AUSTRALIAN
ZIRCONIA LTD
(A wholly owned subsidiary of Alkane Resources Ltd)

# Dubbo Zirconia Project

## Soils and Land Capability Assessment

Prepared by

**Sustainable Soils Management Pty Ltd**

**August 2013**

**Specialist Consultant Studies Compendium**
**Volume 3, Part 10**

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# Soils and Land Capability Assessment

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**August 2013**

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# EXECUTIVE SUMMARY

This report describes soil properties across 3,460ha of land within and surrounding the proposed Dubbo Zirconia Project, which is situated approximately 25km south of Dubbo.

The soils within the survey area are located on undulating landscapes with complex geology. Although this complex geology is an important factor in the high concentration of the minerals that are proposed to be mined, it results in a complex distribution of soil properties.

The soil assessment builds on data from regional scale soil landscape, geology, hydrogeological landscapes, and radiometric mapping. This was supplemented by local data from 23 piezometers drilled to depths of between 40m and 70m, a detailed digital elevation model and aerial imagery. An electromagnetic survey was conducted to quantify variation in soil profiles and was validated by description of soil profiles using both pedological and geotechnical criteria. Laboratory tests were also conducted measuring both soil chemical and engineering properties.

This comprehensive assessment of soil and landscape properties allowed the assessment of the agricultural capability of the land and the likely performance under a range of soil disturbance scenarios that are likely to be associated with the mining development.

The soil assessment resulted in the division of the DZP Site into 10 soil landscapes. Each soil landscape is a tract of land with relatively uniform landform pattern, microclimate, parent material and soil class. As a result, each soil landscape unit generated from this process contains a range of soil types.

A summary of the key features of each soil landscape is provided in **Table A**. The soil landscapes are grouped by the underlying geology as this underlying geology is an important constraint on the range of soil properties. The geological subdivisions are:

- Silurian sedimentary rock and metasediments;
- Mesozoic sedimentary rock;
- Quaternary alluvium;
- Jurassic basalt; and
- Jurassic trachyte.

The Proposal would result in disturbance of up to 808ha of the Soil Survey Area. Disturbance from the Proposal would vary from relatively minor beneath roads to removal of 20 m or more of material from the Open Cut, so the degree of disturbance beneath the structures of the Proposal is outlined below.

Of the land disturbed, up to 140ha has been allocated for the stockpiling of soil (with 11ha of this occurring within the impact footprint of the proposed Salt Encapsulation Cells). It is planned to establish improved pasture on these stockpiles during the life of the Proposal, and graze them conservatively. It should be possible to rehabilitate the land beneath these stockpiles to a state that is similar to that which existed prior to disturbance.

## Table A
## Summary of Key Features of the Soil Survey Area Soil Landscapes

### LANDSCAPES ON SILURIAN GEOLOGY

**ARTHURVILLE** (168ha)

***Landform***: Gently undulating rises and undulating low hills with mixed sedimentary and volcanics in Cowra Trough.

***Vegetation***: White box and yellow box in lower lying areas.

***Soil Type***: Dominant soil types were very deep Red Chromosols with Yellow and Brown Sodosols along drainage lines.

***Soil Properties***: Tested soil had a relatively small capacity to store nutrients, and had moderately acidic topsoil with moderate organic carbon content. Moderate nutrient levels. Low salinity.

***Agricultural Capability***: Class 3 to 5

***Geotech***: Generally unsuitable for evaporation ponds because of undulating landscape

| ***Soil Erodibility factor***: | ***Subsoil settling class***: | ***Soil Stripping Suitability***: |
|---|---|---|
| 0.026 and 0.036 | F | Topsoil likely to be suitable to 25cm |

**SPLITTERS HILL** (193ha)

***Landform***: Undulating and rolling hills on Silurian vertically bedded shale and sandstone.

***Vegetation***: White box associated with Brown Chromosols on andesites.

***Soil Type***: Dominant soil types were Mainly Red Chromosols but a variety of others depending on parent material. Brown Chromosols on andesites.

***Soil Properties***: Tested soil had a relatively small capacity to store nutrients, and had moderately acidic topsoil with moderate organic carbon content. Low nutrient levels. Low salinity.

***Agricultural Capability***: Class 3 and 4 on shallower rocky soils.

***Geotech:*** Generally unsuitable for evaporation ponds because of shallow depth to rock and undulating landscape.

| ***Soil Erodibility factor:*** | ***Subsoil settling class:*** | ***Soil Stripping Suitability:*** |
|---|---|---|
| 0.031 | Not assessed | Topsoil likely to be suitable to 10cm |

**NUBINGERIE** (101ha)

***Landform***: Undulating low hills mainly on andesites and metasediments from the Cowra trough.

***Vegetation***: White box and yellow box in lower lying areas.

***Soil Type***: Dominant soil types were moderately deep to giant Red and Yellow Chromosols.

***Soil Properties***: Tested soil had a relatively small capacity to store nutrients, and had moderately acidic topsoil with moderate organic carbon content. Phosphorous adequate, but other nutrients at low levels. Low salinity.

***Agricultural Capability:*** Generally Class 3 with Class 4 on shallower rocky soils.

***Geotech:*** Material appeared to be adequate for embankment construction, but landscape is dissected by drainage lines.

| ***Soil Erodibility factor***: | ***Subsoil settling class***: | ***Soil Stripping Suitability***: |
|---|---|---|
| 0.021 | Not assessed | Marginal due to weak grade of structure |

**Table A (Cont'd)**
**Summary of Key Features of the Soil Survey Area Soil Landscapes**

## LANDSCAPES ON MESOZOIC SEDIMENTARY ROCK

**BALLIMORE** (940ha)

***Landform***: Footslopes and some undulating low hills on flat lying Napperby Formation sandstone, conglomerates, ferruginous material and siltstone.

***Vegetation***: Grey box with white pine on upper slopes and fuzzy box on lower slopes.

***Soil Type***: Dominated by deep Red Chromosols with possible localised very deep Yellow Sodosols on lower slopes and depressions.

***Soil Properties***: Tested soil had a relatively small capacity to store nutrients, had moderately acidic topsoil, and neutral subsoil with moderate organic carbon content in the surface to 10 cm layer. Low nutrient levels. Low salinity.

***Agricultural Capability:*** Generally 3 and 4 with small areas of 5 on shallow soils and upper slopes and in areas where landscape forms low hills.

***Geotech:*** Estimate that up to half landscape may be suitable for location of evaporation ponds.

| ***Soil Erodibility factor***: | ***Subsoil settling class***: | ***Soil Stripping Suitability***: |
|---|---|---|
| 0.026 to 0.041 | F and C | Topsoil likely to be suitable to 25cm |

**TURKEY RANGE** (68ha)

***Landform***: Undulating to rolling low hills and hills on Jurassic Purlewaugh sandstones and mudstones.

***Vegetation***: Black cypress pine, grey box, and Blakely's red gum and tumbledown gum.

***Soil Type***: Dominant soil types were shallow to moderately deep Brown Kurosols and Yellow Sodosols.

***Soil Properties***: Tested soil had a relatively small capacity to store nutrients, and had moderately acidic topsoil with moderate organic carbon content. Low nutrient levels. Low salinity.

***Agricultural Capability***: Class 5 to with Class 6 on upper slopes.

***Geotech:*** Best left undisturbed.

| ***Soil Erodibility factor***: | ***Subsoil settling class***: | ***Soil Stripping Suitability***: |
|---|---|---|
| 0.032 | Not assessed. | Unsuitable. |

## LANDSCAPE ON QUATERNARY ALLUVIUM

**MITCHELL CREEK** (72ha)

***Landform***: Recent alluvial deposits on floodplains along Wambangalang Creek.

***Vegetation***: River red gum and river she oak with rough barked apple and apple box. Yellow and grey box found on outer edge of floodplain.

***Soil Type***: Highly variable soils including sandy Stratic Rudosols and giant Brown Dermosols.

***Soil Properties***: Tested soil had a relatively small capacity to store nutrients, and had moderately acidic topsoil with moderate organic carbon content. Phosphorous adequate, but other nutrients at low levels. Low salinity.

***Agricultural Capability***: Generally Class 2, but may become Class 1 where floodplain is broader away from survey area. Class 6 along drainage lines.

***Geotech:*** Generally within 200 m of Wambangalang Creek. Sensitive area where it is inappropriate that ponds be constructed.

| ***Soil Erodibility factor***: | ***Subsoil settling class***: | ***Soil Stripping Suitability***: |
|---|---|---|
| 0.031 | Not assessed | Topsoil likely to be suitable to 25cm |

## Table A (Cont'd)
## Summary of Key Features of the Soil Survey Area Soil Landscapes

### LANDSCAPES ON JURASSIC BASALT

**BALD HILL** (84ha)

***Landform***: Low hillocks with moderately steep slopes on basalt rock outcrop.

***Vegetation***: White box and kurrajong.

***Soil Type***: Dominated by shallow to moderately deep Red Ferrosols.

***Soil Properties***: Tested soil had a moderate capacity to store nutrients, and had moderately acidic topsoil with moderate organic carbon content. Phosphorous adequate but other nutrients at low levels. Low salinity.

***Agricultural Capability***: Class 3 to 4 (Lower slopes) and 5.

***Geotech:*** Generally unsuitable for evaporation ponds because of undulating landscape.

| ***Soil Erodibility factor***: | ***Subsoil settling class***: | ***Soil Stripping Suitability***: |
|---|---|---|
| 0.019 | D | Topsoil likely to be suitable, but relatively thin |

**WONGARBON** (450ha)

***Landform***: Gently undulating low hills with minor basaltic hillocks, often with linear gilgai.

***Vegetation***: White box and white pine.

***Soil Type***: Moderately deep Red Ferrosols and deep Red and Brown Vertosols with occasional very deep Vertic Red Dermosols (possible Ferrosols) where soil is deep but drainage is impeded below the soil.

***Soil Properties***: Tested soil had a moderate capacity to store nutrients, and had neutral topsoil with moderate organic carbon content. Moderate nutrient levels. Low salinity, but measurable in some subsoil samples.

***Agricultural Capability***: Generally Class 3 and 4.

***Geotech:*** Variable landscape which may contain patches which are suitable for construction of ponds. Would require detailed investigation.

| ***Soil Erodibility factor***: | ***Subsoil settling class***: | ***Soil Stripping Suitability***: |
|---|---|---|
| 0.015 to 0.019 | D (4 locations) | Topsoil likely to be suitable to 25cm |

### LANDSCAPES ON JURASSIC TRACHYTE

**BELOWRIE** (960ha)

***Landform***: Undulating, occasionally rolling rises and hills on Jurassic Trachyte.

***Vegetation***: Grey box and Blakely's red gum.

***Soil Type***: Complex landscape with Red Chromosols with Red Kandosols and Brown Chromosols on more stable lower slopes and Yellow Sodosols on flatter lower areas. Shallow Rudosols and Tenosols on rocky crests. Hard setting and acidic surfaces.

***Soil Properties***: The capacity of the tested soil to hold nutrients varied from relatively low to moderate, and had a neutral topsoil with moderate organic carbon content. Low nutrient levels. Low salinity in surface layers, moderate salinity in the subsoil.

***Agricultural Capability:*** Generally 3 to 5 with localised areas of 6 on crests and outcrop.

***Geotech:*** Generally unsuitable for evaporation ponds because of undulating landscape.

| ***Soil Erodibility factor***: | ***Subsoil settling class***: | ***Soil Stripping Suitability***: |
|---|---|---|
| 0.036 and 0.046 | F and C | Variable |

**Table A (Cont'd)**
**Summary of Key Features of the Soil Survey Area Soil Landscapes**

| LANDSCAPES ON JURASSIC TRACHYTE (CONT'D) | | |
|---|---|---|
| **DOWD** (445ha) | | |
| ***Landform***: Hills of rock pavements and scarps on Jurassic Trachyte. | | |
| ***Vegetation***: Black and white pine forest. | | |
| ***Soil Type***: Very shallow soils; Leptic Rudosols, with pockets of Shallow Red Kandosol. | | |
| ***Soil Properties***: Chemical properties not assessed. | | |
| ***Agricultural Capability:*** Generally 7 with small areas of 6 where soil is deeper. | | |
| ***Geotech:*** Unlikely to be suitable for construction of ponds. | | |
| ***Soil Erodibility factor:*** | ***Subsoil settling class***: | ***Soil Stripping Suitability***: |
| Not assessed | Not assessed. | Topsoil thin, so not assessed. |

Approximately 425ha would be used for a Liquid Residue Storage Facility (LRSF). Topsoil from this area would be stored in designated stockpiles, while the subsoil would be used to construct part of the embankments. Rehabilitation would consist of forming the subgrade to the desired landform, then placing subsoil and topsoil. This should result in a profile of soil and weathered rock with similar properties to those that currently exist.

Only topsoil would be stripped from the Haul Road (7.3ha), Run of Mine Pad (4.2ha) and Processing Plant and DZP Site Administration Area (43.3ha). Rehabilitation of these areas would consist of forming the land to the desired landform, then placing topsoil. This should also result in a profile of soil and weathered rock with similar properties to those that currently exist.

Both topsoil and subsoil would be stripped from the Waste Rock Emplacement (20ha), Solid Residue Storage Facility (SRSF) (103ha) and Salt Encapsulation Cells (35ha). These areas would be used to permanently store the solid residue generated by the processing operations or crystallized salt accumulated in the LRSF. They would be rehabilitated by constructing a relatively shallow soil over the stockpiles. Capability of this land would be determined both by the utility of the stockpiled material as a deep water store for plants and the fertility and stability of the constructed soil. It would be prudent to manage this land conservatively to maximize the chances of successful rehabilitation.

The open cut (40ha) would have both topsoil and subsoil removed and stockpiled. This soil would be placed on relatively fresh rock, consequently, it would be expected that plants growing on this land would have limited agricultural productivity.

The effect of the Proposal on agricultural productivity was determined by calculating the change in estimated carrying capacity of first cross ewes on the 808ha that is planned to be disturbed. The current carrying capacity of this land was estimated to be 3 553 first cross ewes. It was estimated that this would be reduced to 387 first cross ewes during the life of the mine, and 2 138 first cross ewes after the site is rehabilitated.

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# 1. BACKGROUND

## 1.1 SCOPE

Australian Zirconia Ltd ("the Applicant") plans to develop and operate the Dubbo Zirconia Project ("the Proposal"). The Proposal would result in significant soil disturbance within the disturbance footprint which would take the forms of:

- excavation of one open cut; and
- construction of a waste rock emplacement, solid and liquid residue storage facilities, a processing plant, and other associated infrastructure.

This disturbance is described in more detail in Section 1.3.

Sustainable Soils Management was commissioned by R.W. Corkery & Co Pty Limited on behalf of the Applicant to conduct a soil survey and land capability assessment to enable the development of appropriate soil management practices during the soil stripping, storage and rehabilitation phases of the Proposal.

## 1.2 OBJECTIVES AND APPROACH TO ASSESSMENT

Soil properties vary continuously across the landscape. The aim of soil assessment is to quantify variation in relevant soil properties across the area being assessed. The assessment described in this report was conducted to assist the Applicant with soil and land management. This has been achieved by surveying the soil resources and conducting a pre-mining assessment of land capability with the objectives of:

- describing the soil and agricultural land capability within the areas of potential mining impact;
- assessing the susceptibility to water erosion of the land within the Dubbo Zirconia Project (DZP) Site;
- assessing the susceptibility to salinisation of the land within the DZP Site;
- assessing the suitability of the land for construction of the salt crystallisation cells of the Liquid Residue Storage Facility;
- assessing the suitability of the identified soil units for use during rehabilitation of areas impacted during the proposed operations; and
- developing recommendations about soil management strategies during soil stripping and stockpiling.

The assessment was conducted in the following four phases.

1. Examination of existing landscape information, principally geology, regolith and soil surveys.
2. Electromagnetic induction surveys using Geonics EM 38 and EM 31 instruments to map the pattern of subsoil salinity and permeability.
3. Soil profile descriptions to describe soil physical and morphological properties.
4. Analyses to assess soil physical and chemical properties and their variation.

## 1.3 DESCRIPTION OF THE PROPOSAL

### 1.3.1 The Application Area and Soil Survey Area

The DZP would comprise a small scale open cut mine supplying approximately 1Mt of ore containing rare metals (zirconium and niobium) and rare earth elements (REE's) (including hafnium and tantalum) to a processing plant annually (18 million tonnes of ore over a period of up to 20 years). The land on which the proposed open cut, processing plant and associated facilities for the management of waste generated by these activities is collectively referred to as the DZP Site.

The Proposal also incorporates the following four component areas (see **Figure 1**).

- Upgrade and reactivation of the Toongi to Dubbo Section of the Dubbo-Molong Rail Line. AZL also proposes to construct a pipeline to deliver compressed natural gas (CNG) from the Central West Pipeline operated by APA Group within the 'Toongi-Dubbo Rail Line and Natural Gas Pipeline Corridor';
- Construction of a water pipeline to deliver up to 4.05GL of water from the Macquarie River to the processing plant (referred to hereafter as the Macquarie River Water Pipeline).
- Upgrades, including minor realignment, creek crossing upgrade and pavement strengthening, of the public road network (Toongi Road and Obley Road).
- Construction of a 132kV electricity transmission line (ETL) from a sub-station to the southwest of Geurie to the DZP Site. The construction of this ETL is to be assessed separately under Part 5 of the EP&A Act.

Excluding the 132kV ETL, the four component areas identified above comprise the DZP Application Area.

For the purposes of the Land Capability and Soils Assessment, the Soil Survey Area consists of approximately 3 460ha which incorporates the DZP Site and additional areas beyond the DZP Site which were under consideration by the Applicant during the planning stages of the (see **Figure 2**).

### 1.3.2 Overview of the Proposal

As discussed in Section 1.3.1, the Application Area for the Proposal incorporates four distinct areas, namely:

- the DZP Site;
- Toongi-Dubbo Rail Line and Natural Gas Pipeline Corridor;
- Macquarie River Water Pipeline; and
- public road network (Toongi Road and Obley Road).

The following provides an overview of the activities to be undertaken within each of these areas.

**Figure 1 Locality Plan**

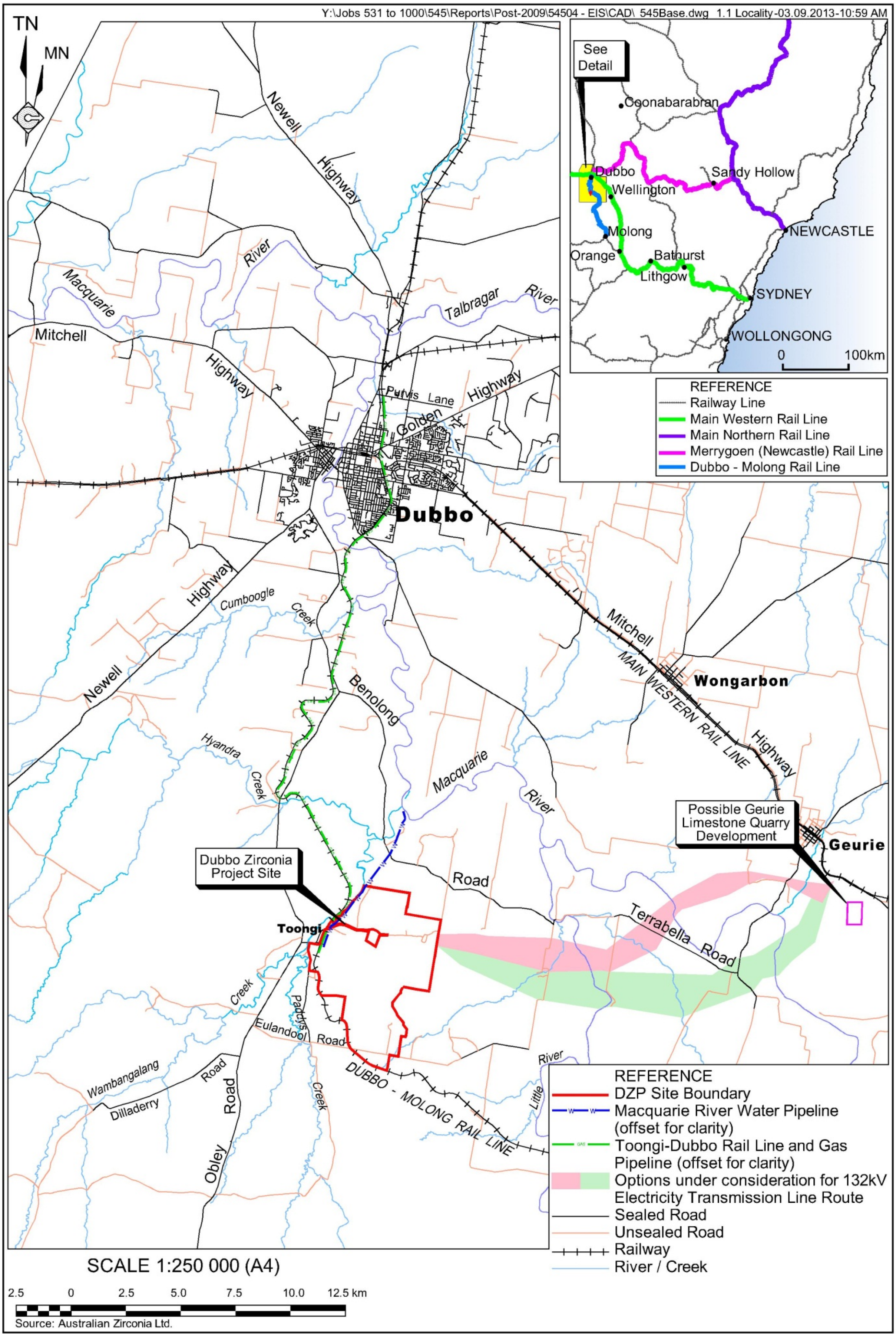
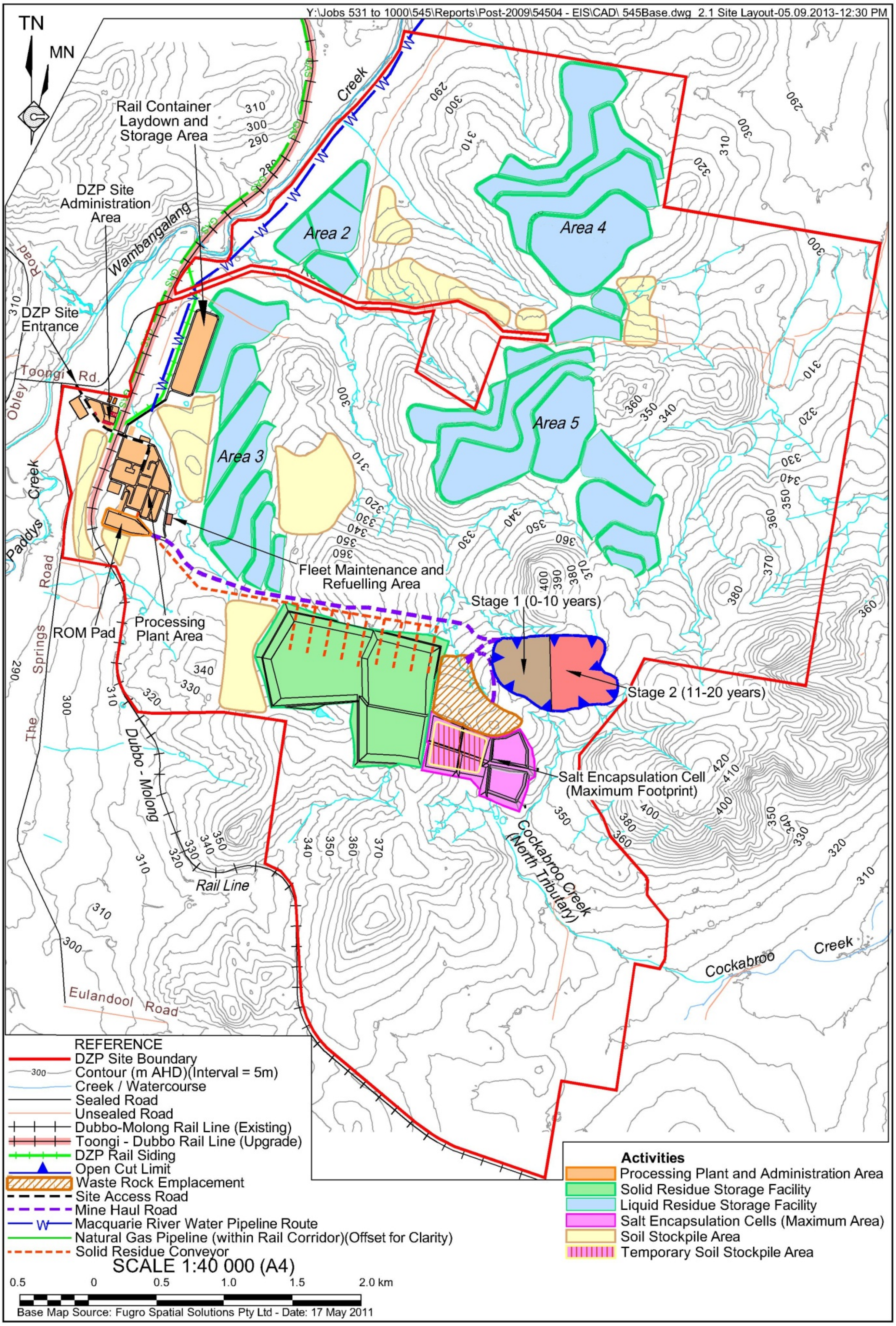


**Figure 2 DZP Site Layout**



### DZP Site Operations

The following provides an overview of principal components and activities to be undertaken on the DZP Site (and illustrated on **Figure 2**).

- Extraction of approximately 19.5Mt of ore at a maximum rate of 1.1Mt per year from a shallow open cut developed to a maximum depth of 32m (355m AHD) (remaining above the groundwater table). At the proposed rate of mining, the open cut design proposed would provide for a mine life of 20 to 22 years.
- Extraction and placement of approximately 3.5Mt of waste rock (weathered material or rock containing insufficient grades of rare metals or REEs for processing) within a small waste rock emplacement (WRE) to the southwest of the open cut.
- Haulage of ore to a Run-of-Mine (ROM) Pad for crushing and grinding.
- Processing of the crushed and ground ore by:
  - Sulphation roast of ore and leaching to dissolve sulphated metals.
  - Solvent extraction, precipitation, thickening, washing and drying of the various rare metal and REE products.

  The sulphuric acid required as part of the sulphation process would be manufactured within the DZP processing plant from imported raw sulphur.
- Construction and operation of a rail siding from the Toongi-Dubbo Rail Line and a Rail Container Laydown and Storage Area for the unloading and temporary storage of reagents and loading of products for despatch.

  Other reagents would be transported to the DZP Site via the public road network, with sections of Obley Road and Toongi Road to be upgraded to accommodate the proposed increase in heavy vehicle traffic.
- Mixing of solid residues produced by the processing of the ore with crushed and washed limestone and transportation via conveyor to a Solid Residue Storage Facility (SRSF).
- Pumping of water used in the processing operations, which cannot be recycled, to a Liquid Residue Storage Facility (LRSF), comprising a series of terraced and lined crystallisation cells.
- Recovery and disposal of an estimated 6.7Mt of salt which would accumulate within the LSRF within a series of Salt Encapsulation Cells adjoining the WRE and SRSF.
- Other ancillary activities including equipment maintenance, clearing and stripping of the areas to be disturbed and rehabilitation activities.

The maximum development footprint on the DZP Site would not exceed 808ha (see **Figure 2**) with the component areas of disturbance as follows:

- Open Cut Mine – 40.3ha.
- Waste Rock Emplacement Area – 20.4ha.
- ROM Pad – 4.2ha.

- Processing Plant and DZP Site Administration Area (incorporating the processing plant and associated reagent storage areas, rail siding and container laydown areas and site offices and administration complex) – 43.3ha.
- Solid Residue Storage Facility – 102.8ha.
- Liquid Residue Storage Facilities (Evaporation Ponds) – up to 425.4ha.
- Salt Encapsulation Cell – up to 34.6ha.
- Internal Haul Road and other Infrastructure – up to 7.3ha.
- Soil Stockpile Areas – up to 130ha.

The ore body to be mined is a roughly elliptical stock in shape with outcrop dimension of 600m x 400m. Exploration completed by AZL has identified the ore body extends below a thin veneer of soil and recent sediments to be approximately 900m x 500m (surface area of 36ha and appears to be a near vertical body of indeterminate depth.

### Toongi-Dubbo Rail Line and Natural Gas Pipeline Corridor

The processing operations require significant volumes of chemical reagents and other raw materials. While significant volumes of these reagents and materials would be delivered by road, the Applicant has identified the upgrade and use of the Toongi to Dubbo section of the currently disused Dubbo-Molong Rail Line as an opportunity to reduce the volume of traffic on the public road network.

**Figure 3** provides the proposed alignment of the Toongi-Dubbo Rail Line. **Figure 3** also identifies the proposed natural gas pipeline between the Central West Pipeline (of APA Group) at Purvis Lane, Dubbo, and the DZP Site which would deliver up to 970TJ/year of natural gas for the heating of various circuits within the processing plant.

### Macquarie River Water Pipeline

Processing operations would require up to 4.05GL of water annually which would be sourced (partially or completely) from the Macquarie River (under licence) and transferred to the DZP Site by water pipeline.

**Figure 4** provides the proposed alignment of the Macquarie River Water Pipeline, the key features of which are as follows.

- A pumping station which incorporates a dual water inlet, wet well and vertical mounted axial flow pump configuration.
- A 400mm to 450mm diameter HDPE pipeline within an embedded trench.

The easement to be created for the pipeline would be approximately 15.2ha (20m x 7.6km), although the actual area of disturbance would be much less.

### Public Road Network

Significant quantities of the processing reagents and other raw materials would be delivered by road, via the Newell Highway, Obley Road and Toongi Road. To accommodate the proposed heavy vehicle traffic associated with this transport, the alignment and pavement depth of the two roads would be improved in several locations, with a number of creek crossings, rail level crossings and intersections to be upgraded. **Figure 5** provides the locations of these works.

A more detailed description of the Proposal is provided by Section 2 of the EIS, of which this assessment forms Part 6 of the accompanying Specialist Consultant Studies Compendium.

**Figure 3 Toongi – Dubbo Rail Line and Gas Pipeline Corridor**

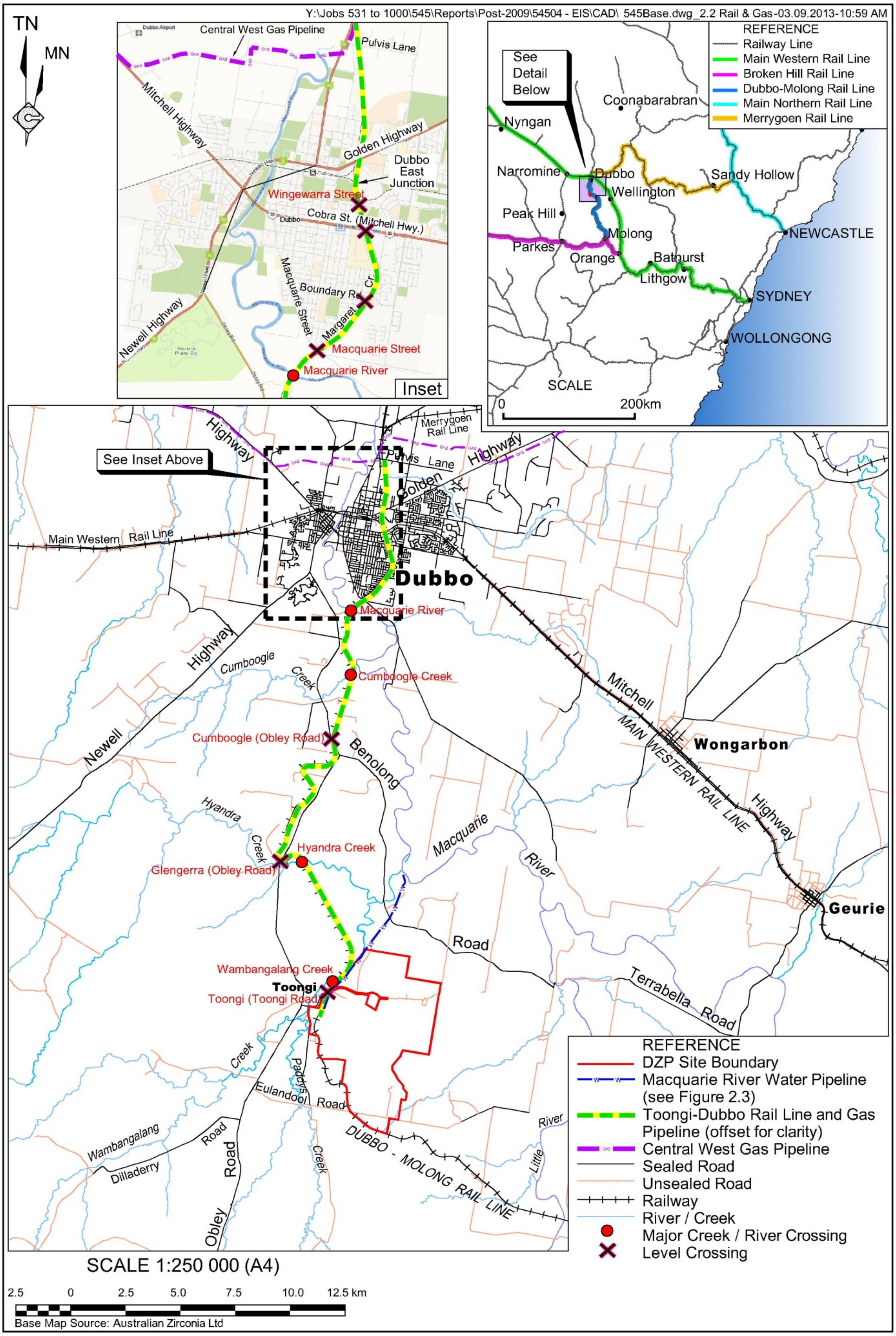


**Figure 4 Macquarie River Water Pipeline and Pump Station**

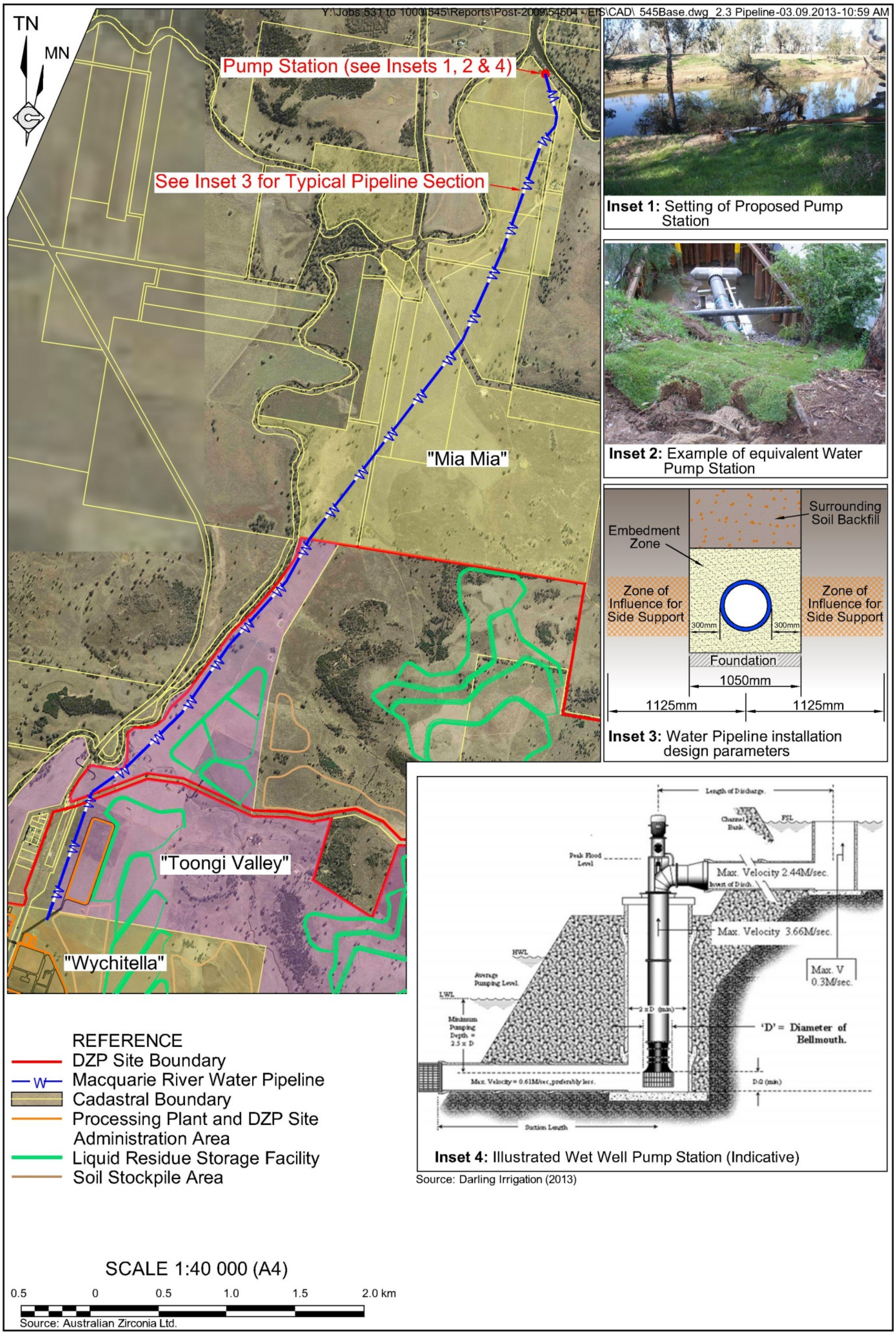
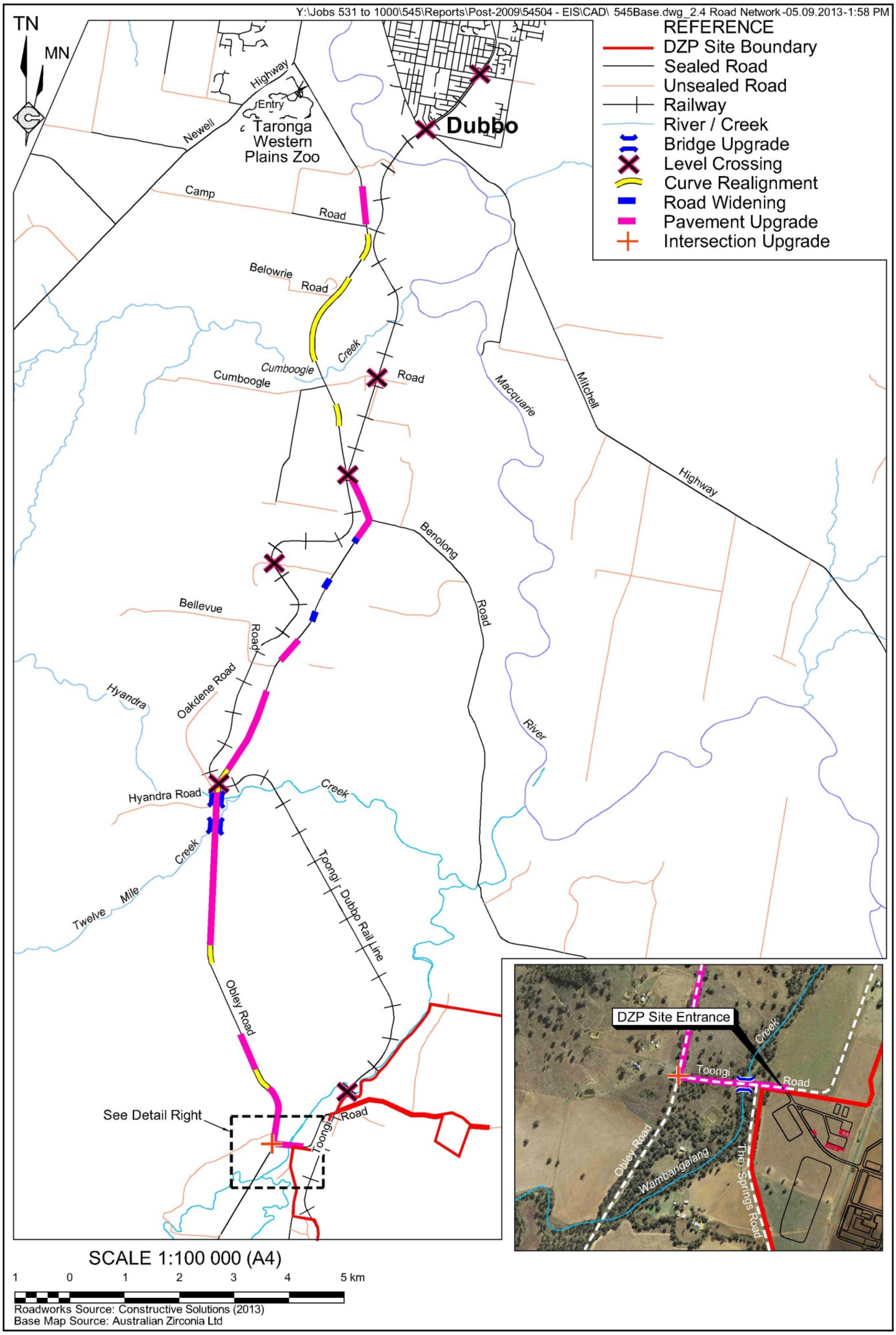


**Figure 5 Public Road Network**



# 2. REGIONAL SETTING

## 2.1 INTRODUCTION

The land which includes the Soil Survey Area has been mapped by the following three regional scale mapping projects.

- Raymond *et al*. (1999) mapped basement rocks and surficial geology. This has been modified slightly by Australian Zirconia geologists after more detailed investigation.
- Murphy and Lawrie (1998) mapped soil landscapes which are tracts of land with relatively uniform landform pattern, climate, parent material and soil classes.
- Wilford *et al*. (2009) mapped hydrogeological landscapes which are areas with similar hydrological characteristics, salinity process and management approaches.

In addition, two landscape assessments were conducted during the early phase of project planning in 2002. These were:

- Soil and Landscape Capability study by G Cunningham (2002); and
- construction of 23 piezometers by Golder Associates Pty Ltd.

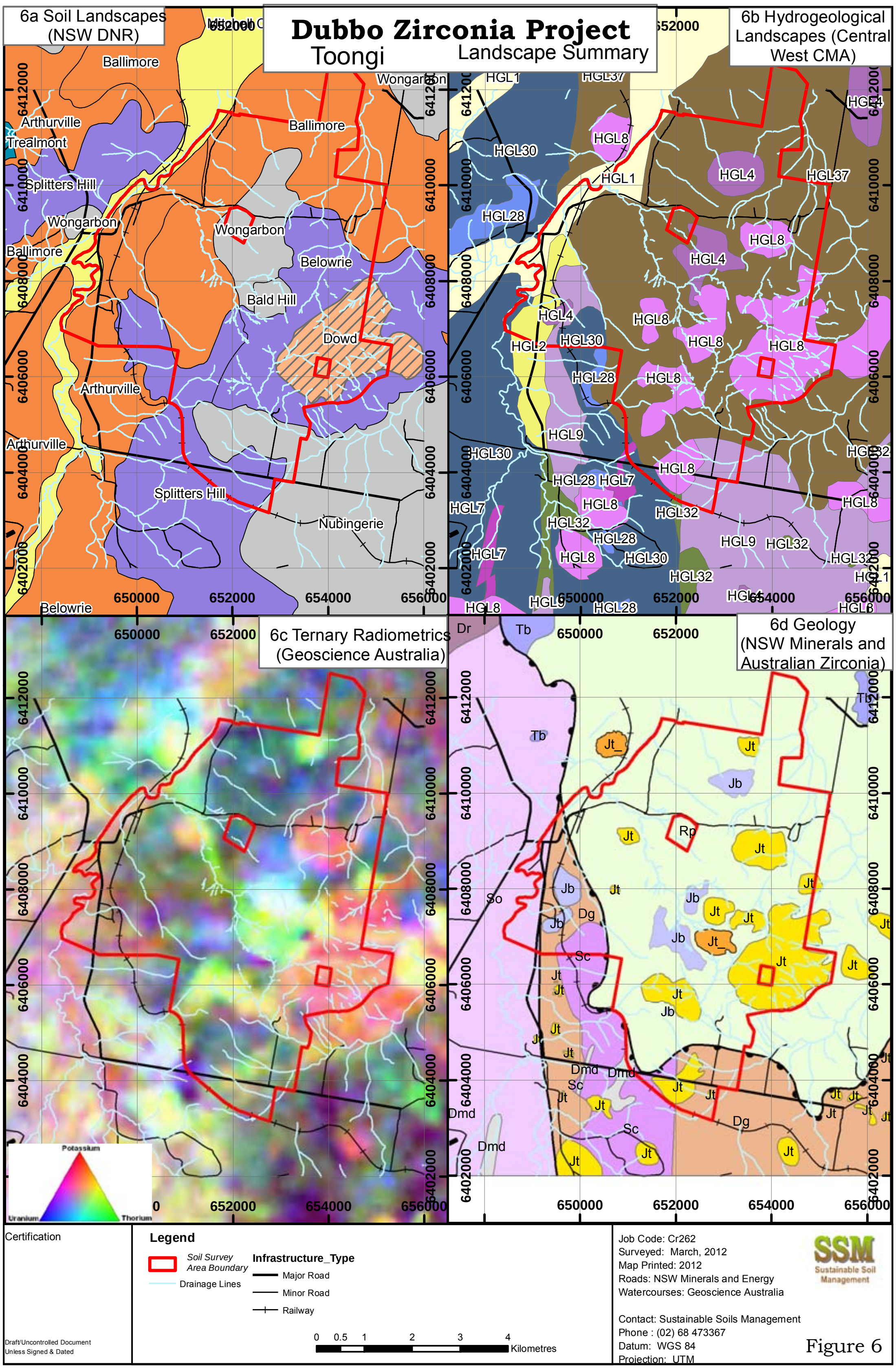
The following sub-sections provide a review of relevant data to provide the regional setting of the DZP Site soils.

## 2.2 GEOLOGY

The Soil Survey Area covers an area where the surface layers have been formed as a result of complex geological processes. The simplified geology in **Figure 6d** illustrates two ages of sedimentary rock and four types of igneous rock. The older sedimentary rock is the Toongi Group (So) and Cudal Group (Sc) which were deposited in the Silurian Period (443 to 417 million years ago), and is beneath the western and south-western margins of the Soil Survey Area, and contains a small area of intrusive Devonian rocks (Dmd). The younger sedimentary rock is Napperby Formation (Rp) which was deposited in the Triassic Period (248 to 200 million years ago) and is beneath the majority of the Soil Survey Area. The Napperby Formation is part of the Great Artesian Basin.

The igneous rocks have been formed predominantly as volcanic rocks approximately 400 million years ago. The oldest volcanics were laid down in the Devonian Period (417 to 354 million years ago) and are mapped as Gregra Group (Dg). The geochemistry is described to intermediate-alkaline (Latite), which would be expected to weather moderately reactive (moderately shrinking and swelling) clayey soil. The Gregra Group is mapped as occurring near the western and southern boundaries of the Soil Survey Area.

## Figure 6 Landscape Summary



The northern and eastern part of the Soil Survey Area contains outcrops of Jurassic Trachyte (Jt). This rock was formed approximately 180 to 190 million years ago (Meakin and Morgan, 1999), and has felsic – intermediate geochemistry, which would be expected to weather to clayey soil with moderate to low shrink-swell capacity. The northern half of the Soil Survey Area contains patches of basalt which were formed during 2 events; one slightly older than the trachytes (207 million years ago, Meakin and Morgan, 1999) and the other at a more recent time (possibly during the Tertiary). The geochemistry of basalt is described as mafic, which implies that it contains no quartz and will weather to clayey soil which often has a large shrink-swell capacity.

In summary, the geology of the Soil Survey Area consist of some Silurian Toongi and Cudal Group sedimentary rocks near western and southwestern margins, with Triassic Napperby Group sedimentary rock over much of the remainder. There are about 12 patches of trachyte, which are mostly in hills in the eastern half of the Soil Survey Area. These four geological formations would be expected to weather to generally sandy soil with a clay fraction that has a relatively low shrink and swell capacity. Along the southern boundary and near the western margin of the Soil Survey Area there is Intermediate-Alkaline Devonian volcanic rock belonging to the Gregra Group. There are also 5 patches of basalt in the western half of the Soil Survey Area. These would be expected to initially to weather to reactive, clayey soil. More intense weathering can result in stable, clayey soil.

## 2.3 SOIL LANDSCAPES

The Soil Survey Area was mapped by Murphy and Lawrie (1999) as containing nine soil landscapes. This reflects the complex geology describe in Section 2.2. To simplify discussion the nine landscapes were grouped into five classes on the basis of dominant profile form (**Table 1** and **Figure 6a**).

Three of these five classes, Chromosols, Red Podzolics and Shallow Soils form a continuum from deeper soil in the footslopes and depositional parts of the landscape through strongly leached soil (Red Podzolics) in mid and upper slopes to the shallow soil on the crests of hills. The more clayey Euchrozems appear to be associated with the Jurassic basalts in the northern part of the Soil Survey Area, and older volcanic rocks near the southeastern corner of the Soil Survey Area. The alluvial Mitchell Creek landscape was mapped only along the Wambangalang Creek floodplain.

The majority of the Soil Survey Area was described as having moderate (Class 3) to severe (Class 5) limitations for agriculture according to the Central West CMA (2008) system. The land most suitable for agriculture is the Alluvium and Euchrozems landscape groups.

## 2.4 HYDROGEOLOGICAL LANDSCAPES

The landscape complexity of the Soil Survey Area is also reflected in the seven hydrogeological landscapes which are mapped. The greatest complexity occurs near the boundary between the Triassic Napperby Formation, the Silurian Toongi Group, and the Devonian volcanic Hyandra Creek Group (see **Figure 6b**). An assessment of the potential salinity hazard presented by each hydrogeological landscape is presented in **Table 2**.

**Table 1**
**Summary of Soil Landscapes in the Soil Survey Area**

| Landscape Name | Landscape Summary |
|---|---|
| **Alluvium** | |
| Mitchell Creek<br>mi | Recent alluvial deposits with highly variable soils including sandy Stratic Rudosols and loamy alluvial soils (Brown Dermosols) along Wambangalang Creek. Land Class and Soil 2 with 6 in drainage lines. River red gum and River she-oak with Rough barked apple. Yellow and Grey box further from the creek. |
| **Chromosols (Duplex, but not acidic)** | |
| Arthurville<br>ar | Gently undulating rises and undulating low hills with mixed sedimentary and volcanics in Cowra Trough. Red Chromosols with Yellow Sodosols along drainage lines. Land and Soil Class 3 to 5. White box and Yellow box in lower lying areas. |
| Ballimore<br>bm | Undulating low hills on flat lying Napperby formation of sandstone, conglomerates ferruginous material and siltstone. Red Chromosols with Siliceous Sands on steeper scarps and Yellow Sodosols on lower slopes and depressions. Land and Soil Class 3 to 5. Grey box with White pine on upper slopes and Fuzzy box on lower slopes. |
| **Red Podzolics (Duplex and Acidic)** | |
| Belowrie<br>bi | Rises and low hills Jurassic trachyte. Red Chromosols Land and Soil Class 4 with Red Kandosols and Brown Chromosols on more stable lower slopes Class 3 and Yellow Sodosols on flatter lower areas with Grey box and Blakely's red gum. Shallow Rudosols and Tenosols on rocky crests. Hard setting and acidic surfaces. |
| Splitters Hill<br>sh | Undulating and rolling hills on Silurian vertically bedded shale and sandstone. Mainly Red Chromosols but a variety of others depending on parent material. Grey box and Yellow box on lower slopes. White box associated with Brown Chromosols on andesites. If sandstones are present the soils can be very acidic and have aluminium toxicity. Land and Soil Classes range from 3 to 6 depending on geology. |
| **Euchrozems (Clayey soil with little shrink/swell capacity)** | |
| Bald Hill<br>bh | Low hillocks with moderately steep slopes. Basalt rock outcrop and shallow Red Ferrosols Land and Soil Class 6 and Brown Ferrosols Class 4 & 5 on lower slopes. White box and Kurrajong. |
| Wongarbon<br>wg | Gently undulating and low hills with minor basaltic hillocks. Red Ferrosols and Red & Brown Vertosols with linear gilgais. White box and White pine on upper slopes. Fertile soils. |
| Nubingerie<br>nb | Undulating low hills mainly andesites from Cowra trough. Red Ferrosols Land and Soil Class 3 and Red & Brown Vertosols Class 2. White box with Yellow box in drainage lines. |
| **Shallow Soils** | |
| Dowd<br>dw | Hills of rock pavements and scarps. Trachyte volcanic plugs may be sodic. Mainly uncleared Black & White pine forest and bare rock. Shallow soils Leptic Rudosols low fertility not suitable for stripping. Land and Soil Classes 7 & some shallow Red Chromosols Class 6. |
| Source: J. Lawrie (pers. Comm.) | |

**Table 2**
**Salinity Hazard Assessment for the Hydrogeological Landscapes**

| HAZARD ASSESSMENT | Limited potential impact | Significant potential impact | Severe potential impact |
|---|---|---|---|
| **High** likelihood of occurrence | | | HGL 30 - Wambangalang<br>HGL 37 - Purlewaugh/Napperby |
| **Moderate** likelihood of occurrence | | HGL 1 - Macquarie Alluvial Sediments<br>HGL 2 - Macquarie Colluvial Sediments<br>HGL 4 - Dubbo Basalts<br>HGL 8 -Garrawilla and Mebul | HGL 9 - Curga Burga |
| **Low** likelihood of occurrence | | | |

The greatest salinity hazard is allocated to the Napperby Formation (HGL 37) which occupies the majority of the Soil Survey Area. The most likely landscape position for salinity to develop in this formation is near the break of slope between the steep mid slope of hillsides and the flatter footslopes (A Wooldridge pers comm.). A review of local groundwater conditions completed as part of a hydrogeological assessment of the Proposal by Environmental Earth Sciences (EES, 2013), provides further evidence for this elevated risk at the slope break. At various points over Soil Survey Area, minor rises in the groundwater table resultant from increased recharge following higher rainfall periods result in an intersection of the groundwater table and surface. These 'springs' are not perennial, however, the groundwater outflow at and around the discharge point has the potential to increase the salinity of these soils.

Wambangalang (HGL 30), the second high salinity hazard hydrogeological landscape, occupies a small area near the south western corner of the Soil Survey Area.

## 2.5 TERNARY RADIOMETRICS

The ternary radiometrics also reflect the complexity of the Soil Survey Area (see **Figure 6c**). In erosional landscapes, such as the Soil Survey Area, the radiometrics signal is influenced strongly by parent material (Wilford, 2002). Consequently, the pattern of radiometrics is discussed in terms of its correlation with the location of underlying rock.

On the eastern side of the Soil Survey Area, some areas of Trachyte and associated drainage lines have a high proportion of potassium (pink). Other patches of trachyte have similar levels of potassium, thorium and uranium, so are white in the image. The areas of basalt appear to have similar levels of potassium and uranium, but low thorium, so are blue and purple. The floodplain of Wambangalang Creek has a signature of high potassium south of 6410000 m north, but the floodplain within the Soil Survey Area to the north of this appears to be covered by material that has been transported from the south east.

## 2.6 LANDFORM TOPOGRAPHY

The elevation surface generated from an airborne LiDAR survey conducted for the Applicant indicates that there is approximately 100m of relief from the floodplain of Wambangalang Creek near the northern end of the Soil Survey Area and Dowds Hill, which is near the eastern boundary of the Soil Survey Area (**Figure 7a**). The landform essentially consists of a ridge that extends west from the southwestern boundary of the Soil Survey Area in a northeasterly direction to Dowds Hill then north to the northern boundary of the Soil Survey Area. The Jurassic Trachyte and Basalt shown in **Figure 6d** occur primarily on this elevated land, as far north as 641000m north and is flanked by the Triassic Napperby Formation. The pattern reflects the higher resistance to erosion of the igneous rock than the surrounding sedimentary rock. Despite this, the Napperby Formation occupies the highest part of the landscape at the northern end of the Soil Survey Area.

The slope surface (see **Figure 7b**) was derived from the elevation surface, and indicates that the steepest land occurs around the margins of the igneous rock. The flatter land, with slope less than 7.5% occurs on the floodplain of Wambangalang Creek on the western side of the Soil Survey Area, and extending toward the centre of the Soil Survey Area. There is a second patch of relatively flat land near the southern tip of the Soil Survey Area, but this area is intersected by a road and three drainage lines. The third area of relatively flat land occurs slightly to the east of the centre of northern boundary of the Soil Survey Area. This area coincides with land mapped as Jurassic Trachyte and Basalt in (see **Figure 6d**) but extends to the Napperby Formation at the northern end of the area assessed. There are some other small patches of relatively flat land near the centre and northeastern corner of the Soil Survey Area. The relatively steep landform contributes to the relatively low land capability rating in **Table 1**, and presents constraints for the location of evaporation ponds.

## 2.7 PREVIOUS SOIL SURVEYS

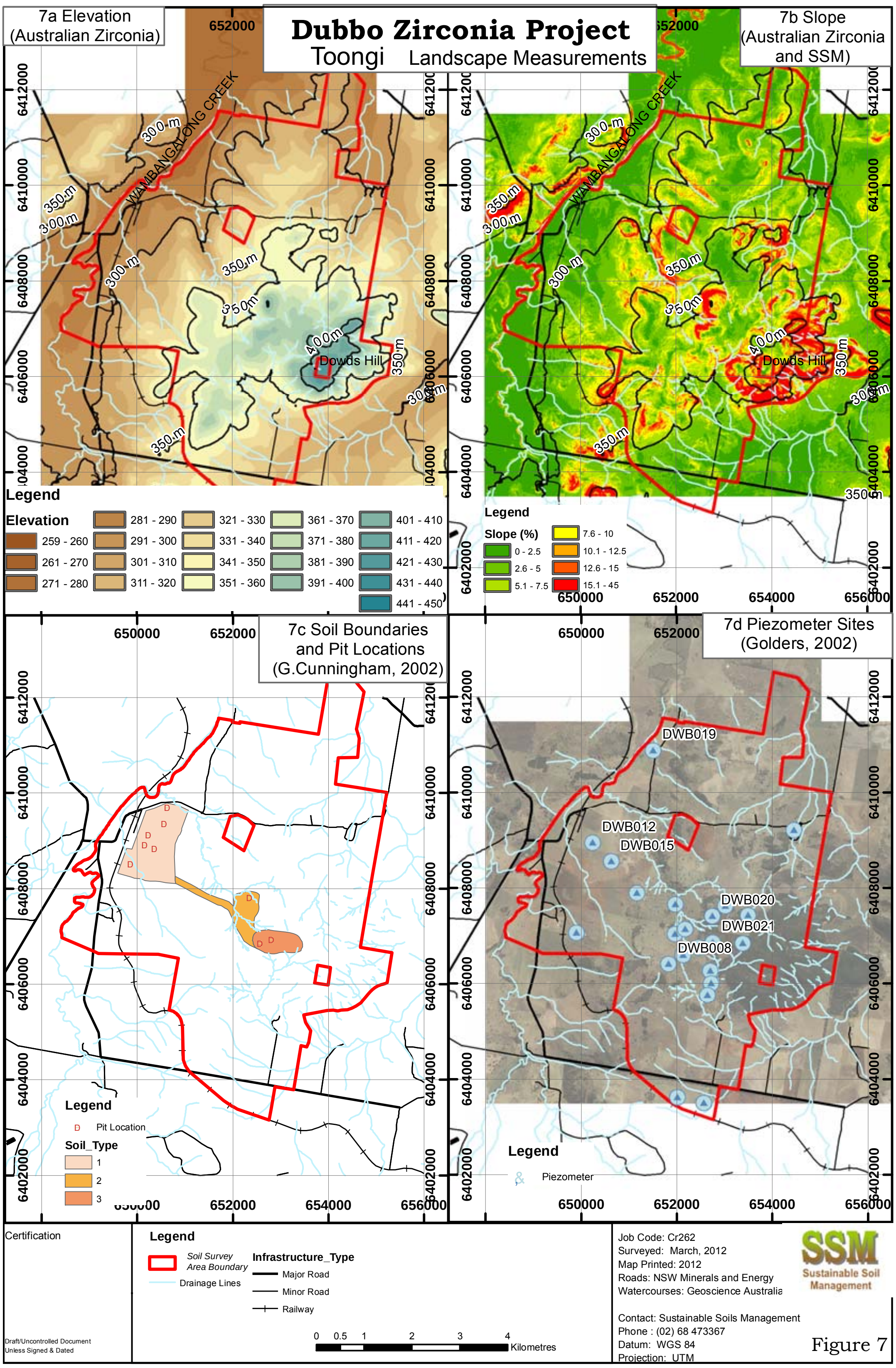
The soil survey conducted by Cunningham (2002) covered the footprint of the open cut area, access road and part of the proposed site for the processing plant. The survey consisted of 9 pits (**Figure 7c**) and encountered only soil that was classified as Chromosols. The landscape was divided into the following three units (see **Figure 7c**) on the basis of soil depth.

- Unit 1 - Lower Slopes.
- Unit 2 - Upper Slopes.
- Unit 3 - Ridge Crests.

These units are equivalent to the Chromosols, (Unit 1), Red Podzolics (Unit 2) and Shallow Soils (Unit 3) in **Table 1**. The landscape assessed was classified as suitable for pasture, with the better land in Unit 1 rated as suitable for improved pasture and occasional cropping.

Cunningham (2002) reported that the topsoil assessed was suitable for stripping and use as topsoil to a depth of 25cm. The remaining topsoil and subsoil to a depth of 75cm was rated as suitable for stripping as subsoil provided it was not mottled.

## Figure 7 Landscape Measurements



## 2.8 HYDROGEOLOGICAL STUDIES

The 23 piezometers constructed by Golder Associates in 2002 were generally drilled to a depth of 70m (see **Figure 7d**). Sections were constructed across the Soil Survey Area to give an understanding of the subsurface material. The sections are presented in **Appendix 2** and indicate the following.

- The regolith is variable to 70m, with a range of material encountered at the bottom of the piezometers.
- The material logged as alluvial clay (DWB019 and DWB012) is more than 40m thick at the two sites sampled.
- The Basalt beneath the small hill near the proposed plant site (DWB015) is continuous for at least 60m.
- Although the Trachyte (DWB020 and DWB021) at the proposed open cut area continues beyond 70m, a circle of 8 piezometers around the open cut area intercepted substantial depths of sedimentary rock. This sedimentary rock provides paths for water flow.
- A basalt flow was encountered in one piezometer (DWB008).

Environmental Earth Sciences (2013) has completed a more recent hydrogeological study of the Proposal, however, this has not involved any additional drilling.

## 2.9 SUMMARY

In summary, the landscape beneath the Soil Survey Area results in variable soils, and has variable groundwater flow properties. Within this variation, there is a pattern that the soil is likely to be relatively stable, with the capability being controlled by soil depth which is generally determined by the shape of the landscape.

# 3. SOIL ASSESSMENT METHODOLOGY

## 3.1 EM 38 AND EM 31 SURVEYS

### 3.1.1 Introduction

Electromagnetic (EM) induction was used to provide an overview of the soil variability within the Soil Survey Area. The results from this survey were then used to help choose locations of interest in the field for closer investigation.

The EM instruments are frequency domain electromagnetic devices with a transmitter and receiver that are separated by a distance that is fixed for each instrument. The transmitter coils transmit a continuous magnetic field with a sinusoidal wave form. This magnetic field induces an electric current in conductive material, which in turn induces a secondary magnetic field. The strength of the secondary magnetic field is influenced predominantly by the conductivity of the soil that is sensed. The receiver coils pick up changes in the primary magnetic fields from the transmitter coils and as well as the secondary magnetic fields induced from currents in the soil. The reported apparent electrical conductivity (ECa) is a measurement of the strength of the secondary magnetic field.

The depth sensed by the EM instruments varies with the separation of the coils and the orientation of the coils. Vertical coil orientation was used in this survey because the measured conductivity in the horizontal orientation is influenced strongly by near-surface properties, whereas the measured conductivity in the vertical orientation is most strongly influenced by properties near the centre of the depth range sensed. The EM 38 in the vertical orientation responds to properties of the surface 1.5m of soil. The EM 31 in the vertical orientation responds to properties of the surface 6m of soil.

The ECa measured in the EM survey is influenced most strongly by the electrical conductivity of the liquid phase, which is a measure of soil salinity. However, ECa is also influenced by soil moisture content, the surface charge of clay particles and bulk density. The magnitude of ECa is also influenced by soil temperature.

Variation in ECa across the surveyed area is used to identify soil types within a field, usually on the basis of drainage. The belief is that salts have been added to the landscape at a relatively uniform rate, but the current soil salt content can vary by more than one order of magnitude. The salt remaining in the soil is inversely proportional to the rate at which water has drained from the soil. The resulting ECa surface can also be used to map variation in other properties such as texture, which are correlated with soil conductivity.

### 3.1.2 EM Survey Methods

The EM survey was conducted by Terrabyte Services using a Geonics EM 31 and EM 38 (**Plate 1**). Readings were taken at approximately 5 m spacings along 50m transects giving approximately 40 readings per hectare.

Sampling locations were recorded using a Trimble Pro XL 12 channel Global Positioning System (GPS) receiver. The position was differentially corrected using a Fugro Omnistar system to give a position accuracy of 80 to 120cm. The location of each reading is shown in **Figures 10** and **11** (see Section 4).

**Plate 1 EM Survey Equipment. EM 31 is on frame beside operator, EM 38 is on conveyor belt dragged behind 4 wheel bike.**

Contours of the readings of ECa were fitted using ArcGIS Spatial Analyst. The surfaces were presented with each 10 mS/m interval allocated a different colour. To help identify the range of soil classes present in the Soil Survey Area, the ECa values were plotted onto frequency histogram charts that are presented with the EM surfaces.

## 3.2 SOIL PROFILE DESCRIPTIONS

Soil properties were assessed by examining soil profiles in sites identified from the EM Survey. The soil profiles were examined in 24 backhoe pits excavated to a maximum of approximately 3m deep. Locations of the pits were recorded using a handheld Garmin GPS, giving position accuracy of 5m radius. The backhoe pits were supplemented by 29 cores to 1.5m or refusal, and 5 documented soil observations. Field observations during this survey were supplemented by 9 soil profile descriptions by Cunningham (2002). This provides a total of 67 documented soil observation sites within the 3 460ha Soil Survey Area, which is within the range recommended by Schoknecht *et al*. (2008) for soil surveys at a scale of 1: 50 000. This information was supplemented by lithological logs of holes drilled for 23 piezometers by Golder Associates.

Selected soil properties in each pit were described according to the 'Australian Soil and Land Field Survey Handbook' (NCST, 2009). The soil properties described were:

- Depth of each horizon.
- Texture.
- Field pH using a kit based on the specifications of Raupach and Tucker.
- Dispersion.
- Root density.
- Proportion of soil occupied by gravel.
- Main colour and degree of mottling.
- Grade and type of structure and primary ped size.
- Size and type of concretions.
- Effervescence as an indication of the proportion of soft carbonates.
- Permeability and drainage were assessed for the profile as a whole.
- Nature of surface 2cm of soil, i.e. whether or not soil was hard setting.

Additional measurements taken were as follows:

- Potential rooting depth for annual field crops was estimated from structure, texture and pH.
- Volume of Readily Available Water (RAW) was calculated from rooting depth and standard estimates of available water for each texture class.
- Salinity was estimated by measuring the electrical conductivity of a suspension of 1 volume of soil in 5 volumes of water.
- SOILpak score according to McKenzie (1998).

Each profile was classified according to the Australian Soil Classification of Isbell (2002).

Soil chemical analysis of selected properties from 0 to 10, 10 to 30, 30 to 60 and 60 to 100cm depths in selected pits was undertaken by Incitec Pivot Laboratories. Properties measured for all depths were: pH, salinity, exchangeable cations, and Dispersion Index (a subset of the Emerson Class). Additional properties measured for the 0 to 10cm layer were: organic carbon, chloride and available concentrations of the nutrients of nitrogen, phosphorus, sulphur, manganese, iron and boron.

## 3.3 GEOTECHNICAL DESCRIPTIONS

Geotechnical properties were assessed in 21 of the pits described during the soil survey. The material in these pits was described according to AS1726-1993. Properties described vary with the material classification. They can be summarised as follows.

For coarse soil (more than 50% by mass larger than 0.075mm)

- Material Group.
- Colour.

- Moisture.
- Field estimates of grain size, shape and grading.
- Proportion and type of fine particles.
- Packing.
- Significant soil structure.
- Proportion of large roots.

For fine soil (more than 50% by mass smaller than 0.075mm)

- Material Group.
- Colour.
- Moisture.
- Consistence.
- Plasticity, dilatancy.
- Proportion and type of coarse particles.
- Significant soil structure.

Dispersion and slaking after 20 minutes in distilled water was measured for each soil layer in the field. $EC_{1:5}$ was also measured for 2 layers in each pit.

For rock

- Rock type.
- Colour.
- Moisture.
- Degree of Weathering.
- Strength.
- Rock Structure.
- Defects.

Unconfined compressive strength was measured in each layer shallower than 1.5m with a pocket penetrometer.

## 3.4 SOIL BOUNDARIES

The soil units were determined from the background information described in Section 2, aerial imagery, landform, and a field traverse. Soil units were examined in the field and then boundaries were modified to include detail appropriate for 1:50 000 mapping, using information from the EM survey, aerial imagery, landform, field observations and soil pit descriptions, supported by laboratory analysis. In this way a more precise soil landscape map was generated.

The position of unit boundaries was mapped in the field using observation of surface properties to determine the boundary location, and a hand held GPS to mark the location. Polygons were then generated from these GPS points.

## 3.5 LAND AND SOIL CAPABILITY ASSESSMENT

The land and soil capability was determined according to the NSW Office of Environment and Heritage Land and Soil Capability Assessment Scheme (OEH, 2012). Capability assessment is based on slope, wind hazard, soil pH, surface structural stability, salinity, rocky outcrop, waterlogging potential and existing erosion. The appropriate land use for each Capability class is summarised in **Table 3**.

**Table 3**
**Rural Land and Soil Capability Classes**

| Land and Soil Capability Class | Most Intensive Use | Land Definition (Central West CMA, 2008) |
|---|---|---|
| Class 1 | Regular Cultivation including intensive crops | Prime agricultural land and the best cropping country in the catchment |
| Class 2 | Regular Cultivation | Very good cropping land with fertile soils and short, gradual slopes |
| Class 3 | Regular cultivation, but must be consciously managed to prevent degradation | Moderate limitations that can be managed by more intensive management practices |
| Class 4 | Grazing, intermittent cultivation with specialised practices | Moderate to severe limitations for more intensive use (e.g. cropping). Limitations more easily managed for grazing |
| Class 5 | Grazing, very occasional cultivation for pasture establishment | Severe limitations for cropping and other high impact land management. Moderate limitations for grazing |
| Class 6 | Grazing only | Severe limitations for wide range of land uses |
| Class 7 | Unsuitable for rural production | Includes steep (slope 33% to 50%) or extremely erodible, or saline or shallow |
| Class 8 | Unusable for any agricultural purpose | Extremely severe limitation, includes precipitous slopes (>50%), areas with large proportion of rock outcrop and frequently inundated |
| Source: OEH (2012) | | |

## 3.6 SOIL ERODIBILITY FACTOR (K)

The soil erodibility factor (K, t ha h/ha MJ mm) was estimated for each site using a combination of measured and estimated data and the formulae used in the SOILLOSS program (Rosewell, 1993).

The inputs used were: organic matter obtained by multiplying organic carbon of the 0 to 10cm layer by 1.72; soil texture estimated in the field; surface soil structure; and profile permeability described in the field. These estimates were entered into the formulae described in Rosewell (1993). The estimates generated from this process were supplemented by estimates of K presented by Cunningham (2002).

Rosewell (1993) indicates that sites with a K value less than 0.02 have soil with low erodibility, K between 0.02 and 0.04 indicates moderate erodibility, and K greater than 0.04 indicates high erodibility.

## 3.7 SOIL STRIPPING AND RESTORATION OF LAND CAPABILITY

Restoration of land capability requires the restoration of both slope and soil depth. Topsoil that would be used for site rehabilitation should be stripped and stockpiled on site. Subsoil necessary for site restoration should be stripped, stockpiled on site and covered with topsoil. Subsoil can then be used from the stockpile for rehabilitation to achieve the required soil depth and slope prior to covering with topsoil.

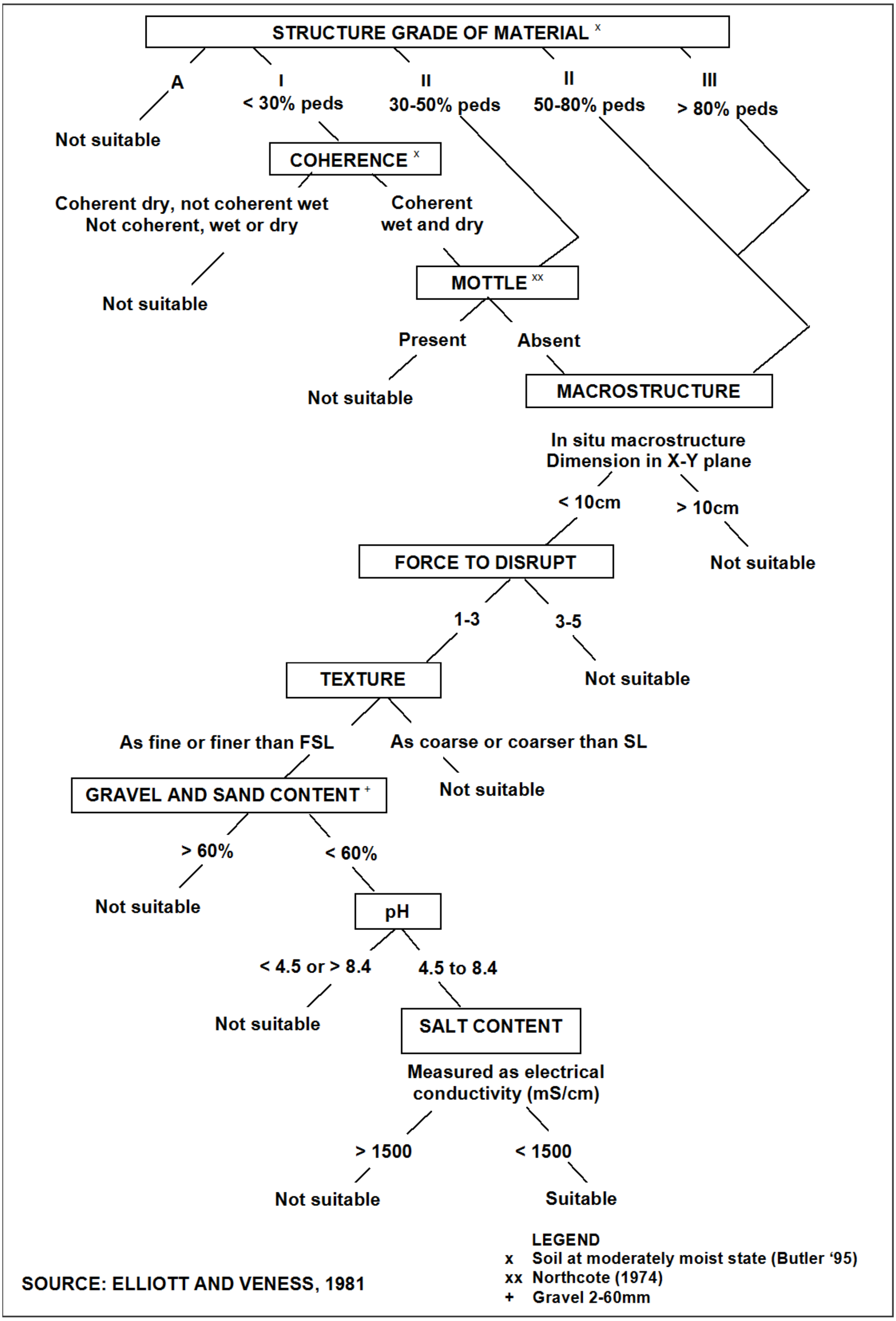
The suitability of soil for use during rehabilitation was determined while assessing soil pits using the physical assessment method of Elliott and Veness (1981) as presented in NSW Minerals Council (2007) and shown in **Figure 8**.

## 3.8 SUBSOIL SETTLING CLASS

The subsoil settling class was estimated according to Landcom (2004) and the following procedure.

- Particles larger than 2mm (gravel) are excluded from calculations.
- If more than 10% of remaining material (sand and fines) disperses, calculated by multiplying the dispersion percentage by clay content plus half silt content, then the sample is allocated to class D (dispersive).
- If the sample is not class D and less than 33% of the fraction smaller than 2mm is silt or clay (fines), the sample is class C (coarse); otherwise it is class F (fine).

**Figure 8 Flowchart for selection of topdressing material**



# 4. RESULTS AND DISCUSSION

## 4.1 EM SURVEY RESULTS

### 4.1.1 Site Conditions

Vegetation influences the EM survey by changing the soil moisture status, particularly beyond the 70 to 100 cm depth from which annual crops extract moisture. This is important to the EM survey as soil moisture is one of the factors that influences the ECa measured in the EM survey (**Appendix I**). Land use across the Soil Survey Area covers a wide range from annual rainfed crops grown in rotation with pasture, through native pasture to dense woodland and forest (**Figure 9**). Rainfall in the 2 years before the EM survey had been about 30% above the long term average of 530mm/year. This wet period would be expected to result in more water seeping beyond the 1m crop rootzone in cropped areas than pasture areas. The subsoil is likely to be dry in timbered areas because of the relatively shallow soil depth combined with the deeper rootzone of trees than either pasture or crops.

The interaction between rainfall and plant water use would be expected to create wetter subsoil beneath cropped areas than pasture, consequently, EM values would be expected to be higher in areas under crop than pasture, given that other soil properties are similar. This pattern would be expected to be clearest along fence lines between paddocks with different management histories.

Access to much of the Soil Survey Area was restricted by outcropping rocks and fallen timber in pasture areas and woodland, and by steep banks of drainage lines. As a result, the area covered by the EM survey was constrained to 2 330ha (**Figure 9**), meaning that approximately 1 130ha of the Soil Survey Area was not surveyed with the EM. The area not surveyed was primarily in the more elevated parts of the Soil Survey Area where the soil would be expected to be shallow.

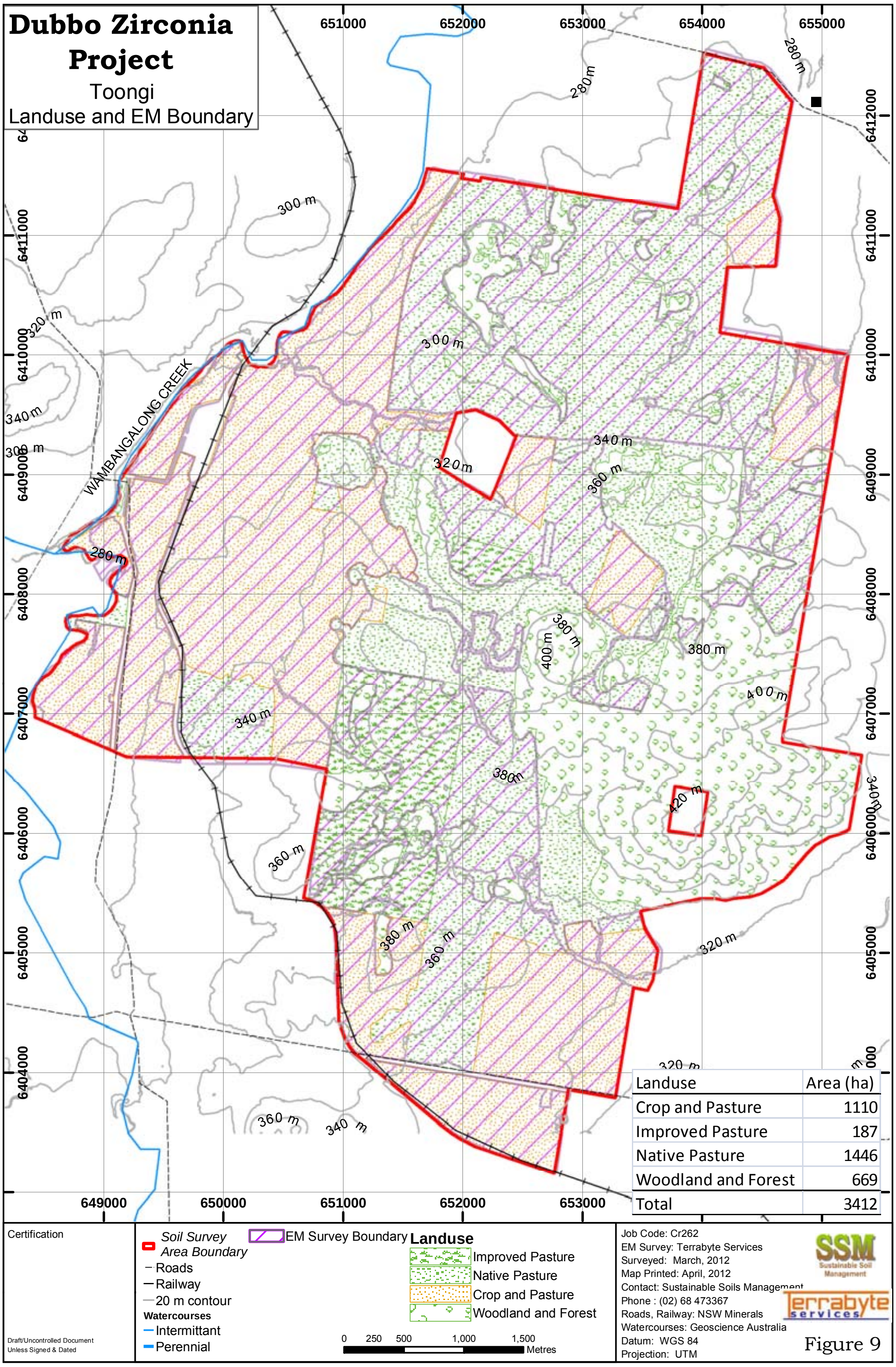
### 4.1.2 EM 38 Survey Results

Values of ECa from the EM 38 are generally low, with a median value for 210 000 readings of 43mS/m, and 75% of values less than 60mS/m. This is consistent with well drained sandy and loamy textured soil derived from sedimentary and felsic igneous rocks. Less than 1 000 of the EM 38 ECa values were above 150mS/m that is associated with saline soil (Slavich and Petterson, 1990).

EM 38 ECa values followed a complex pattern, which reflects the complex pattern of geology within the Soil Survey Area as described in Section 2. However, this complex pattern contained some areas with relatively uniform ECa. These can be summarised as follows.

- EM 38 ECa was generally low within the broad valley draining toward the village of Toongi from the southeast (**Figure 7**).
- A strip of low EM 38 ECa ran north of Toongi and parallel to and 300m east of Wambangalang Creek.
- EM 38 ECa was generally low in the northeastern corner of the Soil Survey Area.
- There was a pattern that EM 38 ECa was low in elevated areas centred on 652 000 m E 6 407 000 m N, with higher ECa on the footslopes of these areas.
- EM 38 ECa was generally low in a band running westward from a creek at 653 300 m E 6 404 800 m N. This band is not associated with the current drainage line.

**Figure 9 Land Use and EM *Boundary***




| Landuse | Area (ha) |
|---|---|
| Crop and Pasture | 1110 |
| Improved Pasture | 187 |
| Native Pasture | 1446 |
| Woodland and Forest | 669 |
| Total | 3412 |

- A patch of elevated EM 38 ECa was centred on a hill at 649 700m E 6 408 000m N. This is about 1km southwest of piezometer DWB015 in which 70m of basalt was logged.
- Two patches of elevated EM 38 ECa occurred on the western side of the Soil Survey Area near the boundary between colluvial material and alluvial material from Wambangalang Creek. The clearest patch runs north from 648 700m E 6 406 800m N. The second one runs slightly east of north from 651 000m E 6 407 800m N.
- Four broad patches of elevated ECa occurred in relatively level areas with slope generally less than 3%. These are; north from 653 000m E 6 408 000m N, south from 652 300m E 6 405 000m N, north from 652 000m E 6 404 000m N, and north and north east of 652 800m E 6 409 700m N.
- EM 38 ECa was generally high in elevated areas in the northeastern quadrant of the surveyed area. These were associated with land mapped as having basalt parent material. EM 38 ECa values around these areas were generally moderate rather than low.

The broad area of the patches of high and low ECa indicate that it is likely that much of the variation is associated with variation in landscape properties, rather than being artefacts of management or the EM survey process.

### 4.1.3 EM 31 Survey Results

Values of ECa from the EM 31 survey were of the order of 30mS/m greater than those from the EM 38. The median value of EM 31 ECa of 68mS/m was 25mS/m greater than the median of the EM 38 ECa, while 75% of EM 31 ECa values were less than 90mS/m, which was 30mS/m higher than the same centile for the EM 38 ECa. The higher ECa for the EM 31 than the EM 38 reflects an increase in moisture, clay content and salinity between the surface metre, which is sensed by the EM 38, and underlying 3 metres (or more), which is sensed by the EM 31.

The pattern of ECa values from the EM 31 (**Figure 11**) was similar to the pattern for the EM 38 (**Figure 10**). As a result, the points below focus on locations where the EM 31 ECa followed a different pattern to the EM 38 ECa.

- A patch of very low EM 31 ECa centred on 650 000m E 6 407 000m N was surveyed by the EM 31 but not the EM 38.
- There were some patches of low EM 31 ECa around the area of elevated ECa centred on 653 000m E 6 410 300m N.
- A 30 to 50m wide strip of elevated EM 31 ECa ran in an east-northeast direction from 650 000m E 6 408 000m N. This is associated with a paddock boundary and farm track. This anomaly is partly to the south of the track, and may be associated with interference of surface water flows by the track.
- The patches of elevated EM 31 ECa in the strip near the boundary between colluvium and Wambangalang Creek alluvium that runs north from 648 700m E 6 406 800m N are larger in the EM 31 than the EM 38 survey.

**Figure 10 Toongi EM 38**

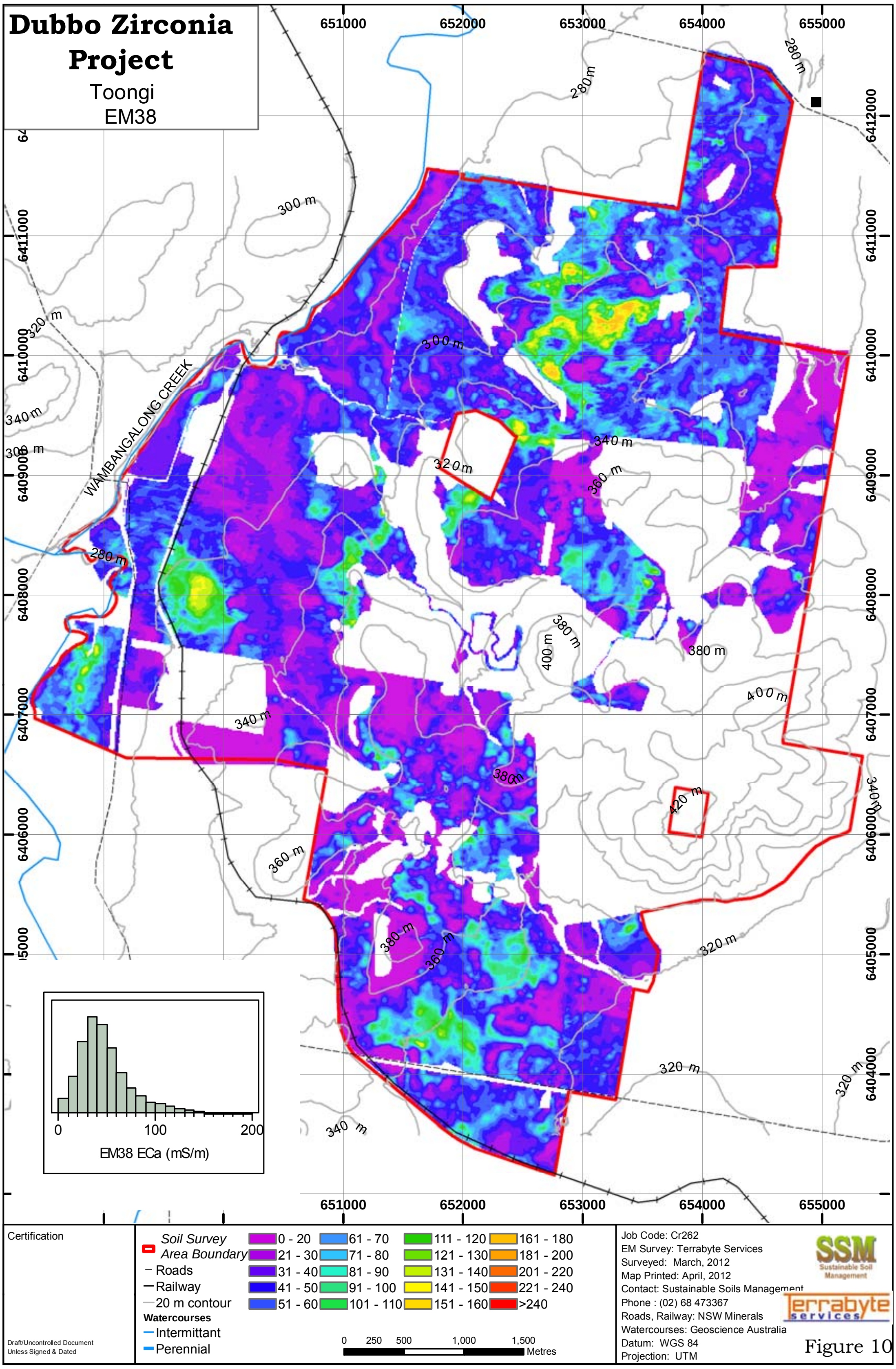
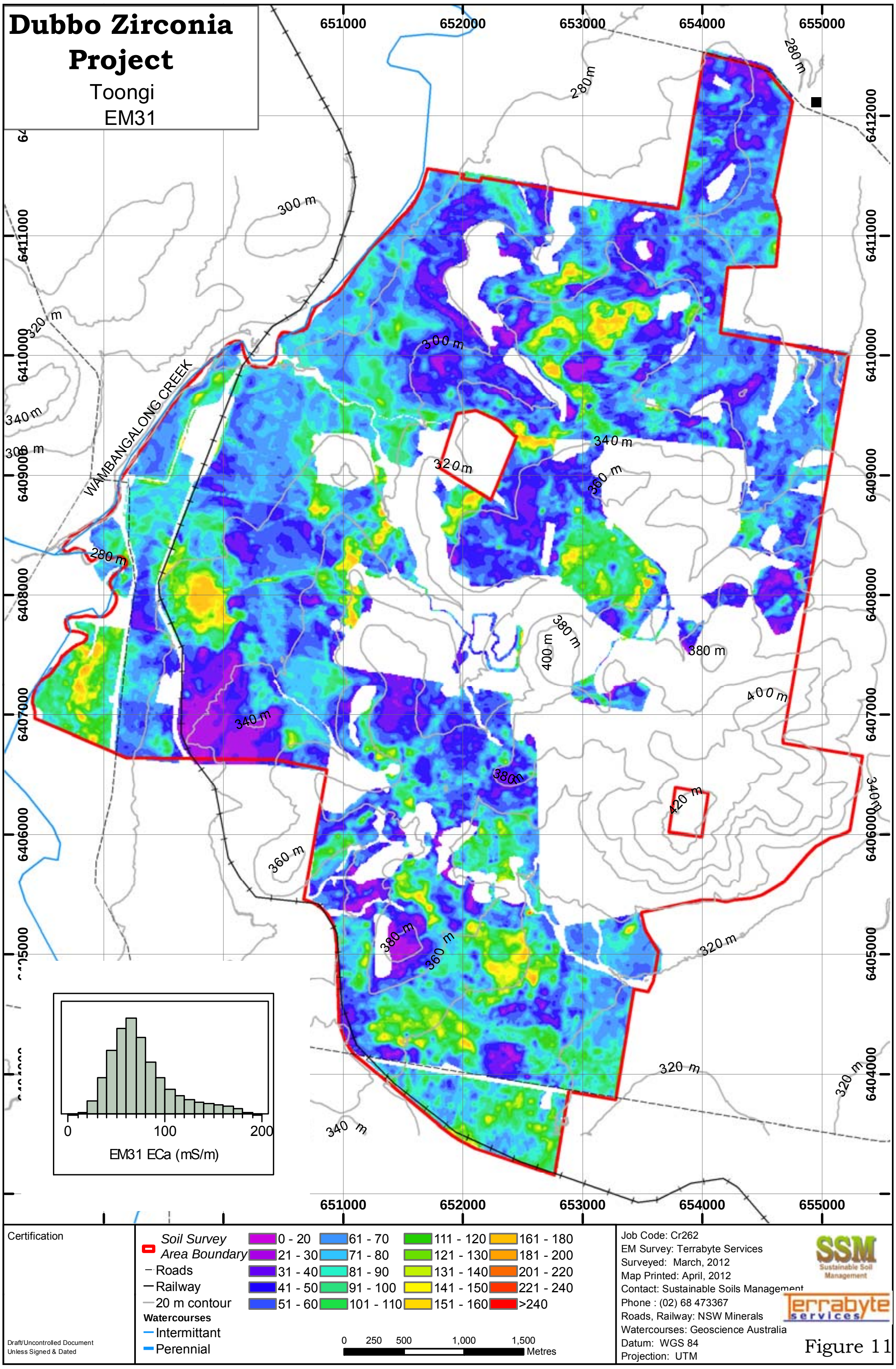


**Figure 11 Toongi EM 31**



- There are several patches of elevated EM 31 ECa north and east of 651 000m E 6 408 000m N that are outside the margin of areas mapped as either basalt or trachytes. This location within the landscape has potential to be associated with elevated salinity (A. Wooldridge, A. Nicholson, pers comm.).
- The variation in EM 31 ECa south of 6 405 000m N is poorly correlated with landform. There appear to be 2 patches of moderately high ECa, with small patches of high EM 31 ECa that may be associated with gilgai microrelief. The patches are centred on 652 200m E 6 405 000m N and 651 500m E 6 404 400m N separated by a band of low ECa.

The reason for the areas of elevated EM 31 ECa should be investigated as these can be associated with elevated salinity. EM 38 was higher relative to EM 31 ECa in the northeastern 600ha of the area assessed than in the west of the area assessed. This area was surveyed 3 months after the majority of the area surveyed.

### 4.1.4 EM 38 divided by EM 31 Results

The reasonably good correlation between ECa from the EM 38 and EM 31 is reflected in a relatively uniform surface for the EM 38 divided by EM 31 (**Figure 12**). The ratio between EM 38 and EM 31 is lowest in areas where the topsoil would be expected to be sandiest or deepest. The EM 38 ECa was greater than EM 31 ECa in some areas that were cultivated at the time of the EM survey. These were near the centre of the northern and western sides of the Soil Survey Area. Areas in the southern half of the Soil Survey Area where EM 38 ECa was greater than EM 31 ECa were generally associated with very low EM 31 ECa rather than elevated EM 38 ECa.

## 4.2 SOIL DESCRIPTION

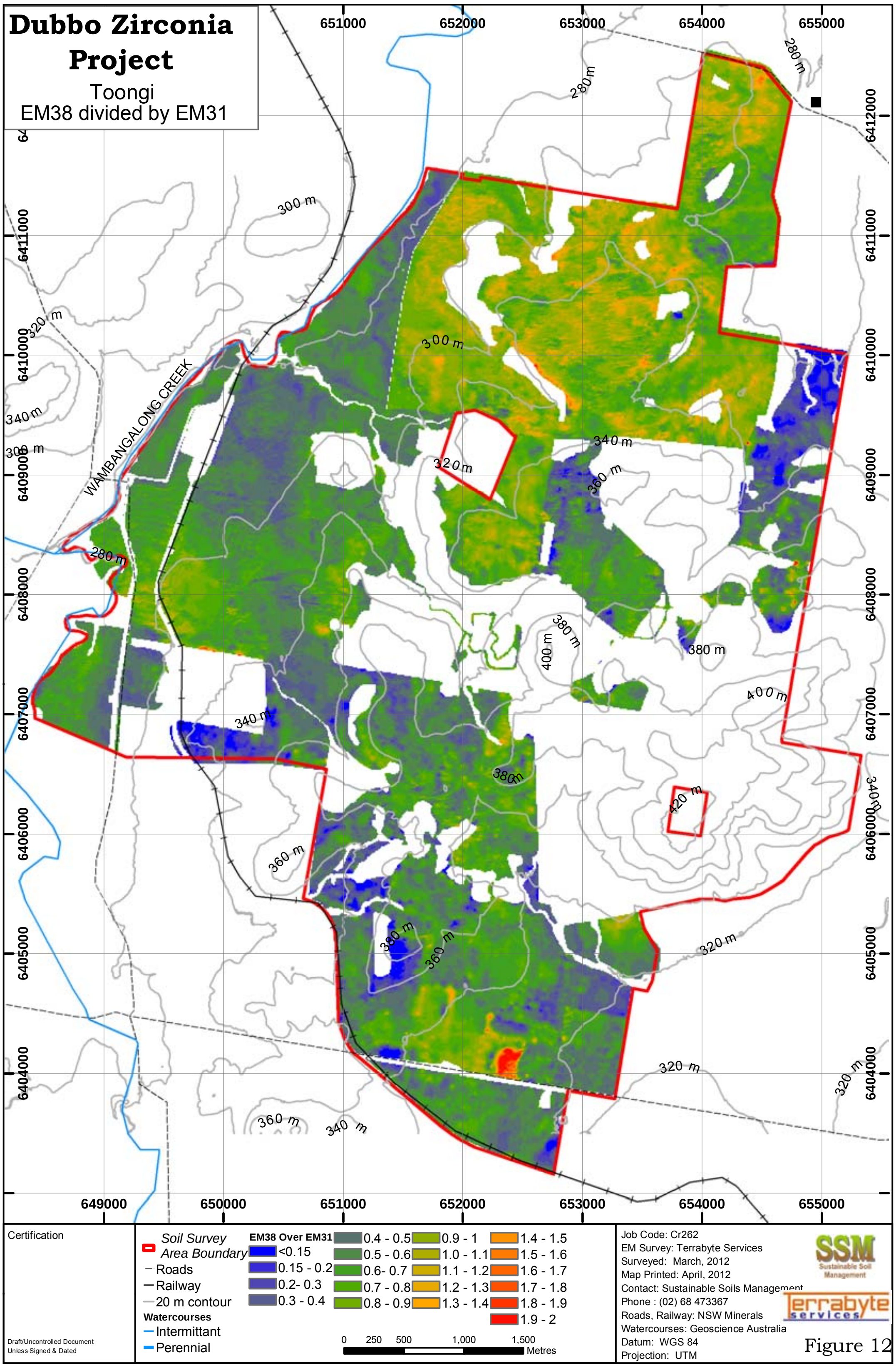
### 4.2.1 Introduction

The soil sampled in all except nine of the 33 pits and 29 cores showed a relatively consistent pattern of 10 to 40cm of loam to light clay topsoil over light to heavy clay subsoil (**Figure 13**). The remaining nine profiles, which were predominantly in Wongarbon landscape and one in Belowrie landscape, had a consistent clay texture throughout the profile. The subsoil clay content was lower in the Mitchell Creek and Turkey Range landscapes than the other remaining seven landscapes.

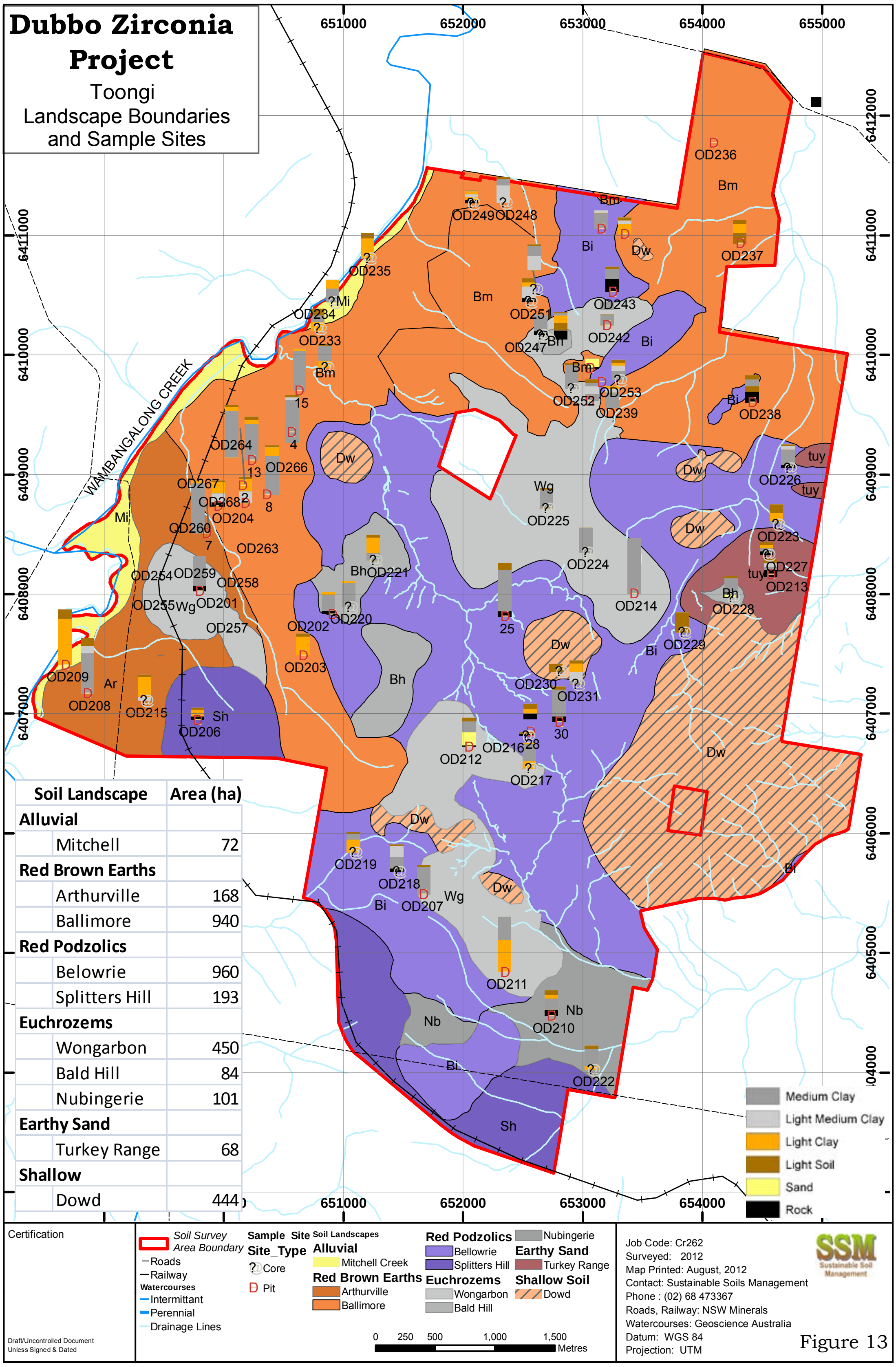
There was large variation in soil properties within the general pattern of light textured topsoil over clayey subsoil. The majority of the profiles described had a sharp boundary between the topsoil and subsoil, so were described as duplex soil. These had mostly developed from sedimentary rocks.

The duplex profiles in the Soil Survey Area were separated in to soil orders of Chromosols, Sodosols and Kurosols. Chromosols have relatively stable topsoil and nearly neutral soil pH. Red and Brown Chromosols develop on well drained sites, while Yellow and Grey Chromosols develop on sites with poorer drainage. Sodosols are generally unstable because of high sodium content. The sodium generally comes either from parent material, or has been leached from higher parts of the landscape. Kurosols develop where rapid drainage has leached many minerals from the soil, and have low pH.

**Figure 12 Toongi EM 38 Divided by EM 31**



## Figure 13 Toongi Landscape Boundaries and Sample Sites




| Soil Landscape | Area (ha) |
| --- | --- |
| **Alluvial** | |
| Mitchell | 72 |
| **Red Brown Earths** | |
| Arthurville | 168 |
| Ballimore | 940 |
| **Red Podzolics** | |
| Belowrie | 960 |
| Splitters Hill | 193 |
| **Euchrozems** | |
| Wongarbon | 450 |
| Bald Hill | 84 |
| Nubingerie | 101 |
| **Earthy Sand** | |
| Turkey Range | 68 |
| **Shallow** | |
| Dowd | 444 |

Profiles with a less abrupt texture change were also described. Deep profiles with limited development of structure are classified as Kandosols, while shallower profiles were classified as Tenosols, and very shallow and rocky profiles were described as Rudosols.

Igneous rocks have weathered to form a separate range of profiles across the Soil Survey Area. Some profiles with relatively low topsoil clay content were classified as Ferrosols. Ferrosols are rich in iron, and generally have very stable physical properties. Profiles with structured, clayey subsoil but limited shrink-swell capacity were classified as Dermosols, while strongly shrinking and swelling soil was classified as Vertosols.

The soil landscape boundaries within the Soil Survey Area were modified to a relatively small degree from those in the regional soil survey in **Figure 6a**. This is to be expected in a more detailed survey.

Soil Landscapes were generally correlated with the underlying geology in the following way.

- Felsic rocks in the oldest Silurian geology supported the Arthurville landscape, while less felsic geology of the same age supported the more clayey and productive Nubingerie landscape. Shale in the Silurian geology supported Splitters Hill landscape.
- Napperby Formation supported Ballimore landscape, while more sodic rock of similar age supported Turkey Range landscape.
- Basaltic rocks supported well drained Bald Hill and clayey Wongarbon landscapes.
- Trachyte rocks supported shallow, unstable soil of the Belowrie landscape, and the rocky Dowd landscape.
- There was a continuous range in geochemistry between the basalt and trachytes in the northern part of the Belowrie landscape where some deeper clayey soil developed on rock described as trachytes.
- Recent alluvial deposition has formed the Mitchell Creek landscape.

### 4.2.2 Landscape Description

#### 4.2.2.1 Introduction

The summaries of each landscape below provide general information about physical and chemical properties as well as the agricultural capability and some geotechnical properties. The intensity of observations was appropriate for farm planning for low intensity agricultural uses such as grazing or dryland cropping (NCST, 2009). Given the complex nature of the landscape more detailed investigation would be warranted for more intensive land use.

#### 4.2.2.2 Arthurville Landscape on Silurian Geology

**Landform and Typical Vegetation**

Gently undulating rises and undulating low hills with mixed sedimentary and volcanics in Cowra Trough. White box and Yellow box in lower lying areas.

The Arthurville landscape covers 168ha or 5% of the Soil Survey Area. The average slope was 2.4% with a standard deviation (s.d.) of 1.4%, average EM 38 ECa was 49mS/m (s.d. 19mS/m), and the average EM 31 ECa was 80mS/m (s.d. 27mS/m). It is located along the western slope of the western-most part of the Soil Survey Area (**Figure 13**).

### Soil Types

Very deep Red Chromosols with Yellow and Brown Sodosols along drainage lines. Soil Profiles OD208, OD215. Pit OD208 was classified as a Brown Sodosol, and described as:

0 to 30cm
Dark brown clay loam with moderate grade of angular blocky structure and 2cm peds. Good to excellent structure for root growth indicated by SOILpak score and many roots. Clods were not dispersive, did not slake in distilled water.

30 to 40cm
Brown silty clay loam with massive grade of structure. Good structure for root growth indicated by SOILpak score and an average number of roots. Clods dispersed slightly, partially slaked in distilled water.

40 to 80cm
Strong brown light medium clay with strong grade of angular blocky structure and 4cm peds. Moderate to good structure for root growth indicated by SOILpak score and few roots. Clods dispersed slightly, partially slaked in distilled water.

80 to 115cm
Strong brown medium clay with strong grade of prismatic structure and 5cm peds. Poor to moderate structure for root growth indicated by SOILpak score and no roots. Clods were not dispersive, partially slaked in distilled water.

### Chemical Properties of Selected Soil Profile

Profile OD208 had a relatively small capacity to store nutrients, indicated by the moderately low cation exchange capacity, and had moderately acidic topsoil with moderate organic carbon content (**Table 4**). Available soil phosphorus and nitrate nitrogen were high for a pasture profile, but sulphate sulphur was moderately low throughout the profile. Tested micronutrients were generally present at adequate levels, but manganese was elevated, indicating that the soil may have been waterlogged. Salinity was desirably low through the profile, and cation ratios in the surface layers were acceptable. Exchangeable aluminium was elevated in the surface 60cm, and very high in the 10 to 30cm layer. The surface layers were moderately dispersive, and the soil sampled deeper than 30cm was strongly dispersive.

**Table 4**
**Results of soil tests performed by Incitec Pivot Laboratories on samples collected from Arthurville Landscape in March, 2012**

| DRYLAND WHEAT RATING | Very Low | Low | Moderately low | OK | Moderately high | High |
|---|---|---|---|---|---|---|

| | | | | | | |
|---|---|---|---|---|---|---|
| Pit | **OD208** | **OD208** | **OD208** | **OD208** | | |
| Depth (cm) | **0 to 10** | **10 to 30** | **30 to 60** | **60 to 100** | | |
| Colour | Orange/Yellow | Brown | Orange/Yellow | Orange/Yellow | | |
| Texture | Sandy Loam | Clay Loam | Clay Loam | Clay Loam | Clay Loam | Clay |
| CEC (meq/100g) | 5.8 | 3.4 | 12.0 | 13.2 | 13.1 | 26.1 |
| pH water | 5.6 | 5.6 | 6.2 | 8.2 | 6.5 | 8.8 |
| pH $CaCl_2$ | 4.7 | 4.2 | 4.7 | 6.8 | 5.4 | 7.9 |
| Organic C (%) | 1.9 | | | | 2 | |
| Nitrate N (mg/kg) | 21 | 1.5 | 1 | 1.8 | 5.9 | 0.5 |
| Phosphorus Colwell (mg/kg) | 78 | | | | 13 | |
| Sulphate S-KCl (mg/kg) | 3.6 | 4.6 | 2.3 | 3.4 | 2.6 | 1.9 |
| Sulphate S-MCP (mg/kg) | | | | | | |
| Potassium (meq/100 g) | 1.10 | 0.37 | 0.43 | 0.50 | 0.0551724 | 0.0153257 |
| Calcium (meq/100 g) | 3.3 | 1.4 | 2.7 | 2.3 | 8 | 10 |
| Magnesium (meq/100 g) | 1.2 | 0.77 | 7.2 | 8.1 | 3.9 | 13 |
| Aluminium (meq/100 g) | 0.19 | 0.79 | 0.24 | | 0.1 | |
| Sodium (meq/100 g) | 0.03 | 0.1 | 1.4 | 2.3 | 0.33 | 2.7 |
| Chloride (mg/kg) | <10 | <10 | 25 | 73 | <10 | 58 |
| Electrical Conductivity $_{(1:5)}$ | 0.07 | 0.02 | 0.05 | 0.1 | 0.06 | 0.26 |
| Electrical Conductivity$_{se}$ (dS/m) | 0.7 | 0.2 | 0.4 | 0.7 | 0.4 | 1.6 |
| Copper (mg/kg) | 1.5 | | | | 1.1 | |
| Zinc (mg/kg) | | | | | 0.85 | |
| Manganese (mg/kg) | 100 | | | | 91 | |
| Iron (mg/kg) | 170 | | | | 64 | |
| Boron (mg/kg) | 0.62 | | | | 0.61 | |
| **Percentages of Exchangeable Cations** | | | | | | |
| ECaP (Calcium) | 56.7% | 40.8% | 22.6% | 17.4% | 61.3% | 38.3% |
| EMgP (Magnesium) | 20.6% | 22.4% | 60.2% | 61.4% | 29.9% | 49.8% |
| EKP (Potassium) | 18.9% | 10.8% | 3.6% | 3.8% | 5.5% | 1.5% |
| ESP (Sodium) | 0.5% | 2.9% | 11.7% | 17.4% | 2.5% | 10.3% |
| EAlP (Aluminium) | 3.3% | 23.0% | 2.0% | 0.0% | 0.8% | 0.0% |
| Ca/Mg ratio | 2.8 | 1.8 | 0.4 | 0.3 | 2.1 | 0.8 |
| K/Mg ratio | 0.9 | 0.5 | 0.1 | 0.1 | 0.2 | 0.0 |
| ESI | 0.14 | 0.01 | 0.00 | 0.01 | 0.02 | 0.03 |
| Dispersion Index | 2 | 3 | 14 | 11 | 8 | 8 |
| Slaking | Partial | Considerable | Partial | Partial | Considerable | Considerable |

## Limitations

Moderate fertility, inherent sheet erosion risk, localised high water tables, potential saline discharge area, dryland salinity, localised shallow soils.

**Land and Soil Capability Classes**: Class 3 to 5.

### Soil Erodibility Factor (K)

Soil represented by the pit OD208 was given a moderate K factor of 0.026. Cunningham (2002) attributed a K value of 0.036 to the topsoil layer of Pit 7, which was in the Arthurville landscape.

### Geotechnical Suitability for LRSF Construction

Pit OD208 was logged as 30cm Silty SAND (SM), over low plasticity Silty CLAY (CL) to 1.2m, over plastic CLAY (CH) to the bottom of the pit at 3m (**Appendix 3**). The clay content also increased with depth at Site 7 sampled by Cunningham (2002) (**Table 5**).

**Table 5**
**Engineering properties of Site 7, in the Arthurville landscape (from Cunningham, 2002).**

| Site | Depth range (cm) | Clay (%) | Silt (%) | Fine Sand (%) | Coarse Sand (%) | Gravel (%) | Liquid Limit (%) | Plastic Limit (%) | Plasticity Index (%) | Linear shrinkage (%) | USCS Class |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Site 7 | 0 to 14 | 26 | 16 | 50 | 8 | 0 | | | | | |
| Site 7 | 14 to 28 | 27 | 15 | 38 | 17 | 3 | | | | | |
| Site 7 | 28 to 91 | 37 | 10 | 34 | 18 | 1 | | | | | |
| Site 7 | 91 to 148 | 48 | 14 | 29 | 8 | 1 | | | | | |
| Site 7 | 148 to 288 | 57 | 10 | 27 | 6 | 0 | | | | | |

It is likely that this material could be used to construct an embankment subject to more detailed laboratory testing.

### Soil Stripping Suitability

The topsoil to a depth of 25cm is likely to be suitable for stripping. The topsoil was 30cm deep in pit OD208, but only 10cm deep in core OD215 (**Appendix 4**). The subsoil in pit OD208 and core OD215 was suitable for stripping to a depth of 70cm.

### Subsoil Settling Class

Both the measurements of dispersion percentage and the Emerson Aggregate Test indicated that the material sampled from Site 7 by Cunningham (2002) was relatively stable (**Table 6**).

**Table 6**
**Laboratory indicators of soil stability of Site 7 in the Arthurville landscape (from Cunningham, 2002)**

| Site | Depth range (cm) | Dispersion (%) | Emerson Test | Calculated Total Dispersion | Subsoil Settling Class |
|---|---|---|---|---|---|
| Site 7 | 0 to 14 | 17 | 8/3[2] | 6 | F |
| Site 7 | 14 to 28 | 13 | 3[3] | 4 | F |
| Site 7 | 28 to 91 | 10 | 3[1] | 4 | F |
| Site 7 | 91 to 148 | 12 | 4 | 7 | F |
| Site 7 | 148 to 288 | 18 | 3[3] | 11 | D |

#### 4.2.2.3 Splitters Hill Landscape on Silurian Geology

**Landform and Typical Vegetation**

Undulating and rolling hills on Silurian vertically bedded shale and sandstone. Grey box and Yellow box on lower slopes. White box associated with Brown Chromosols on andesites.

The Splitters Hill landscape covers 193ha or 6% of the Soil Survey Area. The average slope was 5.0% with a standard deviation (s.d.) of 2.7%, average EM 38 ECa was 38mS/m (s.d. 22mS/m), and the average EM 31 ECa was 68mS/m (s.d. 31mS/m). It is located near the southern boundary of the Soil Survey Area (**Figure 13**).

**Soil Types**

Mainly Red Chromosols but a variety of others depending on parent material. Brown Chromosols on andesites. Shallow gravelly Red Dermosol similar to a Ferrosol found in this survey. Pit OD206 was classified as a Red Dermosol, and described as:


0 to 10cm
Dark reddish brown clay loam with moderate grade of polyhedral structure and 1cm peds breaking to 0.5cm. Good to excellent structure for root growth indicated by SOILpak score and many roots. Clods were not dispersive, did not slake in distilled water.

10 to 45cm
Red light clay with strong grade of angular blocky structure and 2cm peds breaking to 0.5cm. Good to excellent structure for root growth indicated by SOILpak score and an average number of roots. Clods were not dispersive, did not slake in distilled water.

>45cm
Bedrock of hard metasediment.

**Chemical Properties of Selected Soil Profile**

Profile OD206 had a relatively small capacity to store nutrients, indicated by the moderately low cation exchange capacity, and had moderately acidic topsoil with moderate organic carbon content (**Table 7**). Available soil phosphorus, nitrate nitrogen and sulphate sulphur were lower than optimum. Tested micronutrients were generally present at adequate levels, but manganese was elevated, indicating that the soil may have been waterlogged. Salinity was desirably low through the profile, and cation ratios in the surface layers were acceptable. Exchangeable aluminium was moderately elevated in the surface 30cm. The sampled soil was moderately dispersive.

**Table 7**

**Results of soil tests performed by Incitec Pivot Laboratories on samples collected from Splitters Hill Landscape in March, 2012**

| **DRYLAND WHEAT RATING** | Very Low | Low | Moderately low | OK | Moderately high | High |
|---|---|---|---|---|---|---|

| Pit | **OD206** | **OD206** | **OD206** |
|---|---|---|---|
| Depth (cm) | **0 to 10** | **10 to 30** | **30 to 45** |
| Colour | Red | Red | Red |
| Texture | Clay Loam | Clay Loam | Clay Loam |
| CEC (meq/100g) | 4.6 | 6.5 | 7.9 |
| pH water | 5.8 | 6.4 | 6.9 |
| pH $CaCl_2$ | 4.7 | 5.4 | 5.8 |
| Organic C (%) | 1.1 | | |
| Nitrate N (mg/kg) | 6.6 | 2.3 | 1 |
| Phosphorus Colwell (mg/kg) | 10 | | |
| Sulphate S-KCl (mg/kg) | 1.8 | 1.8 | <1.0 |
| Sulphate S-MCP (mg/kg) | | | |
| Potassium (meq/100 g) | 0.79 | 0.26 | 0.19 |
| Calcium (meq/100 g) | 2.8 | 4.8 | 6 |
| Magnesium (meq/100 g) | 0.78 | 1.3 | 1.7 |
| Aluminium (meq/100 g) | 0.22 | 0.1 | |
| Sodium (meq/100 g) | <0.02 | <0.02 | <0.02 |
| Chloride (mg/kg) | <10 | <10 | <10 |
| Electrical Conductivity $_{(1:5)}$ | 0.03 | 0.02 | 0.02 |
| Electrical Conductivity$_{se}$ (dS/m) | 0.3 | 0.1 | 0.1 |
| Copper (mg/kg) | 4 | | |
| Zinc (mg/kg) | | | |
| Manganese (mg/kg) | 72 | | |
| Iron (mg/kg) | 21 | | |
| Boron (mg/kg) | 0.42 | | |
| **Percentages of Exchangeable Cations** | | | |
| ECaP (Calcium) | 60.7% | 74.1% | 75.9% |
| EMgP (Magnesium) | 16.9% | 20.1% | 21.5% |
| EKP (Potassium) | 17.1% | 4.0% | 2.4% |
| ESP (Sodium) | 0.4% | 0.3% | 0.3% |
| EAlP (Aluminium) | 4.8% | 1.5% | 0.0% |
| Ca/Mg ratio | 3.6 | 3.7 | 3.5 |
| K/Mg ratio | 1.0 | 0.2 | 0.1 |
| ESI | 0.07 | 0.06 | 0.08 |
| Dispersion Index | 2 | 0 | 2 |
| Slaking | Water Stable | Water Stable | Partial |

### Limitations

If sandstones are present the soils can be very acidic and have aluminium toxicity. Complex soils, localised gully erosion risk, inherent sheet erosion risk, localised poor moisture availability, potential recharge area, localised rock outcrop, widespread shallow soils and localised low fertility.

**Land and Soil Capability Classes**: Class 3 and 5 on shallower rocky soils.

### Soil Erodibility Factor (K)

Soil represented by the pit OD206 was given a moderate K factor of 0.031. This value, and the shallow soil depth render the Splitters Hill landscape susceptible to degradation with the loss of any soil.

### Geotechnical Suitability for LRSF Construction

Pit OD206 described was too shallow to be suitable for the site for the construction of salt crystallisation cells as part of the LRSF. Other locations within the landscape may be suitable.

### Soil Stripping Suitability

The topsoil to a depth of 10cm is likely to be suitable for stripping. The subsoil was also suitable for stripping to a depth of 40cm, although it is noted that the profile described was shallow.

### Subsoil Settling Class

Not assessed.

## 4.2.2.4 Nubingerie Landscape on Silurian Geology

### Landform and Typical Vegetation

Undulating low hills mainly on andesites and metasediments from the Cowra trough. White box with Yellow box in drainage lines.

The Nubingerie landscape covered 101ha or 3% of the Soil Survey Area. The average slope was 3.0% with a standard deviation (s.d.) of 1.7%, average EM 38 ECa was 48mS/m (s.d. 26mS/m), and the average EM 31 ECa was 81mS/m (s.d. 25mS/m). It is located on the western side of the southern end of the Soil Survey Area (**Figure 13**).

### Soil Types

Red and Brown Vertosols reported by Lawrie, however found to be dominated by moderately deep to giant Red and Yellow Chromosols in this study which is near the western margin of the Nubingerie Landscape. Soil profiles OD210 and OD222. Pit OD210 was classified as a Yellow Chromosol, and described as:

0 to 25cm
Dark reddish brown clay loam with weak grade of angular blocky structure and 0.5cm peds. Excellent structure for root growth indicated by SOILpak score and many roots. Clods were not dispersive, did not slake in distilled water.


25 to 45cm
Brown light clay with moderate grade of angular blocky structure and 2cm peds. Good structure for root growth indicated by SOILpak score and an average number of roots. Clods were not dispersive, partially slaked in distilled water.

45 to 105cm
Strong brown heavy clay with strong grade of prismatic structure and 6cm peds. Poor to moderate structure for root growth indicated by SOILpak score and few roots. Soil had few, fine, faint, grey mottles. Clods were not dispersive, partially slaked in distilled water.

105 to 110cm
Greyish yellow weathered Andesite.

### Chemical Properties of Selected Soil Profile

Profile OD210 had a relatively small capacity to store nutrients, indicated by the moderately low cation exchange capacity, and had moderately acidic topsoil with moderate organic carbon content (**Table 8**). Available soil phosphorus was high for a pasture profile, but nitrate nitrogen and sulphate sulphur were low throughout the profile. Tested micronutrients were generally present at adequate levels, but manganese was elevated, indicating that the soil may have been waterlogged. Salinity was desirably low through the profile, and cation ratios in the surface layers were acceptable. Exchangeable aluminium was moderately high in the surface 30cm.

**Table 8**
**Results of soil tests performed by Incitec Pivot Laboratories on samples collected from Nubingerie Landscape in March, 2012**

**Table 8.** Suitability for Wheat Production. Results of soil tests performed by Incitec/Pivot Laboratories on samples collected from Nubingerie Landscape in March, 2012.

| DRYLAND WHEAT RATING | Very Low | Low | Moderately low | OK | Moderately high | High |
|---|---|---|---|---|---|---|

| Pit | OD210 | OD210 | OD210 | OD210 |
|---|---|---|---|---|
| Depth (cm) | 0 to 10 | 10 to 30 | 30 to 60 | 60 to 100 |
| Colour | Red | Red | Orange/Yellow | Orange/Yellow |
| Texture | Sandy Loam | Clay Loam | Clay Loam | Clay |
| CEC (meq/100g) | 5.1 | 7.8 | 5.9 | 13.2 |
| pH water | 6 | 6.5 | 7.4 | 7.7 |
| pH $CaCl_2$ | 4.9 | 5.4 | 6.1 | 6.6 |
| Organic C (%) | 1.6 | | | |
| Nitrate N (mg/kg) | 9.2 | 3.2 | 1.3 | 1 |
| Phosphorus Colwell (mg/kg) | 41 | | | |
| Sulphate S-KCl (mg/kg) | 1.6 | <1.0 | <1.0 | 4.1 |
| Sulphate S-MCP (mg/kg) | | | | |
| Potassium (meq/100 g) | 0.84 | 0.43 | 0.14 | 0.16 |
| Calcium (meq/100 g) | 2.8 | 4.9 | 3.1 | 5 |
| Magnesium (meq/100 g) | 1.3 | 2.3 | 2.6 | 7.7 |
| Aluminium (meq/100 g) | 0.11 | 0.1 | | |
| Sodium (meq/100 g) | <0.02 | 0.05 | 0.07 | 0.33 |
| Chloride (mg/kg) | <10 | <10 | <10 | <10 |
| Electrical Conductivity $_{(1:5)}$ | 0.05 | 0.02 | 0.02 | 0.04 |
| Electrical Conductivity$_{se}$ (dS/m) | 0.5 | 0.1 | 0.1 | 0.2 |
| Copper (mg/kg) | 2.1 | | | |
| Zinc (mg/kg) | | | | |
| Manganese (mg/kg) | 55 | | | |
| Iron (mg/kg) | 57 | | | |
| Boron (mg/kg) | 0.46 | | | |
| **Percentages of Exchangeable Cations** | | | | |
| ECaP (Calcium) | 55.2% | 63.0% | 52.5% | 37.9% |
| EMgP (Magnesium) | 25.6% | 29.6% | 44.0% | 58.4% |
| EKP (Potassium) | 16.6% | 5.5% | 2.4% | 1.2% |
| ESP (Sodium) | 0.4% | 0.6% | 1.2% | 2.5% |
| EAlP (Aluminium) | 2.2% | 1.3% | 0.0% | 0.0% |
| Ca/Mg ratio | 2.2 | 2.1 | 1.2 | 0.6 |
| K/Mg ratio | 0.6 | 0.2 | 0.1 | 0.0 |
| ESI | 0.13 | 0.03 | 0.02 | 0.02 |
| Dispersion Index | 2 | 2 | 5 | 3 |
| Slaking | Water Stable | Partial | Considerable | Considerable |

## Limitations

Localised engineering hazard, stoniness, fertility, gully erosion risk, inherent sheet erosion risk, potential discharge area, high run-on, potential dryland salinity, localised seasonal waterlogging.

**Land and Soil Capability Classes**: Generally Class 3 with Class 5 on shallower rocky soils.

### Soil Erodibility Factor (K)

Soil represented by the pit OD210 was given a moderate K factor of 0.021. This relatively low K value indicates that the soil is relatively stable, and is likely to be tolerant of some tillage.

### Geotechnical Suitability for LRSF Construction

Pit OD210 was logged as 30cm low plasticity Sandy SAND (SC), over plastic CLAY (CH) to 90cm, and then Grey yellow distinctly weathered Andesite to the bottom of the pit at 1.4 m (**Appendix 3**).

It is likely that this material could be used to construct and embankment subject to laboratory testing. However, the Nubingerie landscape is dissected by several drainage lines and consequently has substantial run-on.

### Soil Stripping Suitability

The topsoil at the 2 sites sampled was marginally suitable for stripping due to its weak grade of structure. The subsoil in pit OD210 was mottled below 45cm, which limited the depth of material suitable for stripping to this depth.

### Subsoil Settling Class

Not assessed.

## 4.2.2.5 Ballimore Landscape on Triassic Napperby Formation

### Landform and Typical Vegetation

Footslopes and some undulating low hills on flat lying Napperby Formation sandstone, conglomerates, ferruginous material and siltstone. Grey box with White cypress pine on upper slopes and Fuzzy box on lower slopes.

The Ballimore landscape covered 940ha or 27% of the Soil Survey Area. The average slope was 4.6% with a standard deviation (s.d. of 2.7%), average EM 38 ECa was 43mS/m (s.d. 16mS/m), and the average EM 31 ECa was 63mS/m (s.d. 17mS/m). The Ballimore landscape was mapped in 2 locations. The western patch occupied a valley running to north-northeast from 651 000m E 6 406 500m N (**Figure 13**). The eastern patch was more complex, occupying 2 valleys beneath Belowrie Landscape, and the northern tip of the surveyed area. Two piezometers (DWB012 and DWB019) drilled in the centre of this unit intercepted more than 30m of continuous “clay” from the surface. The second patch was near the northeastern extremity of the Soil Survey Area.

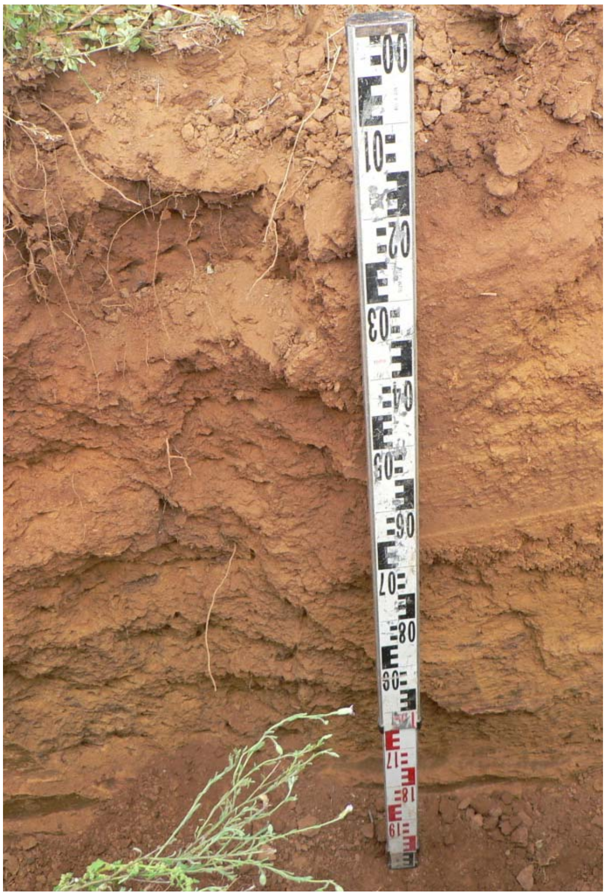
### Soil Types

Dominated by deep Red Chromosols with possible localised very deep Yellow Sodosols on lower slopes and depressions. Soil Profiles OD203, OD204, OD205, OD232, OD236, OD237, OD238, OD241, OD245, OD248, OD249, OD251. Pit OD203 was classified as a Red Chromosol, and described as:

0 to 15 cm
Dark reddish brown silty clay loam with moderate grade of angular blocky structure and 5 cm peds breaking to 1 cm. Good to excellent structure for root growth indicated by SOILpak score and many roots. Clods were not dispersive, did not slake in distilled water.

15 to 60 cm
Yellowish red light clay with moderate grade of prismatic structure and 5 cm peds breaking to 1 cm. Good to excellent structure for root growth indicated by SOILpak score and an average number of roots. Clods were not dispersive, partially slaked in distilled water.

60 to 135 cm
Yellowish brown silty clay with moderate grade of prismatic structure and 2 cm peds breaking to 1 cm. Poor to moderate structure for root growth indicated by SOILpak score and few roots. Soil had common, coarse, faint, red mottles. Clods were not dispersive, slaked completely in distilled water.



### Chemical Properties of Selected Soil Profiles

Profiles OD203, OD204 and OD238 had a relatively small capacity to store nutrients, indicated by the moderately low cation exchange capacity, had moderately acidic topsoil, and neutral to moderately alkaline subsoil with a moderate organic carbon content in the surface to 10 cm layer (**Table 9**). Available soil phosphorus, nitrate nitrogen and sulphate sulphur were moderately low throughout the profile. Tested micronutrients were generally present at adequate levels, but manganese was elevated, indicating that the soil may have been waterlogged. Salinity was desirably low through the profile, and cation ratios in the surface layers were acceptable. Exchangeable aluminium was elevated in the surface 10cm, and desirably low in deeper layers. The surface layers were moderately dispersive, and 5 of the 6 samples from deeper layers only slightly stable. The surface layers did not slake, but deeper layers slaked to a greater extent.

Soil represented by pit OD238 had high exchangeable sodium percentages which is associated with unstable structure.

This is consistent with properties observed in the soil pit and may reflect slightly different parent material to the majority of the Ballimore Landscape.

## Table 9a
## Results of soil tests performed by Incitec Pivot Laboratories on samples collected from Ballimore Landscape in March and July, 2012.

| DRYLAND WHEAT RATING | Very Low | Low | Moderately low | OK | Moderately high | High |
|---|---|---|---|---|---|---|

| Pit | OD203 | OD203 | OD203 | OD203 | OD204 | OD204 | OD204 | OD204 | OD237 | OD237 | OD237 | OD237 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Depth (cm) | 0 to 10 | 10 to 30 | 30 to 60 | 60 to 100 | 0 to 10 | 10 to 30 | 30 to 60 | 60 to 100 | 0 to 10 | 10 to 30 | 30 to 60 | 60 to 100 |
| Colour | Brown | Red | Orange/Yellow | Orange/Yellow | Red | Red | Red | Orange/Yellow | Red | Red | Orange/Yellow | Orange/Yellow |
| Texture | Clay Loam | Clay Loam | Clay Loam | Clay Loam | Clay Loam | Sandy Loam | Clay Loam | Clay Loam | Clay Loam | Clay Loam | Clay Loam | Clay Loam |
| CEC (meq/100g) | 7.3 | 10.3 | 9.9 | 11.2 | 9.0 | 4.0 | 11.7 | 6.3 | 8.7 | 13.1 | 23.5 | 16.8 |
| pH water | 5.4 | 6.7 | 7.3 | 7.7 | 5.7 | 6.8 | 6.8 | 7.7 | 6.1 | 6.6 | 8.3 | 8 |
| pH $CaCl_2$ | 4.3 | 5.9 | 6.5 | 6.8 | 4.6 | 6 | 5.8 | 6.8 | 5 | 5.6 | 7.7 | 7.3 |
| Organic C (%) | 1.1 | | | | 1 | | | | 1.4 | | | |
| Nitrate N (mg/kg) | 8.7 | 17 | 8.2 | 3.2 | 2.3 | 1.9 | 2 | 1 | 3.8 | 1.9 | 1.4 | 1.3 |
| Phosphorus Colwell (mg/kg) | 15 | | | | 6 | | | | 11 | | | |
| Sulphate S-KCl (mg/kg) | 8.0 | 4.6 | 4.7 | 2.0 | 1.8 | 2.6 | 1.7 | 2.3 | 5.1 | 3.6 | 2.0 | 1.7 |
| Sulphate S-MCP (mg/kg) | | | | | | | | | | | | |
| Potassium (meq/100 g) | 2.00 | 1.30 | 0.71 | 0.48 | 1.50 | 0.46 | 1.00 | 0.14 | 0.15 | 0.07 | 0.02 | 0.02 |
| Calcium (meq/100 g) | 4 | 7.5 | 7 | 8 | 6 | 2.8 | 8.5 | 4.3 | 6 | 10 | 21 | 14 |
| Magnesium (meq/100 g) | 0.75 | 1.5 | 2.1 | 2.7 | 1.2 | 0.69 | 2.2 | 1.8 | 1.2 | 2.1 | 2.1 | 2.3 |
| Aluminium (meq/100 g) | 0.48 | | | | 0.32 | | | | 0.1 | | | |
| Sodium (meq/100 g) | <0.02 | 0.03 | 0.05 | 0.05 | <0.02 | <0.02 | 0.03 | 0.04 | 0.06 | 0.04 | 0.08 | 0.06 |
| Chloride (mg/kg) | <10 | 13 | 17 | 15 | <10 | <10 | <10 | <10 | <10 | <10 | <10 | <10 |
| Electrical Conductivity $_{(1:5)}$ | 0.05 | 0.07 | 0.05 | 0.04 | 0.03 | 0.03 | 0.03 | 0.04 | 0.04 | 0.03 | 0.16 | 0.08 |
| Electrical Conductivity$_{se}$ (dS/m) | 0.40 | 0.50 | 0.40 | 0.30 | 0.30 | 0.40 | 0.20 | 0.3 | 0.3 | 0.2 | 1.2 | 0.6 |
| Copper (mg/kg) | 1.4 | | | | 1.4 | | | | 0.98 | | | |
| Zinc (mg/kg) | | | | | | | | | 0.51 | | | |
| Manganese (mg/kg) | 130 | | | | 52 | | | | 64 | | | |
| Iron (mg/kg) | 44 | | | | 25 | | | | 66 | | | |
| Boron (mg/kg) | 0.86 | | | | 0.85 | | | | 0.69 | | | |
| **Percentages of Exchangeable Cations** | | | | | | | | | | | | |
| ECaP (Calcium) | 55.2% | 72.6% | 71.0% | 71.2% | 66.4% | 70.5% | 72.5% | 68.5% | 69.3% | 76.5% | 89.2% | 83.6% |
| EMgP (Magnesium) | 10.3% | 14.5% | 21.3% | 24.0% | 13.3% | 17.4% | 18.8% | 28.7% | 13.9% | 16.1% | 8.9% | 13.7% |
| EKP (Potassium) | 27.6% | 12.6% | 7.2% | 4.3% | 16.6% | 11.6% | 8.5% | 2.2% | 15.0% | 7.1% | 1.5% | 2.3% |
| ESP (Sodium) | 0.3% | 0.3% | 0.5% | 0.4% | 0.2% | 0.5% | 0.3% | 0.6% | 0.7% | 0.3% | 0.3% | 0.4% |
| EAlP (Aluminium) | 6.6% | 0.0% | 0.0% | 0.0% | 3.5% | 0.0% | 0.0% | 0.0% | 1.2% | 0.0% | 0.0% | 0.0% |
| Ca/Mg ratio | 5.3 | 5.0 | 3.3 | 3.0 | 5.0 | 4.1 | 3.9 | 2.4 | 5.0 | 4.8 | 10.0 | 6.1 |
| K/Mg ratio | 2.7 | 0.9 | 0.3 | 0.2 | 1.3 | 0.7 | 0.5 | 0.1 | 1.1 | 0.4 | 0.2 | 0.2 |
| ESI | 0.18 | 0.24 | 0.10 | 0.09 | 0.14 | 0.06 | 0.12 | 0.06 | 0.06 | 0.10 | 0.47 | 0.22 |
| Dispersion Index | 6 | 2 | 2 | 2 | 6 | 10 | 2 | 0 | 6 | 6 | 2 | 4 |
| Slaking | Water Stable | Partial | Partial | Considerable | Water Stable | Water Stable | Partial | Water Stable | Partial | Water Stable | Partial | Partial |

**Table 9b**
**Results of soil tests performed by Incitec Pivot Laboratories on samples collected from Ballimore Landscape in July, 2012**

| DRYLAND WHEAT RATING | Very Low | Low | Moderately low | OK | Moderately high | High |
|---|---|---|---|---|---|---|

| Pit | OD238 | OD238 | OD238 | OD238 | OD245 | OD245 | OD245 | OD245 |
|---|---|---|---|---|---|---|---|---|
| Depth (cm) | **0 to 10** | **20 to 30** | **30 to 60** | **60 to 100** | **0 to 10** | **10 to 30** | **30 to 60** | **60 to 100** |
| Colour | Grey | Brown | Orange/Yellow | Orange/Yellow | Orange/Yellow | Orange/Yellow | Orange/Yellow | Orange/Yellow |
| Texture | Clay Loam | Clay Loam | Clay Loam | Clay Loam | Clay Loam | Clay Loam | Clay Loam | Clay Loam |
| CEC (meq/100g) | 5.6 | 6.7 | 13.2 | 13.9 | 5.7 | 12.7 | 20.3 | 21.9 |
| pH water | 6.2 | 7.2 | 8.2 | 8.7 | 6.1 | 6.5 | 7.1 | 7.6 |
| pH $CaCl_2$ | 5.1 | 5.6 | 7.2 | 7.7 | 4.8 | 5.4 | 6.1 | 6.5 |
| Organic C (%) | 1.1 | | | | 0.91 | | | |
| Nitrate N (mg/kg) | 3 | 0.6 | 0.5 | 0.5 | 0.9 | 0.8 | 0.5 | 0.5 |
| Phosphorus Colwell (mg/kg) | 5 | | | | 12 | | | |
| Sulphate S-KCl (mg/kg) | 1.9 | 1.0 | 4.2 | 8.1 | 2.2 | 1.7 | 9.2 | 5.8 |
| Sulphate S-MCP (mg/kg) | | | | | | | | |
| Potassium (meq/100 g) | 0.03 | 0.01 | 0.01 | 0.01 | 0.16 | 0.03 | 0.02 | 0.01 |
| Calcium (meq/100 g) | 3 | 2 | 2.6 | 2.1 | 3.4 | 8.5 | 13 | 14 |
| Magnesium (meq/100 g) | 2.2 | 4.1 | 9.1 | 9.9 | 1.2 | 3.6 | 6.7 | 7.3 |
| Aluminium (meq/100 g) | 0.1 | | | | 0.1 | 0.1 | | |
| Sodium (meq/100 g) | 0.11 | 0.48 | 1.3 | 1.7 | 0.07 | 0.1 | 0.26 | 0.4 |
| Chloride (mg/kg) | <10 | 13 | 42 | 69 | <10 | <10 | <10 | <10 |
| Electrical Conductivity $(_{1:5})$ | 0.03 | 0.03 | 0.1 | 0.15 | 0.03 | 0.03 | 0.06 | 0.04 |
| Electrical Conductivity$_{se}$ (dS/m) | 0.3 | 0.2 | 0.7 | 1.1 | 0.3 | 0.2 | 0.4 | 0.3 |
| Copper (mg/kg) | 0.47 | | | | 0.62 | | | |
| Zinc (mg/kg) | 0.18 | | | | 2.6 | | | |
| Manganese (mg/kg) | 15 | | | | 93 | | | |
| Iron (mg/kg) | 72 | | | | 58 | | | |
| Boron (mg/kg) | 0.33 | | | | 0.3 | | | |
| **Percentages of Exchangeable Cations** | | | | | | | | |
| ECaP (Calcium) | 53.6% | 30.0% | 19.8% | 15.2% | 60.1% | 67.1% | 64.1% | 63.8% |
| EMgP (Magnesium) | 39.3% | 61.5% | 69.1% | 71.4% | 21.2% | 28.4% | 33.1% | 33.3% |
| EKP (Potassium) | 3.4% | 1.3% | 1.2% | 1.2% | 15.7% | 2.8% | 1.5% | 1.1% |
| ESP (Sodium) | 2.0% | 7.2% | 9.9% | 12.3% | 1.2% | 0.8% | 1.3% | 1.8% |
| EAIP (Aluminium) | 1.8% | 0.0% | 0.0% | 0.0% | 1.8% | 0.8% | 0.0% | 0.0% |
| Ca/Mg ratio | 1.4 | 0.5 | 0.3 | 0.2 | 2.8 | 2.4 | 1.9 | 1.9 |
| K/Mg ratio | 0.1 | 0.0 | 0.0 | 0.0 | 0.7 | 0.1 | 0.0 | 0.0 |
| ESI | 0.02 | 0.00 | 0.01 | 0.01 | 0.02 | 0.04 | 0.05 | 0.02 |
| Dispersion Index | 4 | 12 | 14 | 14 | 7 | 1 | 0 | 0 |
| Slaking | Partial | Partial | Considerable | Considerable | Partial | Partial | Partial | Partial |

### Limitations

Gully erosion risk, inherent sheet erosion risk, potential recharge and discharge area, high run-on, and localised dryland salinity.

**Land and Soil Capability Classes**: Generally 3 and 4 with small areas of 5 on shallow soils and upper slopes and in areas where landscape forms low hills

### Soil Erodibility Factor (K)

Soil represented by the Pit OD203 was given a high K factor of 0.041, Pit OD236 had a similar K of 0.041, while Pit OD204 had a much lower K factor of 0.026. Cunningham (2002) attributed a K value of 0.026 to the topsoil layer of Pit 8, which was in the Ballimore landscape. The key difference between the sites was a higher proportion of silt in the topsoil of pit OD203 than the remaining 2 sites.

### Geotechnical Suitability for LRSF Construction

Pit OD203 was logged as 120cm Sandy CLAY (SC), while Pit OD204 was logged as 120cm Gravelly Clay (GC) over Extremely Weathered Conglomerate. Pit OD236 had a more complex profile of 80cm of predominantly plastic Clay (CH) over sandy Clay (CL) on Sandstone (Appendix III). Laboratory tests indicated that the material was dominated by clay and sand fractions, with a moderately low proportion of silt (**Table 10**).

**Table 10**
**Engineering properties of subsoil in pits OD203 and OD204, conducted by SCS laboratory, Scone, and Site 8, in the Ballimore landscape (from Cunningham, 2002)**

| Site | Depth range (cm) | Clay (%) | Silt (%) | Fine Sand (%) | Coarse Sand (%) | Gravel (%) | Liquid Limit (%) | Plastic Limit (%) | Plasticity Index (%) | Linear shrinkage (%) | USCS Class |
|---|---|---|---|---|---|---|---|---|---|---|---|
| OD203 | 50 to 100 | 33 | 12 | 36 | 18 | 1 | 33 | 13 | 20 | 10 | SC |
| OD204 | 50 to 100 | 30 | 6 | 11 | 8 | 45 | 51 | 22 | 29 | 11.5 | GC |
| Site 8 | 0 to 10 | 14 | 7 | 48 | 30 | 1 | | | | | |
| Site 8 | 10 to 57 | 32 | 4 | 36 | 27 | 1 | | | | | |
| Site 8 | 57 to 120 | 51 | 9 | 32 | 8 | 0 | | | | | |
| Site 8 | 120 to 165 | 38 | 10 | 39 | 13 | 0 | | | | | |
| Site 8 | 165 to 270 | 52 | 6 | 33 | 9 | 0 | | | | | |
| OD236 | 130 to 200 | 38 | 24 | 23 | 14 | 1 | 61 | 19 | 42 | 13.5 | CH |

The combination of relatively coarse particle size, low shrinkage (**Table 10**), and low dispersion (**Table 11**) indicate that the material sampled in the Ballimore landscape is likely to be suitable for use in the construction of embankments, but it may be difficult to form barriers with low permeability from some of this material.

The material sampled from 50 to 100cm in Pit OD203 had a permeability of $2*10^{-9}$ m/sec (equivalent to 0.2mm/day/m head, **Appendix 6**) when compacted to 95% of the maximum dry density of 1.78t/m$^3$ at the optimum moulding moisture of 13.3% (gravimetric). This is adequate performance for water storages.

The California Bearing Ratio of material sampled from 50 to 100cm in Pit OD203 was 3.5% after compacting and soaking for 4 days (**Appendix 6**). This was relatively weak.

### Soil Stripping Suitability

The topsoil to a depth of 25cm is likely to be suitable for stripping on the basis on observations in pits OD203, OD204, OD232, OD236, OD237, OD238, OD241 and OD245 (**Appendix 4**), but would require careful handling to avoid compaction. The remaining topsoil and subsoil to a depth of 75cm that is not mottled could be stripped and stockpiled. This is consistent with the observations of Cunningham (2002). It would be advisable to undertake further sampling when the final design is selected to ensure that the material to be stripped is consistently suitable for this purpose.

### Subsoil Settling Class

Both the measurements of dispersion percentage and the Emerson Aggregate Test indicated that the material sampled from Site 8 by Cunningham (2002) and from Pits OD203 and OD204 in this assessment was relatively stable (**Table 11**). In contrast the material from Pit OD236 was strongly dispersive. This supports a trend that the material in the Ballimore Landscape on the northeastern side of the surveyed area was more dispersive than material in the Ballimore Landscape along the western side of the surveyed area.

**Table 11**
**Laboratory indicators of soil stability of pits OD203 and OD204 conducted by SCS Laboratory, Scone, and from Site 8 in the Ballimore landscape (from Cunningham, 2002).**

| Site | Depth range (cm) | Dispersion (%) | Emerson Test | Calculated Total Dispersion | Subsoil Settling Class |
|---|---|---|---|---|---|
| OD203 | 50 to 100 | 15 | 3(1) | 6 | F |
| OD204 | 50 to 100 | 7 | 5 | 2 | F |
| Site 8 | 0 to 10 | 25 | 8/3[2] | 4 | C |
| Site 8 | 10 to 57 | 6 | 3[1] | 2 | F |
| Site 8 | 57 to 120 | 8 | 5 | 4 | F |
| Site 8 | 120 to 165 | 15 | 5 | 6 | F |
| Site 8 | 165 to 270 | 18 | 3[3] | 10 | F |
| OD236 | 130 to 200 | 44 | 2[1] | 22 | D |

## 4.2.2.6 Turkey Range Landscape on Jurassic Purlewaugh Formation

### Landform and Typical Vegetation

Undulating to rolling low hills and hills on Jurassic Purlewaugh sandstones, shales, lutite and mudstones with broad crests and gently sloping upper footslopes. One main occurrence is where a basalt cap has protected this outcrop from significant erosion in the north east of the survey area. Turkey Range Landscape not been previously mapped in the area, and chosen for its similarity to the Turkey Range Landscape that occurs east of Dubbo.

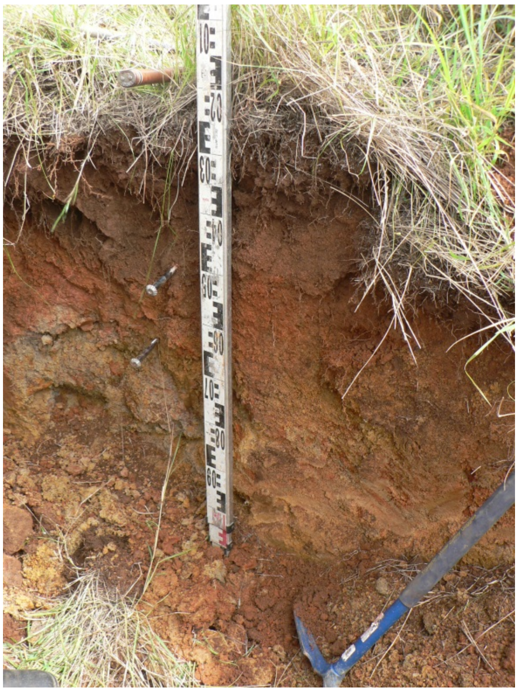
Woodland, open-woodland, and open dry sclerophyll forests dominated by Black cypress pine, grey box, and Blakely's red gum and Tumbledown gum.

The Turkey Range landscape covered 68ha or 2% of the Soil Survey Area. The average slope was 6.5% with a standard deviation (s.d.) of 2.9%, average EM 38 ECa was 31mS/m (s.d. 15mS/m), and the average EM 31 ECa was 54mS/m (s.d. 18mS/m). It is located along the eastern boundary of the Soil Survey Area (**Figure 13**).

### Soil Types

In the survey area, this landscape is dominated by shallow to moderately deep Brown Kurosols and Yellow Sodosols. Soil profiles OD213 and OD227. Pit OD213 was classified as a Yellow Sodosol, was a less fragile soil than the majority of the landscape, and was described as:

0 to 25cm
Reddish brown sandy clay loam with weak grade of subangular blocky structure and 3cm peds. Moderate to good structure for root growth indicated by SOILpak score and many roots. Clods were not dispersive, did not slake in distilled water.



20 to 45cm
Weak red light medium clay with strong grade of prismatic structure and 4cm peds. Good to excellent structure for root growth indicated by SOILpak score and an average number of roots. Soil had common, medium, distinct, grey mottles. Clods dispersed slightly, partially slaked in distilled water.

45 to 60cm
Yellowish brown medium clay with strong grade of prismatic structure and 6cm peds. Good to excellent structure for root growth indicated by SOILpak score and few roots. Soil had many, medium, prominent, grey mottles. Clods dispersed slightly, partially slaked in distilled water.

60 to 100cm
Weathered trachyte.

### Chemical Properties of Selected Soil Profile

Profile OD213 had a relatively small capacity to store nutrients, indicated by the moderately low cation exchange capacity, and had moderately acidic topsoil with moderate organic carbon content (**Table 12**). Available soil phosphorus, nitrate nitrogen and sulphate sulphur were moderately low throughout the profile. Tested micronutrients were generally present at adequate levels, but manganese was elevated, indicating that the soil may have been waterlogged. Salinity was desirably low through the profile, and cation ratios in the surface layers were acceptable. All layers were moderately dispersive.

**Table 12**
**Results of soil tests performed by Incitec Pivot laboratories on samples collected from the Turkey Range landscape in March 2012**

| DRYLAND WHEAT RATING | Very Low | Low | Moderately low | OK | Moderately high | High |
|---|---|---|---|---|---|---|

| Pit | OD213 | OD213 | OD213 |
|---|---|---|---|
| Depth (cm) | 0 to 10 | 10 to 30 | 30 to 60 |
| Colour | Orange/Yellow | Orange/Yellow | Orange/Yellow |
| Texture | Sandy Loam | Clay Loam | Clay Loam |
| CEC (meq/100g) | 11.6 | 8.5 | 17.2 |
| pH water | 6.4 | 6.6 | 7.3 |
| pH $CaCl_2$ | 5.5 | 5.2 | 6 |
| Organic C (%) | 1.2 | | |
| Nitrate N (mg/kg) | 8.7 | 1.7 | 1 |
| Phosphorus Colwell (mg/kg) | 8 | | |
| Sulphate S-KCl (mg/kg) | 2.3 | <1.0 | 1.2 |
| Sulphate S-MCP (mg/kg) | | | |
| Potassium (meq/100 g) | 0.06 | 0.03 | 0.01 |
| Calcium (meq/100 g) | 8 | 5.5 | 9.5 |
| Magnesium (meq/100 g) | 2.8 | 2.5 | 7 |
| Aluminium (meq/100 g) | | 0.1 | |
| Sodium (meq/100 g) | 0.07 | 0.16 | 0.61 |
| Chloride (mg/kg) | <10 | 11 | <10 |
| Electrical Conductivity ($_{1:5}$) | 0.05 | 0.02 | 0.03 |
| Electrical Conductivity$_{se}$ (dS/m) | 0.5 | 0.2 | 0.2 |
| Copper (mg/kg) | 0.47 | | |
| Zinc (mg/kg) | | | |
| Manganese (mg/kg) | 60 | | |
| Iron (mg/kg) | 32 | | |
| Boron (mg/kg) | 0.6 | | |
| **Percentages of Exchangeable Cations** | | | |
| ECaP (Calcium) | 68.9% | 64.8% | 55.2% |
| EMgP (Magnesium) | 24.1% | 29.4% | 40.7% |
| EKP (Potassium) | 6.4% | 2.7% | 0.5% |
| ESP (Sodium) | 0.6% | 1.9% | 3.5% |
| EAIP (Aluminium) | 0.0% | 1.2% | 0.0% |
| Ca/Mg ratio | 2.9 | 2.2 | 1.4 |
| K/Mg ratio | 0.3 | 0.1 | 0.0 |
| ESI | 0.08 | 0.01 | 0.01 |
| Dispersion Index | 4 | 3 | 3 |
| Slaking | Partial | Partial | Considerable |

### Limitations

Aluminium toxicity, generally poor drainage, low fertility, gully erosion risk, inherent sheet erosion risk, localised permanently high water tables, poor moisture availability, potential discharge area, localised rock outcrop, high run-on, localised seasonal waterlogging, localised seepage scalds, localised shallow soils and woody weeds.

**Land and Soil Capability Classes**: Generally class 5 with some areas of 6 on shallow, stony upper slopes.

### Soil Erodibility Factor (K)

Soil represented by the Pit OD213 was given a moderate K factor of 0.032.

### Geotechnical Suitability for Pond Construction

Fragile soil and better left undisturbed if possible.

### Soil Stripping Suitability

Fragile soil that is poorly suited for stripping.

### Subsoil Settling Class

Not assessed.

## 4.2.2.7 Mitchell Creek Landscape on Quaternary Alluvium

### Landform and Typical Vegetation

Recent alluvial deposits on floodplains along Wambangalang Creek. River red gum and River she oak with rough barked apple and apple box. Yellow box and Grey box found on outer edge of floodplain.

The Mitchell Creek landscape covered 72ha or 2% of the Soil Survey Area. The average slope was 3.2% with a standard deviation (s.d.) of 3.9%, average EM 38 ECa was 46mS/m (s.d. 18mS/m), and the average EM 31 ECa was 79mS/m (s.d. 20mS/m). It is located along the western margin of the Soil Survey Area (**Figure 13**).

### Soil Types

Highly variable soils including sandy Stratic Rudosols and giant Brown Dermosols (similar to Chernozems). Soil profiles OD209, OD234 and OD235. Pit OD209 was classified as a Brown Dermosol, and described as:


0 to 30cm
Dark brown clay loam with moderate grade of angular blocky structure and 1.5cm peds. Good to excellent structure for root growth indicated by SOILpak score and many roots. Clods were not dispersive, partially slaked in distilled water.

30 to 50cm
Brown silty clay loam with weak grade of massive structure. Moderate to good structure for root growth indicated by SOILpak score and an average number of roots. Clods dispersed completely, slaked completely in distilled water.

50 to 115cm
Reddish brown light clay with strong grade of angular blocky structure and 5cm peds. Moderate to good structure for root growth indicated by SOILpak score and few roots. Soil had common, medium, faint, grey mottles. Clods were not dispersive, partially slaked in distilled water.

115 to 170cm
Strong brown light clay with moderate grade of angular blocky structure and 5cm peds. Poor to moderate structure for root growth indicated by SOILpak score and no roots. Clods were not dispersive, partially slaked in distilled water.

### Chemical Properties of Selected Soil Profile

Profile OD209 had a relatively small capacity to store nutrients, indicated by the moderately low cation exchange capacity, and had moderately acidic topsoil with moderate organic carbon content (**Table 13**). Available soil phosphorus was high for a pasture profile, but nitrate nitrogen and sulphate sulphur were very low throughout the profile. Tested micronutrients were generally present at adequate levels. Salinity was desirably low through the profile, and cation ratios in the surface layers were acceptable. Exchangeable aluminium was moderately high in the surface 30cm. The surface layers were moderately dispersive, and the soil sampled deeper than 30cm was strongly dispersive. The surface sample was water stable, but deeper samples slaked considerably.

### Limitations

Flood hazard, productive arable land, high run-on, potential episodic waterlogging.

**Land and Soil Capability Classes**: Generally Class 2, but may become Class 1 where floodplain is broader away from survey area. Class 6 along drainage lines

**Table 13**
**Results of soil tests performed by Incitec Pivot laboratories on samples collected from Mitchell Creek landscape in March, 2012**

| DRYLAND WHEAT RATING | Very Low | Low | Moderately low | OK | Moderately high | High |
|---|---|---|---|---|---|---|

| Pit | OD209 | OD209 | OD209 | OD209 |
|---|---|---|---|---|
| Depth (cm) | 0 to 10 | 10 to 30 | 30 to 60 | 60 to 100 |
| Colour | Brown | Brown | Brown | Orange/Yellow |
| Texture | Clay Loam | Sandy Loam | Clay Loam | Clay Loam |
| CEC (meq/100g) | 5.2 | 4.7 | 7.6 | 13.6 |
| pH water | 5.5 | 6.4 | 6.8 | 7.8 |
| pH $CaCl_2$ | 4.5 | 5.2 | 5.5 | 6.3 |
| Organic C (%) | 1.1 | | | |
| Nitrate N (mg/kg) | 7.7 | 2 | 1 | 1 |
| Phosphorus Colwell (mg/kg) | 59 | | | |
| Sulphate S-KCl (mg/kg) | 1.8 | <1.0 | <1.0 | <1.0 |
| Sulphate S-MCP (mg/kg) | | | | |
| Potassium (meq/100 g) | 0.78 | 0.13 | 0.19 | 0.43 |
| Calcium (meq/100 g) | 3.3 | 3.3 | 4.7 | 8 |
| Magnesium (meq/100 g) | 0.82 | 1.1 | 2.6 | 4.6 |
| Aluminium (meq/100 g) | 0.23 | 0.1 | | |
| Sodium (meq/100 g) | 0.03 | 0.06 | 0.15 | 0.57 |
| Chloride (mg/kg) | <10 | <10 | <10 | <10 |
| Electrical Conductivity ($_{1:5}$) | 0.04 | 0.01 | 0.02 | 0.03 |
| Electrical Conductivity$_{se}$ (dS/m) | 0.4 | 0.1 | 0.2 | 0.2 |
| Copper (mg/kg) | 0.82 | | | |
| Zinc (mg/kg) | | | | |
| Manganese (mg/kg) | 49 | | | |
| Iron (mg/kg) | 110 | | | |
| Boron (mg/kg) | 0.42 | | | |
| **Percentages of Exchangeable Cations** | | | | |
| ECaP (Calcium) | 64.0% | 70.4% | 61.5% | 58.8% |
| EMgP (Magnesium) | 15.9% | 23.5% | 34.0% | 33.8% |
| EKP (Potassium) | 15.1% | 2.8% | 2.5% | 3.2% |
| ESP (Sodium) | 0.6% | 1.3% | 2.0% | 4.2% |
| EAIP (Aluminium) | 4.5% | 2.1% | 0.0% | 0.0% |
| Ca/Mg ratio | 4.0 | 3.0 | 1.8 | 1.7 |
| K/Mg ratio | 1.0 | 0.1 | 0.1 | 0.1 |
| ESI | 0.07 | 0.01 | 0.01 | 0.01 |
| Dispersion Index | 2 | 2 | 7 | 13 |
| Slaking | Water Stable | Considerable | Considerable | Considerable |

### Soil Erodibility Factor (K)

Soil represented by the Pit OD208 was given a moderate K factor of 0.031.

### Geotechnical Suitability for LRSF Construction

Too close to Wambangalang Creek to consider for this purpose.

### Soil Stripping Suitability

The topsoil to a depth of 25cm is likely to be suitable for stripping, but would require careful handling to avoid compaction. Subsoil to a depth of 75cm could be stripped where it is not mottled

### Subsoil Settling Class

Not assessed.

## 4.2.2.8 Bald Hill Landscape on Basalt Outcrop

### Landform and Typical Vegetation

Low hillocks with moderately steep slopes on basalt rock outcrop. White box and Kurrajong.

The Bald Hill landscape covered 84ha or 2% of the Soil Survey Area. The average slope was 5.7% with a standard deviation (s.d. of 2.7%), average EM 38 ECa was 53mS/m (s.d. 32mS/m), and the average EM 31 ECa was 79mS/m (s.d. 36mS/m). It occurs in four patches near the centre of the Soil Survey Area (**Figure 10**).

### Soil Types

Dominated by shallow to moderately deep Red Ferrosols. Soil profiles OD202, OD 220, OD221, OD228, and OD246. Pit OD202 was classified as a Red Ferrosol, and described as:


0 to 15cm
Dark reddish brown light clay with strong grade of crumb structure and 0.2cm peds. Excellent structure for root growth indicated by SOILpak score and many roots. Clods were moderately dispersive, did not slake in distilled water.

15 to 65cm
Dark red medium heavy clay with strong grade of angular blocky structure and 5cm peds breaking to 0.5cm. Excellent structure for root growth indicated by SOILpak score and an average number of roots. Clods were not dispersive, partially slaked in distilled water.

65 to 100cm
Red medium heavy clay with strong grade of angular blocky structure and 5cm peds breaking to 0.5cm. Good to excellent structure for root growth indicated by SOILpak score and an average number of roots. Clods were not dispersive, partially slaked in distilled water.

100 to 120cm
Distinctly weathered Trachyte.

### Chemical Properties of Selected Soil Profile

Profile OD202 had a moderate capacity to store nutrients, indicated by the moderate cation exchange capacity, and had moderately acidic topsoil with moderate organic carbon content (**Table 14**). Available soil phosphorus was adequate for a pasture profile, but nitrate nitrogen and sulphate sulphur were moderately low throughout the profile. Tested micronutrients were generally present at adequate levels, but manganese was elevated, indicating that the soil may have been waterlogged. Salinity was desirably low through the profile, and cation ratios in the surface layers were acceptable. Exchangeable aluminium was desirably low throughout the profile. The surface layers were moderately dispersive, while the subsoil layers were more stable.

**Table 14**
**Results of soil tests performed by Incitec Pivot laboratories on samples collected from Bald Hill landscape in March, 2012**

**Table 14.** Suitability for Wheat Production. Results of soil tests performed by Incitec/Pivot Laboratories on samples collected from Bald Hill Landscape in March, 2012.

| **DRYLAND WHEAT RATING** | Very Low | Low | Moderately low | OK | Moderately high | High |
|---|---|---|---|---|---|---|

| Pit | **OD202** | **OD202** | **OD202** | **OD202** |
|---|---|---|---|---|
| Depth (cm) | **0 to 10** | **10 to 30** | **30 to 60** | **60 to 100** |
| Colour | Red | Red | Red | Red |
| Texture | Clay Loam | Clay Loam | Clay | Clay Loam |
| CEC (meq/100g) | 16.4 | 19.7 | 19.9 | 20.8 |
| pH water | 6 | 6.9 | 7.8 | 8.1 |
| pH $CaCl_2$ | 5.1 | 6 | 6.8 | 7 |
| Organic C (%) | 1.8 | | | |
| Nitrate N (mg/kg) | 7.6 | 2.3 | 1 | 1 |
| Phosphorus Colwell (mg/kg) | 27 | | | |
| Sulphate S-KCl (mg/kg) | 2.5 | 1.8 | 2.9 | 1.4 |
| Sulphate S-MCP (mg/kg) | | | | |
| Potassium (meq/100 g) | 2.20 | 1.40 | 0.67 | 0.67 |
| Calcium (meq/100 g) | 11 | 14 | 13 | 13 |
| Magnesium (meq/100 g) | 3.1 | 4.3 | 6.1 | 7 |
| Aluminium (meq/100 g) | 0.1 | | | |
| Sodium (meq/100 g) | 0.03 | 0.03 | 0.08 | 0.13 |
| Chloride (mg/kg) | <10 | <10 | <10 | <10 |
| Electrical Conductivity $_{(1:5)}$ | 0.06 | 0.04 | 0.04 | 0.04 |
| Electrical Conductivity$_{se}$ (dS/m) | 0.40 | 0.30 | 0.20 | 0.30 |
| Copper (mg/kg) | 2.3 | | | |
| Zinc (mg/kg) | | | | |
| Manganese (mg/kg) | 140 | | | |
| Iron (mg/kg) | 40 | | | |
| Boron (mg/kg) | 0.78 | | | |
| **Percentages of Exchangeable Cations** | | | | |
| ECaP (Calcium) | 67.0% | 71.0% | 65.5% | 62.5% |
| EMgP (Magnesium) | 18.9% | 21.8% | 30.7% | 33.7% |
| EKP (Potassium) | 13.4% | 7.1% | 3.4% | 3.2% |
| ESP (Sodium) | 0.2% | 0.2% | 0.4% | 0.6% |
| EAIP (Aluminium) | 0.6% | 0.0% | 0.0% | 0.0% |
| Ca/Mg ratio | 3.5 | 3.3 | 2.1 | 1.9 |
| K/Mg ratio | 0.7 | 0.3 | 0.1 | 0.1 |
| ESI | 0.33 | 0.26 | 0.10 | 0.06 |
| Dispersion Index | 7 | 7 | 2 | 2 |
| Slaking | Water Stable | Partial | Partial | Considerable |

## Limitations

Localised, moderate fertility, inherent sheet erosion risk, localised poor moisture availability, potential recharge area, localised rock outcrop, localised steep slopes and localised shallow soils.

**Land and Soil Capability Classes**: Class 3 to 4 (Lower slopes) and 5

### Soil Erodibility Factor (K)

Soil represented by the Pit OD202 was given a desirably low K factor of 0.019.

### Geotechnical Suitability for LRSF Construction

Pit OD202 was logged as 1m of low plasticity Clay (CL) over distinctly weathered Trachyte (**Appendix 3**). Laboratory testing indicated that the material had greater plasticity than indicated by field testing (**Table 15**). This may be associated with weak cementing of clay particles iron oxides associated with the Ferrosol soil classification.

**Table 15**
**Engineering properties of subsoil in pits OD203 and OD204, conducted by SCS laboratory, Scone, and Site 8, in the Bald Hill landscape (from Cunningham, 2002)**

| Site | Depth range (cm) | Clay (%) | Silt (%) | Fine Sand (%) | Coarse Sand (%) | Gravel (%) | Liquid Limit (%) | Plastic Limit (%) | Plasticity Index (%) | Linear shrinkage (%) | USCS Class |
|---|---|---|---|---|---|---|---|---|---|---|---|
| OD202 | 50 to 100 | 46 | 11 | 18 | 21 | 4 | 57 | 19 | 38 | 15 | CH |

The moderately high shrink and swell capacity of the material tested indicate that care should be taken when using this material for constructing earthworks. The undulating nature of the landscape would render the Bald Hill landscape as a generally poor location for the LRSF.

### Soil Stripping Suitability

The topsoil is likely to be suitable for stripping. However, the topsoil was relatively shallow, being 15cm thick in Pits OD202 and OD221, and only 10 cm thick in Pit OD228. The subsoil had stable structure and could be stripped to 75cm where sampled (**Appendix 4**).

### Subsoil Settling Class

The subsoil material tested from the Bald Hill landscape was moderately dispersive indicated by the Emerson Aggregate Test of 3(1), and was allocated to the D subsoil settling class (**Table 16**).

**Table 16**
**Laboratory indicators of soil stability of pits OD 202 in the Bald Hill landscape conducted by SCS laboratory, Scone**

| Site | Depth range (cm) | Dispersion (%) | Emerson Test | Calculated Total Dispersion | Subsoil Settling Class |
|---|---|---|---|---|---|
| OD202 | 50 to 100 | 28 | 3(1) | 14 | D |

#### 4.2.2.9 Wongarbon Landscape on Basaltic Outcrops

### Landform and Typical Vegetation

Gently undulating low hills with minor basaltic hillocks, often with linear gilgai. White box and White cypress pine.

The Wongarbon landscape covered 450ha or 13% of the Soil Survey Area. The average slope was 4.3% with a standard deviation (s.d. of 2.3%), average EM 38 ECa was 60mS/m (s.d. 33mS/m), and the average EM 31 ECa was 83mS/m (s.d. 35mS/m). It occurs in 3 patches: near the centre of the northern part of the Soil Survey Area, running southward from the centre of the Soil Survey Area, and in a hill near the centre of the western side of the Soil Survey Area (**Figure 13**).

### Soil Types

Moderately deep Red Ferrosols and deep Red and Brown Vertosols with occasional very deep Vertic Red Dermosols (possible Ferrosols) where soil is deep but drainage is impeded below the soil. Soil profiles OD201, OD207, OD211 and OD212, OD214, OD217, OD224, OD225, OD239, OD241, OD242, OD247 and OD252. Pit OD211 was classified as a Red Vertosol, and described as:

0 to 10cm
Dark reddish brown heavy clay with strong grade of polyhedral structure and 0.4cm peds. Good to excellent structure for root growth indicated by SOILpak score and an average number of roots. Clods were not dispersive, did not slake in distilled water.


10 to 55cm
Dark reddish brown heavy clay with strong grade of prismatic structure and 3cm peds. Good to excellent structure for root growth indicated by SOILpak score and few roots. Clods were moderately dispersive, partially slaked in distilled water.

55 to 125cm
Reddish brown heavy clay with strong grade of lenticular structure and 5cm peds. Good structure for root growth indicated by SOILpak score and few roots. Clods dispersed strongly, partially slaked in distilled water.

### Chemical Properties of Selected Soil Profiles

The soil tested from the Wongarbon landscape had a moderate capacity to store nutrients, indicated by a larger cation exchange capacity than the other sites tested (**Table 17**). The soil was less acidic than the remaining profiles tested, and the organic carbon content was slightly higher. Available soil phosphorus varied from deficient in Pit OD242 to being present at luxury levels in Pit OD212. Nitrate nitrogen and sulphur were low throughout all profiles tested. Tested micronutrients were generally present at adequate levels. Salinity was desirably low through the profile except the 60 to 90cm layer of OD242, but was higher in the Wongarbon profiles than the other sites tested. Cation ratios were acceptable. Exchangeable aluminium was desirably low. The tested soil showed little tendency to disperse, apart from slight dispersion in OD207 and OD242, and the surface 10cm of OD212.

## Table 17a
## Results of soil tests performed by Incitec Pivot laboratories on samples collected from Wongarbon landscape in March, 2012

| DRYLAND WHEAT RATING | Very Low | Low | Moderately low | OK | Moderately high | High |
|---|---|---|---|---|---|---|

| Pit | OD201 | OD201 | OD201 | OD201 | OD207 | OD207 | OD207 | OD207 | OD211 | OD211 | OD211 | OD211 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Depth (cm) | 0 to 10 | 10 to 30 | 30 to 60 | 60 to 100 | 0 to 10 | 10 to 30 | 30 to 60 | 60 to 100 | 0 to 10 | 10 to 30 | 30 to 60 | 60 to 100 |
| Colour | Brown | Red | Red | Red | Brown | Red | Red | Brown | Red | Red | Red | Red |
| Texture | Clay | Clay | Clay | Clay | Clay Loam | Clay Loam | Clay Loam | Clay Loam | Clay | Clay | Clay | Clay |
| CEC (meq/100g) | 37.5 | 50.6 | 51.9 | 50.9 | 13.0 | 20.9 | 28.4 | 44.2 | 35.8 | 36.2 | 37.7 | 53.0 |
| pH water | 7 | 8.4 | 8.5 | 8.6 | 6.3 | 8 | 8.6 | 9.5 | 8.2 | 8.4 | 8.9 | 9.1 |
| pH $CaCl_2$ | 6.2 | 7.8 | 7.9 | 8 | 5.5 | 7 | 7.7 | 8.7 | 7.6 | 7.5 | 7.8 | 8.2 |
| Organic C (%) | 1.4 | | | | 2.7 | | | | 1.4 | | | |
| Nitrate N (mg/kg) | 9 | 1.8 | 2.1 | 1 | 18 | 1 | 1.5 | 1 | 15 | 4.9 | 2.2 | 1.6 |
| Phosphorus Colwell (mg/kg) | 34 | | | | 19 | | | | 11 | | | |
| Sulphate S-KCl (mg/kg) | 2.2 | 1.8 | 2.3 | 5.2 | 2.8 | 1.2 | 1.8 | 2.5 | 2.4 | <1.0 | <1.0 | 4.8 |
| Sulphate S-MCP (mg/kg) | | | | | | | | | | | | |
| Potassium (meq/100 g) | 1.30 | 0.35 | 0.34 | 0.41 | 1.90 | 1.60 | 1.80 | 0.58 | 0.04 | 0.02 | 0.01 | 0.01 |
| Calcium (meq/100 g) | 27 | 38 | 36 | 32 | 7.5 | 8 | 10 | 16 | 27 | 27 | 23 | 30 |
| Magnesium (meq/100 g) | 9.1 | 12 | 15 | 17 | 3.6 | 11 | 16 | 24 | 7.2 | 8.2 | 13 | 19 |
| Aluminium (meq/100 g) | | | | | | | | | | | | |
| Sodium (meq/100 g) | 0.14 | 0.28 | 0.57 | 1.5 | 0.04 | 0.27 | 0.61 | 3.6 | 0.13 | 0.36 | 1.4 | 3.6 |
| Chloride (mg/kg) | <10 | <10 | <10 | <10 | 13 | <10 | <10 | 130 | 15 | <10 | 12 | 43 |
| Electrical Conductivity ($_{1:5}$) | 0.09 | 0.16 | 0.17 | 0.22 | 0.1 | 0.06 | 0.12 | 0.43 | 0.17 | 0.09 | 0.09 | 0.27 |
| Electrical Conductivity$_{se}$ (dS/m) | 0.70 | 0.70 | 0.80 | 1.60 | 0.9 | 0.4 | 0.9 | 3.2 | 0.8 | 0.4 | 0.4 | 1.2 |
| Copper (mg/kg) | 1 | | | | 0.89 | | | | 0.81 | | | |
| Zinc (mg/kg) | | | | | | | | | | | | |
| Manganese (mg/kg) | 22 | | | | 91 | | | | 6.8 | | | |
| Iron (mg/kg) | 19 | | | | 97 | | | | 5.5 | | | |
| Boron (mg/kg) | 1 | | | | 0.66 | | | | 1.2 | | | |
| **Percentages of Exchangeable Cations** | | | | | | | | | | | | |
| ECaP (Calcium) | 71.9% | 75.1% | 69.4% | 62.9% | 57.5% | 38.3% | 35.2% | 36.2% | 75.4% | 74.6% | 61.0% | 56.6% |
| EMgP (Magnesium) | 24.2% | 23.7% | 28.9% | 33.4% | 27.6% | 52.7% | 56.3% | 54.3% | 20.1% | 22.6% | 34.5% | 35.8% |
| EKP (Potassium) | 3.5% | 0.7% | 0.7% | 0.8% | 14.6% | 7.7% | 6.3% | 1.3% | 4.2% | 1.8% | 0.8% | 0.8% |
| ESP (Sodium) | 0.4% | 0.6% | 1.1% | 2.9% | 0.3% | 1.3% | 2.1% | 8.1% | 0.4% | 1.0% | 3.7% | 6.8% |
| EAlP (Aluminium) | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| Ca/Mg ratio | 3.0 | 3.2 | 2.4 | 1.9 | 2.1 | 0.7 | 0.6 | 0.7 | 3.8 | 3.3 | 1.8 | 1.6 |
| K/Mg ratio | 0.1 | 0.0 | 0.0 | 0.0 | 0.5 | 0.1 | 0.1 | 0.0 | 0.2 | 0.1 | 0.0 | 0.0 |
| ESI | 0.24 | 0.29 | 0.15 | 0.07 | 0.33 | 0.05 | 0.06 | 0.05 | 0.47 | 0.09 | 0.02 | 0.04 |
| Dispersion Index | 0 | 0 | 0 | 0 | 4 | 4 | 2 | 2 | 0 | 0 | 0 | 0 |
| Slaking | Partial | Partial | Partial | Partial | Water Stable | Partial | Partial | Partial | Water Stable | Partial | Partial | Partial |

## Table 17b
## Results of soil tests performed by Incitec Pivot laboratories on samples collected from Wongarbon landscape in March and July, 2012

**DRYLAND WHEAT RATING**

| Very Low | Low | Moderately low | OK | Moderately high | High |
|---|---|---|---|---|---|

| Pit | OD212 | OD212 | OD212 | OD212 | OD239 | OD239 | OD239 | OD239 | OD242 | OD242 | OD242 | OD242 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Depth (cm) | 0 to 10 | 10 to 30 | 30 to 60 | 60 to 100 | 0 to 10 | 10 to 30 | 30 to 60 | 60 to 100 | 0 to 10 | 10 to 30 | 30 to 60 | 60 to 100 |
| Colour | Red | Red | Red | Red | Red | Red | Red | Red | Red | Red | Red | Red |
| Texture | Clay Loam | Clay | Clay | Clay Loam | Clay Loam | Clay Loam | Clay Loam | Clay Loam | Clay | Clay | Clay | Clay |
| CEC (meq/100g) | 20.0 | 22.1 | 22.8 | 33.0 | 5.4 | 11.8 | 23.1 | 28.9 | 38.6 | 39.4 | 40.9 | 53.2 |
| pH water | 6.5 | 7.2 | 7.5 | 7.7 | 5.8 | 7.6 | 9 | 9.2 | 7.8 | 8.3 | 8.9 | 7.4 |
| pH $CaCl_2$ | 5.7 | 6.3 | 6.5 | 6.6 | 4.2 | 6.1 | 7.8 | 8.5 | 6.9 | 7.3 | 8 | 6.9 |
| Organic C (%) | 2 | | | | 1.1 | | | | 1.2 | | | |
| Nitrate N (mg/kg) | 6.9 | 1 | 2 | 1 | 0.9 | 0.5 | 0.5 | 2.4 | 0.8 | 0.6 | 0.5 | 0.5 |
| Phosphorus Colwell (mg/kg) | 100 | | | | 14 | | | | 5 | | | |
| Sulphate S-KCl (mg/kg) | 1.1 | <1.0 | <1.0 | <1.0 | 2.4 | 1.7 | 1.9 | 30.0 | 2.4 | 1.9 | 2.1 | 36.0 |
| Sulphate S-MCP (mg/kg) | | | | | | | | | | | | |
| Potassium (meq/100 g) | 0.09 | 0.05 | 0.02 | 0.01 | 0.04 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.00 |
| Calcium (meq/100 g) | 14 | 16 | 17 | 25 | 2.1 | 4.2 | 6 | 7 | 26 | 25 | 23 | 23 |
| Magnesium (meq/100 g) | 4.1 | 5 | 5.3 | 7.5 | 1.6 | 5.8 | 12 | 13 | 11 | 12 | 14 | 20 |
| Aluminium (meq/100 g) | | | | | 1.2 | | | | | | | |
| Sodium (meq/100 g) | 0.03 | 0.04 | 0.07 | 0.1 | 0.33 | 1.6 | 4.8 | 8.7 | 1.2 | 2 | 3.6 | 10 |
| Chloride (mg/kg) | <10 | <10 | <10 | <10 | <10 | 15 | 150 | 850 | 12 | <10 | 32 | 790 |
| Electrical Conductivity $_{(1:5)}$ | 0.07 | 0.04 | 0.04 | 0.03 | 0.03 | 0.06 | 0.22 | 0.94 | 0.1 | 0.11 | 0.25 | 0.98 |
| Electrical Conductivity$_{se}$ (dS/m) | 0.5 | 0.2 | 0.2 | 0.2 | 0.3 | 0.4 | 1.6 | 7 | 0.5 | 0.5 | 1.1 | 4.4 |
| Copper (mg/kg) | 1.7 | | | | 1.5 | | | | 1.2 | | | |
| Zinc (mg/kg) | | | | | 0.52 | | | | 0.18 | | | |
| Manganese (mg/kg) | 47 | | | | 94 | | | | 17 | | | |
| Iron (mg/kg) | 31 | | | | 88 | | | | 19 | | | |
| Boron (mg/kg) | 1 | | | | 0.52 | | | | 1.2 | | | |
| **Percentages of Exchangeable Cations** | | | | | | | | | | | | |
| ECaP (Calcium) | 69.9% | 72.3% | 74.5% | 75.8% | 38.7% | 35.7% | 26.0% | 24.2% | 67.3% | 63.5% | 56.3% | 43.2% |
| EMgP (Magnesium) | 20.5% | 22.6% | 23.2% | 22.7% | 29.5% | 49.4% | 52.1% | 44.9% | 28.5% | 30.5% | 34.3% | 37.6% |
| EKP (Potassium) | 9.5% | 5.0% | 2.0% | 1.2% | 3.7% | 1.3% | 1.1% | 0.8% | 1.1% | 0.9% | 0.6% | 0.3% |
| ESP (Sodium) | 0.1% | 0.2% | 0.3% | 0.3% | 6.1% | 13.6% | 20.8% | 30.1% | 3.1% | 5.1% | 8.8% | 18.8% |
| EAIP (Aluminium) | 0.0% | 0.0% | 0.0% | 0.0% | 22.1% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| Ca/Mg ratio | 3.4 | 3.2 | 3.2 | 3.3 | 1.3 | 0.7 | 0.5 | 0.5 | 2.4 | 2.1 | 1.6 | 1.2 |
| K/Mg ratio | 0.5 | 0.2 | 0.1 | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| ESI | 0.47 | 0.22 | 0.13 | 0.10 | 0.00 | 0.00 | 0.01 | 0.03 | 0.03 | 0.02 | 0.03 | 0.05 |
| Dispersion Index | 3 | 0 | 0 | 0 | 12 | 16 | 14 | 5 | 2 | 3 | 4 | 4 |
| Slaking | Water Stable | Water Stable | Partial | Considerable | Partial | Partial | Considerable | Considerable | Partial | Water Stable | Partial | Considerable |

### Limitations

Generally fertile soils. Soil engineering hazard (high shrink – swell potential), inherent sheet erosion risk and potential recharge area.

**Land and Soil Capability Classes**: Generally Class 3 and 4.

### Soil Erodibility Factor (K)

Soil represented by the pit OD201 was given a desirably low K factor of 0.015, OD207 had a K factor of 0.020, OD211 had a K factor of 0.013 and both OD212 and OD242 had a K factor of 0.019. These desirably low values are consistent with land that is moderately tolerant of disturbance.

### Geotechnical Suitability for LRSF Construction

The five pits in the Wongarbon landscape that were described consisted predominantly of plastic Clay (CH) (**Appendix 3, Table 18**). This material has generally low permeability, but is prone to shrink and swell.

**Table 18**
**Engineering properties of subsoil in pits OD201, OD 207, OD 211, OD214 and OD242 conducted by SCS Laboratory, Scone, in the Wongarbon landscape.**

| Site | Depth range (cm) | Clay (%) | Silt (%) | Fine Sand (%) | Coarse Sand (%) | Gravel (%) | Liquid Limit (%) | Plastic Limit (%) | Plasticity Index (%) | Linear shrinkage (%) | USCS Class |
|---|---|---|---|---|---|---|---|---|---|---|---|
| OD201 | 80 to 120 | 59 | 15 | 18 | 7 | 1 | 76 | 24 | 52 | 20.5 | CH |
| OD207 | 50 to 100 | 68 | 10 | 11 | 10 | 1 | 93 | 28 | 65 | 20 | CH |
| OD211 | 50 to 100 | 57 | 15 | 21 | 7 | 0 | 79 | 25 | 56 | 20.5 | CH |
| OD214 | 60 to 80 | 53 | 15 | 23 | 9 | 0 | 64 | 17 | 47 | 15 | CH |
| OD242 | 100 to 130 | 64 | 21 | 9 | 5 | 1 | 100 | 28 | 72 | 19.5 | CH |

The shrinking and swelling nature of the soil indicate that care should be taken to thoroughly compact material used in embankments to avoid degradation of embankments by tunnelling. The susceptibility to tunnelling is also indicated by the moderate dispersion percentage in **Table 19**.

The material sampled from 60 to 80cm in pit OD214 had a permeability of $4x10^{-8}$m/sec (equivalent to 3.5mm/day/m head, **Appendix 6**) when compacted to 95% of the maximum dry density of 1.64t/$m^3$ at the optimum moulding moisture of 20.4% (gravimetric). Lining with more permeable material would be required for this to provide adequate performance for water storage.

The California Bearing Ratio of material sampled from 60 to 80cm in pit OD214 was 2.5% after compacting and soaking for 4 days (**Appendix 6**). This was very weak.

### Soil Stripping Suitability

The strong grade of structure and low dispersion render much of the topsoil in the Wongarbon landscape suitable for stripping. In general, clayey soil is less susceptible to structural degradation if it is worked when it is moderately dry, in contrast to loamy soil, which tends to suffer dramatic breakdown of structure if worked when dry. The subsoil to 75cm was also generally suitable for stripping due to its stable structure. Only one of the 13 sites sampled was mottled at depths shallower than 60cm (**Appendix 4**).

### Subsoil Settling Class

Both the measurements of dispersion percentage and the Emerson Aggregate Test indicated that the material sampled from Pits OD201, OD207, OD211, OD214 and OD242 was moderately dispersive and allocated to subsoil settling class D (**Table 19**).

**Table 19**
**Laboratory indicators of soil stability of Pits OD201, OD207, OD211 and OD214 conducted by SCS Laboratory, Scone, in the Wongarbon landscape**

| Site | Depth range (cm) | Dispersion (%) | Emerson Test | Calculated Total Dispersion | Subsoil Settling Class |
|---|---|---|---|---|---|
| OD201 | 80 to 120 | 26 | 4 | 17 | D |
| OD207 | 50 to 100 | 36 | 4 | 26 | D |
| OD211 | 50 to 100 | 50 | 4 | 32 | D |
| OD214 | 60 to 80 | 41 | 4 | 25 | D |
| OD242 | 100 to 130 | 58 | 2[1] | 43 | D |

### 4.2.2.10 Belowrie Landscape on Weathered Trachyte

### Landform and Typical Vegetation

Undulating, occasionally rolling rises and hills on Jurassic trachyte with Grey box and Blakely's red gum.

Red Chromosols with Red Kandosols and Brown Chromosols on more stable lower slopes and Yellow Sodosols on flatter lower areas. Shallow Rudosols and Tenosols on rocky crests. Hard setting and acidic surfaces.

The Belowrie landscape covered 960ha or 28% of the Soil Survey Area. The average slope was 6.8% with a standard deviation (s.d.) of 3.8%, average EM 38 ECa was 42mS/m (s.d. 20mS/m), and the average EM 31 ECa was 68mS/m (s.d. 24mS/m). It occupies much of the central north-south axis of the Soil Survey Area (**Figure 13**).

### Soil Types

Crests dominated by shallow, rocky Rudosols, with shallow to moderately deep Red Chromosols on gentle midslope positions and shallow to deep Red and Yellow Sodosols on footslopes and along drainage lines. The patches of Belowrie in the north of the surveyed area had deeper soil that was more clayey. Soil profiles included OD216, OD218, OD219, OD223, OD226, OD229, OD231, OD240, OD243, OD244 and OD253. Core OD218 was classified as a Red Chromosol, and described as:

0 to 10cm
Dark reddish brown clay loam with strong grade of polyhedral structure and 0.3cm peds. Excellent structure for root growth indicated by SOILpak score and abundant roots. Clods dispersed slightly, partially slaked in distilled water.

10 to 70cm
Red light medium clay with strong grade of angular blocky structure and 3cm peds. Good to excellent structure for root growth indicated by SOILpak score and an average number of roots. Clods dispersed slightly, partially slaked in distilled water.

70 to 130cm
Light grey heavy clay with strong grade of prismatic structure and 5cm peds. Moderate structure for root growth indicated by SOILpak score and few roots. Soil had common, fine, prominent, red mottles. Clods dispersed completely, partially slaked in distilled water.

### Chemical Properties of Selected Profiles

The soil sampled from Pits OD243 and OD244 toward the northern end of the surveyed area was regarded as close to an intergrade between the Belowrie and Wongarbon landscapes. The soil in OD244 was generally more clayey than OD243. As such, it had a higher capacity to store nutrients and higher pH than OD243 (**Table 20**).

However both pits had relatively low levels of the major nutrients of phosphorous, nitrate nitrogen and sulphur. The soil was generally sodic and dispersive with a trend of increasing salinity throughout the profile. The soil was moderately to strongly dispersive throughout the profile.

**Table 20**

**Results of soil tests performed by Incitec Pivot Laboratories on samples collected from Belowrie Landscape in July, 2012**

**Table 20.** Suitability for Wheat Production. Results of soil tests performed by Incitec/Pivot Laboratories on samples collected from Belowrie Landscape in July, 2012.

| **DRYLAND WHEAT RATING** | Very Low | Low | Moderately low | OK | Moderately high | High |
|---|---|---|---|---|---|---|

| Pit | **OD243** | **OD243** | **OD243** | **OD243** | **OD244** | **OD244** | **OD244** | **OD244** |
|---|---|---|---|---|---|---|---|---|
| Depth (cm) | **0 to 10** | **10 to 30** | **30 to 60** | **60 to 100** | **0 to 10** | **10 to 30** | **30 to 60** | **60 to 100** |
| Colour | Brown | Orange/Yellow | Orange/Yellow | Brown | Grey | Brown | Brown | Brown |
| Texture | Clay Loam | Clay Loam | Clay Loam | Clay Loam | Clay | Clay | Clay Loam | Clay |
| CEC (meq/100g) | 6.2 | 9.1 | 12.7 | 20.0 | 21.6 | 25.5 | 29.5 | 23.7 |
| pH water | 6.1 | 6.9 | 7.1 | 8.7 | 7.5 | 8.4 | 9 | 5.3 |
| pH $CaCl_2$ | 4.9 | 5.5 | 6.2 | 8.1 | 6.3 | 7.2 | 8.2 | 4.7 |
| Organic C (%) | 1.3 | | | | 1.1 | | | |
| Nitrate N (mg/kg) | 3.1 | 0.5 | 0.6 | 0.5 | 0.7 | 0.5 | 0.5 | 0.5 |
| Phosphorus Colwell (mg/kg) | 5 | | | | 6 | | | |
| Sulphate S-KCl (mg/kg) | 1.4 | 1.0 | 1.3 | 3.4 | 1.4 | 1.6 | 21.0 | 84.0 |
| Sulphate S-MCP (mg/kg) | | | | | | | | |
| Potassium (meq/100 g) | 0.10 | 0.02 | 0.01 | 0.01 | 0.03 | 0.01 | 0.01 | 0.01 |
| Calcium (meq/100 g) | 3.4 | 2.8 | 2.5 | 2.1 | 10 | 10 | 8.5 | 4.5 |
| Magnesium (meq/100 g) | 2 | 5.6 | 8.2 | 12 | 9.9 | 13 | 15 | 12 |
| Aluminium (meq/100 g) | 0.1 | | | | | | | 0.44 |
| Sodium (meq/100 g) | 0.11 | 0.52 | 1.9 | 5.7 | 1.1 | 2.1 | 5.7 | 6.5 |
| Chloride (mg/kg) | 15 | 15 | 260 | 750 | 19 | 44 | 510 | 950 |
| Electrical Conductivity ($_{1:5}$) | 0.03 | 0.04 | 0.22 | 0.76 | 0.08 | 0.11 | 0.6 | 0.82 |
| Electrical Conductivity$_{se}$ (dS/m) | 0.3 | 0.3 | 1.6 | 5.6 | 0.4 | 0.5 | 4.4 | 5.1 |
| Copper (mg/kg) | 0.46 | | | | 0.95 | | | |
| Zinc (mg/kg) | 0.32 | | | | 0.27 | | | |
| Manganese (mg/kg) | 21 | | | | 17 | | | |
| Iron (mg/kg) | 68 | | | | 34 | | | |
| Boron (mg/kg) | 0.36 | | | | 1 | | | |
| **Percentages of Exchangeable Cations** | | | | | | | | |
| ECaP (Calcium) | 54.8% | 30.8% | 19.6% | 10.5% | 46.3% | 39.3% | 28.8% | 19.0% |
| EMgP (Magnesium) | 32.2% | 61.7% | 64.4% | 60.1% | 45.8% | 51.1% | 50.8% | 50.6% |
| EKP (Potassium) | 9.7% | 1.8% | 1.1% | 0.8% | 2.9% | 1.4% | 1.0% | 1.1% |
| ESP (Sodium) | 1.8% | 5.7% | 14.9% | 28.6% | 5.1% | 8.2% | 19.3% | 27.4% |
| EAlP (Aluminium) | 1.6% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 1.9% |
| Ca/Mg ratio | 1.7 | 0.5 | 0.3 | 0.2 | 1.0 | 0.8 | 0.6 | 0.4 |
| K/Mg ratio | 0.3 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 |
| ESI | 0.02 | 0.01 | 0.01 | 0.03 | 0.02 | 0.01 | 0.03 | 0.03 |
| Dispersion Index | 4 | 11 | 10 | 4 | 11 | 12 | 3 | 0 |
| Slaking | Partial | Vater Stable | Partial | Partial | Partial | Partial | ;onsiderable | Partial |

## Limitations

Highly variable fertility, localised gully erosion risk, inherent sheet erosion risk, localised poor moisture availability, potential recharge area, rock outcrop common, run-on on crests and upper slopes shallow soils, localised steep slopes.

**Land and Soil Capability Classes**: Generally 3 to 5 with localised areas of 6 on crests and outcrop.

### Soil Erodibility Factor (K)

Pit OD243 had a K value of 0.043, and OD244 had a K value of 0.035. Cunningham (2002) attributed a K value of 0.036 to the topsoil layer of Site 25, and 0.046 to the topsoil layer of Site 26 which were in the Belowrie landscape. These values are at the upper end of the moderate range, and the lower end of the undesirably high range, and indicate that care should be taken to minimise disturbance of surface soil in the Belowrie landscape.

### Geotechnical Suitability for LRSF Construction

The Belowrie landscape was generally regarded as poorly suited for the location for LRSF because of the undulating nature of the landscape. However the two patches near the northern end of the Soil Survey Area assessed were flatter and had deeper soil. It is likely that the LRSF could be constructed in these areas with care. Laboratory tests conducted by Cunningham (2002) indicate that material sampled from the Belowrie landscape was dominated by gravel (**Table 21**).

**Table 21**
**Engineering properties of Site 25 and Site 28 (from Cunningham, 2002) and Pits OD243 and OD244, in the Belowrie landscape**

| Site | Depth range (cm) | Clay (%) | Silt (%) | Fine Sand (%) | Coarse Sand (%) | Gravel (%) | Liquid Limit (%) | Plastic Limit (%) | Plasticity Index (%) | Linear shrinkage (%) | USCS Class |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Site 25 | 0 to 18 | 18 | 16 | 39 | 19 | 8 | | | | | |
| Site 25 | 18 to 40 | 20 | 5 | 20 | 13 | 42 | | | | | |
| Site 25 | 40 to 64 | 54 | 5 | 15 | 11 | 15 | | | | | |
| Site 25 | 64 to 130 | 24 | 3 | 11 | 11 | 51 | | | | | |
| Site 25 | 130 to 270 | 12 | 4 | 7 | 21 | 56 | | | | | |
| Site 28 | 0 to 27 | 10 | 12 | 51 | 19 | 8 | | | | | |
| Site 28 | 27 to 54 | 6 | 8 | 16 | 28 | 42 | | | | | |
| OD243 | 70 to 130 | 31 | 23 | 43 | 3 | 0 | 36 | 15 | 21 | 8.5 | CI |
| OD244 | 50 to 100 | 55 | 14 | 25 | 6 | 0 | 59 | 16 | 43 | 13 | CH |

### Soil Stripping Suitability

It is likely that many areas of the Belowrie landscape are suitable for stripping, but the variable nature of the soil means that each site should be assessed for its suitability for stripping.

There was a general pattern that the soil was thin in the parts of the Belowrie landscape that are close to the site of the planned mine. The topsoil to 10cm had a medium to strong grade of structure and was rated as suitable for stripping in approximately half the sites examined in this area. The topsoil was suitable for stripping in the remaining sites examined. The subsoil was generally suitable for stripping to a depth of 50 to 70cm where the topsoil was suitable for stripping (**Appendix 4**).

### Subsoil Settling Class

Both the measurements of dispersion percentage and the Emerson Aggregate Test indicated that the material sampled from Site 25 and Site 28 by Cunningham (2002) was relatively stable (**Table 22**). In contrast the clayey material sampled in Pit OD201 was dispersive.

**Table 22**
**Laboratory indicators of soil stability of Site 8 in the Belowrie landscape (from Cunningham, 2002)**

| Site | Depth range (cm) | Dispersion (%) | Emerson Test | Calculated Total Dispersion | Subsoil Settling Class |
|---|---|---|---|---|---|
| Site 25 | 0 to 18 | 23 | 8/3[3] | 6 | F |
| Site 25 | 18 to 40 | 14 | 3[3] | 3 | F |
| Site 25 | 40 to 64 | 16 | 5 | 9 | D |
| Site 25 | 64 to 130 | 17 | 4 | 4 | F |
| Site 25 | 130 to 270 | 17 | 4 | 2 | F |
| Site 28 | 0 to 27 | 13 | 8/3[1] | 2 | C |
| Site 28 | 27 to 54 | 29 | 8/3[1] | 3 | C |
| OD243 | 70 to 130 | 84 | 2[2] | 36 | D |
| OD244 | 50 to 100 | 65 | 2[2] | 40 | D |

#### 4.2.2.11 Dowd Landscape on Weathered Trachyte

**Landform and Typical Vegetation**

Hills of rock pavements and scarps Jurassic Trachyte Volcanic plugs may be sodic. Mainly uncleared Black cypress and White cypress pine forest and bare rock.

The Dowd landscape covered 445ha or 13% of the Soil Survey Area. The average slope was 12.3% with a standard deviation (s.d.) of 6.5%, the EM survey was only conducted over a small portion of the Dowd landscape, and so average values are not presented. The Dowd landscape occurs in the east of the Soil Survey Area (**Figure 10**), with 6 small patches near the centre of the Soil Survey Area and one in the north.

### Soil Types

Very shallow soils; Leptic Rudosols, with pockets of Shallow Red Kandosol. Soil core OD230 was classified as a Red Kandosol, and described as:


0 to 10cm
Pink loam with massive structure. Moderate structure for root growth indicated by SOILpak score and an average number of roots. Clods were not dispersive, did not slake in distilled water.

10 to 45cm
Light red loam, fine sandy with massive grade of structure and  cm peds breaking to  cm. Moderate structure for root growth indicated by SOILpak score and no roots. Clods were not dispersive, did not slake in distilled water.

### Limitations

Inherent sheet erosion risk, large areas of rock outcrop, shallow soils low fertility soils and woody weeds.

**Land and Soil Capability Classes**: Generally 7 with small areas of 6 where soil is deeper.

### Geotechnical Suitability for LRSF Construction

Landform is unsuitable for location of the LRSF

### Soil Stripping Suitability

It is likely that much of the topsoil is suitable for stripping, but the undulating nature of the landscape and shallow topsoil depth would cause the process of stripping topsoil to be challenging.

## 4.2.3 Land and Soil Capability

Each soil landscape polygon in **Figure 13** has been allocated a range of Land and Soil Capability Classes (labelled in **Figure 14**), as well as a dominant Land and Soil Capability Class (colour in **Figure 15**)[1]. The dominant Land and Soil Capability Classes are 3 (grazing and regular cultivation) and 4 (grazing and sufficient cultivation to establish improved pasture), which together account for 83% of the area assessed. This is largely in accord with the land use shown on **Figure 9**. However, it should be noted that the broad scale of the assessment will result in patches of lower capability land (higher Land and Soil Capability Class number) within each polygon.

A small area of Class 2 was mapped along the floodplain of Wambangalang Creek (**Figure 15**). This was mapped as Mitchell Creek landscape and has a deep, loamy textured fertile soil that is flooded sporadically.

[1] Roman Numerals are interchangeable with respective Arabic Numerals (as presented in Table 3).

**Figure 14 Toongi Land and Soil Capability Class Ranges**

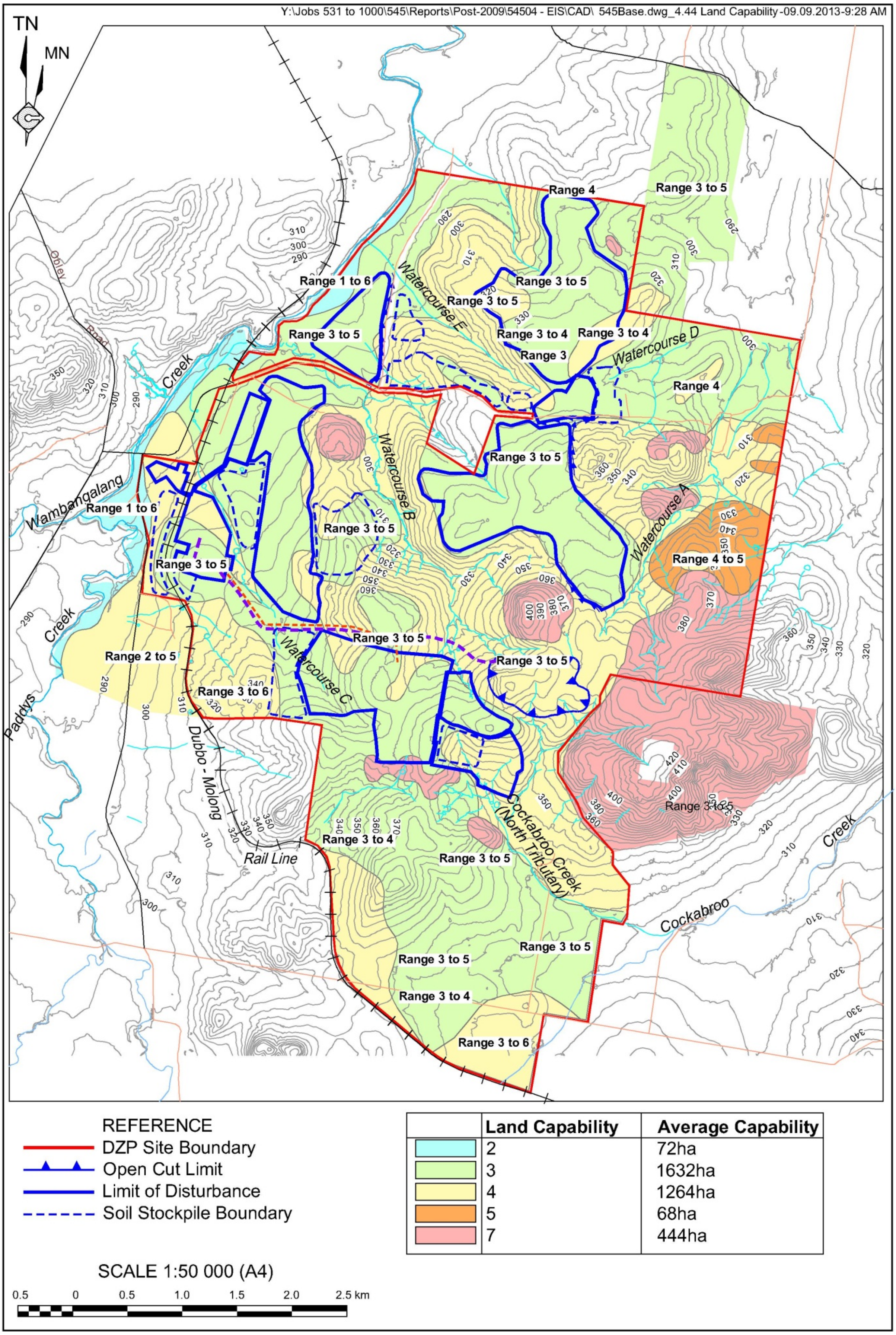
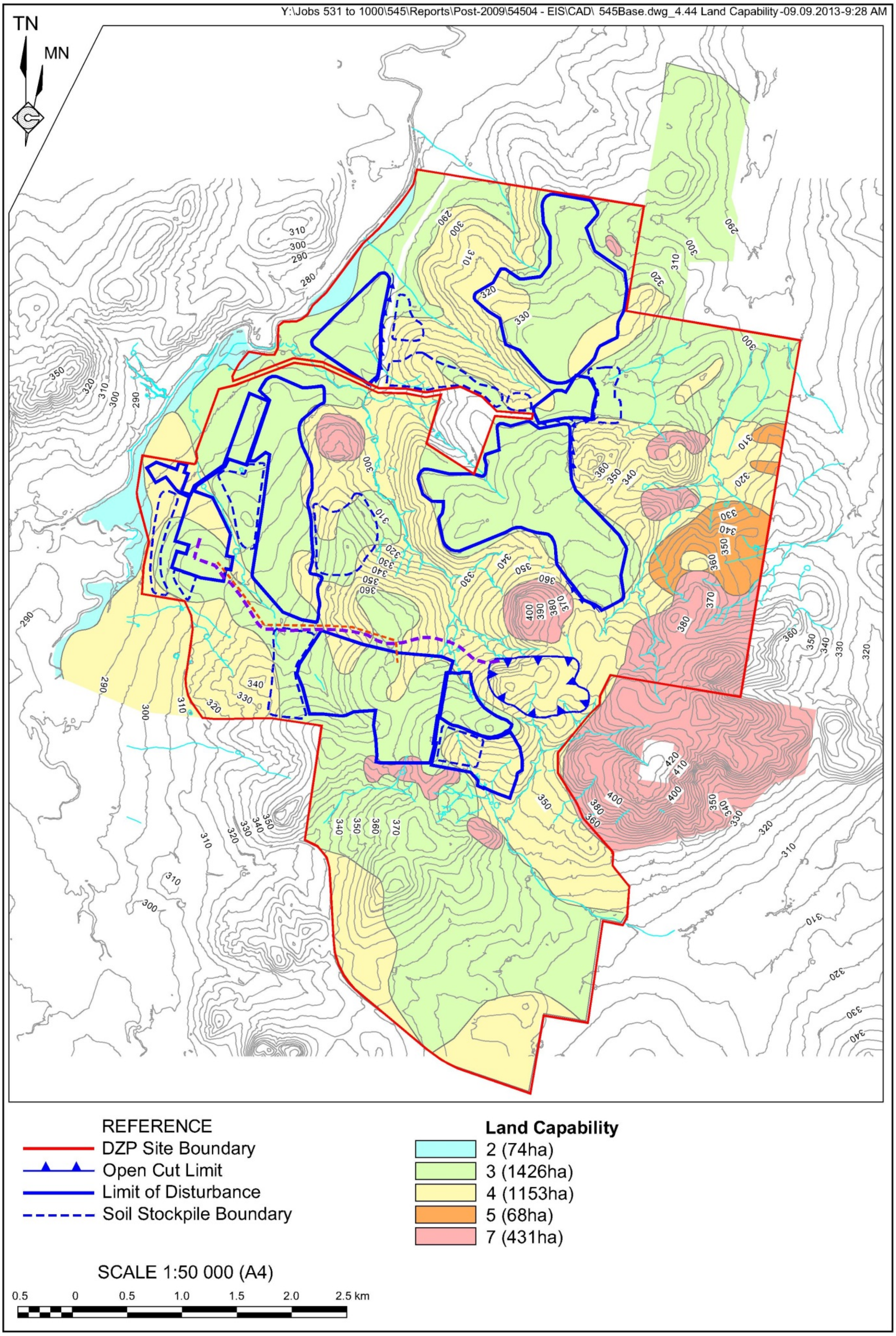


**Figure 15 Dominant Toongi Land and Soil Capability Classes**



All of the area mapped as Bald Hill, Nubingerie and Wongarbon landscapes, the majority of Ballimore landscape, the northernmost 2 polygons of Belowrie landscape were mapped as Class 3 land. Use of this land for cropping was limited by common surface stones, susceptibility of the surface soil to erosion, long slopes and moderate soil fertility. All of the Arthurvillle and Splitters Hill landscapes, a polygon of Ballimore landscape with steep slopes, and the majority of Belowrie landscape were mapped as Class 3. The suitability of Arthurville landscape for cultivation was limited by patches of apparently saline subsoil, and other patches of shallow topsoil. The area of Splitters Hill landscape sampled had shallow soil and common surface stones. The Belowrie landscape was generally characterised by large short range variation in soil properties and included areas of very shallow soil. Such soil is not suitable for cultivation.

The Turkey Range landscape with strongly dispersive topsoil was mapped as Class 5. The Dowd landscape was characterised by very shallow soil and allocated to Class 7. This land generally supports dense woodland, indicating that land managers have generally decided that it has limited potential for grazing.

Observations during the assessment indicate that most of the land that is shown in **Figure 14** as Class 2, 3 and 4 has been cultivated at some time. Cultivation has been most frequent in the better parts of the Class 3 land, and principally in the Ballimore, Wongarbon and Nubingerie landscapes. Cultivation has been less frequent in the steeper and stonier parts of these landscapes. It is likely that the areas of land best suited to agriculture would also be better suited than steeper land to the construction of mine infrastructure such as stockpiles, LRSF and processing plant.

### 4.2.4 Summary of Suitability for Construction of the LRSF

The undulating landform of the Soil Survey Area renders much of the site too steep for efficient construction of the salt crystallisation cells of the LRSF. Areas that are flat enough to construct the cells generally have deeper soil than the steeper landscapes. It is likely that the areas best suited to construction of the LRSF occur in 2 landscapes; Ballimore and Wongarbon (**Table 23**).

**Table 23**
**Summary of suitability of landscapes of Dubbo Zirconia Project Soil Survey Area for location of evaporation ponds**

Page 1 of 2

| Landscape | Potential Pond Area (ha) | Suitability for constructing ponds and providing material for embankments. |
|---|---|---|
| **Landscapes on Silurian Geology** | | |
| Arthurville (168ha) | 0 | Likely to contain some areas that are OK, however, generally unsuitable. Concern that the flattest patch, which is immediately east of Wambangalang Creek is a discharge area, as indicated by the elevated salinity. |
| Splitters Hill (193ha) | 0 | Relatively steep, rock encountered at shallow depth. Generally unsuitable. |
| Nubingerie (101ha) | 40 | Material examined appeared capable of being used in embankment construction. However, landscape is dissected by watercourses. May be 40 ha that is suitable near eastern boundary of landscape. |

**Table 23 (Cont'd)**
**Summary of suitability of landscapes of Dubbo Zirconia Project Soil Survey Area for location of evaporation ponds**

Page 2 of 2

| Landscape | Potential Pond Area (ha) | Suitability for constructing ponds and providing material for embankments. |
|---|---|---|
| **Landscapes on Mesozoic Sedimentary Rocks** | | |
| Ballimore (424ha) | 270 | Mapped in 3 locations. The patch running from the centre of the Soil Survey Area to the northwest appears to contain the locations within this landscape that are most suitable. This patch is intersected by 2 drainage lines.<br>Soil likely to be suitable for constructing embankments; it has moderate clay content, moderate shrink and swell potential, and relatively low potential to disperse. Piezometer logs indicate that there is a 30m or more of clayey material in at least 2 locations.<br>Estimate that approximately half (180ha) the western patch of the Ballimore landscape may be suitable for construction of evaporation ponds from a material suitability, and subject to further investigation. |
| Turkey Range (68ha) | 0 | Best left undisturbed |
| **Landscapes on Recent Alluvium** | | |
| Mitchell Creek (72ha) | 0 | Generally within 200m of Wambangalang Creek. Sensitive area where it is inappropriate that ponds be constructed. |
| **Landscapes on Igneous Rocks** | | |
| Bald Hill (78ha) | 0 | Relatively steep landscape with stable, relatively shallow soil. Challenging landscape for construction of evaporation ponds, but some sections may form evaporation pond or waste rock emplacement floors.<br>Laboratory testing indicated that the subsoil material sampled was likely to be moderately permeable, even if compacted |
| Wongarbon (385ha) | 210 | Landscape has a variable depth of moderately reactive, plastic clayey soil. It is generally near watersheds, so run-on is not a great concern. Material has moderate shrink swell capacity, and is moderately dispersive, so care should be taken to compact embankments constructed from this material well enough to minimise seepage that could lead to significant erosion. It is likely that the surface of embankments constructed from this material would need protection to minimise erosion.<br>Landscape is mapped in 3 patches. It appears that the majority of the northernmost patch, which covers 170ha, could be used as the location of evaporation ponds. Steep landform is likely to restrict pond sites to less than 40ha in the remainder. |
| Belowrie (941ha) | 90 | Undulating landscape with variable soil that is near the watershed of the soil survey area. The landscape may contain patches that are suitable for location of pond or waste rock emplacements. These patches would require further investigation. |
| Dowd (445ha) | 0 | Shallow, rocky soil on undulating landform that is generally covered with woodland. Unlikely to be suitable for construction of ponds. |

The landscape summary indicates that approximately 600ha could be suitable for the construction of evaporation ponds or waste rock emplacements.

# 5. DISTURBANCE MANAGEMENT

## 5.1 OVERVIEW

Soil would be removed from the footprint of the area disturbed by the Proposal. This would be stockpiled during operations and used to rehabilitate the disturbed land when operations are completed. The areas that would be disturbed are spread across the DZP Site, but are concentrated between the open cut and the Processing Plant Area (**Figure 2**).

The aim when managing this process would be to restore the majority of the disturbed land to a state where it can support perennial pasture species. An important part of this process would be to form a land surface that has a shape that is moderately susceptible to erosion. The shape of this landform would be determined by soil properties and climate (principally rainfall intensity). A conservative batter slope of 3 horizontal to 1 vertical has been adopted for stockpiles, such as the Waste Rock Emplacement, Solid Residue Storage Facility and Salt Encapsulation Cells.

Soil management for rehabilitation should be managed across the DZP Site as shown in **Table 24**. Topsoil and subsoil that are suitable for stripping from the open cut, Waste Rock Emplacement, Solid Residue Storage Facility and Salt Encapsulation Cells should be stored in separate stockpiles near each structure. The subsoil stockpiles would have a cap of topsoil and it is planned that these stockpiles be used to grow pasture and would be grazed. Only topsoil should be stripped from the internal haul road, ROM Pad, and processing plant and DZP Site Administration Area. The stockpiled soil should be used to rehabilitate these disturbed areas during mine closure.

**Table 24**
**Areas disturbed and treatment of stripped material**

| Infrastructure | Area (ha) | Material to be stripped | Timing |
|---|---|---|---|
| Open Cut | 40.3 | Topsoil stockpiled separately from subsoil | Project Establishment |
| Waste Rock Emplacement | 20.4 | Topsoil stockpiled separately from subsoil | Project establishment |
| Solid Residue Storage Facility | 102.8 | Topsoil stockpiled separately from subsoil | Staged as required |
| Liquid Residue Storage Facility | 425.4 | Topsoil stockpiled separately from subsoil | Staged as required |
| Salt Encapsulation Cells | 34.6 | Topsoil stockpiled separately from subsoil | Prior to or at mine closure |
| Haul Road | 7.3 | Topsoil only | Project establishment |
| Run of Mine Stockpile | 4.2 | Topsoil only | Project establishment |
| Processing Plant | 43.3 | Topsoil only | Project establishment |
| Soil Stockpiles | 129.4 | None | Project establishment |

Topsoil and subsoil from the LRSF should be handled separately. Topsoil, which is defined as the A horizon to a maximum depth of 15cm should be stockpiled near the relevant Area (2 to 5) of the LRSF. These stockpiles should also be used to grow pasture during mine operation and the soil used as topsoil during rehabilitation of the LRSF. The subsoil, which is defined as the remainder of material suitable for stripping, could be used to construct embankments of lined cells that make up the LRSF. This material should be recovered during the mine closure process and used as subsoil during rehabilitation of the land used for the LRSF.

The outline of the process of handling the soil should be divided into two sections because of the different treatment of the majority of stripped topsoil and subsoil of the LRSF.

## 5.2 MANAGEMENT OF TOPSOIL AND STOCKPILED SUBSOIL

The aim in managing the stockpiled topsoil and subsoil is to maintain biological activity and aeration in the whole of the stockpiled soil to the extent that is practicable. For this reason, the soil should be treated in a way that minimises compaction and encourages growth of plants and the associated organisms.

### 5.2.1 Estimated Volume of Topsoil Available

The volume of topsoil available for stockpiling would be determined primarily by the suitability of the soil for stripping as determined when it is being removed. An estimate of the volume of soil available for stripping (**Table 25**) was generated from interpretation of variation in soil properties and the suitability for stripping each soil landscape outlined in Section 4.2.2. The majority of soil would be stripped from the Ballimore, Belowrie, and Wongarbon Soil Landscapes with relatively small areas from Arthurville and Bald Hill Soil Landscapes, and with a very small area of the Dowd Soil Landscape (**Figure 13**). It was estimated that there may be as much as 970 000$m^3$ of topsoil material suitable for stripping beneath the 808ha that is planned to be disturbed during the Proposal. The plan is to strip soil from 679ha of this area, giving an average depth of topsoil stripped of as much as 15cm.

### 5.2.2 Topsoil Stripping

The following topsoil stripping and handling techniques should be implemented where practicable to minimise soil deterioration.

- Strip material to the depths tabulated in **Table 25**. These depths are considered the maximum depth of material that is suitable for use in rehabilitation.
- The soil material should be maintained in a slightly moist condition during stripping. Material should not be stripped in either an excessively dry or wet condition.
- Strip soil by grading or pushing soil into windrows with graders or bulldozers for later collection by elevating scrapers, or for loading into rear dump trucks by front-end loaders. This minimises compaction by the heavy equipment that is often necessary for economical transport of soil material.

### 5.2.3 Topsoil Stockpiling

The topsoil should be stored in a way that minimises compaction of the whole stockpile, and maximises biological activity. The following techniques should be implemented where practicable to achieve these goals.

- 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. bulldozer or excavator) to avoid tracking over previously laid soil by the scraper. If material is deposited directly by scrapers it should be deposited in thick "lifts" to minimise compaction.

**Table 25**
**Maximum volumes of topsoil available for stripping beneath each type of infrastructure in Dubbo Zirconia Project**

| Structure | Soil Landscape | Area (ha) | Proportion Stripped | Depth (m) | Volume (m³) | Subtotal (m³) |
|---|---|---|---|---|---|---|
| Open Cut | Belowrie | 40.3 | 67% | 0.15 | 40 300 | |
| | | | | | | **40 300** |
| Waste Rock Emplacement | Belowrie | 1.9 | 100% | 0.15 | 2 850 | |
| | Wongarbon | 18.5 | 100% | 0.15 | 27 750 | |
| | | | | | | **30 600** |
| Solid Residue Storage | Ballimore | 35.1 | 100% | 0.15 | 52 650 | |
| | Belowrie | 14.9 | 100% | 0.1 | 14 900 | |
| | Wongarbon | 35.9 | 100% | 0.15 | 53 850 | |
| | Bald Hill | 15.9 | 100% | 0.15 | 23 850 | |
| | Dowd | 1 | 0% | | | |
| | | | | | | **145 250** |
| Liquid Residue Storage Facility | Ballimore | 152.7 | 100% | 0.15 | 229 050 | |
| | Belowrie | 74.3 | 100% | 0.15 | 111 450 | |
| | Wongarbon | 192.7 | 100% | 0.15 | 289 050 | |
| | Bald Hill | 5.7 | 100% | 0.15 | 8 550 | |
| | | | | | | **638 100** |
| Salt Encapsulation Cell | Belowrie | 28.1 | 80% | 0.15 | 33 720 | |
| | | | 20% | 0.1 | 5 610 | |
| | Wongarbon | 5.9 | 50% | 0.15 | 4 420 | |
| | | | 50% | 0 | | |
| | Dowd | 0.6 | 100% | 0.1 | 600 | |
| | | | | | | **44 350** |
| Haul Road | Ballimore | 0.9 | 100% | 0.15 | 1 350 | |
| | Belowrie | 4.2 | 90% | 0.15 | 5 670 | |
| | Wongarbon | 1.4 | 100% | 0.15 | 2 100 | |
| | Bald Hill | 0.8 | 100% | 0.15 | 1 200 | |
| | | | | | | **10 320** |
| ROM Pad | Wongarbon | 4.2 | 100% | 0.15 | 6 300 | |
| | | | | | | **6 300** |
| Processing Plant | Arthurville | 15.9 | 100% | 0.15 | 23 850 | |
| | Ballimore | 12.4 | 100% | 0.15 | 18 600 | |
| | Wongarbon | 15.0 | 100% | 0.15 | 22 650 | |
| | | | | | | **65 100** |
| Total | | 672 | | | | **980 320** |

- Driving of machinery on stockpiles, other than scrapers during unloading, should be kept to an absolute minimum to minimise compaction.
- As a general rule, maintain a maximum stockpile depth of 3m. Ideally, topsoil stockpiles should be less than 2m high. The aim in managing soil stockpiles is to minimise the volume and duration of waterlogging which causes reducing conditions (as opposed to oxidising) resulting in unwanted chemical changes in the soil.
- Stockpile surfaces should generally be even but with a rough surface condition to assist runoff control and seed germination and emergence.
- If long term storage (>3 months) is planned, fertilise stockpiles as soon as possible and seed with stabilising species. The aim should be to establish a healthy sward that provides sufficient competition to minimise the establishment of undesirable weed species.
- When grazing livestock on stockpiles, livestock should be removed when the soil is wet enough that stock cause poaching of the soil. Livestock should also be removed when groundcover is less than 60% to encourage survival and growth of the pasture species.

### 5.2.4 Topsoil Respreading

The aim of respreading is to construct a layered material with properties that can perform similar functions to the undisturbed soil. Topsoil provides a path for entry of water and air, storage of nutrients and water, and plant support. Subsoil should have continuous pores to allow entry of water and air as well as root growth. Subsoil has a larger role in storage of water than nutrients, and is important in supporting plants. The soil should not have large differences between the properties of layers as the discontinuities at these boundaries can slow water movement. The spreading of topsoil and subsoil should be carried out to achieve these aims. The recommended process for spreading of topsoil is as follows.

- The material to be respread should be tested before spreading to determine the ameliorants required to achieve the desired level of plant growth.
- The surface of underlying material should be tined below the depth of compaction to minimise formation of a dense layer at the top of the subsoil / growth material. This may be 60cm or more below the undisturbed surface.
- The topsoil should be moist to just moist rather than wet or dry when being respread.
- It is important that traffic patterns be managed to minimise compaction of topsoiled areas.
- The topsoil should be placed with few lifts from an elevating scraper or similar with sufficient regrading to create a density similar to natural soil.
- It is vital that vegetation be established on topsoiled areas as quickly as possible to minimise the risk of erosion from wind or water.

## 5.3 SUBSOIL MANAGEMENT

Subsoil would be stockpiled during the life of the Proposal in two forms. Subsoil stripped from the open cut, Waste Rock Emplacement, SRSF and Salt Encapsulation Cells would be stripped and stored in designated subsoil stockpiles near these component areas of disturbance. These would be capped with topsoil and used to grow improved pasture for grazing during the life of the mine.

Subsoil stripped from the LRSF would be used to construct embankments. The subsoil would be protected from contamination by the liquid being stored by plastic liners. For this reason, the material in embankments can be compacted to the minimum density required for structural integrity of the embankments rather than the density required to minimise seepage. It is likely that the embankments would be constructed from both material borrowed beneath the subsoil to be used for rehabilitation and from subsoil suitable for stripping. It would be important to keep materials from these two sources separate. In general, the subsoil can be subjected to more compaction than the topsoil. As a result, practices for handling the subsoil have been amended accordingly.

### 5.3.1 Estimated Volume of Subsoil Available

The volume of subsoil available for stripping would be determined primarily by the suitability of the soil for stripping as determined when it is being removed. An estimate of the volume of subsoil available for stripping (**Table 26**) was generated from the requirement for stripping (**Table 24**) and interpretation of variation in soil properties and the suitability for stripping of each soil landscape in outlined in Section 4.2.2. It was estimated that there is nearly 2 980 500m$^3$ of subsoil material that could be stripped from 624ha. The average depth of subsoil that could be stripped was estimated to be 55cm beneath the LRSF and an average of 30cm for the remaining areas of disturbance where subsoil stripping is to be undertaken (**Table 24**). The differences in depth of subsoil available to be stripped reflect differences in landscape properties. The LRSF will be constructed on relatively level land within the Soil Survey Area with deep soil. The other infrastructure would be constructed on more undulating land which contains patches of shallow soil.

### 5.3.2 Subsoil Stripping

The following subsoil stripping and handling techniques should be implemented, where practicable, to minimise soil deterioration.

- Strip subsoil material to the depths stated in Section 5.2.1 and **Table 26**. These depths are considered the maximum depth of subsoil material that is suitable for use in rehabilitation.
- Subsoil should be maintained in a slightly moist condition during stripping. Material should not be stripped in either an excessively dry or wet condition.
- Subsoil can be stripped by elevating scrapers.

**Table 26**
**Maximum volumes of subsoil available from Liquid Residue Storage Facility.**

| Structure | Soil Landscape | Area (ha) | Proportion Stripped | Depth (m) | Volume ($m^3$) | Subtotal ($m^3$) |
|---|---|---|---|---|---|---|
| Open Cut | Belowrie | 40.3 | 67% | 0.3 | 81 000 | |
| | | | | | | **81 000** |
| Waste Rock Emplacement | Belowrie | 1.9 | 100% | 0.2 | 4 000 | |
| | Wongarbon | 18.5 | 100% | 0.35 | 65 000 | |
| | | | | | | **69 000** |
| Solid Residue Storage Facility | Ballimore | 35.1 | 50% | 0.6 | 105 000 | |
| | | | 50% | 0.4 | 70 000 | |
| | Belowrie | 14.9 | 100% | 0.15 | 22 350 | |
| | Wongarbon | 35.9 | 50% | 0.6 | 107 700 | |
| | | | 50% | 0.3 | 53 850 | |
| | Bald Hill | 15.9 | 50% | 0.6 | 47 700 | |
| | | | 50% | 0.2 | 15 900 | |
| | Dowd | 1.0 | 0% | | | |
| | | | | | | **422 500** |
| Liquid Residue Storage Facility | Ballimore | 152.7 | 100% | 0.5 | 763 500 | |
| | Belowrie | 74.3 | 100% | 0.5 | 371 500 | |
| | Wongarbon | 192.7 | 100% | 0.6 | 1 156 000 | |
| | Bald Hill | 5.7 | 100% | 0.6 | 34 000 | |
| | | | | | | **2 325 000** |
| Salt Encapsulation Cell | Belowrie | 28.1 | 40% | 0.4 | 45 000 | |
| | | | 40% | 0.2 | 22 500 | |
| | | | 20% | 0.0 | | |
| | Wongarbon | 5.9 | 50% | 0.5 | 15 000 | |
| | | | 50% | 0.0 | | |
| | Dowd | 0.6 | 100% | 0.1 | 500 | |
| | | | | | | **83 000** |
| Total | | 624 | | | | **2 980 500** |

### 5.3.3 Subsoil Stockpiling

The following techniques should be implemented, where practicable, when stockpiling subsoil.

- Subsoil from the open cut, Waste Rock Emplacement, SRSF and Salt Encapsulation Cells that is to be used for rehabilitation should be placed in stockpiles with a maximum depth of 3m.
- Driving of machinery on these stockpiles should be kept to an absolute minimum to minimise compaction.
- The subsoil stockpiles should be capped with at least 15cm of topsoil. This should be placed as soon as possible after the stockpiles are constructed. The topsoil should be fertilised and planted with stabilising species as soon as practicable after it is placed.

- Subsoil from the LRSF that is to be used for rehabilitation should be placed in locations where it would be separated from other material used to construct embankments. This may be in specific layers of the embankment (e.g. surface 1m to 2m) or in sections of embankment that have been identified (e.g. smallest embankment in pond group).
- Subsoil that is to be used for rehabilitation should be compacted to the minimum density consistent with stable embankments. This should be determined by suitably qualified engineers.
- The compaction should be achieved by placing material from elevating scrapers or similar and rolling material to achieve the required density. Compaction with sheepsfoot, padfoot or similar compactors should be avoided if possible as these machines remould the material and destroy its structure.

### 5.3.4 Subsoil Respreading

The respread subsoil should be dense enough to support plants, but not so dense that it forms a barrier to water movement. The recommended process for respreading subsoil is as follows.

- Test the subsoil to ensure that it is not toxic to plant growth. Major threats are salinity that has built up from adjacent liquid residue storage facilities, and elevated levels of some micronutrients from prolonged reducing (waterlogged) conditions.
- Ensure that subsoil to be worked is moist, or dry but not wet.
- Form subgrade to desired shape.
- Tine subgrade (approximately 60cm deep) to provide and undulating boundary and disrupt barriers to water movement from compaction.
- Place subsoil to achieve similar density (or slightly less) than natural subsoil. It is likely that this can be achieved by placing subsoil in relatively thick lifts (20 cm) with an elevating scraper and minimising further traffic on areas where material has been placed.
- Lightly tine the surface between lifts to reduce creation of slowly permeable layers.

## 5.4 MONITORING AND REPORTING

Success of the rehabilitation of the DZP Site with soil would depend on the following key steps.

1. Stripping and stockpiling sufficient soil to provide topsoil and subsoil for the area to be rehabilitated.
2. Maintaining biological activity and adequate aeration in the stockpiled soil.
3. Preparation of the subgrade and construction of the rehabilitated soil.
4. Establishment of desired plants on the rehabilitated soil.

All these steps would require some degree of monitoring. It is likely that steps 1 and 3 would require the most intensive monitoring, and annual monitoring of vegetation health, groundcover percentage, weed presence, gully erosion presence, soil subsidence and water pooling is recommended.

# 6. EFFECT OF PROPOSAL ON SOIL AND LANDSCAPE

## 6.1 INTRODUCTION

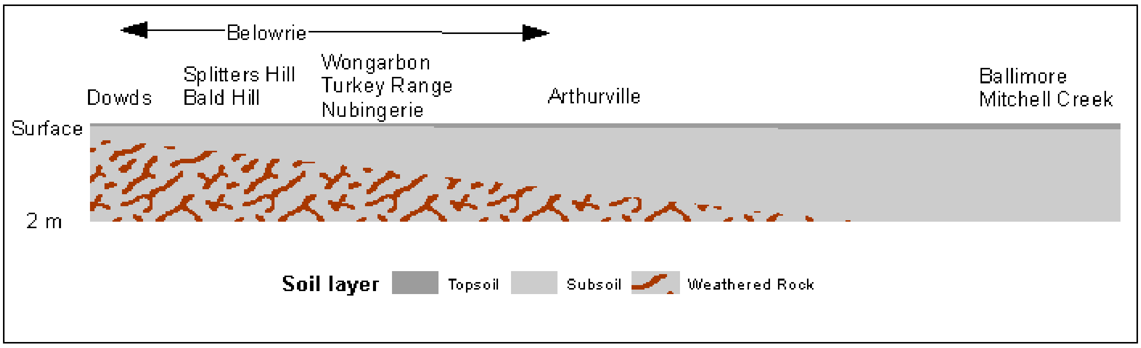
Land would be removed from agricultural production during the life of the Proposal as the footprint would be occupied by mine infrastructure. At the completion of the Proposal, the landscape would be rehabilitated. The majority of land such as the LRSF, Haul Road, ROM Pad, processing plant, and Soil Stockpiles would ultimately have similar properties and capability to undisturbed land, however, disturbance would be more permanent beneath the Waste Rock Emplacement, SRSF, Salt Encapsulation Cells, and open cut.

## 6.2 SOIL PROPERTIES

### 6.2.1 Current

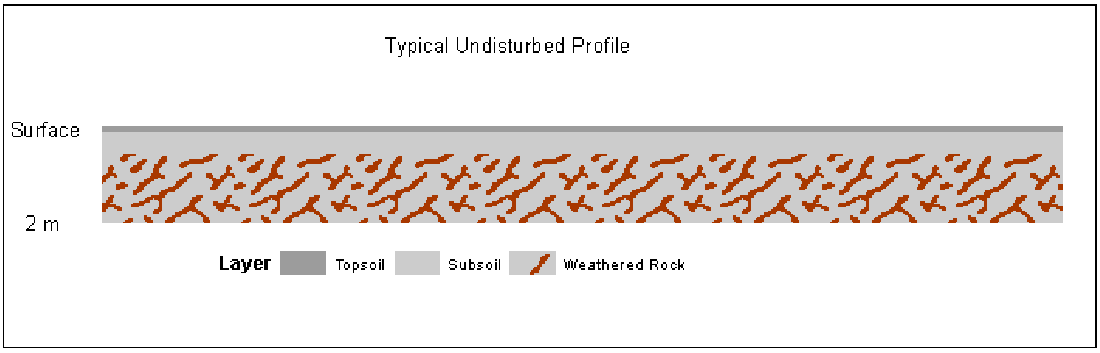
A typical soil profile in the DZP Site consists of a layer of sandy to clayey topsoil, and a layer of clayey subsoil over weathered rock (**Figure 16**). Generally, the soil is shallow in the elevated areas, like Dowd, Splitters Hill and Bald Hill Soil Landscapes, deeper in the areas of Wongarbon, Turkey Range, Nubingerie and Arthurville Soil Landscapes; and deepest in the lower lying landscapes of Ballimore and Mitchell Creek Soil Landscapes. The Belowrie Soil Landscape consists of undulating hills with a mix of shallow soil and moderately deep soil.

**Figure 16 Cross-section of the range of typical profiles across Dubbo Zirconia Project footprint**




The impact of the Proposal on soil properties will be described from a profile that contains all three layers shown in **Figure 16**. The profile chosen as a typical profile has 15cm of topsoil over 90cm of subsoil over weathered bedrock (**Figure 17**). This profile was selected as it represents some of the more challenging landscapes that would be encountered across the DZP Site.

**Figure 17 Cross-section of typical soil beneath Dubbo Zirconia Project.**




Exceptions include Mitchell Creek landscape, which consists of topsoil up to 50cm thick and subsoil deeper than 120cm, and Ballimore landscape which consists of subsoil soil depth greater than 20m in certain areas.

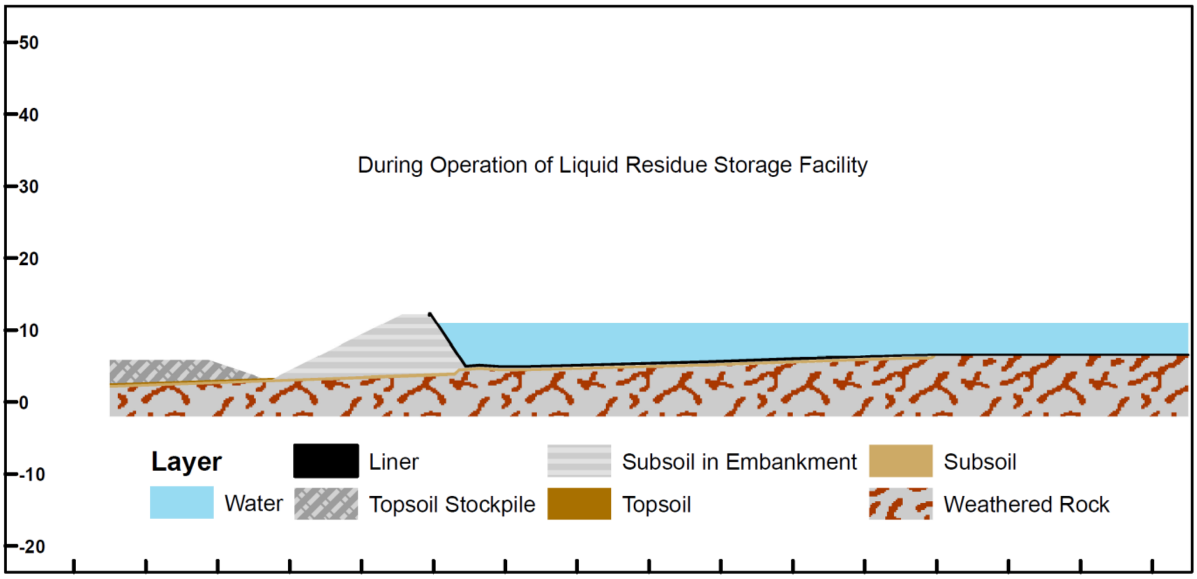
### 6.2.2 During Mine Operation

Soil disturbance would occur in essentially the following three forms.

1. **LRSF (topsoil stockpiled, subsoil used in embankments)**

Topsoil beneath the LRSF would be stripped and stockpiled nearby. Subsoil would be stripped and used to make the embankments, and a liner would be placed over the floor. This liner would prevent contamination of the floor and embankments by the liquid residue (**Figure 18**).

**Figure 18 Cross-section of a typical cell of the LRSF**

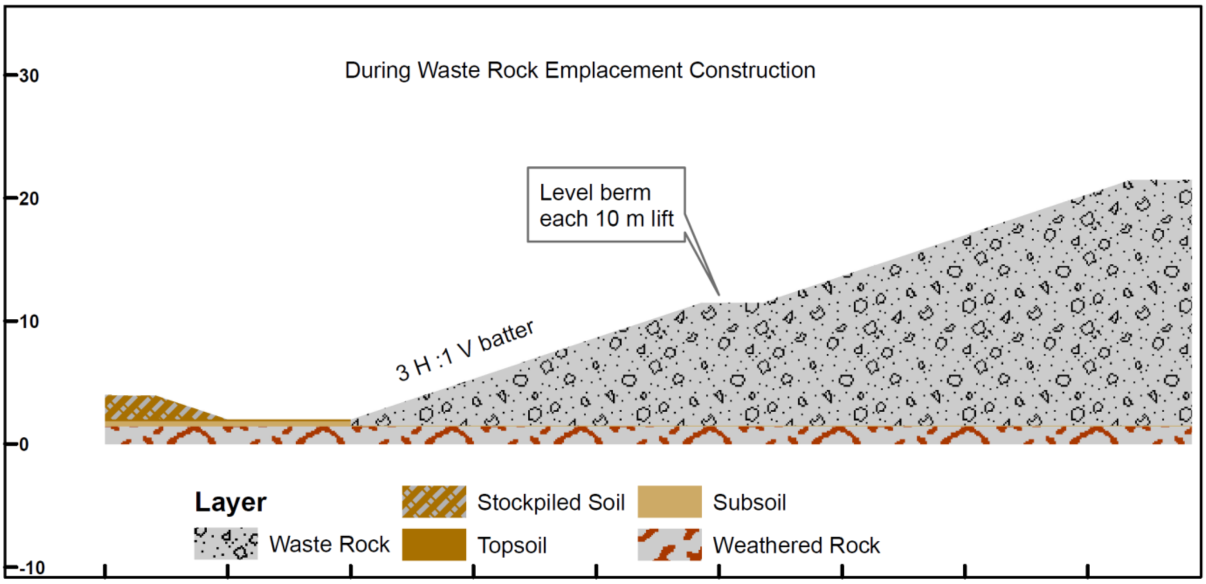



2. **Waste Rock Emplacement, SRSF, Salt Encapsulation Cells and Open Cut (topsoil and subsoil stockpiled, in separate stockpiles)**

Land beneath the Waste Rock Emplacement, SRSF, Salt Encapsulation Cells and open cut would have topsoil and subsoil layers stripped and stockpiled in separate stockpiles. The stockpiled material would be placed on the subgrade (**Figure 19**). Details of stockpile construction would be determined by the properties of the material being stockpiled. Waste

Rock can support itself while both the Solid Residue and Salt would be supported by compacted embankments (Cooper and Associates, 2013).

**Figure 19 Cross-section of Waste Rock Emplacement, Solid Residue Storage Facility, and Salt Encapsulation Cell**




Land beneath the Solid Residue Storage Facility would have topsoil and subsoil stripped and stockpiled in separate areas. Embankments would comprise of waste rock and material from beneath the topsoil and subsoil that would be removed and stockpiled. An impermeable liner would be placed on the embankments and floor of the SRSF. This would take the form of 2 layers of high density polyethylene (HDPE) separated by a layer of sand (Cooper and Associates, 2013). The primary function of the HDPE liner is to prevent the leaching of wastes into the groundwater. It is intended that the height of the embankments would increase in stages. The initial embankment, which makes up about half the final stockpile height, would be constructed on the existing subgrade while additional lifts would be supported partly by the existing embankment and partly by the solid residue.

It is expected that the salt would be collected over the life of the Proposal as it accumulates sufficiently within the salt crystallisation cells of the LRSF to be removed safely and without damaging the liner. At the completion of the Proposal, the remaining salt would be collected and stockpiled as the Liquid Residue Storage Facilities are decommissioned. As a result, the footprint of the Salt Encapsulation Cells would be developed progressively over the life of the Proposal, although it is not expected that initial salt collection and disposal would be required for 5 to 10 years.

### 3. Haul Road, Processing Plant and ROM Pad (topsoil stripping only)

Land beneath the Haul Road, processing plant and ROM Pad would have only topsoil stripped and stockpiled. The subgrade would then be formed beneath the infrastructure and the land would be covered by a slowly permeable layer such as road base.

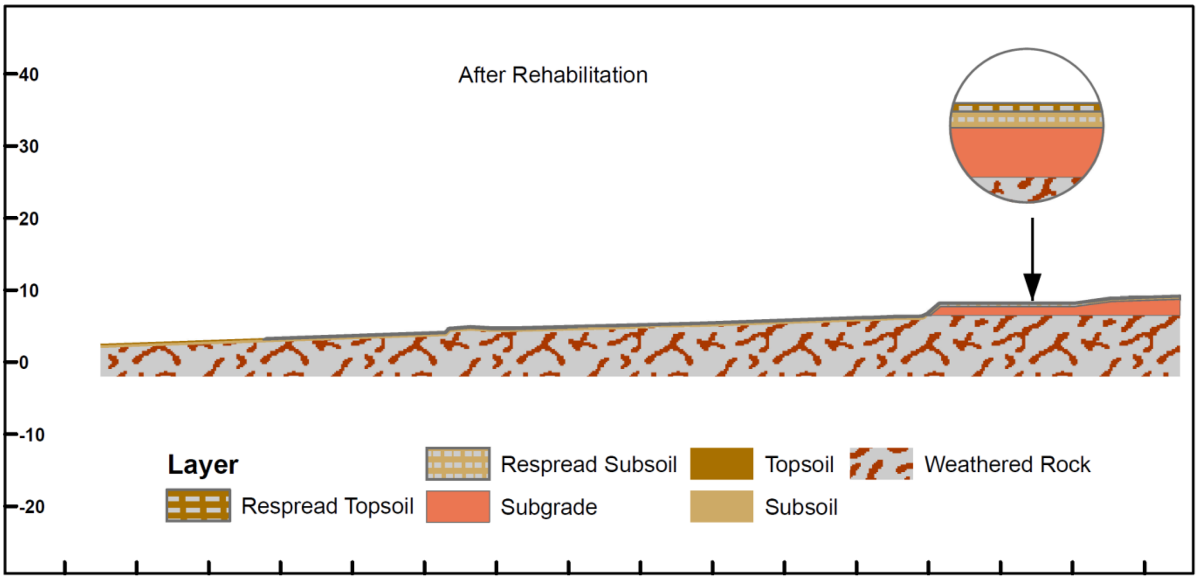
### 6.2.3 Post Rehabilitation

With the exception of the open cut, the landscape would be rehabilitated in line with the three modes of disturbance described above.

1. **LRSF**

The residue and liner from the LRSF would be removed and the subgrade spread to recreate the natural slope. This would effectively require the reverse cut and fill operations to those undertaken to create the flat bottomed cells on the sloping landform. Subsoil from the embankments would then be excavated and respread, followed by the topsoil (**Figure 20**). This would result in soil profiles with a range of properties. Areas beneath the topsoil stockpiles would have a profile similar to the undisturbed profile (left hand quarter of **Figure 20**). Areas beneath the floor of the LRSF would have uniform layers of topsoil and subsoil over a subgrade of varying depths. Some areas would have relatively undisturbed subsoil, while other areas would have subgrade that has been placed at a range of thicknesses. This would result in a soil that could be much deeper than the 50cm of material that would be spread.

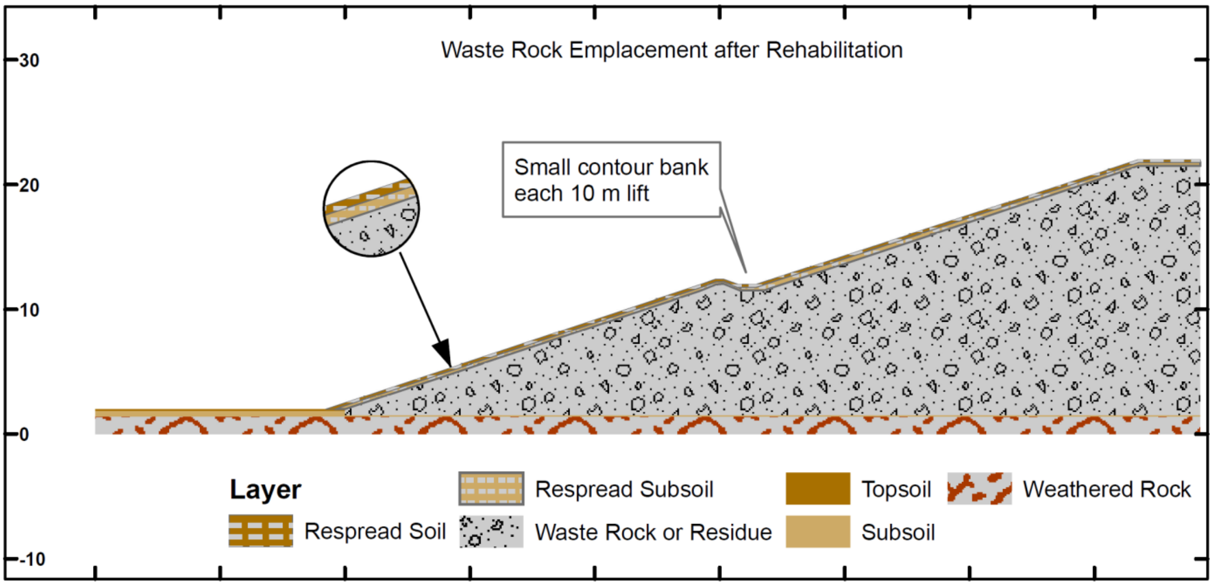
**Figure 20 Cross-section of Liquid Residue Storage Facility after rehabilitation**




2. **Waste Rock Emplacement**

The Waste Rock Emplacement, would have a relatively thin layer of topsoil and subsoil spread over the waste material. The final outcome would be high mounds with stable but relatively steep sides (**Figure 21**). It is estimated that an average of 50cm can be stripped from the Waste Rock Emplacement (**Tables 25** and **26**). The soil would consist of a 50cm layer of reconstituted soil over the waste rock. The waste rock is likely to act as a weathered rock horizon at best, so would provide few resources to plants.

**Figure 21 Cross-section of Waste Rock Emplacement after Rehabilitation**




## 3. Solid Residue Storage Facility

The Solid Residue Storage Facility would be rehabilitated in a way that protects the external batters from erosion, redirects runoff from the roof of the stockpile to the natural surface while protecting the integrity of stockpile, and minimises drainage into the stockpile.

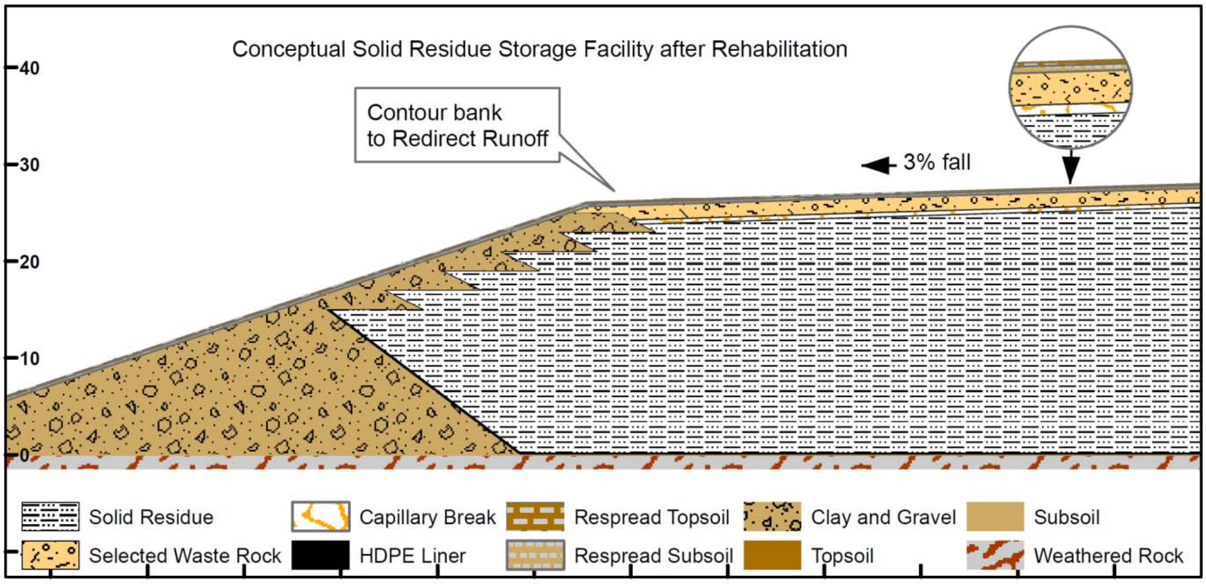
The planned rehabilitation process would be relatively complex. First, the outside batters of the stockpile would have topsoil and subsoil would be respread over them in a manner similar to the waste rock. Vegetation would be established on this material. The soil would come from an estimated average of 50cm that can be stripped from the footprint of the SRSF (**Tables 25** and **26**).

A cover is planned for the top of the stockpile to contain the residue and to minimise the effects of rainfall moisture on the stockpiled material. The surface of the cover would drain to the edge of the stockpile, and a drainage system would be constructed to redirect water to the natural surface while protecting the integrity of the stockpile.

The cover is planned to act as a store and release system (DITR, 2007) in which heavy rainfall is allowed to drain from the surface while rainfall moisture that enters the soil is stored until it is released by evaporation or plant transpiration. The layers of the cover proposed are as follows (**Figure 22**).

- Subsoil and topsoil to function as a growth medium for vegetation. It should have continuous pores for root growth, sufficiently absorb air and water, and be able to store water and nutrients.
- A layer of selected waste rock which must contain clay to silt sized particles, and can contain fragments up to boulder sized (Fourie & Tibbett, 2012). This layer would capture and store rainfall moisture.
- A capillary break consisting of coarse material that is typically fine gravel (K= > $10^{-5}$ m/s or 1 m/day). The prime function of the capillary break is to minimise capillary rise of leachate from the solid residue into the store and release layer.

**Figure 22 Conceptual Cross-section of Solid Residue Storage Facility after Rehabilitation**




### 4. Salt Encapsulation Cells

Following completion of the mine, crystallised salts from the Liquid Residue Storage Facilities would be placed within the Salt Encapsulation Cells. The Salt Encapsulation Cells would be contained within an embankment, and the floor and inside of the embankments would be lined with a double HDPE Liner.

The planned rehabilitation process would be relatively complex. First, the outside batters of the stockpile would have topsoil and subsoil would be respread over them in a manner similar to the Waste Rock Emplacement (see 2 above). Vegetation would be established on this material. The soil would come from an estimated average of 50cm that can be stripped from the stripped from the footprint of the Salt Encapsulation Cells (**Tables 25** and **26**).

A cover would constructed over the Salt Encapsulation Cells that would be similar to the cover over the SRSF with an additional impermeable layer beneath the capillary break (**Figure 23**). This could take the form of a geotextile or compacted clay liner of low hydraulic conductivity (K= < $10^{-7}$ m/s or 300 mm/year, DITR, 2007). This liner would limit water diffusion into the salt and limit the movement of salts into the above layers by capillary rise. Material for the liner could be sourced from the deconstructed Liquid Residue Storage Facility.

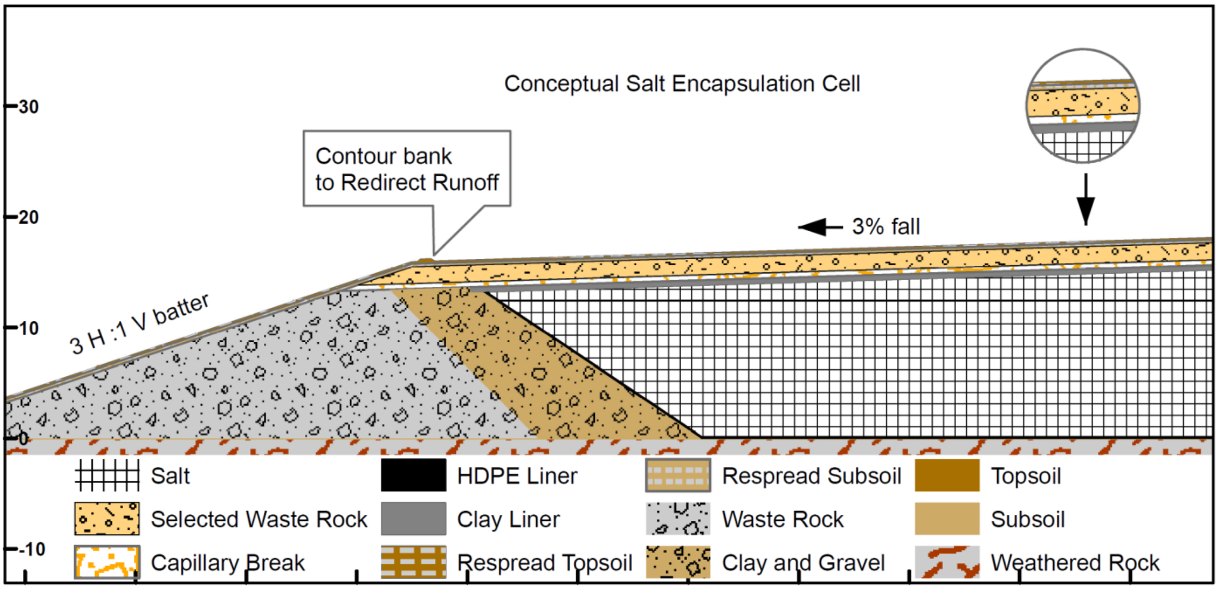
### 5. Haul Road, Processing Plant and Run of Mine Stockpile

The weather proof cap would be removed from the Haul Road, ROM Pad, and processing plant before the topsoil is respread over the underlying subsoil material. This would result in a soil with similar properties to the undisturbed soil.

### 6. Open Cut

Stripped soil material from the open cut area would be respread around the perimeter of the open cut and on safely accessible berms. This would result in a variable soil depth with some areas potentially not having soil material respread.

**Figure 23 Conceptual Cross-section of Salt Encapsulation Cell after Rehabilitation**




## 6.3 LAND AND SOIL CAPABILITY

### 6.3.1 Summary of Land Capability (Pre- and Post Proposal)

The Proposal would have dramatic effects on the land capability of the DZP Site. At present (pre development) the majority of the land beneath those areas of the DZP Site to be disturbed is Class 3 or Class 4 (**Figure 15** and **Table 27**). This land can support cultivation and high intensity grazing (OEH, 2012). The majority of the disturbance footprint would be covered by infrastructure for the life of the Proposal. As a result, this land would be removed from agricultural use for the life of the Proposal and would therefore be rated as Class 8. An exception would be soil stockpiles which can perform as Land and Soil Capability Class 4. Rehabilitation would construct land with a range of capability that is influenced by landscape properties before disturbance, the extent of disturbance, and the type of rehabilitation.

**Table 27**
**Range of Land and Soil Capability Classes during the life of Dubbo Zirconia Project**

| Infrastructure Type | Current | During Mine Operation | Post Rehabilitation |
|---|---|---|---|
| Open Cut | 4 | 8 | 8 |
| Waste Rock Emplacement | 3, 4 | 8 | VI |
| Solid Residue Storage Facility | 3, 4, 7 | 8 | VI |
| Liquid Residue Storage Facility | 3, 4 | 8 | IV |
| Salt Encapsulation Cells | 3, 4, 7 | 8 | 7 |
| Haul Road | 3, 4 | 8 | 3, 4 |
| ROM Pad | 3 | 8 | 3 |
| Processing Plant | 3, 4 | 8 | 3, 4 |
| Soil Stockpiles | 2, 3, 4, 7 | 4 | 2, 3, 4, 7 |

### 6.3.2 Pre-Proposal Land Capability

Approximately three-quarters of land to be disturbed by the Proposal is Class 3, and approximately one quarter is Class 4 (**Table 28**). Approximately 20% of the Class 3 land would be subjected to major disturbance (Waste Rock Emplacement, SRSF and Salt Encapsulation Cells). The remainder of Class 3 land would be subjected to less disruptive disturbance. There would be greater disruption to the Class 4 land with approximately 45% being subjected to the major disturbance of the Open Cut, Waste Rock Emplacement, SRSF and Salt Encapsulation Cells.

**Table 28**
**Soil and Land Capability Class Area (ha) beneath Infrastructure Types of before mining**

| Infrastructure Type | 3 | 4 | 7 | Total |
|---|---|---|---|---|
| Open Cut | 0.0 | 40.3 | 0.0 | 40 |
| Waste Rock Emplacement | 18.8 | 1.6 | 0.0 | 20 |
| Solid Residue Storage Facility | 85.5 | 16.2 | 1.1 | 102.8 |
| Liquid Residue Storage Facility | 381.0 | 44.4 | 0.0 | 425.4 |
| Salt Encapsulation Cells | 5.8 | 28.7 | 0.1 | 34.6 |
| Haul Road | 2.9 | 4.4 | 0.0 | 7.3 |
| ROM Pad | 4.2 | 0.0 | 0.0 | 4.2 |
| Processing Plant | 26.5 | 16.8 | 0.0 | 43.3 |
| Soil Stockpiles | 88.4 | 41.0 | 0.0 | 129.4 |
| **Total** | **613.1** | **193.4** | **1.2** | **807.7** |

### 6.3.3 During Mine Operation

Few plants would grow on the proposed disturbance footprint during the life of the Proposal as the land would be covered by roads, buildings, stockpiles of rock and mine residues, while the LRSF would be covered by plastic liners and water. As a result, the land would not be able to be used for agriculture, so is Class 8. Conversely, soil stockpiles can be constructed as Class 4. It is recommended that the soil stockpiles are sown with pasture immediately after stockpiling and used for rotational grazing. Land outside the infrastructure footprint but within the Soil Survey Area (approximately 2 650ha) would retain the same capability throughout the life of the Proposal (subject to appropriate land management).

### 6.3.4 Post Rehabilitation

Land and soil capability class after rehabilitation would be determined by properties of the reconstructed land slope for areas subjected to the greatest disturbance. The final capability of areas disrupted less would be determined by both the extent of disturbance and properties of the underlying landscape.

The open cut are would not undergo full rehabilitation and vegetation establishment and would remain as Class 8 as it would be unusable for any agricultural purposes (**Table 29**).

The Waste Rock Emplacement and SRSF are expected to be Class 6. This land would support trees and an understorey that can support occasional grazing, but would not be suitable for cultivation. Limitations include steep sloping surfaces that can erode severely even without cultivation, shallow soils (less than 50cm deep), and stoniness. Tunnel erosion and ‘blowouts’ would also be a risk due to unstable topsoil.

**Table 29**
**Soil and Land Capability Class Area (ha) beneath Infrastructure Types of the DZP Site after rehabilitation**

| Infrastructure Type | 2 | 3 | 4 | 6 | 7 | 8 | Total |
|---|---|---|---|---|---|---|---|
| Open Cut | 0 | 0 | 0 | 0 | 0 | 40.3 | 40.3 |
| Waste Rock Emplacement | 0 | 0 | 0 | 20.4 | 0 | 0 | 20.4 |
| Solid Residue Storage Facility | 0 | 0 | 0 | 102.8 | 0 | 0 | 102.8 |
| Liquid Residue Storage Facility | 0 | 0 | 425.4 | 0 | 0 | 0 | 425.4 |
| Salt Encapsulation Cells | 0 | 0 | 0 | 0 | 34.6 | 0 | 34.6 |
| Haul Road | 0 | 2.9 | 4.4 | 0 | 0 | 0 | 7.3 |
| ROM Pad | 0 | 4.2 | 0 | 0 | 0 | 0 | 4.2 |
| Processing Plant | 0 | 26.5 | 16.8 | 0 | 0 | 0 | 43.3 |
| Soil Stockpiles | 0 | 88.4 | 41.0 | 0 | 0 | 0 | 129.4 |
| **Total** | **0** | **122.0** | **487.6** | **123.2** | **34.6** | **40.3** | **807.7** |

Barriers that surround the residue in the Salt Encapsulation Cells would restrict the rootzone of rehabilitated land to the depth of the constructed soil. As a result, this land is likely to be more fragile and is expected to perform as Class 7 land.

It should be possible to rehabilitate land beneath the LRSF to Class 4 providing the shape of the landscape is not altered excessively during mine operation. Grazing would be the main land use, although occasional cultivation for sowing pastures and crops would be able to be tolerated. Limitations would include severe water erosion hazard, due to weak soil structure (especially in the first several years after rehabilitation).

It should be possible to rehabilitate land beneath the Haul Road, ROM Pad, and processing plant to the same Class as they were before mine operation. This is because only 15cm of topsoil would be removed and stockpiled from these areas. After mine closure, material forming the Haul Road and ROM Pad would be removed, the processing plant would be decommissioned and removed, the topsoil would be replaced, and the land should return to moderate to high capability land. Soil stockpiles would also return to the same Class as before mine operation since the soil would not be disturbed rather, soil would be placed on top during mine operation and removed for rehabilitation.

## 6.4 AGRICULTURAL SUITABILITY

The land surrounding the DZP Site is used for a range of rain fed cropping and grazing enterprises. However, cropping within the proposed disturbance footprint has recently been limited to forage crops to supplement stock-feed from pasture. This can be attributed to shallower and more variable soils within the DZP Site than in flatter land to the east of the DZP Site. The reduction of land and soil capability caused by the Proposal on parts of the footprint would further restrict the range of agricultural enterprises that the land would support. The following predictions are based on the assumption that the soil stripping, stockpiling and respreading techniques outlines in Section 4 would be followed.

The open cut would be unsuitable for agriculture indefinitely. Following commencement of mine operations, the open cut would remain a generally bare, deep hole in the ground. This would have almost no value for agriculture.

The Waste Rock Emplacement, SRSF, and Salt Encapsulation Cells should be able to support some grazing of sheep and cattle after rehabilitation. The land would not support crops. Grazing management on these areas should focus on maintaining groundcover rather than high short term animal productivity. It is understood that the Applicant intends on maintaining this land predominantly for biodiversity establishment and conservation with occasional grazing for property management purposes which fits with this recommended land management. It would be paramount that groundcover is established on these areas as soon as possible after they are formed to protect the surface from raindrop impact and subsequent erosion. Similarly, it would be better to have pasture based on perennial species rather than annuals because the perennials have greater groundcover than annuals during the summer when rainfall is most intense.

The LRSF should be able to be rehabilitated to the state where they can support grazing of sheep and cattle. It is unlikely that the land would be suitable for cropping. The pasture could be based on introduced perennial (perennial rye grass, phalaris and lucerne) and annual (clover, medics) species provided adequate nutrients are available. It is likely that the soil would become more stable with time as organic matter levels in the surface few centimetres increase.

The Haul Road, ROM Pad and processing plant can be rehabilitated to a similar state as it was before mining. Therefore, better quality soils classified as Ballimore, Wongarbon and Bald Hill Soil Landscapes would be suitable for rotational cropping of dryland cereal crops (wheat, barley, oats), and forage crops. Improved annual and perennial pasture would be better suited on the Arthurville and Belowrie Soil Landscapes. All this land would be suitable for grazing sheep and cattle.

The topsoil stockpiles can be returned to the same agricultural suitability as they were before mine operations. These areas would be subjected to the minimal disturbance of supporting the topsoil stockpiles. Nevertheless, it is likely that the areas would require some rehabilitation in the form of planting desirable species, addition of fertiliser and perhaps some tillage.

## 6.5 AGRICULTURAL PRODUCTIVITY

### 6.5.1 Overview

It is noted that a more detailed analysis of agricultural productivity of the DZP Site and surrounds has been completed as part of an Agricultural Impact Statement (AIS) for the Proposal (Diana Gibbs & Partners / RWC). The following provides a more general analysis of the effect of the Proposal on agricultural productivity by estimating the effect of mining on the stocking rate of sheep. This enterprise was selected as the majority of land to be disturbed by the Proposal currently supports grazing by sheep. The crops planted appear to be used primarily as forage crops for the sheep.

The base stocking rate selected was 5 first-cross ewes/ha, which Farrell (2009) found was the optimum stocking rate on improved pasture in the Dubbo area. This was applied to Class 3 land. The stocking rate was arbitrarily discounted to 3hd/ha on Class 4 land, 1hd/ha on Class 5 land, 0.5hd/ha on Class 6 land, and essentially 0 on Class 7 land.

These estimates represent one scenario for rehabilitation of a number of possible scenarios. It can be argued both that the estimated carrying capacity of rehabilitated soil in this analysis is pessimistic because it is likely that rehabilitated soil would be more fertile than undisturbed soil and the estimated carrying capacity of rehabilitated soil is optimistic since we have no guarantee of the quality of rehabilitation. We have selected a level of production that we believe is achievable. It is likely that the productivity of rehabilitated land would be measurably less than that of undisturbed land. Orndorff *et al*. (2011) found that crop yields of rehabilitated mine land were 25 to 40% lower than yields from local farmland under identical management.

### 6.5.2 Current

The current carrying capacity of the 808 hectares within the proposed disturbance footprint is estimated to be 3,553 first-cross ewes (**Table 30**). This is an average of 4.4hd/ha.

**Table 30**
**Estimated carrying capacity of areas to be disturbed by the Proposal**

| Infrastructure Type | Land and Soil Capability Class | Area (ha) | Stocking Rate (hd/ha) | Total Stock |
|---|---|---|---|---|
| Open Cut | 5 | 40 | 1 | 40 |
| Waste Rock Emplacement | 3 | 19 | 5 | 94 |
| | 4 | 1 | 3 | 3 |
| Solid Residue Storage Facility | 3 | 86 | 5 | 430 |
| | 4 | 16 | 3 | 48 |
| Liquid Residue Storage Facility | 3 | 381 | 5 | 1905 |
| | 4 | 44 | 3 | 132 |
| Salt Encapsulation Cells | 3 | 6 | 5 | 30 |
| | 4 | 29 | 3 | 87 |
| Haul Road | 3 | 3 | 5 | 15 |
| | 4 | 4 | 3 | 12 |
| Run of Mine Stockpile | 3 | 4 | 5 | 20 |
| Processing Plant | 3 | 27 | 5 | 135 |
| | 4 | 17 | 3 | 34 |
| Soil Stockpiles | 2 | 0 | 5 | 0 |
| | 3 | 89 | 5 | 445 |
| | 4 | 41 | 3 | 123 |
| **Total** | | **808** | | **3553** |
| Note: Areas have been rounded. | | | | |

### 6.5.3 During Mine Operation

**Table 27** shows that the Soil Stockpiles can be Land and Soil Capability Class 4 during mine operation whereas the remaining structures would be Class 8. Therefore, only the Soil Stockpiles can carry sheep during mine operation. It is estimated that 387 first-cross ewes can be grazed during this phase.

### 6.5.4 Post Rehabilitation

It is estimated that the carrying capacity of the rehabilitated land would be 2 138 first-cross ewes (**Table 31**). This is approximately 60% of the current estimated carrying capacity.

**Table 31**
**Estimated carrying capacity of areas to be disturbed by the Proposal after rehabilitation**

| Infrastructure Type | Land and Soil Capability Class | Area (ha) | Stocking Rate (hd/ha) | Total Stock |
|---|---|---|---|---|
| Open Cut | 7 | 40 | 0 | 0 |
| Waste Rock Emplacement | 6 | 20 | 0.5 | 10 |
| Solid Residue Storage Facility | 6 | 103 | 0.5 | 52 |
| Liquid Residue Storage Facility | 4 | 425 | 3 | 1275 |
| Salt Encapsulation Cells | 7 | 35 | 0 | 0 |
| Haul Road | 3 | 3 | 5 | 15 |
| | IV | 4 | 3 | 12 |
| Run of Mine Stockpile | 3 | 4 | 5 | 20 |
| Processing Plant | 3 | 27 | 5 | 135 |
| | 4 | 17 | 3 | 51 |
| Soil Stockpiles | 2 | 0 | 5 | 0 |
| | 3 | 89 | 5 | 445 |
| | 4 | 41 | 3 | 123 |
| **Total** | | **808** | | **2138** |

Carrying capacity of the area of the LRSF is predicted to decline by 762 first-cross ewes because of a reduction in average pasture growth associated with a reduction in the estimated plant available water capacity of the constructed soil compared to the undisturbed soil. The average carrying capacity of this area is predicted to decline from 4.8hd/ha to 3 hd/ha over 425ha. Carrying capacity of the area of SRSF is predicted to decline by 426 first-cross ewes. This is caused by a large decline in carrying capacity from a current estimate if 4.8 hd/ha to a predicted 0.5 hd/ha. There are two reasons for the estimated reduction in carrying capacity. First, there would be a substantial reduction in the rootzone volume of rehabilitated soil compared to the undisturbed soil. Second, the rehabilitated land should be grazed sparingly to protect the integrity of the constructed soil. Carrying capacity would also be reduced in the areas of the Waste Rock Emplacement. Few stock are likely to be carried on the area of the Salt Encapsulation Cells, and no stock on the open cut. These three structures account for approximately 12% of the total reduction in carrying capacity.

## 6.6 COMPATABILITY WITH CENTRAL WEST CATCHMENT MANAGEMENT PLAN

The Central West Catchment Action Plan 2011-2021 (Central West CMA, 2011) is a broad plan for the Central West Catchment. The catchment includes the Castlereagh, Macquarie and Bogan River valleys and their distributary floodplains. The DZP Site is east and south of the geographic centre of the Central West Catchment.

The catchment plan covers general topics of Community, Biodiversity, Water and Land. This discussion will focus on aspects of the Water and Land topics.

The actions recommended by the Central West Catchment Action Plan to improve the condition of water dependent ecosystems are as follows.

1. Manage salinity.
2. Manage total grazing pressure.
3. Reduce runoff by increasing infiltration.
4. Manage point source and diffuse source pollution.

The Proposal could affect salinity largely through its effect on groundwater flows. The proposed infrastructure is predominantly located on three hydrogeological landscapes (**Figure 6b**); Purlawaugh/Napperby (HGL 37), Dubbo (HGL 4), and Garrawilla and Mebul (HGL 8). Wilford *et al*. (2009) indicated that the risk of salinity is greater in the Purlawaugh/Napperby than the Dubbo, and Garrawilla and Mebul hydrogeological landscapes.

Recharge in the Purlawaugh/Napperby hydrogeological landscape occurs primarily on the top of flat-topped ranges. Discharge of generally saline groundwater occurs primarily above "steps" in the landscape that are caused by layers of rock that are resistant to weathering and are also slowly permeable. The volume of discharge can be minimised by minimising water movement past the plant rootzone in the recharge areas. This is achieved by maintaining vigorous growth of deep-rooted perennials such as trees, and lucerne where appropriate.

Recharge from land disturbed by the Proposal can be minimised by minimising infiltration in areas that are not vegetated. This would have the side-effect of increasing runoff compared to undisturbed land.

The second action to improve water quality is to manage total grazing pressure. This implies that grazing by livestock, feral animals and native herbivores would be monitored and the grazing pressure would be reduced if it is deemed necessary.

The third recommended action is to reduce runoff by increasing infiltration. This can be achieved outside the disturbance footprint by maintaining the vigour of pasture. However, as noted above, it is important that deep-rooted plants be grown to minimise deep drainage past the plant rootzone.

The fourth recommended action is to minimise point source and diffuse source pollution. This will be addressed by other parts of the *Environmental Impact Statement*.

The actions to achieve the soil goal of increasing the area of soil managed to achieve 70% groundcover and the critical threshold in the slopes of 1.2% organic carbon are as follows.

1. Manage total grazing pressure.
2. Manage threatening processes e.g. acidity, erosion, salinity, invasive species.
3. Increase perenniality in pastures and establish deep-rooted perennials.

These actions generally overlap with those listed above to improve water quality with exception of the action to increase organic carbon, and that the topics addressing soil degradation are broadened to include acidity, erosion and invasive species as well as salinity. The action to increase perenniality in pastures is consistent with the actions to reduce recharge.

One goal in managing rehabilitated land would be to increase organic carbon levels from low levels that are likely to be less than 0.5% in the mixed 0 to 50cm soil (Chan et al., 2010) to the desired level of 1.2% which is common in the 0 to 10cm layer of undisturbed profiles across the DZP Site (**Tables 4** to **20**). This increase in soil organic carbon would require an additional 7 tonnes of carbon/ha in the surface 10cm. It would take 10 years to sequester this amount of carbon at the maximum rate of 0.7t carbon/ha/year observed by Chan *et al*. (2010). The high rate of carbon sequestration is associated with improved pasture, conservative stocking rates and fertiliser application if nutrient levels are limiting.

Invasive species management would be part of the monitoring and reporting programme outlined in Section 4.4.

In summary, the Proposal would present some threats to the goals of the Central West Catchment Action Plan, but these can be addressed by appropriate actions.

# 7. CONCLUSIONS AND RECOMMENDATIONS

In summary, the following conclusions and recommendation for the Proposal are provided.

1. The Dubbo Zirconia Project Soil Survey Area of approximately 3460ha essentially consists of a spine of igneous hills with shallow soil (Dowd landscape), variable soil (Belowrie landscape), well drained, stable soil (Bald Hill landscape) or clay (Wongarbon landscape). This spine is flanked by soil that developed on sedimentary rock. The dominant soil is deep moderately stable loamy soil on the west and north (Ballimore landscape). It contains a small patch of the fragile Turkey Range landscape. Deep moderately stable loamy soil also occurs in the westernmost corner of the Soil Survey Area (Arthurville landscape). The southern slope of the Soil Survey Area contains the shallow Splitters Hill landscape, and the western margins of the clayey, productive Nubingerie landscape. A small strip of alluvium flanks the Wambangalang Creek (Mitchell Creek landscape).
2. The soil tested had neutral to acidic surface soil, and slightly alkaline to neutral subsoil. The loamy soil had a relatively small capacity to store nutrients, while the soil that developed on basalt had a larger capacity to store nutrients. Soil phosphorus was low to adequate, nitrate nitrogen was variable, and sulphate sulphur was generally low to very low. Soil salinity was desirably low in the soil tested. Exchangeable aluminium was elevated in some of the better drained soils.
3. The land is generally suited to either cropping with practices that minimise soil degradation (49%), grazing with occasional cultivation to establish pasture (38%) or not suited to agricultural use (13%). This capability rating is consistent with the current land use.
4. The proposed development and rehabilitation is likely to reduce the proportion of land suited to cropping with practices that minimise soil degradation to 35% of the Soil Survey Area. Approximately 50% of the land would be suited to grazing with occasional cultivation to establish pasture, and 15% not suited to agricultural use.
5. This change in land capability was predicted to reduce the predicted carrying capacity of the 808ha affected by the project by an estimated 1400 first cross ewes.
6. The topsoil of most soil landscapes was rated as suitable for stripping, but the topsoil depth was variable.
7. It is likely that approximately 600ha of the Soil Survey Area could be used as the floor of evaporation ponds, but the land is still steep for this purpose.

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