APPENDIX R

Soils Survey and Land Capability Impact Assessment

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Coalpac Consolidation Project
Soils Survey and Land Capability Impact Assessment Report
Coalpac Pty. Ltd.

Coalpac Consolidation Project Soil Survey and Land Capability Impact Assessment Report

February 2011

Report prepared for Coalpac Pty. Ltd. with instruction from Hansen Bailey Pty. Ltd.

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Executive Summary

Coalpac Pty Ltd ("Coalpac") seeks a Project Approval under Part 3A of the *Environmental Planning & Assessment Act 1979* (EP&A Act) to consolidate the operations and management of the Cullen Valley Mine and Invincible Colliery sites under a single, contemporary planning approval to allow coal mining operations within its current mining tenements to continue for a further 21 years (the Project).

ecobiological was commissioned by Hansen Bailey Pty Ltd to provide expert sub-consultant assistance in preparing a Soil Survey and Land Capability Impact Assessment Report for the Project.

This assessment has been undertaken in accordance with the Director General's Environmental Assessment Requirements and relevant guidelines.

Preliminary soil data for the project was derived from the Atlas of Australian Soils. Background information related to geology was derived from past reports such as the Coalpac Pty. Ltd. Environmental Assessment 2006 and the Invincible Colliery Mining Operations Plan 2009.

The survey assessment involved sampling 24 soil test pits in a range of aspects and topographical locations within the Project Boundary. Samples were taken from individual soil layers within each profile and analysed for their textural and chemical properties. Four soil units were identified within the Project Boundary including a Deep Sandy Loam, a Deep Orange Clay Loam, a Shallow Brown Clay Loam and a Skeletal Sandy Loam. All of these soils were formed *in situ* (Residual Soil Landscape) with the exception of the Deep Sandy Loam which is a transferral soil. The distribution of these soils was mainly dependent on topography, which was also reflected in vegetation community mapping.

Recommended stripping depths of soils were calculated from average topsoil availability for each soil unit. The deepest recommended stripping depth identified was 20-30cm, which was recommended for areas containing the Deep Dark Sandy Loam. The majority of the area within the Project Boundary was recommended to be stripped up to 15 cm. Shallower stripping depths were recommended for all other soil units and it was recommended that no stripping should be conducted in areas containing Skeletal Sandy Loams.

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Ref: 403-767

Laboratory analysis indicated that most soil samples were relatively stable with only slightly dispersive properties. Skeletal Sandy Loams were identified as the most erodible soils. This soil type has the potential to impact downstream watercourses if it is disturbed within drainage lines. Geochemical assessment revealed that all soils had an Electrical Conductivity <2 which indicated consistently low salinity within the Project Boundary. The assessment also revealed that no acid generating materials such as Acid Sulphate Soils were identified.

The land capability assessment identified the majority of land within the Project Boundary as Class V. Due to soil characteristics and topography, this land is economically unviable for crops but is marginally suited for high quality grazing. This is consistent with neighbouring, cleared agricultural land outside the Project Boundary. Skeletal soils were identified as Class VIII land which is more susceptible to degradation if disturbed.

Individual land suitability assessments were conducted for cropping and grazing. With respect to cropping, the majority of land within the Project Boundary was identified either as Class 4 or Class 5 land, which indicates marginal suitability for cropping. With respect to grazing, the majority of land within the Project Boundary was identified as Class 4 land, which is land suitable for native pastures and or improved pastures established using minimum tillage techniques (overall level of production is likely to be comparatively low due to environmental constraints). Skeletal soils were identified as Class 5 land which is unsuitable for grazing due to its inaccessibility and susceptibility to erosion.

Given that the majority of land within the Project Boundary is currently occupied by state forest, post mining rehabilitation will mainly involve reforestation with native flora. The proposed post mine disturbance impacts to native forest are considered to be manageable and recommendations have been made to ensure that land is restored to the most representative state possible in terms of the original vegetation communities.

Definitions

A Horizon

The original top layer of mineral soil divided into A1 (typically from 5 to 30 cm thick; generally referred to as topsoil.

Alluvial Soils

Soils developed from recently deposited alluvium, normally characterise little or no modification of the deposited material by soil forming processes, particularly with respect to soil horizon development.

Arable Land

Land that is fit for cultivation, as opposed to pasture or woodland (the term is applied to agricultural land used for growing crops).

Brown Clays

Soil determined by high clay contents. Typically, moderately deep to very deep soils with uniform colour and texture profiles, weak horizonation mostly related to structure differentiation.

Consistence

Comprises the attributes of the soil material that are expressed by the degree and kind of cohesion and adhesion or by the resistance to deformation or rupture.

Disturbance Boundary

The area within which project activities are likely to disturb the surface.

Electrical Conductivity

The property of the conduction of electricity through water extract of soil. Used to determine the soluble salts in the extract, and hence soil stability.

Emmerson's Aggregate Test (EAT)

A classification of soil based on soil aggregate coherence when immersed **in** water. Classifies soils into eight classes and assists in identifying whether soils will slake, swell or disperse.

Gravel

The >2 mm materials that occur on the surface and in the A1 horizon and include hard, coarse fragments.

Lithosols

Stony or gravelly soils lacking horizon and structure development. They are usually shallow and contain a large proportion of fragmented rock.

Textures

Usually range from sands to clay loams.

Loam

A medium, textured soil of approximate composition 10 - 25% clay, 25 - 50% silt and <50% sand.

Mottling

The presence of more than one soil colour in the same soil horizon, not including different nodule or cutan colours.

Particle Size Analysis (PSA)

The determination of the of the amount of the different size fractions in a soil sample such as clay, silt, fine sand, coarse sand and gravel.

Ped

An individual, natural soil aggregate.

Pedality

Refers to the relative proportion of peds in the soil (as strongly pedal, weakly pedal or non-pedal).

pH

A measure of the acidity or alkalinity of a soil.

Podzolics

Podzolic soils are acidic throughout and have a clear boundary between the topsoil and subsoil. The topsoils are loams with a brownish grey colour. The lower part of the topsoil has a pale light colour and may be bleached with a nearly white, light grey colour.

Project Boundary

The area defining the Project within which all activities directly related to the Project will occur.

Refusal depth

The depth at which parent rock is reached during excavation of a soil test pit

Regolith

The layer of loose rock resting on bedrock, constituting the surface of most land. Also called *mantle rock*.

Skeletal soils

Sandy to loamy surface soils with variable gravel, minimal profile differentiation (ie no subsoil), hard or weathered basement rock underlies the soil within a metre and usually within 50 cm.

Sodicity

A measure of exchangeable sodium in the soil. High levels adversely affect soil stability, plant growth and/or land use.

Soil mantle

The upper layer of the Earth's mantle, between consolidated bedrock and the surface, that contains the soil. Also known as the regolith.

Soil Unit

Soils with similar textural and chemical properties are grouped into soil units to allow identification of soil characteristics across large areas within the Project Boundary.

Solodic Soils

Strong texture differentiation with a very abrupt wavy boundary between A and B horizons, a well-developed bleached A2 horizon and a medium to coarse blocky clay B horizon.

Soloths

Similar to a solodic soil but acidic throughout the profile. Tends to be a more typical soil of the humid regions where the exchangeable cations in the B Horizon of the solodised soils have been leached out.

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1. Introduction

Coalpac Pty Ltd ("Coalpac") seeks a Project Approval under Part 3A of the *Environmental Planning & Assessment Act 1979* (EP&A Act) to consolidate the operations and management of the Cullen Valley Mine and Invincible Colliery sites under a single, contemporary planning approval to allow coal mining operations within its current mining tenements to continue for a further period of 21 years (Project). The Project Application Boundary (Project Boundary) and the proposed Disturbance are shown in Figure 1.

Coalpac was established in 1989 and has successfully owned and operated coal mines in the Lithgow district for over 20 years. Coalpac has operated Invincible Colliery using various mining methods since that time, including underground (continuous miner), open cut excavator and truck, and highwall mining operations. In November 2006, CET Resources purchased a controlling interest in Coalpac, with the aim of fully realising the potential of the available coal reserves at Invincible Colliery through innovative mining techniques and increased efficiencies. In February 2008, Coalpac purchased the Cullen Valley Mine and with Invincible Colliery, has operated the two mines in unison since that time. It is the intention to utilise these mines as a base from which to grow Coalpac's operations in the Western Coalfields of NSW.

The Project is generally comprised of the following:

- Consolidation and extension of the existing Cullen Valley Mine and Invincible Colliery operations to produce up to a total of 3.5 Mtpa product coal, including:
    - The continuation of mining operations at Cullen Valley Mine (the area west of the Castlereagh Highway) via both open cut and highwall mining methods to access an additional resource of approximately 40 Mt ROM; and
    - The continuation of mining operations at Invincible Colliery (including an extension north into the East Tyldesley area) via open cut and highwall mining methods to access an additional resource of approximately 60 Mt ROM;

1.1. Objective

ecobiological was commissioned by Hansen Bailey Pty Ltd to provide expert sub-consultant assistance in preparing a Soil Survey and Land Capability Assessment Report to support an Application for a new Project Approval for the Project under Part 3A of the EP&A Act.

The specific scope of work for Soils & Land Capability included the following:

- Review of previous relevant assessments;
- Undertake up to 24 test pit excavations (already approved by Forests NSW to determine soil types and onsite analysis of land classifications as required)
- Soil assessment of areas to be disturbed at a sufficient level of detail to satisfy the Director Generals' Requirements for the Project and the requirements of NSW Industry & Investment (I&I) guidelines;
- Pre and post mining land capability and classes assessment in accordance with I&I and NSW Office of Water (NOW) Guidelines including figures of each;
- Pre and post mining agricultural suitability assessment in accordance with I&I guidelines;
- Assessment of available topsoil resources for mining and infrastructure area rehabilitation, management and mitigation measures;
- Assessment of suitable post-mining land uses for the open cut operations;
- Mitigation and management measures as required.

1.2. Location

The Project is located adjacent to the Castlereagh Highway, approximately 25 km north-west of Lithgow, NSW (Figure 1). The Project is located on lands adjacent the township of Cullen Bullen, with Invincible Colliery and Cullen Valley Mine located approximately 1 km to the south-east and north-west, respectively. All of Coalpac's mining activities occur within the Lithgow City Council Local Government Area (LGA).

Figure 1 - Locality Map

Legend

- Project Boundary
- NPWS Estate
- State Forests of NSW
- Road Network

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Project Ref:	403-767
Plot Date:	15/11/2011 11:03
Revision:	004 (gayle.j)

Map Projection:
NSW Lamberts Conformal Conic

Data Sources:
Bing Maps - 2011
LPMA - 2006
DECCW - 2011
Hansen Bailey -2011
ecobiological - 2011

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1.3. Geology

The Project is located within the Western Coalfield of NSW which is geologically located on the western edge of the Sydney Basin. The Sydney Basin consists of a series of gently dipping sedimentary beds of shale and sandstone of Permo-Carboniferous age capped by massive sandstones of Triassic Age. Directly beneath the Triassic sandstone these beds contain coal seams and form the Upper Coal Measures. The measures extend from the western boundary of the Western Coalfield in an easterly direction, dipping generally at an angle of 1-3° to the northeast, towards the coast, and extending out to sea.

The Western Coalfield is characterised by the prominent cliffs and eroding plateaus of the Triassic age sandstone and shale Narrabeen Group which overlies the shale, sandstone, conglomerate and coal of the Permian aged Illawarra Coal Measures which form the slopes which fall away from the sandstone and shale cliffs.

The Western Coalfield extends from south of Lithgow to north of Ulan and is generally bound to the west by outcroppings of the Lithgow seam, the deepest coal seam of the measures. There is no defined eastern boundary given the dipping of coal measures to the northeast (below the Hawkesbury Sandstone of the Blue Mountains).

There are seven identified coal seams in the Illawarra Coal Measures, which in descending order are as follows:

- Katoomba Seam;
- Middle River Seam;
- Moolarben Seam;
- Upper Irondale Seam;
- Irondale Seam;
- Lidsdale Seam; and
- Lithgow Seam.

The Project will mine coal from all of the seams of the Illawarra Coal Measures that outcrop in the Project Boundary. As occurs elsewhere in the Western Coalfield north of Blackmans Flat, the Lithgow and Lidsdale Seams tend to merge.

The Lithgow Seam has been worked extensively at the Invincible Colliery by underground and open cut methods in the past; however, mining will form the primary source of coal mined by open cut and highwall mining methods.

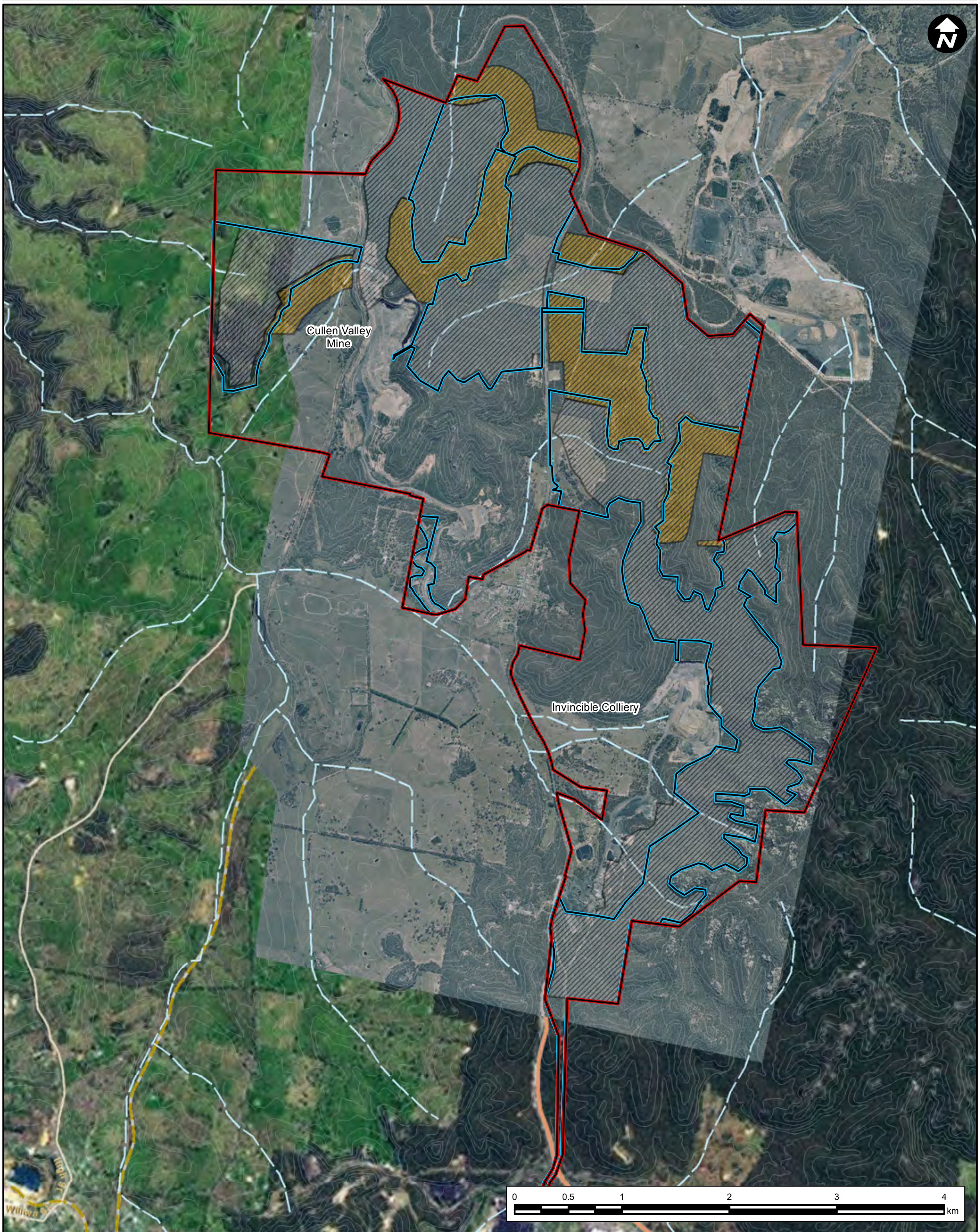
Previous mining experience indicates that the coal seams to be mined are generally free of faults and are not excessively wet.

1.4. Topography

The terrain within the Project Boundary is variable throughout and includes low lying areas to steeply undulating terrain of between 875m and 1050m AHD elevation.

The majority of slopes exceed 5º and can exceed 45º (Figure 2).

Figure 2 - Project Boundary and Surrounding Landscape



Legend

- Project Boundary
- Disturbance Boundary
- Existing Operations Areas
- High Wall Mining Areas
- Watercourse (Non-perennial)
- 10m Contours (SRTM Derived)

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Project Ref:	403-767
Plot Date:	15/11/2011 10:50
Revision:	004 (gayle.j)

Map Projection:
NSW Lamberts Conformal Conic

Data Sources:
NASA - 2006
ESRI - 2011
Hansen Bailey -2011
Cumberland Ecology - 2010
Geoscience 2011
ecobiological - 2011

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1.5. Vegetation

The Project Boundary is generally forested and occurs across a landscape characterised by sandstone plateaus with rocky out-cropping formations on the crests and shallow drainage lines.

A wide variety of woodland and open forest flora and fauna are known to occur in the locality and a considerable diversity of species have been identified in previous environmental surveys conducted on and surrounding the Invincible Colliery, Cullen Valley and Baal Bone Colliery operations. Cumberland Ecology (2010) reports that the vegetation of the exploration area is generally in good condition with few exotic species occurring. The following vegetation communities have been recorded:

- Capertee Rough-barked Apple - Red Gum - Yellow Box Grassy Woodland
- Capertee Rough-barked Apple - Red Gum - Yellow Box Grassy Woodland Derived Native Grassland
- Capertee Rough-barked Apple - Red Gum - Yellow Box Woodland: non grassy
- Capertee Rough-barked Apple Red Gum Yellow Box Woodland Derived Native Grassland
- Tableland Gully Ribbon Gum Blackwood Applebox Forest
- Tableland Gully Ribbon Gum Blackwood Applebox Forest Derived Native Grassland
- Tableland Scribbly Gum – Narrow-leaved Stringybark Shrubby Open Forest
- Tableland Broad-leaved Peppermint - Brittle Gum - Red Stringybark Grassy Woodland
- Tableland Broad-leaved Peppermint - Brittle Gum - Red Stringybark Grassy Woodland Low Diversity Derived Native Grassland
- Tableland Slopes Brittle Gum – Broad-leaved Peppermint Grassy Forest

- Tableland Slopes Brittle Gum – Broad-leaved Peppermint Grassy Forest Derived Native Grassland
- Tableland Gully Mountain Gum - Broad-leaved Peppermint Grassy Forest
- Tableland Gully Mountain Gum Broad-leaved Peppermint Grassy Forest Derived Native Grassland
- Tableland Gully Mountain Gum Broad-leaved Peppermint Grassy Forest Low Diversity Derived Native Grassland
- Tableland Gully Snow Gum - Ribbon Gum Grassy Forest
- Tableland Gully Snow Gum - Ribbon Gum Grassy Forest Low Diversity Derived Native Grassland
- Pagoda Rock Sparse Shrubland
- Cox's Permian Red Stringybark - Brittle Gum Woodland
- Exposed Blue Mountains Sydney Peppermint - Silvertop Ash Shrubby Woodland

Details on ecology are provided in the Ecological Impact Assessment (Cumberland Ecology, 2011) as part of the EA.

1.6. Preliminary Soil Analysis

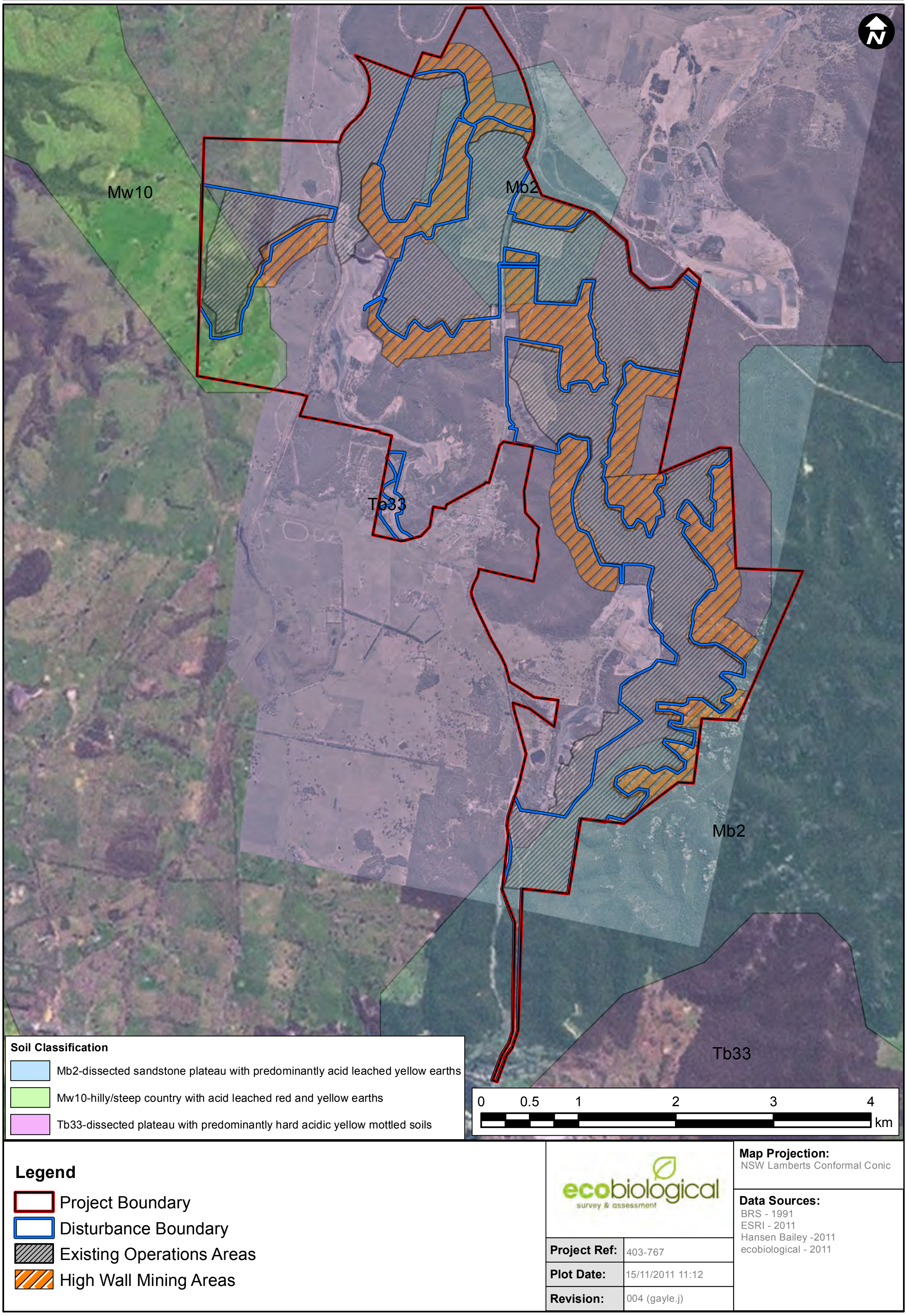
Three broad scale soil units were identified within the Project Boundary using the Atlas of Australian Soils (Figure 3). The majority of the site was mapped as soil unit Tb33, two small areas in the north-east and southern corners were mapped as soil unit Mb2 and a small portion in the north western corner was mapped as soil unit Mw10. Descriptions of the soil units include:

- Mb2: Dissected sandstone plateau of moderate to strong relief with sandstone pillars, ledges, and slabs--level to undulating ridges, irregularly benched slopes, steep ridges, cliffs, canyons, narrow sandy valleys: chief soils are
  (i) on areas of gentle to moderate relief, acid yellow leached earths (Gn2.74) and (Gn2.34) and acid leached yellow earths (Gn2.24)-sometimes these soils contain ironstone gravel; and
  (ii) on, or adjacent to, areas of strong relief, siliceous sands (Uc1.2), leached sands (Uc2.12) and (Uc2.2), and shallow forms of the above (Gn2) soils. Associated are: (i) on flat to gently undulating remnants of the original plateau surface, leached sands (Uc2.3), siliceous sands (Uc1.2), sandy earths (Uc5.22), and (Gn2) soils as for (i) above (these areas are in part comparable with unit (Cb29); (ii) on flat ironstone gravelly remnants of the original plateau surface, (Gn2) soils as for unit Mb5(i); (iii) on gently undulating ridges where interbedded shales are exposed, shallow, often stony (Dy3.41), (Dr2.21), and related soils similar to unit Tb35; (iv) narrow valleys of (Uc2.3) soils flanked by moderate slopes of (Dy3.41) soils; (v) escarpments of steep hills with shallow (Dy) and (Dr) soils between sandstone pillars; and (vi) shallow (Um) soils, such as (Um6.21) on steep hills of basic rocks.

- Mw10 Hilly to steep and rugged country with some flat to undulating areas: chief soils seem to be acid leached red and yellow earths (Gn2.14, Gn2.24, Gn2.34). Associated are (Dy3.41) and possibly other soils.

- Tb33 Dissected plateau: chief soils on undulating ridge crests are hard acidic yellow mottled soils (Dy3.41). Associated are: moderate to steep side slopes of various earths (Gn2), such as (Gn2.14), (Gn2.2), and (Gn2.9); some hilly areas of (Dr2.21), (Dy2.21), (Dy3.41), (Um4.1), and (Um4.2) soils with rock outcrops; some talus slopes of (Uc1.2) and (Uc2.2) soils; and some small flat areas of units Tb32 and Tb39.

Figure 3 - Preliminary Soil Map



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1.7. Legislation

This assessment was undertaken in accordance with the following Acts and Policies and with consideration of a range of Guidelines and Management Plans:

- *Greater Lithgow Local Environmental Plan* (LEP) 1994

  The Project Boundary is currently zoned 1(f) Rural (Forestry) under the Greater Lithgow Local Environmental Plan
- *Forestry Act* 1916
- *Commonwealth Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act);
- *NSW Threatened Species Conservation Act 1995 (TSC Act);*
- *NSW Threatened Species Conservation Amendment Act 2002;*
- *Native Vegetation Act (NV Act) 2003;*
- *Noxious Weeds Act 1993;*
- *Australian and New Zealand Guidelines for the Assessment and Management of Contaminated Sites (ANZECC)*
- *Rural Land Capability Mapping (DLWC)*
- *Agricultural Land Classification (DPI)*
- The assessment was also conducted in accordance with the Director General's Requirements (Project: 10-0178) under the *Environmental Planning and Assessment Act 1979* (EP&A Act to provide a detailed assessment of the likely impact on soil and the soil management measures to avoid, mitigate or offset those impacts, including a detailed assessment of the pre-mining, operational and proposed post mining landforms.

2. Soil Survey Methodology

2.1. Introduction

A soil survey and land resource assessment was undertaken in December 2010 and January 2011 to classify soil profile types, assess suitable topsoil material and identify the potentially unsuitable soil material within the Project Boundary. The survey was conducted in accordance with the survey methodology described in this section. The survey results are presented in Section 3 of this report.

2.2. Mapping

An initial soil map was developed using the following resources and techniques.

1) 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 related to the distribution of soils within the Project Boundary.

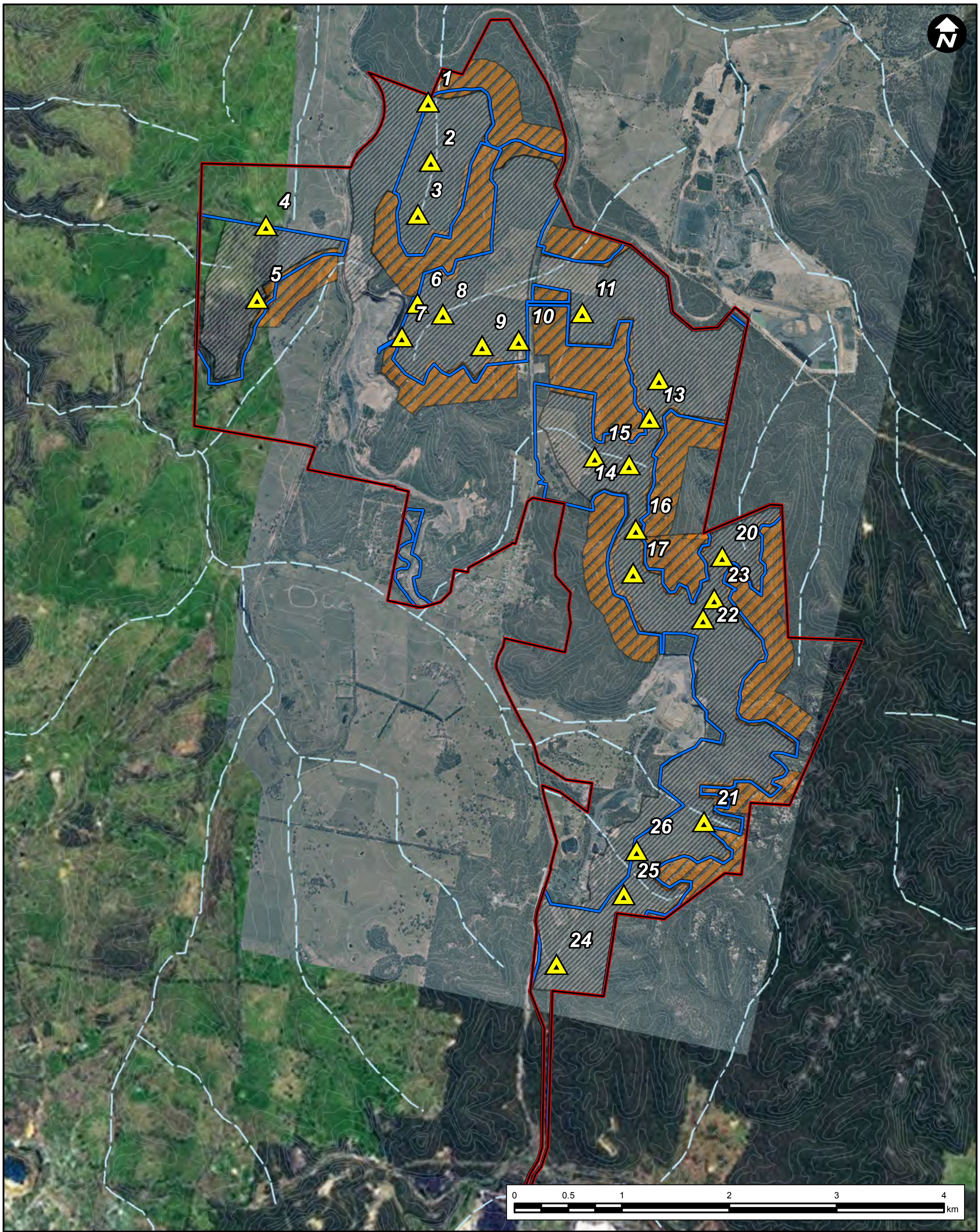
2) Previous soil survey results were derived from the Atlas of Australian Soils which showed broadscale information.

2.3. Profiling

A total of 24 soil profile exposures were assessed at selected sites to enable soil profile descriptions to be made. These soil profile exposures were excavated with a backhoe. Soil profile site locations are shown in Figure 4

Sub-surface exposure locations were selected to provide representative profiles of the soil types encountered over the Project Boundary. The soil layers were generally distinguished on the basis of changes in texture and/or colour. Soil colours were assessed according to the Munsell Soil Colour Charts (Macbeth, 1994). Photographs of soil profile exposures were also taken (see below). Numerous surface exposures were also assessed to confirm soil units and boundaries between different soils.

Figure 4 - Test Pit Locations



Legend

- Project Boundary
- Disturbance Boundary
- Existing Operations Areas
- High Wall Mining Areas
- Test Pit Location
- Watercourse (Non-perennial)
- 10m Contours (SRTM Derived)

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Project Ref:	403-767
Plot Date:	15/11/2011 11:16
Revision:	004 (gayle.j)

Map Projection:
NSW Lamberts Conformal Conic

Data Sources:
NASA - 2006
ESRI - 2011
Bing Maps - 2011
Hansen Bailey - 2011
Geoscience-2011
ecobiological - 2011

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2.4. Field Assessment

Soil profiles within the Project Boundary were assessed generally in accordance with the soil classification procedures in the Australian Soil and Land Survey Field Handbook (McDonald et al, 1990).

Soil layers at each profile site were also assessed according to a procedure devised by Elliot and Veness (1981) for the recognition of suitable topsoil material. This procedure assesses soils based on grading, texture, structure, consistence, mottling and root presence.

A more detailed explanation of the Elliot and Veness procedure is presented in Appendix 1 to this report. The system remains the benchmark for land resource assessment in the Australian coal mining industry.

2.5. Laboratory Testing

Soil samples were collected from the exposed soil profiles to a depth of up to 2 m below ground surface and subsequently despatched to the Department of Lands Soil & Water Testing Laboratory at Scone, NSW for analysis.

Samples were analysed to establish the geochemical suitability of surface and near-surface soil horizons as a potential growth medium, and identify high value or high risk soils. Soil layers are signified by /1, /2 and /3 in the sample ID with the surface horizon being /1 and subsoil horizons being /2 & /3 (Table 1).

Table 1: Soil test pits and layers examined.

Test pit	Soil Layers examined
Site 1	1/1, 1/2, 1/3
Site 2	2/1, 2/2, 2/3
Site 3	3/1, 3/2, 3/3
Site 4	4/1, 4/2
Site 5	5/1, 5/2
Site 6	6/1
Site 7	7/1, 7/2
Site 8	8/1, 8/2, 8/3
Site 9	9/1, 9/2, 9/3
Site 10	10/1, 10/2, 10/3
Site 11	11/1, 11/2, 11/3
Site 12	12/1, 12/2, 12/3, 12/4, 12/5
Site 13	13/1, 13/2, 13/3
Site 14	14/1, 14/2
Site 15	15/1, 15/2, 15/3
Site 16	16/1, 16/2
Site 17	17/1, 17/2, 17/3
Site 20	20/1, 20/2, 20/3
Site 21	21/1, 21/2, 21/3, 21/4
Site 22	22/1, 22/2, 22/3
Site 23	23/1, 23/2
Site 24	24/1, 24/2, 24/3, 24/4
Site 25	25/1, 25/2, 25/3
Site 26	26/1, 26/2, 26/3, 26/4

The samples were subsequently analysed for the following parameters:

- Particle size analysis.
- Emerson Aggregate Test (soil aggregate slaking and coherence).
- Electrical conductivity.
- pH.

(Definitions and methodologies used to measure each of these parameters are presented in Appendix 2).

All profiles were examined during the field assessment, however, several samples were not analysed in the laboratory as they displayed similar soil characteristics to previously sampled profiles. These mainly included test pits in close proximity to each other (see Appendix 4).

The laboratory test results were reviewed 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 in rehabilitation and to identify potentially unsuitable material. The soil test results for the soil survey are provided in Appendix 3.

2.6. Pre and Post Mining Land Capability Assessment

The area within the Project Boundary was assessed in accordance with Rosser et al (1974) for pre-mining land capability. The system includes eight possible classifications and refers to the overall agricultural potential of the land. The various classes are provided in Table 2.

Table 2: Land Capability Classes.

Category	Class	Description	Implication
Suitable for Cultivation	Class I	No special practices required.	No special soil conservation works or practices necessary.
	Class II	Simple management practices required.	Soil conservation practices such as strip cropping, conservation tillage and adequate crop rotations.
	Class III	Complex or intensive practices required to sustain cropping.	Structural soil conservation works such as diversion banks, graded banks and waterways, together with soil conservation practices as in Class II.
	Class IV	Occasional or limited cultivation but with severe management inputs required to prevent degradation.	Soil conservation practices such as pasture improvement, stock control, application of fertiliser and minimal cultivation for the establishment or re-establishment of permanent pasture.
Not Suitable for Cultivation	Class V	Suitable soil and topography for crops but economically not viable. High quality grazing land.	Structural soil conservation works such as absorption banks, diversion banks and contour ripping, together with the practices as in Class IV.
	Class VI	Moderately susceptible to degradation requiring proper management to sustain use.	Soil conservation practices including limitation of stock,broadcasting of seed and fertiliser, prevention of fire and destruction of vermin. This class may require some structural works.
	Class VII	Highly susceptible to degradation requiring severe restrictions on use; grazing may be conducted with rigorous management inputs required to prevent degradation.	Land best protected by green timber.
Not Suitable for Grazing	Class VIII	Wildlife reserves, bushland, recreation or water supply catchments.	Cliffs, lakes or swamps and other lands incapable of sustaining agricultural or pastoral production.

2.7. Pre and Post Mining Agricultural Suitability Assessment

Agricultural land suitability of the Project Boundary has been assessed largely using criteria provided in the Agricultural Land Classification NSW Agriculture (NSW Department of Primary Industries).

The method of land suitability assessment takes into account a range of factors including climate, soils, geology, geomorphology, soil erosion, topography and the effects of past land uses. The classification does not necessarily reflect the existing land use. Rather, it indicates the potential of the land for such uses as crop production, pasture improvement and grazing. The system allows for land to be allocated into five possible classes (with land suitability decreasing progressively from Class 1 to Class 5) on the basis of a specified land use that allows optimum production with minimal degradation to the land resource in the long term.

Land is considered less suitable as the severity of limitations for a land use increase. Increasing limitations may reflect any combination of reduced potential for production; increased inputs to achieve an acceptable level of production; and/or increased inputs required to prevent land degradation. The agricultural land suitability classes are described in Table 3.

Table 3: Land Suitability Classes.

Class	Description
Class 1	Arable land suited to continuous cultivation for uses such as intensive horticulture and field crops. Constraints to sustain high levels of production are absent or minor.
Class 2	Arable land suited to regular cultivation for uses such as intensive horticulture and field crops. Constraints to sustain levels of production are minor to moderate.
Class 3	Land suited to cropping but not continuous cultivation. Production risks are managed through a pasture phase, conservation tillage and or fallowing. Constraints to sustain levels of production are moderate.
Class 4	Land suited to grazing but not cultivation. Agriculture is based on native pastures and or improved pastures established using minimum tillage techniques. Overall level of production is comparatively low due to major environmental constraints.
Class 5	Land not suited to agriculture or only slight grazing. Agricultural production, if any, is low due to major environmental constraints.

3. Results

3.1. Soils

The following soil units were identified within the Project Boundary:

- Deep Dark Sandy Loam (Transferral Landscape).
- Deep Orange Clay Loam (Residual Landscape).
- Shallow Brown Clay Loam (Residual Landscape).
- Skeletal Sandy Loam (Residual Landscape).

The distribution of these soils is illustrated in Figure 5. Distributions were extrapolated from test pit data, topographical maps, vegetation maps and on site observations.

Exposed profiles of major soil units are shown in Plates 1 to 4 and discussed further below.

3.1.1. Deep Dark Sandy Loam

The soil unit occurs in a transferral landscape and occurs within valley flats and along drainage lines (alluvial/colluvial). This soil unit generally consists of a deep sandy loam. Colour is generally uniform throughout the profile. Very little textural change occurs between the upper and lower layers. No parent rock material was encountered (no refusal). Some water seepage was identified in some areas (>2.5m depth). Alluvial sand was also identified in one test pit (>2.5m depth).

The soil unit encompasses approximately 5.5% of the Project Boundary. A representative description of the soil unit profile is presented in Table 4 and a photograph is shown in Plate 1.

Topsoil

The topsoil is approximately 50 cm in depth and dark to brown in colour. Texture was a sandy loam, with a weak granular structure. Clay content varied between 5% and 15%.

Emerson ratings of 3(1), 5 and 8 occurred which indicates that the soil is slightly dispersive, does not swell and is generally stable. The topsoil is non-saline (EC ,0.02 to 0.05 dS/m) and generally slightly acid (pH 4.9-6).

Subsoil

The lower boundary of the soil varied between 187 cm and 250 cm in depth. Subsoil colour is brown to dark brown. Texture is a sandy loam. Structure is generally weak and granular.

The subsoils are moderately dispersible to generally stable (Emerson ratings of 5, 6, and 3(1) and acidic (pH 4.3-5.1). Clay content in the subsoils was between 5% and 15% and is non-saline (>0.01).

Root penetration was noted as common to none and stone content was low.

Limiting Factors

The Deep Dark Sandy Loam is slightly more dispersive than other soils within the Project Boundary; however, with correct handling and sediment control procedures, the soil does not display any specific management risk related to potential disturbance during stripping. The subsoil has similar textural and chemical properties to the topsoil and therefore stripping to depths lower than 50 cm may be achieved in some areas depending on profile characteristics.

Salinity levels and acidity are not prohibitive with respect to supporting vegetation. The topsoil is suitable for stripping to a depth of 50 cm. The topsoil is generally considered suitable as a surface cover in the establishment of vegetation.

Table 4: Deep Dark Sandy Loam.

Soil Unit: 3		
Layer	Depth (cm)	Description
1	0-43	Dull Brown (7.5YR4/4) Loam. Moderate consistency and pedality. granular, 2-4 mm peds. Roots moderately abundant. Boundary is clear to layer 2.
2	43-201	Dark (7.5YR3/4) Sandy Loam. Loam. Moderate consistency and pedality. granular, 2-4 mm peds. Roots low abundance.

Plate 1: Deep Dark Sandy Loam

3.1.2. Deep Orange Clay Loam

The soil unit occurs in a residual soil landscape and mainly occurs on lower gradual slopes. The soil unit generally consists of a shallow dull brown loam –clay loam above an orange clay loam – heavy clay. Colour variability occurs in the deeper clay loam layers with increasing orange-cream mottling with depth. Textural changes occur between the upper and lower layers. Lower layers displayed higher clay content and greater weathered parent rock fragments.

The soil unit encompasses approximately 70% of the Project Boundary. A representative description of the soil unit profile is presented in Table 5 and a photograph is shown in Plate 2.

Topsoil

The topsoil is approximately 20 cm in depth and dull brown in colour. Textures include sandy loam to clay loam, with a loose consistency and weak granular structure. Clay content varied between 10% and 32%.

Emerson ratings of class 3(1) and class 8 indicate that the soil is slightly dispersive, does not swell and is generally stable. The topsoil is non-saline (EC ,<0.01 to 0.23 dS/m) and generally slightly acidic (pH 5-5.5).

Subsoil

The lower boundary of the subsoil varied between 117 cm and 240 cm. Subsoil colour is dull orange to yellow orange. Textures include clay loams to heavy clay. Structure is generally angular and blocky with a firm consistency.

The subsoils are moderately dispersible to generally stable (Emerson ratings of 5, 6, 3(1), 3(2) and acidic (pH 4.9-6.1). Clay content in the subsoil is between 16% and 76% and non-saline (>0.01-0.06).

Root penetration was noted as moderate to none and stone content was low to high.

Limiting Factors

Generally the Deep Orange Clay Loam topsoil does not display any specific management risk related to potential disturbance during stripping. The clay subsoil however is texturally and structurally unsuitable for stripping and should not be retained for topsoil respreading. Salinity levels and acidity are not prohibitive with respect to supporting vegetation. The clay subsoils should not be recovered or used as a surface cover in rehabilitation, due to high clay content and massive structure.

The topsoil is suitable for stripping to a depth of 15-20 cm. The topsoil is generally considered suitable as a surface cover in the establishment of vegetation.

Table 5: Deep Orange Clay Loam

Soil Unit: 1		
Layer	Depth (cm)	Description
1	0-21	Dull Brown (7.5YR5/3) loam. Moderate consistency and pedality. Angular blocky, 4-10 mm peds. Roots moderately abundant. Boundary is clear to layer 2.
2	21-52	Dull Orange (7.5YR7/3) clay loam. Moderate To firm consistence. Angluar to blocky, 4-10 mm peds. Roots Low abundance. Low content sandstone fragments 6-20 mm diameter. Boundary is blurred and wavey to layer 3.
3	52-1170	Orange (7.5YR6/6) clay loam. Firm to hard consistency. Apedal to massive. No roots present. Sandstone fragments present above parent rock 10-20 cm in diameter.

Plate 2: Deep Orange Clay Loam.

3.1.3. Shallow Brown Sandy Loam

The soil unit occurs in a residual soil landscapes and mainly occurs on the upper gradual slopes. This soil unit generally consists of a shallow dull brown clay loam. Colour variability occurs in the deeper layers with moderate orange-cream mottling. Textural change occurs between the upper and lower layers. Lower layers displayed higher clay content and greater weathered parent rock fragments.

The soil unit differs from the 'Deep Orange Clay Loam' in that it has a shallower topsoil layer, lower clay content and a lower refusal depth.

The soil unit encompasses approximately 14.5% of the Project Boundary. A representative description of the soil unit profile is presented in Table 6 and a photograph is shown in Plate 3.

Topsoil

The topsoil is approximately 15 cm in depth and dull brown in colour. Textures include clay loam to sandy loam, with a weak granular structure. Clay content varies between 5% and 18%.

Emerson ratings of class 5 and class 8 occurred which indicated that the soil is slightly dispersive and is generally stable. The topsoil is non-saline (EC ,<0.01 to 0.02 dS/m) and generally slightly acid (pH 4.6-6.1).

Subsoil

The lower boundary of the soil varied between 50 cm and 114 cm in depth. Subsoil colour is brown to dull orange. Texture is consistently sandy loam. Structure is generally angular.

The subsoils are generally stable (Emerson ratings of 5 and acidic (pH 4.6-6.2). Clay content in the subsoils was between 12% and 18% and is non-saline (>0.01).

Root penetration was noted as moderate and stone content was variable.

Limiting Factors

Generally the 'Shallow Brown Sandy Loam' topsoil does not display any specific management risk related to potential disturbance during stripping. The clay subsoil is texturally and structurally unsuitable for stripping.

Salinity levels and acidity are not prohibitive with respect to supporting vegetation. The clay subsoils should not be recovered or used as a surface cover in rehabilitation, due to higher clay content.

The topsoil is suitable for stripping to a depth of 10-15 cm. The topsoil is generally considered suitable as a surface cover in the establishment of vegetation.

Table 6: Shallow Brown Clay Loam.

Soil Unit: 2		
Layer	Depth (cm)	Description
1	0-14	Dull Brown (7.5YR5/4) loam. Moderate consistency and pedality. Granular, 2-5 mm peds. Roots moderately abundant. Boundary blurred to layer 2.
2	14-75	Dull Orange (7.5YR7/4) Sandy loam. Moderate To firm consistence. Granular, 2-5 mm peds. Roots Low abundance. Low content sandstone fragments 6-20 mm diameter.

Plate 3: Shallow Brown Clay Loam.

3.1.4. Skeletal Sandy Loam

The soil unit occurs in a residual soil landscapes and mainly occurs on crests and upper steep slopes. The soil unit generally consists of a shallow sandy loam /weathered sandstone. The colour is generally uniform through the profile with very little textural change. High weathered parent rock fragments.

The soil unit encompasses approximately 10% of the Project Boundary. A representative description of the soil unit profile is presented in Table 7 and a photograph is shown in Plate 4.

Topsoil

The topsoil is approximately 2 cm in depth and brown in colour. Textures are a sandy loam with a weak granular structure. Clay content varied between 6% and 8%.

An Emerson ratings of class 3(1) occurred which indicated that the soil is slightly dispersive. The topsoil is non-saline (EC ,<0.01 dS/m) and generally slightly acid (pH 5.1).

Subsoil

The subsoil is approximately 2 cm in depth and brown in colour. Texture is a sandy loam with a weak granular structure interspersed between large sandstone fragments. Clay content varied between 6% and 8%.

An Emerson ratings of class 3(1) occurred which indicated that the soil is slightly dispersive. The topsoil is non-saline (EC ,<0.01 dS/m) and generally slightly acid (pH 5.1).

Root penetration was noted as common to none and stone content was high.

Limiting Factors

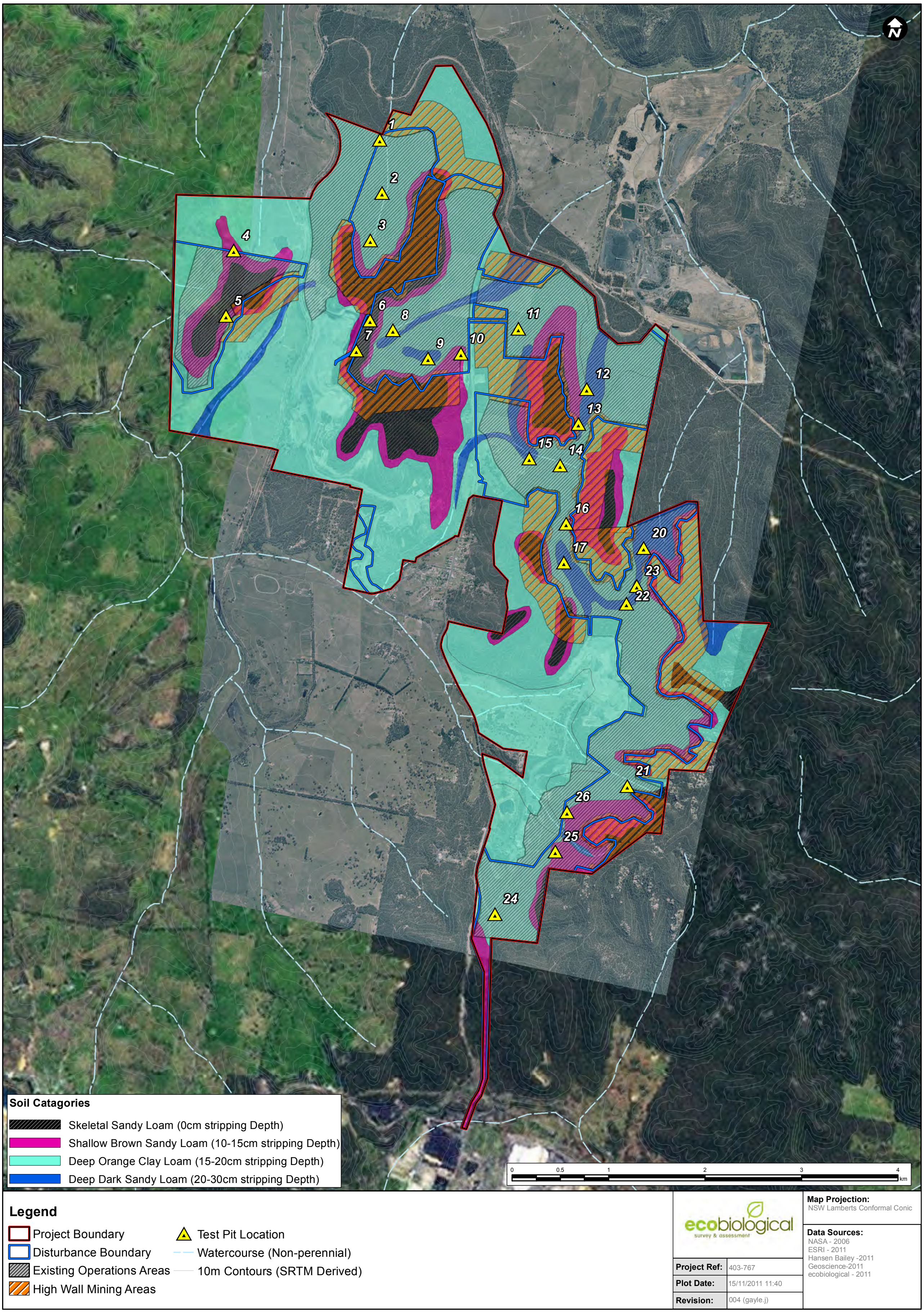
Given that the topsoil is extremely shallow and the subsoil contains high density parent rock material, the soil is texturally and structurally unsuitable for stripping and should not be retained for topsoil respreading. Salinity levels and acidity are not prohibitive with respect to supporting vegetation; however disturbance of these soils could lead to erosion due to the slight dispersibility of the soil (EAT).

Table 7: Skeletal Sandy Loam.

Soil Unit: 4		
Layer	Depth (cm)	Description
1	0-2	Brown (7.5YR6/3) sandy loam. Loose consistency. Granular 2-5 mm peds. Roots low to moderately abundant.
	2-39	Light Brown (7.5YR7/2) sandy loam/weathered sandstone. Loose consistency. Granular 2-5 mm peds. Large sandstone fragments (2-25cm) Roots low to moderately abundant.

Plate 4: Skeletal Sandy Loam

Figure 5 - Soil Categories and Suggested Stripping Depths



3.2. Topsoil Suitability

Soil analysis results (refer Appendix 3) were used in conjunction with the field assessment (refer Appendix 1) to determine the depth or thickness of soil materials suitable for recovery.
Structural and textural properties of subsoils are the most significant limiting factors in determining depth of soil suitability for re-use. However, dispersion potential was also a limiting factor for some soils within the Project Boundary.

It is important to note that both the Deep Dark Sandy Loam and the Deep Orange Clay Loam have been used successfully in past rehabilitation efforts in other operations within the Project Boundary.

Indicative soil analyte levels with respect to soil suitability are provided in Table 8.

Table 8: Topsoil Suitability Limiting Factors

Structure	Deep Dark Sandy Loam	Deep Orange Clay Loam	Shallow Brown Sandy Loam	Skeletal Sandy Loam
30% peds present	✓	✓	✓	✓
Coherent when wet or dry	✓	✓	✓	✓
No mottle present	✓	✓	✓	✓
As fine as a sandy loam	✓	✓	✓	✓
Sand & gravel content < 60%	✓	✓	✓	✓
Dispersion - EAT > 2 (2)	✓	✓	✓	✓
pH >4.5 & < 8.4	✓	✓	✓	✓
Conductivity < 1.5 dS/m	✓	✓	✓	✓

Recommended topsoil stripping depths for each soil unit are provided in Table 9 and are presented previously in Figure 5.

It is likely that adequate topsoil is available for successful rehabilitation within the project boundary.

Topsoil stripping will not occur in areas where Highwall Mining occurs within the Project Boundary.

Table 9: Recommended Topsoil Stripping Depth, Ha and M^3 estimates within the Project Boundary and Disturbance Boundary.

Soil unit	Recommended Stripping Depth (cm)	Ha (within Project Boundary)	M^3 (within Project Boundary)	Ha (within Disturbance Boundary)	M^3 (within Disturbance Boundary)
1: Deep Dark Sandy Loam	20-30	117	234000-351000	87	180000-270000
2: Deep Orange Clay Loam	15-20	1486.8	2230200 - 2973600	593.3	889950-1186600
3: Shallow Brown Sandy Loam	10-15	227	227000-340500	141.1	161600-242400
4: Skeletal Sandy Loam	Not suitable for stripping	109	Not suitable for stripping	45.1	Not suitable for stripping

3.3. Erosion Potential

Emersion Aggregate Test ratings indicates that some soil samples had a moderate erosion and dispersion potential (Emerson Aggregate Test ratings of 2 to 3 (See Appendix 2 for greater detail).

Once this material is disturbed, the potential for erosion may be increased. If this disturbance occurs within the vicinity of a drainage line, this could impact on the health of downstream watercourses, through an increase in the sediment load. These soils should, therefore, be managed to ensure that the soils are not disturbed without suitable erosion and sediment controls being implemented.

These measures include the construction of structural soil conservation works such as contour, graded and diversion banks and drop structures together with sediment control dams. The use of sterile cover crops and/or organic ameliorants will reduce soil dispersion and surface crusting thereby reducing runoff and increasing infiltration which will subsequently reduce erosion and sedimentation.

3.4. Potential Acid Generating Material

Analysis of the geochemical properties of soils (Appendix) indicate that the potential for acid generation from regolith material (topsoil and subsoil) within the Project Boundary is low.

Acid Sulphate Soils (ASS) are the main cause of acid generation within the soil mantle and are commonly found less than 5 m above sea level, particularly in low-lying coastal areas such as mangroves, salt marshes, floodplains, swamps, wetlands, estuaries, and brackish or tidal lakes.

ASS were not identified within the Project Boundary and therefore there is low potential for acid generation from regolith material (topsoil and subsoil).

3.5. Land Capability

The majority of the Project Boundary is considered Class V land – Suitable soil and topography for crops but economically not viable (Table 10). This land is however suited for high quality grazing. This is consistent with neighbouring agricultural land outside the Project Boundary.

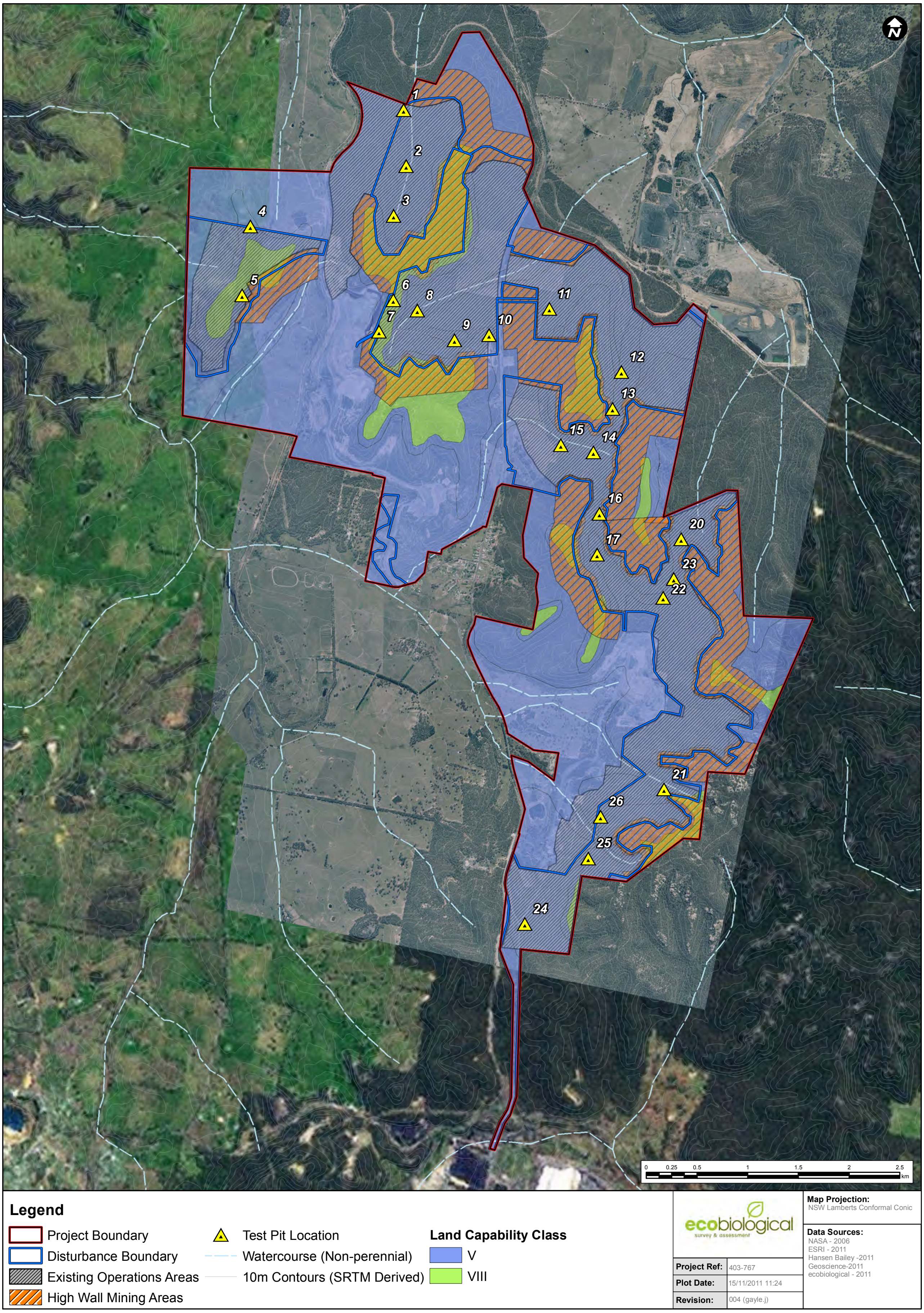
Class VIII land occurs on the more elevated crests where Skeletal Soils were identified. Class VIII land is highly susceptible to degradation requiring severe restrictions for use. Given that the land is highly elevated with steep slopes, it is more suitable for wildlife reserves, bushland, recreation or water supply catchment. It is also important to note that one Endangered Ecological Community and 21 threatened flora species have been identified within the Project Boundary. Areas containing such assemblages are protected under both state and federal legislation.

The distribution of land capability classes within the Project Boundary can be found in Figure 6.

Table 10: Land Capability Class.

Soil unit	Class
1: Deep Dark Sandy Loam	V
2: Deep Orange Sandy Loam	V
3: Shallow Brown Sandy Loam	V
4: Skeletal Sandy Loam	VIII

Figure 6 - Land Capability Class



3.6. Land Suitability

3.6.1. Pre-Mining

The Project Boundary is currently vegetated with native forest (Ben Bullen State Forest) and historically there has been minor selective logging within the area. Neighbouring land is predominantly used for low intensity cattle and sheep grazing.

Land suitability classes, with respect to both cropping and grazing are provided in Table 11 for each soil unit. These are also displayed in Figures 7 and 8.

With respect to cropping, the majority of land within the Project Boundary was identified as Class 5. This indicates that the land is unsuitable for cropping which was mainly due to the inaccessibility of the undulating terrain and a lack of available topsoil for most soil units.

Soil unit 3 (Deep Dark Sandy Loam) was identified as Class 4 land due to its greater topsoil availability; however, this still indicates that it is only marginally suited for cropping due to low available area and inaccessibility.

With respect to grazing, the majority of the site is identified as Class 4 land which indicates that the land is suited to support native pastures and or improved pastures using minimum tillage techniques. The overall level of production for this land would however be comparatively low due to environmental constraints such as low topsoil availability and undulating terrain.

Skeletal Soils were identified as Class 5 (unsuitable for grazing) due to their low topsoil availability, higher erosion potential and inaccessibility.

Table 11: Land Suitability Classes.

Soil unit	Cropping	Grazing
1: Deep Dark Sandy Loam	4	4
2: Deep Orange Sandy Loam	5	4
3: Shallow Brown Sandy Loam	5	4
4: Skeletal Sandy Loam	5	5

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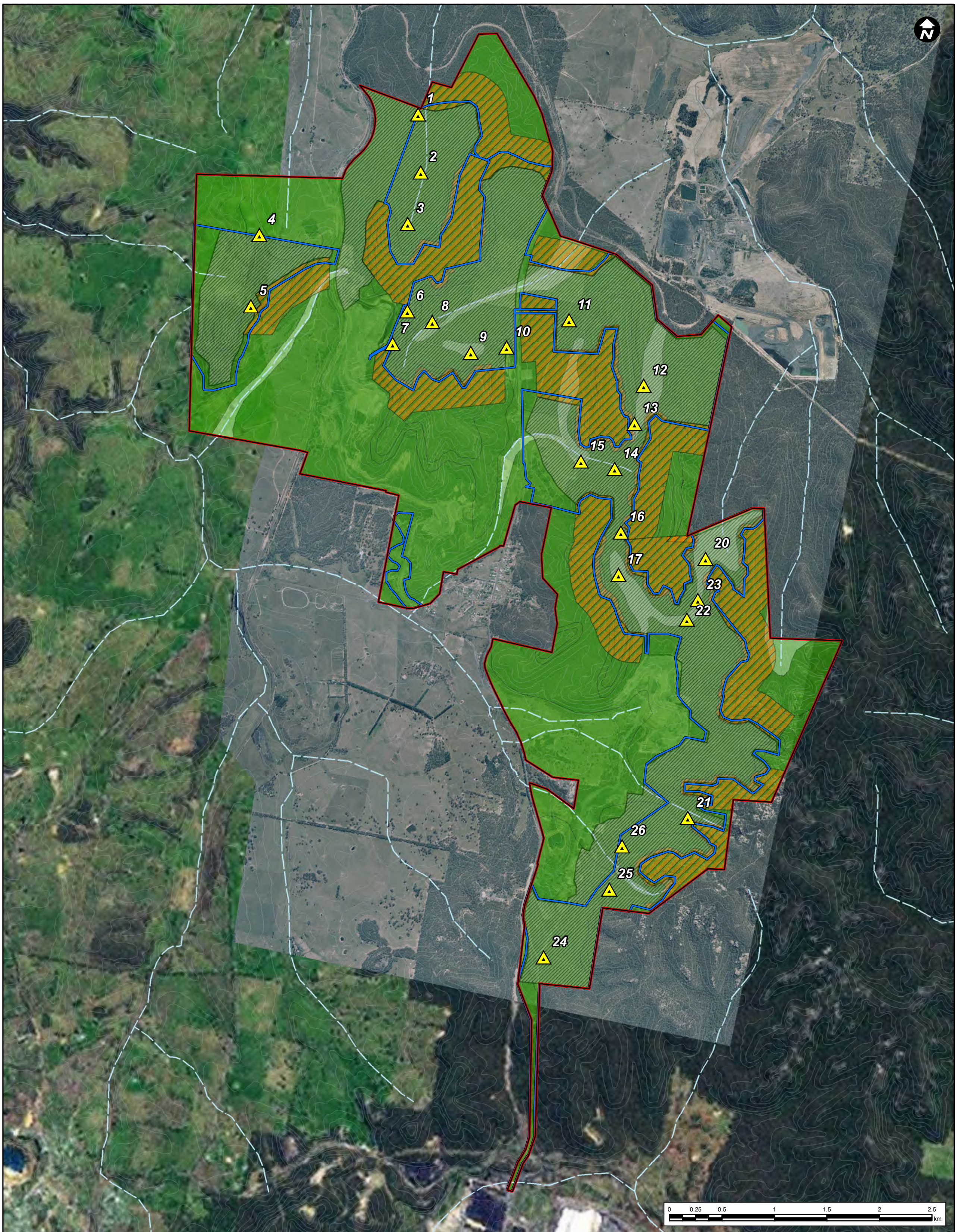
Figure 7 - Land Suitability Class for Cropping



Legend

Project Boundary
Disturbance Boundary
Existing Operations Areas
High Wall Mining Areas
Test Pit Location
Watercourse (Non-perennial)
10m Contours (SRTM Derived)

Land Suitability Class - Cropping

4
5

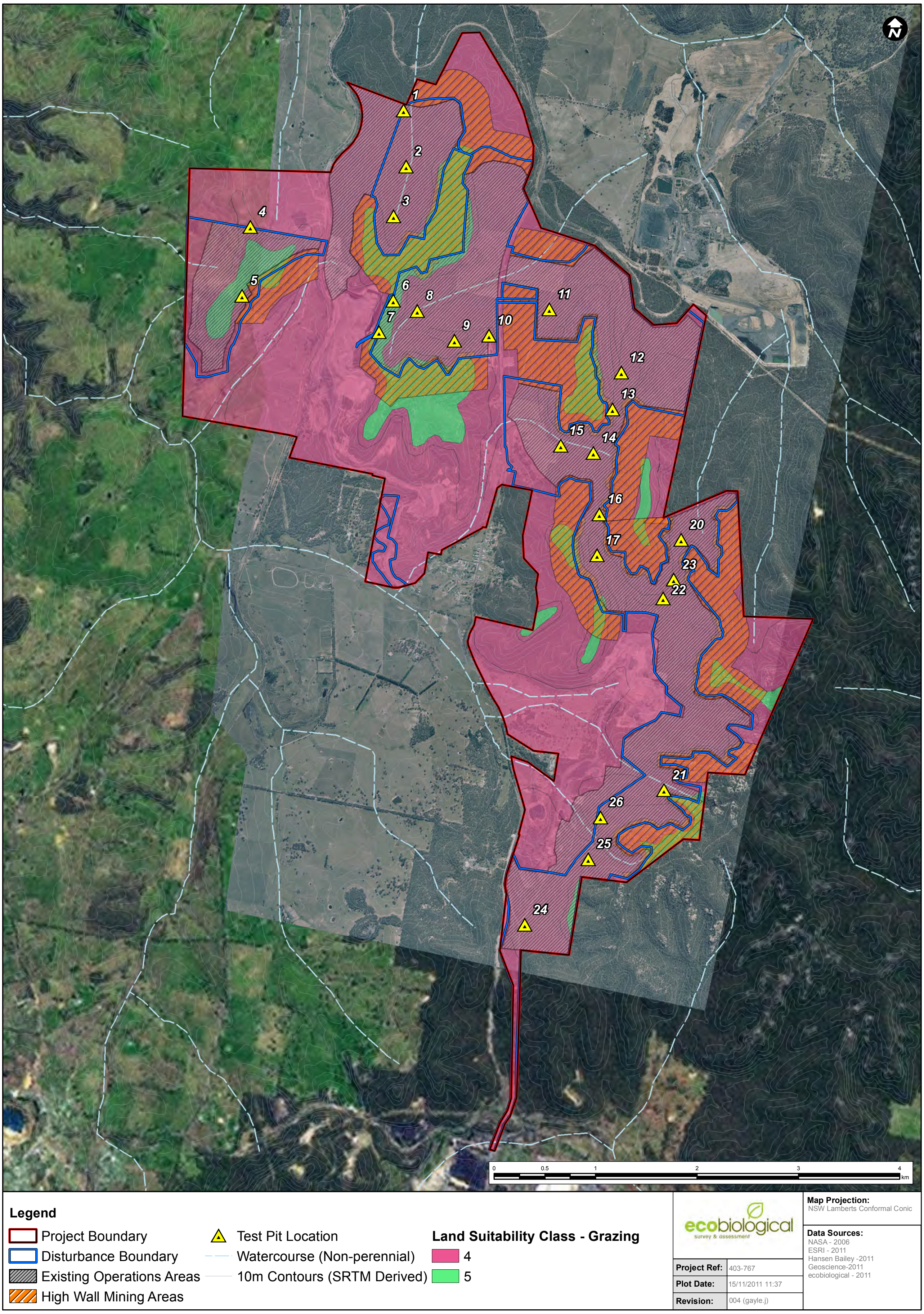
ecobiological survey & assessment

Project Ref:	403-767
Plot Date:	15/11/2011 11:34
Revision:	004 (gayle.j)

Map Projection:
NSW Lamberts Conformal Conic

Data Sources:
NASA - 2006
ESRI - 2011
Hansen Bailey -2011
Geoscience-2011
ecobiological - 2011

Figure 8 - Land Suitability Class for Grazing



3.6.2. Post Mining

Within the Project Boundary, it is expected that the impacts of disturbance through mining activities will vary between areas. In most cases this will likely result in modification of land thereby affecting its suitability and capability.

To sustain the desired land use without severe land degradation, it is important that the post-mining land only be used in accordance with the limits of the land suitability assessment.

The post mining land capability target is to rehabilitate disturbed areas back to either high quality grassland and or bushland (depending on original land use).

There are several factors which should be considered to ensure that post mining land is restored to the most useable state. These considerations include:

- Maintaining the ability to access and manage livestock,
- Maintaining flood free and relatively dry ground conditions,
- Providing adequate stock drinking water and shelter,
- Allowing for the creating of stock routes throughout the land,
- Provide environmental controls such as structural soil conservation works, and
- Developing effective revegetation management plans during mine operation and closure.

Impacts should be strictly restricted to the Disturbance Boundary to reduce potential adverse effects to neighbouring land.

4. Management and Mitigation Recommendations

The following management and mitigation strategies are recommended for implementation during mining, in order to reduce the potential for degradation within the Project Boundary and adjoining lands. These recommendations are based on the assessment of the existing site conditions and experience with the management of mining surface impacts at sites throughout New South Wales and Central Queensland.

4.1. Topsoil Stripping and Handling

Where topsoil stripping and transportation is required, the following topsoil handling techniques are recommended to prevent excessive soil deterioration.

- Strip material generally to the depths stated in Table 9, 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.
- Marker pegs should be used to indicate required stripping depth in the uniform clays (brown clays and dark clays). Especially where over-stripping may expose potentially dispersive subsoils.
- 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 elevating scrapers, or for loading into rear dump trucks by front-end loaders, are examples of less aggressive soil handling systems. This minimises compression effects of the heavy equipment that is often necessary for economical transport of soil material and reduces potential negative impacts on the seedbank.
- Soil transported by dump trucks may be placed directly into storage. Soil transported by bottom dumping scrapers is best pushed to form

stockpiles by other equipment (e.g. dozer) to avoid tracking over previously laid soil.

- The surface of soil stockpiles should be left in as coarsely textured a condition as possible in order to promote infiltration and minimise erosion until vegetation is established and to prevent anaerobic zones forming.
- As a general rule, maintain a maximum stockpile height of 3 m. Clayey soils, such as the brown clay topsoil, should be stored in lower stockpiles for shorter periods of time (i.e. less than 12 months) compared to sandier soils, selected from the alluvial 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.
- An inventory of available suitable surface cover material should be maintained to ensure adequate topsoil materials are available for planned rehabilitation activities.

4.2. Topsoil Re-spreading

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

Where possible, suitable topsoil should be re-spread directly onto reshaped areas. Where topsoil resources allow, topsoil should be spread to a minimum depth of 10 cm on all regraded spoil.

Topsoil should be spread, treated with fertilizer or ameliorants (if required) and seeded in one consecutive operation, to reduce the potential for topsoil loss to wind and water erosion.

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

4.3. Landform Design and Erosion Control

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

4.3.1. 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.

4.3.2. Erosion and Sediment Control

The most significant means of controlling surface flow on disturbed areas is to construct contour furrows or contour banks at intervals down the slope. The effect of these is to divide a long slope into a series of short slopes with the catchment area commencing at each bank or furrow. This prevents runoff from reaching a depth of flow or velocity that would cause erosion. As the slope angle increases, the banks or furrows must be spaced closer together until a point is reached where they are no longer effective.

Contour ripping across the grade is by far the most common form of structural erosion control on mine sites as it simultaneously provides some measure of erosion protection and cultivates the surface in readiness for sowing.

Graded banks are essentially a much larger version of contour furrows, with a proportionately greater capacity to store runoff and/or drain it to some chosen discharge point. The banks are constructed away from the true contour, at a designed gradient (0.5% to 1%) so that they drain water from one part of a slope to another; for example, towards a watercourse or a sediment control dam.

Eventually, runoff that has been intercepted and diverted must be disposed of down slope. The use of engineered waterways using erosion blankets, ground-cover vegetation and/or rip rap is recommended to safely dispose of runoff down slope.

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

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

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

4.3.3. Seedbed Preparation

Thorough seedbed preparation should be undertaken to ensure optimum establishment and growth of vegetation. All topsoiled areas should be contour ripped using a small dozer with a 3 tyned ripper attachment (after topsoil spreading) to create a "key" between the soil and the spoil.

Ripping should be undertaken on the contour and the tynes lifted for approximately 2 m every 200 m to reduce the potential for channelized erosion. Best results will be obtained by ripping when soil is moist and when undertaken immediately prior to sowing. The respread topsoil surface should be scarified prior to, or during seeding, to reduce run-off and increase infiltration. This can be undertaken by contour tilling with a fine-tyned plough or disc harrow.

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Appendix 1: Field Assessment Procedure

Elliott and Veness (1981) have described the basic procedure, adopted in this survey, for the recognition of suitable topdressing materials. In this procedure, the following soils factors are analysed. They are listed in decreasing order of importance.

Structure Grade

Good permeability to water and adequate aeration are essential for the germination and establishment of plants. The ability of water to enter soil generally varies with structure grade (Charman, 1978) 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.

Consistence - Shearing Test

The shearing test is used as a measure of the ability of soils to maintain structure grade.

Brittle soils are not considered suitable for revegetation where structure grade is weak or moderate because peds are likely to be destroyed and structure is likely to become massive following mechanical work associated with the extraction, transportation and spreading of topdressing material.

Consequently, surface sealing and reduced infiltration of water may occur which will restrict the establishment of plants.

Consistence - Disruptive Test

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

Mottling

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 unsuitable for revegetation purposes.

Macrostructure

Refers to the combination or arrangement of the larger aggregates or peds in the soil. Where these peds are larger than 10 cm (smaller dimension) in the subsoil, soils are likely to either slake or be hardsetting and prone to surface sealing. Such soils are undesirable as topdressing materials.

Texture

Soils with textures coarser than sandy loams are considered unsuitable as topdressing materials for climates of relatively unreliable rainfall

Root Density and Root Pattern

Root abundance and root branching is a reliable indicator of the capability for propagation and stockpiling.

Field Exposure Indicators

The extent of colonisation of vegetation on exposed materials as well as the surface behaviour and condition after exposure is a reliable field indicator for suitability for topdressing purposes. These layers may alternate with other layers which are unsuitable. Unsuitable materials may be included in the topdressing mixture if they are less than 15cm thick and comprise less than 30 per cent of the total volume of soil material to be used for topdressing. Where unsuitable soil materials are more than 15cm thick they should be selectively discarded.

Appendix 2: Test Significance and Typical values

Particle Size Analysis

Particle size analysis measures the size of the soil particles in terms of grainsize fractions, and expresses the proportions of these fractions as a percentage of the sample. The grainsize fractions are:

- clay (<0.002 mm)
- silt (0.002 to 0.02 mm)
- fine sand (0.02 to 0.2 mm)
- medium and coarse sand (0.2 to 2 mm)

Particles greater than 2 mm, that is gravel and coarser material, are not included in the analysis.

Emerson aggregate test

Emerson aggregate test measures the susceptibility to dispersion of the soil in water. Dispersion describes the tendency for the clay fraction of a soil to go into colloidal suspension in water. The test indicates the credibility and structural stability of the soil and its susceptibility to surface sealing under irrigation and rainfall. Soils are divided into eight classes on the basis of the coherence of soil aggregates in water.

The eight classes and their properties are:

- Class 1 - very dispersible soils with a high tunnel erosion susceptibility.
- Class 2 - moderately dispersible soils with some degree of tunnel erosion susceptibility.
- Class 3 - slightly or non-dispersible soils which are generally stable and suitable for soil conservation earthworks.
- Class 4-6 - more highly aggregated materials which are less likely to hold water. Special compactive efforts are required in the construction of earthworks.

- Class 7-8 - highly aggregated materials exhibiting low dispersion characteristics.

The following subdivisions within Emerson classes may be applied:

- (1) slight milkiness, immediately adjacent to the aggregate
- (2) obvious milkiness, less than 50% of the aggregate affected
- (3) obvious milkiness, more than 50% of the aggregate affected
- (4) total dispersion, leaving only sand grains.

Salinity

Salinity is measured as electrical conductivity on a 1:5 soil:water suspension to give EC (1:5). The effects of salinity levels expressed as EC at 25o (dS/cm), on plants are:

- 0 to 1 very low salinity, effects on plants mostly negligible.
- 1 to 2 low salinity, only yields of very sensitive crops are restricted.
- > 2 saline soils, yields of many crops restricted.

pH

The pH is a measure of acidity and alkalinity. For 1:5 soil:water suspensions, soils having pH values less than 4.5 are regarded as strongly acid, 4.5 to 5.0 moderately acidic, and values greater than 7.0 are regarded as alkaline. Most plants grow best in slightly acidic soils.

Phosphorus

Phosphorus is an important soil component indicating a main limiting growth factor. The phosphorus that is available to the plant is only a small fraction of the total amount of phosphorus in the soil. Extractable phosphorus was determined by the Bray No. 2 test.

Available phosphorus at 5 ppm is considered the deficiency limit whereas levels greater than 25 ppm are very high.

Phosphorus Sorption

Phosphorus sorption relates to the ability of a soil to remove phosphorus from solution and assimilate it within the soil matrix. Sorption index ratings are:

- 0 – 3 low
- 3 – 4.5 moderate
- 4.5 – 6 high
- >6 very high

Nitrogen

Nitrogen is another important component of soil indicating a main limiting growth factor. The total amount of nitrogen in the soil was determined by the Kjeldahl method, which is essentially a wet-oxidation procedure. The total nitrogen of soils ranges from less than 0.2 per cent in subsoils to greater than 2.5 per cent in peats. The surface layer of most cultivated soils contains between 0.06 to 0.5% N. As a guide, the following figures for total nitrogen may be used:

- less than 0.1% N low
- 0.1 to 0.2% N medium
- more than 0.2% N high

Cation Exchange Capacity and Exchangeable Cations

The concentration of cations is expressed as milli-equivalents (me)/100 g or mmol/kg. This takes account of their different valencies and atomic weights. The total quantities of cations that a soil can hold is called the cation exchange capacity (CEC), also expressed as me/100 g.

The five most abundant cations in soils are calcium (Ca^{2+}), magnesium (Mg^{2+}), potassium (K^{+}), sodium (Na^{+}) and in strongly acid soils, aluminum (Al^{3+}). The cations manganese (Mn^{2+}), iron (Fe^{2+}), copper (Cu^{2+}) and zinc (Zn^{2+}) are usually in amounts that do not contribute significantly to the cation complement. The following rankings are applicable:

Cation (me/100g)	Ranking				
	Very Low	Low	Moderate	High	Very High
CEC	<5	5-10	0.-15	15-35	>35
Na	<0.1	0.1-0.3	0.3-0.7	0.7-2.0	>2.0
K	<0.2	0.2-0.4	0.4-0.7	0.7-2.0	>2.0
Ca	<2	2-5	5-10	10-20	>20
Mg	<0.3	0.3-1.0	1.0—3.0	3.0-8.0	>8.0

Soils or substrates having values of exchangeable sodium percentage (ESP) exceeding 5 me% are described as sodic and greater than 15 me% as strongly sodic. The clay particles in such soils are liable to disperse on wetting, causing structure to deteriorate and surface sealing to occur.

Organic Carbon

Organic Carbon content can be directly related to the levels of soil organic matter and is based on the (Walkley – Black) chromic acid method. Percentage organic matter can be obtained by multiplying percentage organic carbon by 1.72. This factor is based on the assumption that organic matter in the soil has a constant carbon composition of 58 per cent. The following rankings of organic carbon are applicable:

- 0 – 0.5% very low
- 0.5 – 1.5% low
- 1.5 – 2.5% moderate
- 2.5 – 5.0% high
- >5% very high

Appendix 3: Laboratory Test Methods

Particle Size Analysis

Determination by sieving and hydrometer of percentage, by weight, of particle size classes: Gravel >2mm, Coarse Sand 0.2-2 mm, Fine Sand 0.02-0.2 mm, Silt 0.002-0.2 mm and Clay <0.002 mm SCS Standard method. Reference - Bond, R, Craze B, Rayment G, and Higginson (in press 1990) Australia Soil and Land Survey Laboratory Handbook, Inkata Press, Melbourne.

Emerson Aggregate Test

An eight class classification of soil aggregate coherence (slaking and dispersion) in water. SCS Standard Method closely related to Australian Standard AS1289. The degree of dispersion is included in brackets for class 2 and 3 aggregates. Reference -Bond R., Craze, B., Rayment, G., Higginson, F.R., (in press 1990). Australian Soil and Land survey Laboratory Handbook, Inkata Press, Melbourne.EC

Electrical Conductivity

Determined on a 1:5 soil:water suspension. Prepared from the fine earth fraction of the sample. Reference - Bond R, Craze B, Rayment G, Higginson FR (in press 1990) Australian Soil and Land Survey Handbook. Inkata Press, Melbourne.

pH

Determined on a 1:5 soil:water suspension. Soil refers to the fine earth fraction of the sample. Reference - Bond, R., Craze, B., Rayment, G., Higginson, F.R. (in press 1990). Australian Soil and Land Survey Handbook. Inkata Press, Melbourne.

Nitrogen

Measurement of soil total N is based on wet oxidation known as the Kjeldahl method. Reference - Bond, R., Craze, B., Rayment, G., Higginson, F.R. (in press 1990).Australian Soil and Land Survey Handbook. Inkata Press, Melbourne.

Phosphorus

The Bray phosphorus method extracts plant available phosphorus from the soil matrix using fluoride after centrifugation. Reference - Bond, R., Craze, B., Rayment, G., Higginson, F.R. (in press 1990). Australian Soil and Land Survey Handbook. Inkata Press, Melbourne.

Phosphorus Sorption

A standard phosphorus solution is added to a soil. After equilibrium the phosphorus remaining in solution is measured colorimetrically and the phosphorus "fixed" by the soil determined by difference. Reference – Abott TS (1987) BCRI Soil Testing Methods.

Cation Exchange Capacity

CEC and exchangeable cations are determined by a single extraction using unbuffered (AgTU)+. Reference - Bond, R., Craze, B., Rayment, G., Higginson, F.R. (in press 1990). Australian Soil and Land Survey Handbook. Inkata Press, Melbourne.

Organic Carbon

Walkley-Black method. Organic matter is oxidized by dichromate. The amount of dichromate reduced is determined by titration with ferrous sulphate using Ferroin indicator. Reference – Allison LE in Black CA et al (1965). Methods of Soil Analysis 1372-1378.

Appendix 4: Soil Test Laboratory Data

Lab No	Sample ID	P7B/2 Particle Size Analysis (%)					P9B/2	C1A/4	C2A/3	C2B/3
		clay	silt	f sand	c sand	gravel	EAT	EC (dS/m)	pH	pH (CaCl2)
1	TP 1 L2	16	16	25	32	11	3(1)	0.01	4.9	3.9
2	TP1 L3	35	9	14	30	12	5	0.01	5.0	3.8
3	TP4 L1	32	31	17	11	9	3(1)	0.23	5.0	4.4
4	TP4 L2	76	14	8	2	0	6	0.08	5.1	4.0
5	TP6 L1	6	7	17	46	24	3(1)	<0.01	5.1	4.1
6	TP8 L2	11	8	15	51	15	5	<0.01	5.2	4.1
7	TP9 L2	9	10	15	41	25	5	0.01	5.7	4.6
8	TP10 L1	10	19	30	17	24	5	0.02	6.1	5.1
9	TP10 L2	13	20	25	12	30	5	<0.01	6.2	4.9
10	TP10 L3	18	17	41	6	18	5	0.01	5.8	4.1
11	TP11 L1	13	16	24	40	7	8	0.01	5.5	4.3
12	TP11 L2	14	14	25	38	9	5	<0.01	5.8	4.2
13	TP11 L3	28	13	17	28	14	5	<0.01	6.1	4.2
14	TP12 L1	7	3	19	61	10	8	0.02	5.6	4.6
15	TP12 L2	5	4	13	55	23	3(1)	<0.01	6.1	4.9
16	TP12 L3	5	4	11	55	25	5	<0.01	6.5	4.9
17	TP12 L4	11	8	15	42	24	5	0.01	6.4	4.9
18	TP12 L5	6	9	16	51	18	5	<0.01	6.5	5.0
19	TP13 L1	8	7	14	39	32	8	0.05	6.0	5.2
20	TP13 L2	8	9	11	36	36	5	<0.01	6.4	5.1
21	TP13 L3	3	3	7	38	49	3(1)	<0.01	6.7	5.1
22	TP16 L1	2	2	5	26	65	8	<0.01	4.6	3.5
23	TP16 L2	12	7	11	47	23	5	<0.01	4.9	4.1
24	TP17 L1	6	9	11	40	34	8	0.02	5.8	4.8
25	TP17 L2	8	6	10	52	24	6	<0.01	5.6	4.7
26	TP20 L1	11	14	18	38	19	5	0.04	4.9	4.1
27	TP20 L2	15	16	17	34	18	5	<0.01	5.6	4.3
28	TP20 L3	9	12	19	47	13	5	<0.01	6.7	4.8
29	TP21 L1	14	17	20	25	24	8	0.17	5.1	4.5
30	TP21 L2	18	17	18	22	25	3(1)	0.01	5.4	4.1
31	TP24 L1	10	12	29	35	14	8	0.03	5.5	4.4
32	TP24 L2	19	17	27	29	8	3(2)	0.01	5.0	3.9
33	TP24 L3	41	19	12	20	8	5	<0.01	5.0	3.8
34	TP24 L4	32	21	13	22	12	5	0.06	5.0	3.8
35	TP25 L1	16	22	34	23	5	5	0.01	5.0	3.9
36	TP25 L2	34	18	21	19	8	5	0.01	4.9	3.8
37	TP25 L3	40	15	28	10	7	5	0.02	5.3	3.7
38	TP26 L1	13	15	32	32	8	3(1)	0.01	5.3	4.2
39	TP26 L2	19	18	22	25	16	3(1)	0.01	4.6	3.7
40	TP26 L3	37	12	12	21	18	5	<0.01	4.8	3.7
41	TP26 L4	34	19	23	17	7	2(1)	<0.01	5.0	3.7

Appendix 5: Test Pit Field Data

Test Pit No	Layer	Depth (cm)	Moisture	Colour	Mottles	Ped Size (mm)	Consistency	Structure	Boundary
	1	21	low	7.5yr 5/3	Low	4 to 10	Loose	Granular	Clear
	2	52	low	7.5yr 7/3	Low	4 to 10	Hard	Blocky	Clear
1	3	117	medium	7.5 yr 6/6	Medium Cream Orange	4 to 8	Hard	Blocky	
	Refusal								
	1	24	low	7.5yr 5/3	Low	4 to 10	Low	Granitic	Clear
	2	60	low	7.5yr 7/3	Low	4 to 10	Hard	Blocky	Clear
	3	240	medium	7.5yr 6/6	Medium Cream Orange	4 to 8	Hard	Blocky	
2	Refusal								
	1	25	low	7.5yr 5/3	low	2 to 6	loose	Granular	Clear/Wavey
	2	74	low	7.5yr 7/3	low	2 to 5	medium dense	Blocky/Granular	Clear/Wavey
	3	180	medium	7.5yr 6/6	high	4 to 10	Hard	Blocky	
3	Refusal								
	1	25	low	7.5yr 7/5	None	>1	Soft	Granular/Fine Gravel	Clear
4	2	75	low	7.5yr 7/4	Low Cream Orange	5 to 8	Firm	Blocky	
	1	7	low	7.5yr 7/5	None	1 to 2	Loose	Granular	Clear
	2	50	low	7.5yr 7/4	None	1 to 5	medium dense	Granular	
5	No Refusal								
	1	39	low	7.5yr 6/3	low	2 to 5	loose	granular	Clear
6	Refusal								
	1	20	low	7.5yr 6/3	Low	2 to 5	loose	Granular	Clear
	2	40	low	7.5yr 7/2	Low	1 to 3	loose	Granular	
7	Refusal								

Test Pit No	Layer	Depth (cm)	Moisture	Colour	Mottles	Ped Size (mm)	Consistency	Structure	Boundary
	1	5	low	7.5yr 5/3	None	1 to 2	loose	Granular	Blurred
	2	50	medium	7.5yr 7/3	Low	2 to 5	Firm	Granular	Clear/Wavey
	3	170	medium	7.5yr 6/6	Medium Cream Orange	2 to 5	Firm	Granular	
8	Refusal								
	1	5	low	7.5yr 4/4	None	2 to 3	Low	Granular	Blurred
	2	110	low	7.5yr 3/4	None	3 to 5	medium dense	Granular	Blurred
	3	280	High	7.5yr 6/6	Low	2 to 3	Loose	Granular	
9	No Refusal								
	1	22	low	7.5yr 5/6	None	1 to 2	loose	Granular/Fine	Blurred
	2	72	low	7.5yr 6/6	None	2 to 4	loose	Granular/fine	Clear
	3	110	low	7.5yr 7/6	Medium Cream Orange	3 to 5	loose	Blocky	Clear
10	Refusal								
	1	14	low	7.5yr 5/3	Low	less than 3	Firm	Granular	Wavey
	2	59	medium	7.5yr 7/3	Medium Grey/Yellow	3 to 5	Firm	Granular	Wavey
	3	153	medium	7.5yr 6/6	High Grey/Yellow	2 to 5	Hard	Blocky	
11	Refusal								
	1	12	low	7.5yr 4/4	Low	less than 2	loose	Granular	clear
	2	80	low	7.5yr 3/4	Low	2 to 4	loose	Granular	clear
	3	150	medium	7.5yr 6/4	Low	2 to 5	loose	Granular	clear
12	Refusal								

Test Pit No	Layer	Depth (cm)	Moisture	Colour	Mottles	Ped Size (mm)	Consistency	Structure	Boundary
	1	25	low	7.5yr 4/4	Low	2 to 3	loose	Granular	Clear/wavey
	2	78	low	7.5yr 3/4	Low	2 to 5	loose	Granular	Blurred
	3	187	medium	7.5yr 6/4	Medium Charcoal/Sand	3 to 6	medium dense	Granular	
13	Refusal								
	1	35	low	7.5yr 5/3	None	1 to 2	loose	Granular	Clear/Wavey
	2	200	low	7.5yr 7/8	low	2 to 6	Firm	Blocky	
14	No Refusal								
	1	59	medium	7.5yr 4/4	None	2 to 5	Firm	Granular	Clear
	2	130	medium	7.5yr 3/4	Low	2 to 6	Firm	Blocky	Clear
	3	250	medium	7.5yr 6/6		1 to 2	Loose	Granular	
15	No Refusal								
	1	9	low	7.5yr 6/3	low	2 to 5	loose	granular	Wavey
	2	47	low	7.5yr 7/2	Medium Grey/Yellow	2 to 5	hard	granular	
16	Refusal								
	1	21	low	7.5yr 4/4	Low	2 to 4	loose	Granular	Clear
	2	145	medium	7.5yr 3/4	Low	2 to 6	medium dense	Granular	Clear
	3	220	medium	7.5yr 6/4	Medium Cream Orange	2 to 8	Loose	Blocky	
17	No Refusal								
	1	57	medium	7.5yr 5/3	Low	1 to 3	Loose	Granular	Blurred
	2	100	medium	7.5yr 4/3	Medium	3 to 8	medium dense	Blocky	Blurred
	3	230	medium	7.5yr 6/6	Medium	2 to 7	Firm	Granular	Blurred
20	No Refusal								

Test Pit No	Layer	Depth (cm)	Moisture	Colour	Mottles	Ped Size (mm)	Consistency	Structure	Boundary
	1	7	low	10yr 3/2	None	5	soft	Blocky	Clear
	2	40	low	10yr 5/3	None	7 to 10	Soft	Blocky	Blurred
	3	114	low	10yr 6/8	low	5 to 8	Firm	Blocky/Gravel	Blurred
	4	220		10yr 7/1	High with Silt Fragments and cobblestones	10	Firm	Blocky/Shale	clear and wavey
21	Refusal				Highly variable refusal due to weathered siltstone shelf				
	1	43	low	7.5yr 4/4	None	2 to 5	loose	Granular	Clear
	2	125	medium	7.5yr 3/4	low	less than 1	medium dense	Blocky	Blurred
	3	201	medium	7.5yr 6/6	low	2 to 5	loose	Granular	
22	No Refusal								
	1	70	medium	7.5yr 5/3	None	2 to 4	loose	Granular	Clear Wavey
	2	200	medium	7.5yr 4/3	Low	3 to 8	medium dense	Granular	
23	No Refusal								
	1	5	low	10yr 5/3	None	2	Soft Loose	Granular	Clear
	2	22	low	10yr 6/4	None	<4	Soft	Granular	Blurred
	3	90	low	10yr 6/8	Medium Cream Orange	5 to 7	Firm	Blocky	Wavey
24	4	210	low	10yr 8/3	High Grey/Yellow	5 to 10	Hard	Blocky	
	No Refusal								
	1	20	low	10yr 6/8	None	<2	soft	Granular	Blurred
	2	34	low	10yr 7/8	None	<4	soft	Granular	Blurred
	3	105	low	10yr 5/6	Medium Grey/Yellow	<5	Firm	Blocky	Clear
25	Refusal								

Test Pit No	Layer	Depth (cm)	Moisture	Colour	Mottles	Ped Size (mm)	Consistency	Structure	Boundary
	1	9	low	10yr 6/4	None	>2	Soft	Granular	Blurred
	2	27	low	10yr 6/6	None	>2	Soft	Granular	Blurred
	3	67	low	10yr 6/6	Low Cream/Orange	5	Firm	Blocky	Wavey
	4	114	low	10yr 7/2	Low Cream/Orange	5	Firm	Blocky	Clear
26	Refusal								