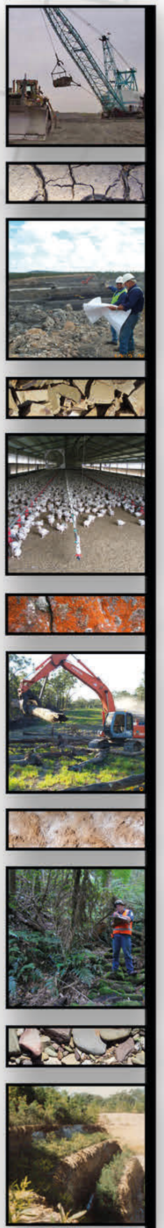
BENGALLA Mining Company

V

Soils and Land Capability Impact Assessment



Soil and Land Capability Impact Assessment

Continuation of Bengalla Mine

July 2013

HAN05-001

GSS ENVIRONMENTAL
Environmental, Land and Project Management Consultants

Prepared on behalf of Hansen Bailey for Bengalla Mining Company Pty Limited

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EXECUTIVE SUMMARY

GSS Environmental was commissioned by Hansen Bailey Pty Ltd on behalf of Bengalla Mining Company Pty Ltd to undertake a soil and land capability assessment for the Continuation of Bengalla Coal Mine, located approximately 4km west of Muswellbrook. This continuation of mining will see operations progress for a further 24 years at production rate of up to 15 Million tonnes per annum, the ongoing use and upgrade of existing infrastructure and the temporary diversion and reinstatement of Dry Creek.

The total area assessed was 1,370 ha and included the proposed disturbance area within the Project Boundary. The land within this area has been extensively cleared and its predominant land use is cattle grazing. Seven soil types and one variant were identified within the survey area; Red Chromosols occur on the upper slopes, and cover 13% of the area; Brown Chromosols are the dominant soil type present and cover 41.8% on the mid-slopes; Brown Vertosols occur on the low slopes and on the areas of gentle incline, covering 11.7% of the area. Red Sodosols occur on the mid to lower slopes and cover 5% of the area; a zone of Brown Kurosols draining into Dry Creek covers 1.4% of the area. A moderately deep Brown Sodosol covering 6.5% of the area is a variant of a deep Brown Sodosol, which is found in Dry Creek and covers 4.4% of the area. Rudosols are found on upper slopes and crests, predominately in the west and covers 16.1% of the area.

In terms of Rural Land Capability classification, the Brown Vertosols are a mix of Class II and Class IV land (comprising 11.7% of the survey area; suitable for regular cultivation and grazing respectively); the Red & Brown Chromosols and Red Sodosol are Class V land (comprising 59.8% of the area, suitable for grazing and occasional cultivation); the Brown Kurosol and Brown Sodosols are Class VI land (comprising 12.3% of the area, suitable for grazing only), while the Rudosols are Class VII land (comprising 16.1% of the area, which should be maintained under green timber). In terms of Agricultural Suitability, the land is assessed as being predominately moderate to marginal, with 67.6% of the area being Class 3 land (moderately productive, suited to grazing and occasional cropping) and 28.4% of the area being Class 4 land (marginal land, unsuited to cultivation, but suitable for low intensity grazing). A small area of Class 2 land (suitable for cultivation) comprises 4.1% of the area. All soils within the study area are assessed as having a moderate soil erosion risk and, therefore, require careful management, such as maintaining adequate ground cover, maintaining low stocking rates, using erosion control measures such as contour banks and ripping, and maintain riparian vegetation.

The assessment has shown that the capability of the soils subject to disturbance within the Project Boundary have a recommended topsoil stripping depths of 0 – 0.60 m varying between soil types. Brown Chromosols and Brown Kurosols can be stripped to 0.10 m; Red Chromosols to 0.15 m; Brown Vertosols and Red Sodosols to 0.20 m and Brown Sodosols to 0.60 m. Rudosols should not be stripped. Allowing for a 10% handling loss, approximately 1,549,800 m^3 of suitable topdressing material is available within the Disturbance Boundary. The recommended depths relate to soil that could be salvaged via the stripping process and re-used in progressive and post construction rehabilitation works. All subsoils are undesirable for topsoil use due to severe physical and/or chemical limitations.

Stripped soils should be carefully managed in accordance with established protocols and wherever possible, used in rehabilitation as soon as practicable after stripping to preserve native seed banks and soil microflora. Land disturbance should be minimised by clearing the smallest practical area of land ahead of construction. General vegetation clearing and soil stripping should not be undertaken until earthwork and construction operations are ready to commence. All proposed erosion and sediment control measures should be implemented in advance of, or in conjunction with, clearing activities.

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1.0 INTRODUCTION

GSS Environmental (GSSE) was commissioned by Hansen Bailey Pty Ltd (Hansen Bailey) on behalf of Bengalla Mining Company Pty Limited (BMC) to undertake a soil and land capability impact assessment for the Continuation of Bengalla Mine Project (the Project). This assessment will form part of the Environmental Impact Statement (EIS) supporting an application for Development Consent under Part 4, Division 4.1 of the *Environmental Planning and Assessment Act 1979* (EP&A Act). The Project involves the continuation of mining to the west of the existing extraction limit at a rate of up to 15 Mtpa for 24 years. The mining will largely be conducted within current mining leases. The Project will enable the extraction of an additional 316 Mt of ROM coal from the Whittingham Coal Measures.

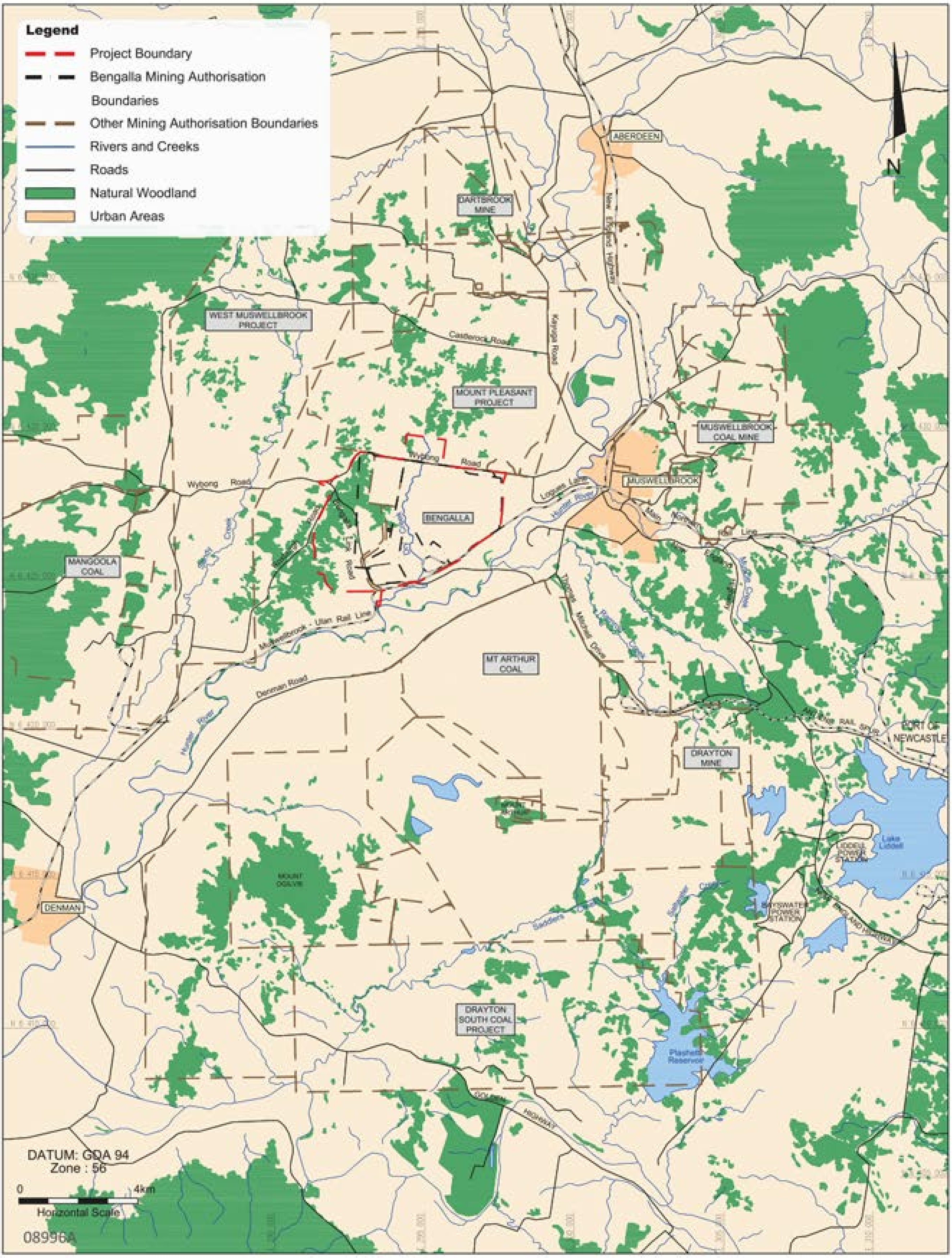
The Project consists of the following characteristics:

- Open cut mining towards the west at a rate of up to 15 Mtpa ROM coal for 24 years;
- Continued use of the existing dragline, truck fleet and excavator fleet (with progressive replacement);
- An out of pit Overburden Emplacement Area (OEA) to the west of Dry Creek which may be utilised for excess spoil material until it is intercepted by mining;
- Continued use, extension or relocation to existing infrastructure, including administration and parking facilities, in-pit facilities (including dragline shut down and erection pad), helipad, tyre laydown area, explosives and reload storage facility, core shed workshop and administration buildings, roads, reject bin, ROM Hopper, water management infrastructure, supporting power infrastructure, and ancillary infrastructure;
- Construction and use of various items of new infrastructure (including radio tower, extensions to Main Infrastructure Area (MIA), MTP Staged Discharge Dam and associated water reticulation infrastructure, additional ROM coal stockpile and upgrade to the emergency ROM coal stockpile along with associated conveyor network);
- Processing, handling and transportation of coal via the (upgraded) CHPP and rail loop for export and domestic sale;
- Continued rejects and tailings co-disposal in the Eastern OEA and temporary in pit reject emplacement;
- Relocation of a 3 km section of Bengalla Link Road around Year 13 near the existing mine access road to facilitate coal extraction;
- The diversion of Dry Creek via dams and pipe work with a later permanent alignment of Dry Creek through rehabilitation areas when emplacement areas are suitably advanced;
- Relocation of water storage infrastructure as mining progresses through existing dams (including the Staged Discharge Dam, raw water dam); and
- A workforce of approximately 900 full time equivalent personnel (plus contractors) at peak production.

1.1 Project Description and Project Boundary

Bengalla is located in the Upper Hunter Valley of NSW, approximately 130 km north-west of Newcastle and 4 km west of the township of Muswellbrook (**Figure 1**). Bengalla is a strip mining, open cut operation where current mining advances in a westerly direction based on dragline strips approximately 60 m in width. Overburden is removed by two methods: a truck and excavator operation, and through the use of a dragline. Coaling is undertaken by a truck and excavator operation.

The Project Boundary for the entire Bengalla Lease encompasses an area of 2,341 ha. The Survey Area within the Project Boundary relevant to this report encompasses an area of 1,370 ha which includes a Disturbance Boundary of 964 ha. A soil survey covering 390 ha of the Project Boundary has been previously undertaken by Global Soil Systems (GSS) as documented in *Bengalla Coal Mine: Soil Survey Report* (GSS, 2005). The soils component of this report focuses on the Disturbance Area of 1,370 ha, the majority of which occurs west of Dry Creek.



BENGALLA MINE

BENGALLA

Hansen Bailey
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Regional Locality

FIGURE 1

1.2 Assessment Objectives

The major objectives of the assessment undertaken by GSSE were to:

Objective 1 Classify and provide a description and mapping of the soil types within the Project Boundary;

Objective 2 Provide a description and mapping of the pre and post mining land capability within the Project Boundary;

Objective 3 Provide a description and mapping of the pre and post mining agricultural suitability within the Project Boundary;

Objective 4 Provide recommendations for stripping depths of proposed disturbance areas, including any recommendations for topsoil handling, stockpiling and amelioration for reuse in rehabilitation; and

Objective 5 Describe necessary erosion and sediment control measures to manage disturbed in-situ and stockpiled soil resources.

This report outlines the methodology and results of the soil and land capability assessment conducted to satisfy the assessment objectives. This includes background research, field assessment, laboratory analysis of soil samples sourced from within the Project Boundary and proposed soil management measures.

1.3 Standards

To satisfy Objective 1 of the Soil and Land Capability Impact Assessment (the Assessment):

- The soil taxonomic classification system utilised was the Australian Soil Classification System (Isbell, 1996);
- The soil survey system implemented with regard to survey type and scale was the *Guidelines for Surveying Soil and Land Resources* (NCST, 2008). This is a recognised guideline for Australian soil and land capability assessments; and
- The soil survey system to be applied with regards to recording information from field soil survey observations is the *Australian Soil and Land Survey Field Handbook* (NCST, 2009). This is a recognised guideline for Australian soil and land capability assessments.

To satisfy Objective 2 of the Assessment, Rural Land Capability classification was conducted in accordance with the requirements of the NSW Department of Trade and Investment, Regional Infrastructure and Services (DTIRIS). This system was introduced by the Soil Conservation Service of NSW and the relevant guideline is provided in *Systems Used to Classify Rural Lands in New South Wales* (Emery, 1986).

To satisfy Objective 3 of the Assessment, Agricultural Suitability Classification was conducted in accordance with the requirements of the DTIRIS. This system was introduced by the former NSW Agricultural & Fisheries Service of NSW and the relevant guideline is provided in the *Agricultural Suitability Maps – uses and limitations* (NSW Agricultural & Fisheries, 1990).

To satisfy Objective 4 of the Assessment, the system implemented to determine which soils are suitable for conserving and utilising in the Project's rehabilitation program was the *Soils and Extractive Industries* (Elliot & Reynolds, 2007). This procedure assesses soils based on grading, texture, structure, consistence, mottling, and root presence. The approach described in this guideline remains the benchmark for land resource assessment in the Australian mining industry.

To satisfy Objective 5 of the Assessment, the Australian guideline *Managing Urban Stormwater: Soils and Construction – Volume 2E Mines and Quarries* (Department of Environment and Climate Change, 2008) was utilised to describe the necessary erosion and sediment control measures to manage disturbed *in situ* and stockpiled soil resources.

1.4 Director General's Requirements

Director General's Requirements (DGRs) were issued on March 13th, 2012, for the Continuation of Bengalla Mine Project (SSD-5170). Within these DGRs, several are relevant for this report, namely:

The EIS must address the following specific matters:

- **Land Resources** – including an Agricultural Impact Statement and a detailed assessment of the potential impacts on:
  - Soils and land capability (including salinisation and contamination);
  - Landforms and topography, including steep slopes; and
- **Water Resources** – including:
  - Details and staging for the proposed Dry Creek re-diversion.

This report focusses on the Land Resources component of the EIS requirements (excluding contamination), although the Dry Creek diversion and issues surrounding it are also discussed here. These will be elaborated on in the forthcoming Bengalla Continuation Rehabilitation Management Strategy.

2.0 BIOPHYSICAL ENVIRONMENT

2.1 Climate

The Project Boundary is located in the Hunter region of NSW, typically having a cool temperate climate with moderately dry winters and wetter summers. The annual average rainfall is 622.3 mm with the majority of this rainfall falling in the summer months of December to February (Muswellbrook (Lower Hill St) Bureau of Meteorology (BOM) station No. 06012824, 2012). Temperatures within the region range from an average monthly maximum of 31.7 ^{0}C in January to an average monthly minimum of 3.8^{0}C in July (Jerry Plains Post Office BOM station No. 061086, 2011). The average annual evaporation within the Project Boundary ranges between 1400 - 1800 mm (Average pan Evaporation (Annual) Map 2008 BOM Product Code: IDCJCM0006) (BOM, 2008; 2012).

2.2 Hydrology and Topography

The Project Boundary is located within the Hunter River catchment, specifically the Hunter Residual sub-catchment. This sub-catchment is a planform controlled, meandering river, containing gravelly sediments and can be primarily characterised as a ‘sediment transfer zone’. Medium energy flow transports sediment, gravel and sand in this sub-catchment.

The topography within the Project Boundary is typical of the Bayswater soil landscape unit (Kovac & Lawrie, 1991) and is characterised by low to undulating hills that range from Reduced Level (RL) 40 to 220 m with slopes generally ranging between 3 to 10%. Small areas have gently to moderately inclined slopes of 10-18%. A Hunter River tributary, Dry Creek is located to the within the Disturbance Boundary and drains in a southerly direction. This Creek is a minor tributary of the Hunter River and is ephemeral in nature, only flowing during periods of prolonged or intense rainfall. The Creek bed is predominately covered in grasses and weeds, with riparian vegetation scattered and severely disturbed after an extensive period of grazing. Erosion is evident in sections of the Creek and its tributaries.

2.3 Geomorphic Domains and Geology

Bengalla is located in the Central Lowlands topographic zone within the Sydney Basin geological province. Two soil landscape units underpin the Project Boundary. These are the Roxburgh and Bayswater soil landscapes as delineated by the Soil Landscapes of the Singleton 1:250,000 Sheet (Kovac & Lawrie, 1991).

The Bayswater soil landscape describes soils that have formed from the underlying Permian Singleton Coal Measures on landscapes with between 40-60 m RL (Reduced Level) with an elevation of RL 140 to 220 m. These measures are composed of sandstone shale, mudstone, conglomerate and coal parent material and have been derived from ancient marine sediments. Due to the sediments origin, salt levels are usually high and soils are often dispersive and highly erodible with sheet and gully erosion common landscape features.

The Roxburgh soil landscape also describes soils that have formed from Permian Singleton Coal Measures on slightly higher and steeper landscapes with between 60-120 m local relief. These measures also comprise sandstone, shale, mudstone, conglomerate and coal which has in situ weathered parent rock material derived from colluvium. The Roxburgh unit covers undulating low hills and undulating hills with an elevation of 80-370 m ASL (Above Sea Level) and minor to moderate sheet erosion. Soils are primarily yellow podzolic soils (Yellow Chromosols) on upper to midslopes with red solodic soils (Red Sodosols) and brown podzolic soils (Brown Chromosols) on upper concave slopes, and Lithosols (Rudosols/Tenosols) on steeper slopes.

2.4 Vegetation and Land Use

The Project Boundary has been mostly cleared for agriculture and is dominated by grasslands, although some areas of woodland remain. The original character of the vegetation has been greatly altered as a result of previous agricultural land use. Small patches of remnant woodland vegetation occur in the western portion of the Project Boundary, which provide the majority of habitat for flora and fauna including habitat for several threatened species.

Landuse in the surrounding area is a mixture of open cut mining activity and grazing. In areas close to the Hunter River, more intensive agricultural practices (e.g. cropping) are undertaken. The majority of the area surrounding Bengalla Mine has been heavily modified by agricultural practices and mining activity.

3.0 SOIL SURVEY AND ASSESSMENT

This section outlines the methods used to conduct the soil survey component of the assessment and reports the results of the survey.

3.1 Soil Survey Methodology

Both a field survey and a desktop study were undertaken within the Project Boundary.

3.1.1 Reference Map

An initial soil map (reference map) was developed using the following 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 Project Boundary.

- **Reference information;**

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

- **Previous reports;**

  - Soil Landscapes of the Singleton 1:250,000 Sheet (Kovac and Lawrie, 1991);
  - Soil Survey for the Proposed Bengalla Coal Mine (Envirosciences Pty Ltd, 1993);
  - Bengalla Coal Mine Soil Survey Report (GSS, 2005); and
  - Soil and Land Capability Impact Assessment, Bengalla Development Consent Modification (GSSE, 2010).

- **Stratified observations**

  Following the production of a broad soil map, surface soil exposures, topography and vegetation throughout the Project Disturbance Area were visually assessed to verify potential soil types, delineate soil type boundaries, and determine preferred locations for targeted subsurface investigations (hereafter referred to as soil pits).

3.1.2 Field Survey Methodology

Two approaches were used to map soils within the 1,370 ha Survey Area: a field survey, to cover the area which will be severely affected by the open cut mining process, and mapping extrapolated from the field survey, supporting information and reconnaissance for the area within the Disturbance Boundary that will be minimally affected by open cut mining.

The field survey was undertaken at a medium intensity scale of 1:50,000, enabling the production of a map sufficiently detailed for project and district-level planning. To satisfy this scale, in accordance with the *Guidelines for Surveying Soil and Land Resources* (NCST, 2008), the number of observations per unit area required is 4 observations per 100 ha. For the field survey area, 10 representative sites were selected for full soil profile descriptions (excavated pits). Additionally, numerous field observations (e.g. details recorded from cuttings, stream banks, shovel excavations) were taken where possible, satisfactory to meet the required observation density.

A description of the field observation categories is provided in **Table 1**.

Table 1 – Field Observation Categories

Class	Observation Type	Description	Actual Number for Project
1	Detailed profile description	Soil pit excavation with soil profile described in accordance with the *Australian Soil Survey Handbook* (NCST, 2009).	10
2	Deep borings	Deep borings examine material below the normal depth of the soil description and are important where subsolum and substrate properties influence land use. This is particularly so where irrigated land use is proposed. No irrigated land was assessed during the survey or is proposed for the Project, meaning that soil description beyond the normal depth, via deep borings, was not necessary.	0
3	Laboratory soil assessment	Samples were taken from 10 Class 1 observations (soil pits) with each identified layer assessed for many level C and D type analyses as specified in **Table 17.9** of the *Guidelines for Surveying Soil and Land Resources*.	10 (pits)
4	Minor field observations	Minor field observations are brief observations to confirm mapping boundaries, soil type distributions or other characteristics being mapped in the survey. These are always brief, and generally constitute the majority of field observations in soil surveys due to the efficiency in gathering good quality field data to supplement and refine detailed information collected using Type I observations. Mapping observations during the survey included exposed cuttings, exposure of topsoil to 40 cm using a spade, vegetation associations and rock outcrops.	20
Total			**40**

The field survey was undertaken as a ‘Free Survey’ where observations were irregularly located according to the survey team’s judgement based on reference map interpretation with survey information obtained across traverses where soil type was expected to change. Observations were in the form of soil profile descriptions from pits and/or soil profile exposures. Detailed descriptions accompanied sampling of representative soil profiles for subsequent laboratory analysis.

3.1.2.1 Soil Field Assessment

Ten exposed soil profiles were assessed across the Project Boundary that focused on areas within the Disturbance Boundary. The soil profile locations are shown in **Figure 2**. Each soil profile exposure pit was excavated to the required depth of 1.2 m and to a suitable width to receive maximum light on the profile exposure from which the samples were removed. All pits were backfilled immediately after assessment. All soil profiles were assessed for soil type and distribution, with 31 samples taken from the ten pits for subsequent laboratory analysis.

Soil profiles within the Project Boundary were assessed in accordance with the Australian Soil and Land Survey Field Handbook (NCST, 2009) soil classification procedures. Detailed soil profile descriptions recorded information that covered the parameters as specified in **Table 2**. Soil profile logging was undertaken in the field using soil data sheets.

Global Positioning System (GPS) recordings were taken for all sites where detailed soil descriptions were undertaken. Vegetation type and land use were also recorded. Soil exposures from excavated pits were photographed during field operations as colour photography of profile sites is a useful adjunct to description of land attributes.

Soil layers from each test pit were also assessed according to a procedure adapted from Elliot and Reynolds (2007) for the recognition of suitable topdressing material. This procedure assesses soils based on grading, texture, structure, consistency, mottling and root presence. A more detailed explanation of the Elliot and Reynolds procedure is presented in **Section 5** of this report.

Table 2 – Detailed Soil 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

3.1.2.2 Soil Laboratory Assessment

Soil samples from ten soil profile sites were utilised in a laboratory testing programme. Samples were analysed to determine:

- Soil taxonomy;
- Land capability and agricultural suitability classification; and
- Suitability of soil as topdressing media.

LEGEND

- Project Boundary (DA)
- Disturbance Boundary
- Approved Bengalla Mine
- Soil Pit Location (2005, GSSE)
- Project Soil Pit Location (2011, GSSE)
- Contours
- Creeks
- Rivers

0 500m 1.0km

Scale 1: 35 000

FIGURE 2

Soils Sampling Sites

Project:	Bengalla Continuation: Soil and Land Capability Report
Client:	Hansen Bailey
File:	Fg2_HAN05-001_Soil Sampling Sites_121130
Projection:	MGA94 Zone 56

Version:	Date:	Author:	Checked:	Approved:
1	30/11/12	KC	RW	AC

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The laboratory test results were used in conjunction with the field assessment results to determine the depth of soil material that is suitable for stripping and re-use for the rehabilitation of disturbed areas.

Soil samples of approximately 1 – 2 kg were collected from each soil layer. In total, 31 soil samples were sent to the Department of Lands (Scone Research Centre) for analysis. A certificate of analysis for these results is contained in **Appendix 2**. The selected physical and chemical laboratory analysis parameters, and their relevant application, are listed in **Table 3**.

All samples were laboratory tested for relevant physical and chemical parameters (**Table 3**). Their application to the soil and land assessment is also described in **Table 3** for each parameter. A description of the significance of each test and typical values for each soil characteristic is included in **Appendix 2**.

The laboratory test results were used in conjunction with the field assessment results to determine the depth of soil material that is suitable for recovery and use as a growth medium for rehabilitation of disturbed areas. Similarly, potentially unfavourable soil material was identified. The soil test results for the soil survey are provided in **Appendix 2**.

Table 3 – Laboratory Analysis Parameters

Property	Application
Physical:	
Colour	Soil colour based on Munsell Colour chart.
Coarse fragments (>2mm)	Soil workability; root development; droughtiness
Particle-size distribution (<2mm)	Nutrient retention; exchange properties; erodibility; droughtiness; workability; permeability; sealing; drainage; interpretation of most other physical and chemical properties and soil qualities
Aggregate stability (Emerson Aggregate Test)	Susceptibility to surface sealing under rainfall or irrigation; effect of raindrop impact and slaking; permeability; infiltration; aeration; seedling emergence; correlation with other properties
Chemical:	
Soil reaction (pH) (1:5, soil: water suspension)	Nutrient availability; nutrient fixation; toxicities (especially Al, Mn); liming; sodicity; correlation with other physical, chemical and biological properties
Electrical conductivity (EC) (1:5, soil: water suspension)	Appraisal of salinity hazard in soil substrates or groundwater, total soluble salts
Cation exchange capacity (CEC) and exchangeable cations	Nutrient status; calculation of exchangeable sodium percentage (ESP); assessment of other physical and chemical properties, especially dispersivity, shrink – swell, water movement, aeration
Organic Carbon (OC) (%)	Essential nutrient for plant growth

The laboratory methods used by Scone Research Centre for each physical and chemical parameter are provided in **Table 4**.

Table 4 – Laboratory Test Methods

Analyte	Method
Particle Size Analysis (PSA)	Sieve & hydrometer
pH	1:5 soil/water extract
Electrical conductivity	1:5 soil/water extract
Emerson Rating	Emerson Aggregate Test (EAT)
CEC & exchangeable cations	(AgTU)+ extraction

3.1.2.3 Mapping Observations

Mapping observations consisted of exposed cuttings (such as “cut” slopes), topsoil exposure of up to 40 cm using a spade, vegetation cover associations and rock outcrops. These were utilised to confirm mapping boundaries, soil type distributions and any other characteristics being mapped in the survey. This information generally constitutes the majority of field observation data collected in soil surveys (NCST, 2008) and is used to refine information collected from detailed soil profile observations.

3.1.3 Soil Classification

The applicable technical standard adopted for naming the types of soil identified within the Project Boundary is the Australian Soil Classification (ASC) system (Isbell, 1996).

3.2 Soil Survey Results

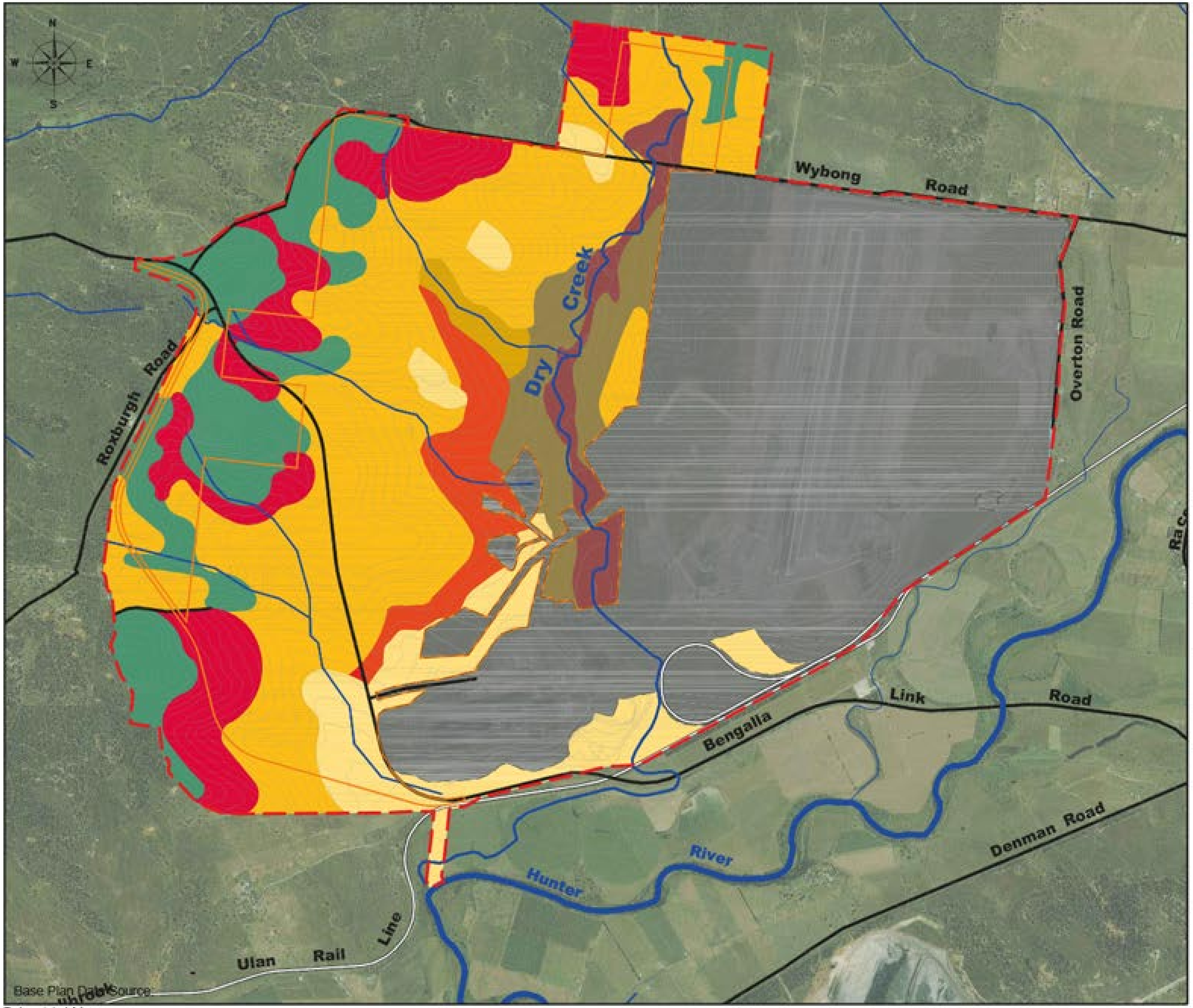
3.2.1 Soil Types Overview

Eight soil types were identified within the Project Boundary. **Table 5** provides an overview of each soil type and their quantitative distribution within the Project Boundary (final percentage is rounded). **Figure 3** illustrates the spatial distribution of soil types.

Table 5 – Soil Types Overview

Soil Type #	Australian Soil Classification Name	Survey Area	
		Area (%)	Area (ha)
1	Brown Chromosol	41.8	571
2	Red Chromosol	13.0	179
3	Brown Vertosol	11.7	161
4	Red Sodosol	5.0	69
5	Brown Kurosol	1.4	20
6	Deep Brown Sodosol	4.4	60
6(V)	Brown Sodosol	6.5	89
7	Rudosol	16.1	221
	Total	100	1,370

The distribution of these soils is illustrated in **Figure 3**. Exposed profiles of major soil units and landscape photos of areas where each soil unit was observed are shown in **Plates 1** to **12.** A glossary of commonly used soils terms is presented in **Appendix 1**. All soil interpretations have been derived from Hazelton & Murphy (2007) unless otherwise stated. Colour was analysed on moist samples unless they were bleached layers.



LEGEND

- Project Boundary
- Disturbance Boundary
- Approved Bengalla Mine
- Red Chromosol
- Brown Chromosol
- Brown Vertosol
- Red Sodosol
- Brown Kurosol
- Deep Brown Sodosol
- Brown Sodosol
- Rudosol
- Contours

0 500m 1.0km
Scale 1: 35 000

FIGURE 3

Soils Map

Project: Bengalla Continuation: Soil and Land Capability Report

Client: Hansen Bailey

File: Fg3_HAN05-001_Soil Map_121206

Projection: MGA94 Zone 56

Version:	Date:	Author:	Checked:	Approved:
1	23/05/12	KC	RW	AC
2	28/06/12	ZJ	RW	AC
3	06/12/12	KC	RW	AC

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Environmental, Land and Project Management Consultants

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3.2.2 Soil Type 1 – Brown Chromosol

Soil Type 1 is a Brown Chromosol and covers 46.2% of the Project Boundary. A soil profile overview, physical characteristics and laboratory results are presented in **Table 6**. It is derived from sandstone shale, mudstone, conglomerate and coal parent materials from the Singleton Coal Measures. This soil type complex has well developed duplex profiles with fine loamy surfaces overlying dark brown clay subsoils containing red mottles.

This soil type is located on the less steep waning slopes (slope <5%). These soils are reasonably fertile and less susceptible to sheet and gully erosion when managed to their correct capacity, as compared to the soil covering the steeper waxing slopes. Land that is accessible for agriculture has been grazed in the past. Sheet erosion and gully erosion is likely to occur if protective vegetative cover is removed.

Table 6 – Overview: Brown Chromosol

Site Description

Plate 1 – Profile (Pit 2)

Plate 2 – Landscape (Pit 2)

ASC Soil Type	Brown Chromosol; moderate
Sample Pit	2
Dominant Geology Association	Shale, conglomerate floaters (20-100 mm)
Dominant Slope Association	Mid-slope; very gently to gently inclined (3-10%)
Land Use and Vegetation	Cattle grazing, isolated ironbark, spear grass, wheat grass, red grass
Land Capability Class	Class V – limited by slope, sodicity, depth to BC
Erosion Risk Class	Topsoil K-factor = 0.04; moderate erosion risk
Soil Stripping Recommendation	0-0.10 m – Highly suitable; subsoil unsuitable due to fine texture and high dispersability

Physical Characteristics		
Horizon	**Depth (m)**	**Description**
A1	0.00 - 0.10	Dark Brown (7.5YR3/4) moderate consistence silty clay loam. Sub angular blocky 5-25 mm. Roots fine/medium and common. Boundary is clear and wavy.
B21	0.10 - 0.30	Dark Brown (7.5YR3/4) heavy clay, strong consistence, strong structure (angular blocky 25-50 mm). Roots fine/medium and common up to 60 cm. Boundary is gradual and wavy.
B22	0.30 - 0.60	Dark Brown (7.5YR3/4), strong consistence silty clay. Strong (prismatic 25-100 mm). Roots fine/medium and common up to 60 cm. Boundary clear and even.
BC	0.60 - 0.90	Red, strong consistence clay throughout, decomposing parent material. Sub angular blocky 50-100 mm, roots few and fine to 70 cm. Boundary is gradual and wavy.
C	0.90 - 1.40	Conglomerate, sandstone and shale.

Analytical Description							
Analyte	**Units**	**A1**		**B21**		**B22**	
Depth	m	0 - 0.1		0.1 - 0.3		0.3 – 0.6	
Colour	Munsell	Dark brown		Dark brown		Dark brown	
pH	pH unit	6.6	Neutral	5.9	Moderately acid	8.0	Moderately alkaline
EC	dS/m	0.2	Non-saline	0.02	Non-saline	0.3	Non-saline
CEC	meq/100g	25.4	High	26.9	High	31.7	High
ESP	%	3.9	Non-sodic	2.6	Non-sodic	11.4	Moderately sodic
EAT	Class	3(1)	Slight	3(3)	Moderate	2(1)	High-Moderate

3.2.3 Soil Type 2 – Red Chromosol

Soil Type 2 is a Red Chromosol and covers 7.6% of the Project Boundary. A soil profile overview, physical characteristics and laboratory results are presented in **Table 7**. It is derived from sandstone, shale, mudstone, conglomerate and coal parent materials from the Singleton Coal Measures. This soil type has well developed duplex profiles with silty clay loam surfaces overlying heavy clay to silty clay subsoils.

This soil type is located on the steeper waxing slopes (slope >5%). These soils are less susceptible to sheet and gully erosion when managed to their correct capacity, as compared to the less steep waning slope soils. They do not have sodic subsoils which are highly susceptible to sheeting when the surface is exposed or disturbed. Land that is accessible for agriculture has been grazed in the past. Sheet erosion and gully erosion is likely if protective vegetative cover is removed.

Table 7 – Overview: Red Chromosol

Site Description

Plate 3 – Profile (Pit 9)

Plate 4 – Landscape (Pit 9)

ASC Soil Type	Red Chromosol
Sample Pit	9 – mapped as a Brown Chromosol but similar to soils found in this soil mapping unit
Dominant Geology Association	Shale, sandstone, mudstone, conglomerate
Dominant Slope Association	Upper slope; gently inclined (3-10%) & moderately inclined (10-18%)
Land Use and Vegetation	Grazing cattle; Red Ironbark, Kurrajong, Native Grasses
Land Capability Class	Class IV
Erosion Risk Class	Topsoil K-factor = 0.04; moderate erosion risk
Soil Stripping Recommendation	0-0.15 m – Highly suitable; subsoil unsuitable due to fine texture

Physical Characteristics		
Horizon	**Depth (m)**	**Description**
A1	0.00 - 0.15	Dark Brown (7.5YR3/4) moderate consistence silty clay loam. Moderate pedality rough faced peds (sub angular blocky 10-20 mm). Boundary clear and wavy.
B21	0.15 - 0.30	Yellowish Red (5YR4/6) strong consistence heavy clay. Strong pedality smooth faced peds (angular-blocky 20-50 mm). Roots course and abundant up to 30 cm. Boundary gradual and wavy.
B22	0.30 - 60	Dark Brown (7.5YR4/6) strong consistence silty clay. Moderate pedality smooth faced peds (sub angular blocky to prismatic 50-200 mm). Boundary clear and even to BC layer.

Analytical Description							
Analyte	**Units**	**A1**		**B21**		**B22**	
Depth	m	0.00 - 0.15		0.15 - 0.30		0.30 – 0.60	
Colour	Munsell	Dark Brown		Yellowish Red		Dark Brown	
pH	pH unit	6.8	Neutral	7.4	Mildly alkaline	8.5	Strongly alkaline
EC	dS/m	0.2	Non-saline	0.1	Non-saline	0.2	Non-saline
CEC	meq/100g	20.2	Moderate	29.5	High	34.5	High
ESP	%	4.3	Non-sodic	4.0	Non-sodic	4.6	Non-sodic
EAT	Class	3(1)	Slight	3(1)	Slight	4	Negligible

3.2.4 Soil Type 3 – Brown Vertosol

Soil Type 3 is a Brown Vertosol and covers 12.6% of the Project Boundary. A soil profile overview, physical characteristics and laboratory results are presented in **Table 8**. It is derived from sandstone, shale, mudstone, conglomerate and coal parent materials from the Singleton Coal Measures. This soil type exhibits a gradational profile and has a silty clay topsoil and heavy clay subsoil. Cracking was in evidence at the surface of this soil type.

This soil type is located on the plateaued benches of lower and midslopes, as well as lower slopes in the south of the Project Boundary. These soils are generally not susceptible to sheet or gully erosion when managed to their correct capacity, as compared to duplex soils with sodic characteristics. The land associated with this soil type has been extensively cleared for grazing, however, vegetation cover on the soil has largely been continual and this has prevented enhanced runoff and sheet erosion that is commonly associated with agricultural activities.

Table 8 – Overview: Brown Vertosol

Site Description: Soil Type 3

Plate 5 – Profile (Pit 10)

Plate 6 – Landscape (Pit 10)

ASC Soil Type	Brown Vertosol
Sample Pit	10
Dominant Geology Association	Shale
Dominant Slope Association	Flat areas on mid-slopes/ lower slopes
Land Use and Vegetation	Grazing, isolated White Box with cotton bush shrubs and white top grasses (*Danthonia* spp.)
Land Capability Class	Class IV (sodicity at depth)
Erosion Risk Class	Topsoil K-factor = 0.025; moderate erosion risk
Soil Stripping Recommendation	0 – 0.20 m suitable for stripping; subsoil unsuitable because of texture, alkalinity and sodicity.

Physical Characteristics		
Horizon	**Depth (m)**	**Description**
A1	0.00 – 0.20	Dark Brown (7.5YR3/4) strong consistence silty clay. Moderate pedality (angular blocky 20-50mm) earthy face peds. Boundary gradual and wavy.
A21	0.20 – 0.30	Dark Reddish Brown (5YR3/4) strong consistence heavy clay. Strong pedality (angular blocky 20-50mm) smooth face peds. Boundary diffuse and irregular.
B1	0.30 – 0.60	Dark Reddish Brown (5YR3/4) strong consistence heavy clay. Strong pedality (angular blocky 50-100mm) smooth face peds. Boundary clear and irregular.
B2	0.60 – 1.10	Yellowish Brown (10YR5/6) moderate consistence silty clay. Moderate pedality (sub-angular prismatic 100-500mm) rough faced peds.

Analytical Description									
Analyte	**Units**	**A1**		**A21**		**B1**		**B2**	
Depth	m	0 – 0.20		0.20 – 0.30		0.30 – 0.60		0.60 – 1.10	
Colour	Munsell	Dark brown		Dark reddish brown		Dark reddish brown		Yellowish brown	
pH	pH unit	7.2	Neutral	8.2	Moderately alkaline	8.7	Strongly alkaline	9.2	Very strongly alkaline
EC	dS/m	0.1	Non-saline	0.2	Non-saline	0.2	Non-saline	0.7	Non-saline
CEC	meq/100g	26.4	High	37	High	37.3	High	37.9	High
ESP	%	3	Non-sodic	4.9	Non-sodic	5.9	Non-sodic	10.8	Moderately sodic
EAT	Class	8	Negligible	3(1)	Slight	3(1)	Slight	4	Negligible

3.2.5 Soil Type 4 – Red Sodosol

Soil Type 4 is a Red Sodosol and covers 13.9% of the Project Boundary. A soil profile overview, physical characteristics and laboratory results are presented in **Table 9**. It is derived from sandstone, shale, mudstone, conglomerate and coal parent materials from the Singleton Coal Measures. This soil complex has well developed duplex profiles with clay loam surfaces overlying heavy clay subsoils.

This soil type is located on the gently to very gently inclined midslopes (slope 3 - 10%). These soils are susceptible to sheet and gully erosion due to the dispersive nature of their subsoils. Incorrect management practices can lead to the topsoil being detached and cause enhanced erosion rates when the subsoil is exposed. Land that is accessible for agriculture has been grazed in the past but currently is not used for agriculture and the condition of the soil is improving due to the increased ground cover of native pastures and invading weeds. However, sheet erosion and consequential gully erosion is likely if protective vegetative cover is removed.

Table 9 – Overview: Red Sodosol

Site Description: Soil Type 4

Plate 7 – Profile (Pit 13)

Plate 8 – Landscape (Pit 13)

ASC Soil Type	Red Sodosol
Sample Pit	13
Dominant Geology Association	Sandstone and shale
Dominant Slope Association	Midslope; gently to very gently inclined (3 - 10%)
Land Use and Vegetation	Cattle grazing; Forest Oak regrowth, native grasses, weed species
Land Capability Class	Class V
Erosion Risk Class	Topsoil K-factor = 0.03. Moderate risk
Soil Stripping Recommendation	0 – 0.20 m suitable for stripping; subsoil unsuitable because of texture and sodicity

Physical Characteristics		
Horizon	**Depth (m)**	**Description**
A1	0.00 – 0.20	Very Dark Brown (7.5YR2.5/3) weak consistence clay loam. Moderate pedality (sub-angular blocky 10-50 mm), earthy faced peds. Many course roots. Boundary clear and even.
B21	0.20 – 0.50	Dark Red (2.5YR3/6) strong consistence heavy clay. Strong pedality (angular blocky 20-50 mm) smooth faced peds. Fine and course roots common. Boundary diffuse and even.
B22	0.50 – 0.80	Yellowish Red (5YR4/6) strong consistence heavy clay. Strong pedality (angular blocky 20-50 mm) sandy faced peds. Fine common roots. Boundary clear and irregular.
BC	0.80 – 1.20	Yellowish Brown moderate consistence clay. Moderate pedality (sub angular – prismatic 100-500 mm) rough faced peds. Fine few roots.

Analytical Description							
Analyte	**Units**	**A1**		**B21**		**B22**	
Depth	m	0 – 0.20		0.20 – 0.50		0.50 – 0.80	
Colour	Munsell	Very dark brown		Dark red		Yellowish red	
pH	pH unit	6.6	Neutral	8.2	Moderately alkaline	8.9	Strongly alkaline
EC	dS/m	0.1	Non-saline	0.2	Non-saline	1.0	High – Very High
CEC	meq/100g	18	Moderate	31.6	High	39.4	High
ESP	%	3.9	Non-sodic	10.4	Moderately sodic	18.0	Strongly sodic
EAT	Class	2(1)	High-moderate	2(2)	High	2(2)	High

3.2.6 Soil Type 5 – Brown Kurosol

Soil Type 5 is a Brown Kurosol and covers 3.1% of the Project Boundary. A soil profile overview, physical characteristics and laboratory results are presented in **Table 10**. It is derived from sandstone, shale, mudstone, conglomerate and coal parent materials from the Singleton Coal Measures. This soil complex has well developed duplex profiles with loam to sandy loam surfaces overlying sandy clay subsoils.

This soil type is located on the level to very gently inclined slopes of lower slopes and drainage lines (slope 0 - 3%). These soils are susceptible to sheet and gully erosion due to the high erodibility and dispersive nature of their subsoils. Incorrect management practices can lead to the topsoil being detached and cause enhanced erosion rates when the subsoil is exposed. Land that is accessible for agriculture has been grazed in the past but currently is not used for agriculture. Sheet erosion and consequential gully erosion is likely if protective vegetative cover is removed by intensifying agricultural activity or by localised flooding.

Table 10 – Overview: Brown Kurosol

Site Description: Soil Type 5

Plate 9 – Profile (Pit 4)

Plate 10 – Landscape (Pit 4)

ASC Soil Type	Brown Kurosol; deep
Sample Pit	4
Dominant Geology Association	Shale
Dominant Slope Association	Lower slope (within drainage line); level to very gently inclined (0 – 3%)
Land Use and Vegetation	Grazing cattle, native grasses and forbes; 100% ground cover
Land Capability Class	Class VI
Erosion Risk Class	Topsoil K-factor = 0.04; Moderate risk
Soil Stripping Recommendation	0-0.10 m suitable; 0.10-0.30 m marginally suitable; A2 and B2 subsoil unsuitable for stripping due to combination of acidity, sodicity and dispersability

Physical Characteristics		
Horizon	**Depth (m)**	**Description**
A11	0.00 – 0.10	Dark Brown (7.5YR3/3) weak consistence loam. Weak pedality (sub angular blocky 100-200 mm) earthy face peds. Boundary gradual and weak.
A12	0.10 – 0.30	Strong Brown (7.5YR4/6) weak consistence sandy loam. Apedal. Boundary diffuse and wavy.
A2	0.30 – 0.60	Bleached (7.5YR4/6) weak consistence clay loam. Apedal. Boundary clear and irregular.
B2	0.60 – 1.00	Strong Brown (7.5YR5/6) moderate consistence sandy clay. Sandy fabric (sub angular blocky 100-200 mm).

Analytical Description									
Analyte	**Units**	**A11**		**A12**		**A2**		**B2**	
Depth	m	0 – 0.10		0.10 – 0.30		0.30 – 0.60		0.60 – 1.00	
Colour	Munsell	Dark brown		Strong brown		Strong brown		Strong brown	
pH	pH unit	5.9	Moderately acid	5.5	Strongly acid	5.7	Moderately acid	4.9	Very strongly acid
EC	dS/m	0.08	Non-saline	0.02	Non-saline	0.02	Non-saline	0.09	Non-saline
CEC	meq/100g	7.3	Low	4.2	Very low	6.1	Low	12.1	Moderate
ESP	%	5.5	Non-sodic	4.8	Non-sodic	8.2	Moderately sodic	14.9	Strongly sodic
EAT	Class	8	Negligible	8	Negligible	2(1)	High-moderate	2(1)	High-moderate

3.2.7 Soil Type 6 – Brown Sodosol

Soil Type 6 is a Brown Sodosol; mapped at two depths within the Project Boundary. The Brown Sodosol – Deep (>100 cm) to weathered material covers 5.9% of the Project Boundary. A soil profile overview, physical characteristics and laboratory results are presented in **Table 11**. It is derived from sandstone shale, mudstone, conglomerate and coal parent materials from the Singleton Coal Measures.

The Brown Sodosol – Deep occurs on level to slightly undulating flats and gullies. Sheet erosion and gully erosion is likely if protective vegetative cover is removed due to localised flooding. The Brown Sodosol - Moderately Deep is located on the less steep waning slopes (slope <5%). These lower slope soils are more fertile and less susceptible to sheet and gully erosion when managed to their correct capacity, as compared to soils on steeper waxing slopes. Land that is accessible for agriculture is grazed.

A variant of this soil type (Soil Type 6V) is present as a Brown Sodosol - Moderately Deep (<75 cm). It covers 10.8% of the Disturbance Boundary. The laboratory and physical characteristics of the Brown Sodosol - Deep are representative for the variation (excluding depth range).

Table 11 – Overview: Brown Sodosol

Site Description: Soil Type 6

Plate 11 – Profile (Pit 5)

Plate 12 – Landscape (Pit 5)

ASC Soil Type	Brown Sodosol – Deep (representative) & Brown Sodosol - Moderately Deep.
Sample Pit	5
Dominant Geology Association	Shale
Dominant Slope Association	Broad gully floor; level to very gently inclined (0-3%)
Land Use and Vegetation	Grazing; mixed grasses
Land Capability Class	Deep - Class VI; waterlogging potential with severe erosion possible; Moderately Deep – Class IV
Erosion Risk Class	Topsoil K-factor = 0.30, Moderate

Soil Stripping Recommendation	0 – 0.6 m: Highly suitable; subsoil unsuitable due to highly dispersive, sodic properties

Physical Characteristics		
Horizon	**Depth (m)**	**Description**
A11	0.00 – 0.10	Dark Brown (7.5YR3/4) strong consistence clay loam. Moderate pedality (sub angular blocky 50-100 mm) earthy peds. Boundary is diffuse, even.
A12	0.10 – 0.30	Brown (7.5YR4/3) strong consistence clay loam. Moderate pedality (sub angular blocky 50-200 mm) earthy peds. Boundary is diffuse, even.
A13	0.30 – 0.60	Dark Brown (7.5YR3/4) strong consistence clay loam. Moderate pedality (sub angular blocky 100-200 mm) earthy peds. Boundary is clear, wavy.
B2	0.60 – 1.00	Brown (7.5YR4/4) moderate consistence light clay. Moderate pedality (sub angular blocky 100-200 mm) earthy peds.

Analytical Description									
Analyte	**Units**	**A11**		**A12**		**A13**		**B2**	
Depth	m	0 - 0.1		0.1 - 0.3		0.3 – 0.6		0.6 – 1.00	
Colour	Munsell	Dark brown		Brown		Dark brown		Brown	
pH	pH unit	7.2	Neutral	7.3	Neutral	8.1	Moderately alkaline	9.1	Very strongly alkaline
EC	dS/m	0.0	Non-saline	0	Non-saline	0	Non-saline	0.2	Non-saline
CEC	meq/100g	21	Moderate	20.3	Moderate	18.4	Moderate	22.6	Moderate
ESP	%	1.9	Non-sodic	2.5	Non-sodic	3.8	Non-sodic	15.0	Strongly sodic
EAT	Class	8	Negligible	3(1)	Slight	3(2)	Slight	2(3)	Very high

3.2.8 Soil Type 7 – Rudosol

Soil Type 7 is a Rudosol; mapped from aerial reconnaissance information and existing soils maps; as such, no laboratory results are available. Rudosols, with a variable depth to bedrock, cover 16.1% of the Project Boundary. They are derived from sandstone shale, mudstone, conglomerate and coal parent materials from the Singleton Coal Measures (**Table 12**).

Rudosols occur primarily in the western area of the Project Boundary and occur on upper slopes to crests. Sheet and gully erosion is likely if protective vegetative cover is removed, however native vegetation is still commonly found on steeper, rockier slopes. Land that is accessible for agriculture is lightly grazed.

Table 12 – Overview: Rudosol

Site Description: Soil Type 7	
ASC Soil Type	Rudosol
Sample Pit	N/A – Inferred from supporting data and field observations
Dominant Geology Association	Shale, sandstone, mudstone
Dominant Slope Association	Upper slopes and crests (>10%)
Land Use and Vegetation	Light Grazing; native trees and mixed grasses
Land Capability Class	Class VII; shallow, sandy loam soils on steep slopes and crests
Erosion Risk Class	N/A
Soil Stripping Recommendation	0 cm: Not suitable; shallow, sandy with bedrock at 35 cm

4.0 LAND ASSESSMENT

The Project Boundary has been assessed for its Rural Land Capability and Agricultural Suitability classification. The methods and results for both these assessments are presented in this section fulfilling report Objectives 2 and 3.

4.1 Rural Land Capability Assessment

4.1.1 Methodology

The land capability system applied to the Project Boundary is in accordance with the DTIRIS (formerly the NSW Soil Conservation Service) classification system. The relevant guideline is called S*ystems Used to Classify Rural Lands in New South Wales* (Cunningham *et al*., 1988). This system classifies the land on its potential for sustainable agricultural use if developed, rather than its current land use, and includes three types of land uses:

- Land suitable for cultivation;
- Land suitable for grazing; and
- Land not suitable for rural production.

The system consists of eight classes, which classify the land based on the severity of long-term limitations. Limitations are the result of the interaction between physical resources and a specific land use. A range of factors are used to assess this interaction. These factors include climate, soils, geology, geomorphology, soil erosion, topography and the effects of past land uses. The principal limitation recognised by these capability classifications is the stability of the soil mantle and classes are ranked on their increasing soil erosion hazard and decreasing versatility of use. A description of the eight land capability classes (and special zonings) is provided in **Table 13**.

Table 13 – Rural Land Capability Classes

Class	Land Use	Management Options
I	Regular Cultivation	No erosion control requirements
II	Regular Cultivation	Simple requirements such as crop rotation and minor strategic works
III	Regular Cultivation	Intensive soil conservation measures required such as contour banks and waterways
IV	Grazing, occasional cultivation	Simple practices such as stock control and fertiliser application
V	Grazing, occasional cultivation	Intensive soil conservation measures required such as contour ripping and banks
VI	Grazing only	Managed to ensure ground cover is maintained
VII	Unsuitable for rural production	Green timber maintained to control erosion
VIII	Unsuitable for rural production	Should not be cleared, logged or grazed
Special Zonings		
U	Urban areas	Unsuitable for rural production
SF	State Forests	Unsuitable for rural production
M	Mining & quarrying areas	Unsuitable for rural production

Source: Cunningham et al., 1988

4.1.2 Land Capability Results

The relevant pre-mining land capability classification land within the Project Boundary is quantified in **Table 14**. The spatial distribution of the pre-mining land capability classification is shown in **Figure 4**.

4.1.2.1 Pre-Mining

The Project Boundary is composed of land capability classes II, IV, V, VI and VII. Overall, the major limitations impacting land capability classification within the Project Boundary are slope, soil depth, sodicity, acidity/alkalinity, waterlogging potential and erosion risk.

Class II Land

Class II land consists of Soil Type 3 (Brown Vertosol), specifically land located on low slope areas in the southern extent within the Project Boundary. This classification indicates that the land is suitable for regular cultivation and cropping.

Class IV Land

Class IV land consists of Soil Type 3 (Brown Vertosol), specifically land located on several flat areas west of Dry Creek. This classification indicates that the land is suitable for grazing with only occasional cultivation. This class of land is limited by its sodicity at depth. The choice of plants is restricted and the land requires careful management. This land is capable of pasture improvement and can be tilled for an occasional crop. The preferred pasture establishment method for this land class is no-till or zero tillage and pasture grass cover should be maintained at >70% with a minimum height of 5 cm.

Class V Land

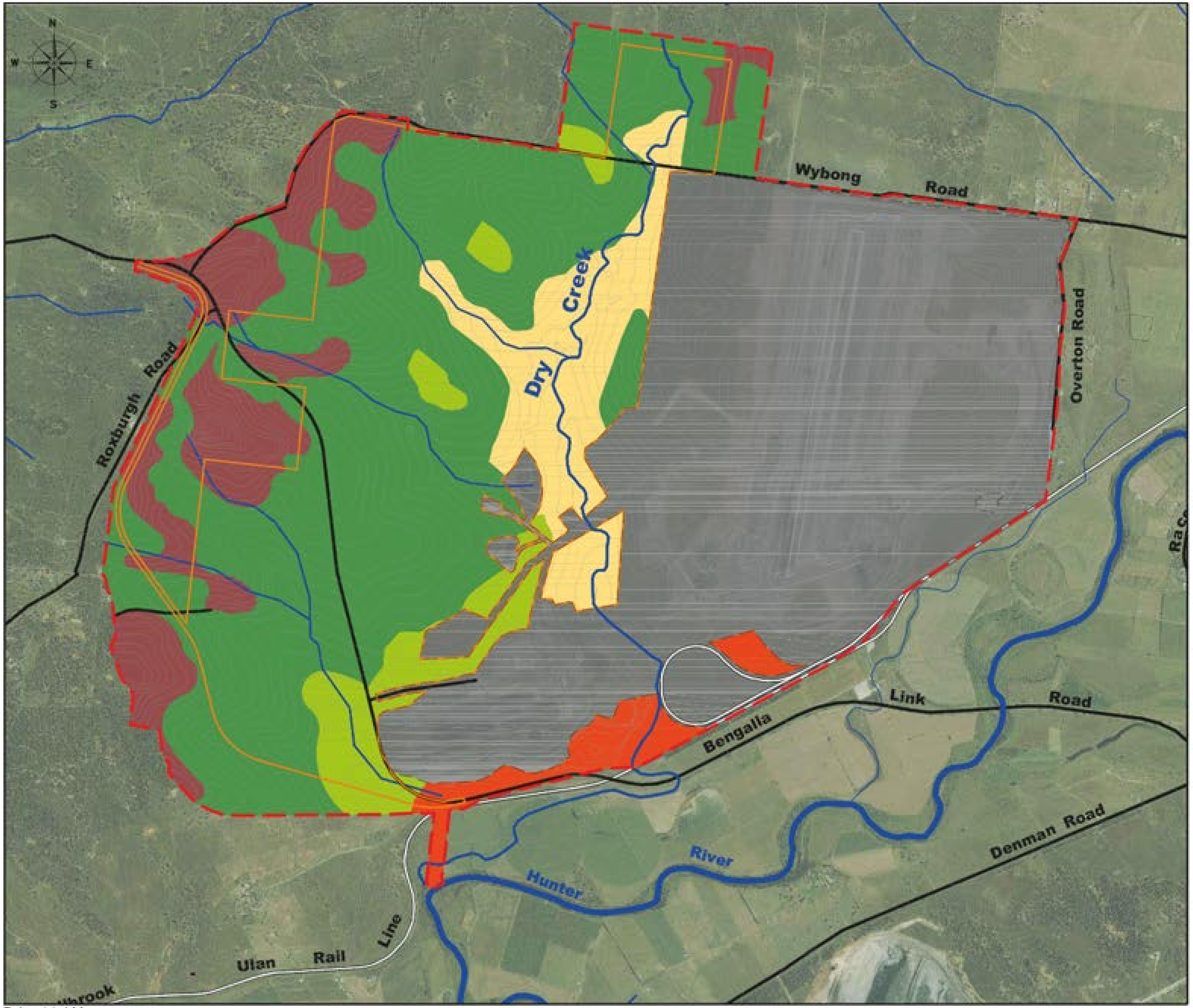
Class V land consists of Soil Types 1 (Brown Chromosol), 2 (Red Chromosol) and 4 (Red Sodosol). Class V land is only suitable for grazing with very occasional cultivation. If cultivated then intensive soil conservation measures are required such as contour ripping and banks. Similar to Class IV, this land is considered to be moderately productive and suited to improved pasture. However, higher level management practices are required due to slope and/or higher erosion risks as compared to Class IV land.

Class VI Land

Class VI land consists of Soil Type 5 (Brown Kurosol), Soil Type 6 and Soil Type 6 (V) (Brown Sodosol – Deep and Moderately Deep, respectively). This classification indicates that the land must not be cultivated for cropping or for establishing pasture, however, the land can be used for grazing if careful management and stocking practices are implemented.

Soil Type 5 is constrained by its shallow topsoil depth, acidity and susceptibility to erosion due to inherent sodicity. Pasture improvement is recommended via by no-till practices, specifically, aerial broadcasting of seed.

Soil Types 6 and 6 (V) are found in and adjacent to Dry Creek. It is likely that Soil Type 6 is a buried soil profile, with up to 60 cm of the upper profile material likely derived from erosional processes upslope. Whilst this material is of reasonable quality, the lower profile material is very alkaline, strongly sodic and highly dispersive and as a significant drainage line, prone to periodic high velocity water flows and waterlogging. This combination of factors makes it unsuitable for cultivation (which would exacerbate the erosion risk) and it is important for an adequate vegetation cover to be maintained to minimise erosion potential.



LEGEND

- Project Boundary
- Disturbance Boundary
- Approved Bengalla Mine
- Contours
- Class II - Simple requirements such as crop rotation and minor strategic works
- Class IV - Land suitable for grazing and occasional cultivation with soil conservation practices
- Class V - Land suitable for grazing but not suitable for cultivation on a regular basis. Structural soil conservation works required
- Class VI - Land suitable only for grazing providing stock limited
- Class VII - Land unsuitable for rural production; green timber should be maintained to control erosion

0 500m 1.0km

Scale 1: 35 000

FIGURE 4

Pre-Mining Land Capability

Project: Bengalla Continuation: Soil and Land Capability Report

Client: Hansen Bailey

File: Fg4_HAN05-001_Pre-Mining Land Capability_121206

Projection: MGA94 Zone 56

Version:	Date:	Author:	Checked:	Approved:
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Class VII Land

Class VII land consists of Soil Type 7 (Rudosol). This classification indicates that the land is unsuitable for rural production and green timber should be maintained to control erosion. Soil Type 7 tends to be sandy and of variable, shallow depth to bedrock and as such, has not been as extensively cleared as other soil types. It is often found in areas or rocky outcrop and becomes increasingly prevalent in the western areas of the Project Boundary, at higher elevations.

Table 14 – Pre-Mining Rural Land Capability for the Project Boundary

Class	Pre-Mining		
	Associated Soil Type	%	ha
I	-	Nil	Nil
II	3	4.1	56
III	-	Nil	Nil
IV	3	11.7	105
V	1, 2, 4	59.8	819
VI	5, 6, 6(V)	12.3	169
VII	7	16.1	221
VIII	-	Nil	Nil
M	-	Nil	Nil
Total		**100%**	**1,370**

4.1.2.2 Post-Mining

The post-mining Land Capability classification is indicative only, as the baseline data provided is illustrative of the conceptual 24 year mine plan. Post-mining land capability is illustrated in **Figure 5**. The landforms associated with the year 24 mining surface design for the Project Boundary are predominately flats and slopes, commonly up to 18% and occasionally up to 32%. These landforms are typically associated with Classes II to VI. Where the final void is located, steep slopes will likely render this land unsuitable for agricultural production and this land will be classified Rural Land Capability VIII. The conceptual 24-year mine plan currently shows this area as Special Zoning M (land disturbed by Mining).

Class II land can be re-instated where Brown Vertosol material is salvaged and then re-instated, although the total land area will be limited in extent. Class IV land can be extensively re-instated where slope varies between 3-10%. On slopes over 10%, land will require careful management and is limited to Classes V, VI or VII. This land is suitable for low intensity grazing only, or where the land falls under Class VII, land should be returned to green timber to stabilise slopes and minimise erosion.

LEGEND

- Project Boundary
- Disturbance Boundary
- Approved Bengalla Mine
- Contours
- Class II - Simple requirements such as crop rotation and minor strategic works
- Class IV - Land suitable for grazing and occasional cultivation with soil conservation practices
- Class V - Land suitable for grazing but not suitable for cultivation on a regular basis. Structural soil conservation works required
- Class VI - Land suitable only for grazing providing stock limited
- Class VII - Land unsuitable for rural production; green timber should be maintained to control erosion
- Class VIII - Mined Land/Dams/ Infrastructure/Rehabilitation Areas

0 500m 1.0km

Scale 1: 35 000

FIGURE 5

Year 24
Land Capability

Project: Bengalla Continuation: Soil and Land Capability Report

Client: Hansen Bailey

File: Fg5_HAN05-001_Year 24 Land Capability_121206

Projection: MGA94 Zone 56

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4.2 Agricultural Suitability Assessment

4.2.1 Methodology

The Agricultural Suitability classification system applied to the assessment is in accordance with the NSW DPI (formerly NSW Agriculture & Fisheries) guideline. The relevant guideline is the *Agricultural Suitability Maps – Uses and Limitations* (NSW Agriculture & Fisheries, 1990). The system consists of five classes, providing a ranking of rural lands according to their productivity for a wide range of agricultural activities with the objective of determining the potential for crop growth within certain limits. Class 1 ranks the land as most suitable for agricultural activities and Class 5 the least suitable. Classes 1 to 3 are generally considered suitable for a wide variety of agricultural production, whereas, Classes 4 and 5 are unsuitable for cropping however are suitable for some grazing activities

The overall suitability classification for each specific soil type is determined by the most severe limitation, or a combination of the varying limitations. A description of each Agricultural Suitability Class is provided in **Table 15**.

Table 15 – Agricultural Suitability Classes

Class	Land Use	Management Options
1	Highly productive land suited to both row and field crops.	Arable land suitable for intensive cultivation where constraints to sustained high levels of agricultural production are minor or absent.
2	Highly productive land suited to both row and field crops.	Arable land suitable for regular cultivation for crops but not suited to continuous cultivation.
3	Moderately productive lands suited to improved pasture and to cropping within a pasture rotation.	Grazing land or land well suited to pasture improvement. It may be cultivated or cropped in rotation with pasture.
4	Marginal lands not suitable for cultivation and with a low to very low productivity for grazing.	Land suitable for grazing but not for cultivation. Agriculture is based on native or improved pastures established using minimum tillage.
5	Marginal lands not suitable for cultivation and with a low to very low productivity for grazing.	Land unsuitable for agriculture or at best suited only to light grazing.

Source: NSW Agriculture & Fisheries (1990)

4.2.2 Agricultural Suitability Results

The main soil properties and other landform characteristics considered significant for the Agricultural Suitability assessment are topsoil texture, topsoil pH, solum depth, external and internal drainage, topsoil stoniness and slope as well as bio-physical factors such as elevation, rainfall and temperature.

4.2.2.1 Pre-Mining

Table 16 quantifies the relevant pre-mining Agricultural Suitability classes for the Project Boundary. **Figures 6** and **7** shows the spatial distribution of the pre and post-agricultural suitability classes respectively.

Table 16 – Pre-Mining Suitability Classes

Agricultural Suitability Class	Land Capability Class	Soil Type #	Project Boundary	
			ha	%
2	II	3	56	4.1
3	IV, V	1, 2, 3, 4	924	67.5
4	VI, VII	5, 6, 6(V), 7	390	28.4

Class 2 Land

Class 2 land consists of Soil Type 3 (Brown Vertosol). This class indicates that the land is highly productive and suitable for regular cultivation for crops, but not suited to continuous cultivation. A limitation for land classified as Class 2 is the disjointed nature of the land and its close proximity to mining infrastructure.

Class 3 Land

Class 3 land consists of Soil Types 1 (Brown Chromosol), 2 (Red Chromosol), 3 (Brown Vertosol) and 4 (Red Sodosol). This class indicates that the land is moderately productive and well suited to grazing with pasture improvement, or to an occasional crop with a pasture rotation. A major limitation for land classified as Class 3 is slope gradient of up to 10%, and its main constraints limiting cultivation frequency are soil structure breakdown and erosion hazard. All soil types display a moderate erosion risk and soil conservation and drainage works are likely to be required if the land is to be used for anything other than grazing activity.

Class 4 Land

Class 4 land consists of Soil Types 5 (Brown Kurosol), Soil Type 6 and Soil Type 6 (V) (Brown Sodosol – Deep and Moderately Deep, respectively) and Soil Type 7 (Rudosols). This classification indicates that this land must not be cultivated for cropping or for establishing pasture grasses, however, the land can be used for grazing if careful management and stocking practices are implemented. Grazing productivity is low to very low and pastures are to be based on native or improved pastures established with zero or minimum tillage techniques. Although production may be high seasonally, the overall level of production is low as a result of a number of major constraints, both environmental and edaphic.

A major constraint for Soil Types 5, 6 and 6 (V) in this Class is their association with water and prolonged water logging conditions. Erosion risk in this environment is high due to periodic water flow combined with weak soil structure due to sodic subsoils. The cultivation of these soils for agriculture, which involves removal of the protective vegetative cover, will facilitate rapid erosion processes. These erosion processes typically take the form of tunnel and gully erosion leading to severe land degradation. Sodicity, in addition to increasing the tendency of the soil particles to disperse in wet conditions can also negatively affect plant root growth depending on plant type and other soil conditions.

4.2.2.2 Post-Mining

The conceptual post-mining landforms are typically associated with Agricultural Suitability Classes 3 and 4. Given the dominant existing surrounding land uses, the post mining land use of the Project Boundary is best suited to low intensity grazing. On areas where steeper slopes occur, cattle grazing should be minimised and a good cover of pasture maintained. The return of local box woodland species would also increase the habitat value of the land and addresses concerns of the Muswellbrook Shire Council (MSC, 2011) regarding increasing the amount of woody vegetation present on post-mining land forms.

The re-instated Dry Creek should be managed with particular care to ensure erosion is not exacerbated. Further discussion in relation to the reinstatement of Dry Creek is discussed in Section 5.5.1. Where possible, stock grazing should be minimised and riparian vegetation established to increase bank stability.

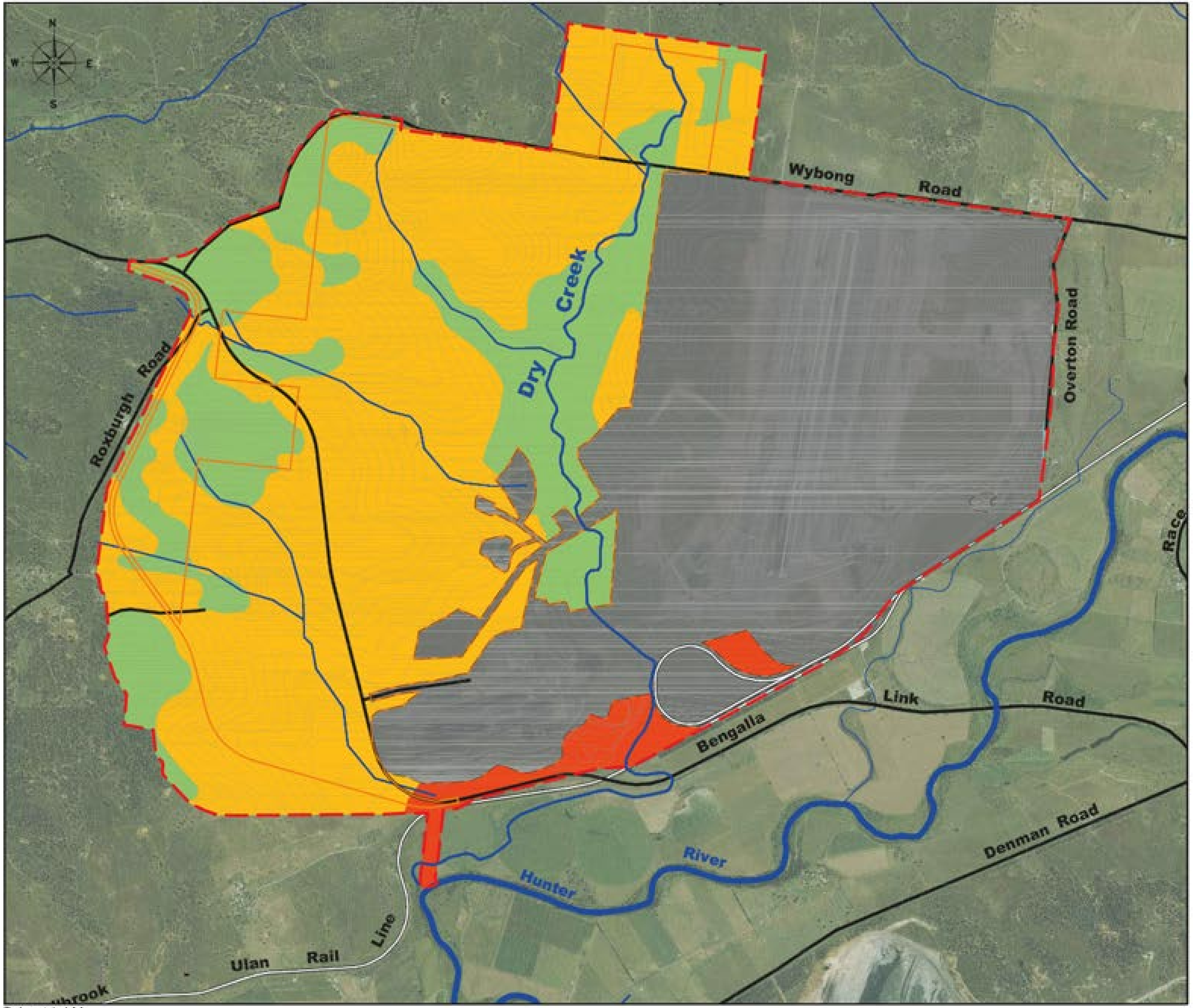

FIGURE 6

Pre-Mining Agricultural Suitability

Project:	Bengalla Continuation: Soil and Land Capability Report
Client:	Hansen Bailey
File:	Fg6_HAN05-001_Pre-Mining Ag Suitability_121206
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LEGEND

- Project Boundary
- Disturbance Boundary
- Approved Bengalla Mine
- Contours
- Class 2
- Class 3
- Class 4
- Mined Land

0 500m 1.0km

Scale 1: 35 000

FIGURE 7

Year 24
Agricultural Suitability

Project:	Bengalla Continuation: Soil and Land Capability Report
Client:	Hansen Bailey
File:	Fg7_HAN05-001_Year 24 Ag Suitability_121206
Projection:	MGA94 Zone 56

Version:	Date:	Author:	Checked:	Approved:
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4.3 Strategic Regional Land Use Policy – Upper Hunter

The Draft Upper Hunter Strategic Regional Land Use Plan (DP&I, 2012) (SRLUP) is a component of the broader Strategic Regional Land Use Policy, which consists of various initiatives to manage land use conflicts in regional areas, in relation to agriculture, coal mining and coal seam gas. The plan defines strategic agricultural land as:

> *"…highly productive land that has both unique natural resource characteristics (such as soil and water resources) as well as socio-economic value (such as high productivity, infrastructure availability and access to markets)."* (DP&I 2012).

The plan defines areas of both Biophysical Strategic Agricultural Land (BSAL) and Critical Industry Clusters, including clusters for the equine and viticulture industries. A description of the interactions between mapped strategic agricultural land and the Project is provided below.

The Project is moving in a general westerly direction away from the Hunter River alluvial floodplain and mapped BSAL.

The important values and criteria that relate to BSAL are outlined in **Table 17**, which also shows where each is addressed in this report. The Gateway Criteria (and where they are addressed in this report) are outlined in **Table 18**.

Table 17 – Strategic Agricultural Land Values and Criteria

Value	Criteria	Where Addressed
Biophysical Strategic Agricultural Land	• Land that falls under soil fertility classes 'high' or 'moderately high' under the Draft Inherent General Fertility of NSW (OEH), and • Land capability classes I, II or III under the Land and Soil Capability Mapping of NSW (OEH), and • Reliable water of suitable quality, characterised by having rainfall of 350mm or more per annum (9 out of 10 years); or properties within 150m of a regulated river, or unregulated rivers where there are flows for at least 95% of the time (i.e. the 95th percentile flow of each month of the year is greater than zero) or 5th order and higher rivers; or groundwater aquifers (excluding miscellaneous alluvial aquifers, also known as small storage aquifers) which have a yield rate greater than 5L/s and total dissolved solids of less than 1,500mg/L. • land that falls under soil fertility classes 'moderate' under the Draft Inherent General Fertility of NSW (OEH), and • land capability classes I or II under the Land and Soil Capability Mapping of NSW (OEH), • AND • reliable water of suitable quality, characterised by having rainfall of 350mm or more per annum (9 out of 10 years); or properties within 150m of a regulated river, or unregulated rivers where there are flows for at least 95% of the time (i.e. the 95th percentile flow of each month of the year is greater than zero) or 5th order and higher rivers; or groundwater aquifers (excluding miscellaneous alluvial aquifers, also known as small storage aquifers) which have a yield rate greater than 5L/s and total dissolved solids of less than 1,500mg/L.	• Section 4.3.1 of this report • Section 4.1 of this report • Agricultural Impact Statement (Scott Barnett & Associates, 2013) • Agricultural Impact Statement (Scott Barnett & Associates, 2013)
Critical Industry Cluster (Equine and Viticulture)	• Industry clusters that meet the following criteria: o There is a concentration of enterprises that provides clear development and marketing advantages and is based on an agricultural product; o The productive industries are interrelated; o It consists of a unique combination of factors such as location, infrastructure, heritage and natural resources; o It is of national and/or international importance;	• Main Volume of EIS

Value	Criteria	Where Addressed
	○ It is an iconic industry that contributes to the region's identity; and ○ It is potentially substantially impacted by coal seam gas or mining proposals. ○	

Source: Draft Upper Hunter Strategic Regional Land Use Plan, (DP&I, 2012)

Table 18 – Gateway Criteria

Value	Gateway Criteria	Where Addressed
Site Verification	• Whether the mapped land does not meet the criteria for biophysical strategic agricultural land and/or the critical industry cluster	• Throughout report
Biophysical Strategic Agricultural Land	• Impacts on the land through surface area disturbance and subsidence; • Impacts on: ○ Soil fertility ○ Rooting depth, or ○ Soil profile materials and thickness. • Increases in land surface microrelief or soil salinity, or significant changes to soil PH, and • Impacts on Highly Productive Groundwater, including the provisions of the Aquifer Interference Policy and the advice on the Minister for Primary Industries (note that the Minister for Primary Industries will be required to take into account the advice of the Commonwealth Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development in providing advice in this stage).	• Section 4.3.1 of this report • Section 4.3.1 of this report • Section 3; 4.3 • Agricultural Impact Statement (Scott Barnett & Associates, 2013)
Critical Industry Cluster (Equine and Viticulture)	• Whether the proposal would lead to significant impacts on the critical industry cluster through:	
	○ Surface area disturbance	Agricultural Impact Statement (Scott Barnett & Associates, 2013)
	○ Subsidence	Not Applicable
	○ Reduced access to agricultural resources	Agricultural Impact Statement (Scott Barnett & Associates, 2013)
	○ Reduced access to support services and infrastructure	Agricultural Impact Statement (Scott Barnett & Associates, 2013)
	○ Reduced access to transport routes	Agricultural Impact Statement (Scott Barnett & Associates, 2013)
	○ Loss of scenic and landscape values	Agricultural Impact Statement (Scott Barnett & Associates, 2013)

4.3.1 Biophysical Strategic Agricultural Land

The Study Area has been assessed against the maps and criteria provided with the SRLUP and ground truthed during the soil and land capability survey, to gain an appreciation of the extent and likely impact of the Project on potential Biophysical Strategic Agricultural Land (BSAL).

The Project is located adjacent to the Hunter River alluvial floodplain which is mapped under the criteria for BSAL (Scott Barnett & Associates, 2013). Approximately 28 ha of BSAL falls within the Project Boundary.

This area of mapped BSAL within the Project Boundary is largely associated with the Approved Bengalla Mine or is currently used for grazing associated with dairying. A small area of approximately 1 ha of BSAL mapped land is located within the Disturbance Boundary and is associated with the realignment of Bengalla Road.

4.3.2 Critical Industry Cluster (Equine & Viticulture)

The Project Boundary, based on Map 6 of the SRLUP, also contains a small area of land which occurs within the Equine Critical Industry Cluster as defined as having a slope of less than 18% and being within the 2km of the Muswellbrook Denman Road (DP&I, 2012).

There is no land within the Disturbance Boundary which occurs within into the Equine Critical Industry Cluster.

The Appendix of the SRLUP provides a definition for the Viticulture Critical Industry Cluster as presented on Map 6 of the SRLUP (DP&I, 2012). This definition and how it has been used to verify the Viticulture Critical Industry Cluster in detailed in the Agricultural Impact Assessment (Scott Barnett & Associates, 2013).

Table 19 – Viticulture Critical Industry Cluster

Definition	Where Addressed
The Viticulture Critical Industry Cluster is spatially defined as the following land (excluding State Forests and National Park):	
• The Broke-Fordwich and Pokolbin Geographical Indicators (GI) sub-regions;	Not Applicable
• The parish of Belford and the suburbs of Lovedale, Nulkaba, Mount View and Rothbury;	Not Applicable
• Properties proximate to the Hunter Wine Country Private Irrigation District pipeline to the east of Lovedale Road as well as those properties bounded by Mears Lane, Majors Lane and the Suburb of Lovedale; and	Not Applicable
• Land (excluding National Park and State Forests) within 20 km of Denman; and that falls under soil fertility classes ‘high’, moderately high, moderate or moderately low under the Draft Inherent General Fertility of NSW (OEH, 2012a), and land capability classes I, II, III, IV or V under the Land and Soil Capability Mapping of NSW (OEH, 2012b) and is within 2 km of a mapped alluvial water source.	Not Applicable

Table 20 - Viticulture Critical Industry Cluster Verification

Definition	Within Project Boundary
• Land (excluding National Park and State Forests) within 20 km of Denman; and	Yes - Agricultural Impact Statement (Scott Barnett & Associates, 2013)
• Falls under soil fertility classes 'high', moderately high, moderate or moderately low under the Draft Inherent General Fertility of NSW (OEH, 2012a); and	Yes – See Section 4.3.3
• Land capability classes I, II, III, IV or V under the Land and Soil Capability Mapping of NSW (OEH, 2012b); and	Yes – See Section 4.2.2
• Is within 2 km of a mapped alluvial water source.	Yes – Agricultural Impact Statement (Scott Barnett & Associates, 2013)

As described above the Project Boundary lies within the Equine Critical Industry Cluster, the Viticulture Critical Industry Cluster and mapped BSAL, an assessment has been conducted against the gateway criteria for BSAL and the Equine and Viticulture Critical Industry Clusters as provided in the SRLUP.

No existing vineyards occur within the Project Boundary or Disturbance Boundary. The nearest operating vineyards are located approximately 6 km south of the south east corner of the Project Boundary and 14.5 km west of the western Project Boundary (Scott Barnett & Associates, 2013).

There is limited area of 494 ha within the Project Boundary mapped as Viticulture Critical Industry. The verified Viticulture Critical Industry Cluster within the Disturbance Boundary is 369 ha. The Agricultural Impact Assessment has determined that the Project will not impact significantly on Viticulture Critical Industry Cluster nor any component of the viticulture industry in the Hunter Valley (Scott Barnett & Associates, 2013).

In the 1,370 ha of land assessed in this report, only 56 ha is mapped as Class II land, with all the remaining land mapped as Class IV or higher. Some land in the south of the Project Boundary is Class II land, given its location relative to Hunter River alluvials and other soils in the area being mapped as Class II land in similar landscape locations.

However, only 1 ha of Class II land is located within the Disturbance Boundary, the remaining Class II land will remain undisturbed and continue to be used for agricultural purposes.

Despite the existence of this Class II land within the Project Boundary, the operations of the Project are likely to have little to no impact on this land which is currently being used for agricultural production, which will continue. Future mining disturbance will not affect this area and as such there is unlikely to be surface area disturbance, soil fertility or rooting depth effects, or other physical / chemical effects on the soil.

4.3.3 Soils and the SRLUP

The assessment of soil fertility results conducted on nine of the samples for the soil survey indicates that all soils have low to moderate fertility under the Draft Inherent General Fertility of NSW OEH, 2012a).

Table 21 - Inherent and Interpreted Soil Fertility

Soil Type	OEH Draft Inherent Fertility	Interpreted Fertility	Soil Test Sample ID (see Appendix 3)
Red Chromosol	Moderate	Moderately Low	Sample P9-1
Brown Chromosol	Moderate	Moderately Low	Sample P2-1, P8-1, P-12-1
Brown Vertosol	Moderate	Moderate	Sample P3-1
Red Sodosol	Moderately Low	Moderately Low	Sample P13-1
Brown Kurosol	Moderately Low	Moderately Low	Sample P4-1
Deep Brown Sodosol	Moderately Low	Moderately Low	Sample P5-1
Brown Sodosol	Moderately Low	Moderately Low	Not Tested
Rudosol	Low	Low	Not Tested

With the exception of the Brown Vertosol, all soil types are extremely low to very low in nitrogen and phosphorus. This led to the interpreted fertility in **Table 21** being slightly different to the OEH Inherent Fertility. **Appendix 3** contains full details of the soil fertility test data run on nine samples (sample depth of 0-10 cm).

Salinity is not an issue for topsoil management. Only the Red Sodosol soil type displays salinity (at depth in the B horizon), however this material is not recommended for stripping due to a range of other physical and chemical attributes.

4.3.4 Acid Sulphate Soils

Acid sulfate soils are naturally occurring soils, sediments or organic substrates (e.g. peat) formed under waterlogged conditions that contain iron sulfide minerals (predominantly as the mineral pyrite) or their oxidation products. When exposed to the air following the lowering of the water table (through, for example. dewatering, groundwater abstraction, drainage or excavation) the sulfides in these soils readily oxidise, releasing sulfuric acid and iron into the soil and groundwater. This acid can, in turn, release aluminium, nutrients and heavy metals (particularly arsenic) held within the soil matrix (Ahern et al., 2004).

Acid sulfate soils, 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. Bengalla Mine is located within Upper Hunter Valley region (approximately 130 km from the coast) and has an elevation range of 40–220 m above sea level. It is therefore unlikely that acid sulfate soils (to a depth of 1.5 m) are present at Bengalla.

Given that any identified BSAL is likely to remain under agricultural production (grazing and cropping) and no land currently within the Project Boundary is utilised for any equine industry related uses, the continuation of Bengalla Mine should not trigger any issues with the Equine Critical Industry Cluster located in the area.

5.0 IMPACT ASSESSMENT AND MITIGATION MEASURES

Continuation of mining will disturb land to the west of the current Bengalla Mine. This land has been widely cleared and is primarily used for cattle grazing, with some small areas of remnant (albeit modified) native vegetation, primarily Grassy Box woodland. Each component of the Project has a construction and operational disturbance footprint with some parts of the disturbance footprint being progressively rehabilitated immediately after construction with the remainder being rehabilitated at the end of operational use.

This report provides information on the following key areas related to the management of topsoil resources for the area within the Disturbance Boundary:

- Dry Creek Reinstatement;
- Soil erosion hazard assessment which assesses potential soil erosion during land disturbance activities;
- Soil resource assessment which assesses soil quality for salvage and re-use for rehabilitation works;
- Topsoil management recommendations of stripped and salvaged soil resources; and
- Erosion and sediment control recommendations to be implemented on the site.

Soil to be disturbed has been assessed to determine its capability for stripping and re-use on rehabilitation sites. This assessment is an integral process for successful rehabilitation within the Project. This report provides information on the following key areas related to the management of the topsoil resources at Bengalla:

- Topsoil stripping assessment which provides a topsoil stripping plan indicating recommended stripping depths for topsoil salvage and re-use as topdressing media in rehabilitation; and
- Topsoil management for soil that is stripped, stored and re-spread as a topdressing material for rehabilitation.

5.1 Dry Creek Reinstatement

Dry Creek is an ephemeral creek that generally only flows following intense rainfall periods due to its relatively small catchment area. Dry Creek occasionally holds small pools of water for a few days following rainfall events. As mining progresses to the west, it is anticipated that Dry Creek will be intercepted at Year 2 of operations. As such, the construction of a water storage dam and interim diversion of Dry Creek will be required to divert clean water around mining operations through the use of a pipe network. Prior to the completion of mining, a permanent re-alignment of Dry Creek will be constructed to ensure successful stabilisation.

The predominant soil type identified in Dry Creek is a deep Brown Sodosol. It should be noted that in the vicinity of the sample pit (the southern portion of the Project Boundary), it appears as though the original soil profile has been buried by eroded material up to 50 cm in depth. This material is a clay loam with minimal profile development. It is likely this is colluvial material derived from adjacent low hills and from higher up in the Dry Creek catchment and its minor tributaries.

5.2 Soil Erosion Hazard

5.2.1 Methodology

Soil erosion can be a significant hazard on and downstream of construction sites where vegetative cover is disturbed and the soil is subject to the erosive agents of water and wind. Soil erosion and sedimentation occurs when soil particles detach and are transported offsite. This detachment is affected by a range of site specific factors. The main factors to consider for the assessment of the Disturbance Boundary are soil erodibility and steepness of terrain.

Soil erodibility is quantified using the soil erodibility factor (hereafter referred to as the K factor, derived from the Universal Soil Loss Equation). Soil texture is the principle component affecting K, however, other factors such as soil structure, soil organic matter content as well as soil profile permeability also contribute to the soil's inherent soil erodibility. Soils that have the highest erodibility are those which have weak bonds between soil particles and contain an abundance of easily transportable soil particles. Soil erodibility has been determined on the A1 topsoil texture class, with interpretation based on Hazelton & Murphy (2007).

5.2.2 Soil Erosion Hazard Assessment

The Project Boundary covers land that has a moderate K-factor and soil erosion hazard ratings. This hazard is predominately present due to the sodicity and fine texture (high clay content) of many soils in the B horizon. **Table 23** summarises the erosion hazard ratings for the Project Boundary.

Table 23 – Soil Erosion Hazard

Soil Type	Project Boundary		Dominant Slope	K Factor[1]	Erosion Hazard
	Ha	%	Description	Rating	Rating
Brown Chromosol	571	41.8	Very gently to gently inclined	0.04	Moderate
Red Chromosol	179	13.0	Gently to moderately inclined	0.04	Moderate
Brown Vertosol	161	11.7	Level to very gently inclined	0.025	Moderate
Red Sodosol	69	5.0	Very gently to gently inclined	0.03	Moderate
Brown Kurosol	20	1.4	Level to very gently inclined	0.04	Moderate
Deep Brown Sodosol	60	4.4	Level to very gently inclined	0.03	Moderate
Brown Sodosol	89	6.5	Very gently to gently inclined	0.03	Moderate
Rudosol	221	16.1	Moderately to steeply inclined; crests	N/A	High
Total	1,370	100			

[1] K – factor determined on A1 topsoil texture class, with interpretation based on Hazelton & Murphy (2007)

5.3 Soil Stripping Resource Assessment

5.3.1 Methodology

Determination of suitable soil to conserve for later use in mine rehabilitation has been conducted in accordance with Elliott and Reynolds (2007). This procedure involves assessing soils based on a range of physical and chemical parameters. These are summarised in **Table 24** and further discussed in the text below.

Table 24 – Topsoil Stripping Suitability Criteria

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

Structural grade is important in terms of the soil's ability to permeate and hold water as well as provide for adequate aeration. These characteristics 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. Better-structured soils have higher infiltration rates and better aeration characteristics. Structureless soils, without pores, are considered unsuitable as topdressing materials.

Soils with structural grades of 'weak' or 'moderate' are considered of low capability for salvage and revegetation works as soil peds are likely to be destroyed and structure can 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. Dispersive (or 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 permeabilities; 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 generally unsuitable for revegetation purposes.

Gravel and sand content, pH and salinity were 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 24** were determined during the field assessment.

5.3.2 Soil Stripping Assessment

The assessment has shown that the capability of the soil subject to disturbance has a recommended stripping depth stripping depth of 0 – 0.6 m, varying between soil types. The recommended depths correspond to salvage depths via the stripping process and re-used in progressive and post construction rehabilitation works.

All subsoils were undesirable for use because of severe physical and/or chemical limitations. The Brown Kurosol topsoils are acidic and would benefit from amelioration with lime to increase soil pH. **Table 25** details the maximum recommended stripping depths for each soil type and their major constraints. **Figure 8** provides the spatial distribution of the recommended stripping depths.

Table 25 – Topsoil Stripping Depths

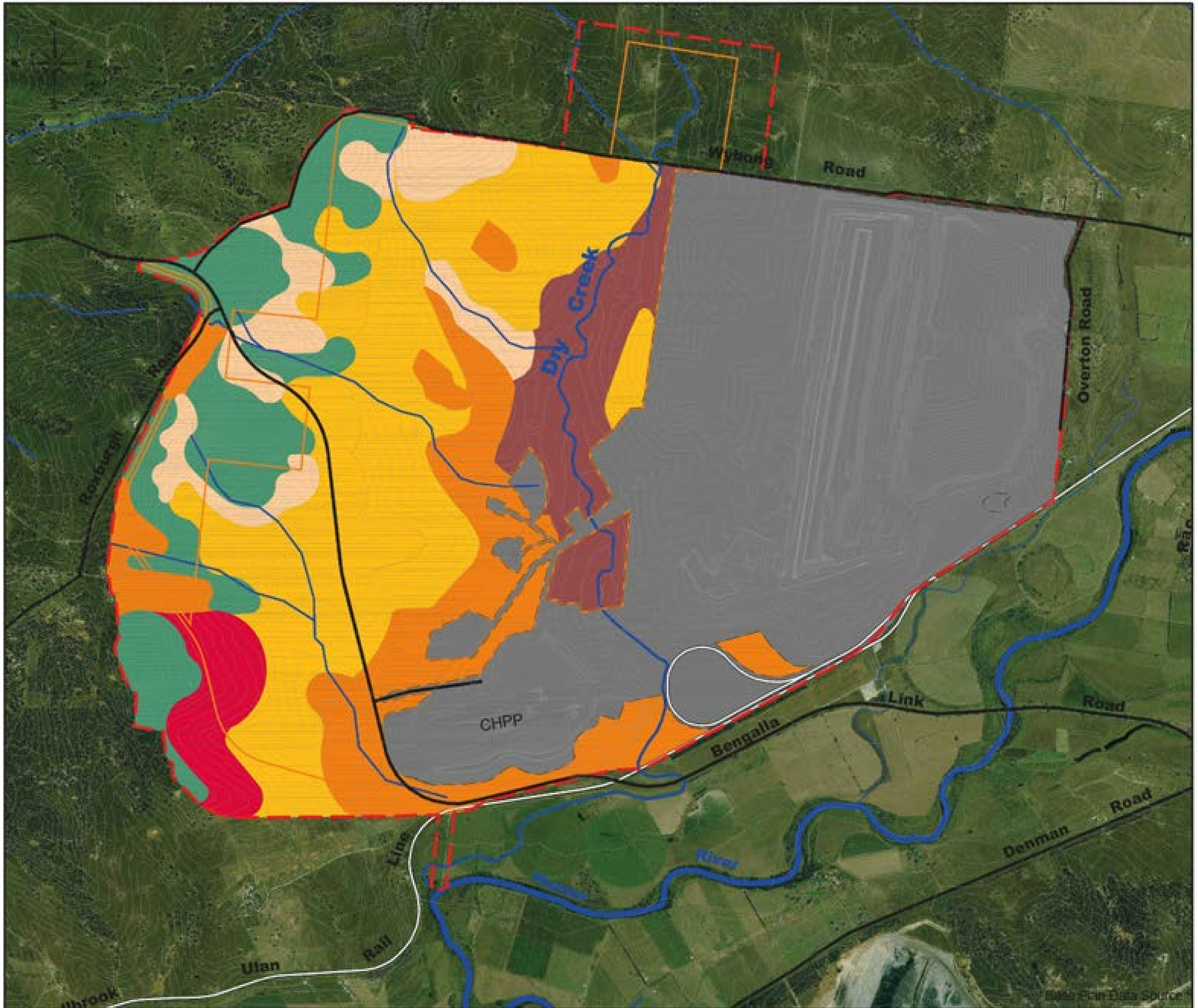
Soil Type		Recommended Stripping Depth	Main Limitation(s)	Capability
#	ASC Name	m	Description	
1	Brown Chromosol	0 – 0.10	Slope, texture	Highly Suitable
2	Red Chromosol	0 – 0.15	Slope, texture	Highly Suitable
3	Brown Vertosol	0 – 0.20	Texture; chemical properties of subsoil	Highly Suitable
4	Red Sodosol	0 – 0.20	Texture; sodicity in B horizon	Highly Suitable
5	Brown Kurosol	0 – 0.10	Texture, chemical properties of subsoil	Suitable
6	Brown Sodosol (Deep)	0 – 0.60	B horizon sodic, alkaline and highly dispersive	Highly Suitable
6(V)	Brown Sodosol (Moderately Deep)	0 – 0.60	B horizon sodic, alkaline and highly dispersive	Highly Suitable
7	Rudosol	0	Slope; variable depth to bedrock; texture	Unsuitable

Laboratory soil analytical results were used in conjunction with the field assessment (refer **Appendix 2**) to determine the depth of soil material suitable for recovery and re-use as a topdressing material in rehabilitation. Structural and textural properties of subsoils, dispersion potential, sodicity and acidity/alkalinity are the most common and significant limiting factors in determining depth of soil capability for re-use.

Allowing for a 10% handling loss, approximately 1,549,800 m^3 of suitable topdressing is available within the entire Disturbance Boundary. The Brown Sodosol and Red & Brown Chromosol soils will generate the largest topsoil resource. **Table 26** below provides the recommended stripping depth for each soil unit within the Disturbance Boundary together with the land area occurrence for each soil type and the calculated volume of available soil for re-use in rehabilitation activities.

Table 26 – Recommended Stripping Depths

Soil Type	Topsoil		
	Recommended Stripping Depth (m)	Stripping Area (ha)	Soil Volume m^3
1	0.10	42	42,000
2	0.15	356	534,000
3	0.20	81	162,000
4	0.20	68	136,000
5	0.10	20	20,000
6, 6(V)	0.60	138	828,000
7	0	0	0
		Total Volume	1,722,000
		Total Volume with 10% handling loss allowance	1,549,800



LEGEND

- Project Boundary
- Disturbance Boundary
- Approved Bengall Mine
- 0.1m Soil Stripping Depth
- 0.15m Soil Stripping Depth
- 0.2m Soil Stripping Depth
- 0.6 Soil Stripping Depth
- Not Suitable for Stripping
- Contours

0 500m 1.0km
Scale 1: 35 000

FIGURE 8

Topsoil Stripping Depths

Project: Bengalla Continuation: Soil and Land Capability Report

Client: Hansen Bailey

File: Fg8_HAN05-001_Topsoil Stripping Depths_130711

Projection: MGA94 Zone 56

Version:	Date:	Author:	Checked:	Approved:
1	30/11/12	KC	RW	AC
2	11/07/13	LH	AK	AC

GSS ENVIRONMENTAL
Environmental, Land and Project Management Consultants

To be printed A4
V:\HAN05-001\Figures\Final\CAD\Fg8_HAN05-001_Topsoil Stripping Depths_130711.dwg

5.4 Topdressing Management

Topsoil Stripping and Handling

The following topsoil handling techniques are recommended to prevent excessive soil deterioration.

- Strip material to the depths stated in Section 5.3, subject to further investigation as required.
- Topsoil should be maintained in a slightly moist condition during stripping. Material should not be stripped in either an excessively dry or wet condition.
- Place stripped material directly onto reshaped overburden and spread immediately (if mining sequences, equipment scheduling and weather conditions permit) to avoid the requirement for stockpiling.
- Grading or pushing 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, 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 an as coarsely textured 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 sandier 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 should be spread to a minimum depth of 0.1 m, more where the resource is available.

5.5 Topsoil Balance

An approximate topsoil balance has been determined based on the Year 24 landform. Using this as a basis (and excluding the pit void area), approximately 38 ha will be classed as a “Dry Creek re-alignment area”; 118 ha as Class IV land (lower slopes) and 117 ha as Class V/VI land (moderate slopes).

It is suggested that the Dry Creek realignment re-instate 0.4 m of topsoil, for which there is adequate resource available from the recommended stripping regime. It is also suggested, where possible, to replace approximately 0.4 m of subsoil in the Dry Creek realignment area in addition to the topsoil. For the low slope Class IV land, it is suggested a minimum of 0.2 m of topsoil over 0.4 m of subsoil be re-instated. Again, there are adequate topsoil resources available to fulfil this objective.

Finally, for the Class V/VI land, a minimum or 0.1 m but preferably 0.2 m of topsoil should be re-instated. Where possible, up to 0.2 m of subsoil should also be re-instated. If subsoil is re-instated, 0.1 m of topsoil will be adequate. At this stage of final landform planning, there is adequate topsoil resource available to re-instate 0.2 m of topsoil on the Class V/VI areas. Volumes needed and available for topsoil use are outlined in **Table 27**.

Table 27 – Year 24 Landform Topsoil Balance

Land Class	Ha	Topsoil Depth (m)	Required Volume (m^3)	Soil Type For Use	Available Volume (m^3)
Class IV	118	0.2	236,000	1, 2	576,000
Class V + VI	117	0.2	234,000	1, 2	576,000
Dry Creek Re-alignment	38	0.4	152,000	3, 6, 6(V)	990,000

5.6 Erosion and Sediment Control Recommendations

The land within the Disturbance Boundary has a moderate erosion hazard rating and as such appropriate erosion and sediment controls will be implemented to ensure that adverse effects of construction and operations activities are minimized. A detailed *Erosion and Sediment Control Plan* will be developed prior to the commencement of construction works. The principle objectives of the *Erosion and Sediment Control Plan* are outlined below.

5.6.1 Minimising Disturbance

Land disturbance will be minimised by clearing the smallest practical area of land ahead of construction, as well as ensuring the land is disturbed for the shortest possible and practical time. This will be achieved by:

- Limiting the cleared width to that required to accommodate the proposed operations;
- Staging the clearing activities where ever possible so that only the areas which are being actively cleared, therefore, limiting the time the areas are exposed; and
- Rehabilitating topsoil stockpiles as soon as practical.

General vegetation clearing and soil stripping should not be undertaken until earthwork and construction operations are ready to commence. All proposed erosion and sediment control measures will be implemented in advance of, or in conjunction with, clearing activities.

Prior to clearing and soil stripping commencing, the limits of these works should be clearly delineated by pegs placed at intervals on each side of the disturbed area by a suitably qualified supervisor. All operations will be planned to ensure that there is no damage to any trees and pasture areas outside the limits to be cleared.

Rehabilitation strategies and concepts proposed below have been formulated according to results of industry-wide research and experience.

5.6.2 Post Disturbance Regrading

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.

5.6.3 Control Options

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 will cause significant erosion. As the slope angle of the land increases, the banks or furrows must be spaced closer together, although on steeper slopes a point is reached where these structures are so close together as to be no longer effective.

5.7 Summary of Mitigation

Bengalla mine has in place comprehensive rehabilitation commitments and these are outlined in the existing Rehabilitation Management Plan (BMC, 2013a) and Landscape Management Plan (BMC, 2013b). Key to these documents are management commitments for soil stripping and management (further detailed within this document), revegetation, progressive rehabilitation, erosion and sediment control, overburden management and reshaping, final void management, monitoring and maintenance and completion criteria.

It is suggested that the Dry Creek realignment re-instate 0.4 m of topsoil, and approximately 0.4 m of subsoil in the Dry Creek realignment area in addition to the topsoil. For the low slope Class IV land, it is suggested a minimum of 0.2 m of topsoil over 0.4 m of subsoil be re-instated, while for the Class V/VI land, a minimum or 0.1 m but preferably 0.2 m of topsoil should be re-instated. Where possible, up to 0.2 m of subsoil should also be re-instated.

As part of the EIS process for the Bengalla Continuation Project, a Rehabilitation Management Strategy is currently being developed which will address the DGRs regarding rehabilitation and set long term goals for the rehabilitation and relinquishment of the site. The rehabilitation and post-mining management at Bengalla will continue to build upon commitments made in existing documents and will also build upon successful techniques developed and applied at the site.

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Glossary of Terms and Definitions

APPENDIX 1

Glossary of Terms and Definitions

Term	Definition
Acidity	A property expressed by the pH value when this is below 7.0 in a soil/water suspension.
Aggregate	A unit of soil structure usually formed by natural processes in contrast with natural processes, and generally <10 mm in diameter.
Alkalinity	A property expressed by the pH value when this exceeds 7.0 in a soil/water suspension.
Availability	General expression referring to the ease with which plants can absorb a particular nutrient form the soil.
Available Water Capacity	The amount of water in the soil, generally available to plants, that can be held between field capacity and the moisture content at which plant growth ceases. Sometimes also known as the *Plant Available Water Capacity*.
Bulk Density	The mass of dry soil per unit bulk volume; a measure of soil porosity, with low values meaning a highly porous soil and vice versa. It does not, however, give any indication of the number, sizes, shapes, distribution or continuity of soil pores.
Cation	An element with a positive charge.
Cation Exchange	Process whereby cations interchange between the soil solution and the clay or organic matter complexes in the soil.
Cation Exchange Capacity	The total amount of exchangeable cations that a soil can adsorb, expressed in centimoles of positive charge per kilogram of soil
Clay	A soil separate consisting of particles <0.002 mm in equivalent diameter.
Consistence Force	Consistence force refers to the strength of cohesion and adhesion in the soil.
Course Fragments	Particles greater than 2mm
Electrical Conductivity	A measure of the conduction of electricity through water or a water extract of soil. It can be used to determine the soluble salts in the extract and hence soil salinity. The unit of electrical conductivity is the Siemens and soil salinity is normally expressed as decisiemens per meter at 25 ℃ (dS/m).
Emerson Aggregate Test	A classification of soil aggregates based on their coherence in water.
Exchangeable Cation	A positively charged ion held on or near the surface of a solid particle by a negative surface charge of a colloid and which may be replaced by other positively charged ions in the soil solution.

Term	Definition
Exchangeable Sodium Percentage	Exchangeable sodium fraction expressed as a percentage.
Field Texture Grade	Field texture is a measure of the behaviour of a small handful of soil when moistened and kneaded into a ball and then passes out between thumb and forefinger. The recommended field texture grades are characterised by the behaviour of the moist bolus.
Field Colour	The colour of soil material is determined by comparison with a standard Munsell colour chart.
Gravel	A mixture of coarse mineral particles larger than 2 mm, but less than 75 mm in diameter.
Hydraulic Conductivity	The flow of water through soil per unit of energy gradient. For practical purposes, it may be taken as the steady state of percolation rate of a soil when infiltration and internal drainage are equal, measured as depth per unit time.
Infiltration	The downward entry of water into the soil through the soil surface.
Leaching	The removal of materials in solution from the soil.
Mottles	Spots, blotches or streaks of subdominant colours different from the matrix colour and also different from the colour of the ped surface.
Organic Carbon	Gives an estimate of the amount of organic matter in a soil as a percentage by weight.
Organic Matter	Is the sum of all natural and thermally altered biologically derived organic materials found in the soil. These materials, in various states of decay, include leaf litter, plant roots, branches, living, and dead organism, and excreta.
pH (soil)	A measure of the acidity or alkalinity of a soil. It represents the negative logarithm of the hydrogen ion concentration in a specified soil/water suspension on a scale of 0 to 14.
Parent Material	The unconsolidated and more or less chemically weathered mineral or organic matter form which the solumn of soils is developed by pedogenic processes.
Particle Size Analysis	The laboratory determination of the amounts of the different separates in a soil sample such as clay, silt, fine sand, coarse sand and gravel. The amounts are normally expresses as percentages by weight of dry soil.
Ped	A unit of soil structure such as an aggregate, crumb, prism, block or granule, formed by natural processes (in contrast with a clod which is artificially formed).
Permeability (soil)	The ease with which gases, liquids or plant roots penetrate or pass through a bulk mass of soil or layer of soil.
Physical Properties (soil)	Those characteristics, processes or reactions of a soil which is caused by physical forces and which can be described by, or expressed in, physical terms or equations. These can be difficult to separate from chemical properties; hence terms, physical-chemical or physico-chemical.

Term	Definition
Pores	The part of the bulk volume of the soil not occupied by soil particles.
Sampling Site	A georeferenced point within a monitoring unit where one or more samples are taken for analysis.
Sand	A soil particle that in the USDA soil texture system is of size 0.05 mm to 2.0 mm in diameter.
Silt	A soil particle that in the USDA soil texture system is of size 0.002 mm to 0.05 mm in diameter.
Sodicity	A property expressed by the amount of exchangeable sodium present relative to the cation capacity of a soil horizon.
Soil Classification	The systematic arrangement of soils into groups or categories on the basis of similarities and differences in their characteristics.
Soil Consistence	The resistance of soil material to deformation or rupture.
Soil Erodibility	The susceptibility of a soil to the detachment and transportation of soil particles by erosive agents.
Soil Horizon	A layer of soil or soil material approximately parallel to the land surface and differing from adjacent genetically related layers in physical, chemical, biological properties such as colour structure, texture, consistency, kinds and number of organisms present, degrees or acidity or alkalinity.
Soil Profile	A vertical section of the soil through all its horizons.
Soil Salinity	The amount of soluble salts in a soil. The convention measure of soil salinity is the electrical conductivity of a saturation extract.
Soil Structure	Refers to the way soil particles are arranged and bound together to form aggregates or peds.
Soil Texture	The relative proportions of the various soil separates in as soil as described by the classes of soil texture. It is the general coarseness or fineness of soil material as it affects the behaviour of a moist ball (bolus) when pressed between the thumb and forefinger.
Solum	The upper part of a soil profile above the parent material, in which current processes of soil formation are active. The solum consists of either the A and B horizons or the A horizon alone when no B is present.
Structure Pedality Grade	Is the degree of development and distinction of ped.
Structure Ped and Size	Refers to the distinctness, size and shape of peds.
Subsoil	Refers to B soil horizon
Topsoil	Refers to A1 and A2 soil horizons.

Soil Laboratory Results

APPENDIX 2

NSW GOVERNMENT | Soil Conservation Service

SOIL TEST REPORT

Scone Research Centre

REPORT NO:	SCO12/040R3
REPORT TO:	Adele Calandra GSS Environmental PO Box 907 Hamilton NSW 2303
REPORT ON:	Thirty three soil samples Ref: HAN05-001
PRELIMINARY RESULTS ISSUED:	3 March 2012
REPORT STATUS:	Final
DATE REPORTED:	3 March 2012
METHODS:	Information on test procedures can be obtained from Scone Research Centre

TESTING CARRIED OUT ON SAMPLE AS RECEIVED
THIS DOCUMENT MAY NOT BE REPRODUCED EXCEPT IN FULL

SR Young

SR Young
(Laboratory Manager)

Scone Research Centre, PO Box 283 Scone 2337, 709 Gundy Road Scone 2337
Ph: 02 6545 1666, Fax: 02 6545 2520

SOIL CONSERVATION SERVICE
Scone Research Service Centre

Report No: SCO12/040R3
Client Reference: Adele Calandra
GSS Environmental
PO Box 907
Hamilton NSW 2303

Lab No	Method	P7B/2 Particle Size Analysis (%)					P9B/2	Colour	
	Sample Id	clay	silt	f sand	c sand	gravel	EAT	Dry	Moist
1	P1-1	nt	nt	nt	nt	nt	nt	7.5YR5/3	7.5YR3/3
2	P1-2	nt	nt	nt	nt	nt	nt	5YR6/4	5YR4/4
3	P2-1	38	25	28	8	1	3(1)	7.5YR5/4	7.5YR3/4
4	P2-2	59	22	16	3	0	3(3)	7.5YR5/4	7.5YR3/4
5	P2-3	51	27	18	4	<1	2(1)	7.5YR5/4	7.5YR3/4
6	P3-1	31	27	28	14	<1	8	7.5YR5/3	7.5YR3/2
7	P3-2	41	25	26	8	<1	8	7.5YR4/2	7.5YR3/2
8	P3-3	55	32	7	6	<1	4	10YR6/4	10YR4/6
9	P4-1	17	15	35	33	0	8	10YR5/4	7.5YR3/3
10	P4-2	16	12	36	36	<1	8	10YR6/4	7.5YR4/6
11	P4-3	24	10	34	31	1	2(1)	7.5YR7/4	7.5YR4/6
12	P4-4	35	3	28	33	1	2(1)	7.5YR6/6	7.5YR5/6

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	Sample Id	clay	silt	f sand	c sand	gravel	EAT	Dry	Moist
13	P5-1	32	13	47	8	0	8	7.5YR5/4	7.5YR3/4
14	P5-2	32	15	45	8	0	3(1)	7.5YR5/4	7.5YR4/3
15	P5-3	29	12	50	9	0	3(2)	7.5YR4/6	7.5YR3/4
16	P5-4	37	9	41	13	0	2(3)	7.5YR5/4	7.5YR4/4
17	P8-1	29	26	40	5	0	8	7.5YR5/4	7.5YR2.5/2
18	P8-2	64	18	16	2	<1	3(1)	5YR5/4	5YR3/4
19	P8-3	66	21	10	3	<1	4	5YR5/6	5YR4/6
20	P9-1	28	34	34	4	<1	3(1)	7.5YR5/4	7.5YR3/4
21	P9-2	61	23	15	1	0	3(1)	5YR5/4	5YR4/6
22	P9-3	58	25	16	1	<1	4	7.5YR5/4	7.5YR4/6
23	P10-1	43	27	24	5	1	8	7.5YR4/4	7.5YR3/4
24	P10-2	63	19	14	3	1	3(1)	5YR4/4	5YR3/4
25	P10-3	59	19	17	5	0	3(1)	5YR4/4	5YR3/4
26	P10-4	55	32	8	4	1	4	10YR6/4	10YR5/6

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Lab No	Method	P7B/2 Particle Size Analysis (%)					P9B/2	Colour	
	Sample Id	clay	silt	f sand	c sand	gravel	EAT	Dry	Moist
27	P12-1	27	17	33	23	0	8	7.5YR4/3	7.5YR2.5/3
28	P12-2	58	11	19	12	0	5	7.5YR4/6	7.5YR3/4
29	P12-3	61	11	23	5	0	4	5YR5/4	5YR3/4
30	P12-4	52	10	18	11	9	4	5YR5/4	5YR4/6
31	P13-1	31	14	35	19	1	2(1)	7.5YR4/3	7.5YR2.5/3
32	P13-2	57	9	21	12	1	2(2)	2.5YR4/4	2.5YR3/6
33	P13-3	68	8	14	9	1	2(2)	5YR5/6	5YR4/6

S R Young

SOIL CONSERVATION SERVICE
Scone Research Service Centre

Report No: SCO12/040R3
Client Reference: Adele Calandra
GSS Environmental
PO Box 907
Hamilton NSW 2303

Lab No	Method	C1A/4	C2A/3	C2B/3	C5A/3 CEC & exchangeable cations (me/100g)						C6A/2
	Sample Id	EC (dS/m)	pH	pH ($CaCl_2$)	CEC	Na	K	Ca	Mg	Al	OC (%)
1	P1-1	nt	nt	nt	nt	nt	nt	nt	nt	nt	3.03
2	P1-2	nt	nt	nt	nt	nt	nt	nt	nt	nt	0.72
3	P2-1	0.20	7.0	6.6	25.4	1.0	1.7	11.5	9.8	nt	3.14
4	P2-2	0.02	7.1	5.9	26.9	0.7	1.5	9.0	12.7	nt	1.24
5	P2-3	0.34	8.9	8.0	31.7	3.6	0.3	12.9	16.1	nt	nt
6	P3-1	0.14	6.8	6.3	32.0	0.5	2.6	19.9	7.4	nt	6.34
7	P3-2	0.04	7.0	6.1	33.2	0.5	1.6	20.0	8.1	nt	4.88
8	P3-3	0.09	8.9	7.9	28.1	0.5	0.9	21.0	7.9	nt	nt
9	P4-1	0.08	6.4	5.9	7.3	0.4	0.6	4.0	1.7	nt	1.71
10	P4-2	0.02	6.4	5.5	4.2	0.2	0.4	1.7	1.1	0.2	0.40
11	P4-3	0.02	6.7	5.7	6.1	0.5	0.3	1.6	3.3	0.2	nt
12	P4-4	0.09	6.0	4.9	12.1	1.8	0.2	2.0	5.6	0.2	nt

SOIL CONSERVATION SERVICE
Scone Research Service Centre

Report No: SCO12/040R3
Client Reference: Adele Calandra
GSS Environmental
PO Box 907
Hamilton NSW 2303

Lab No	Method	C1A/4	C2A/3	C2B/3	C5A/3 CEC & exchangeable cations (me/100g)						C6A/2
	Sample Id	EC (dS/m)	pH	pH ($CaCl_2$)	CEC	Na	K	Ca	Mg	Al	OC (%)
13	P5-1	0.06	7.2	6.4	21.0	0.4	1.1	10.9	5.9	nt	1.71
14	P5-2	0.03	7.3	6.3	20.3	0.5	1.2	10.6	5.7	nt	1.14
15	P5-3	0.02	8.1	6.6	18.4	0.7	0.5	9.4	6.4	nt	nt
16	P5-4	0.16	9.1	7.8	22.6	3.4	0.3	8.8	8.0	nt	nt
17	P8-1	0.02	6.3	5.3	15.7	0.5	1.0	9.5	2.9	<0.1	nt
18	P8-2	0.01	7.0	5.7	22.8	0.7	0.7	13.3	6.1	<0.1	nt
19	P8-3	0.12	8.6	7.6	35.8	0.8	0.5	26.3	8.4	nt	nt
20	P9-1	0.07	6.8	6.3	16.3	0.7	0.7	8.6	3.8	<0.1	nt
21	P9-2	0.04	7.4	6.4	27.8	1.1	0.6	12.4	8.8	nt	nt
22	P9-3	0.18	8.5	7.6	32.6	1.5	0.4	20.0	10.1	nt	nt
23	P10-1	0.05	7.2	6.5	26.4	0.8	1.3	13.3	7.0	<0.1	nt
24	P10-2	0.15	8.2	7.4	37.0	1.8	1.0	18.2	12.6	nt	nt
25	P10-3	0.17	8.7	7.7	37.3	2.2	0.7	20.4	14.9	nt	nt
26	P10-4	0.71	9.2	8.3	37.9	4.1	0.9	20.1	15.6	nt	nt

S R Young

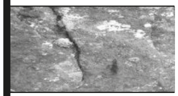
SOIL CONSERVATION SERVICE
Scone Research Service Centre

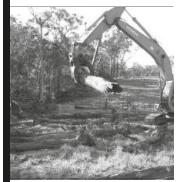
Report No: SCO12/040R3
Client Reference: Adele Calandra
GSS Environmental
PO Box 907
Hamilton NSW 2303

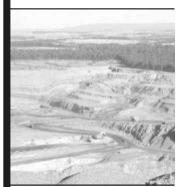
Lab No	Method	C1A/4	C2A/3	C2B/3	C5A/3 CEC & exchangeable cations (me/100g)						C6A/2
	Sample Id	EC (dS/m)	pH	pH ($CaCl_2$)	CEC	Na	K	Ca	Mg	Al	OC (%)
27	P12-1	0.18	6.9	6.7	20.2	0.2	1.0	12.6	3.8	<0.1	nt
28	P12-2	0.10	7.6	6.9	29.5	0.5	1.1	17.8	7.8	nt	nt
29	P12-3	0.15	8.3	7.5	34.5	0.4	0.7	21.4	8.4	nt	nt
30	P12-4	0.11	8.7	7.8	34.7	0.5	0.3	22.4	10.0	nt	nt
31	P13-1	0.09	6.6	6.0	18.0	0.7	0.9	7.1	5.4	<0.1	nt
32	P13-2	0.21	8.2	7.1	31.6	3.3	0.5	10.0	15.2	nt	nt
33	P13-3	0.96	8.9	8.2	39.4	7.1	0.3	15.7	18.2	nt	nt

nt = not tested

END OF TEST REPORT







Soil Laboratory Results - Fertility

APPENDIX 3

ALS Group
Environmental Division

CERTIFICATE OF ANALYSIS

Work Order	: **EB1217097**	Page	: 1 of 4
Client	: **GSS ENVIRONMENTAL**	Laboratory	: Environmental Division Brisbane
Contact	: MR MATT HEMINGWAY	Contact	: Customer Services
Address	: LEVEL 1241 DENISON STREET BROADMEADOW NEWCASTLE NSW AUSTRALIA 2292	Address	: 32 Shand Street Stafford QLD Australia 4053
E-mail	: hemingway@gssenvironmental.com	E-mail	: Brisbane.Enviro.Services@alsglobal.com
Telephone	: ----	Telephone	: +61 7 3243 7222
Facsimile	: ----	Facsimile	: +61 7 3243 7218
Project	: ----	QC Level	: NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Order number	: ----		
C-O-C number	: ----	Date Samples Received	: 28-JUN-2012
Sampler	: ----	Issue Date	: 12-JUL-2012
Site	: ----		
		No. of samples received	: 9
Quote number	: BN/372/11	No. of samples analysed	: 9

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

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

NATA Accredited Laboratory 825

Accredited for compliance with ISO/IEC 17025.

WORLD RECOGNISED ACCREDITATION

Signatories

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

Signatories	*Position*	*Accreditation Category*
Andrew Epps	Metals Production Chemist	Brisbane Inorganics
Ankit Joshi	Inorganic Chemist	Sydney Inorganics
Stephen Hislop	Senior Inorganic Chemist	Brisbane Inorganics
Stephen Hislop	Senior Inorganic Chemist	Stafford Minerals - AY

Page	:	2 of 4
Work Order	:	EB1217097
Client	:	GSS ENVIRONMENTAL
Project	:	----

General Comments

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

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

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

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

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

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

Analytical Results

Sub-Matrix: **SOIL** (Matrix: **SOIL**)			*Client sample ID*	P2-1 0 - 10	P3-1 0 - 10	P4-1 0 - 10	P5-1 0 - 10	P8-1 0 - 10
			Client sampling date / time	[28-JUN-2012]	[28-JUN-2012]	[28-JUN-2012]	[28-JUN-2012]	[28-JUN-2012]
Compound	*CAS Number*	*LOR*	*Unit*	**EB1217097-001**	**EB1217097-002**	**EB1217097-003**	**EB1217097-004**	**EB1217097-005**
EA055: Moisture Content								
Moisture Content (dried @ 103°C)	----	1.0	%	**5.0**	**5.7**	**10.9**	**4.6**	**3.2**
ED040S : Soluble Sulfate by ICPAES								
Sulfate as SO4 2-	14808-79-8	10	mg/kg	**40**	**40**	**40**	**30**	**20**
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								
Nitrite + Nitrate as N (Sol.)	----	0.1	mg/kg	**0.9**	**5.7**	**4.1**	**0.5**	**2.7**
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N	----	20	mg/kg	**3390**	**5830**	**1580**	**1460**	**1820**
EK062: Total Nitrogen as N (TKN + NOx)								
^ **Total Nitrogen as N**	----	20	mg/kg	**3390**	**5840**	**1580**	**1460**	**1820**
EK072: Phosphate Sorption Capacity								
Phosphate Sorption Capacity	----	250	mg P sorbed/kg soil	**1210**	**871**	**677**	**571**	**923**
Phosphate Sorption Index	----	1	mgkg-1/log10	**36**	**29**	**30**	**28**	**30**
EK074: Fluoride Extractable Phosphorus (Bray)								
Fluoride Extractable P (Bray)	----	1.0	mg/kg	**2.6**	**4.6**	**2.7**	**1.8**	**2.8**
EP003: Total Organic Carbon (TOC) in Soil								
Total Organic Carbon	----	0.02	%	**3.25**	**5.92**	**1.69**	**1.72**	**2.84**

Page	: 4 of 4
Work Order	: EB1217097
Client	: GSS ENVIRONMENTAL
Project	: ----

Analytical Results

Sub-Matrix: **SOIL (**Matrix: **SOIL)**			*Client sample ID*	**P9-1 0 - 10**	**P10-1 10 - 20**	**P12-1 0 - 13**	**P13-1 0 - 20**	----
			Client sampling date / time	[28-JUN-2012]	[28-JUN-2012]	[28-JUN-2012]	[28-JUN-2012]	----
Compound	*CAS Number*	*LOR*	*Unit*	**EB1217097-006**	**EB1217097-007**	**EB1217097-008**	**EB1217097-009**	**----**
EA055: Moisture Content								
Moisture Content (dried @ 103°C)	----	1.0	%	**3.3**	**5.4**	**6.0**	**3.6**	----
ED040S : Soluble Sulfate by ICPAES								
Sulfate as SO4 2-	14808-79-8	10	mg/kg	**20**	**10**	**50**	**20**	----
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								
Nitrite + Nitrate as N (Sol.)	----	0.1	mg/kg	**0.8**	**1.6**	**4.3**	**0.9**	----
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N	----	20	mg/kg	**1410**	**1740**	**3030**	**1570**	----
EK062: Total Nitrogen as N (TKN + NOx)								
^ **Total Nitrogen as N**	----	20	mg/kg	**1410**	**1740**	**3030**	**1570**	----
EK072: Phosphate Sorption Capacity								
Phosphate Sorption Capacity	----	250	mg P sorbed/kg soil	**714**	**1130**	**736**	**1160**	----
Phosphate Sorption Index	----	1	mgkg-1/log10	**30**	**34**	**31**	**36**	----
EK074: Fluoride Extractable Phosphorus (Bray)								
Fluoride Extractable P (Bray)	----	1.0	mg/kg	**1.3**	**1.1**	**2.7**	**2.0**	----
EP003: Total Organic Carbon (TOC) in Soil								
Total Organic Carbon	----	0.02	%	**1.88**	**1.98**	**2.83**	**2.32**	----