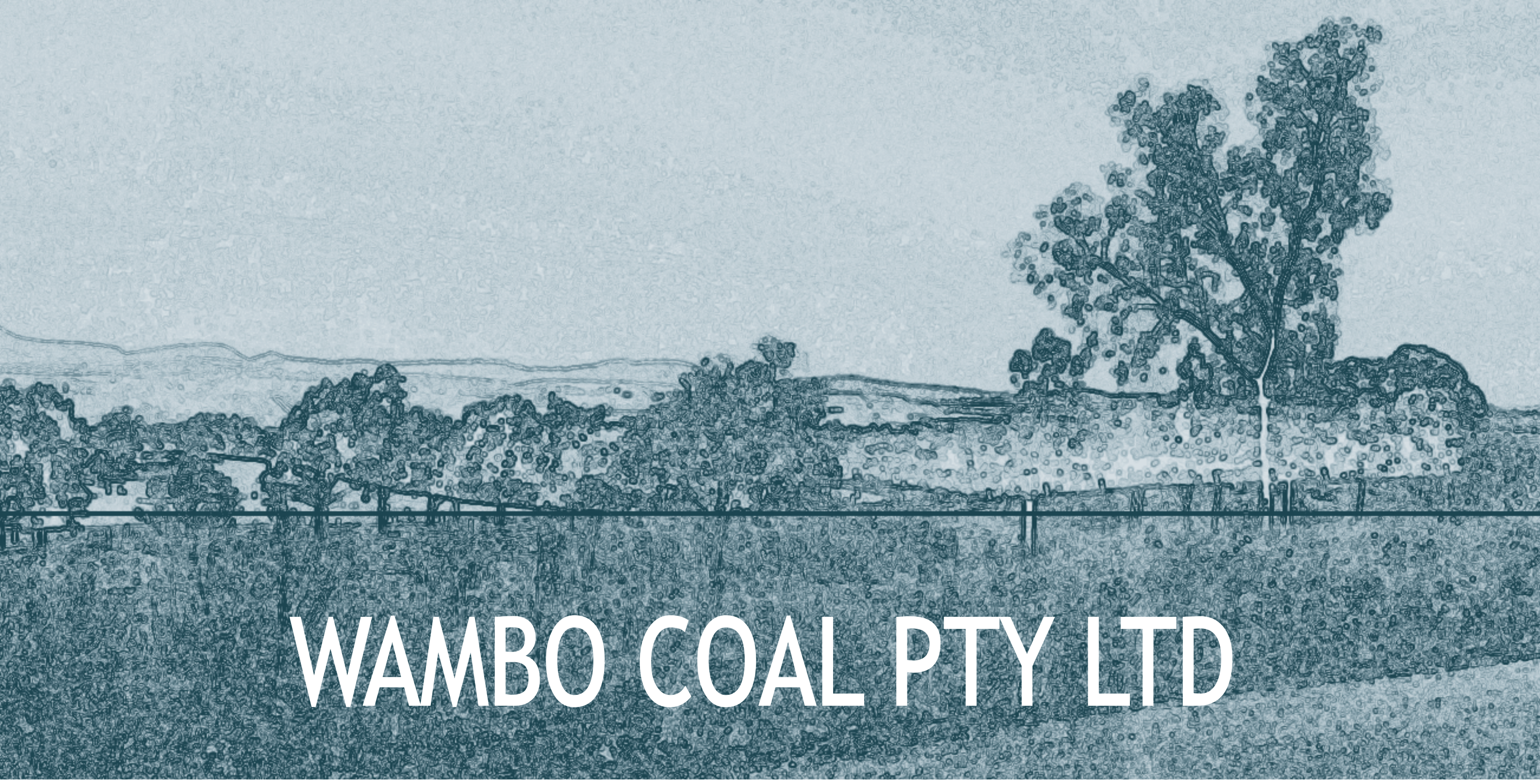

WAMBO COAL PTY LTD

NORTH WAMBO UNDERGROUND MINE MODIFICATION

ENVIRONMENTAL ASSESSMENT

APPENDIX F

AGRICULTURAL RESOURCE ASSESSMENT

Peabody ENERGY

October

2012

Agricultural Resource Assessment: "North Wambo Underground Mine Modification", Wambo NSW

Prepared for Wambo Coal Pty. Ltd.

Dr. David McKenzie

McKenzie Soil Management Pty. Ltd.

Orange NSW

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1.0 INTRODUCTION

1.1 Background

The Wambo Coal Mine (Wambo) is situated approximately 15 kilometres (km) west of Singleton, near the village of Warkworth, New South Wales (NSW) (Figure 1). Wambo is owned and operated by Wambo Coal Pty Ltd (WCPL), a subsidiary of Peabody Energy Australia Pty Limited.

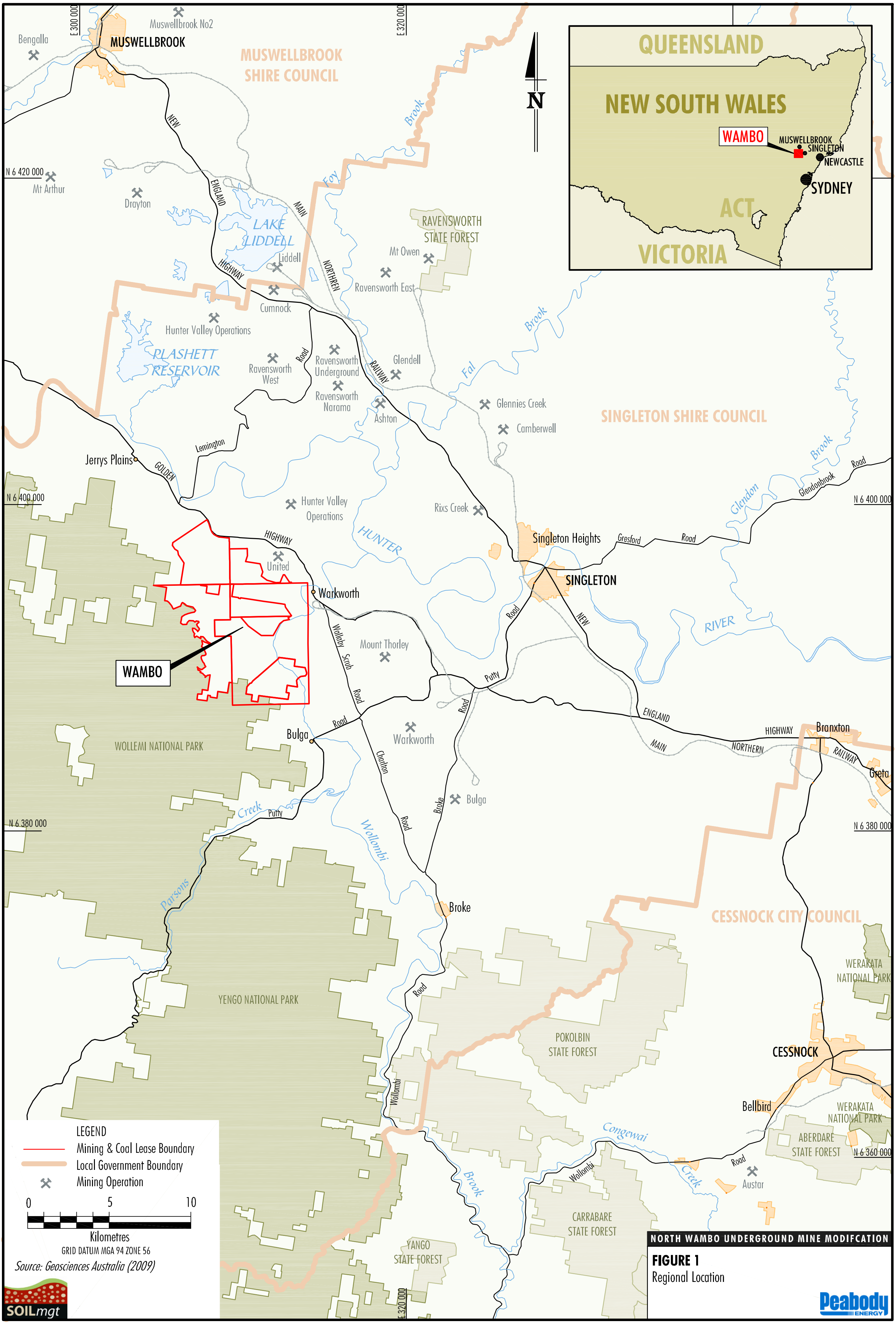
A range of open cut and underground mine operations have been conducted at Wambo since mining operations commenced in 1969. Mining under Development Consent DA 305-7-2003 commenced in 2004 and currently both open cut and underground operations are conducted. An aerial photograph of Wambo, illustrating the approved extent of the open cut and underground mine operations and locations of key infrastructure is provided on Figure 2.

1.2 Scope and Objectives

This agricultural resource assessment has been prepared to support an application to modify Development Consent DA 305-7-2003 to allow for the extension of the North Wambo Underground Mine (the North Wambo Underground Mine Modification [the Modification]) (Figures 2 and 3).

The objectives of this assessment were to:

- Describe the agricultural resources (focusing on soil resources) and enterprises of the lands associated with the Modification area.
- Recommend management measures for agricultural resources, with emphasis on soil assessment and management in the Modification area.
- Assess the potential impacts on agricultural enterprises and productivity as a result of the Modification.


QUEENSLAND
NEW SOUTH WALES
WAMBO
MUSWELLBROOK
SINGLETON
NEWCASTLE
SYDNEY
ACT
VICTORIA
MUSWELLBROOK
MUSWELLBROOK SHIRE COUNCIL
SINGLETON SHIRE COUNCIL
CESSNOCK CITY COUNCIL
SINGLETON
Singleton Heights
Jerrys Plains
Warkworth
Bulga
Broke
Branxton
Greta
CESSNOCK
Bellbird
LAKE LIDDELL
PLASHETT RESERVOIR
HUNTER RIVER
WAMBO
WOLLEMI NATIONAL PARK
YENGO NATIONAL PARK
RAVENSWORTH STATE FOREST
POKOLBIN STATE FOREST
CARRABARE STATE FOREST
YANGO STATE FOREST
ABERDARE STATE FOREST
WERAKATA NATIONAL PARK
Bengalla
Muswellbrook No2
Mt Arthur
Drayton
Liddell
Cumnock
Hunter Valley Operations
Ravensworth West
Ravensworth Underground
Ravensworth Narama
Ravensworth East
Mt Owen
Glendell
Ashton
Glennies Creek
Camberwell
Rixs Creek
United
Mount Thorley
Warkworth
Bulga
Austar
NEW ENGLAND HIGHWAY
MAIN NORTHERN RAILWAY
GOLDEN HIGHWAY
Putty Road
Wallaby Scrub Road
Charlton Road
Broke Road
Gresford Road
Glendonbrook Road
Lemington
N 6 420 000
N 6 400 000
N 6 380 000
N 6 360 000
E 300 000
E 320 000
N
LEGEND
Mining & Coal Lease Boundary
Local Government Boundary
Mining Operation
0 5 10
Kilometres
GRID DATUM MGA 94 ZONE 56
Source: Geosciences Australia (2009)
SOILmgt
NORTH WAMBO UNDERGROUND MINE MODIFCATION
FIGURE 1
Regional Location
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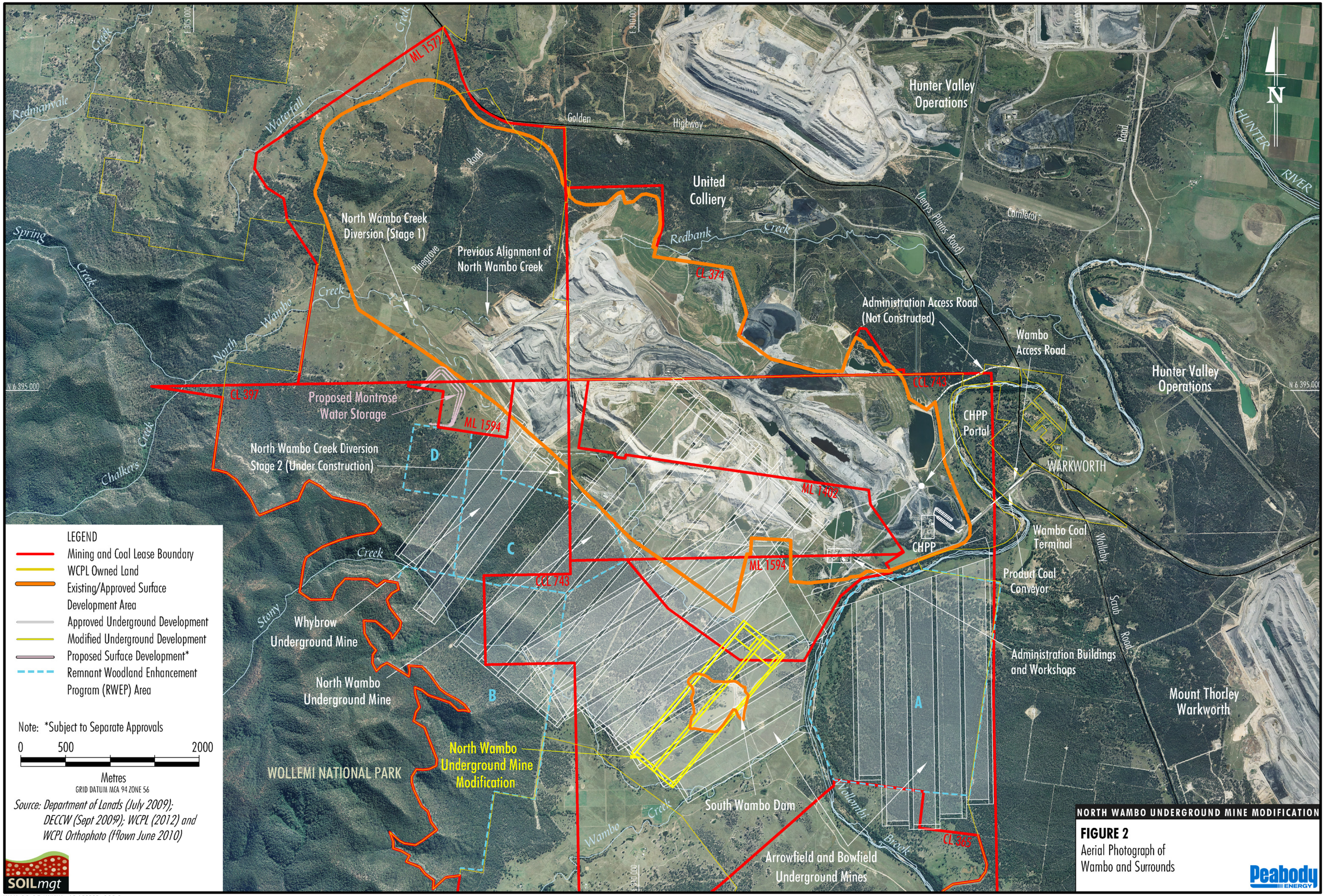
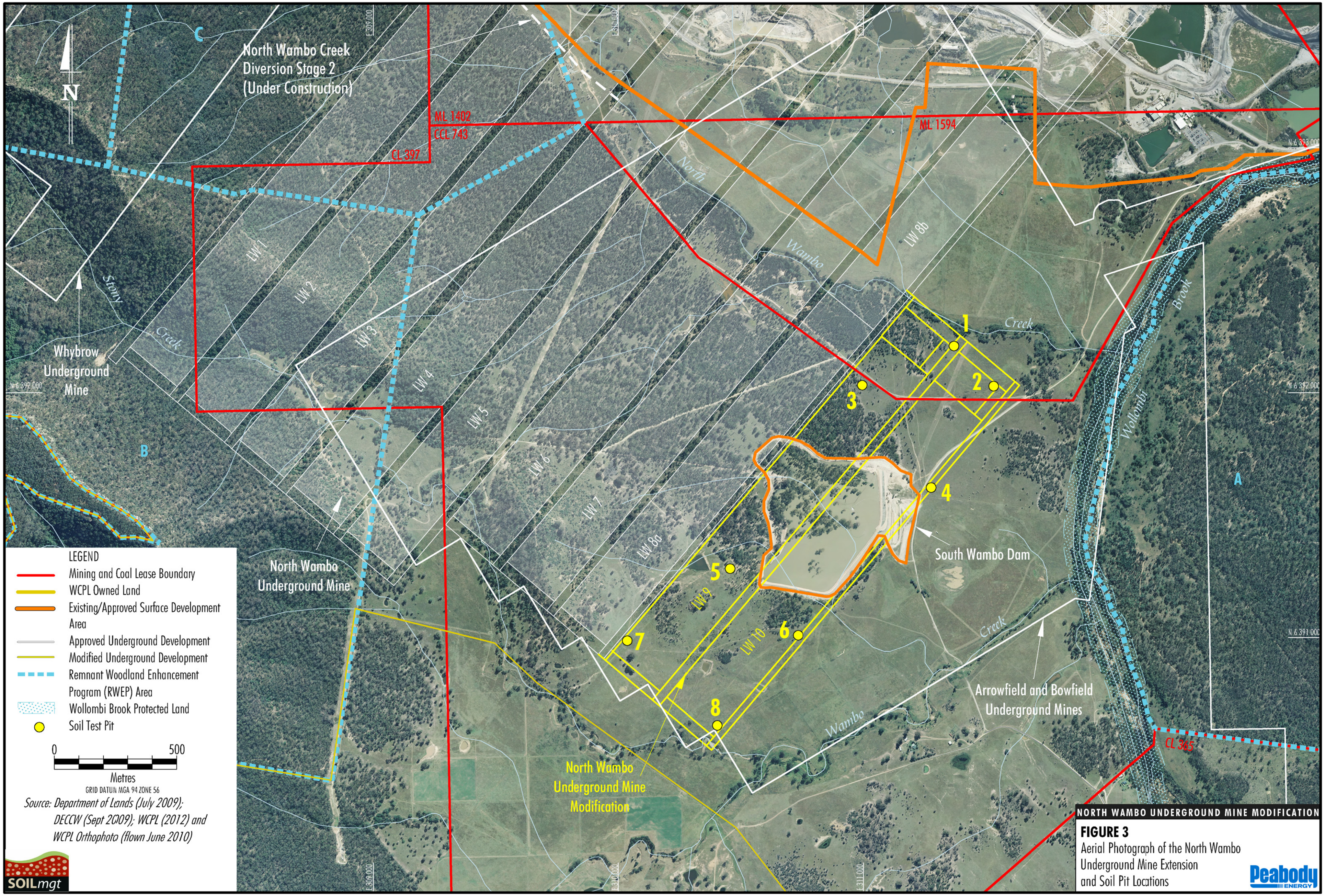


NORTH WAMBO UNDERGROUND MINE MODIFICATION

FIGURE 2
Aerial Photograph of
Wambo and Surrounds



NORTH WAMBO UNDERGROUND MINE MODIFICATION

FIGURE 3
Aerial Photograph of the North Wambo Underground Mine Extension and Soil Pit Locations

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2.0 PROJECT OVERVIEW

The Modification would include the development of two additional longwall panels in the Wambo Seam adjacent to the existing North Wambo Underground Mine (Figure 3). Access to the modified longwall panels would be via the existing North Wambo Underground Mine. The Modification would use the existing surface infrastructure of the North Wambo Underground Mine.

Additional details of the Modification are provided in the Environmental Assessment.

3.0 DESCRIPTION OF NORTH WAMBO UNDERGROUND MINE MODIFICATION AREA

Wambo is located in the Upper Hunter Valley region where landforms are characterised by gently sloping flood plains associated with the Hunter River and the undulating foothills, ridges and escarpments of the Mount Royal Range and Great Dividing Range. Wambo adjoins grazing land to the south, other coal mining operations to the east and north, grazing land to the north-west and Wollemi National Park to the west and south-west.

Elevations in the vicinity of Wambo range from approximately 60 metres (m) Australian Height Datum (AHD) at Wollombi Brook to approximately 650 m AHD at Mount Wambo within the Wollemi National Park to the west of Wambo. Elevations in the Modification area range from approximately 65 m AHD at the North Wambo Creek and Wollombi Brook to approximately 85 m AHD on low hills along the south-western boundary (Figure 3).

Land use in the Modification area includes approved underground mining areas, mining-related infrastructure, remnant vegetation and cleared grazing land (Figure 3). The cleared grazing land is under unimproved pasture. There is no evidence of recent cropping activities or vineyards in the Modification area.

Mean annual rainfall figures over a period of approx 120 years at the nearby towns of Jerry's Plains and Broke, respectively, are 645 millimetres (mm) (range = 234 to 1,191 mm) and 655 mm (range = 306 to 1,156 mm) (Bureau of Meteorology 2012).

4.0 SOIL RESOURCES

4.1 Review of Existing Information

The following existing information relevant to the Modification area was reviewed for this agricultural resources assessment:

- Soil Profile Attribute Data Environment (SPADE) soil profiles (part of the NSW Natural Resource Atlas);
- Soil type and landscape mapping (Kovac and Lawrie 1991);
- Hunter Coalfield Regional Geology 1:100,000 Sheet (Department of Mineral Resources 1993);
- Biophysical Strategic Agricultural Land (BSAL) mapping (NSW Government 2012);
- Critical Industry Cluster mapping (NSW Government 2012);
- Rural Land Capability mapping (Soil Conservation Services of NSW 1985); and
- Agricultural Suitability mapping (NSW Agriculture 1983).

A brief summary of relevant information from these reports is provided in the following subsections.

SPADE Soil Profile Database

A search of the NSW Government's SPADE website (part of the NSW Natural Resource Atlas) was conducted to identify any existing soil profile information in the Modification area. No SPADE soil profiles were located in the Modification area.

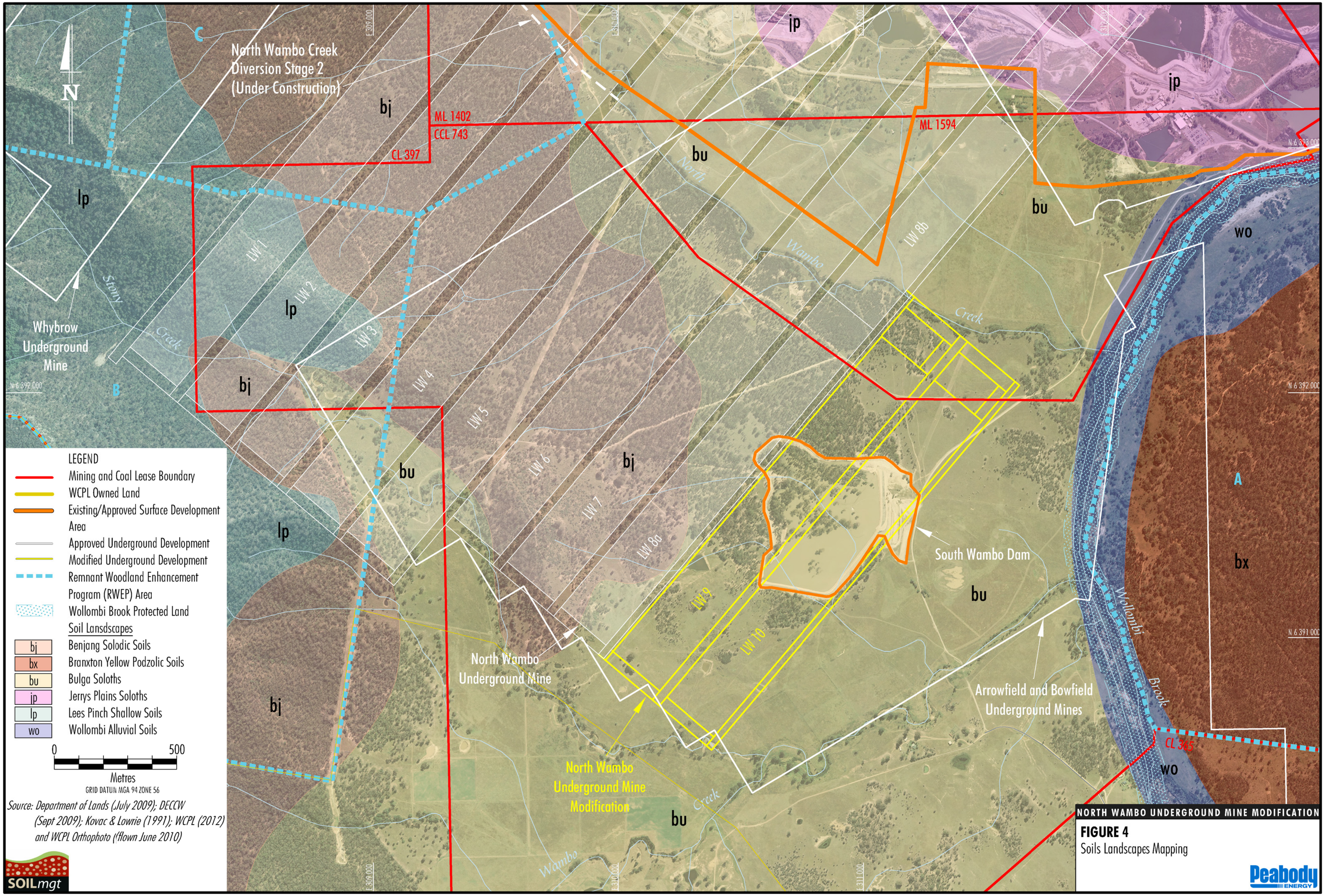
Soil Types and Landscapes

Figure 4 shows the location of soil landscape units as mapped and described by Kovac and Lawrie (1991) in the vicinity of the Modification area. The descriptions of these units indicate the presence of soil conditions that generally are poor for plant growth (Table 1).

The Modification area is part of the 'Bulga Soloths' Soil Landscape unit.

Table 1. Soil landscape units (Kovac and Lawrie 1991) in the vicinity of the North Wambo Underground Mine Modification area

Soil landscape unit	Soil types present	Likely constraints for agricultural production based on these descriptions
Bulga Soloths (**bu**)	Yellow soloths on upper to midslopes; sometimes Yellow and Brown Solodic Soils and Brown Earths on lower slopes.	Poor aeration in subsoils when wet, very hard when dry. Prone to water erosion when bare. Acidic.
Benjang Solodic Soils (**bj**)	Yellow, red and brown Solodic Soils on imperfectly drained benched slopes, with Brown Podzolic Soils on upper slopes and Non-calcic Brown Soils on lower parts of flatter slopes.	Poor aeration in subsoils when wet, very hard when dry. Prone to water erosion when bare.



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Geology / Parent Materials for Soil Formation

The Hunter Coal Fields Geology 1:100,000 Sheet shows the rock types that are the parent material for soil formation in the vicinity of the Modification area shown in Figure 5. The presence of siltstone and tuffaceous claystone in the 'Wollombi Coal Measures' and 'Wittingham Coal Measures' units indicates that there may be pockets of soil in the vicinity of the Modification area with soil conditions significantly better than those shown in Table 1.

Strategic Agricultural Land

The *Upper Hunter Strategic Regional Land Use Plan* (SRLUP) (NSW Government 2012) includes mapping of lands identified as Strategic Agricultural Lands. Strategic Agricultural Lands include BSAL and Critical Industry Clusters. BSAL is classified as land with reliable water of suitable quality, with a soil fertility of 'high' or 'moderately high' (NSW Office of Environment and Heritage [OEH], 2012a) and Class I, II or III Land and Soil Capability (LSC), or a soil fertility of 'moderate' and Class I or II Land Soil Capability (NSW Government 2012). Figure 6 shows BSAL mapped in the vicinity of Wambo. The closest mapped BSAL is associated with the Hunter River and is located approximately 7 km to the north-west of the Modification area (Figure 6).

The SRLUP includes mapping of lands identified as Viticulture and Equine Critical Industry Clusters (Figure 6). The Modification area is located within a Viticulture Critical Industry Cluster (Figure 6). The closest Equine Critical Industry Cluster is located approximately 12 km to the north-west of the Modification area (Figure 6).

Rural Land Capability

The Rural Land Capability classification in NSW was developed by the NSW Soil Conservation Service (Emery 1986). It was derived from the scheme of Klingebiel and Montgomery (1961).

Land is allocated to one of eight classes, with emphasis on the erosion hazards in the use of the land. The Rural Land Capability classes are as follows (Emery 1986; Sonter and Lawrie 2007):

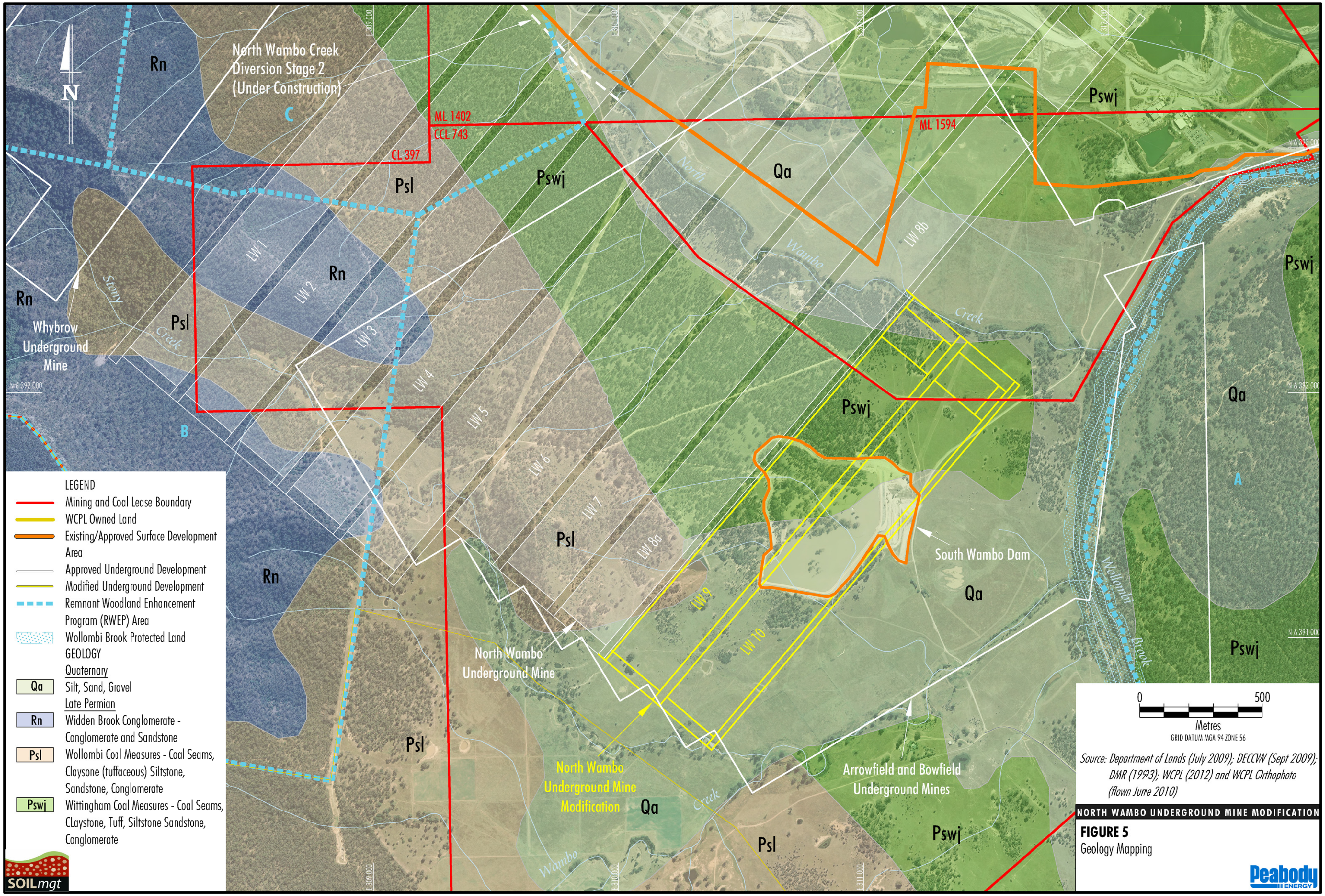
Class I-III: Land Suitable for Regular Cultivation / Cropping.

Class IV-VI: Land Suitable Mainly for Grazing.

Class VII: Land best protected by Trees.

Class VIII: Land Unsuitable for Agriculture.

The regional Rural Land Capability mapping (Soil Conservation Services of NSW 1985) indicates that the Modification area is Class IV and V (Figure 7).



LEGEND

- Mining and Coal Lease Boundary
- WCPL Owned Land
- Existing/Approved Surface Development Area
- Approved Underground Development
- Modified Underground Development
- Remnant Woodland Enhancement Program (RWEP) Area
- Wollombi Brook Protected Land

GEOLOGY

Quaternary

- Qa — Silt, Sand, Gravel

Late Permian

- Rn — Widden Brook Conglomerate - Conglomerate and Sandstone
- Psl — Wollombi Coal Measures - Coal Seams, Claystone (tuffaceous) Siltstone, Sandstone, Conglomerate
- Pswj — Wittingham Coal Measures - Coal Seams, Claystone, Tuff, Siltstone Sandstone, Conglomerate

0 500
Metres
GRID DATUM MGA 94 ZONE 56

Source: Department of Lands (July 2009); DECCW (Sept 2009); DMR (1993); WCPL (2012) and WCPL Orthophoto (flown June 2010)

NORTH WAMBO UNDERGROUND MINE MODIFICATION

FIGURE 5
Geology Mapping

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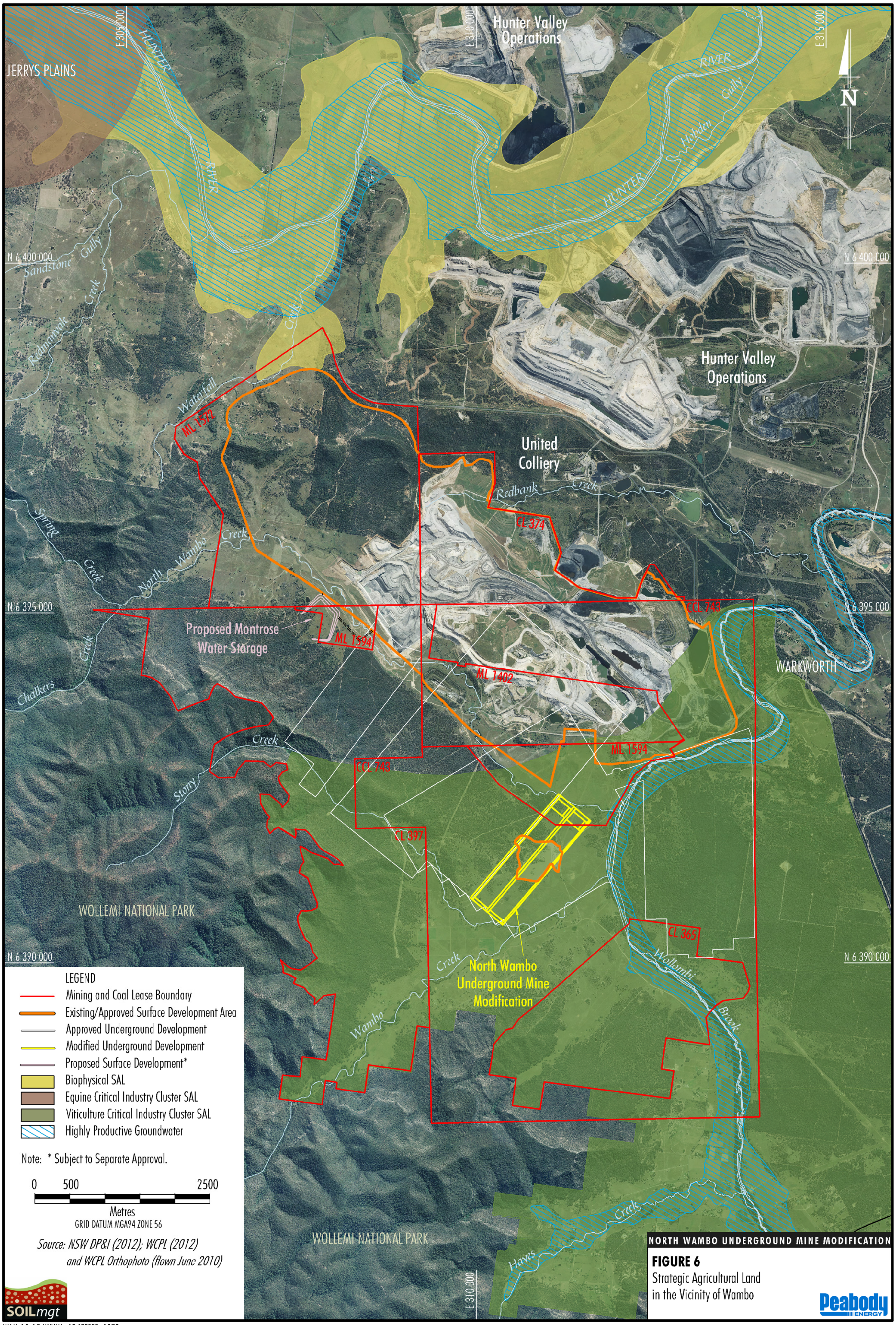
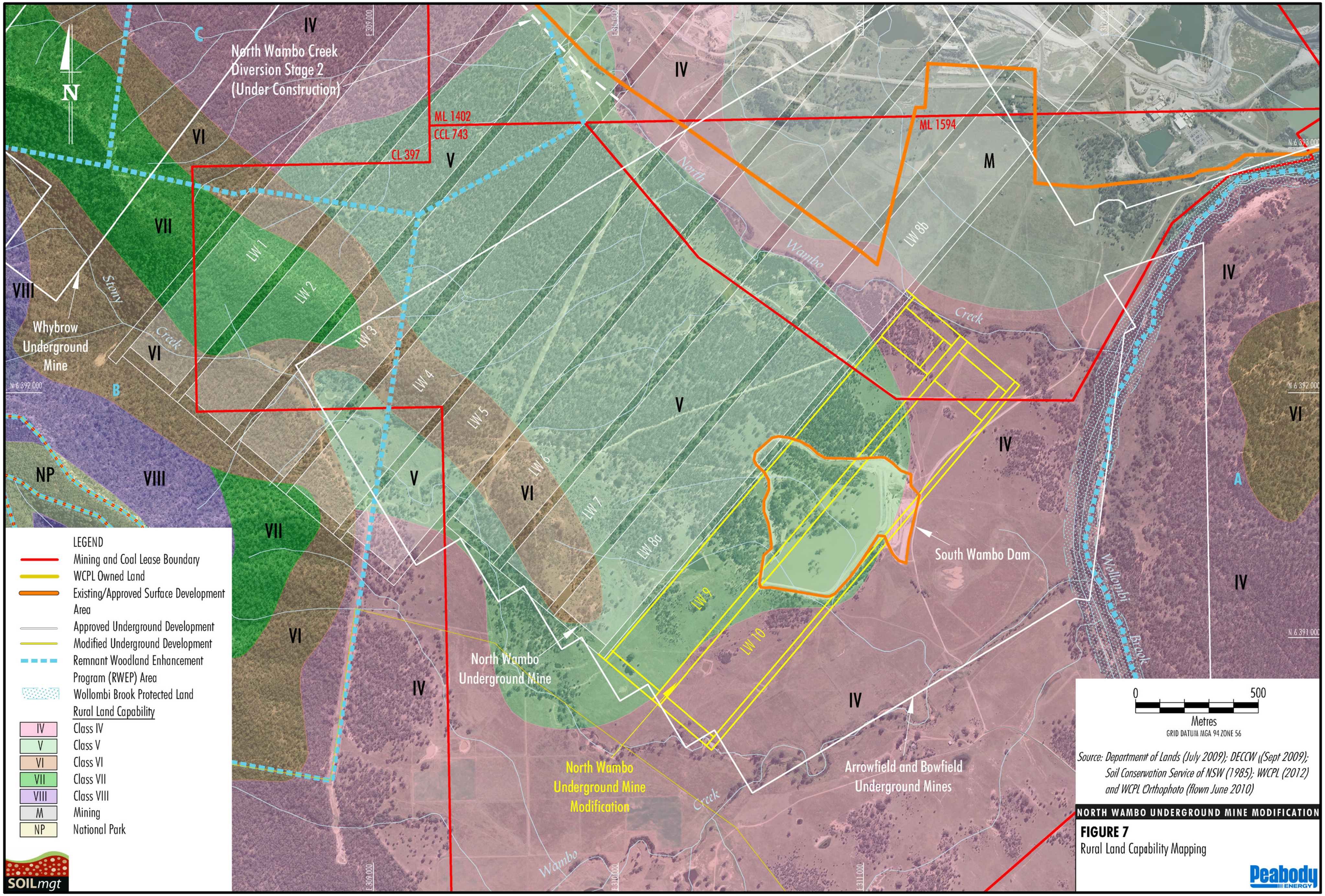

JERRYS PLAINS
Hunter Valley Operations
HUNTER
RIVER
Hunter Valley Operations
United Colliery
Redbank Creek
CL 374
CCL 743
WARKWORTH
ML 1572
Waterfall
North Wambo Creek
Spring Creek
Sandstone Gully
Proposed Montrose Water Storage
ML 1594
ML 1402
Chalkers Creek
Stony Creek
CCL 743
CL 397
CL 365
WOLLEMI NATIONAL PARK
North Wambo Underground Mine Modification
Wambo Creek
Wollombi Brook
Hayes Creek
WOLLEMI NATIONAL PARK
N 6 400 000
N 6 395 000
N 6 390 000
E 305 000
E 310 000
E 315 000
N
LEGEND
Mining and Coal Lease Boundary
Existing/Approved Surface Development Area
Approved Underground Development
Modified Underground Development
Proposed Surface Development*
Biophysical SAL
Equine Critical Industry Cluster SAL
Viticulture Critical Industry Cluster SAL
Highly Productive Groundwater
Note: * Subject to Separate Approval.
0 500 2500
Metres
GRID DATUM MGA94 ZONE 56
Source: NSW DP&I (2012); WCPL (2012) and WCPL Orthophoto (flown June 2010)
SOILmgt
NORTH WAMBO UNDERGROUND MINE MODIFICATION
FIGURE 6
Strategic Agricultural Land in the Vicinity of Wambo
Peabody ENERGY



NORTH WAMBO UNDERGROUND MINE MODIFICATION

FIGURE 7
Rural Land Capability Mapping

WAM-10-15 NUWM_AG ASSESS_108E

Agricultural Suitability

This five class system used by NSW Agriculture classifies land in terms of its suitability for general agricultural use (Hulme *et al*. 2002). It was developed specifically to meet the objectives of the NSW *Environmental Planning and Assessment Act, 1979*.

Agricultural land is classified by evaluating biophysical, social and economic factors that may constrain the use of land for agriculture. In general terms, the fewer the constraints on the land, the greater its value for agriculture (Hulme *et al*. 2002). Higher quality lands (Classes 1 and 2) have fewer constraints and a greater versatility for agriculture than poorer quality lands. The essential characteristics of the five classes are as follows (Hulme *et al*. 2002):

Class 1: Arable land suitable for intensive cultivation where constraints to sustained high levels of agricultural production are minor or absent.

Class 2: Arable land suitable for regular cultivation for crops, but not suited to continuous cultivation.

Class 3: Grazing land or land well suited to pasture improvement.

Class 4: Land suitable for grazing but not for cultivation.

Class 5: Land unsuitable for agriculture.

The regional Agricultural Suitability mapping (NSW Agriculture 1983) indicates that most of the Modification area is Class 3 with minor sections of Class 2 (Figure 8).

4.2 Methodology

A soil survey was conducted to characterise and assess the soils in the Modification area. This section provides a description of the soil survey methodology and outcomes.

The following soil information is regarded by Ward (1998) as being important for soil and overburden assessment associated with mine site reclamation:

- Classification (structure, texture, etc.); allows existing data and experience on managing similar soils elsewhere to be applied.
- Dispersion index and particle size analysis; indicates soil structural stability and erodibility.
- pH; need to identify extreme ranges for treatment of lime or selection of suitable plant species.
- Electrical conductivity (EC); indicates soluble salt status.
- Macro- and micro-nutrients.

More specifically, Elliott and Reynolds (2007) suggest that the following soil factors need to be considered when assessing suitability of topdressing materials for mine site reclamation:

- Structure grade, which affects the ability of water and oxygen to enter soil.
- The ability of a soil to maintain structure grade following mechanical work associated with the extraction, transportation and spreading of topdressing material.
- The ability of soil peds to resist deflocculation when moist.
- Macrostructure; where soil peds are larger than 100 mm in the subsoil, they are likely to slake or be hardsetting and prone to surface sealing.
- Mottling; its presence may indicate reducing conditions and poor soil aeration.

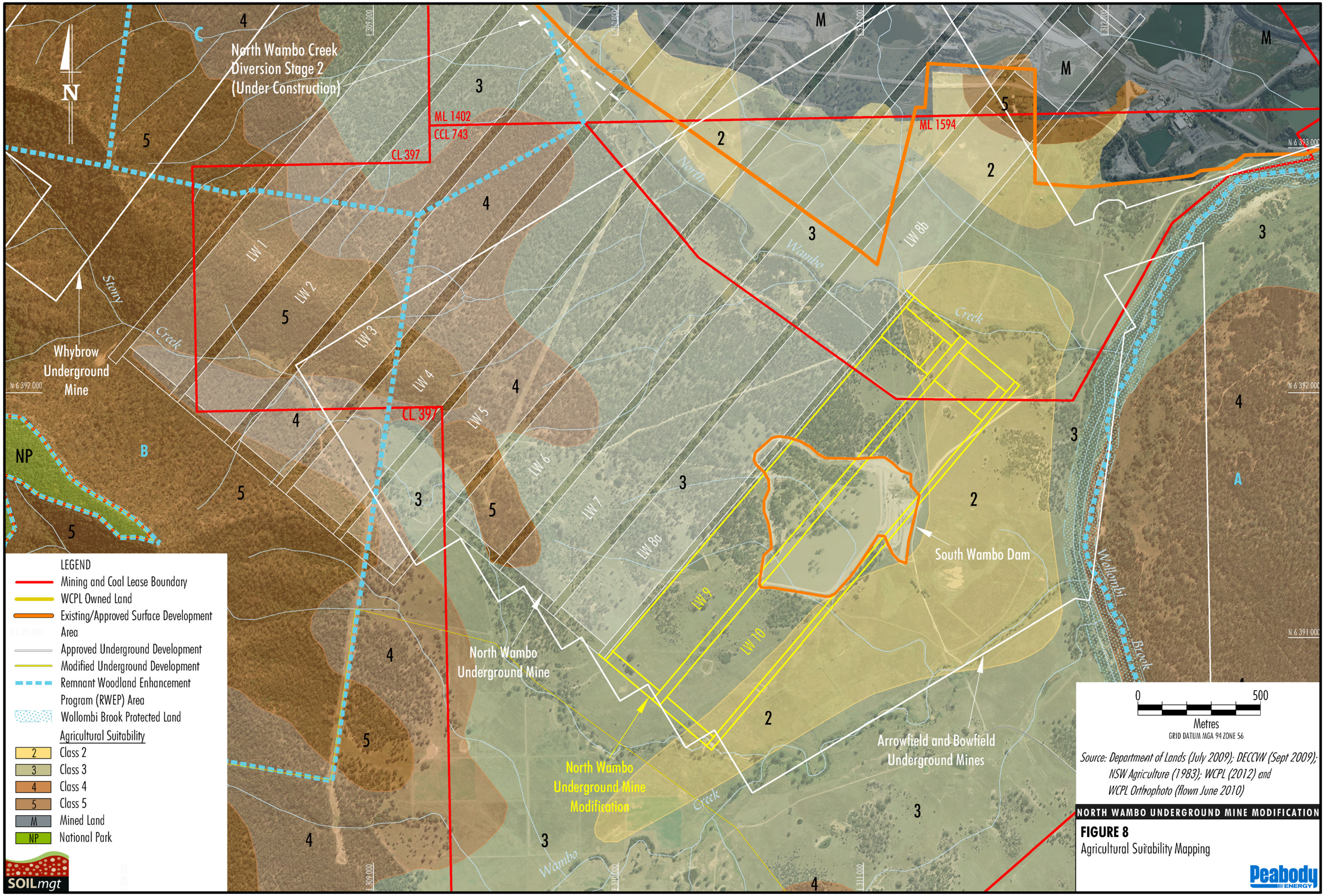


FIGURE 8
Agricultural Suitability Mapping

WAM-10-15 NUWM_AG ASSESS_109C

- Texture; soil with textures equal to or coarser than sandy loam are considered unsuitable as topdressing materials because they are extremely erodible and have low waterholding capacities.
- Material with a gravel and sand content greater than 60 percent (%) is unsuitable.
- Saline material is unsuitable.

These soil factors have been taken into account when planning the soil assessment methodology.

The assessment has also been prepared with regard to 'Soil and Landscape Issues in Environmental Impact Assessment' (Department of Land and Water Conservation 2000), and with a sampling intensity recommended by Gallant *et al.* (2008) for detailed project planning i.e. 'Moderately High (Detailed) Intensity Level' (approximately 1 pit per 10 hectares).

Field Survey

A site inspection and soil survey was conducted as part of the agricultural resource assessment. The field work was carried out on 12 April and 30 May 2012. Eight backhoe pits (approx. 1.4 m deep; shallower where hard rock was encountered) were assessed across the North Wambo Underground Mine area. Where possible, extra pits were dug more deeply (and immediately refilled) within 15 m of the 1.4 m deep pits to allow collection of deeper soil samples, where possible, to a depth of 3 m. The locations are shown on Figure 3. The pits were located in a way that covered as many of the major variations in elevation and landforms as possible.

A Garmin '*GPSmap 62S*' instrument with an accuracy of about ±4 m was used to record the pit coordinates (Appendix 1).

The field description methods were as described in the 'Australian Soil and Land Survey Field Handbook' (National Committee on Soil and Terrain 2009) and the 'Guidelines for Surveying Soil and Land Resources, Chapter 29' (McKenzie *et al*. 2008). The soil profiles have been classified (Appendix 1) according to the Australian Soil Classification (Isbell 2002).

Field Soil Observations/Testing

The soil pits were trimmed with a geological pick to allow photography and description of the undisturbed structure and root growth.

The following characteristics were assessed for the layers identified in each of the soil profiles:

- thickness of each layer (horizon);
- soil moisture status at the time of sampling;
- pH (using Raupach test kit);
- colour of moistened soil (using Munsell reference colours);
- pedality of the soil aggregates;
- amount and type of coarse fragments (gravel, rock, manganese oxide nodules);
- texture (proportions of sand, silt and clay), estimated by hand;
- presence/absence of free lime and gypsum;
- root frequency; and
- dispersibility and the degree of slaking in deionised water (after 10 minutes).

Field observations for each pit are presented in Appendix 1.

The soil structure information (Appendix 1) has been summarised to give SOILpak 'compaction severity' scores (McKenzie 2001). This allows deep tillage recommendations to be made from the structure observations. The score is on a scale of 0.0 to 2.0, with a score of 0.0 indicating very poor structure for crop root growth and water entry/storage. Ideally, the SOILpak score of the root zone should be in the range 1.5 to 2.0.

Hand texturing (National Committee on Soil and Terrain 2009) provides an approximation of the clay content of a soil. In conjunction with the estimation of coarse fragment (gravel) content, it provides a low-cost alternative to particle size analysis.

Total available water (TAW) for the upper 1 m of soil has been estimated using texture, structural form and coarse fragment content data (McKenzie *et al*. 2008).

Laboratory Soil Testing

All of the pits were sampled for laboratory analysis. The sampling intervals for laboratory analysis were 0 to 15 centimetres (cm), 15 to 30 cm, 30 to 60 cm, 60 to 90 cm and 90 to 120 cm (where appropriate), and 2 m and 3 m where possible.

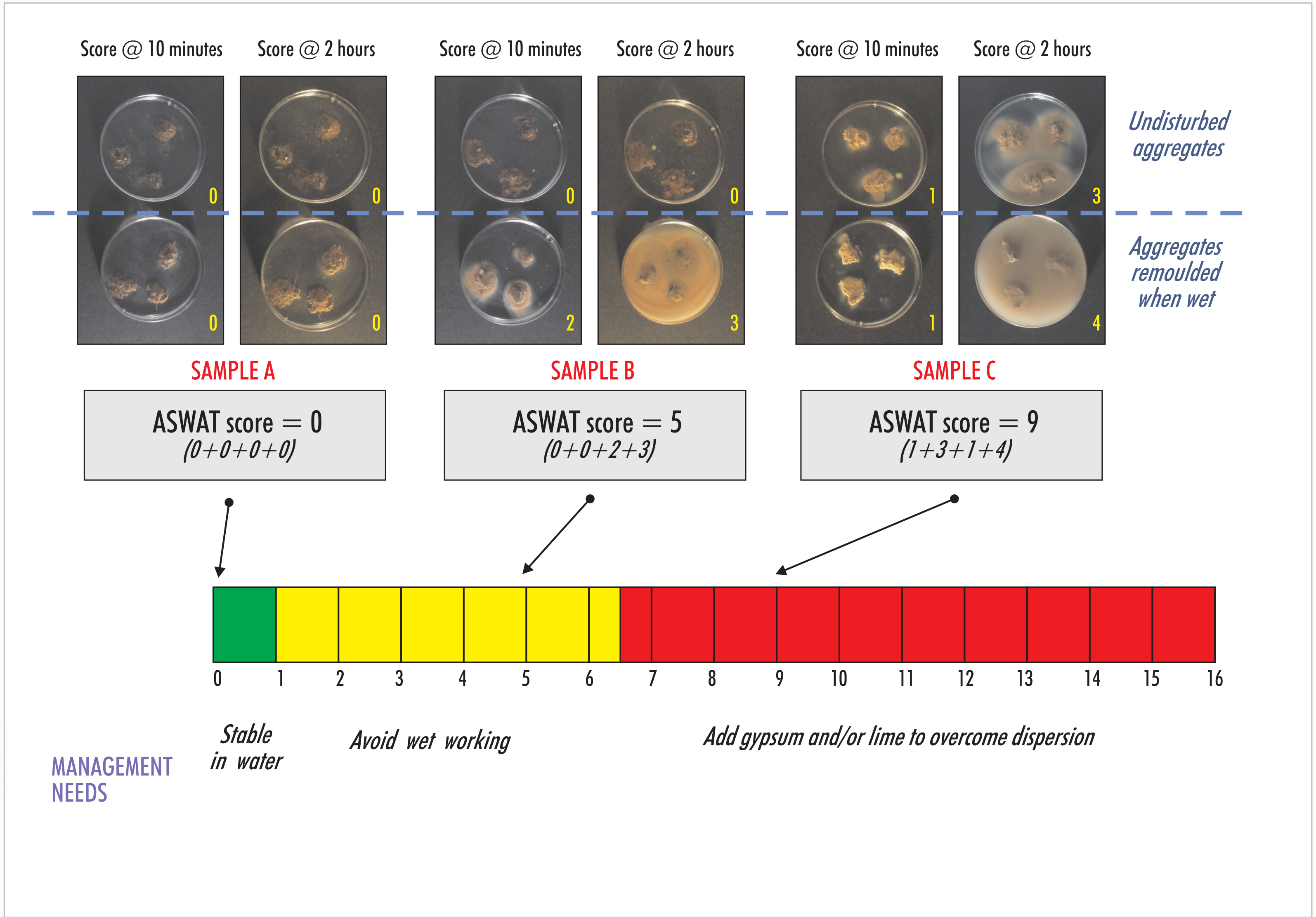
The soil from these pits was analysed by Incitec-Pivot Laboratory, Werribee Victoria for exchangeable cations, pH, EC, chlorides, nutrient status (nitrate-nitrogen, phosphorus, sulfur, zinc, copper, boron) and organic matter content. An ammonium acetate method was used for the extraction of exchangeable cations. The cation exchange capacity (CEC) values are the sum of exchangeable sodium, potassium, calcium, magnesium and aluminium. Phosphorus was determined using the Colwell method, sulphur by the CPC method, boron by a calcium chloride ($CaCl_2$ extraction) and zinc/copper by a DTPA extraction (see Rayment and Lyons [2011] for further details).

Soil dispersibility, as measured by the Aggregate Stability in Water (ASWAT) test (Field *et al.* 1997), was assessed by McKenzie Soil Management in Orange. The results are presented in Appendix 1. The ASWAT test has been related to the well known Emerson aggregate stability test by Hazelton and Murphy (2007) – see Table 2. An advantage of the ASWAT test is that the results can be linked with management issues such as the need for gypsum application and avoidance of wet working (Figure 9).

Table 2. The relationship between the Emerson aggregate stability test and the ASWAT test that assess the severity of dispersion when soil aggregates are added to water

Dispersibility	Emerson Aggregate Classes	Probable Score for the ASWAT Test (Field *et al.* 1997)
Very high	1 and 2(3)	12-16
High	2(2)	10-12
High to moderate	2(1)	9-10
Moderate	3(4) and 3(3)	5-8
Slight	3(2), 3(1) and 5	0-4
Negligible/aggregated	4, 6, 7, 8	0

The conversion factors of Slavich and Petterson (1993) allowed the EC of saturated paste extracts (EC_e) to be calculated from the EC of 1:5 soil:water suspensions ($EC_{1:5}$) and texture.



Source: Central West Catchment Management Authority (2011)

NORTH WAMBO UNDERGROUND MINE MODIFICATION

FIGURE 9
The Link between
ASWAT Results and
Soil Management Options

Peabody ENERGY

SOILmgt

WAM-09-15_NWUM_Ag Assess_001A

4.3 Soil Types

The Australian Soil Classification (Isbell 2002) has been used to determine soil types at each of the eight pits (Table 3).

Table 3. Soil types according to the Australian Soil Classification and Great Soil Groups

Pit Site	Australian Soil Classification	Great Soil Group
1	Stratic Rudosol	Alluvial Soils (less fertile)
2	Stratic Rudosol	Alluvial Soils (less fertile)
3	Grey Kandosol	Grey Earth
4	Brown Sodosol	Solodic Soils
5	Brown Kandosol	Brown Earth
6	Brown-Orthic Tenosol	Alluvial Soils
7	Red Kandosol	Red Earth
8	Black-Orthic Tenosol	Alluvial Soils (less fertile)

The soil types at the Modification area have the following characteristics:

- Stratic Rudosols are characterised by a number of alluvial depositional layers that have been little altered by pedogenic processes except at or near the surface. The uppermost depositional layers may be as young as recent floods (McKenzie *et al*. 2004).
- Kandosols lack strong texture contrast and have poorly structured massive subsoils.
- Sodosols have a strong texture contrast between topsoil and sodic (exchangeable sodium percentage of 6 or greater) subsoil which is not strongly acidic.
- Tenosols are sandy soils with only weak pedological development apart from the A horizons.

Photos of the soils found in the Modification area are presented in Figure 10.

4.4 Soil Conditions for Plant Growth

Soil Depth, Texture and Waterholding Capacity

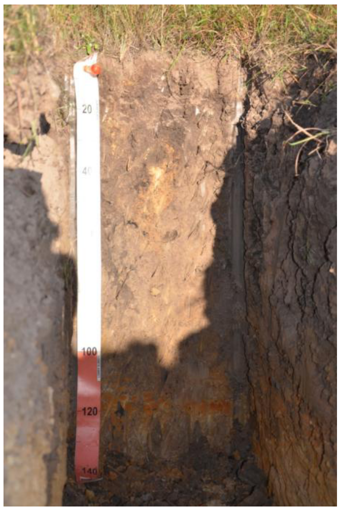
As soil becomes shallower, stonier and/or sandier, its ability to store water declines (White 2006).

The shallowest soil in the Modification area was in Pit 5. The impact of profile shallowness/stoniness and sandiness on the ability of the soil to store plant available water (measured as TAW) is shown in Appendix 1.

Plants are more likely to suffer drought stress where soil has a poor water storage capacity, particularly in hot weather with extended dry periods between rainfall events. At the Modification area, the lack of water holding capacity in shallow soils is a major constraint to agricultural productivity.

Pit 1: Stratic Rudosol

Pit 2: Stratic Rudosol



Pit 3: Grey Kandosol

Pit 4: Brown Sodosol

Pit 5: Brown Kandosol

Pit 6: Brown-Orthic Tenosol

Pit 7: Red Kandosol

Pit 8: Black-Orthic Tenosol

Figure 10. Soil Types Identified during the Survey

Waterlogging Hazard

When soil is waterlogged, several adverse processes take place (Batey 1988):

- The lack of oxygen reduces the ability of plant roots to function properly.
- Anaerobic conditions can cause large losses of soil nitrogen to the atmosphere.
- Near-surface waterlogging is associated with inefficient storage of water due to excessive evaporation losses.

Pits 3 and 4 had evidence of waterlogging, i.e. subsoil mottling (Appendix 1).

pH Imbalance

Topsoil acidity was widespread across the North Wambo Underground Mine area (Appendix 1) and was associated with the presence of exchangeable aluminium (Appendix 1). The low CEC values (see below) in the topsoil indicate a low buffering capacity. However, deep subsoil acidity was not a problem. The topsoil acidity problems can be overcome through the use of agricultural lime.

Soil Stability in Water – Dispersion and Slaking

Dispersion is the separation of soil micro-aggregates into sand, silt and clay particles, which tend to block soil pores and create problems with poor aeration (Levy 2000). Excessive hardness is a problem when the soil is dry. Dispersion is a process with the potential to reduce root growth and adversely affect profitability of most crop and pasture enterprises.

Dispersion may be associated with slaking, which is the collapse of soil aggregates to form micro-aggregates under moist conditions (So and Aylmore 1995). Slaking is associated with a lack of organic matter, which is important for the binding of soil micro-aggregates.

Soil prone to slaking, and particularly dispersion, is much more likely to be lost by water erosion than stable soil. This is because the soil tends to seal over under moist conditions and lose water as runoff, rather than taking in the water for storage in the subsoil (So and Aylmore 1995).

Pits 2, 3, 4, 5 and 7 have strongly dispersive subsoil. The other pits are less sodic, but are prone to dispersion because of low electrolyte concentrations. However, these dispersion problems can be overcome in a cost-effective manner through the use of gypsum application.

The main chemical factors influencing the behaviour of clay particles in sodic soils are exchangeable sodium and low electrolyte concentrations, but elevated exchangeable magnesium concentrations (calcium/magnesium ratios <1; see Appendix 1) also can make clay particles in soil less stable in water (Levy 2000). Exchangeable aluminium, however, is a trivalent cation that tends to minimise dispersion.

Compaction Status

Compaction can strongly restrict plant growth because of poor water entry, poor efficiency of water storage, waterlogging when moist, and poor access to nutrients by plant roots (McKenzie 1998).

Compaction was assessed in this study using the SOILpak scoring system (Appendix 1). Four of the sites had topsoil that was not compacted and tended to be associated with relatively high organic carbon contents (Appendix 1). The other four were in a compacted state because of dispersion.

Structure Self-repair Ability

The ability of a soil to overcome compaction through shrinking and swelling induced by wet-dry cycles (soil structural resilience) can be estimated via CEC values (McKenzie 1998). The topsoil had a poor shrink-swell capacity, so the rate of recovery from compaction damage would be slow. Only Pit 7 had a sufficiently high content of swelling clay minerals to have favourable structural resilience.

Salt Concentrations

Topsoil in the Modification area was non-saline. However, the subsoils at Pits 2 to 5 and Pit 7 were sufficiently saline to reduce the water uptake of most crop and pasture species.

Nutrients

The soil was deficient (from an agricultural perspective) in phosphorus in the North Wambo Underground Mine area. Sulfur and nitrogen deficiencies were present in the lighter-textured soil (Pits 1 and 8) (Appendix 1).

As the sum of exchangeable cations (an approximation of CEC) increases, the ability of soil to hold cation nutrients such as calcium, magnesium and potassium becomes greater (White 2006). CEC values (Appendix 1) show a poor ability for the subsoil to store cation nutrients at Pits 3 and 6.

Soil Carbon and Soil Biological Health

The favourable organic carbon concentrations in the topsoil (0 to 15 cm) (Appendix 1) mean that beneficial soil organisms have a ready supply of food.

Summary of Soil Constraints

A broad range of soil physical and chemical constraints for agricultural land use have been identified in the Modification area including:

- **Soil acidity and associated aluminium toxicity** is a major constraint to agricultural productivity. Acidic soil lacks versatility in terms of agricultural management as many plant species do not thrive with this chemical constraint to crop/pasture production. Agricultural lime can be used to overcome acidity, but the required mechanical incorporation of the lime would be difficult to achieve and would leave the soil prone to erosion losses.
- **A lack of waterholding capacity** where there is a large stone content in the soil and/or bedrock close to the soil surface and/or a sandy texture; poor subsoil structure limits root growth and creates a similar effect. This is not a major concern when irrigation water and/or frequent showers of rain are applied to soil, but prolonged dry spells will induce drought stress in plants when they are grown in shallow and/or stony and/or sandy soil (e.g. Pits 5 and 6).
- **Dispersive subsoil** due to sodicity, a lack of electrolyte and excessive exchangeable magnesium percentage. Dispersion induces waterlogging stress under moist conditions and excessive hardness when the soil is dry.
- **Subsoil salinity** in five of the eight pits. Some pasture species, particularly legumes, have a poor ability to extract water from the soil when soil salinity is elevated.
- **Nutrient deficiencies**, particularly phosphorus, limit the growth of plants even when other essential requirements such as water and adequate aeration are present in the soil.

5.0 STRATEGIC AGRICULTURAL LAND ASSESSMENT

Biophysical Strategic Agricultural Land

The SRLUP outlines the following definition for BSAL:

- *land that falls under soil fertility classes 'high' or 'moderately high' under the Draft Inherent General Fertility of NSW (OEH), and*
- *land capability classes I, II or III under the Land and Soil Capability Mapping of NSW (OEH), and*
- *reliable water of suitable quality, characterised by having rainfall of 350mm or more per annum (9 out of 10 years); or properties within 150m of a regulated river, or unregulated rivers where there are flows for at least 95% of the time (ie the 95th percentile flow of each month of the year is greater than zero) or 5th order and higher rivers; or groundwater aquifers (excluding miscellaneous alluvial aquifers, also known as small storage aquifers) which have a yield rate greater than 5L/s and total dissolved solids of less than 1,500mg/L.*

OR

- *land that falls under soil fertility classes 'moderate' under the Draft Inherent General Fertility of NSW (OEH), and*
- *land capability classes I or II under the Land and Soil Capability Mapping of NSW (OEH), and*
- *reliable water of suitable quality, characterised by having rainfall of 350mm or more per annum (9 out of 10 years); or properties within 150m of a regulated river, or unregulated rivers where there are flows for at least 95% of the time (ie the 95th percentile flow of each month of the year is greater than zero) or 5th order and higher rivers; or groundwater aquifers (excluding miscellaneous alluvial aquifers, also known as small storage aquifers) which have a yield rate greater than 5L/s and total dissolved solids of less than 1,500mg/L.*

It is noted that the SRLUP requires all components of the BSAL definition to be met for land to be considered BSAL. An assessment of the Modification area has been conducted against these criteria listed in the SRLUP (Table 4).

An assessment of the LSC of the Modification area has been conducted in accordance with the Land and Soil Capability Assessment Scheme (OEH 2012b) (Table 4). Section 4.3 of the Land and Soil Capability Assessment Scheme (OEH 2012b) states 'When an initial LSC [Land and Soil Capability] determination does not match known or indicative conditions of the landscape or soils, expert knowledge is used to record a modified LSC class that overrides the original assessment.' In accordance with Section 4.3 of the Land and Soil Capability Assessment Scheme (OEH 2012b), the following assumption regarding the assessment of salinity has been adopted for the Modification area:

- The presence of saline subsoil (ECe >5 dS/m) gives an LSC classification of Class 5 because it restricts the ability of landholders to grow sufficient biomass to protect the soil from soil degradation processes.

The Modification area is considered to have a LSC classification of Class 4 and 5 as all of the soil pits had serious soil limitations for plant growth (Table 4). As the LSC of the Modification area is not Class 1, 2 or 3, the Modification area cannot be classified as BSAL, even though Pit 2 may potentially have "moderately high" soil fertility, as defined in 'Draft Inherent General Fertility of NSW' (OEH 2012a) (Table 4), and Pits 5 and 7 may potentially have "moderate" soil fertility.

Given the above, it is considered that the Modification area does not meet the BSAL criteria outlined in the SRLUP.

Table 4. Summary of Biophysical Strategic Agricultural Land Assessment

Pit	Soil constraints relevant to LSC classification	Is it 'High' Fertility class[1]?	Is it 'Moderately High' Fertility class[1]?	Is it 'Moderate' Fertility class[1]?	Land & Soil Capability classification[2]	Is the land under consideration BSAL[3]?
1	Acidic topsoil (requires lime), low cation exchange capacity	No (Alluvial Soils – Light Textured)	No	No	Class 4; because of the following most limiting factor, 'surface pH $CaCl_2$ = 4.9, low buffering capacity'	**No**
2	Saline/sodic subsoil	No (Alluvial Soils – Medium Textured)	Potentially	–	Class 5; because of the following most limiting factor, Saline subsoil	**No**
3	Saline subsoil, sodic throughout	No (Grey Earth)	No	No	Class 5; because of the following most limiting factor, Saline subsoil	**No**
4	Acidic topsoil (requires lime), saline/sodic subsoil)	No (Solodic Soils)	No	No	Class 5; because of the following most limiting factor, Saline subsoil	**No**
5	Sodic throughout, saline subsoil	No (Brown Earth)	No	Potentially	Class 5; because of the following most limiting factor, Saline subsoil	**No**
6	Acidic topsoil; very low cation exchange capacity throughout	No (Alluvial Soils – Light Textured)	No	No	Class 4; because of the following most limiting factor, 'surface pH $CaCl_2$ = 4.8, low buffering capacity'	**No**
7	Sodic throughout, saline subsoil	No (Brown Earth)	No	Potentially	Class 5; because of the following most limiting factor, Saline subsoil	**No**
8	Acidic to 60 cm (requires lime), dispersive deep subsoil; poor cation exchange capacity	No (Alluvial Soils – Light Textured)	No	No	Class 4; because of the following most limiting factor, 'surface pH $CaCl_2$= 5.1, low buffering capacity'	**No**

[1] In accordance with Draft Inherent General Fertility of NSW (OEH 2012a).

[2] In accordance with Land and Soil Capability Assessment Scheme Second Approximation (OEH 2012b).

[3] In accordance with SRLUP (NSW Government 2012) - i.e. 'High' or "Moderately High' fertility class, Class 1, 2 or 3 according to the 'Land & Soil Capability' classification, or 'Moderate' fertility class, Class 1 or 2 according to the 'Land & Soil Capability' classification.

Critical Industry Clusters

The Modification area is located within a Viticulture Critical Industry Cluster (Figure 6). There is no evidence of vineyards in the Modification area.

The closest Equine Critical Industry Clusters is located approximately 12 km to the north-west of the Modification area (Figure 6).

It is considered that the Modification would not have any significant adverse impacts on the Critical Industry Clusters as there are no equine or viticulture-related activities in the vicinity of the Modification area.

6.0 PROJECT SITE AGRICULTURAL PRODUCTIVITY

Agricultural enterprises known to have been conducted on the Modification area include cattle grazing for beef production on rain-fed unimproved pastures.

The NSW Department of Primary Industries (DPI) Gross Margin Budget for 'North Coast Weaners – Unimproved Land' (DPI 2012) would provide the best estimate of productivity in the Modification area. The productivity of this agricultural enterprises is summarised in Table 5.

Table 5. Approximate productivity of the agricultural enterprises on the North Wambo Underground Mine Modification area

Enterprise	Stocking Rate (Dry Sheep Equivalents per hectare)	Gross Margin (Dollars per hectare per year)
Beef cattle grazing (weaners) on unimproved pastures or low productivity improved pastures; conducted on the majority agricultural areas on the Project site	**3**	**53.06**

Given the serious soil limitations for plant growth (Table 1) and the previous agricultural activities conducted (beef cattle production on rain-fed unimproved pasture), the Modification area is not considered to be highly productive agriculture land.

Potential impacts to agricultural productivity

Potential impacts to agricultural productivity as a result of the Modification would be generally associated with potential subsidence impacts. Potential impacts on agricultural activities would include:

- possible injury to persons undertaking agricultural activities;
- injury to livestock caused by ground cracking;
- loss of integrity of stock fences;
- loss of water storage of small farm dams through tilting or surface cracking; and
- minor and temporary disturbance associated with the installation of dewatering boreholes.

The existing North Wambo Underground Mine Subsidence Management Plan (WCPL 2006) (the SMP) includes the following in relation to potential impacts on agricultural activities:

> *To minimise the risks to stock and agistees, areas being subjected to subsidence with a depth of cover of less than 80 m will be excluded from agistment grazing, where practicable. This will minimise the exposure of cattle and stock owners to areas with the highest potential for surface cracking effects. In addition, prior to longwall mining, agistees will be informed that longwall mining associated with the North Wambo Underground Mine will be undertaken and that subsidence will occur … The areas subjected to the subsidence with depth of cover less than 80 m will be reviewed at the end of each longwall panel.*
>
> *Prior to mining, the condition of fencing will be inspected and where warranted, integrity improvements may be undertaken to improve resistance to potential subsidence effects. During mining, fences will be monitored and repaired where necessary. Monitoring of fences and other rural infrastructure will be undertaken. …*
>
> *In addition, inspections of surface cracking effects will be undertaken during mining, and where surface cracking presents a potential risk to stock or people, the cracks will be repaired.*

The SMP also includes details the repairs of subsidence cracking:

> *The occurrence of surface cracking that requires remediation is expected to be limited to areas of shallow surface cover and creeklines. Notwithstanding, some other areas may be identified during inspections that also require remediation.*
>
> *Remediation of surface cracks will generally be undertaken using conventional earthmoving equipment (such as a bulldozer or backhoe). Minor cracks that develop are not expected to require remediation as geomorphological processes will result in these cracks filling naturally over time.*
>
> *If surface crack remediation works are required in remnant vegetation areas, compact mobile equipment will be utilised, where practicable, to minimise damage to surrounding vegetation. Vegetation that requires clearance will be subject to the Vegetation Clearance Protocol, which is a component of the Flora and Fauna Management Plan ...*

It is anticipated that similar measures outlined in the SMP would be implemented for the Modification.

It is also noted that Frazier *et al. (*2010) found no significant effect of longwall mining subsidence on agricultural production, including cattle grazing, in the Hunter Valley region.

Given the above, and with the implementation of the management measures described above, it is considered that there would be no significant change to the long term productivity of the Modification area.

7.0 REFERENCES

Batey T (1988) *Soil Husbandry.* (Soil and Land Use Consultants: Aberdeen).

Bureau of Meteorology (2012) *Bureau of Meteorology Website*.

Department of Land and Water Conservation (2000) *Soil and Landscape Issues in Environmental Impact Assessment*, Technical Report No. 34, 2nd edition.

Department of Mineral Resources (1993) *Hunter Coalfield Regional Geology 1:100,000 Sheet, NSW.*

Department of Primary Industries (2012) *North Coast Weaners – Unimproved Land*. Website: http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0005/175523/16

Elliott GL, Reynolds KC (2007) Soil rehabilitation for extractive industries. In Charman PEV, Murphy BW (eds.) *Soils: Their Properties and Management, 3rd Edition*, pp. 406-412. (Oxford University Press).

Emery KA (1986) *Rural Land Capability Mapping.* (Soil Conservation Service of New South Wales, Sydney).

Field DJ, McKenzie DC, Koppi AJ (1997) Development of an improved Vertisol stability test for SOILpak. *Australian Journal of Soil Research* 35, 843–852.

Frazier P, Jenkins R, Trotter T (2010) *Monitoring the effect of longwall mine subsidence on native vegetation and agricultural environments.* Ecological Australia, ACARP Project C15013.

Gallant JC, McKenzie NJ, McBratney AB (2008) Scale. In: *Guidelines for surveying soil and land resources: Second edition* (eds. NJ McKenzie, MJ Grundy, R Webster, AJ Ringrose-Voase); Chapter 3, pp. 27-43. (CSIRO Publishing, Collingwood).

Hazelton P, Murphy B (2007) *Interpreting Soil Test Results: What do all the numbers mean?* (CSIRO Publishing, Collingwood).

Hulme T, Grosskopf T, Hindle J (2002) *Agricultural Land Classification*; Agfact AC. 25. (NSW Agriculture, Orange).

Isbell, R (2002) *The Australian Soil Classification, Revised Edition.* (CSIRO, Melbourne).

Klingbiel AA, Montgomery PH (1961) *Land Capability Classification*; US Department of Agriculture Handbook 210. (Government Printer, Washington DC).

Kovac M, Lawrie JW (1991) Soil Landscapes of the Singleton 1:250 000 Sheet. (Soil Conservation Service of NSW, Sydney).

Levy GJ (2000) Sodicity. In: Sumner ME (ed.) *Handbook of Soil Science*; pp. G27-G63. (CRC Press: Boca Raton).

McKenzie DC (ed.) (1998) *SOILpak for Cotton Growers, 3rd Edition.* (NSW Agriculture, Orange).

McKenzie N, Jacquier D, Isbell R, Brown K (2004) *Australian Soils and Landscapes: An Illustrated Compendium.* (CSIRO Publishing, Collingwood).

McKenzie DC (2001). Rapid assessment of soil compaction damage. I. The SOILpak score, a semi-quantitative measure of soil structural form. *Australian Journal of Soil Research* 39, 117–125.

McKenzie DC, Rasic J, Hulme PJ (2008) Intensive survey for agricultural management. In: *Guidelines for surveying soil and land resources: Second edition* (eds. NJ McKenzie, MJ Grundy, R Webster, AJ Ringrose-Voase); Chapter 29, pp. 469-490. (CSIRO Publishing, Collingwood).

National Committee on Soil and Terrain (2009) *Australian Soil and Land Survey Field Handbook: Third Edition.* (CSIRO Publishing, Collingwood).

NSW Agriculture (1983) *Agricultural Land Classification for Part of the Singleton Shire between Bulga and Jerrys Plains, NSW.*

NSW Government (2012) *Upper Hunter Strategic Regional Land Use Plan*.

Office of Environment and Heritage (2012a) *Draft Inherent Fertility of NSW*.

Office of Environment and Heritage (2012b) *The Land and Soil Capability Assessment Scheme Second Approximation – A general rural land evaluation system for New South Wales*.

Rayment GE, Lyons DJ (2011) *Soil Chemical Methods – Australasia.* (CSIRO Publishing, Collingwood).

Slavich PG, Petterson GH (1993) Estimating the electrical conductivity of saturated paste extracts from 1:5 soil:water suspensions and texture. *Australian Journal of Soil Research* 31, 73-81.

So HB, Aylmore LAG (1995) The effects of sodicity on soil physical behaviour. In Naidu R, Sumner ME, Rengasamy P (eds.) *Australian Sodic Soils; Distribution, Properties and Management*, pp. 71-79. (CSIRO Publications, East Melbourne).

Soil Conservation Service of NSW (1985) *1:100,000 Land Capability Mapping, New South Wales*. Department of Sustainable Natural Resources.

Sonter RO, Lawrie JW (2007) Soils and Rural Land Capability. In Charman PEV, Murphy BW (eds.) *Soils: Their Properties and Management*, *3rd Edition*, pp. 287-296. (Oxford University Press).

Wambo Coal Pty Ltd (2006) *North Wambo Underground Mine Subsidence Management Plan*.

Ward S (1998) *Mine Rehabilitation Handbook, Second Edition*. (Mineral Council of Australia).

White RE (2006) *Principles and Practice of Soil Science,* Fourth Edition. (Blackwell Publishing, Oxford).

APPENDIX 1

FIELD OBSERVATIONS AND LABORATORY DATA

North Wambo soil pit #	Landuse / vegetation type	Landscape features	Easting, m WGS84	Northing, m WGS84	Australian Soil Classification	Great Soil Group (modified by Charman 1978)	Total Available Water (TAW), mm/m	Other comments
1	Vigorous pasture	Elevated creek terrace near hill & creek	311370	6392191	Stratic Rudosol	Alluvial Soils - Light Textured	121	
2	Moderately vigorous pasture	Creek flats	311532	6392027	Stratic Rudosol	Alluvial Soils - Medium Textured	139	
3	Moderately vigorous pasture	Flat area - above creek influence	310995	6392031	Grey Kandosol	Grey Earth	97	
4	Moderately vigorous pasture	Gentle upper slope	311277	6391613	Brown Sodosol	Solodic Soils	84	
5	Sparse pasture	Near crest of low hill	310456	6391282	Brown Kandosol	Brown Earth	51	
6	Moderately vigorous pasture	Elevated creek terrace	310733	6391010	Brown-Orthic Tenosol	Alluvial Soils - Light Textured	72	
7	Sparse pasture	Footslope	310036	6390988	Brown Kandosol	Brown Earth	99	Sl. cracking throughout
8	Vigorous pasture	Alluvial terrace above creek	310404	6390642	Black-Orthic Tenosol	Alluvial Soils - Light Textured	80	

North Wambo soil pit #	Horizon	Lower depth cm	Texture	pH water	Moist soil colour (Munsell)	Colour	Mottles	SOILpak compaction score	Gravel fragments, %	Dispersion 10 minutes	Moisture	Lime %	Lime Type	Root score
1	A11	20	Sandy loam	5.5	7.5YR3/2	Dark brown	–	1.7	–	0	S/M	–	–	3
	A12	80	Sandy loam	6.0	7.5YR3/3	Dark brown	–	1.8	–	2	S/M	–	–	3
	2A	140+	–	–	–	–	–	1.5	15		S	–	–	2
2	A1	20	Fine sandy clay loam	5.5	7.5YR2.5/2	Very dark brown	–	1.7	–	0	S/M	–	–	3
	2A	40	Silty loam	5.5	7.5YR3/2	Dark brown	–	1.3	–	0	S	–	–	3
	3B	65	Light clay	7.0	10YR3/2	Very dark greyish brown	–	1.4	–	2	M	–	–	1
	4B	100	Light medium clay	8.0	10YR4/3	Brown	–	1.7	–	2	M	–	–	1
	5B	140+	Light clay	8.0	7.5YR4/4	Brown	–	1.1	–	0	M	–	–	0
3	A1	10	Silty clay loam	5.5	7.5YR3/2	Dark brown	–	0.5	–	0	W	–	–	1
	B1	65	Light clay	6.0	7.5YR4/2	Brown	–	0.7	–	1	M	–	–	2
	B21	100	Medium heavy clay	6.0	7.5YR5/2	Brown	–	1.2	–	0	M	–	–	1
	B22	140+	Medium clay	5.0	10YR7/4	Very pale brown	orange	0.9	–	0	M	–	–	0
4	A1	12	Silty clay loam	5.0	7.5YR3/3	Dark brown	–	1.2	–	0	M	–	–	3
	A2	20	Silty loam	5.5	7.5YR4/4	Brown	–	1.1	–	2	M	–	–	3
	B21	35	Heavy clay	6.0	5YR4/6	Yellowish red	grey	0.9	–	2	M	–	–	2
	B22	73	Heavy clay	7.0	10YR5/8	Yellowish brown	–	0.7	–	0	M	–	–	1
		140+							98 (sandstone)					0
5	A1	15	Silty light clay	6.0	7.5YR4/2	Brown	–	0.7	–	2	S/M	–	–	2
	B2	50	Medium clay	5.5	7.5YR5/4	Brown	–	0.9	–	0	S/M	–	–	1
	BC	140+							Decomp. siltstone					0
6	A1	20	Sandy loam	5.5	7.5YR3/3	Dark brown	–	1.5	–	0	M	–	–	3
	2A	80	Clayey sand	5.5	7.5YR4/4	Brown	–	1.7	–	2	M	–	–	3
	3A	110	Loamy sand	6.5	10YR5/4	Yellowish brown	–	1.4	–	1	M	–	–	2
	4A	140+	Sand	6.0	7.5YR4/4	Brown	–	1.5	–	0	M	–	–	1
7	A1	10	Light clay	5.5	7.5YR4/3	Brown	–	1.2	–	3	S/M	–	–	2
	B21	50	Light medium clay	7.0	7.5YR4/3	Brown	–	0.5	–	0	S/M	–	–	2
	B22	105	Light medium clay	7.5	5YR4/4	Reddish brown	–	1.0	–	0	S/M	–	–	1
	B23	140+	Light medium clay	9.0	7.5YR3/2	Dark brown	–	1.3	–	0	S/M	3	N/P	0
8	A1	15	Fine sandy clay loam	5.5	7.5YR3/2	Dark brown	–	1.7	–	0	S/M	–	–	2
	2A	95	Clayey sand	5.5	7.5YR2.5/2	Very dark brown	–	1.9	–	0	M	–	–	3
	3A	140+	Sandy loam	6.0	7.5YR3/3	Dark brown	–	1.6	–	0	M	–	–	2

North Wambo soil pit #	Horizon	Lower depth cm	PEDALITY Grade	Type	Size, mm	FABRIC	CONSISTENCE	SOILpak compaction score
1	A11	20	M	PO	6	E	2	1.7
	A12	80	M	PO	5	E	1	1.8
	2A	140+						
2	A1	20	M	PO	7	E	2	1.7
	2A	40	M	Pl	12	E	3	1.3
	3B	65	M	PO	10	RP	3	1.4
	4B	100	M	PO	7	RP	2	1.7
	5B	140+	M	LE	12	RP	0	1.1
3	A1	10	W	LE	15	E	4	0.5
	B1	65	M	LE	10	RP	6	0.7
	B21	100	M	PO	7	RP	3	1.2
	B22	140+	M	LE	12	RP	4	0.9
4	A1	12	M	PL	7	E	2	1.2
	A2	20	M	PL	9	E	3	1.1
	B21	35	W	B	12	RP	4	0.9
	B22	73	W	B	20	RP	4	0.7
		140+						
5	A1	15	W	Bl	10	E	4	0.7
	B2	50	M	PO	12	RP	4	0.9
	BC	140+						
6	A1	20	W	PO	6	E	2	1.5
	2A	80	W	PO	5	E	1	1.7
	3A	110	W	PO	8	E	1	1.4
	4A	140+	apedal					1.5
7	A1	10	M	LE	10	RP	3	1.2
	B21	50	S	LE	25	RP	6	0.5
	B22	105	S	LE	12	RP	4	1.0
	B23	140+	S	PO	8	RP	4	1.3
8	A1	15	M	SB	5	E	2	1.7
	2A	95	S	SB	5	E	1	1.9
	3A	140+	M	PO	7	E	2	1.6

North Wambo	Depth,	pH	pH	EC 1:5	ECe	Chloride	Exchangeable cations, meq/100g									ASWAT	NO3-N	Colwell P	SO4-S	DTPA-Cu	DTPA-Zn	Boron	Org C
soil pit #	cm	(water)	(CaCl2)	dS/m	dS/m	mg/kg	Ca	Mg	K	Na	Al	CEC	ESP	ESI	Ca/Mg	score	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	%
1	15	6.1	4.9	0.03	0.41	10	4.0	1.0	0.6	0.0	0.1	5.7	0.2	0.17	4.0	5	2	8	3	0.46	1.90	0.28	1.00
1	30	6.8	5.6	0.02	0.28	10	6.5	1.1	0.4	0.0	0.0	8.0	0.1	0.16	5.9	6	1	5	2	0.45	0.27	0.30	1.00
1	60	7.3	6.1	0.02	0.28	10	8.0	1.0	0.2	0.1	0.0	9.2	0.5	0.04	8.1	11	1	5	2	0.47	0.20	0.30	0.80
1	90	7.7	6.6	0.02	0.28	10	7.5	1.0	0.1	0.1	0.0	8.7	0.7	0.03	7.6	11	1	7	2	0.33	0.14	0.28	0.74
1	120	9.0	8.3	0.06	0.83	10	3.4	0.9	0.1	0.0	0.0	4.4	0.7	0.09	3.7	6	1	6	5	0.12	0.06	0.19	0.29
1	200	8.1	6.8	0.02	0.28	15	1.6	1.5	0.1	0.1	0.0	3.3	3.0	0.01	1.1	13	1	7	3	0.24	0.02	0.23	0.15
1	300	8.5	7.0	0.03	0.41	25	1.1	2.9	0.1	0.4	0.1	4.6	8.9	0.00	0.4	15	1	6	4	0.10	0.02	0.27	0.15
2	15	6.2	5.0	0.03	0.26	10	5.5	2.1	0.3	0.1	0.1	8.1	1.4	0.02	2.6	6	1	7	2	0.81	2.30	0.38	1.60
2	30	6.7	5.3	0.02	0.19	10	5.5	2.6	0.2	0.2	0.1	8.5	2.0	0.01	2.1	7	1	5	1	0.74	0.47	0.38	1.10
2	60	7.8	6.2	0.10	0.86	56	3.9	7.8	0.2	2.6	0.1	14.6	17.8	0.01	0.5	11	1	5	3	1.00	0.23	0.97	1.00
2	90	8.9	7.9	0.28	2.41	250	2.3	8.1	0.2	6.1	0.0	16.7	36.5	0.01	0.3	15	1	5	13	0.55	0.07	2.30	0.33
2	120	9.4	8.4	0.76	6.54	860	1.5	7.2	0.3	9.6	0.0	18.6	51.6	0.01	0.2	12	1	5	45	0.27	0.05	2.00	0.19
2	200	9.5	8.5	0.68	5.84	800	1.2	6.2	0.4	7.4	0.0	15.2	48.7	0.01	0.2	11	1	5	29	0.26	0.05	0.48	0.15
2	300	9.6	8.5	0.48	4.13	570	1.0	6.0	0.4	5.7	0.0	13.1	43.5	0.01	0.2	12	1	8	24	0.30	0.10	0.62	0.15
3	15	6.3	5.2	0.09	1.24	43	4.6	5.9	0.7	1.1	0.1	12.4	8.9	0.01	0.8	11	1	5	4	0.30	0.93	0.42	1.70
3	30	7.3	6.5	0.24	2.06	190	7.5	11.0	0.6	3.1	0.0	22.2	14.0	0.02	0.7	14	1	5	3	0.25	0.21	0.85	1.10
3	60	8.0	7.5	0.73	6.28	820	4.8	9.1	0.3	6.1	0.0	20.3	30.1	0.02	0.5	11	1	5	18	0.13	0.11	0.59	0.37
3	90	8.1	7.7	1.13	8.48	1500	3.7	9.1	0.2	8.3	0.0	21.3	39.0	0.03	0.4	10	1	5	30	0.16	0.12	0.47	0.23
3	120	5.9	5.4	1.10	8.25	1400	2.3	8.0	0.2	7.8	0.1	18.4	42.4	0.03	0.3	13	1	5	35	0.18	0.29	0.11	0.15
4	10	6.1	4.9	0.04	0.55	10	2.1	1.5	0.7	0.1	0.1	4.5	3.1	0.01	1.4	1	2	5	2	0.27	0.72	0.24	0.96
4	20	6.2	4.8	0.03	0.29	15	1.9	1.1	0.4	0.2	0.1	3.7	6.5	0.00	1.7	10	1	5	1	0.09	0.20	0.19	0.64
4	30	6.3	5.4	0.12	0.70	56	10.0	6.1	0.4	1.8	0.1	18.4	9.8	0.01	1.6	15	1	5	5	0.37	0.14	0.57	0.82
4	60	7.3	6.8	0.34	1.97	280	12.0	7.6	0.2	3.6	0.0	23.4	15.4	0.02	1.6	11	1	5	15	0.21	0.09	1.20	0.59
4	90	8.2	7.8	0.58	3.36	510	10.0	6.6	0.2	4.1	0.0	20.9	19.6	0.03	1.5	0	1	5	24	0.12	0.11	0.89	0.19
5	15	6.3	5.0	0.09	0.77	25	5.0	8.1	0.7	1.0	0.1	14.9	6.7	0.01	0.6	12	1	5	6	1.00	1.20	0.48	1.90
5	30	6.3	5.1	0.15	1.13	67	5.0	12.0	0.7	2.0	0.1	19.8	10.1	0.01	0.4	14	1	5	9	0.91	0.33	0.47	1.10
5	60	6.6	5.8	0.50	3.75	390	5.0	15.0	0.6	4.8	0.0	25.4	18.9	0.03	0.3	11	1	5	66	1.10	0.12	0.67	0.51
5	90	8.8	8.3	1.27	9.53	1100	13.0	16.0	0.7	7.4	0.1	37.2	19.9	0.06	0.8	0	1	5	260	0.43	0.13	1.20	0.26
6	15	6.1	4.8	0.04	0.55	10	3.0	0.7	0.8	0.0	0.1	4.6	0.7	0.06	4.4	3	7	5	2	0.45	1.80	0.33	1.10
6	30	6.7	5.5	0.03	0.68	10	2.1	0.5	0.6	0.0	0.0	3.2	0.3	0.10	4.2	6	5	5	1	0.25	0.17	0.25	0.38
6	60	7.4	6.3	0.02	0.46	10	1.3	0.4	0.4	0.0	0.0	2.1	0.5	0.04	3.0	12	1	5	1	0.16	0.08	0.17	0.15
6	90	7.8	6.6	0.02	0.46	10	1.7	0.5	0.5	0.0	0.0	2.7	1.1	0.02	3.4	14	1	5	1	0.20	0.08	0.22	0.16
6	120	7.7	6.7	0.03	0.68	10	1.6	0.8	0.2	0.1	0.0	2.7	2.6	0.01	2.0	12	1	7	4	0.32	0.12	0.16	0.15
6	200	8.7	8.2	0.45	10.22	430	4.5	7.2	0.3	4.4	0.0	16.4	26.8	0.02	0.6	11	1	5	17	0.29	0.13	1.20	0.15
6	300	8.4	7.6	0.21	4.77	220	3.7	6.1	0.3	2.9	0.0	13.0	22.4	0.01	0.6	13	1	5	6	0.31	0.14	0.48	0.15
7	15	6.7	5.5	0.11	0.95	37	4.8	9.9	1.3	1.6	0.0	17.6	9.1	0.01	0.5	13	1	5	5	0.69	0.34	0.57	0.89
7	30	7.1	6.0	0.16	1.38	57	5.5	12.0	1.0	2.3	0.0	20.8	11.1	0.01	0.5	15	1	5	5	0.73	0.15	0.68	0.69
7	60	8.8	7.9	0.50	4.30	490	4.2	12.0	0.4	6.1	0.0	22.7	26.9	0.02	0.4	13	1	5	29	0.28	0.04	1.40	0.34
7	90	9.0	8.3	0.84	7.22	930	4.5	12.0	0.4	8.3	0.0	25.2	32.9	0.03	0.4	2	1	5	63	0.30	0.12	1.40	0.22
7	120	9.0	8.5	1.21	10.41	1400	9.0	12.0	0.5	9.1	0.1	30.7	29.6	0.04	0.8	0	1	5	90	0.36	0.11	1.00	0.18
8	15	6.5	5.1	0.03	0.29	10	5.0	1.2	0.9	0.0	0.1	7.2	0.1	4.17	0.2	5	1	5	2	0.43	1.30	0.44	1.40
8	30	6.4	5.0	0.02	0.45	10	5.5	1.0	0.8	0.0	0.1	7.4	0.4	5.56	0.0	6	1	5	2	0.42	0.94	0.41	1.20
8	60	6.6	5.0	0.01	0.23	10	4.7	1.1	0.3	0.0	0.1	6.3	0.6	4.27	0.0	12	1	5	1	0.44	0.35	0.35	1.10
8	90	6.9	5.5	0.01	0.23	10	5.5	1.3	0.2	0.1	0.0	7.0	0.9	4.23	0.0	12	1	5	2	0.37	0.19	0.35	0.76
8	120	7.3	6.1	0.03	0.41	10	8.0	2.2	0.2	0.1	0.0	10.5	1.2	3.64	0.0	12	1	5	6	0.49	0.33	0.52	0.99
8	200	7.8	6.7	0.06	0.83	56	1.4	1.3	0.2	0.3	0.0	3.2	8.7	1.08	0.0	11	1	5	3	0.11	0.07	0.38	0.15
8	300	9.3	8.0	0.14	1.93	57	2.4	5.0	0.5	1.9	0.0	9.8	19.4	0.48	0.0	12	1	5	8	0.08	0.02	1.50	0.15