September 2016

Site Verification Report: Wambo Coal Mine; Singleton, NSW

Prepared for Wambo Coal Pty Limited

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DISCLAIMER

This report has been prepared in accordance with the brief provided by Wambo Coal Pty Limited via Resource Strategies Pty Ltd. It has relied upon information collected under the weather conditions and time schedule specified herein. All information contained within the report is based only on the aforementioned circumstances. The report is for the use of Wambo Coal Pty Limited only and Soil Management Designs will take no responsibility for its use by other parties.

INFORMATION SOURCES AND REFERENCING

This report was derived from an extensive range of information sources including literature review and discussions with colleagues and landholders. The author has sought to ensure that sources for his use of text, diagrams, maps and images are provided in the report. If the author inadvertently has failed to adequately acknowledge a source of material used, he would appreciate prompt notification so that the matter can be corrected in the electronic version of the document and a full acknowledgement provided.

Contents

List of Figures

List of Tables

List of Soil Maps

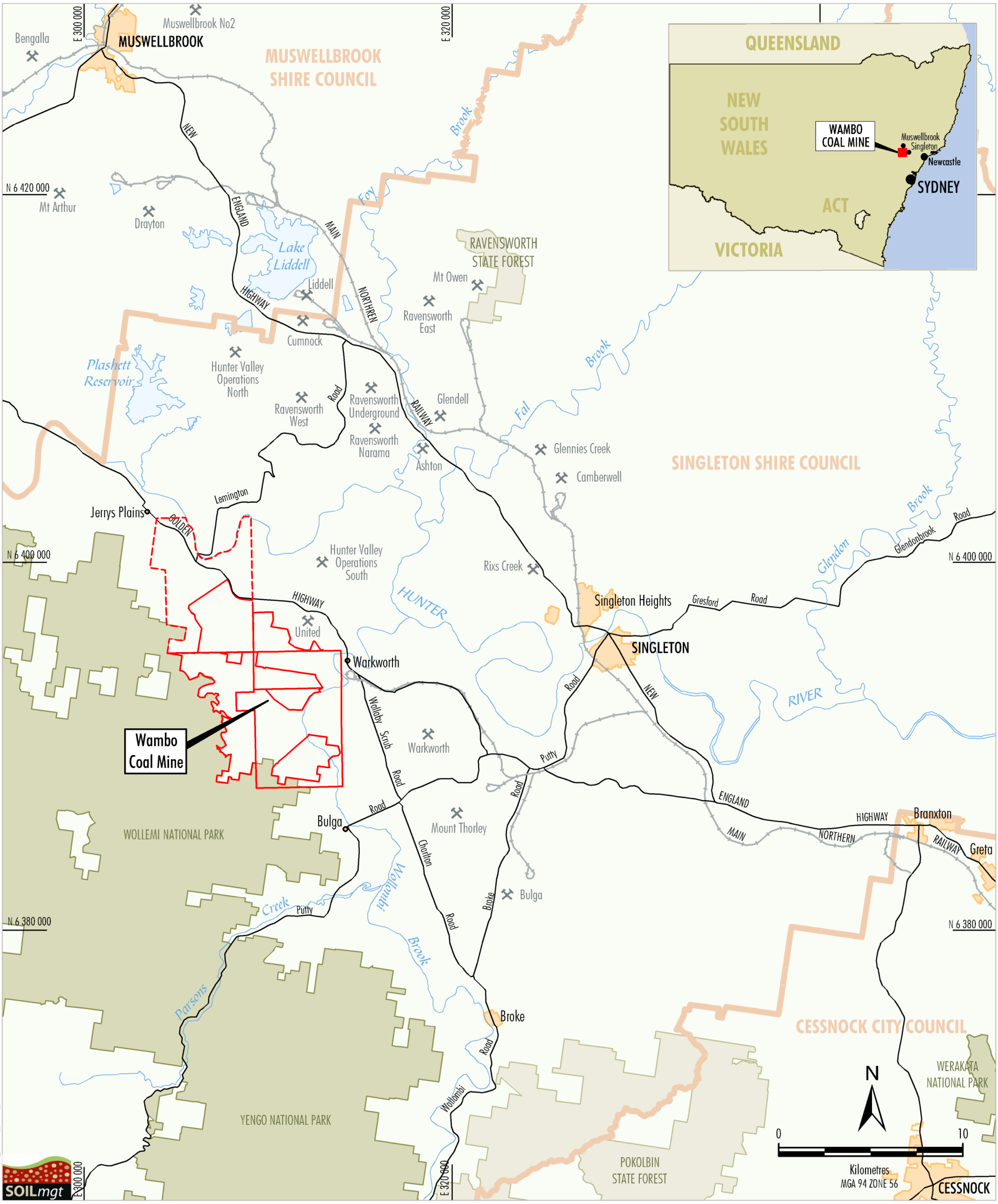
List of Attachments

1 INTRODUCTION

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 Limited (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 the Development Consent (DA 305-7-2003) commenced in 2004 and currently both open cut and underground operations are conducted. The maximum approved run-of-mine coal production rate is 14.7 million tonnes per annum and product coal is transported from Wambo by rail.

WCPL is seeking a Site Verification Certificate (SVC) for part of Authorisation 444, where future underground mining development may be proposed (herein referred to as the SVC Application Area) (Figures 2 and 3). This Site Verification Report has been prepared in accordance with the *Interim Protocol for Site Verification and Mapping of Biophysical Strategic Agricultural Land* (NSW Government 2013) (Interim Protocol) to accompany the SVC application.



LEGEND
- Mining and Coal Lease Boundary
- Exploration Licence Boundary
- Local Government Boundary
- Mining Operation

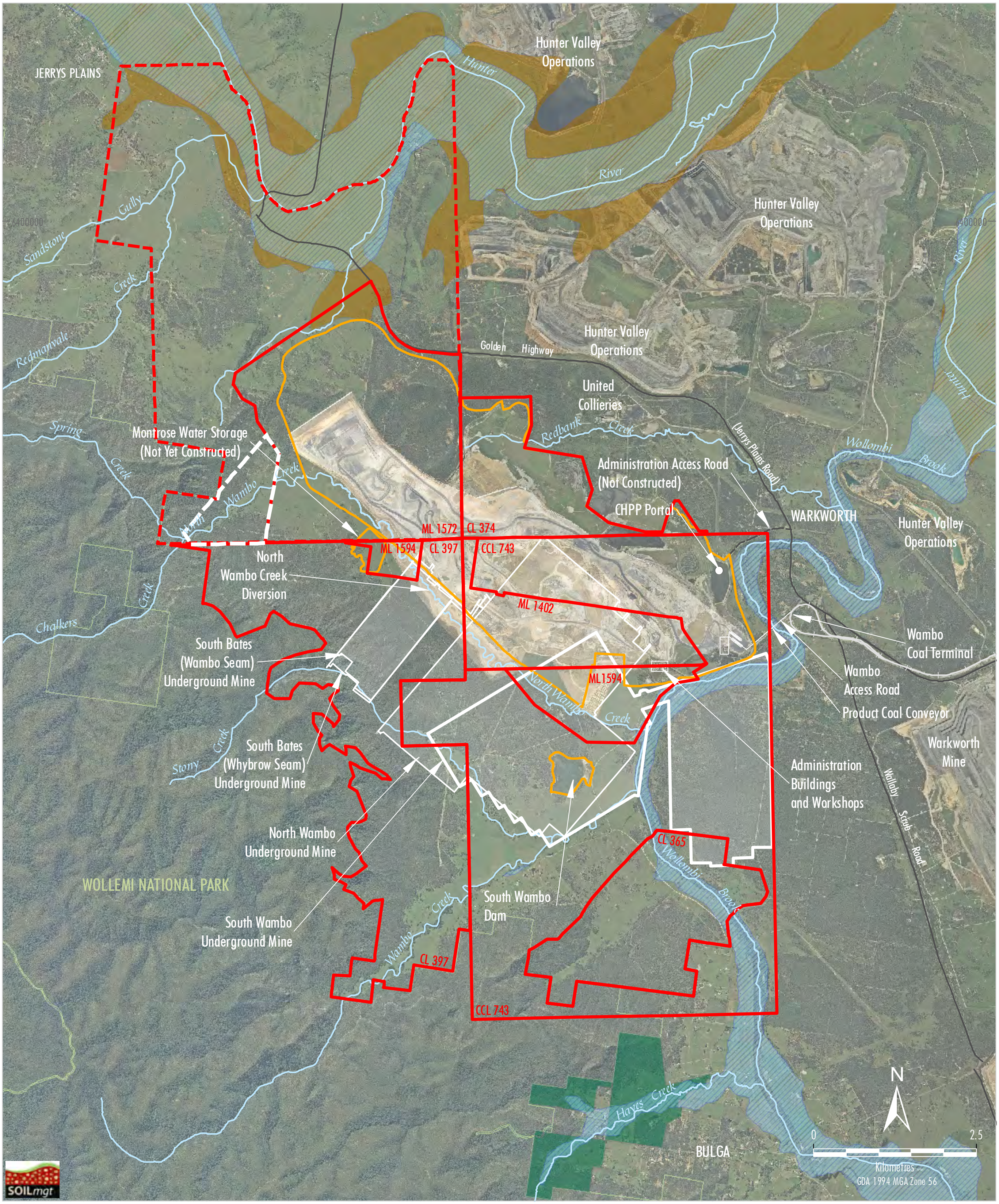
Source: Geoscience Australia (2009)

Peabody ENERGY

WAMBO COAL MINE

Regional Location

Figure 1



LEGEND
- Mining and Coal Lease Boundary
- Exploration Licence Boundary
- Existing/Approved Surface Development Area
- Approved Underground Development
- Site Verification Certificate Application Area
- Highly Productive Groundwater
- Biophysical SAL
- Viticulture Critical Industry Cluster SAL

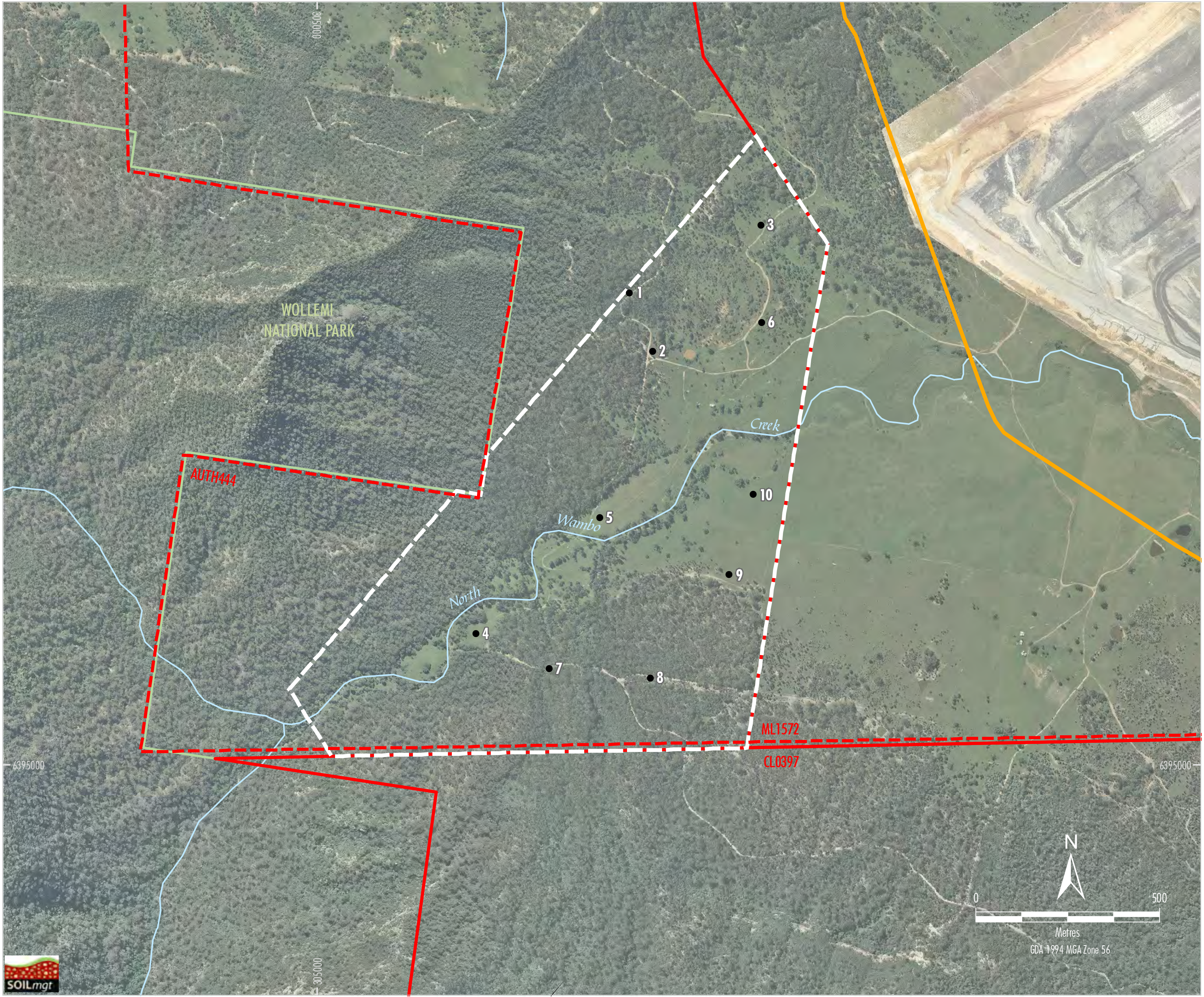
Peabody ENERGY

WAMBO COAL MINE

Strategic Agricultural Land in the Vicinity of Wambo

Source: NSW DP&I (January 2014); Department of Lands (July 2009); WCPL (2016); WCPL Orthophoto (Apr-Oct 2013)

Figure 2



LEGEND
- Mining and Coal Lease Boundary
- Exploration Licence Boundary
- Existing/Approved Surface Development Area
- Site Verification Certificate Application Area
- Soil Test Pit

Source: Department of Lands (July 2009); WCPL (2016); WCPL Orthophoto (Apr-Oct 2013)

Peabody ENERGY

WAMBO COAL MINE

Site Verification Certificate Application Area

Figure 3

WAM-09-15_SBEM_SVCR_201A

2 SITE VERIFICATION CERTIFICATE APPLICATION AREA DESCRIPTION

Wambo is located in the Upper Hunter Valley region of NSW. Local topography in the Upper Hunter Valley region is characterised by gently sloping floodplains associated with the Hunter River and the undulating foothills, ridges and escarpments of the Mount Royal Range and Great Dividing Range.

The main topographic features at Wambo are the alluvial flats and terraces associated with Wollombi Brook, North Wambo Creek and Wambo Creek and its tributary Stony Creek. North Wambo Creek flows across the SVC Application Area from the south-west to north-east (Figure 2).

Elevations in this area range from approximately 60 metres (m) Australian Height Datum (AHD) near Wollombi Brook to approximately 220 m AHD near the base of the Wollemi Escarpment. To the west of Wambo is steeper land with elevations up to approximately 650 m AHD within the Wollemi National Park (Figure 1). Elevations in the SVC Application Area range from 115 m AHD adjacent to the downstream end of North Wambo Creek and 180 m AHD in the south.

Land use in the vicinity of the SVC Application Area is characterised by a combination of coal mining operations, Remnant Woodland Enhancement Program areas, remnant vegetation, agricultural activities and WCPL-owned lands that are not subject to mining operations, utilised for the agistment of beef cattle. The main agricultural land uses in the Wambo region include dairy and beef cattle and pasture production, horse breeding, viticulture and wine making (NSW Government 2012). In the SVC Application Area, land use includes low intensity agricultural activities (beef cattle) and areas of remnant vegetation.

The Wambo area experiences a temperate climate. The long term average annual rainfall at the nearby meteorological stations of Jerrys Plains Post Office and Bulga are 644.5 millimetres (mm) and 665.0 mm, respectively.

The *State Environmental Planning Policy (Mining, Petroleum Production and Extractive Industries) 2007* (Mining SEPP) includes mapping of lands identified as Biophysical Strategic Agricultural Land (BSAL). The closest mapped BSAL in the Mining SEPP is associated with the Hunter River and is located approximately 2 km to the north of the SVC Application Area (Figure 2).

The SVC Application Area is approximately 130 hectares (ha).

3 SOIL RESOURCES

3.1 Review of Existing Information

The following existing information was reviewed as part of this assessment:

- Soil Profile Attribute Data Environment (SPADE) soil profiles (part of the NSW Natural Resource Atlas);
- Hunter Coalfield Regional 1:100,000 Geology Map (Glen and Beckett 1993);
- Soil type and landscape mapping (Kovac and Lawrie, 1991);
- Regional BSAL mapping;
- Critical Industry Cluster mapping.

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

Geology/Parent Materials for Soil Formation

The Hunter Coalfield Regional 1:100,000 Geology Map shows the rock types that are the parent material for soil formation in the vicinity of the SVC Application Area (Figure 4).

The presence of siltstone and tuffaceous claystone in the 'Newcastle Coal Measures' and 'Wittingham Coal Measures' units indicates that there may be pockets of soil within the SVC Application Area with soil conditions significantly better than those derived from conglomerate and sandstone.

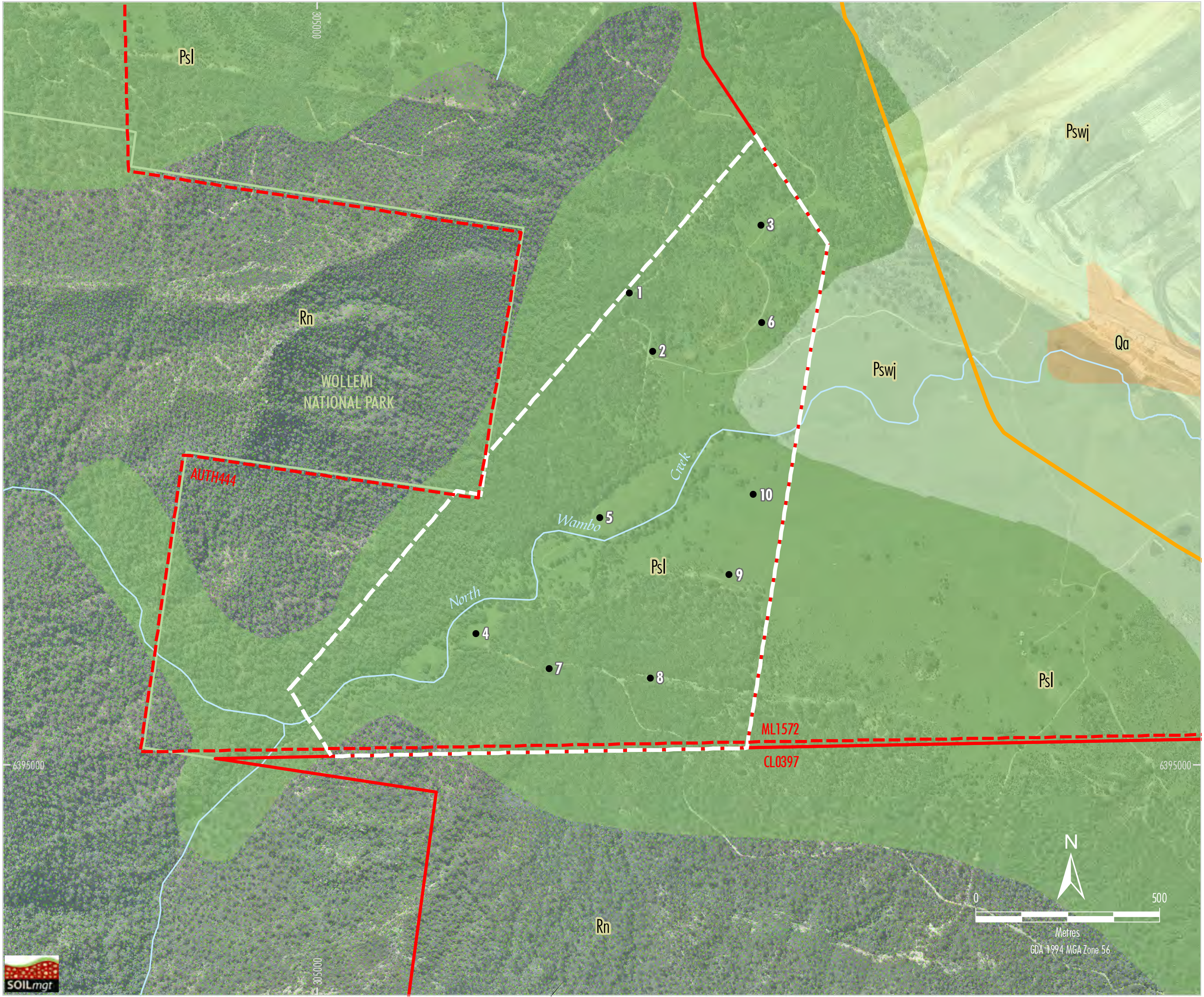
eSPADE Soil Profile Database

A search of the NSW Government's 'eSPADE' website (part of the NSW Natural Resource Atlas) was conducted to identify any existing soil profile information in the SVC Application Area. No eSPADE soil profiles could be found in the SVC Application Area.

Soil Types and Landscapes

Figure 5 shows the location of soil landscape units as mapped and described by Kovac and Lawrie (1991) in the vicinity of the SVC Application Area.

Two soil landscape units are mapped in the SVC Application Area and are described in Table 1. The descriptions of these units indicate the presence of soil conditions that generally are poor for plant growth (Table 1).



LEGEND
Mining and Coal Lease Boundary
Exploration Licence Boundary
Existing/Approved Surface Development Area
Site Verification Certificate Application Area
Soil Test Pit

Quaternary
Qa Silt, Sand, Gravel

Triassic
Rn Widden Brook Conglomerate - Conglomerate and Sandstone

Late Permian
Psl Newcastle Coal Measures - Coal Seams, Claystone (tuffaceous) Siltstone, Sandstone, Conglomerate
Pswj Wittingham Coal Measures - Coal Seams, Claystone, Tuff, Siltstone, Sandstone, Conglomerate

Source: Department of Lands (July 2009); WCPL (2016); Glen and Beckett (1993); WCPL Orthophoto (Apr-Oct 2013)

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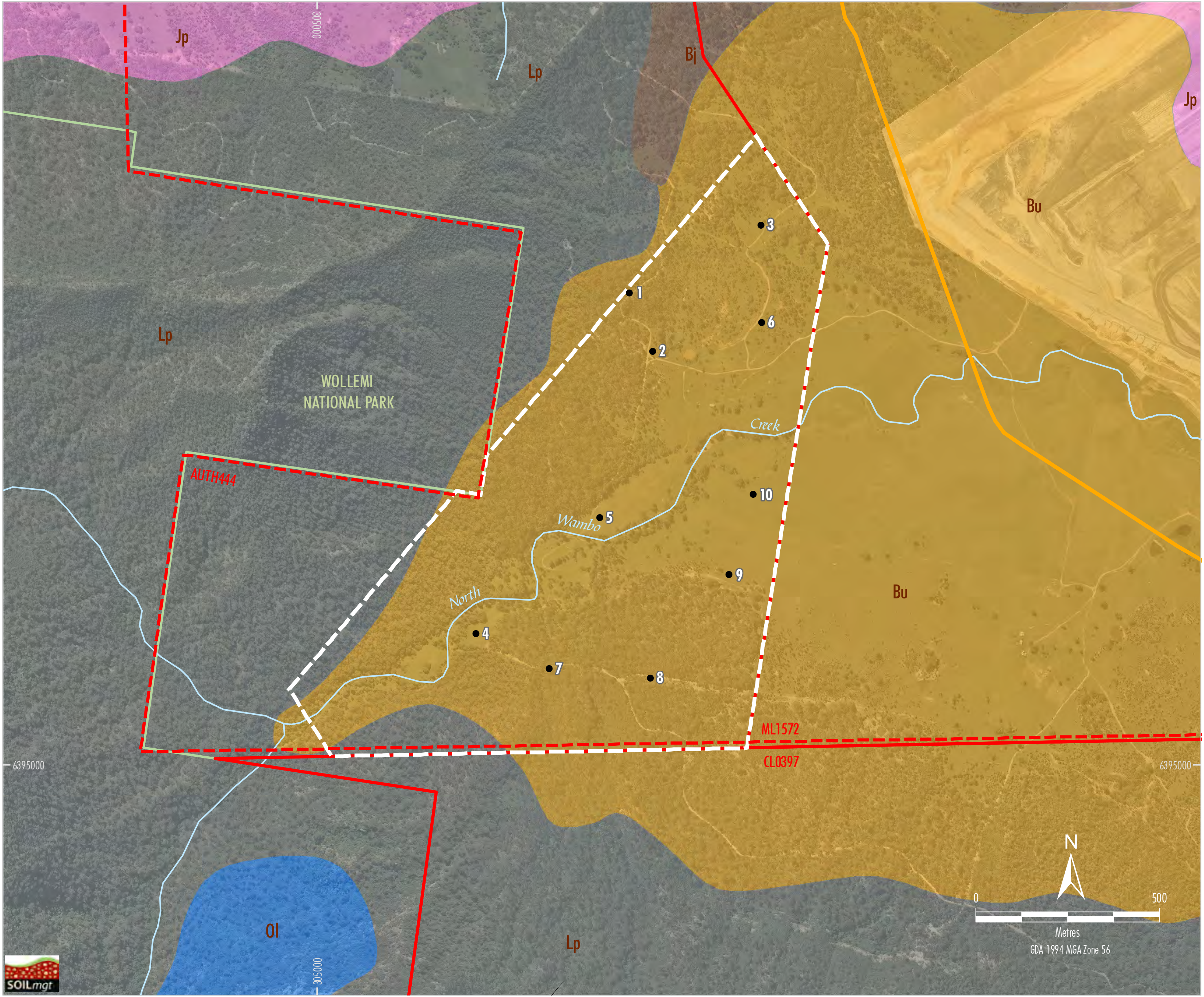
WAMBO COAL MINE

Regional Geology Mapping

Figure 4

WAM-09-15_SBEM_SVCR_203C



LEGEND
- Mining and Coal Lease Boundary
- Exploration Licence Boundary
- Existing/Approved Surface Development Area
- Site Verification Certificate Application Area
- Soil Test Pit

Soil Landscapes

Bj	Benjang Solodic
Bu	Bulga Soloths
Jp	Jerrys Plains Soloths
Lp	Lees Pinch Shallow
Ol	Ogilvie Shallow

Source: Department of Lands (July 2009); WCPL (2016); Kovac & Lawrie (1991); WCPL Orthophoto (Apr-Oct 2013)

Peabody ENERGY

WAMBO COAL MINE

Regional Soil Landscape Mapping

Figure 5

WAM-09-15_SBEM_SVCR_204B

Table 1. Soil Landscape Units (Kovac and Lawrie 1991) Mapped in the SVC Application 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.
Lees Pinch Shallow Soils (**Lp**)	Shallow Silicious Sands, some Yellow and Brown Earths on footslopes. Yellow and Grey Soloths in breaks of slope. Yellow Podzolic Soils and Earthy Sands on some upper slopes.	Very poor water holding capacity, acidity and a lack of nutrients. Prone to water erosion when bare.

3.2 Soil Survey Methodology

WCPL commissioned Soil Management Designs to conduct an assessment of the SVC Application Area. A soil survey was conducted by Soil Management Designs under moist conditions on 1 and 2 August 2016.

The main aim of this study has been to identify any BSAL within the SVC Application Area (Figure 2). BSAL verification within the SVC Application Area has been conducted in accordance with the Interim Protocol (as discussed in Section 4). However, the following soil information is regarded by Ward (1998) as being important for soil assessment associated with mine site reclamation, and has been incorporated into the methodology for this assessment:

- 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 soil 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 hard-setting and prone to surface sealing.
- Mottling; its presence may indicate reducing conditions and poor soil aeration.
- 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 water holding capacities.
- Material with a gravel and sand content greater than 60% is unsuitable.
- Saline material is unsuitable.

Because the NSW Government now requires proponents of new mining and coal seam gas projects in NSW to consider the potential impacts of projects on agricultural resources up-front in the project assessment process, existing soil profiles have to be described in a way that allows the productivity of crops, pasture and trees to be predicted accurately, as well as assisting with prediction of impacts of mining on agriculture, and provision of information about soil materials that will assist with any mine rehabilitation activities that are required. Therefore, in addition to following the BSAL identification process described in the Interim Protocol, the soil survey methodology for intensive agricultural developments described by McKenzie *et al.* (2008) and McKenzie (2013) also has been taken into account when planning the SVC Application soil survey. The combination of techniques from this variety of sources, and its compatibility with requirements of the Interim Protocol, is described in the following sections.

Relevant field observations and laboratory data for all observation sites were submitted to the Office of Environment & Heritage (OEH) via its eDIRT application on 27 September 2016.

Soil Survey

The soil survey of the SVC Application Area involved a survey of 10 detailed soil pit profiles dug with a backhoe (approximately 1.4 m deep; shallower where hard rock was encountered).

A Garmin '*GPSmap 62S*' instrument with an accuracy of about ±4 m was used to record the pit coordinates (Attachment A). Soil pit locations are shown on Figure 3.

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 according to the Australian Soil Classification (ASC) (Isbell 2002).

The soil survey was carried out by Dr David McKenzie. He has Certified Professional Soil Scientist Stage 3 accreditation (http://www.cpss.com.au/) from Soil Science Australia and a PhD in soil science. Dr McKenzie also has 'Chartered Scientist' accreditation with British Society of Soil Science.

Soil Pit Locations

Surface contour and slope information (Maps 1a and 1b) interpreted from detailed LiDAR data obtained by WCPL was used to define BSAL exclusion zones in the SVC Application Area. Approximately 59 ha of the SVC Application Area had a slope greater than 10% and therefore cannot be BSAL in accordance with the Interim Protocol. The remaining 71 ha of the SVC Application Area had a slope less than or equal to 10% and required further investigation.

Seven detailed sites were located in areas with slope less than or equal to 10% inside the SVC Application Area. The soil pits were located in a way that covered as many of the major variations in elevation and landforms as possible at a density of approximately 1 pit per 10 ha within the SVC Application Area. This provided an intensity of sampling (1:25 000) that satisfies the Interim Protocol nominated sampling density of 1 site per 25 to 400 ha for less intensive developments (e.g. underground mining) as well as the nominated sampling density of 1 site per 5 to 25 ha for intensive mining developments (e.g. open cut mining).

Three detailed sites were inspected in the steep slope 'exclusion zone' (i.e. slope greater than 10%) of the SVC Application Area to provide an understanding of soil conditions in those areas.

Field Soil Observations/Testing

The 1.4 m deep pit profiles were dug with an excavator and trimmed with a geological pick to allow high resolution 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) and mottle characteristics;
- 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).

Site factors noted included current land use, landform, slope (measured with a SUUNTO clinometer), aspect, and surface rock. The occurrence of outcropping bedrock was negligible[1] and no gilgai features were observed in the SVC Application Area.

Field observations for each pit are presented in Attachments A, B and C.

The soil structure information (Attachment C) 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 (Attachment A) has been estimated using texture, structural form and coarse fragment content data (McKenzie *et al*. 2008).

The depth range 15 – 60 cm at Site 7 had a very gravelly A3 horizon (15 – 50 cm) with a coarse fragment content of 95%. As a result, insufficient soil was present in the 15 – 30 cm and 30 – 60 cm zones of the soil profile for sample collection. However, in the 60 – 100 cm zone there was a clay-rich B horizon with fewer coarse fragments where it was possible to collect soil samples.

[1] No rock outcropping was observed at the Sites 1 to 10.

Laboratory Soil Testing

All of the soil pits were sampled for laboratory analysis. The sampling intervals for laboratory analysis were as per the Interim Protocol, i.e. 0 to 5 centimetres (cm); 5 to 15 cm; 15 to 30 cm; 30 to 60 cm; and 60 to 100 cm. Where important horizon boundaries did not coincide with these depth intervals, extra samples were taken to ensure that distinctive horizons (e.g. A2 horizons) were kept separate for analysis.

The soil 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 (Attachment D). 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; exchangeable sodium data are presented as exchangeable sodium percentage (ESP). 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). These methods are compatible with the key components of the Interim Protocol.

Soil dispersibility, as measured by the Aggregate Stability in Water (ASWAT) test (Field *et al.* 1997), was assessed by Soil Management Designs in Orange, NSW. The results are presented in Attachment D. 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 (McKenzie 2013) (Figure 6). The conversion factors of Slavich and Petterson (1993) allowed the electrical conductivity of saturated paste extracts (ECe) to be calculated from the EC of 1:5 soil:water suspensions ($EC_{1:5}$) and texture.

Table 2. The Relationship Between the Emerson Aggregate Stability Test and the ASWAT Test

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

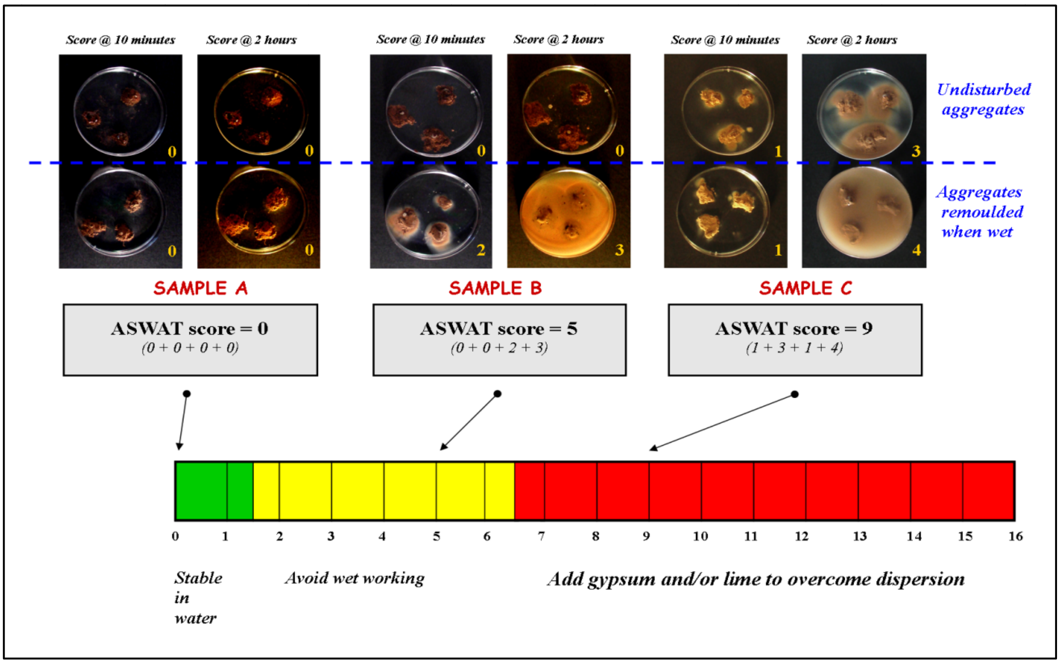


Figure 6. The Link between ASWAT Results and Soil Management Options

The following key soil factors are attached in the form of colour coded maps:

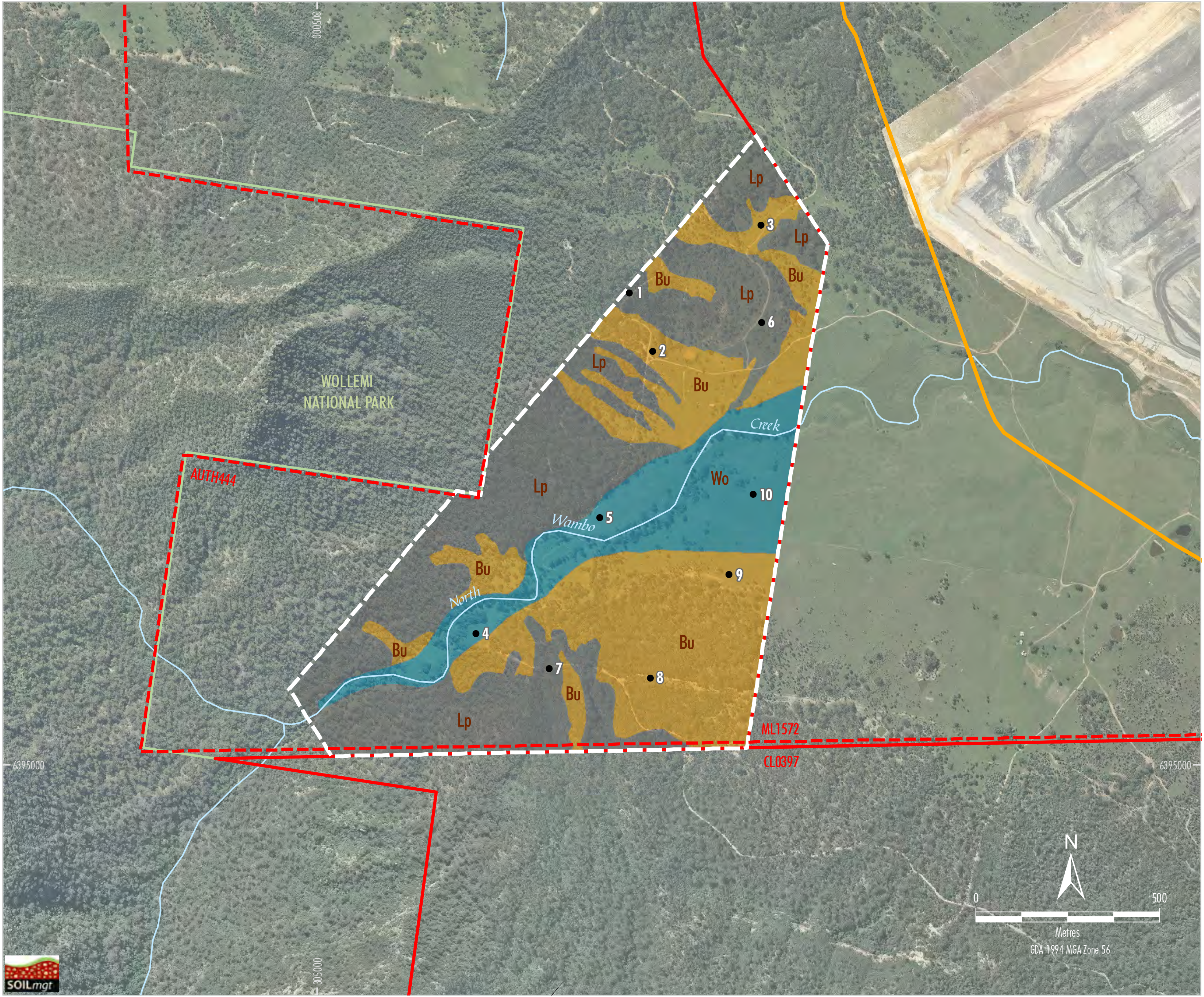
Map 1a. Surface Contours.
Map 1b. Slope Categories.
Map 2. Soil Types (Australian Soil Classification).
Map 3. Depth to Rock.
Map 4. Plant Available Water (TAW).
Map 5. Depth to Mottled Layer.
Map 6. Depth to Layer with Lime.
Map 7a. Dispersion (ASWAT score).
Map 7b. Dispersion (ESP Value).
Map 7c. Dispersion (ESI Value).
Map 8. Compaction Severity (SOILpak Score).
Map 9. Cation Exchange Capacity (CEC).
Map 10. Salinity (Electrical Conductivity [ECe]).
Map 11. pH ($CaCl_2$).
Map 12. Phosphorus (Colwell P).
Map 13. Organic Carbon (%).

3.3 Soil Types and Mapping

Soil Landscape Units

Soil Landscape Units identified in the SVC Application Area that host the soil types described in the next section are described in Table 3 and presented in Figure 7. Soil Landscape Units are associations of soils described and delineated by means of landforms (Dent and Young 1981). Names of the Soil Landscape Units are consistent with the terminology of Kovac and Lawrie (1991).

At least three detailed sites were undertaken for all of the soil landscape units recorded in the SVC Application Area.



LEGEND

- Mining and Coal Lease Boundary
- Exploration Licence Boundary
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Soil Landscape Units

Bu	Bulga Soloths
Lp	Lees Pinch Shallow
Wo	Wollombi Alluvial

Source: Department of Lands (July 2009); WCPL (2016); WCPL Orthophoto (Apr-Oct 2013)

Peabody ENERGY

W A M B O   C O A L   M I N E

Soil Landscape Units

Figure 7

WAM-09-15_SBEM_SVCR_206B

Table 3. Soil Types Associated with the Soil Landscape Units

Soil Landscape Unit	Number of Detailed Sites	Map Code	Dominant or Co-dominant Soil Types[1]	Additional Comments
Wollombi Alluvial Soil (**Wo**)	3	Wo	Stratic Rudosol	Deep young soil with favourable physical subsoil conditions for root growth; derived from alluvium associated with North Wambo Creek.
Bulga Soloths (**Bu**)	4	Bu	Sodosol, Tenosol	Poor root growth in subsoil due to sodicity.
Lees Pinch Shallow Soils (**Lp**)	3	Lp	Sodosol, Chromosol, Kandosol	Mostly shallow/stony soil with restricted water holding capacity in areas with slope >10%.

1 Section 9.6.2 of the Interim Protocol contemplates more than one soil type occurring in a single soil landscape unit.

ASC Soil Types

The ASC (Isbell 2002) has been used to determine soil types at each of the ten observation sites (Map 2). Photographs of representative soil profiles identified during the survey are presented in Figure 8 (for each Soil Landscape Unit and ASC soil type described below). All of the sites have three photographs to record the following: a) Landscape view, b) Trimmed soil profile, and c) Close-up view of soil surface and associated vegetation where required. The Landscape view and Trimmed soil profile photographs for all sites are shown in Attachment E.

Total numbers of the contrasting ASC soil types, and the equivalent Great Soil Group (Stace et al. 1968) terminologies, are shown in Table 4.

Table 4. Soil Types Identified; Classified According to the ASC and Great Soil Groups

ASC Soil Type	Number of Detailed Sites	Great Soil Group Equivalent
Sodosol	4	Solodic Soils
Rudosol	3	Alluvial Soils
Chromosol[1]	1	Red-Brown Earths, Non-calcic brown soils
Kandosol[1]	1	Calcareous Red Earths
Tenosol	1	Lithosols

1 Located in areas where slope is greater than 10%.

The soil types in Table 4 have the following characteristics:

- Sodosols have strong texture contrast between topsoil and subsoil, and the B horizon is sodic (ESP of 6 or greater).
- Rudosols are derived from recently deposited materials that have only minimal profile development.
- Chromosols have strong texture contrast (Isbell 2002) between the A and B horizons, and a non-sodic subsoil with pH_{water} greater than 5.5.
- Kandosols lack strong textural contrast and have a massive or only weakly structured B horizon.
- Tenosols at this location are shallow and have only weak pedological development.

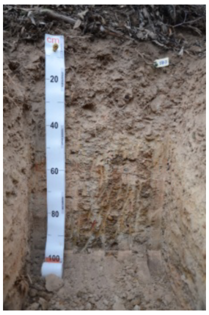
Soil Landscape Unit	Dominant or Co-dominant Soil Types	Landscape View
Wollombi Alluvial Soil	Pit 10: Stratic Rudosol 	Site 10 
Bulga Soloths	Pit 9: Sodosol  Pit 8: Tenosol 	Site 9  Site 8 
Lees Pinch Shallow Soils	Pit 7: Sodosol  Pit 1: Chromosol  Pit 6: Kandosol 	Site 7  Site 1  Site 6 

Figure 8. Photographs of Representative Soil Types for each Soil Landscape Unit

3.4 Soil Conditions for Plant Growth

Soil Depth, Texture and Waterholding Capacity

The impact across the SVC Application Area of profile shallowness/stoniness and sandiness on the ability of the soil to store plant available water (measured as TAW) is shown on Maps 3 and 4. As soil becomes shallower, stonier and/or sandier, its ability to store water declines (White 2006).

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. Within the SVC Application Area, the lack of water holding capacity in shallow/stony soils is a significant constraint to agricultural productivity.

The deeper alluvial soil present in the Wollombi Alluvial Soil landscape unit tended to have very good water holding capacity because of a combination of minimal coarse fragments and favourable soil structure.

Waterlogging Hazard

Much of the sodic subsoil in non-alluvial sections of the SVC Application Area showed signs of waterlogging. 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.

An indicator of waterlogging in the field is the presence of mottling (Map 5). Mottles are blotches of sub-dominant colours different from the matrix colour; for example, grey or yellow blotches within a reddish-brown subsoil. The impedance of internal drainage that creates mottling is usually caused either by impermeable rock close to the surface or dispersive subsoil. Mottling sometimes is associated with the presence of black manganiferous nodules or concretions.

Slow deep drainage is associated with accumulation of naturally occurring lime. Depth to lime is shown in Map 6.

Soil Stability in Water – Dispersion and Slaking

Poor soil structure in the SVC Application Area was associated with instability in water caused by dispersion. 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 then becomes 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).

Three maps relating to soil stability in water are presented (Maps 7a, 7b and 7c). The ASWAT score (Map 7a) shows how prone the soil is to dispersion under conditions that existed when the soil was sampled (Field *et al*. 1997). The 'working when wet' procedure that is part of the ASWAT test is a simulation of processes such as raindrop impact on wet soil and the cutting/stockpiling of moist soil. Dispersion was evident in the sub-surface (15-30 cm) and subsoil (30-60 cm) across most of the SVC Application Area. The near-surface dispersion problems can be overcome in a cost-effective manner through gypsum application, or by use of gypsum-lime blends where soil pH is acidic or neutral.

An important chemical factor influencing the behaviour of clay particles in unstable soils is moderate amounts of ESP (Map 7b), aggravated by low electrolyte concentrations (Levy 2000). Map 7c (electrochemical stability index [ESI]; EC÷ESP) highlights sites affected by this process.

Compaction Status

Compaction was assessed using the SOILpak scoring system (Map 8). Most of the alluvial soil (Stratic Rudosols) in the SVC Application Area had a favourable soil structural form (i.e. high SOILpak score) (i.e. pits 4, 5 and 10). However, most of the non-alluvial soil had subsoil compaction problems, caused apparently by the natural dispersion problems.

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).

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 (Map 9) (McKenzie 1998). Much of the non-alluvial soil in the SVC Application Area had a moderately favourable capacity for self-repair capacity via shrink-swell processes (i.e. pits 1, 2, 3, 6, 7, 8 and 9), but the benefits are short-lived when the soil develops poor structural form because of dispersion in water.

Salt Concentrations

Subsoil salinity (Map 10) was an important constraint to plant growth in Sodosols associated with the 'Bulga' soil landscape unit in the SVC Application Area (i.e. pits 2, 3 and 9).

pH Imbalance

Most sites in the SVC Application Area had favourable near-neutral pH (Map 11), but pits 2 and 8 had near-surface acidity that is likely to respond well to the application of agricultural lime.

Nutrients

The topsoil and subsoil in the SVC Application Area was strongly deficient (from an agricultural point of view) in phosphorus (Map 12). Application of P-fertiliser is likely to produce significant improvements in pasture productivity. Nutritional data in Appendix 5 indicates a lack of sulphur and a widespread lack of nitrogen.

Soil Carbon and Soil Biological Health

The relatively high organic carbon concentrations in much of the topsoil (0-15 cm) in the SVC Application Area (Map 13) provide beneficial soil organisms with a ready supply of food. However, the organic carbon content of deeper layers was mostly poor.

Summary of Soil Limitations

The following soil limitations were identified across the non-alluvial sections of the SVC Application Area:

- poor waterholding capacity in shallow/stony soils;
- waterlogging in subsoil;
- dispersive subsoil;
- compaction in subsoil;
- salt concentrations in some areas;
- near-surface acidity at two sites;
- nutrient deficiency in topsoil and subsoil; and
- poor organic content in deeper layers of soil.

The alluvial soil in the SVC Application Area had much better physical conditions for plant growth (higher water holding capacity, minimal waterlogging, soft when dry) than the non-alluvial areas, but there was a lack of essential nutrients including sulphur, phosphorus and nitrogen.

4 BIOPHYSICAL STRATEGIC AGRICULTURAL LAND ASSESSMENT

The Interim Protocol was used to assess the presence/absence of BSAL within the SVC Application Area. A flow chart showing the Interim Protocol BSAL assessment criteria (Steps 1 to 12) is provided in Figure 9.

An assessment of each observation site within the SVC Application Area has been conducted against the BSAL assessment criteria. The limiting factors in the BSAL verification process are highlighted via a colour-coded matrix in Table 5.

The following description outlines how particular factors in the BSAL flow chart were interpreted for this study:

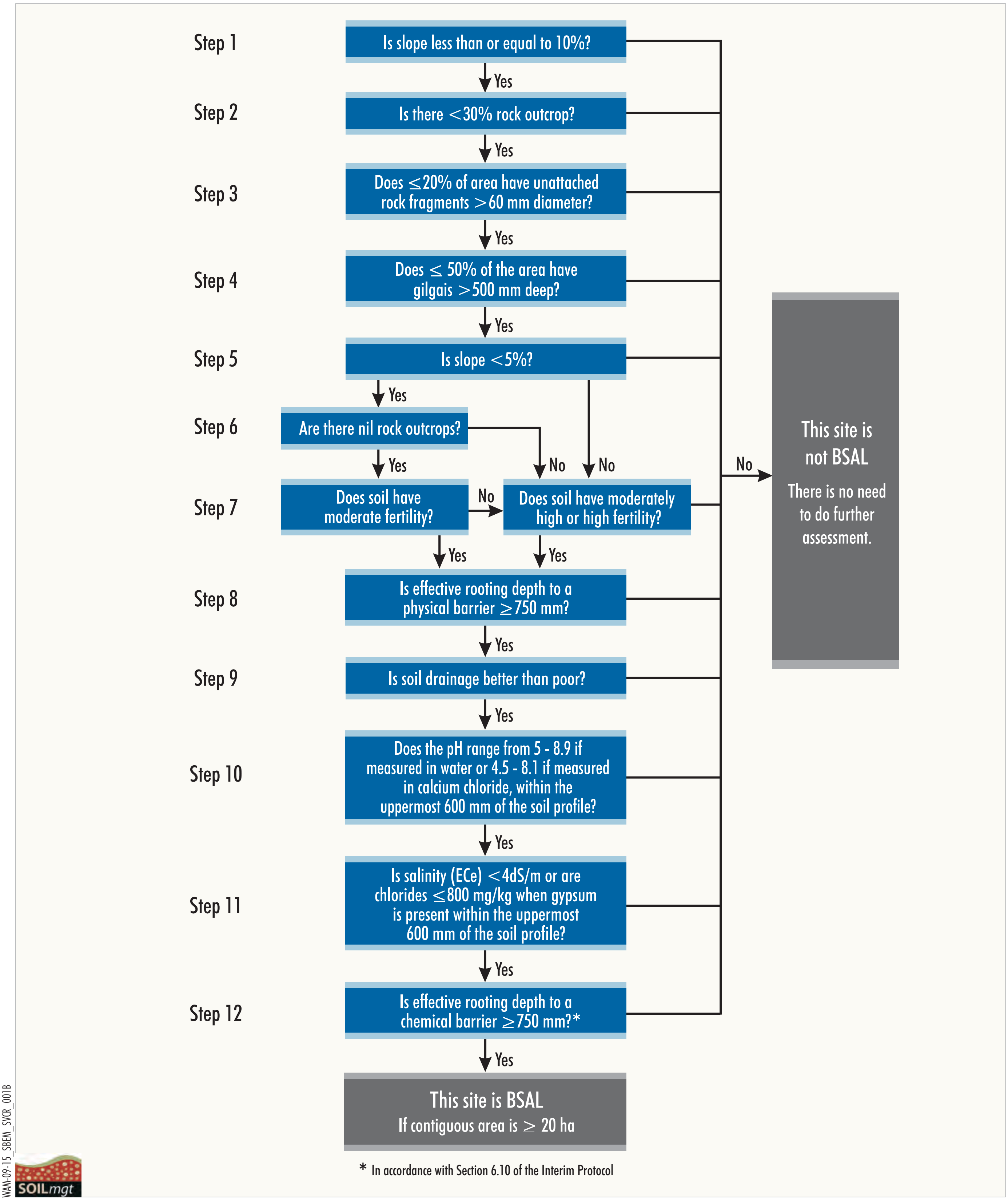
- "Physical barrier" (Step 8) – defined as 'hard rock' or a layer with >90% coarse fragments.
- "Soil drainage better than poor" (Step 9) – poor drainage for the purpose of this report is determined by visual assessment of waterlogging indicators, i.e. the presence of mottling (>10%) and/or black manganiferous nodules or concretions (>20%) within the depth interval 0-750 mm.
- pH (Step 10) – Soil pH is measured most accurately by using the pH (1:5 $CaCl_2$) technique rather than pH (1:5 water). Therefore, BSAL assessment is based exclusively on examination of pH (1:5 $CaCl_2$) data.
- "Chemical barrier" (Step 12) – defined as ESP>6.

Figure 10 shows the BSAL exclusion zones within the SVC Application Area where slope is greater than 10%.

None of the SVC Application Area with slope gentler than 10% has soil pit inspection sites that have BSAL status. The limiting factors include rock close to the soil surface, poor soil drainage (as assessed by waterlogging indicators), sodicity and acidity (Table 5).

The alluvial area does not have these limitations. However, their ASC soil description 'Stratic Rudosol' is associated with 'moderately low' soil fertility ranking (NSW Government 2013), so they are classified as non-BSAL. The low concentrations of essential nutrients for pasture production (phosphorus, sulphur, nitrogen) (see Attachment D), and low CEC values, associated with the sandy texture at these 'Wollombi Alluvial Soil' sites are consistent with their non-BSAL status.

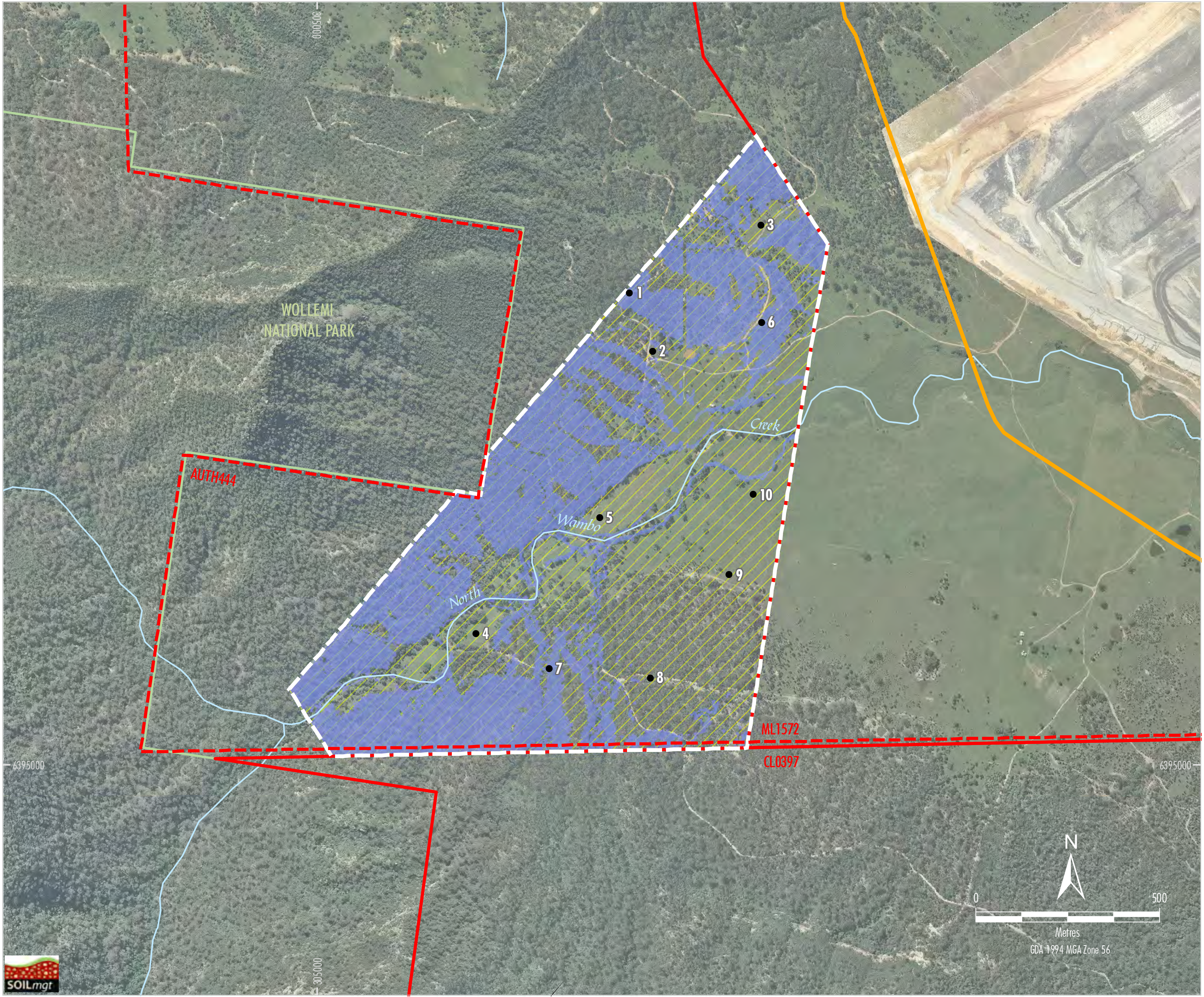
It is concluded therefore that the land within the SVC Application Area is not BSAL. This finding agrees with the NSW Government's regional BSAL mapping.



Source: After NSW Government (2013)

WAMBO COAL MINE
Flow Chart for Site Verification of BSAL

Figure 9



LEGEND

- Mining and Coal Lease Boundary
- Exploration Licence Boundary
- Existing/Approved Surface Development Area
- Site Verification Certificate Application Area
- Soil Test Pit
- BSAL Exclusion Zone where Slope > 10%
- Verified Non-BSAL

Source: Department of Lands (July 2009); WCPL (2016); WCPL Orthophoto (Apr-Oct 2013)

Peabody ENERGY

W A M B O C O A L M I N E

BSAL Exclusion Zone where Slope > 10%

Figure 10

WAM-09-15_SBEM_SVCR_205C

Table 5 BSAL Assessment Matrix for SVC Application Area

Map ID	Physical Barrier	Waterlogging			Chemical Barrier												Field Slope (%)	Suborder	Order	Fertility Status	BSAL
	Depth to >90% Rock (cm)	Depth to >10% Mottles (cm)	Depth to >20% Mn (cm)	Depth to Waterlogged Layer (cm)	pH CaCl2				ESP				Salinity (ECe, deciSiemens/metre)								
					0-5 cm	5-15 cm	15-30 cm	30-60 cm	0-5 cm	5-15 cm	15-30 cm	30-60 cm	0-5 cm	5-15 cm	15-30 cm	30-60 cm					
1	55	40	>140	40	5.0	5.1	5.7	6.5	2.1	2.6	3.0	3.8	0.7	0.6	0.5	0.6	15	Red	Chromosol	mod high	NO
2	>140	>140	>140	>140	4.5	4.2	5.0	6.4	2.5	5.6	14.2	22.6	0.2	0.3	0.8	2.7	7	Red	Sodosol	mod. low	NO
3	120	80	>140	80	5.0	5.2	5.6	8.3	2.5	1.5	4.5	13.2	0.5	0.4	0.3	3.6	8	Yellow	Sodosol	mod. low	NO
4	>140	>140	>140	>140	6.0	5.9	6.1	6.4	0.9	0.5	0.4	0.6	1.6	0.9	0.7	0.7	4	Stratic	Rudosol	mod. low	NO
5	>140	>140	>140	>140	5.3	5.5	5.6	6.0	0.2	0.2	0.8	0.3	0.7	0.7	0.5	0.2	2	Stratic	Rudosol	mod. low	NO
6	90	45	>140	45	5.3	5.3	5.3	6.2	0.8	1.0	1.9	9.7	0.6	0.4	0.3	0.6	12	Red	Kandosol	moderate	NO
7[1]	15	>140	>140	>140	5.8	4.8			2.0	4.2			2.7	0.9			14	Red	Sodosol	mod. low	NO
8	90	>140	>140	>140	4.5	4.2	4.6	4.7	1.0	2.7	5.0	9.2	0.2	0.2	0.2	0.9	6	Brown-Orthic	Tenosol	mod. low	NO
9	>140	32	>140	32	4.5	4.7	5.5	6.1	1.4	6.1	17.3	30.2	0.3	0.3	1.0	2.4	4	Brown	Sodosol	mod. low	NO
10	>140	>140	>140	>140	5.1	4.9	5.5	5.8	0.5	0.4	0.5	1.0	0.7	0.4	0.2	0.2	1	Stratic	Rudosol	mod. low	NO

[1] At pit 7, there was insufficient soil present in the 15 – 30 cm and 30 – 60 cm zones of the soil profile for sample collection.

Colour Codes:

Physical Barrier		Waterlogging		pH		ESP		Salinity		Field Slope		ASC: Fertility Status		Pit BSAL Status	
	<75 cm		<75 cm		<4.5, >8.1		>6		>4		<5%		Low/Moderately Low		Yes
No shading	>75 cm	No shading	>75 cm	No shading	4.5 > 8.1	No shading	<6	No shading	<4		5-10%		Moderate		No
											>10%		Moderately High/High		

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