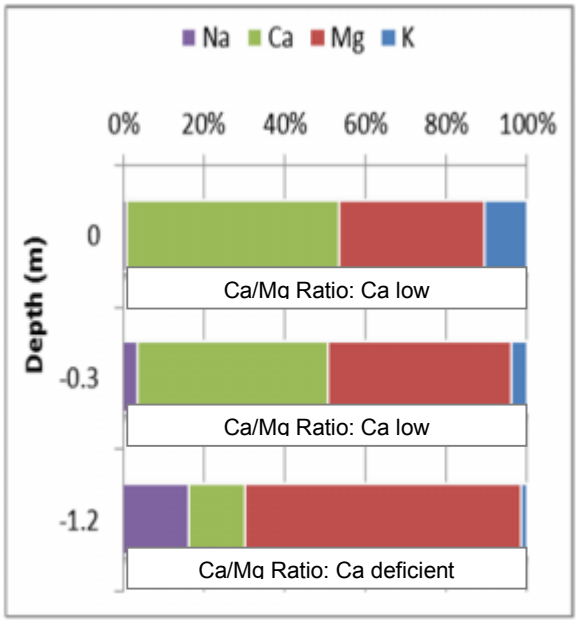


Figure SP3 - C: Exchangeable Cations

3.2.5 Joe Joe Land System

The Joe Joe land system represents a prominent ridge of sandstones on the eastern side of the lease. The crests and upper slopes have open woodlands dominated by silver-leaved ironbark on moderately deep, reddish-yellow, texture-contrast soils, which overlie a hardpan (JJ2). Also on the upper slopes, small areas of deep, red gradational sandy soils supporting low woodlands of yellow jacket-applejack (JJ1) occur at random. Exposures of the underlying ironstone hardpan appear as steep scarps with shallow rocky, gradational soils with mid-tall forests of lancewood (JJ3), whereas the lower slopes have deep texture-contrast profiles with yellowish brown clayey subsoils and tall woodlands of poplar box, bloodwood, and silver-leaved ironbark (JJ4). The drainage depressions have soil types ranging from young sandy alluvial deposits of variable depths supporting tall woodlands of poplar box, to silty loams on incised stream-banks with river red gum, to heavy clay soils on the lower reaches with brigalow (JJ5). Alluvial outwash fans adjacent to the lower drainage depressions are mostly cleared, but once supported woodlands of poplar box, silver-leaved ironbark and ghost gum on deep uniform sandy loam soils (JJ6).

Plate 4: Joe Joe Land System (JJ2)

JJ1

This land unit represents the small areas of red sandy gradational soils Red Kandosols, which occur on the upper slopes along the ridge of the Joe Joe land system. Sites with detailed soil and vegetation information are not available, due to restricted access and relatively small areas of this unit within the Project boundary. No further details on the soil profile are available for this land unit, given the small size within the Study Area and limited access during fieldwork.

JJ2

This land unit is characterised by undulating rises with shallow, gravelly, *Yellow Chromosols (reddish-yellow texture-contrast soils)*, often associated with ferricrete hardpan within 0.5m of the surface.

JJ3

This land unit represents the steep slopes of a scarp, which occupy small areas in several locations along the main ridge of the Joe Joe land system. The shallow Kandosols have stony gradational profiles,

although pockets of sandy loam Orthic Tenosols (uniform-textured profiles), Deeper Yellow Sodosols and Red Chromosols (reddish-brown texture-contrast profiles) are not uncommon: an ironstone hardpan is often exposed.

JJ4

This land unit represents the lower slopes where Brown Chromosols (deep, texture-contrast profiles with sandy loam topsoils and yellowish brown clayey subsoils) have formed in situ. Sites with detailed soil and vegetation information are not available.

JJ5

This land unit represents the shallow depressions and narrow drainage lines. Common soil types include young Tenosols (uniform sandy and silty loam profiles) of variable depths over older clayey profiles and Yellow Sodosols (texture-contrast profiles with sodic subsoils) with silty loam topsoils over mottled clay subsoils.

JJ6

This land unit represents an alluvial fan, and exists to s minor extent in the far eastern corner of the Study Area. Common soil types include Reddish-brown sandy loam Rudosols (uniform-textured profiles without horizon development) predominate. Buried clay horizons of an older soil usually occur at approximately 1m depth and are present throughout.

An overview of the representative soil types for each of these units in provided below.

JJ2 – Grey Sodosol (Site 31)

Soil Description; The Grey Sodosol observed at Site 31 is a texture contrast soil that generally consists of grey loamy sand overlying a bleached loamy sand A2 horizon and a mottled grey sandy clay loam. The profile ranges from slightly acid to moderately acid pH, is non-saline with very low fertility characteristics. The topsoil in marginally sodic, and becomes sodic with depth. Structure in the upper profile is apedal, with subsoil structure being moderate with 10 - 20mm blocky peds. The analytical information of the representative site is presented in **Figure JJ2 – A** and **Table 14** below. The clay subsoil was not subject to laboratory analysis, and texture was determined by field observation.

Management; This soil is unsuitable for stripping and re-use in rehabilitation due to the sodic nature of the material throughout the profile. The soil would require erosion and sediment control structures to be implemented if disturbed.

Plate 4.1: JJ2 – Grey Sodosol

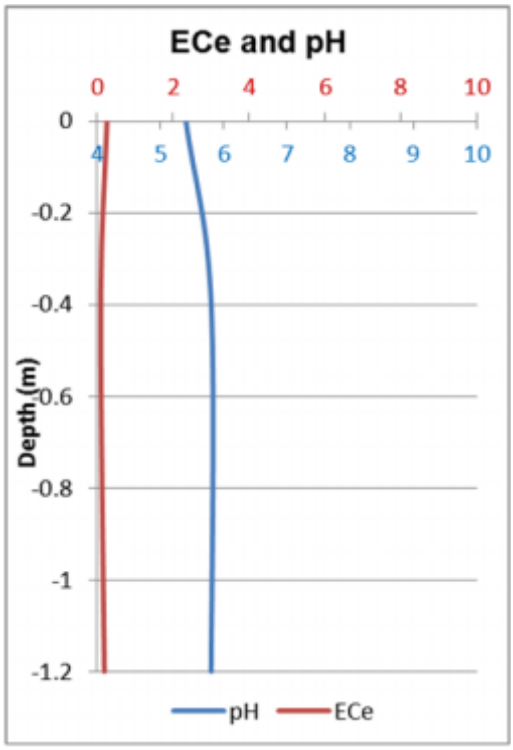


Figure JJ2 - A: ECe and pH

Table 14: Laboratory Analysis (JJ2)

Depth	Colour	pH		ECe		CEC		ESP	
cm		#	Rate	%	Rate	#	Rate	%	Rate
0 - 10	Grey	5.4	Strongly acid	0.253	Non-saline	0.8	Very low	6	Marginally sodic
10 - 20	Grey	5.8	Moderately acid	0.092	Non-saline	0.4	Very low	13	Sodic
40 - 50	Pale Grey	5.8	Moderately acid	0.184	Non-saline	0.4	Very low	13	Sodic

Figure JJ2 - B shows the soil texture throughout the profile, and **Figure JJ2 – C** shows the trend of exchangeable cations with depth. The full suite of analytical results for this soil type can be found in **Appendix 3**. The lower layer PSA was based on field observations.

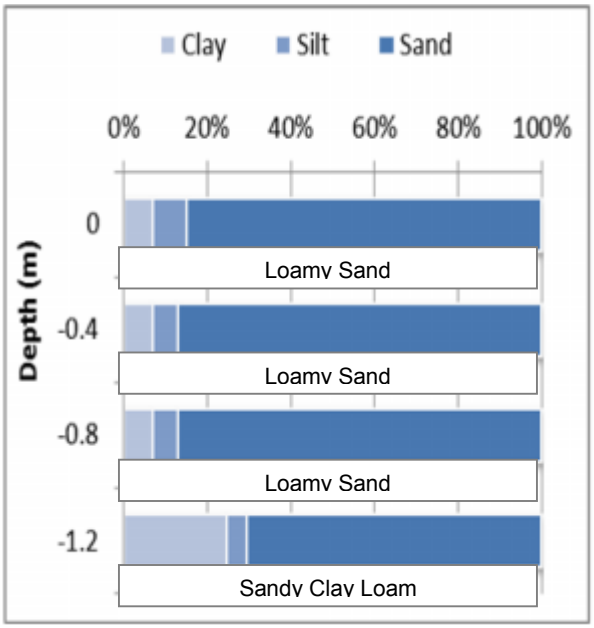


Figure JJ2 - B: Particle Size Analysis

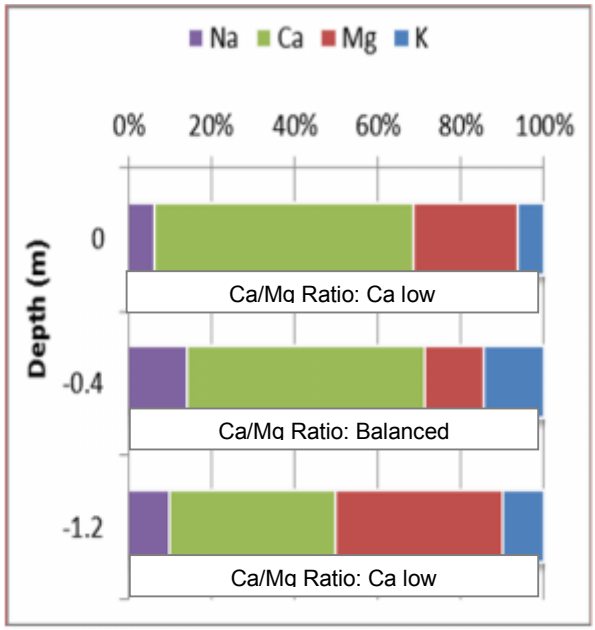


Figure JJ2 - C: Exchangeable Cations

JJ3 – Grey Chromosol (Site 32)

Soil Description; The Grey Chromosol observed at Site 32 is a texture contrast soil that generally consists of grey sand overlying grey sandy clay. These well drained topsoils have apedal structure, whilst the poorly drained subsoils soils are moderately structured with 10mm sub angular blocky peds. Laboratory analysis was not undertaken for this soil type. The above description is based on field observations, however the following information applies to the land unit: The sandy topsoil of this soil type is prone to sheet erosion which has been enhanced by cattle grazing in the area.

Management; The sandy texture and apedal structure of this soil is unsuitable for stripping and re-use in rehabilitation, however in the event extra soil is required, this material can be blended with clay material to create a suitably textured material for rehabilitation. If treated, this soil can be stripped to 1.2m.

Plate 4.2: JJ3 – Grey Chromosol

JJ4 – Brown Chromosol (Site 33)

Soil Description; The Brown Chromosol observed at Site 33 is a texture contrast soil that generally consists of brown to red silty loam overlying grey medium clay. These well drained topsoils are moderately acidic, non saline and non sodic with very low fertility characteristics. The poorly drained subsoil is slightly acidic, non saline and marginally sodic with low fertility characteristics. Structure in the topsoil is weak with blocky peds of 7mm, through to apedal blocky peds in the subsoil. The analytical information of the representative site is presented in **Figure JJ4 - A** and **Table 15** below.

Management; The silty loam topsoil does not display any specific management risk related to potential disturbance during stripping. The upper layers exhibit structure and chemical characteristics that would be suitable as surface cover in rehabilitation. The recommended stripping depth of the topsoil is 0.4m. The recommended stripping depth of the subsoil is 0.4 m, if the clay subsoil is blended with sandy material before reuse in rehabilitation.

Plate 4.3: JJ4 – Brown Chromosol

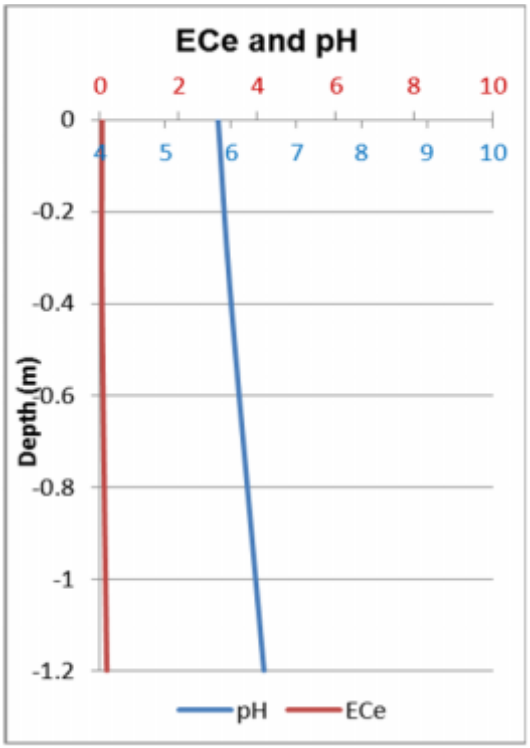


Figure JJ4 - A: ECe and pH

Table 15: Laboratory Analysis (JJ4)

Depth	Colour	pH		ECe		CEC		ESP	
cm		#	Rate	%	Rate	#	Rate	%	Rate
0 - 10	Brown	5.8	Moderately acid	0.048	Non-saline	1.4	Very low	4	Non-sodic
10 - 20	Red	6.0	Moderately acid	0.048	Non-saline	1.4	Very low	4	Non-sodic
40 -50	Grey	6.5	Slightly acid	0.168	Non-saline	11.3	Low	7	Marginally sodic

Figure JJ4 - B shows the soil texture throughout the profile, and **Figure JJ4 - C** shows the trend of exchangeable cations with depth. The full suite of analytical results for this soil type can be found in **Appendix 3**.

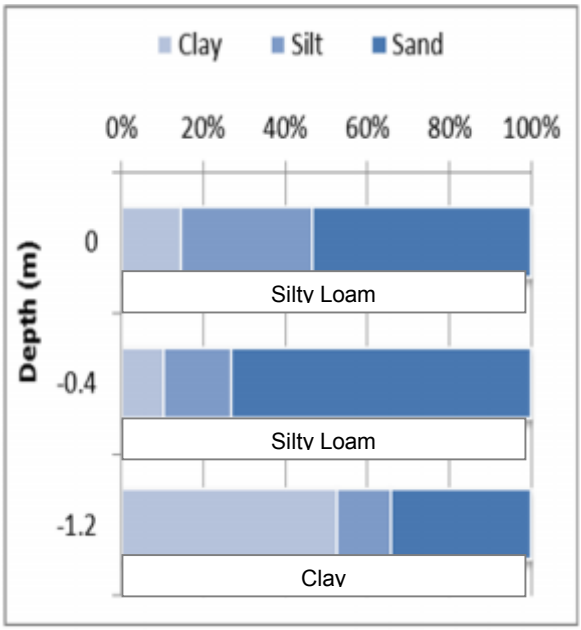


Figure JJ4 - B: Particle Size Analysis

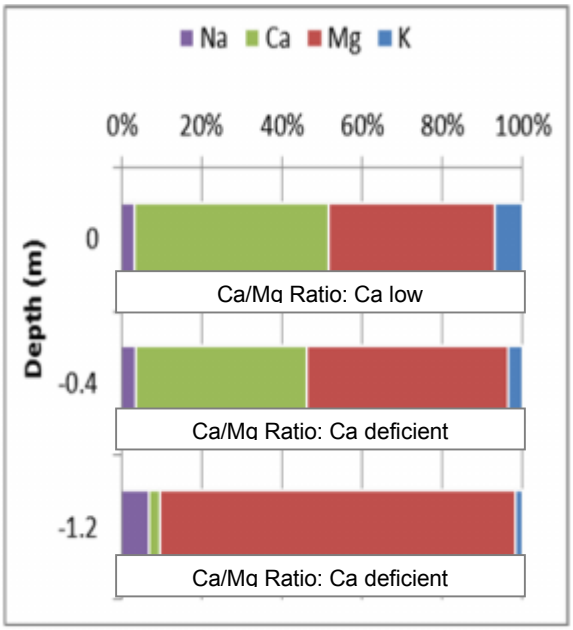


Figure JJ4 - C: Exchangeable Cations

JJ5 – Tenosol (Site 42)

Soil Description; The Tenosol observed at Site 42 is a texturally uniform to gradational soil that generally consists of strong brown loamy sand overlying light brown loam. These well drained soils are slightly acidic in the topsoil to neutral through the profile. They are non-saline and non sodic with very low fertility characteristics. Structure in the topsoil is weak with platy peds of 20 – 50mm, through to apedal structure in the subsoil. Stones of 10mm are at a 10 per cent presence in the subsoil. The analytical information of the representative site is presented in **Figure JJ5 - A** and **Table 16** below.

Management; This soil type does not display any specific management risk related to potential disturbance during stripping. This material is not suitable for stripping and re-use in rehabilitation unless blended with clay material before re-spreading to increase water holding capacity. The potential stripping depth of this soil is 1.2 m, providing it is mixed with clay material.

Plate 4.4: JJ5 – Tenosol

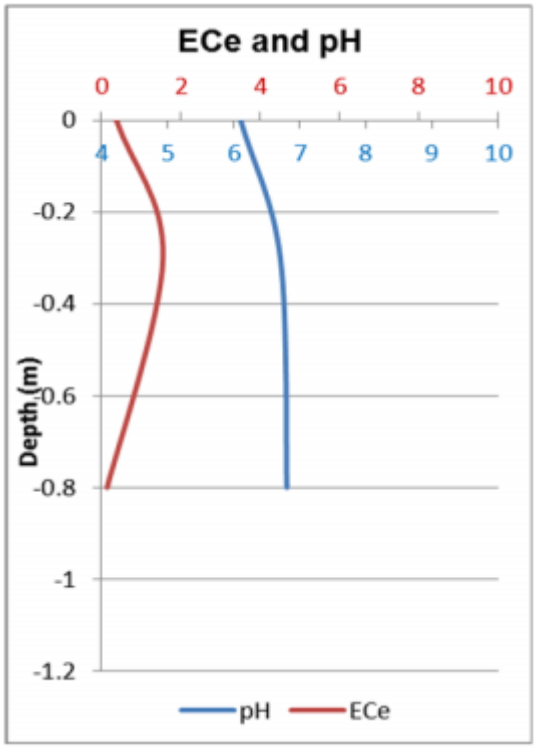


Figure JJ5 - A: ECe and pH

Table 16: Laboratory Analysis (JJ5)

Depth	Colour	pH		ECe		CEC		ESP	
cm		#	Rate	%	Rate	#	Rate	%	Rate
0 - 10	Brown	6.1	Slightly acid	0.36	Non-saline	4.1	Very low	1	Non-sodic
20 - 30	Light brown	6.7	Neutral	1.54	Non-saline	3.3	Very low	2	Non-sodic
70 - 80	Light brown	6.8	Neutral	0.13	Non-saline	1.7	Very low	3	Non-sodic

Figure JJ5 - B shows the soil texture throughout the profile, and **Figure JJ5 - C** shows the trend of exchangeable cations with depth. The full suite of analytical results for this soil type can be found in **Appendix 3**.

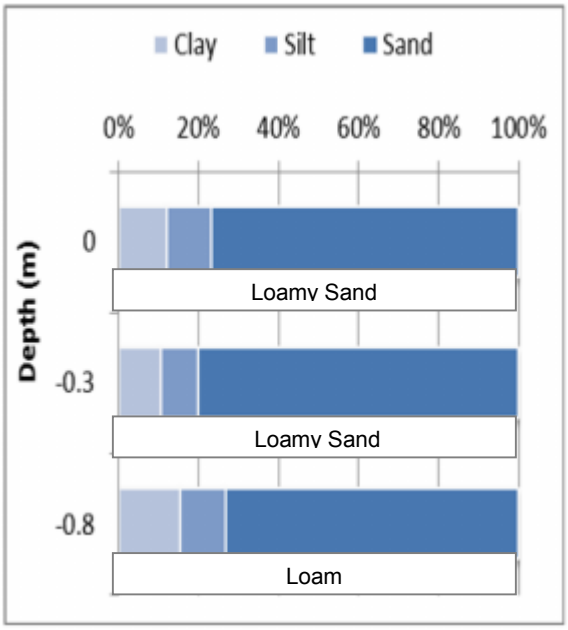


Figure JJ5 - B: Particle Size Analysis

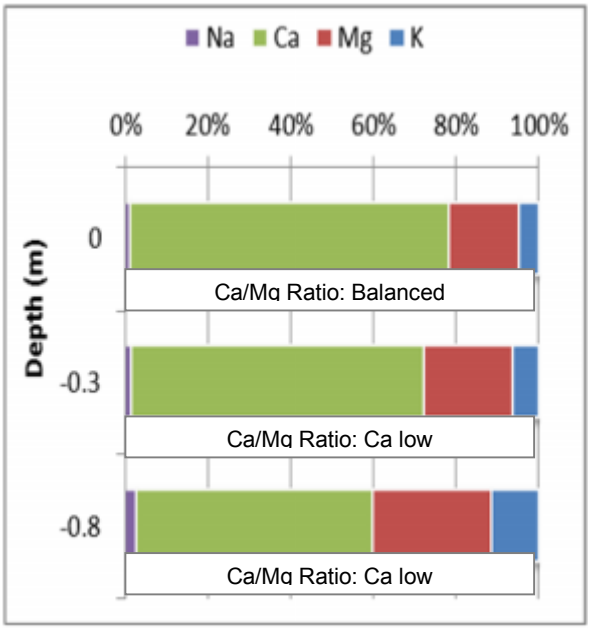


Figure JJ5 - C: Exchangeable Cations

3.2.6 Lambton Meadows Land System

The Lambton Meadows land system represents an extensive alluvial fan, extending in from the south east into Lagoon Creek which runs north through the centre of the lease. The soils on the upper slopes (LM1) overlie a hardpan, and consist of Yellow Chromosols texture-contrast profiles with sodic, reddish yellow, clay loam subsoils, which support tall open woodlands of silver-leaved ironbark, with occasional ghost gum and poplar box. The lower slopes (LM2) also have Sodosols which are texture-contrast soils but the mottled sandy clay subsoil is sodic.

Plate 5: Lambton Meadows Land System (LM2)

LM2

This land unit represents the lower slopes of an extensive alluvial fan. Sites with detailed soil and vegetation information are not available, however general observations indicate that Yellow Sodosols (texture contrast profiles with sodic subsoils) are predominant. Thick sandy loam topsoils (Stratic Rudosols) have also built up from accumulated wash material and overlie a mottled sodic, sandy clay.

LM3

This land unit represents the drainage depression along Sandy Creek, which collect and transport runoff and sediment from the alluvial fan itself and from other land systems at higher elevations to the west. During periods of high runoff and flood, a considerable quantity of sandy material is reworked and transported downstream, causing much variation in texture and depth of the young soil profiles, not to mention the composition and structure of the associated vegetation. Deep sandy Stratic Tenosols (uniform-textured profiles) are common (site 348 and observation 49 is described in detail for this land unit), but more developed profiles with clayey subsoils predominate on the broad interfluves.

An overview of the representative soil types for each of these units in provided below.

LM2 – Stratic Rudosol (Site 47)

Soil Description; The Stratic Rudosol observed at Site 47 is a young texturally layered soil that generally consists of light brown loamy sand through yellow loan overlying yellow clay loam. These well drained soils are slightly acid to moderately acid, non saline and non sodic with very low fertility characteristics. Structure is moderate in the upper layer trending to apedal and weak in the lower layers. The analytical information of the representative site is presented in **Figure LM2 - A** and **Table 17** below.

Management; Generally the soil does not display any specific management risk related to potential disturbance during stripping. The soil is suitable for use in rehabilitation, however the upper sandy layers would benefit by blending with a clay material to improve the water holding capacity. The recommended stripping depth of this soil is 1.2 m.

Plate 5.1: LM2 – Stratic Rudosol

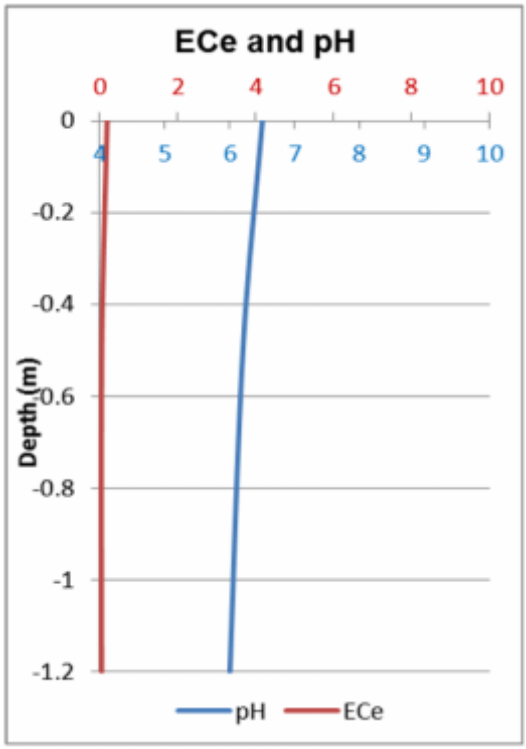


Figure LM2 - A: ECe and pH

Table 17: Laboratory Analysis (LM2)

Depth	Colour	pH		ECe		CEC		ESP	
cm		#	Rate	%	Rate	#	Rate	%	Rate
0 - 10	Light Brown	6.5	Slightly acid	0.184	Non-saline	3.5	Very low	1	Non-sodic
40 - 50	Yellow	6.2	Slightly acid	0.048	Non-saline	2.2	Very low	2	Non-sodic
90 -120	Yellow	6	Moderately acid	0.043	Non-saline	3.3	Very low	2	Non-sodic

Figure LM2 - B shows the soil texture throughout the profile, and **Figure LM2 - C** shows the trend of exchangeable cations with depth. The full suite of analytical results for this soil type can be found in **Appendix 3**.

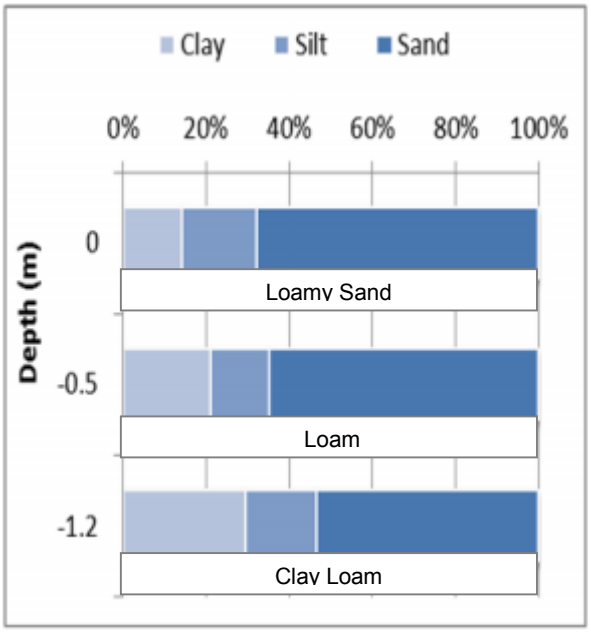


Figure LM2 - B: Particle Size Analysis

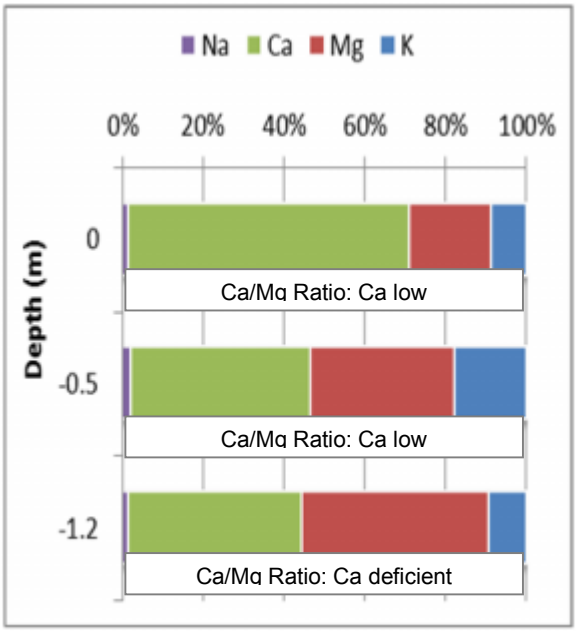


Figure LM2 - C: Exchangeable Cations

LM3 – Stratic Tenosol (Site 91)

Soil Description; The Stratic Tenosol observed at Site 91 is a texturally uniform soil that generally consists of brown loamy sand to sand overlying brown red to red loamy sand. These well drained soils are slight acidity to neutral through the profile. They are non-saline and non sodic with very low fertility characteristics. Structure in the topsoil is weak with platy peds of 20 – 50mm, through to apedal structure in the remainder of the profile. The analytical information of the representative site is presented in **Figure LM3 – A** and **Table 18** below.

Management; This soil type does not display any specific management risk related to potential disturbance during stripping. This material is not suitable for stripping and re-use in rehabilitation unless blended with clay material before re-spreading to increase water holding capacity. The potential stripping depth of this soil is 1.2 m, providing it is mixed with clay material.

Plate 5.2: LM3 – Stratic Tenosol

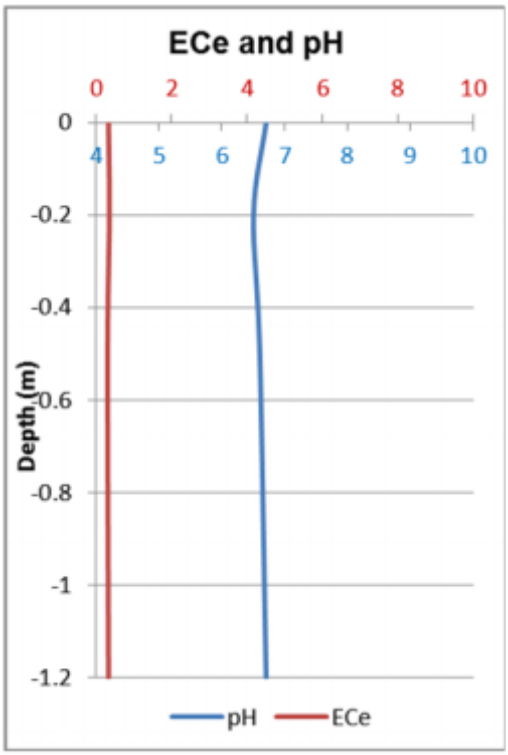


Figure LM3 - A: ECe and pH

Table 18: Laboratory Analysis (LM3)

Depth	Colour	pH		ECe		CEC		ESP	
cm		#	Rate	%	Rate	#	Rate	%	Rate
0 - 10	Brown	6.7	Neutral	0.322	Non-saline	3.2	Very low	2	Non-sodic
10 - 20	Brownish red	6.5	Slightly acid	0.345	Non-saline	3.0	Very low	2	Non-sodic
40 - 50	Red	6.6	Neutral	0.299	Non-saline	1.7	Very low	3	Non-sodic
90 - 120	Red	6.7	Neutral	0.322	Non-saline	1.2	Very low	4	Non-sodic

Figure LM3 - B shows the soil texture throughout the profile, and **Figure LM3 - C** shows the trend of exchangeable cations with depth. The full suite of analytical results for this soil type can be found in **Appendix 3**.

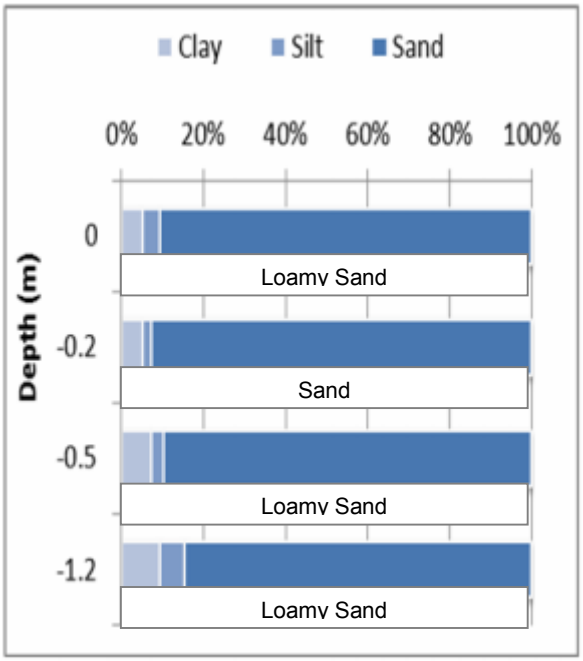


Figure LM3 - B: Particle Size Analysis

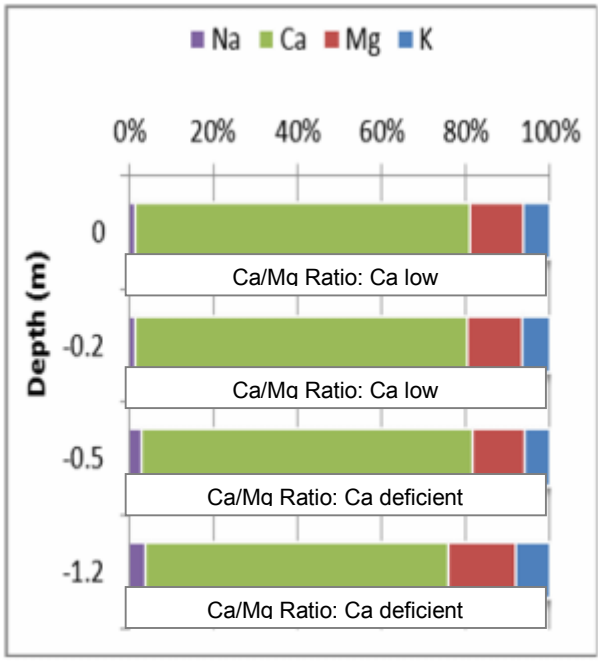


Figure LM3 - C: Exchangeable Cations

Degulla Land System

The Degulla land system represents a large alluvial fan in the central north. The upper slopes (DA1) have Brown Chromosols which are yellowish-brown texture-contrast soils supporting open woodlands of silver-leaved ironbark and poplar box. The lower slopes (DA2) generally have deeper topsoils, resulting from accumulations of sandy wash material. Additional plant species such as bloodwood, white cypress pine and ironwood are common. Land unit DA3 is a complex unit comprising mostly of poplar box on deep soils in the drainage depressions but interspersed with areas of land unit DA2, which vary in size and shape.

Plate 6: Degulla Land System (DA2)

DA2

This land unit represents the lower slopes and the more-recent deposits of sandy alluvium on the outwash fan. Deep Red Chromosols (texture-contrast soil profiles) are predominant, with sandy topsoils of variable depth and reddish-brown sandy clay subsoils.

A detailed overview of the representative soil type for this unit is provided in the following section.

DA2 – Red Chromosol (Site 95)

Soil Description; The Red Chromosol observed at Site 95 is a texture contrast soil that generally consists of light brown loamy sand overlying reddish brown sandy loam to yellow light medium clay. These well drained topsoils and poorly drained subsoils have a neutral to mildly alkaline pH, are non-saline with very low fertility characteristics. The profile is non sodic. Structure in the topsoil is moderate with platy peds of 5 – 10mm, through to strong structure 20mm sub angular blocky peds in the subsoil. The analytical information of the representative site is presented in **Figure DA2 - A** and **Table 19** below.

Management; The sandy topsoil does not display any specific management risk related to potential disturbance during stripping. The uppermost layers exhibit structure and chemical characteristics that would be suitable as surface cover in rehabilitation. The subsoil not recommended for stripping given its high clay content. The recommended stripping depth of this soil is 0.5 m.

Plate 6.1: DA2 – Red Chromosol

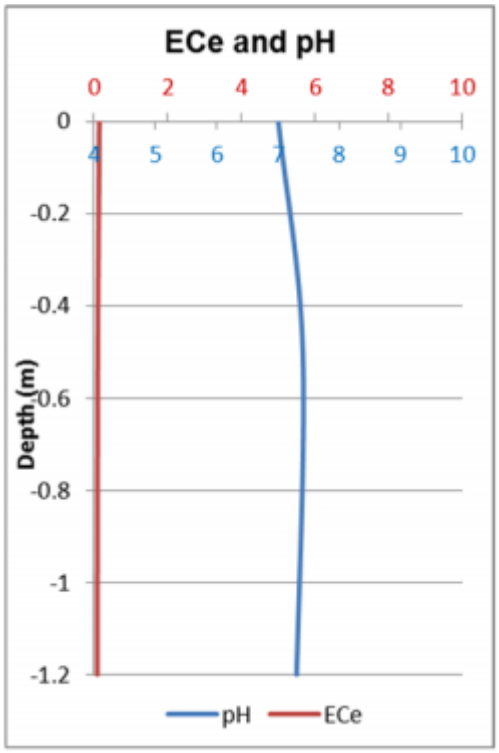


Figure DA2 - A: ECe and pH

Table 19: Laboratory Analysis (DA2)

Depth	Colour	pH		ECe		CEC		ESP	
cm		#	Rate	%	Rate	#	Rate	%	Rate
0 - 10	Light brown	7.0	Neutral	0.14	Non-saline	2.1	Very low	2.38	Non-sodic
30 - 50	Brown yellow	7.4	Mildly alkaline	0.10	Non-saline	2.8	Very low	1.79	Non-sodic
80 - 90	Yellow	7.3	Neutral	0.09	Non-saline	4.9	Very low	1.02	Non-sodic

Figure DA2 - B shows the soil texture throughout the profile, and **DA2 - C** shows the trend of exchangeable cations with depth. The full suite of analytical results for this soil type can be found in **Appendix 3**.

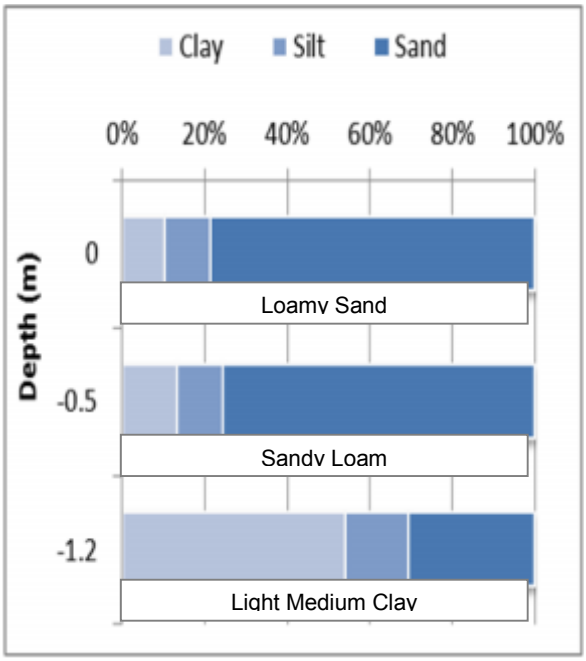


Figure DA2 - B: Particle Size Analysis

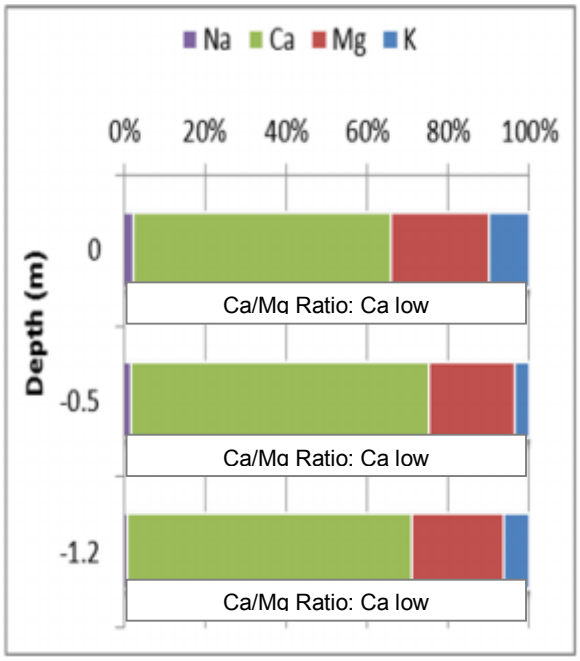


Figure DA2 - C: Exchangeable Cations

3.2.7 Lagoon Creek Land System

The Lagoon Creek land system represents the extended alluvial floodplain of Lagoon Creek. Land unit LC1 is most common with a typical soil-vegetation association of Red Kandosols deep sandy loam gradational profiles with tall sparse woodlands of bloodwood-ghost gum. Numerous small depressions and drainage lines with Chromosols with clayey subsoils cut through this unit. The backplains (LC2) are easily recognised by the Vertosols with heavy clay soils and a characteristic gilgai micro-relief with tall sparse woodlands of blackbutt and a lower tree layer of brigalow. The drainage depressions and creeklines (LC3) have tall open woodlands of river red gum, usually on Tenosols with uniform sandy loam soils, however desert bloodwood and poplar box are common on the sandy levee banks and interfluves.

Plate 7: Lagoon Creek Land System (LC1)

LC1

This land unit represents the alluvial plain associated with Lagoon Creek. The soils are predominantly Red Kandosols (sandy reddish brown gradational-textured profiles), however there are numerous small depressions and minor drainage lines with Chromosols (texture-contrast profiles) and Vertosols (uniform-textured clay profiles).

LC3

This land unit represents the major and minor drainage depressions in the Lagoon Creek floodplain. Soils are extremely variable in texture and depth depending on their location. Young sandy loam Stratic Tenosols (uniform textured profiles) occur in, and along, the creek beds and usually support tall open woodlands of Eucalyptus camadulensis (river red gum). Whereas, on the levee bank and interfluves, older soil profiles are predominantly Red Chromosols (texture contrast profiles) with thick sandy loam topsoils and red, whole-coloured clayey subsoils. The representative profile for this unit is detailed below.

An overview of the representative soil types for each of these units in provided below.

LC1 – Yellow Kandosol (Site 5)

Soil Description; The Yellow Kandosol observed at Site 5 is a gradationally textured soil that generally consists of light brown, pale yellow to yellow silty loam, loam, clay loam to silty clay loam layers throughout the profile that increase in clay content with depth. These well drained layers range from slightly acid in the topsoil, through neutral to mildly alkaline with depth, and are consistently non-saline with very low fertility characteristics. The profile is non sodic until approximately 50cm, where it becomes strongly sodic. Structure in the topsoil is weak with platy peds of 5 – 10mm, through to massive structure in the subsoil. Gravel is at 10 per cent presence in the subsoil. The analytical information of the representative site is presented in **Figure LC1 - A** and **Table 20** below.

Management; The silty loam topsoil does not display any specific management risk related to potential disturbance during stripping. The uppermost layers exhibit structure and chemical characteristics that would be suitable as surface cover in rehabilitation. The deeper subsoil not recommended for stripping given its increased clay content, strong sodicity and presence of gravel. The recommended stripping depth of this soil is 0.5 m.

Plate 7.1: LC1 – Yellow Kandosol

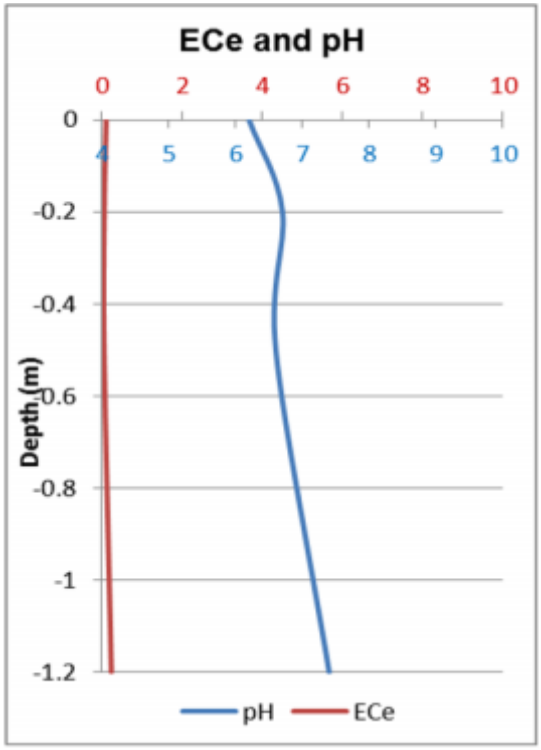


Figure LC1 - A: ECe and pH

Table 20: Laboratory Analysis (LC1)

Depth	Colour	pH		ECe		CEC		ESP	
cm		#	Rate	%	Rate	#	Rate	%	Rate
0 - 10	Light brown	6.2	Slightly acid	0.095	Non-saline	3.4	Very low	1	Non-sodic
10 - 20	Pale Yellow	6.7	Neutral	0.048	Non-saline	3	Very low	2	Non-sodic
40 - 50	Yellow	6.6	Neutral	0.043	Non-saline	4.7	Very low	1	Non-sodic

90 – 120	Yellow	7.4	Mildly alkaline	0.224	Non-saline	7.8	Low	15	Strongly sodic

Figure LC1 - B shows the soil texture throughout the profile, and **Figure LC1 - C** shows the trend of exchangeable cations with depth. The full suite of analytical results for this soil type can be found in **Appendix 3**.

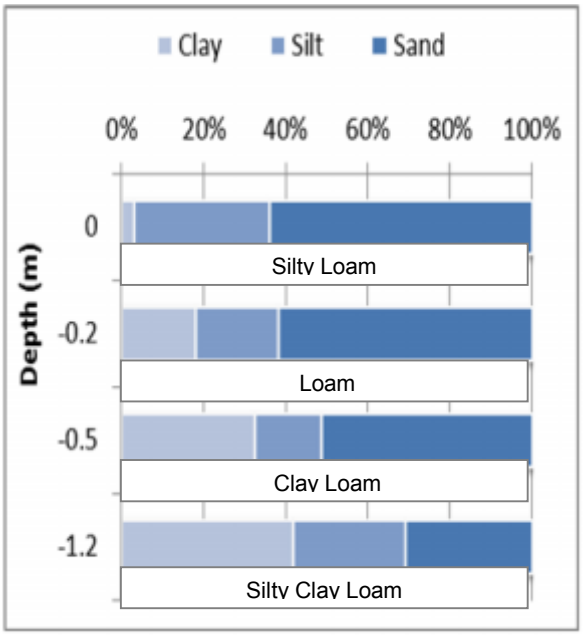


Figure LC1 - B: Particle Size Analysis

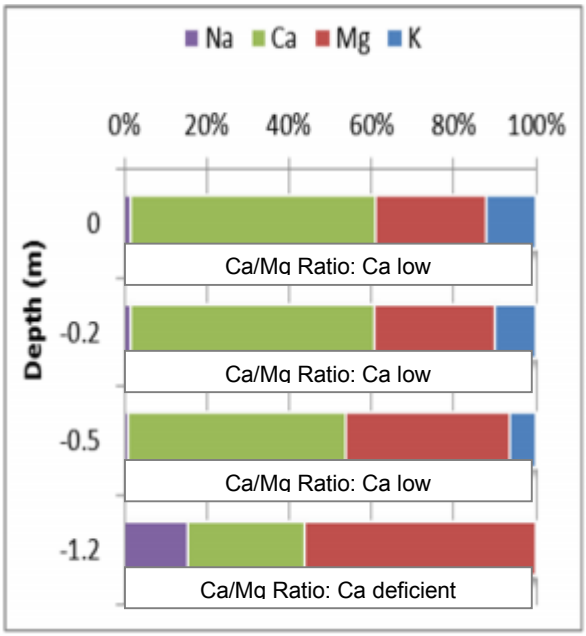


Figure LC1 - C: Exchangeable Cations

LC3 – Stratic Tenosol (Site 45)

Soil Description; The Stratic Tenosol observed at Site 45 is a texturally uniform soil that generally consists of light brown loamy sand overlying red loamy sand. These well drained soils have a slightly acid to moderately acid pH, and are non-saline with very low fertility characteristics. The topsoil is non sodic and the subsoil is marginally sodic. Structure in the topsoil is moderate with sub angular blocky peds of 20 – 30mm, through to weakly structured >10mm blocky peds in the subsoil. The analytical information of the representative site is presented in **Figure LC3 - A** and **Table 21** below.

Management; The loamy sand profile does not display any specific management risk related to potential disturbance during stripping. The structure and chemical characteristics are considered to be suitable as surface cover in rehabilitation if blended with clay material to increase the water holding capacity. The recommended stripping depth of this soil is 1.2 m, providing it is blended with clay material.

Plate 7.2: LC3 – Stratic Tenosol

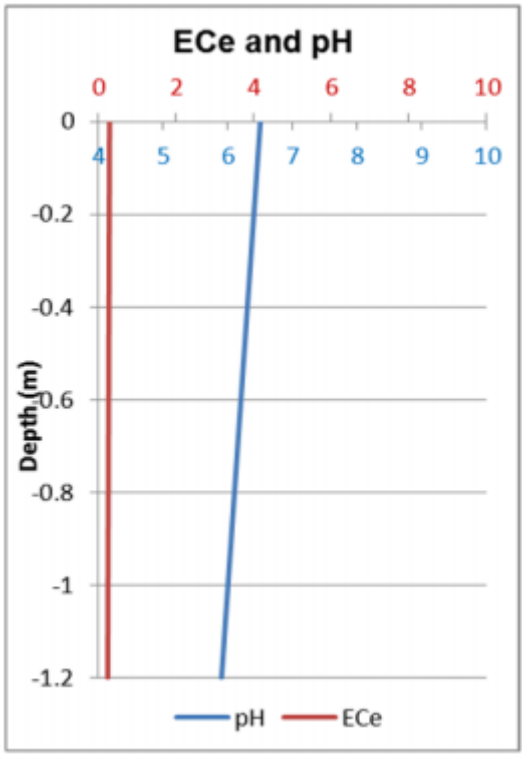


Figure LC3 - A: ECe and pH

Table 21: Laboratory Analysis (LC3)

Depth	Colour	pH		ECe		CEC		ESP	
cm		#	Rate	%	Rate	#	Rate	%	Rate
0 - 15	Light Brown	6.5	Slightly acid	0.276	Non-saline	1.1	Very low	5	Non-sodic
15 - 120	Red	5.9	Moderately acid	0.23	Non-saline	0.5	Very low	10	Marginally sodic

Figure LC3 - B shows the soil texture throughout the profile, and **LC3 - C** shows the trend of exchangeable cations with depth. The full suite of analytical results for this soil type can be found in **Appendix 3**.

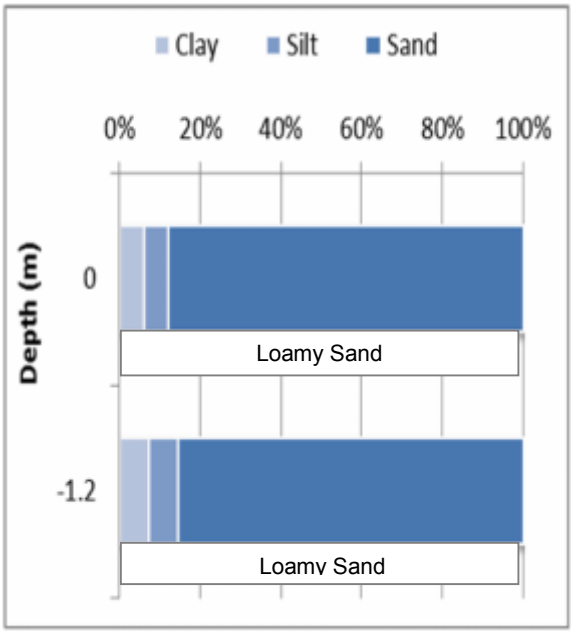


Figure LC3 - B: Particle Size Analysis

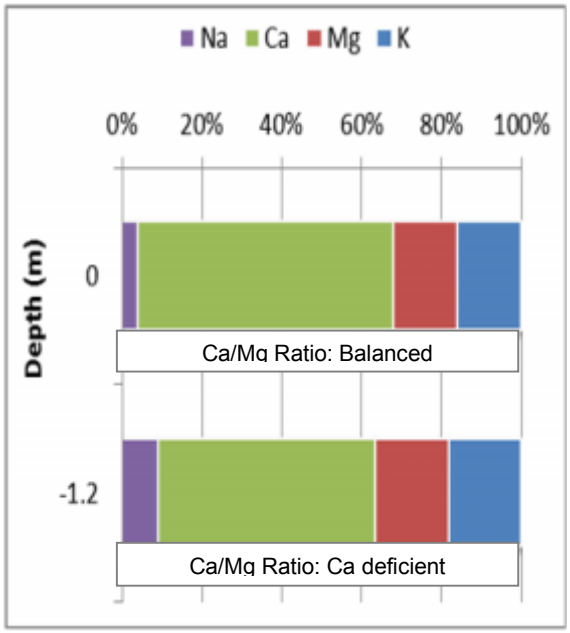


Figure LC3 - C: Exchangeable Cations

Desert Land System

This land system represents an extensive sand plain stretching through the Flinders and Aramac Shires, with large areas also occurring in Belyando and Jericho Shires. The typical "desert country" (DT1) consists of mid-tall woodlands of Queensland yellow jacket, Clarkson's bloodwood, applejack, the occasional rusty jacket and a pasture dominated by spinifex on bright red, deep sandy gradational and texture contrast soils.

Plate 8: Desert Land System (DT1)

Photo courtesy EPA, 2005

DT1

This land unit represents one of the most common, and most extensive, soil-vegetation associations on the Desert Uplands plateau, however only a small section exists in the far north west corner of the Study Area. The very deep, sandy gradational and texture-contrast soils are part of an extensive sandsheet, easily recognised by the bright red colour of the soils and the specific vegetation community. The mid-tall woodlands of Eucalyptus similis (Queensland yellowjacket), Corymbia clarksoniana (Clarkson's bloodwood), C. leichhardtii (rustyjacket) and C. setosa (applejack) often form a "grove-like" pattern across the slope with broad open areas of Triodia species (spinifex) in between each row. A dense understorey dominated by Acacia meleodora (waxy wattle), A. coriacea (desert oak), Alphitonia excelsa (soap tree) and Petalostigma pubescens (quinine tree) benefit from the leaf litter under the tree canopy and the extra soil moisture obtained by "capturing" water runoff from the adjacent spinifex area upslope. No detailed soil data was taken on this soil type due to restricted access.

4.0 AGRICULTURAL LAND ASSESSMENT

Land is assessed for its suitability for agricultural activities and its relative agricultural importance for the region. This comprises a two part process. Firstly, the Survey Area's overall suitability ranking for each soil type is determined in accordance with the DERM land suitability classification system (**Section 4.1**). Secondly, these suitability rankings are interpreted using the *Planning Guidelines: The Identification of Good Quality Agricultural Land* (DPI, 1993) and translated into Agricultural Land Classes (**Section 4.2**). These land classes are subsequently compared against the local shire planning document to determine which classes are considered to be Good Quality Agricultural Land (GQAL) for the specific region (**Section 4.3**). Land Assessment is carried out for both pre and post- mining circumstances.

4.1 Land Suitability Assessment

Agricultural land suitability of the Study Area has been assessed largely using criteria provided in the *Guidelines for agricultural land evaluation in Queensland* (Queensland Department of Primary Industries, Land Resources Branch, 1990). The method of land suitability assessment takes into account a range of factors including climate, soils, geology, geomorphology, soil erosion, topography and the effects of past land uses. The classification does not necessarily reflect the existing land use. Rather, it indicates the potential of the land for such uses as crop production, pasture improvement and grazing. The system allows for land to be allocated into five possible classes (with land suitability for productive agriculture decreasing progressively from Class 1 to Class 5) on the basis of a specified land use that allows optimum production with minimal degradation to the land resource in the long term. Land is considered less suitable as the severity of limitations for a land use increases. Increasing limitations may reflect any combination of:

- reduced potential for production;
- increased inputs to achieve an acceptable level of production; and/or
- increased inputs required to prevent land degradation.

The agricultural land suitability classes are described in **Table 22**.

Table 22 – Scheme for Classifying Land Suitability

LS Class	Orders	LS Class Descriptor	Description
1	S Suitable	S1 None/Minor Limitations (Highly Suitable)	Land with negligible limitations, which is highly productive requiring only simple management practices to maintain economic production.
2		S2 Minor Limitations (Moderately Suitable)	Land with minor limitations which either reduce production or require more than the simple management practices of Class 1 land to maintain economic production.
3		S3 Moderate Limitations (Marginally suitable)	Land with moderate limitations which either further lower production or require more than those management practices of Class 2 land to maintain economic production.
4	N Not Suitable	N1 (or S4) Marginal Land (Presently Unsuitable)	Marginal lands with severe limitations which make it doubtful whether the inputs required achieving and maintaining production outweigh the benefits in the long term (presently considered unsuitable due to the uncertainty of the land to achieve sustained economic production)
5		N2 (or S5) Unsuitable	Unsuitable land with extreme limitations that preclude its use for the proposed purpose.

Reproduced from CSIRO, 2008.

A land suitability assessment provides an analysis on how 'fit' a given area of land is for a specific type of land utilisation (e.g. rainfed cropping or grazing). The analysis considers the area's land use characteristics (e.g. soil pH), land quality attributes (e.g. moisture availability) and how these match conditions that are necessary for 'successful and sustained' implementation of a specific land utilisation type (CSIRO, 2008; DME, 1995; Shields and Williams, 1991).

GSSE's land suitability analysis provides a proportional land suitability assessment whereby each soil type's characteristics and attributes are cross-referenced against the DME (1995) 'criteria checklist' for 'rainfed broadacre cropping' and 'beef cattle grazing'. The overall land suitability ranking for each specific soil type is determined by the most severe limitation, or a combination of the varying limitations. For this reason the major limiting factors determining land suitability are presented. .

4.1.1 Calculation of Plant Available Water Capacity and Effective Rooting Depth

The primary land suitability assessment attribute is 'moisture'. The indicator for moisture is Plant Available Water Capacity (PAWC). PAWC is an estimate of the amount of moisture stored in the soil profile that is available for plant extraction. It is generally defined as the difference between field capacity and permanent wilting point. PAWC is calculated for the soil profile by summing the available water capacity over the soil's effective rooting depth (ERD).

ERD is defined as the soil depth to which 90% of the plant roots will extract water (Burgess, 2005). ERD can be estimated through observed rooting depth, soil chemical parameters or a standardised depth can be used (*Soil Physical Measurement and Interpretation for Land Evaluation*, 2008). For the purposes of this Project area assessment ERD was determined from both observed rooting depth and the chemical parameters as defined in **Table 23**.

Table 23 – Effective Rooting Depth Criteria

Limitation #	Descriptor	ERD occurs where:
1	$EC_{1:5}$ for sorghum and wheat[1] (90% yield reduction threshold)	>0.8 dS/m
2	Cl 1:5	>1,000 ppm
3	ESP	>20% where clay content is >25%
4	pH	<5.5
5	Depth to C horizons	--
6	Unsuitable subsoil structure	moderate or strong columnar structure sandy free draining horizons significant rock content

Source: Burgess, 2003

PAWC can be directly measured in the field, estimated from textural classes or interpolated using a QLD approved software program (PAWCER). GSSE calculated PAWC using textural classes using the QLD Land Suitability Guidelines. Each soil types PAWC is detailed in **Table 24.**

Table 24 –Plant Available Water Capacity (PAWC)

Land System	Land unit	Soil Type	Plant Available Water Capacity
Cudmore	CE1	Brown Sodosol	50 - 75mm
	CE2	Petroferic Rudosol	≤ 50mm
	CE3	Brown Sodosol	50 - 75mm
	CE4	Brown Vertosol	≤ 50mm

Land System	Land unit	Soil Type	Plant Available Water Capacity
	CE5	Stratic Rudosol	75 - 100mm
Colorado	CO1	Red Kandosol	125 - 150mm
	CO2	Red Kandosol	125 - 150mm
	CO3	Lithic Rudosol	75 - 100mm
Southern Plateau	SP1a	Red Dermosol	125 - 150mm
	SP1b	Yellow Kandosol	125 - 150mm
	SP1c	Yellow Sodosol	75 - 100mm
	SP2a	Red Sodosol	≤ 50mm
	SP2b	Brown Dermosol	100 - 125mm
	SP3	Red Sodic Dermosol	50 - 75mm
Joe Joe	JJ1	Red Kandosol	125 - 150mm
	JJ2	Grey Sodosol	75 - 100mm
	JJ3	Grey Chromosol	125 - 150mm
	JJ4	Brown Chromosol	100 - 125mm
	JJ5	Tenosol	50 - 75mm
Lambton Meadows	LM2	Stratic Rudosol	125 - 150mm
	LM3	Stratic Tenosol	75 - 100mm
Degula	DA2	Red Chromosol	125 - 150mm
Lagoon Creek	LC1	Yellow Kandosol	125 - 150mm
	LC3	Stratic Tenosol	75 - 100mm
Desert	DT1	Stratic Rudosol	125 - 150mm

4.1.2 Land Suitability Rankings

The Project area's Soil Types were assessed against the criteria for 'rainfed cropping' and 'broadacre grazing' land utilisation types as per the guidelines. The first limitation for land utilisation is moisture and each Soil Type's average PAWC is provided in **Table 24**. All Soil Types have been classified as unsuitable for cropping due to climatic and soil taxonomic characteristics, these Soil Types have been subsequently assessed for their suitability for pastoral activities (refer **Table 25**). **Figure 3** illustrates the spatial distribution of pre mining land suitability classes for beef cattle grazing.

Table 25 – Land Suitability (LS) Ranking for Beef Cattle Grazing

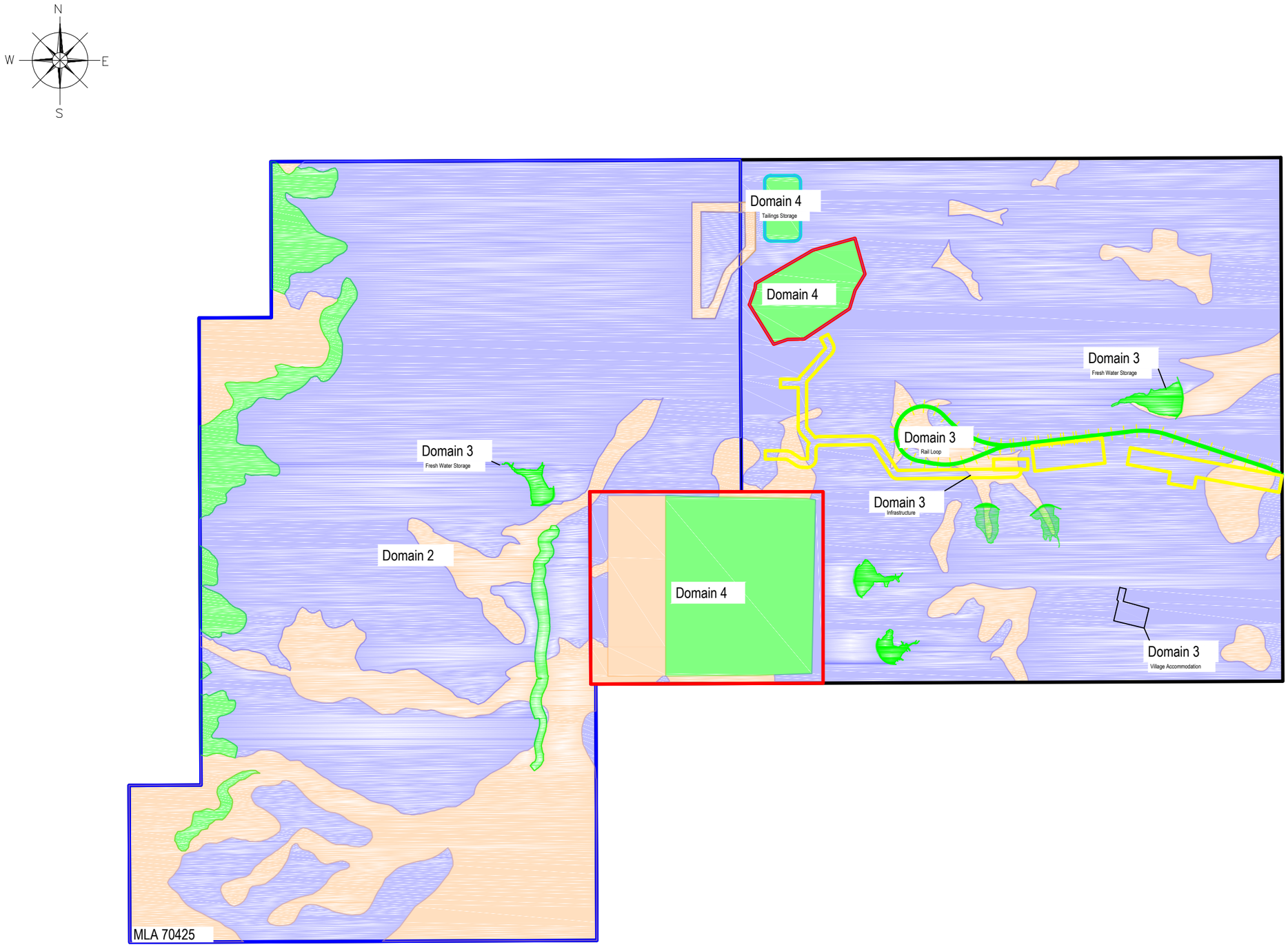
Land System	Land unit Code	Representative Soil Type (ASC)	Water availability	CEC Rating	Soil physical factors	Salinity	Rockiness	Microrelief	pH	ESP%	Wetness	Topography	Water erosion	Flooding	Vegetation regrowth	**Overall Ranking**
1. Cudmore	CE1	Brown Sodosol	4	3	2	3	1	1	2	1	2	1	1	2	1	**4**
	CE2	Petroferic Rudosol	5	4	2	1	3	1	1	1	1	1	1	1	1	**5**
	CE3	Brown Sodosol	4	3	2	1	1	1	n/a	n/a	2	1	1	2	1	**4**
	CE4	Brown Vertosol	4	1	2	4	1	1	2	4	1	1	1	1	1	**4**
	CE5	Stratic Rudosol	3	4	2	1	1	1	2	1	2	1	2	2	1	**4**
2. Colorado	CO1	Red Kandosol	_	_	_	_	_	_	_	_	_	_	_	_	_	**3***
	CO2	Red Kandosol	1	3	2	1	1	1	2	1	1	1	1	1	1	**3**
	CO3	Lithic Rudosol	3	4	1	1	1	1	1	1	1	1	1	1	1	**4**
3. Southern Plateau	SP1a	Red Dermosol	1	3	2	1	1	1	2	1	1	1	1	1	1	**3**
	SP1b	Yellow Kandosol	1	3	2	1	1	1	1	1	1	1	1	1	1	**3**
	SP1c	Yellow Sodosol	3	3	2	1	1	1	1	1	1	1	1	1	1	**3**
	SP2a	Red Sodosol	4	3	1	2	1	1	2	2	2	1	1	2	1	**4**
	SP2b	Brown Dermosol	2	3	1	1	1	1	1	1	1	1	1	1	1	**3**
	SP3	Red Sodic Dermosol	4	3	2	1	1	1	2	1	1	1	1	1	1	**4**
4. Joe Joe	JJ1	Red Kandosol	_	_	_	_	_	_	_	_	_	_	_	_	_	**3***
	JJ2	Grey Sodosol	3	3	1	1	1	1	2	2	1	1	3	1	1	**3**
	JJ3	Grey Chromosol	1	3	1	1	1	1	1	1	2	1	1	1	1	**3**
	JJ4	Brown Chromosol	2	3	1	1	1	1	1	1	2	1	1	1	1	**3**
	JJ5	Tenosol	4	4	1	3	1	1	2	1	2	1	1	2	1	**4**
5. Lambton Meadows	LM2	Stratic Rudosol	1	4	1	1	1	1	1	1	1	1	1	2	1	**4**
	LM3	Stratic Tenosol	3	4	1	1	1	1	1	1	2	1	1	2	1	**4**
6. Degula	DA2	Red Chromosol	1	3	1	1	1	1	2	1	1	1	1	2	1	**3**
7. Lagoon Creek	LC1	Yellow Kandosol	1	3	1	1	1	1	1	1	2	1	1	2	1	**3**
	LC3	Stratic Tenosol	3	3	1	1	1	1	1	2	2	1	1	2	1	**3**
8. Desert	DT1	Stratic Rudosol	_	_	_	_	_	_	_	_	_	_	_	_	_	**3***

*Land Suitability Assessment based on field observations and reference material.

4.1.3 Post-mining Land Suitability

The proposed post-mining land use for the Study Area is expected to be a mosaic of grassland and bushland. In terms of soil conservation and agricultural land suitability, the predicted changes in land suitability class for the Project area are outlined in **Table 26** below and shown in **Figure 4**.

Figure 4 – Post Mining Land Suitability (Beef Cattle Grazing)



LEGEND

- MLA Boundary

Land Suitability Class

- Class 3
- Class 4
- Class 5

0 1.0 2.0 3.0 4.0 5.0 km

FIGURE 4

Kevins Corner
Post Land Suitability

Project:
Soil and Land Capability Assessment
Kevins Corner (2011)

Client:
URS (Brisbane)

File:
Fg4_URS03-012_PostLandSuitability_110908

Projection:
MGA94 Zone 55

Version:	Date:	Author:	Checked:	Approved:
1	19/08/11	LH	MH	CR
2	08/09/11	LH	MH	CR

GSS ENVIRONMENTAL
Environmental, Land and Project Management Consultants

V:\URS03-012\Figures\Final\CAD\Fg4_URS03-012_PostLandSuitability_110908.dwg .ISO full bleed A3 (297.00 x 420.00 MM)

Table 26 – Land Suitability (LS) Pre and Post Mining

		Underground	Open Cut South	Open Cut North	Accommodation	Fresh water dams	Airfield	Light Industrial Area	Infrastructure	Rail Loop	Tailings	Buffer Land	**Total Area**	**% of LS**	**Change in LS Class Post mining**
Pre	LS 3	13,505	1,518	416	41	184	56	100	158	21	130	12,109	28,259	76%	-
	LS 4	5,332	982	0	0	61	99	0	45	6	0	1,484	8,052	22%	-
	LS 5	1,068	0	0	0	0	0	0	0	0	0	0	1,068	3%	-
	Total	19,905	2,501	416	41	245	155	100	202	27	130	13,593	37,380	100%	-
Post	LS 3	13,268	283	0	41	0	56	100	158	0	0	11,870	25,984	70%	-5.8%
	LS 4	5,374	742	0	0	0	99	0	45	0	0	1,583	7,840	21%	-0.6%
	LS 5	1,263	1,475	416	0	245	0	0	0	27	130	245	3,556	9%	6.4%
	Total	19,905	2,500	416	41	245	155	100	202	27	130	13,698	37,380	100%	0.0%
% of Study Area		53.2%	6.7%	1.1%	0.1%	0.7%	0.4%	0.3%	0.5%	0.1%	0.3%	36.5%	100.0%		

In order to sustain the desired land use without degradation, it is important that the post-mining land only be used in accordance with the limits of the agricultural suitability class. Soil conservation practices such as stocking rate control and establishment or re-establishment of permanent pasture are recommended for areas of mining impact. The overriding principle is to maintain the most beneficial future use of land that can be sustained in view of the range of limiting factors. The proposed post-mining land must provide and sustain a sufficient bulk of nutritious forage in addition to the following management considerations in the event of future low density grazing.

- The ability to access and manage livestock.
- Flood free and relatively dry ground conditions.
- Adequate stock drinking water and shelter.
- Stock routes throughout the land.

Provided that environmental controls such as structural soil conservation works (refer **Section 3.3**) and effective revegetation are in place and operating properly during mine construction and operation, there should be minimal adverse effects to the Study Area or the surrounding grazing land.

4.2 Agricultural Land Class Assessment & GQAL

The Study Area, and immediately surrounding land, has also been assessed against the Agricultural Land Class (ALC) system, which is used to identify potential Good Quality Agricultural Land (GQAL) in accordance with the *Guidelines for the identification Good Quality Agricultural Land* (Qld DPI & DHLG&P, 1993) (referred to as the Good Quality Agricultural Land guidelines*)*. Agricultural land is defined as land used for crop or animal production, but excluding intensive animal uses (i.e. feedlots and piggeries). Good quality agricultural land is land which is capable of sustainable use for agriculture, with a reasonable level of inputs, and without causing degradation of land or other natural resources.

The DPI guidelines have been introduced to provide local authorities and development proponents with a system to identify areas of good quality agricultural land for planning and Project approval purposes. Descriptions of the agricultural land classes are provided in **Table 27**.

The ALC classification system combines land suitability assessments for a number of specific land utilisation types into a single land classification. This ALC classification system has four categories: Arable (A), Limited arable (B), Pastoral (C) and Non-agricultural (D) (refer **Table 28**).

Table 27 – Scheme for Classifying Agricultural Land

Class	Name	Description
A	Arable land (Crop land)	Land that is suitable for current and potential crops with limitations to production which range from none to moderate levels.
B	Limited arable land (Limited crop land)	Land that is marginal for current and potential crops due to severe limitations; and suitable for pastures. Engineering and/or agronomic improvements may be required before the land is considered suitable for cropping.
C	Pastoral land	Land that is suitable only for improved or native pastures due to limitations which preclude continuous cultivation for crop production; but some areas may tolerate a short period of ground disturbance for pasture establishment.
D	Non-agricultural land	Land not suitable for agricultural uses due to extreme limitations. This may be undisturbed land with significant habitat, conservation and/or catchment values or land that may be unsuitable because of very steep slopes, shallow soils, rock outcrop or poor drainage.

Source: QDPI (1993).

Table 28 – Broadacre Cropping Land Suitability Ranking and Agricultural Land Class Correlation

LS Ranking	Description	ALC
1	High quality land with few or minor limitations	A
2	Land with minor limitations	A
3	Moderate limitations to sustaining its use.	A
4	Marginal land requiring major inputs to sustain the use.	B or C
5	Unsuitable due to extreme limitations.	C or D

The overall land suitability rating of 1-5 is translated into an ALC rating of A-D, additionally, for the Central West QLD region, ALC C is further divided into three sub-classes of C1, C2 and C3, according to potential grazing quality, as outlined in **Table 11** below.

Table 29 – Beef Cattle Grazing Land Suitability (LS) Ranking and Agricultural Land Class (ALC)

LS Rating	Land Suitability Description (DME, 1995)	ALC	Pastoral Management	B. Forster (per comm., 2010))
1	High quality land with few or minor limitations	C1	Good quality grazing and/or highly suitable for pasture improvement	Brigalow vegetation; appropriate for fattening beef cattle; good grazing on sown pastures and can withstand ground disturbance.
2	Land with minor limitations	C1		Brigalow vegetation and/or transitional vegetation to Poplar Box vegetation communities.

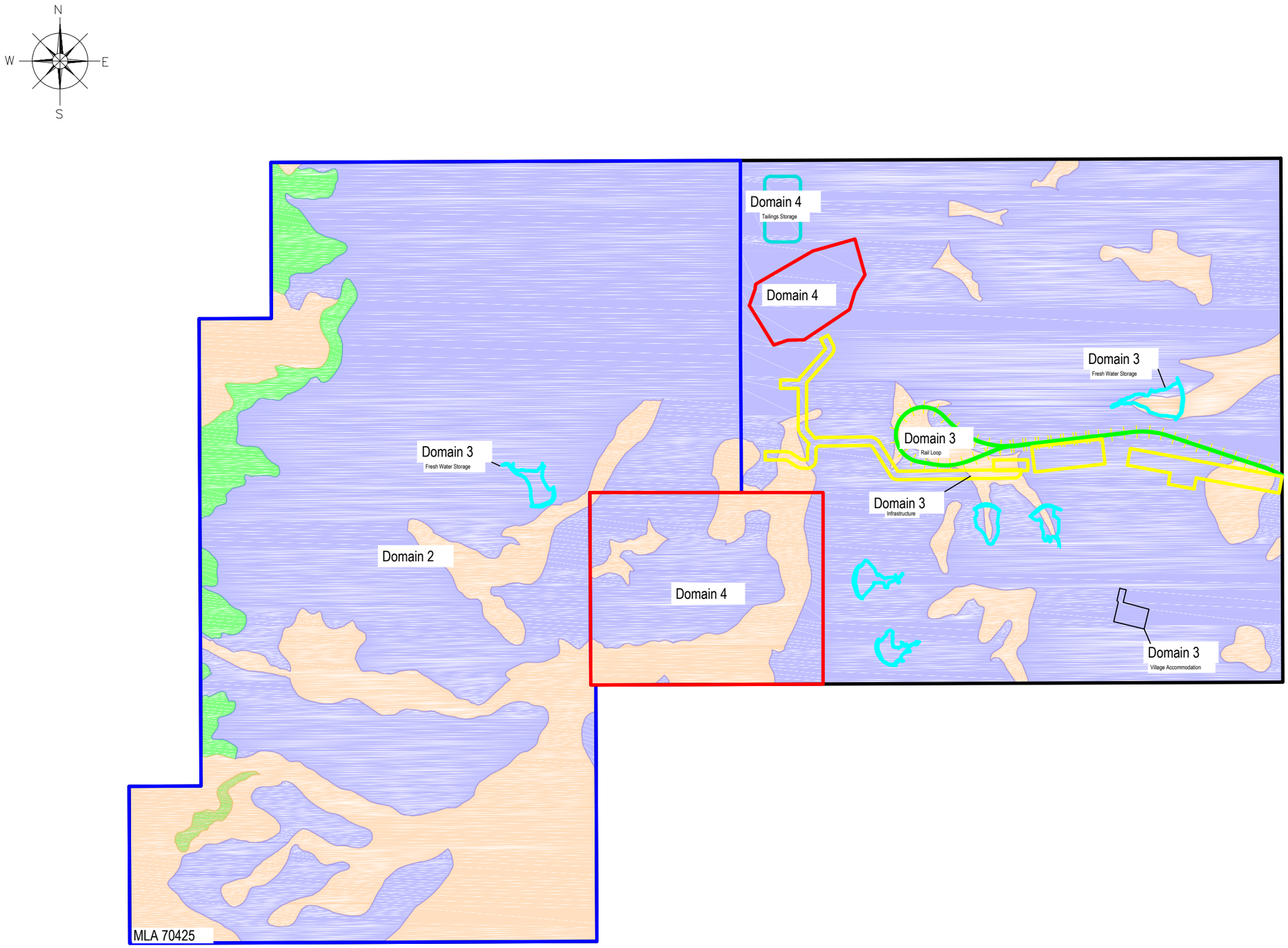
3	Moderate limitations to sustaining its use	C1/C2	Moderate quality grazing and/or moderately suitable for pasture improvement.	Eucalypt woodland, Poplar Box, narrow-leaved Eucalyptus, gum-top woodlands; low-moderate PAWC and low-moderate fertility; good grazing on native pastures without ground disturbance; appropriate for beef cattle breeders.
4	Marginal land requiring major inputs to sustain the use	C3	Low quality grazing, grazing of native pastures with limited suitability for pasture improvement.	Tea-tree vegetation; usually characterised by steep country or mangrove flats.
5	Unsuitable due to extreme limitations.	D	Not suitable	Unsuitable due to extreme limitations.

The relationship(s) between soil type, beef cattle grazing land suitability ranking, ALC and GQAL for the Project area is outlined below in **Table 30.** Note that using the above assessment methodology and assumptions, no Good Quality Agricultural Land was found within the Project area during the survey.

4.2.1 Agricultural Land Class & GQAL Results

Table 30 –GQAL Results

Land System	Land unit Code	Representative Soil Type (ASC)	LS Ranking	ALC Ranking	GQAL
1. Cudmore	CE1	Brown Sodosol	4	C3	No
	CE2	Petroferic Rudosol	5	D	No
	CE3	Brown Sodosol	4	C3	No
	CE4	Brown Vertosol	4	C3	No
	CE5	Stratic Rudosol	4	C3	No
2. Colorado	CO1	Red Kandosol	3	C2	No
	CO2	Red Kandosol	3	C2	No
	CO3	Lithic Rudosol	4	C3	No
3. Southern Plateau	SP1a	Red Dermosol	3	C2	No
	SP1b	Yellow Kandosol	3		
	SP1c	Yellow Sodosol	3		
	SP2a	Red Sodosol	4	C3	No
	SP2b	Brown Dermosol	3		
	SP3	Red Sodic Dermosol	4	C3	No
4. Joe Joe	JJ1	Red Kandosol	3	C2	No
	JJ2	Grey Sodosol	3	C2	No
	JJ3	Grey Chromosol	3	C2	No
	JJ4	Brown Chromosol	3	C2	No
	JJ5	Tenosol	4	C3	No
5. Lambton Meadows	LM2	Stratic Rudosol	4	C3	No
	LM3	Stratic Tenosol	4	C3	No
6. Degula	DA2	Red Chromosol	3	C2	No
7. Lagoon Creek	LC1	Yellow Kandosol	3	C2	No
	LC3	Stratic Tenosol	3	C2	No
8. Desert	DT1	Stratic Rudosol	3	C2	No



LEGEND

- MLA Boundary

Agricultural Land Class

- Class C1
- Class C3
- Class D

0 1.0 2.0 3.0 4.0 5.0 km

FIGURE 5

Kevins Corner
Agricultural Land Class

Project:
Soil and Land Capability Assessment
Kevins Corner (2011)

Client:
URS (Brisbane)

File:
Fg5_URS03-012_ALC_110908

Projection:
MGA94 Zone 55

Version:	Date:	Author:	Checked:	Approved:
1	19/08/11	LH	MH	CR
2	08/09/11	LH	MH	CR

GSS ENVIRONMENTAL
Environmental, Land and Project Management Consultants

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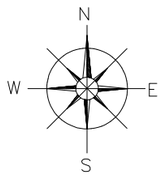

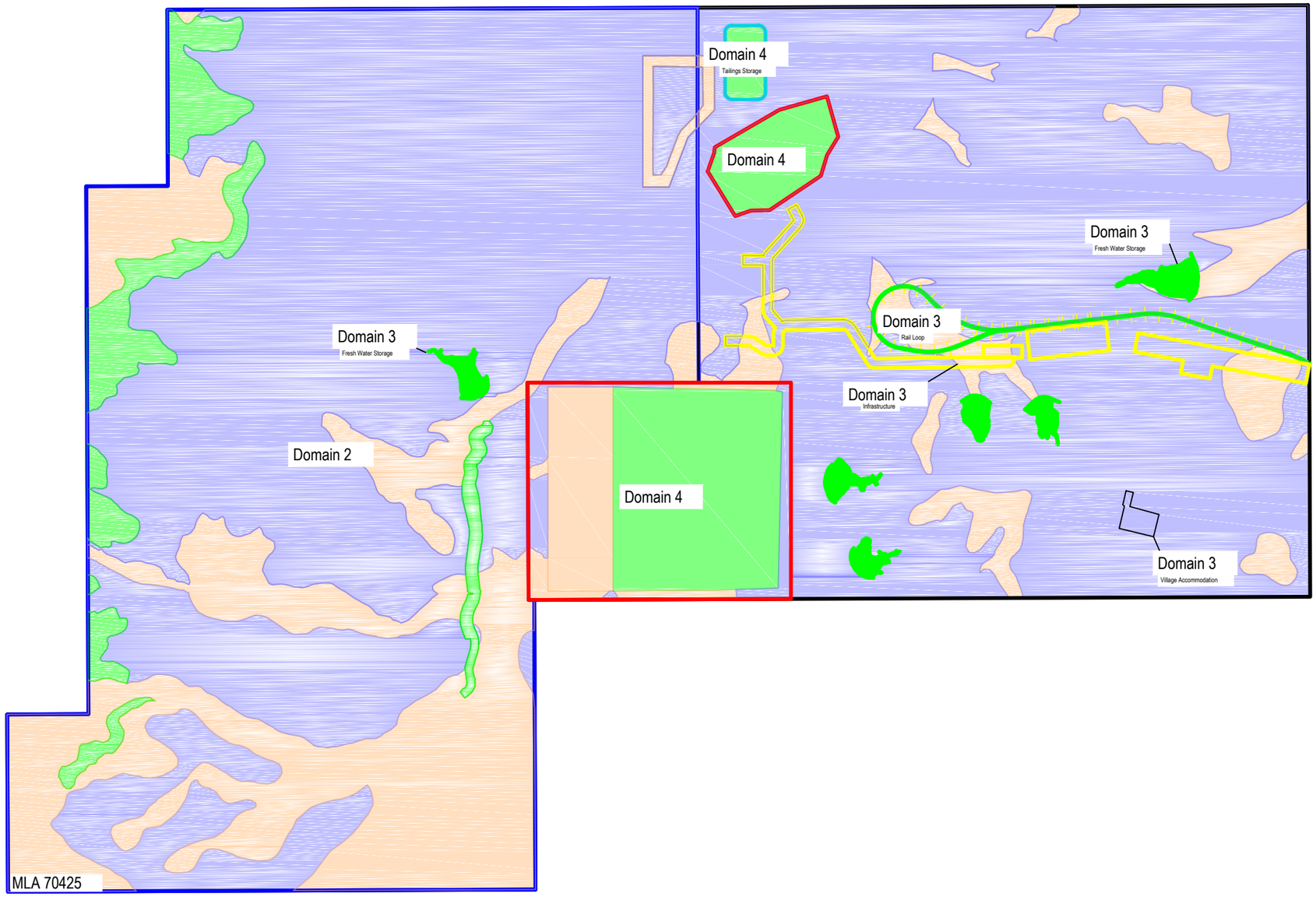

LEGEND

- MLA Boundary

Agricultural Land Class

- Class C1
- Class C3
- Class D

0 1.0 2.0 3.0 4.0 5.0 km

FIGURE 6

Kevins Corner
Post Agricultural Land Class

Project:
Soil and Land Capability Assessment
Kevins Corner (2011)

Client:
URS (Brisbane)

File:
Fg6_URS03-012_PostALC_110908

Projection:
MGA94 Zone 55

Version:	Date:	Author:	Checked:	Approved:
1	19/08/11	LH	MH	CR
2	08/09/11	LH	MH	CR

GSS ENVIRONMENTAL
Environmental, Land and Project Management Consultants

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The areas that will be disturbed as a result of the Project are as follows:

- *Areas subsided by underground mining.* These areas will not be subject to any major earthworks, but will be prone to surface subsidence effects resulting from underground mining operations. The surface subsidence effects will result in the development of an undulating land surface with gentle slopes (refer EIS Subsidence Report for further detail). Most subsidence will not alter the land suitability and the area can continue to be used for grazing. Furthermore conservation works will be implemented to ensure a free draining landscape is maintained.
- *Open Cut Pits and Stockpile areas.* These areas will undergo major earthworks and will not return be returned to original condition. The post mining land use for stockpile areas is intended to be grazing, however the Land Suitability of this are will be reduced to Class 4, or ALC C3, while the void of the pits will remain as permanent features incapable of supporting grazing activity, resulting in an a land suitability Class 5 with ALC of D
- *Surface infrastructure.* Surface infrastructure will be constructed within the Project area. As described in the rehabilitation section of the main volume of the EIS, these areas will be rehabilitated and restored to grazing land post-mining. Their post-mining land suitability will therefore not be changed by the Project.
- *Water Dams and Surface infrastructure*. Surface infrastructure and water dams will be constructed within the Project area. These dams will likely remain as depressions in the landscape with a water storing capacity, for possible uses associated with the post mining grazing landform.
- *Out of Pit Tailings Dam***.** The tailings dam will be used for the disposal of tailings. Given the sensitive nature of the capping and rehabilitation endeavours, and the consequences of impacting on the integrity and stability of the capping layer, the post mining landuse will be limited to vegetative cover for erosion protection. No grazing is recommended for this area and therefore will have a land suitability Class 5 for cropping and grazing with ALC of D.
- *Construction of railway*. A 20 m wide strip of land will be required for the construction of the railway line. The railway will be a permanent feature and therefore not suitable for any other use. The post mining land suitability class will therefore be Class 5, ALC D, for both cropping and grazing assessments.

The pre and post mining land surface topography of the Study Area will vary according to the impacts of subsidence from the longwall mining activities. In predicting post mining and post subsidence Land Suitability rankings, several factors need to be considered, such as predicted landform topography, risk of erosion and sedimentation and modifications to pre mining Land Suitability criteria. It is reasonable to predict that the modifications to pre mining Land Suitability criteria such as PAWC, ERD, pH, EC and rockiness will be negligible, however following subsidence, erosion hazards may become the limiting factors in areas where residual change in tilt has occurred as land that is evenly subsided will have no negative effect.

4.3 Strategic Cropping Land Assessment

Strategic cropping land is a scarce natural resource defined by soil, climatic and landscape characteristics which result in an area highly suitable for crop production. An assessment of the potential for the Project to impact upon SCL was undertaken using the *Protecting Queensland's strategic cropping land: A policy framework as guidance*. Consultation with SCL Draft Trigger Maps C3 and C5 indicates that the Study Area does not lie within a potential SCL area. No further assessment is therefore required under SCL policy.

5.0 SOIL MANAGEMENT

5.1 Acid Sulfate Soil Potential

The potential for acid generation from regolith material (topsoil and subsoil) within the Study Area is low. This does not include acid generation potential within the overburden material (consolidated bedrock below 2-3 m depth). Acid Sulphate Soils (ASS), which are the main cause of acid generation within the soil mantle, are commonly found less than 5 m above sea level, particularly in low-lying coastal areas such as mangroves, salt marshes, floodplains, swamps, wetlands, estuaries, and brackish or tidal lakes. The Study Area is located within the Desert Uplands Bioregion (which is located approximately 400 km from the coast). There has been little history of acid generation from regolith material with this region.

5.2 Soil Stripping Assessment

All soils within the Study Area were assessed to determine its suitability for stripping and re-use on rehabilitation sites. This assessment is an integral process for successful rehabilitation of the Study Area. This report provides information on the following key areas related to the management of the soil resources associated with the Project:

- Soil stripping assessment, which provides a soil stripping depth map indicating recommended stripping depths for soil salvage and re-use as topdressing in rehabilitation; and
- Soil management for soil that is stripped, stored and used as a topdressing material for rehabilitation.

5.2.1 Soil Stripping Assessment Methodology

Determination of suitable soil to conserve for later use in mine rehabilitation is conducted in accordance with Elliott and Veness (1981). The approach remains the benchmark for land resource assessment in the Australian mining industry. This procedure involves assessing soils based on a range of physical and chemical parameters. **Table 31** lists the key parameters and corresponding desirable selection criteria.

Table 31 – Soil Stripping Suitability Criteria

Parameter	Desirable criteria
Structure Grade	>30% peds
Coherence	Coherent (wet and dry)
Mottling	Absent
Macrostructure	>10cm
Force to Disrupt Peds	≤ 3 (moderately weak force and above)
Texture	Finer than a Fine Sandy Loam
Gravel & Sand Content	<60%
pH	4.5 to 8.4
Salt Content	<1.5 dS/m

Source: Elliot and Veness 1981

Gravel and sand content, pH and salinity was determined for all samples using the laboratory test results. Texture was determined in the field and cross referenced with laboratory results, specifically particle size analysis. All other physical parameters outlined in **Table 31** were be determined during the field assessment.

Structural grade is significant in terms of the soil's capability to facilitate water relations and aeration. Good permeability and adequate aeration are essential for the germination and establishment of plants. The ability of water to enter soil generally varies with structure grade and depends on the proportion of coarse peds in the soil surface. Well structured soils have higher infiltration rates and better aeration characteristics. Structureless soils, without pores, are considered unsuitable as topdressing materials.

The shearing test is used as a measure of the soil's ability to maintain structure grade. Brittle soils are not considered suitable for revegetation where structure grade is weak or moderate because peds are likely to be destroyed and structure is likely to become massive following mechanical work associated with the excavation, transportation and spreading of topdressing material. Consequently, surface sealing and reduced infiltration of water may occur which will restrict the establishment of plants.

The force to disrupt peds, when assessed on soil in a moderately moist state, is an indicator of solidity and the method of ped formation. Deflocculated soils are hard when dry and slake when wet, whereas flocculated soils produce crumbly peds in both the wet and dry state. The deflocculated soils are not suitable for revegetation and may be identified by a strong force required to break aggregates.

The presence of mottling within the soil may indicate reducing conditions and poor soil aeration. These factors are common in soil with low permeability, however some soils are mottled due to other reasons, including proximity to high water-tables or inheritance of mottles from previous conditions. Reducing soils and poorly aerated soils are unsuitable for revegetation purposes.

5.2.2 Soil Stripping Depths

Table 32 lists the recommended stripping depths for each soil type within the entire Study Area. Where a soil type has been identified as requiring treatment before re-use, due to the practicality of treating the soil, these soil types have been separated as 'additional material'. If additional material is needed, or treatment is considered feasible, these soils may be stripped to the recommended depth sand then treated as stipulated below.

Table 32 – Recommended Stripping Depth per Soil Type

Land Unit	Soil Type (ASC)	Stripping Depth (m)	Additional Material Depth*	Treatment Required
CE1	Brown Sodosol	.25	Nil	
CE2	Petroferic Rudosol	Nil	Nil	
CE3	Brown Sodosol	Nil	Nil	
CE4	Brown Vertosol	Nil	0.05	Blend with sandy/ loamy material
CE5	Stratic Rudosol	Nil	1.2	Blend with clay
CO1	Red Kandosol	.5	Nil	
CO2	Red Kandosol	1.2	Nil	
CO3	Lithic Rudosol	Nil	1.2	Blend with clay
SP1a	Red Dermosol	Nil	Nil	
SP1b	Yellow Kandosol	1.2	Nil	

Land Unit	Soil Type (ASC)	Stripping Depth (m)	Additional Material Depth*	Treatment Required
SP1c	Yellow Sodosol	0.6	Nil	
SP2a	Red Sodosol	0.3	Nil	
SP2b	Brown Dermosol	1.2	Nil	
SP3	Red Sodic Dermosol	0.3	Nil	
JJ1	Red Kandosol	0.5	Nil	
JJ2	Grey Sodosol	Nil	Nil	
JJ3	Grey Chromosol	Nil	1.2	Intermix sandy topsoil with clay subsoil
JJ4	Brown Chromosol	0.4	0.4	Blend with sand
JJ5	Tenosol	Nil	1.2	Blend with clay
JJ6	Stratic Rudosol	Nil	0.5	Blend with clay
LM2	Stratic Rudosol	Nil	1.2	Blend with clay
LM3	Stratic Tenosol	Nil	1.2	Blend with clay
DA2	Red Chromosol	0.5	Nil	
LC1	Yellow Kandosol	0.5	Nil	
LC3	Stratic Tenosol	Nil	1.2	Blend with clay
DT1	Red Kandosol	Nil	0.5	Blend with clay

The soil types likely to undergo surface disturbance and be stripped of topsoil are shown in **Table 33** below, where volumes have been calculated and classified per disturbance area. Note, there is a high presence of sandy soil throughout Project site, and therefore many soil types are not recommended for stripping, without treatment. These soils are not listed in the Table below. **Table 33** which shows the recommended stripping activities for the Project site, for domains where rehabilitation will be undertaken, including only the soil types that are suitable for stripping..

Table 33: Stripping Volume per Disturbance Area

Land Unit	Soil Type (ASC)	Stripping Depth (m)	Open Cut		Tailings Storage		Infrastructure	
			Area (m^2)	Volume (m^3)	Area (m^2)	Volume (m^3)	Area (m^2)	Volume (m^3)
CO2	Red Kandosol	1.2	7,212,400	8,654,880	-	-	15,300	18,360
SP1b	Yellow Kandosol	1.2*	4,862,100	4,375890	12,500	11,250	-	-
SP1c	Yellow Sodosol	0.6*					-	-
SP2a	Red Sodosol	0.3*	3,959,400	2,969,550	1,285,600	964,200	-	-
SP2b	Brown Dermosol	1.2*					-	-
SP3	Red Sodic Dermosol	0.3	5,500	1,650	-	-	-	-
JJ1	Red Kandosol	0.5	-	-	-	-	58,700	29,350
JJ4	Brown Chromosol	0.4	-	-	-	-	98,900	39,560
LC1	Yellow Kandosol	0.5	3,311,000	1,655,500	-	-	51,040	25,520
		Total	19,350,400	**17,657,470**	1,298,100	**975,450**	223,940	**112,790**
Total Volume (m^3)						**18,745,710**		
Grand Total (Total Volume minus 10% handling loss) (m^3)						**16,871,139**		

**Averages used where more than one soil is stripped within a single land system unit*

5.2.3 Soil Stripping Management

Where soil stripping and transportation is required, the following soil handling techniques are recommended to prevent excessive soil deterioration, note these management principles apply to both topsoil and subsoil stripping:

- Strip material to the depths as stated in **Table 32**, subject to further field investigations during stripping activities.
- Soil should preferably be stripped in a slightly moist condition. Material should not be stripped in either an excessively dry or wet condition.
- Place stripped material directly onto area to be rehabilitated and spread immediately (if mining sequences, equipment scheduling and weather conditions permit) to avoid the requirement for stockpiling.
- Grade or push soil into windrows with graders or dozers for later collection by open bowl scrapers, or for loading into rear dump trucks by front-end loaders. These techniques are examples of preferential less aggressive soil handling systems. This minimises compression effects of the heavy equipment that is often necessary for economical transport of soil material.
- Soil transported by dump trucks may be placed directly into storage. Soil transported by scrapers is best pushed to form stockpiles by other equipment (e.g. dozer) to avoid tracking over previously laid soil.

- The surface of soil stockpiles should be left in as coarsely structured a condition as possible in order to promote infiltration and minimise erosion until vegetation is established, and to prevent anaerobic zones forming.
- As a general rule, maintain a maximum stockpile height of 3 m. Clayey soils should be stored in lower stockpiles for shorter periods of time compared to coarser textured sandy soils.
- If long-term stockpiling is planned (i.e. greater than 12 months), seed and fertilise stockpiles as soon as possible. An annual cover crop species that produce sterile florets or seeds should be sown. A rapid growing and healthy annual pasture sward provides sufficient competition to minimise the emergence of undesirable weed species. The annual pasture species will not persist in the rehabilitation areas but will provide sufficient competition for emerging weed species and enhance the desirable micro-organism activity in the soil.
- Prior to re-spreading stockpiled topsoil onto reshaped overburden (particularly onto designated tree seeding areas), an assessment of weed infestation on stockpiles should be undertaken to determine if individual stockpiles require herbicide application and / or "scalping" of weed species prior to topsoil spreading.
- An inventory of available soil should be maintained to ensure adequate topsoil materials are available for planned rehabilitation activities.
- Topsoil will be spread to a minimum depth range of 0.1 m. Soil respreading on steep slopes at depths exceeding 0.1 m can be deleterious because of the "sponge" effect which can cause slippage of the topsoil from the slope.

Where possible, suitable topsoil should be re-spread directly onto reshaped areas. Where topsoil resources allow, topsoil should be spread to a nominal depth of 100 mm on all re-graded spoil or disturbance areas. Topsoil should be spread, treated with fertiliser and seeded in one consecutive operation, to reduce the potential for topsoil loss to wind and water erosion.

Thorough seedbed preparation should be undertaken to ensure optimum establishment and growth of vegetation. All topsoiled areas should be lightly contour ripped (after topsoil spreading) to create a "key" between the soil and the spoil. Ripping should be undertaken on the contour and the tynes lifted for approximately 2 m every 200 m to reduce the potential for channelised erosion. Best results will be obtained by ripping when soil is moist and when undertaken immediately prior to sowing. The respread topsoil surface should be scarified prior to, or during seeding, to reduce run-off and increase infiltration. This can be undertaken by contour tilling with a fine-tyned plough or disc harrow.

5.3 Erosion Potential

5.3.1 Erosion Potential of Soil Types

All soil samples were laboratory tested for sodicity, using the Exchangeable Sodium Percentage (ESP). These tests indicate the susceptibility of a soil to losing its structure and binding capacity when wet, and therefore the erosion potential of the soil. Field assessments were made on site as to erosion observations which have been considered in the potential erosion rates outlined below.

5.3.2 Potential Erosion Rates

The Revised Universal Soil Loss Equation (RUSLE) was used in this assessment to estimate the long term average soil loss rates that may result from sheet and rill flow during various levels of disturbance. It must be noted that wind and gully erosion is discussed separately in the section below.

The RUSLE calculates annual erosion rates based on the following equation:

$$A = R \cdot K \cdot LS \cdot C \cdot P$$

Where: A = annual soil loss due to erosion [t/ha/yr]
R = rainfall erosivity factor
K = soil erodibility factor
LS = topographic factor derived from slope length and slope gradient
C = cover and management factor
P = erosion control practice factor

The following table offers a comparison of disturbance levels which aims to highlight the higher risk activities in regard to erosion rates. It must be noted that assumptions were made as to the specific values of soil and overburden characteristics, vegetation establishment success, climatic conditions, slope gradients and lengths and various management practices, and therefore the following values should only be used for comparison purposes. The calculations were made with the 'worst case' scenarios used consistently for all disturbance levels.

Table 34 – Estimated Erosion Rates using the RUSLE

Disturbance Level	Rainfall Erosivity Factor (R)	Soil Erodibility Factor	Topographic Factor (LS)	Cover and Management Factor (C)	Erosion Control Practice Factor (P)	**Annual Soil Loss (A) (t/ha/yr)**
Undisturbed Surface Pre Mining and Subsided Underground Areas	1804	0.030	1.00	0.01	1.0	0.54
Surface cleared of vegetation and topsoil (Open Cut Stripping)	1804	0.017	1.00	1.00	1.3	39.87
Unshaped Overburden Emplacements	1804	0.025	8.22	1.00	0.8	296.58
Shaped Overburden Emplacements with Graded Banks and Dam Construction	1804	0.025	3.07	1.00	0.8	110.77
Newly Rehabilitated Shaped Overburden Emplacements and Dam Walls	1804	0.030	3.07	0.45	0.8	59.81
Established Rehabilitated Shaped Overburden Emplacements and Dam Walls	1804	0.030	3.07	0.03	0.8	3.99

Table 34 above shows the disturbance level during mining with the highest risk of severe erosion rates will be the unshaped overburden scenario. The key factor to observe in this result is the topographic factor (LS) where the overburden is free dumped and left at the angle of repose albeit benched in some cases. This practice is unlikely to be modified due to cost effectiveness and practicalities of dumping activities. However it is recommended that these areas and times of highest risk should have adequate sedimentation controls in place downstream to capture any material eroded from these slopes. The shaped overburden dumps with graded banks (but without topsoil or vegetation) was the second highest predicted rate of erosion which indicates the need for the reshaping, grading, topdressing and seeding of overburden dumps to be undertaken in the quickest possible timeframe in order to minimise the risk of severe rainfall events impacting on these exposed slopes over a long period of time.

Gully erosion is not considered within the RUSLE equation above, however given the succession of erosion severity from rill to gully erosion, it is predicted that the same disturbance levels will contain the same risk rankings for gully erosion rates as the RUSLE equation has displayed. Once overburden dumps have been shaped and graded banks established, any gully erosion should be repaired and rehabilitated as soon as possible to reduce further erosion and sedimentation downstream.

Wind erosion has the potential to cause loss of material from overburden emplacement areas during the mining process, especially given the raised elevation of the emplacement areas within the landscape. Management practices during mining may limit the extent of wind erosion, by reducing truck movements and earthworks on highly exposed emplacement areas during periods of extreme wind conditions. Furthermore, mine planning considerations for minimising exposed surfaces and timely rehabilitation activities may protect surface soil from wind erosion of overburden emplacement areas.

5.3.3 Landform Design and Erosion Control Measures

Rehabilitation strategies and concepts proposed below have been formulated according to results of industry-wide research and experience. The main objective of regrading is to produce slope angles, lengths and shapes that are compatible with the proposed land use and not prone to an unacceptable rate of erosion. Integrated with this is a drainage pattern that is capable of conveying runoff from the newly created catchments whilst minimising the risk of erosion and sedimentation. Final slope gradient should not exceed 17%, or approximately 10°.

The most significant means of controlling surface flow on disturbed areas is to construct contour furrows or contour banks at intervals down the slope. The effect of these is to divide a long slope into a series of short slopes with the catchment area commencing at each bank or furrow. This prevents runoff from reaching a depth of flow or velocity that would cause erosion. As the slope angle increases, the banks or furrows must be spaced closer together until a point is reached where they are no longer effective. Contour ripping across the grade is by far the most common form of structural erosion control on mine sites as it simultaneously provides some measure of erosion protection and cultivates the surface in readiness for sowing.

Graded banks are essentially a much larger version of contour furrows, with a proportionately greater capacity to store runoff and/or drain it to some chosen discharge point. The banks are constructed away from the true contour, at a designed gradient (0.5% to 1%) so that they drain water from one part of a slope to another; for example, towards a watercourse or a sediment control dam. Eventually, runoff that has been intercepted and diverted must be managed down slope. The use of engineered waterways using erosion blankets, ground-cover vegetation and/or rip rap is recommended to safely dispose of runoff downslope.

The construction of sediment control dams is recommended for the purpose of capturing sediment laden runoff prior to off-site release. Sediment control dams are responsible for improving water quality throughout the mine site and, through the provision of semi-permanent water storages, enhance the ecological diversity of the area.

The following points should be considered when selecting sites for sediment control dams.

- Each dam should be located so that runoff may easily be directed to it, without the need for extensive channel excavation or for excessive channel gradient. Channels must be able to discharge into the dam without risk of erosion. Similarly, spillways must be designed and located so as to safely convey the maximum anticipated discharge.
- The material from which the dam is constructed must be stable. Dispersive clays will require treatment with gypsum to prevent failure of the wall by tunnel erosion. Failure by tunnelling is most likely in dams which store a considerable depth of water above ground level, or whose water level fluctuates widely. Dams should always be well sealed, as leakage may lead to instability, as well as allowing less control over the storage and release of water.
- The number and capacity of dams should be related to the total area of catchment and the anticipated volume of runoff. The most damaging rains, in terms of erosion and sediment problems are localised, high intensity storms.

5.3.4 Topsoil Respreading & Seedbed Preparation

Sampling and analysis of topsoil resources, whether stockpiled or in-situ, is recommended prior to respreading. This will assist in identifying potential soil deficiencies and estimating required rates of fertiliser or ameliorant (i.e. gypsum or lime) application.

Where possible, suitable topsoil should be re-spread directly onto reshaped areas. Where topsoil resources allow, topsoil should be spread to a minimum depth of 10 cm on all regraded spoil. Topsoil should be spread, treated with fertilizer or ameliorants (if required) and seeded in one consecutive operation, to reduce the potential for topsoil loss to wind and water erosion.

Prior to re-spreading stockpiled topsoil onto reshaped overburden (particularly onto designated tree seeding areas), an assessment of weed infestation on stockpiles should be undertaken to determine if individual stockpiles require herbicide application and / or "scalping" of weed species prior to topsoil spreading.

Thorough seedbed preparation should be undertaken to ensure optimum establishment and growth of vegetation. All topsoiled areas should be contour ripped (after topsoil spreading) to create a "key" between the soil and the spoil. Ripping should be undertaken on the contour and the tynes lifted for approximately 2 m every 200 m to reduce the potential for channelised erosion. Best results will be obtained by ripping when soil is moist and when undertaken immediately prior to sowing. The respread topsoil surface should be scarified prior to, or during seeding, to reduce run-off and increase infiltration. This can be undertaken by contour tilling with a fine-tyned plough or disc harrow.

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