WAMBO COAL PTY LIMITED

SOUTH BATES EXTENSION MODIFICATION

ENVIRONMENTAL ASSESSMENT

APPENDIX H

Agricultural Impact Statement

WAMBO COAL PTY LIMITED

SOUTH BATES EXTENSION MODIFICATION

AGRICULTURAL IMPACT STATEMENT

(Modification 17 to DA 305-7-2003)

PROJECT NO.	WAM-09-15
DOCUMENT NO.	00827288
DATE:	FEBRUARY 2017

TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

LIST OF FIGURES

LIST OF ATTACHMENTS

1 INTRODUCTION

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 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 (Figures 1 and 2).

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 (ROM) coal production rate is 14.7 million tonnes per annum and product coal is transported from Wambo by rail.

Wambo Coal Pty Limited (WCPL) is seeking approval for a modification to Development Consent DA 305-7-2003 under section 75W of the *Environmental Planning and Assessment Act, 1979*.

The purpose of this Agricultural Impact Statement is to address the relevant Secretary's Environmental Assessment Requirements (SEARs) for the Modification issued by the Department of Planning and Environment (DP&E). Relevant to agriculture, the SEARs state the Environmental Assessment (EA) must include:

- *An Agriculture Impact Statement to assess the potential impacts on soils and land capability of the site and surrounds, paying particular attention to any Biophysical Strategic Agricultural Land (BSAL)*
- *an assessment of the likely agricultural impacts of the development;*

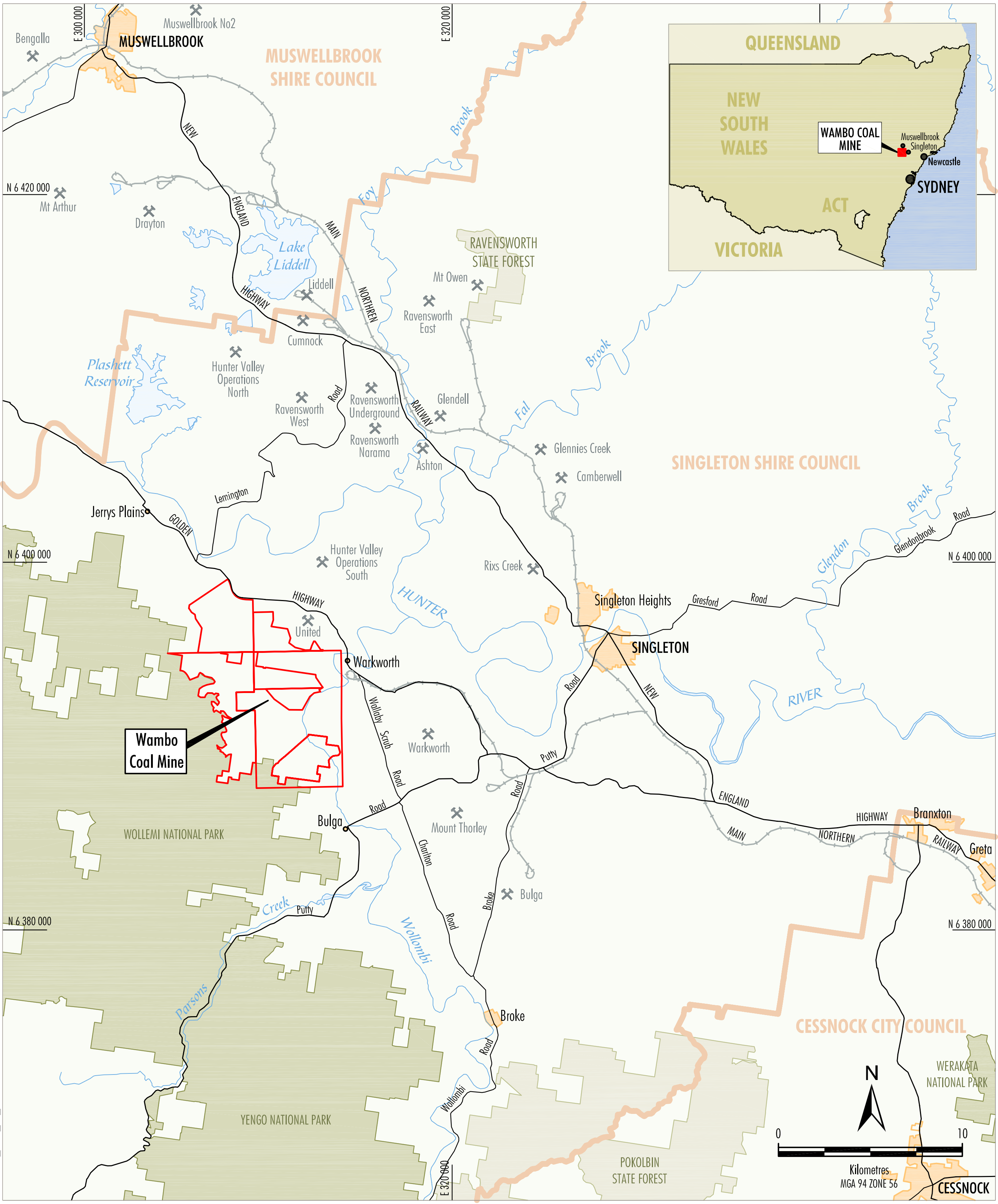
1.1 MODIFICATION OVERVIEW

Wambo includes the approved South Bates Underground Mine that incorporates longwall mining in the Whybrow and Wambo Seams.

WCPL is seeking to modify Development Consent (DA 305-7-2003) to allow extension of mining in the Whybrow Seam to the north-west of the approved South Bates Underground Mine to include nine additional longwall panels (the Modification) (Figure 2).

The Modification would primarily involve use of the existing approved infrastructure at the South Bates Underground Mine, however the Modification would also involve the construction of new ventilation shafts, gas drainage infrastructure and other ancillary infrastructure.

The total ROM coal mined would increase by approximately an additional 18 million tonnes from the modified South Bates Underground Mine.



WAM-09-15_SBEM_AIS_101B

LEGEND

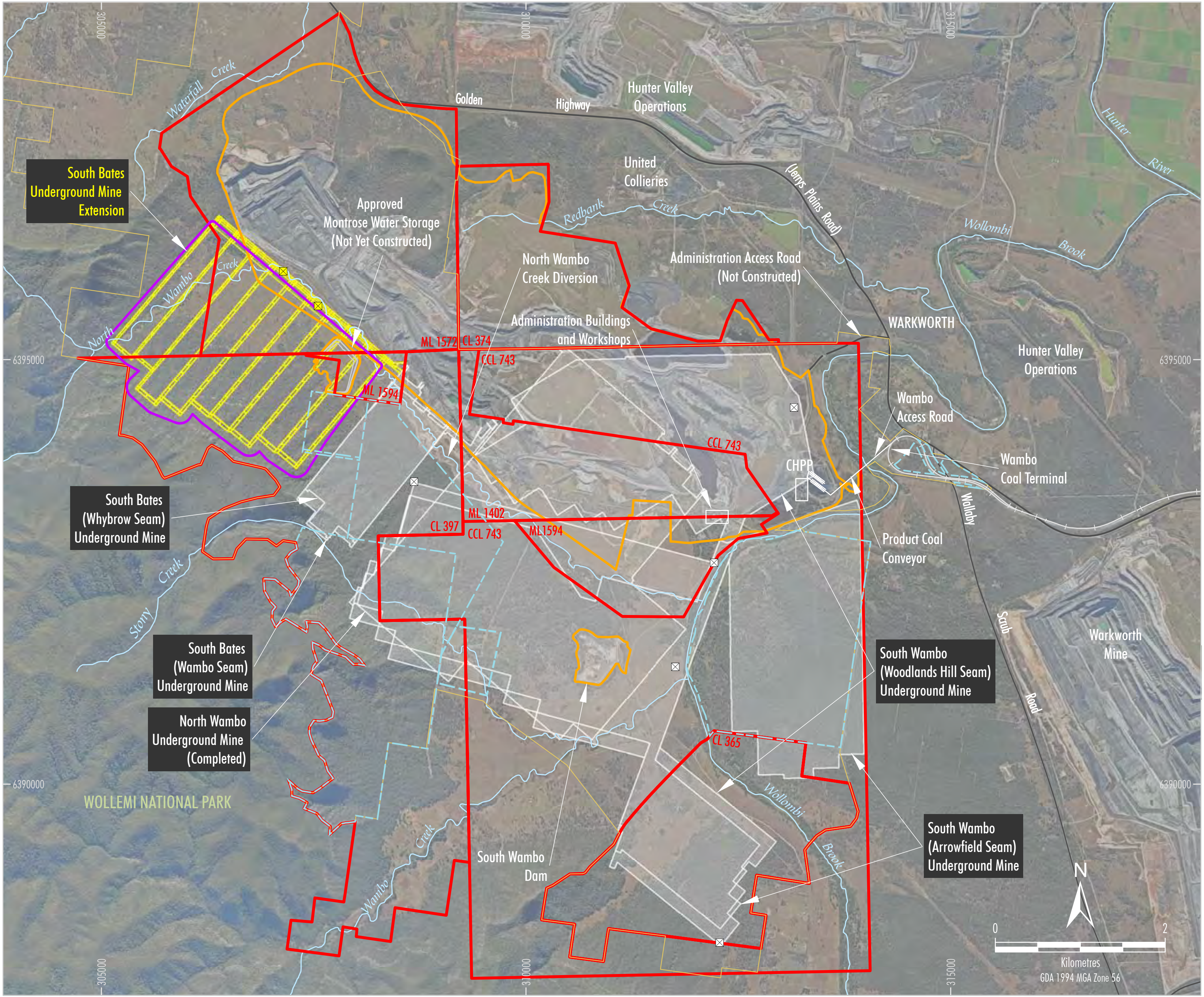
- Mining and Coal Lease Boundary
- Local Government Boundary
- Mining Operation

Source: Geoscience Australia (2009)

WAMBO COAL MINE

Regional Location

Figure 1



WAM-09-15_SBEM_AIS_201B

LEGEND
- Mining and Coal Lease Boundary
- WCPL Owned Land
- Existing/Approved Surface Development Area
- Approved Underground Development
- Modified Underground Development
- Extent of Conventional Subsidence from the Modified Underground Development
- Approved Ventilation Shaft
- Modified Ventilation Shaft
- Remnant Woodland Enhancement Program (RWEP) Area

Source: *Department of Lands (July 2009); WCPL (2016); WCPL Orthophoto (July 2016)*

Peabody ENERGY

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

Approved and Modified Wambo Coal Mine General Arrangement

Figure 2

There are no proposed changes to the approved ROM coal production rate from the underground operations, or overall ROM coal processing rate through the coal handling and preparation plant. The Modification would not change the open cut mining operations.

The Modification would not involve changes to any aspects of the approved South Wambo Underground Mine layout.

Additional details of the Modification are provided in Section 3 of the EA.

The "Modification Area" comprises the extent of conventional subsidence resulting from the modified longwall layout (Figure 2).

The Modification subsidence effects associated with longwall mining in the Whybrow Seam is predicted to be generally similar to or less than the previously approved underground developments at Wambo.

1.2 CONSULTATION

WCPL has ongoing community consultation mechanisms and undertook extensive consultation in support of the Modification, including consultation with relevant State and local government agencies and the community. These consultation programs, key issues raised and ongoing consultation mechanisms are described in Section 1.3 of the EA.

A Site Verification Certificate (SVC) Application for the component of the Modification Area outside existing mining tenements was submitted to the DP&E on 19 October 2016 and subsequently provided to the Office of Environment and Heritage (OEH). A SVC was granted on 23 November 2016.

1.3 STRUCTURE OF THIS REPORT

This document is structured as follows:

Section 1	Provides an introduction and overview of the Modification.
Section 2	Provides a description of the existing agricultural resources, production and enterprises in the region.
Section 3	Describes the potential impacts of the Modification on agricultural resources and enterprises, including potential impacts on water resources.
Section 4	Summarises the mitigation and management measures to be implemented with respect to Modification impacts on agricultural resources and enterprises.
Section 5	Provides a conclusion and justification for the changes to agricultural resources that would arise due to the Modification.
Section 6	References.
Attachment 1	Provides supporting information in the form of a detailed Agricultural Resource Assessment prepared by Soil Management Designs (Dr David McKenzie) (2016a).

The following reports have also been prepared in support of the Modification and should be read in conjunction with this assessment:

- Subsidence Assessment (Mine Subsidence Engineering Consultants [MSEC], 2017) (Appendix A of the EA);
- Groundwater Assessment (HydroSimulations, 2017) (Appendix B of the EA);
- Surface Water Assessment (Advisian, 2016) (Appendix C of the EA);
- Flora Assessment (FloraSearch, 2017) (Appendix D of the EA);
- Fauna Assessment (Eco Logical Australia, 2017) (Appendix E of the EA);
- Aboriginal Cultural Heritage Assessment (South East Archaeology, 2017) (Appendix F of the EA);
- Historic Heritage Assessment (EJE Heritage, 2017) (Appendix G of the EA);
- Noise Review (SLR Consulting Australia Pty Ltd, 2016) (Appendix I of the EA);
- Air Quality and Greenhouse Gas Review (Todoroski Air Sciences, 2016) (Appendix J of the EA); and
- Land Contamination Assessment (GHD Pty Ltd, 2016) (Appendix K of the EA).
- Site Water Balance (Hydro Engineering & Consulting Pty Ltd, 2017) (Appendix L of the EA).

Where relevant, summary content sourced from these documents is provided in this report.

2 EXISTING AGRICULTURAL RESOURCES, PRODUCTION AND ENTERPRISES

2.1 AGRICULTURAL RESOURCES

2.1.1 Climate

Long-term meteorological data for the region is available from Commonwealth Bureau of Meteorology (BoM) meteorological stations.

Temperature

The nearby Jerrys Plains Post Office meteorological station records (BoM, 2016) show that temperatures are warmest from November to February and coolest from June to August.

The Jerrys Plains Post Office meteorological station records show that monthly-average daily maximum temperatures are highest in January (31.8 degrees Celsius [ºC]) and the monthly-average daily minimum temperatures are lowest in July (3.8 ºC) (BoM, 2016).

Rainfall

The long-term average annual rainfall at the nearby meteorological stations of Jerrys Plains Post Office and Bulga are 644.5 millimetres (mm) and 692.0 mm, respectively (BoM, 2016).

The months with the highest monthly-average rainfall at Jerrys Plains Post Office and Bulga are January and February (BoM, 2016).

2.1.2 Land Use

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 (Attachment 1).

Land use in the vicinity of Wambo includes a combination of coal mining operations, Remnant Woodland Enhancement Program (RWEP) areas, agricultural land use and WCPL-owned lands that are not subject to mining operations, utilised for the agistment of beef cattle (Attachment 1). 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).

There is no evidence of recent cropping activities or vineyards in the Modification Area.

2.1.3 Landforms

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 (Attachment 1). To the west of Wambo is steeper land with elevations up to approximately 650 metres (m) Australian Height Datum (AHD) within the Wollemi National Park (Attachment 1).

The main topographic features of the Modification Area are the alluvial flats and terraces associated with North Wambo Creek (Attachment 1).

Elevations in the Modification Area range from approximately 100 m AHD near the North Wambo Creek Diversion in the north-east to approximately 320 m AHD in the south-east.

2.1.4 Soil Survey

Soil Management Designs (2016a) considered soil survey results from 20 soil pits to characterise and assess the soils in the Modification Area as part of the Agricultural Resource Assessment (Attachment 1).

The 20 soil pits that were assessed cover the main variations in vegetation type, topography and land use in the vicinity of the Modification Area, with a focus on the areas to be potentially impacted by the Modification. The soil profiles were classified according to the Australian Soil Classification system (Isbell, 2002).

The main soil types mapped in the Modification Area comprise Sodosols (40 percent [%]), Rudosols (35%), Kandosols (15%) Chromosols (5%) and Tenosols (5%) (Figure 3) (Attachment 1).

Soil Landscape Units containing groupings of the above soil types were identified during the soil survey as including (Attachment 1):

- Wollombi Alluvial Soils: dominated by Stratic Rudosols.
- Bulga Soloths: dominated by Sodosols.
- Lees Pinch Shallow Soils: co-dominated by Sodosol, Chromosol and Kandosol.

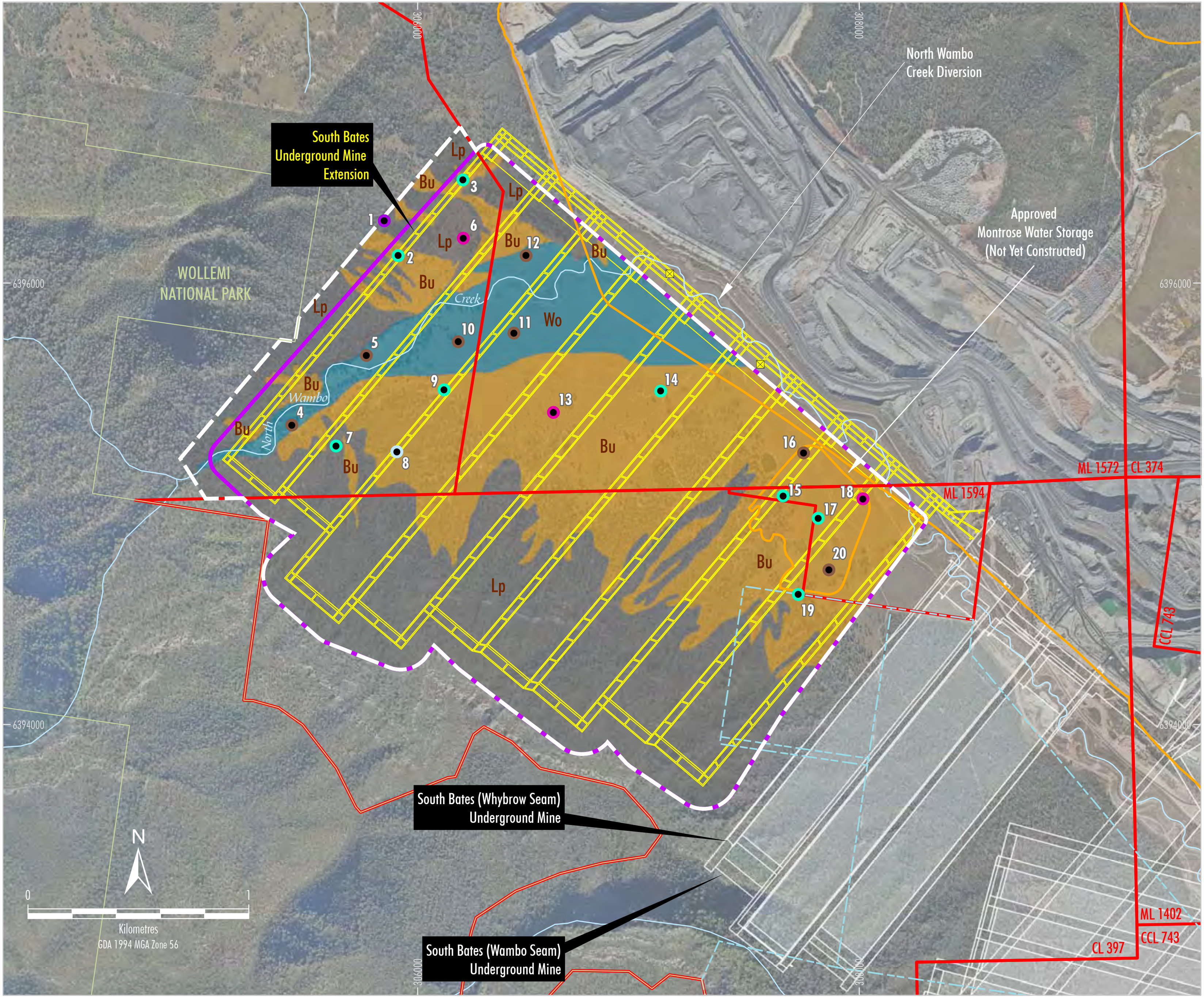
The extent of these Soil Landscape Units and soil types within the Modification Area mapped by Soil Management Designs (2016a) are shown on Figure 3.

Details of the soil surveys are provided in Attachment 1.

Soil Condition

A broad range of soil physical and chemical constraints for agricultural land use were identified across the non-alluvial sections of the Modification Area including (Attachment 1):

- **Waterlogging in subsoil** which causes several adverse processes to take place (e.g. lack of oxygen, large losses of nitrogen to the atmosphere).
- **Dispersive subsoil** which is much more likely to be lost by water erosion than stable soil.
- **Compaction in subsoil** which 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.
- **Acidity in topsoil and subsoil** which is a major constraint to agricultural productivity.
- **Subsoil salinity** in Sodosols associated with the ‘Bulga’ soil landscape unit. When soil salinity levels are elevated it can constrain plant growth rates.
- **Poor water holding capacity in shallow/stony soils**.
- **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.
- **Poor organic content in deeper soil layers**.



LEGEND

- Mining and Coal Lease Boundary
- National Park Boundary
- Existing/Approved Surface Development Area
- Approved Underground Development
- Modified Underground Development
- Extent of Conventional Subsidence from the Modified Underground Development
- Agricultural Resource Assessment Study Area
- Approved Ventilation Shaft
- Modified Ventilation Shaft
- Remnant Woodland Enhancement Program (RWEP) Area
- Soil Test Pit

Australian Soil Classification - Soil Types

- Chromosol
- Kandosol
- Rudosol
- Sodosol
- Tenosol

Soil Landscape Units

- Bu Bulga Soloths
- Lp Lees Pinch Shallow
- Wo Wollombi Alluvial

Source: Department of Lands (July 2009); WCPL (2016); WCPL Orthophoto (July 2016); Soil Management Designs (2016)

Peabody ENERGY

WAMBO COAL MINE

Modification Soil Landscape Units and Soil Types

Figure 3

WAM-09-15_SBEM_AIS_202E

The alluvial soil in the Modification 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 sulphur, phosphorus and nitrogen in the alluvial soils.

2.1.5 Land and Soil Capability

The Land and Soil Capability (LSC) Assessment Scheme uses the biophysical features of the land and soil including landform position, slope gradient, drainage, climate, soil type and soil characteristics to derive detailed rating tables for a range of land and soil hazards (OEH, 2012). The LSC class gives an indication of the land management practices that can be applied to a parcel of land. The LSC classes are outlined below (OEH, 2012).

Land capable of a wide variety of land uses (cropping, grazing, horticulture, forestry, nature conservation)

Class 1: Extremely high capability land: Land has no limitations. No special land management practices required. Land capable of all rural land uses and land management practices.

Class 2: Very high capability land: Land has slight limitations. These can be managed by readily available, easily implemented management practices. Land is capable of most land uses and land management practices, including intensive cropping with cultivation.

Class 3: High capability land: Land has moderate limitations and is capable of sustaining high-impact land uses, such as cropping with cultivation, using more intensive, readily available and widely accepted management practices. However, careful management of limitations is required for cropping and intensive grazing to avoid land and environmental degradation.

Land capable of a variety of land uses (cropping with restricted cultivation, pasture cropping, grazing, some horticulture, forestry, nature conservation)

Class 4: Moderate capability land: Land has moderate to high limitations for high-impact land uses. Will restrict land management options for regular high-impact land uses such as cropping, high-intensity grazing and horticulture. These limitations can only be managed by specialised management practices with a high level of knowledge, expertise, inputs, investment and technology.

Class 5: Moderate–low capability land: Land has high limitations for high-impact land uses. Will largely restrict land use to grazing, some horticulture (orchards), forestry and nature conservation. The limitations need to be carefully managed to prevent long-term degradation.

Land capable for a limited set of land uses (grazing, forestry and nature conservation, some horticulture)

Class 6: Low capability land: Land has very high limitations for high-impact land uses. Land use restricted to low-impact land uses such as grazing, forestry and nature conservation. Careful management of limitations is required to prevent severe land and environmental degradation.

Land generally incapable of agricultural land use (selective forestry and nature conservation)

Class 7: Very low capability land: Land has severe limitations that restrict most land uses and generally cannot be overcome. On-site and off-site impacts of land management practices can be extremely severe if limitations not managed. There should be minimal disturbance of native vegetation.

Class 8: Extremely low capability land: Limitations are so severe that the land is incapable of sustaining any land use apart from nature conservation. There should be no disturbance of native vegetation.

Regional LSC mapping prepared by the OEH (2012) is available for the Modification Area and surrounding lands (Figure 4). The Modification Area is mapped as LSC Class 4 and a small portion of Class 7 in the south (Figure 4). Areas of LSC Class 5 were also mapped south-east and north of the Modification Area (Figure 4).

Adjoining Lands and Wambo Biodiversity Offset Areas

WCPL-owned agricultural lands that adjoin Wambo would continue to be subject to agricultural use, where practicable.

The existing RWEP areas would remain unchanged for the Modification.

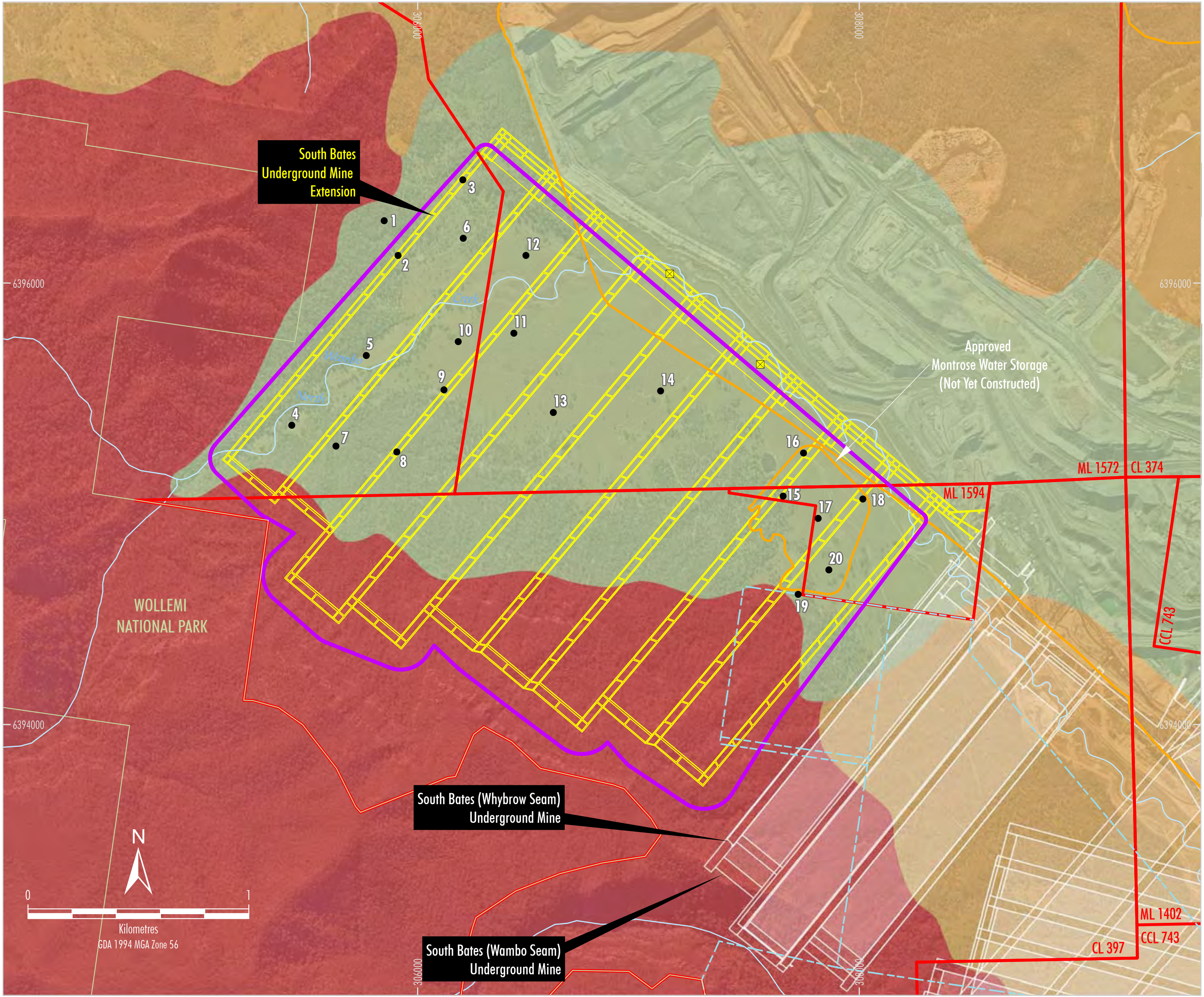
2.1.6 Identification of Strategic Agricultural Lands

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-east of the Modification Area (Figure 5).

The Modification Area is not located within any mapped Viticulture Critical Industry Clusters. The closest Viticulture Critical Industry Cluster is located approximately 7.5 km to the south-east of the Modification Area (Figure 5). This is outside the predicted extent of conventional subsidence for the Modification (MSEC, 2017).

A Site Verification Report (Soil Management Designs, 2016b) was prepared to support a SVC Application for the component of the Modification Area outside existing mining tenements. The Site Verification Report was prepared in accordance with the *Interim protocol for site verification and mapping of biophysical strategic agricultural land* (NSW Government, 2013). The SVC was submitted on 19 October 2016 and subsequently granted on 23 November 2016. The SVC confirmed there was no BSAL within the SVC Application Area.

Adjoining WCPL-owned agricultural lands do not comprise high value or strategic agricultural lands based on the available mapping information.



LEGEND

- Mining and Coal Lease Boundary
- National Park Boundary
- Existing/Approved Surface Development Area
- Approved Underground Development
- Modified Underground Development
- Extent of Conventional Subsidence from the Modified Underground Development
- Approved Ventilation Shaft
- Modified Ventilation Shaft
- Remnant Woodland Enhancement Program (RWEP) Area
- Soil Test Pit

Regional LSC Mapping

- Class 4
- Class 5
- Class 7

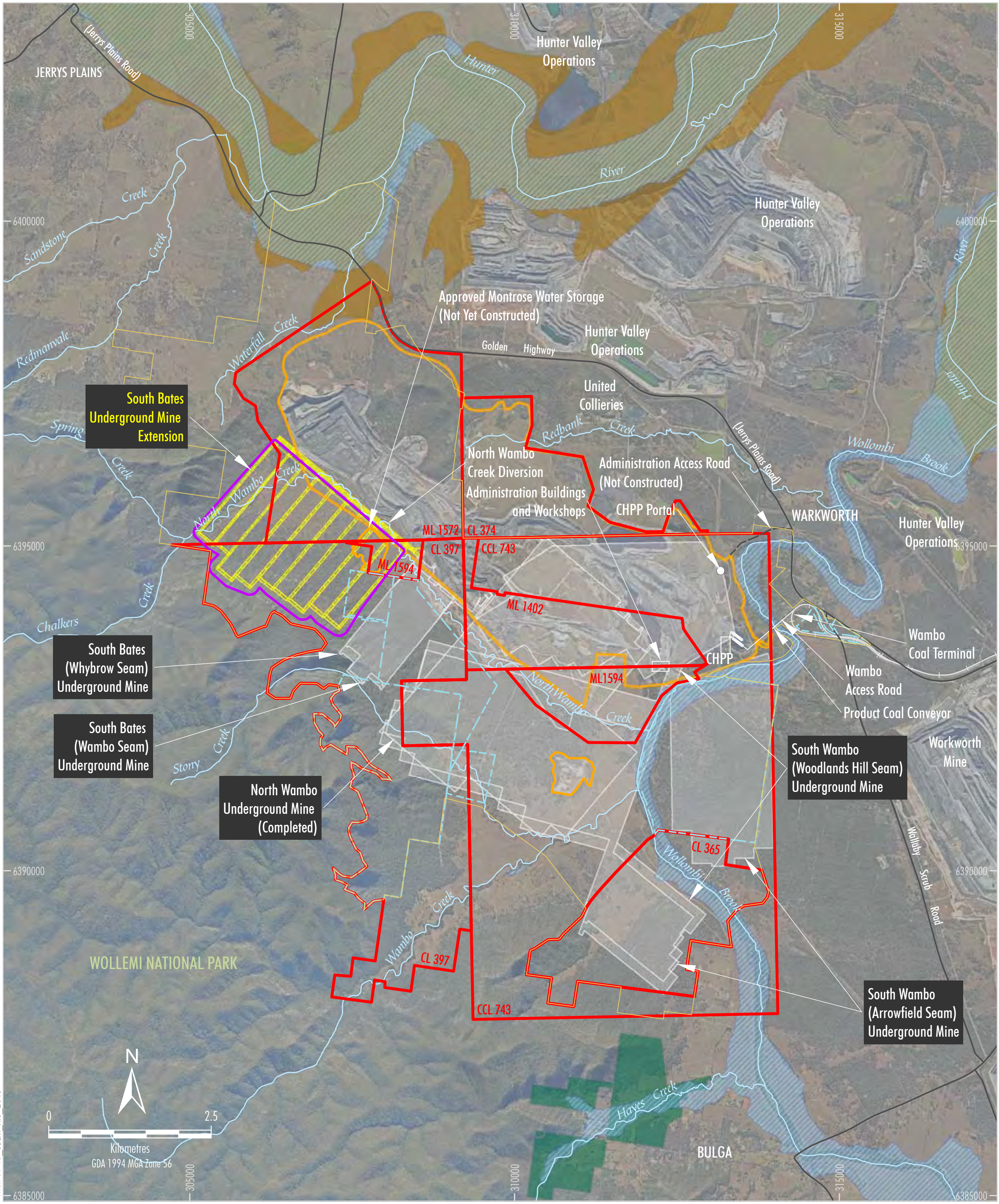
Source: Department of Lands (July 2009); WCPL (2016); WCPL Orthophoto (July 2016); Office of Environment and Heritage (2012); Soil Management Designs (2016)

WAMBO COAL MINE

Land and Soil Capability Mapping

Figure 4

WAM-09-15_SBEM_AIS_203C



LEGEND

- Mining and Coal Lease Boundary
- WCPL Owned Land
- Existing/Approved Surface Development Area
- Approved Underground Development
- Modified Underground Development
- Extent of Conventional Subsidence from the Modified Underground Development
- Remnant Woodland Enhancement Program (RWEP) Area
- Highly Productive Groundwater
- Biophysical SAL
- Viticulture Critical Industry Cluster SAL

Peabody ENERGY

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

Strategic Agricultural Land in the Vicinity of Wambo

Source: DP&I (January 2014); Department of Lands (July 2009); WCPL (2016); WCPL Orthophoto (July 2016)

Figure 5

2.1.7 Water Resources

Groundwater

A Groundwater Assessment for the Modification was undertaken by HydroSimulations (2017) and is presented in Appendix B of the EA. The following discussion is based on this Groundwater Assessment.

Existing Groundwater Regime

The two main groundwater systems which exist in the Modification Area and surrounds are (HydroSimulations, 2017):

- Quaternary alluvial aquifer system of channel fill deposits associated with Wollombi Brook, North Wambo Creek, Wambo Creek and Stony Creek.
- Underlying Permian strata consisting of:
  - hydrogeologically “tight” and hence very low yielding to essentially dry sandstone and siltstone; and
  - low to moderately permeable coal seams, which are the prime water-bearing strata within the Permian measures.

Evidence indicates that the alluvial aquifer is responsive to rainfall recharge and it is likely that the alluvium plays an important role in supplying recharge to the underlying Permian strata as well as contributing to baseflow of surface water features (HydroSimulations, 2017).

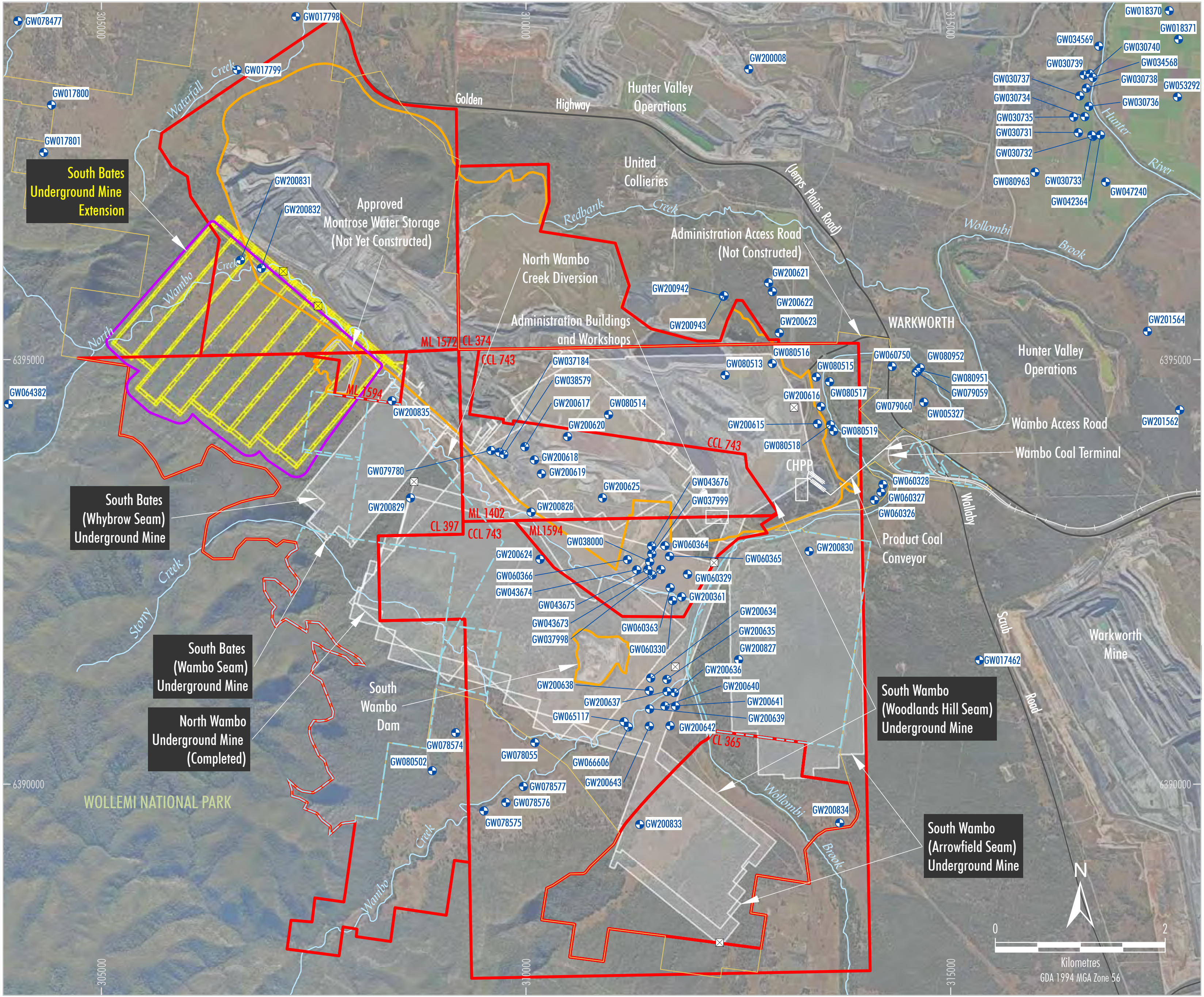
Groundwater flow patterns within the shallow alluvial aquifers reflect topographic levels and the containment of alluvium within the principal drainage pathways. Prior to the commencement of mining operations in the region, the piezometric surface within the Permian aquifers of the Wambo area most probably reflected the topography. Groundwater monitoring bores in close proximity to Wambo have shown historical and ongoing open cut and underground mining within the Wambo area and adjoining operations has created a regional zone of depressurisation within the Permian coal measures (HydroSimulations, 2017).

HydroSimulations (2017) and previous groundwater assessments for Wambo predict that some privately-owned bores may experience more than 2 m cumulative drawdown as a result of the already approved operations at Wambo. These drawdowns are due to the cumulative effects of all mining in the Wambo area.

Groundwater Quality and Use

HydroSimulations (2017) indicates that groundwater quality in the vicinity of Wambo is variable. The salinity of groundwater recently sampled from within Wambo and surrounding mining leases ranges from 314 milligrams per litre (mg/L) to 15,000 mg/L (approximately 500 microSiemens per centimetre [µS/cm] to 22,000 µS/cm). The highest salinities are reported from the surficial groundwater.

A search of the Department of Primary Industries Water (formerly NSW Office of Water) PINNEENA Groundwater Works Database identified 197 registered bores and wells within 5 km of Wambo (Figure 6), the majority (117) of these being monitoring/test bores. The remaining bores comprise 11 mine use/dewatering bores; 49 bores registered for irrigation, domestic and/or stock use; and 20 bores of unknown use.



LEGEND

- Mining and Coal Lease Boundary
- WCPL Owned Land
- Existing/Approved Surface Development Area
- Approved Underground Development
- Modified Underground Development
- Extent of Conventional Subsidence from the Modified Underground Development
- Approved Ventilation Shaft
- Modified Ventilation Shaft
- Remnant Woodland Enhancement Program (RWEP) Area
- Registered Bore

Source: *Department of Lands (July 2009); WCPL (2016); WCPL Orthophoto (July 2016); DPI Water (2015)*

Peabody ENERGY

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

Location of Registered Bores

Figure 6

WAM-09-15_SBEM_AIS_205B

Surface Water

A Surface Water Assessment for the Modification was undertaken by Advisian (2016) and is presented in Appendix C of the EA. The following discussion is based on this Surface Water Assessment.

Wambo is situated adjacent to Wollombi Brook, south-west of its confluence with the Hunter River.

The majority of lands within Wambo mining tenements drain via Wambo (also known as 'South Wambo'), Stony, North Wambo and Redbank Creeks to Wollombi Brook, while Waterfall Creek drains directly to the Hunter River (Figure 2). North Wambo Creek is the only creek within the Modification Area and is considered an ephemeral waterway, which experiences some periods when flow would not be noticeable (Advisian, 2016).

North Wambo Creek flows north-east over the Modification Area to the North Wambo Creek Diversion, a section of North Wambo Creek which has been diverted to avoid the Wambo open cut (Figure 2). North Wambo Creek and a portion of the North Wambo Creek Diversion lie directly above and adjacent to the Modification Area.

Surface Water Quality

Surface water quality at Wambo for the period July 2003 to June 2016 has been reviewed by Advisian (2016).

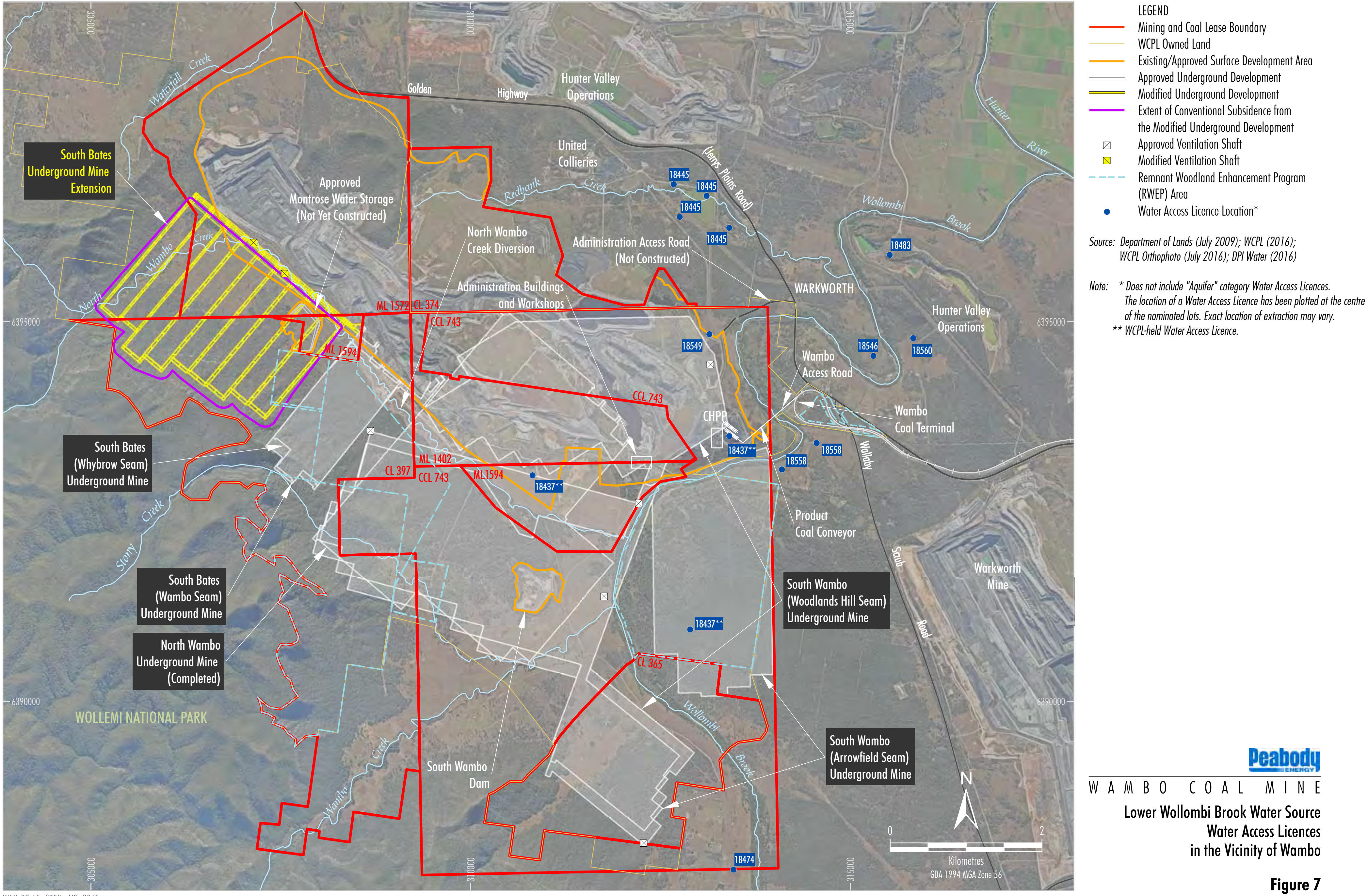
Advisian (2016) note that the water quality of North Wambo Creek indicates slightly alkaline pH conditions with moderate salinity upstream and high salinity downstream.

Other Surface Water Users

Water in Wollombi Brook is used for stock watering and irrigation purposes. There are 110 surface water licences in the Lower Wollombi Brook water source, with a total volumetric surface water licence of 6,663 million litres per year (ML/year), of which 88% is used for irrigation purposes (NSW Department of Water and Energy, 2009). There are six (including one WCPL-held) Water Access Licences associated with surface water extraction along Wollombi Brook and downstream of Wambo (Figure 7). There are no Water Access Licences along North Wambo Creek that are used for domestic or stock use (i.e. not used for water supply).

2.2 AGRICULTURAL PRODUCTION AND ENTERPRISES

The Singleton Local Government Area (LGA) is located in the wider Upper Hunter Region. The Upper Hunter Strategic Regional Land Use Plan (SRLUP) describes the wider regional context of agricultural production over an area that comprises an area of some 2.4 million hectares (ha) and includes the LGAs of Singleton, Muswellbrook, Dungog, Upper Hunter and Gloucester (NSW Government, 2012). The Upper Hunter SRLUP (NSW Government, 2012) notes that intensive agricultural enterprises are of particular significance in the Singleton, Dungog and Gloucester LGAs.



Peabody ENERGY

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

Lower Wollombi Brook Water Source Water Access Licences in the Vicinity of Wambo

Figure 7

WAM-09-15_SBEM_AIS_206C

2.2.1 Agricultural History of the Local Area

While the Lower Hunter Region was developed on a foundation of industrial production, the Upper Hunter Region focussed predominately on agricultural production (RPS, 2016).

EJE Heritage (2017) has prepared a Historic Heritage Assessment for the Modification (Appendix G of the EA). This report indicates that the Modification Area and surrounds were disturbed for previous rural residential and agricultural (cropping, horses, cattle and sheep) uses (EJE Heritage, 2017).

2.2.2 Local Agricultural Productivity and Enterprises

Soil Management Designs (2016a) has identified that agricultural enterprises known to have been conducted in the Modification Area include beef cattle on rain-fed pastures (Attachment 1).

Based on Soil Management Designs' (2016a) analysis and review of the agricultural operations on surrounding lands, it is considered that the majority of the agricultural lands within the Modification Area and surrounds are unimproved pastures, with some medium productivity "improved" pastures relating to the Wollombi Alluvial soil landscape unit (Attachment 1).

Soil Management Designs (2016a) has estimated the gross margins for beef cattle (weaners) production on unimproved and improved pastures in the Modification Area and surrounds as being approximately $117 and $347 per hectare, per year respectively (Attachment 1).

2.2.3 Support Infrastructure, Suppliers and Services

General agricultural improvements (e.g. stock fences and farm dams) are in place across most of the Modification Area and surrounds that reflect its historical development for beef production.

Local rural suppliers and/or services are located in Singleton and Muswellbrook. The Modification Area and surrounds are well serviced for support infrastructure being located adjacent to the Golden Highway and some 15 km west of Singleton.

Access to regional road transport routes are readily available from the Modification Area via the adjacent Golden Highway. Wambo is located within approximately a one hour drive from the major regional centre of Newcastle and approximately a two hour drive from Sydney.

3 POTENTIAL IMPACTS

This section provides an assessment of the potential impacts of the Modification on agricultural resources and productivity.

3.1 CONSIDERATION OF RISKS

The potential impacts of the Modification on groundwater and surface water resources have been considered in the Groundwater and Surface Water Assessments for the Modification (Appendices B and C of the EA). Potential impacts of the Modification on flora and fauna have been considered in the Flora and Fauna Assessments (Appendices D and E of the EA). Potential impacts of subsidence within the Modification Area on Aboriginal cultural heritage have been considered in the Aboriginal Cultural Heritage Assessment (Appendix F of the EA). Potential impacts on adjoining lands through the potential impacts of operational noise and air quality emissions have been considered in the Noise Review and Air Quality and Greenhouse Gas Review (Appendices I and J of the EA). Potential land contamination across the Modification Area was also considered in the Land Contamination Assessment (Appendix K).

3.2 AGRICULTURAL RESOURCES

3.2.1 Land Resources during the Modification Life

Modification Area

Potential impact mechanisms on agricultural resources in the Modification Area as a result of the Modification are likely to be associated with:

- loss of productive agricultural land due to additional minor surface development in the Modification Area; and
- subsidence-related impacts.

Surface Development

The proposed ventilation infrastructure, including ancillary infrastructure for the Modification would be located within the approved surface development area and therefore would result in no additional impacts on agricultural resources beyond the approved operations.

The Modification would result in additional minor surface development (approximately 2 ha) to allow for the construction of gas drainage infrastructure and other ancillary infrastructure. Surface development would be restricted to grassland areas.

The Modification Area is mapped primarily as LSC Class 4 and a small portion of Class 7 in the south (Figure 4) (Attachment 1). The Modification Area is not BSAL or Viticulture Critical Industry Cluster mapped in the Mining SEPP (Section 2.1.6). The closest area of potential high value or strategic agricultural land is located approximately 2 km to the north of the Modification Area (Section 2.1.6).

Additional surface development for gas drainage infrastructure and other ancillary infrastructure would occur progressively over the life of the modified Wambo. The locations of gas drainage infrastructure are flexible and would be located in order to minimise potential impacts on agricultural productivity (e.g. by avoiding stock fences and dams where practicable). Any surface development associated with gas drainage infrastructure would be progressively rehabilitated over the life of the modified Wambo (Attachment 1).

Existing agricultural areas in the Modification Area could continue to be used for agricultural activities until they are required for the Modification.

The additional minor surface development at Wambo would result in the following potential impacts to soil resources (Attachment 1):

- disturbance of *in situ* soil resources;
- alteration of soil structure beneath infrastructure items;
- increased erosion and sediment movement due to exposure of soils during construction; and
- alteration of physical and chemical soil properties (e.g. structure, fertility, permeability and microbial activity) due to soil stripping and stockpiling operations.

WCPL would implement mitigation measures to minimise potential risks to soil resources as described in Section 4.

Subsidence

Subsidence is the vertical and horizontal movement of the overburden and land surface as a result of the extraction of underlying coal. These land surface movements are generically referred to as subsidence effects. The type and magnitude of the subsidence effects is dependent on a range of variables (e.g. mine geometry, topography and geology).

Subsidence may impact the integrity of agricultural infrastructure (e.g. fences) and potential impacts on soils and agricultural productivity would be associated with the following potential subsidence impacts (Attachment 1):

- surface cracking;
- slope instability;
- ponding and changes in stream alignment; and
- ponding in poorly drained areas.

MSEC (2017) has assessed the potential subsidence impacts of the Modification.

The type and magnitude of predicted subsidence effects for the additional mining layout are generally similar to or less than the previously approved underground developments at Wambo.

In addition, it is 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 (Attachment 1).

Given the above, it is considered that the Modification would not have any significant adverse impacts on agricultural production in the Modification Area (Attachment 1).

Notwithstanding the above, WCPL would implement mitigation measures to minimise potential risks to soil resources as described in Section 4.

Adjoining Lands

WCPL-owned agricultural lands that adjoin the Modification Area would continue to be used for agricultural uses, where practicable (e.g. via agistment of stock, leasing or agreements with previous landholders).

RWEP Areas

The existing RWEP areas would remain unchanged for the Modification.

3.2.2 Land Resources Post-mining

Modification Area

Any disturbance associated with the Modification would be progressively rehabilitated over the life of the modified Wambo.

Following the cessation of mining, surface infrastructure would be decommissioned and the disturbed land would be rehabilitated to woodland or agricultural areas suitable for grazing. As such, disturbance associated with Modification surface infrastructure would result in either temporary or permanent impacts to potential agricultural production on WCPL-owned land, depending on the selected final land use.

Adjoining Lands

At the completion of the Modification, lands that adjoin the Modification Area would continue to be used for agricultural uses (e.g. via agistment of stock, leasing or agreements with previous landholders).

RWEP Areas

As described in Section 3.2.1, the existing RWEP areas would remain unchanged for the Modification and therefore, there would be no additional agricultural land sterilised in perpetuity.

3.2.3 Availability of Water for Agriculture

It is not anticipated that the Modification would require any additional groundwater or surface water licence volumetric entitlements beyond the existing groundwater and surface water volumetric entitlements held by WCPL for the existing Wambo.

HydroSimulations (2017) predicts that, as a result of the Modification, there is expected to be negligible impact on the Wollombi Brook or Hunter River alluvium as a result of the Modification. Advisian (2016) concluded that the Modification would have no measurable impact on the flow in Wollombi Brook.

No privately-owned registered bores are expected to be additionally affected by drawdown caused by the Modification (HydroSimulations, 2017).

Given the above, there is not expected to be a significant impact on the availability of water for agriculture as a result of the Modification.

3.2.4 Amenity Effects

Consideration of the potential impacts of the Modification with respect to human health and amenity criteria for nearby private landholders is considered in the Noise Review and Air Quality and Greenhouse Gas Review (Appendices I and J of the EA). Consideration of the road transport and visual amenity impacts of the Modification are outlined in Section 4 of the Main Report of the EA.

No potential impacts have been identified in these assessments that would materially affect the agricultural productivity of adjoining privately-owned lands.

3.3 AGRICULTURAL PRODUCTION, AGRICULTURAL INFRASTRUCTURE, SUPPLIERS AND SUPPORT SERVICES

The area of grazing agricultural lands that would be directly disturbed by the Modification to allow for the construction of gas drainage infrastructure and other ancillary infrastructure (approximately 2 ha) can be considered in the context of the area of land under agricultural production in the State of NSW and in the Hunter Valley region.

The potential impact of the Modification on the area of land that is subject to agricultural use in NSW and in the Hunter Valley region would be very small. In addition, the existing agricultural land that has been identified as being potentially impacted by the Modification consists of LSC Class 4 (Figure 4) and is not mapped as BSAL in the Mining SEPP (Section 2.1.6).

Consideration of the above indicates that the Modification has very little potential to materially affect regional agricultural production or demand for agricultural infrastructure, supplies or services at a local or regional level.

3.4 CONSIDERATION OF POTENTIAL CUMULATIVE IMPACTS

As discussed in Section 3.2.1, the Modification would result in additional minor surface development of approximately 2 ha of the Wambo surface development area suitable for agricultural production. The currently approved surface development area at Wambo is approximately 2,000 ha. Therefore, the Modification would represent an increase in disturbed land of less than 1%.

Given the above, it is considered that, even accounting for cumulative impacts in the region, the Modification would have a very minor impact on local and regional agriculture.

4 MITIGATION AND MANAGEMENT MEASURES

As described in Section 3, the potential impacts of the Modification on agricultural resources and associated employment and support industries would be small in the context of the existing agricultural activities in the region.

In addition, consideration of the cumulative impacts of approved mining operations in the region also indicates that, even accounting for these other approved developments, the potential cumulative impacts on local and regional agriculture would be minor.

Notwithstanding, WCPL would implement a number of mitigation and management measures that would reduce the potential impacts of the Modification on agriculture, as described below.

4.1 MINIMISATION OF DISTURBANCE TO AGRICULTURAL LANDS

The area of agricultural land disturbed by the Modification at any one time would be minimised so that beneficial agricultural uses (i.e. cattle grazing) can continue to be undertaken on available Modification Area grazing lands. As demonstrated by Wambo and other mining operations in the region, grazing agricultural activities can be readily undertaken in conjunction with the operation of a mine.

Surface disturbance associated with the Modification Area would be progressively rehabilitated as the gas management infrastructure is no longer required.

4.2 MANAGEMENT OF SUBSIDENCE IMPACTS

An Extraction Plan would be developed for the modified South Bates Underground Mine that would include the following subsidence management measures to minimise potential agricultural impacts:

- Notification to agistees of areas of longwall mining and active subsidence, and exclusion of agistment grazing from areas where surface cracking presents a reasonable risk to people and/or livestock.
- Remediation of surface cracks[1] where practicable using conventional earthmoving equipment (e.g. a backhoe), including:
  - infilling of surface cracks with soil or other suitable materials; or
  - locally re-grading and re-compacting the surface where hill steepness and water erosion hazard has increased.
- Stabilisation of any areas of surface cracking using erosion protection measures (e.g. vegetation planting, gypsum application in erosion-prone sodic areas).
- Drainage works and rehabilitation of subsidence troughs (i.e. areas of induced ponding) as necessary. Where new ponds are useful as stock watering points, however, consider their retention.
- Repair of fences prior to allowing access for agistment grazing.

---

[1] Minor cracks that develop are not expected to require remediation as geomorphologic processes will result in the natural filling of these cracks over time.

- Measures to stabilise/mitigate impacts to rock faces/cliffs if considered beneficial and practicable in consultation with the DP&E and the Department of Industry – Division of Resources and Energy (e.g. artificial rock support, standing supports, dislodgement of remaining loose rock etc.).
- Management measures in accordance with the Erosion and Sediment Control Plan.

Trigger Action Response Plans would be developed as part of the Extraction Plan process to outline appropriate triggers and remedial actions for subsidence impacts, including a contingency process to respond to unforeseen impacts.

4.3 MANAGEMENT OF ADJOINING WCPL-OWNED LANDS

To minimise the potential direct impacts of the Modification on agricultural production, WCPL-owned agricultural lands that adjoin Wambo would continue to be subject to agricultural use, where practicable.

An Extraction Plan would be developed for the modified South Bates Underground Mine with management measures to allow these lands to continue to be used for agriculture (e.g. repair of stock fences prior to allowing access for agistment grazing).

4.4 RE-ESTABLISHMENT OF AGRICULTURAL LANDS

Following the cessation of mining, surface infrastructure would be decommissioned and the disturbed land would be rehabilitated to woodland or agricultural areas suitable for grazing.

Any disturbance associated with gas drainage infrastructure would be progressively rehabilitated over the life of the modified Wambo.

Existing rehabilitation success at Wambo and other mining operations in the region provides a working demonstration of the practical application of rehabilitating mining operation disturbance areas to productive agricultural land uses. Further detail on the rehabilitation strategy for the Modification is provided in Section 3 of the Main Report of the EA.

4.5 WATER RESOURCES

Measures to minimise the potential impacts of the Modification on water resources, including water resources used by other licensed users of water for agriculture, are provided in Appendices B and C and Sections 4.4 and 4.5 of the Main Report of the EA.

The existing Wambo Site Water Management Plan would be reviewed and, if necessary, revised to incorporate the Modification. This Site Water Management Plan outlines measures to respond to any potential exceedances of surface water or groundwater related criteria, and to provide contingent mitigation/compensation/offset measures that would be implemented in the event that downstream surface water users or groundwater users were adversely affected by Wambo operations.

4.6 OTHER MEASURES

Section 4 of the Main Report of the EA describes a range of management and mitigation measures for potential environmental impacts arising from the Modification, including relevant contingency measures.

Consideration of alternatives and justification for the Modification are also discussed in Section 6 of the Main Report of the EA.

5 JUSTIFICATION OF PROPOSED CHANGES TO AGRICULTURAL LANDS

The results of the site specific soil survey, regional LSC Mapping and review of regional mapping of strategic agricultural land in the Mining SEPP indicate that the Modification Area does not comprise significant strategic value or high productivity agricultural lands.

Similarly, adjoining WCPL-owned lands also do not comprise strategic value or high productivity agricultural lands.

In summary:

- The Modification would at maximum disturb approximately an additional 2 ha of existing grazing agricultural lands that are used for pasture for beef production.
- Following the cessation of mining, surface infrastructure would be decommissioned and the disturbed land would be rehabilitated to woodland or agricultural areas suitable for grazing.
- The Modification residual impacts on agricultural lands would, at State and regional levels, be very minor.
- The Modification cumulative impacts on local or regional agriculture support industries would not be material.

It is considered that the potential economic benefits of the Modification would outweigh the potential economic costs associated with the reduction in regional agricultural production. The potential economic benefits of the Modification would include:

- continued employment of up to approximately 210 direct underground mine operational personnel (excluding support staff) earning an estimated $44M per year in wages during peak production years;
- recovery of approximately 18 Mt of additional ROM coal;
- total royalties in the order of $66M would be generated for the State of NSW;
- State and Commonwealth tax revenue would be generated; and
- the associated flow-on effects of the above listed benefits.

6 REFERENCES

Advisian (2016) *South Bates Extension Modification Surface Water Assessment.*

Bureau of Meteorology (2016) *Weather Station Directory,* Bureau of Meteorology Website, available at: http://www.bom.gov.au/climate/data/stations/

Eco Logical Australia (2017) *Wambo Coal Mine – South Bates Extension Modification Fauna Assessment.*

EJE Heritage (2017) *South Bates Extension Modification Historic Heritage Assessment.*

FloraSearch (2017) *South Bates Extension Modification – Flora Assessment*.

Frazier P, Jenkins R and Trotter T (2010) *Monitoring the effect of longwall mine subsidence on native vegetation and agricultural environments: ACARP project C15013* (Australian Coal Association Research Program: Brisbane).

GHD Pty Ltd (2016) *Stage 1 Preliminary Contamination Investigation, Wambo Coal Mine, Warkworth, NSW 2330*.

Hydro Engineering & Consulting Pty Ltd (2017) *South Bates Extension Modification Site Water Balance.*

HydroSimulations (2017) *South Bates Extension Modification Groundwater Assessment*.

Isbell RF (2002) *The Australian Soil Classification Revised Edition* (CSIRO:Melbourne).

Mine Subsidence Engineering Consultants (2017) *South Bates Extension Underground Mine Modification Subsidence Assessment*.

New South Wales Department of Water and Energy (2009) *Water Sharing Plan for the Hunter unregulated and alluvial water sources – Report card for Lower Wollombi Brook water source*.

New South Wales Government (2012) *Upper Hunter Strategic Regional Land Use Plan* (Department of Planning and Infrastructure: Australia).

New South Wales Government (2013) *Interim protocol for site verification and mapping of biophysical strategic agricultural land* (Office of Environment and Heritage: Australia).

Office of Environment and Heritage (2012) *The land and soil capability assessment scheme: Second approximation – A general rural land evaluation system for New South Wales*.

RPS Australia East Pty Ltd (2016) *South Wambo Underground Mine Modification Cultural Heritage Impact Assessment.*

SLR Consulting Australia Pty Ltd (2016) *South Bates Extension Modification Noise Review.*

Soil Management Designs (2016a) *Agricultural Resource Assessment: South Bates Extension Modification, Wambo Coal Mine, Singleton, NSW*.

Soil Management Designs (2016b) *Site Verification Report: Wambo Coal Mine; Singleton, NSW*.

South East Archaeology (2017) *South Bates Extension Modification Aboriginal Cultural Heritage Assessment.*

Todoroski Air Sciences (2016) *Air Quality and Greenhouse Gas Review – South Bates Extension Modification Underground Mine Modification.*

ATTACHMENT 1

AGRICULTURAL RESOURCE ASSESSMENT

December 2016

Agricultural Resource Assessment: South Bates Extension Modification, Wambo Coal Mine; Singleton, NSW

Prepared for Wambo Coal Pty Limited

Dr. David McKenzie
Soil Management Designs
Orange NSW

DOCUMENT CONTROL

Prepared for client:	Wambo Coal Pty Limited		
First draft preparation:	Author: D McKenzie	Reviewer: L Burns & M Mahon	Date: 23.10.16
Second draft:	Author: D McKenzie	Reviewer: L Burns & M Mahon	Date: 28.11.16
Final:	Author: D McKenzie	Date: 7.12.16	

ACKNOWLEDGEMENTS

Important contributions were provided by Resource Strategies (preparation of figures and maps) and Incitec Pivot Laboratory (soil analysis).

CITATION OF THIS REPORT

McKenzie DC (2016) *Agricultural Resource Assessment: South Bates Extension Modification, Wambo Coal Mine; Singleton, NSW*. A report prepared for Wambo Coal Pty Limited by Soil Management Designs, Orange NSW; November 2016.

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. 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

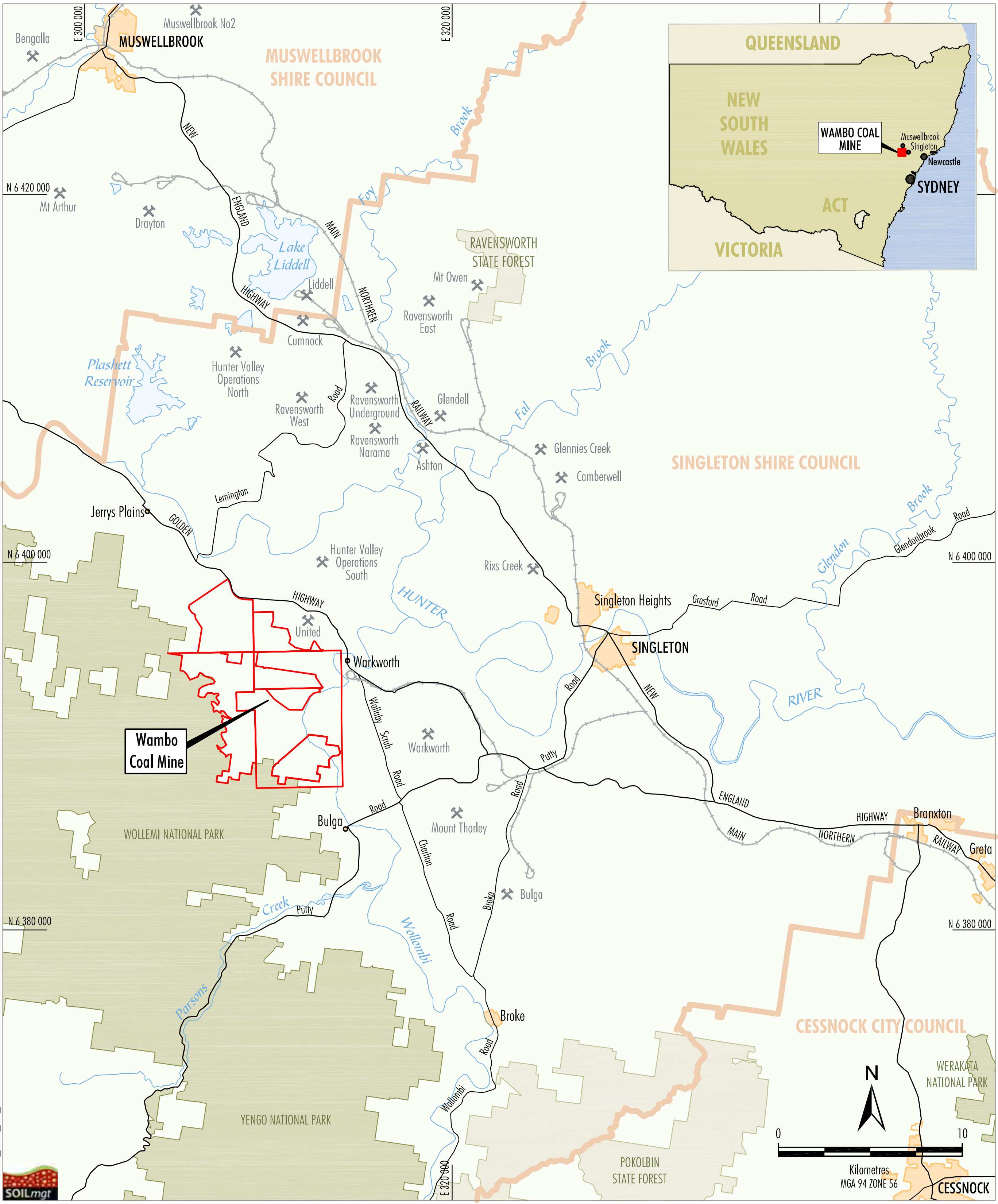
1. INTRODUCTION

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 (ROM) coal production rate is 14.7 million tonnes per annum and product coal is transported from Wambo by rail. An aerial photograph of Wambo, illustrating the existing/approved layout including key infrastructure, is provided on Figure 2.

WCPL is seeking to modify Development Consent (DA 305-7-2003) to allow extension of mining in the Whybrow Seam to the north-west of the approved South Bates Underground Mine to include nine additional longwall panels (the Modification) (Figure 2).

Soil Management Designs was commissioned by WCPL to carry out an Agricultural Resource Assessment for the Modification.



LEGEND
Mining and Coal Lease Boundary
Local Government Boundary
Mining Operation

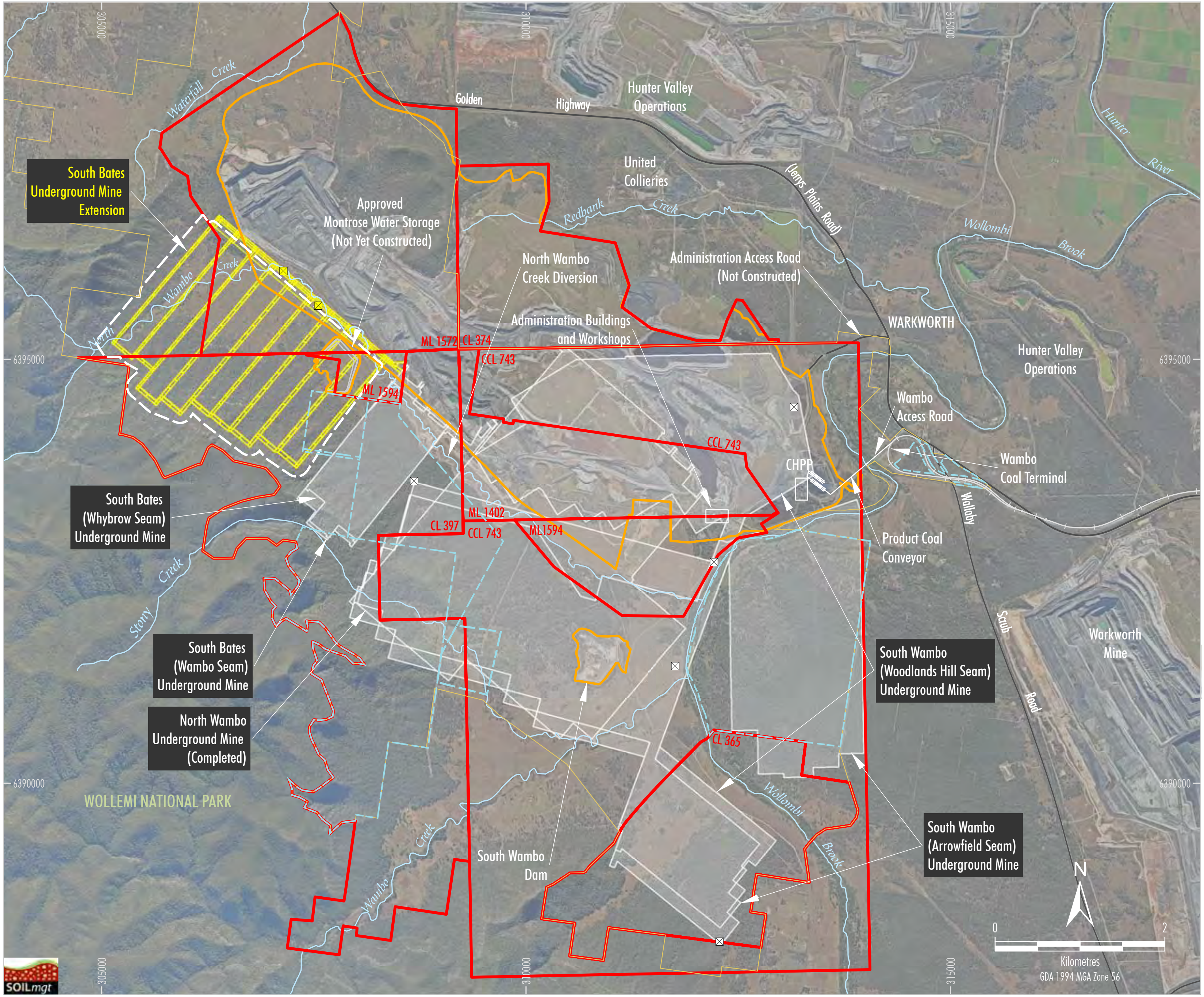
Source: Geoscience Australia (2009)

Peabody ENERGY

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

Regional Location

Figure 1



LEGEND
- Mining and Coal Lease Boundary
- WCPL Owned Land
- Existing/Approved Surface Development Area
- Approved Underground Development
- Modified Underground Development
- Approved Ventilation Shaft
- Modified Ventilation Shaft
- Remnant Woodland Enhancement Program (RWEP) Area
- Study Area

Source: Department of Lands (July 2009); WCPL (2016); WCPL Orthophoto (July 2016)

Peabody ENERGY

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

Aerial Photograph of Wambo and Surrounds

Figure 2

WAM-09-15_SBEM_ARA_208C

2. MODIFICATION OVERVIEW

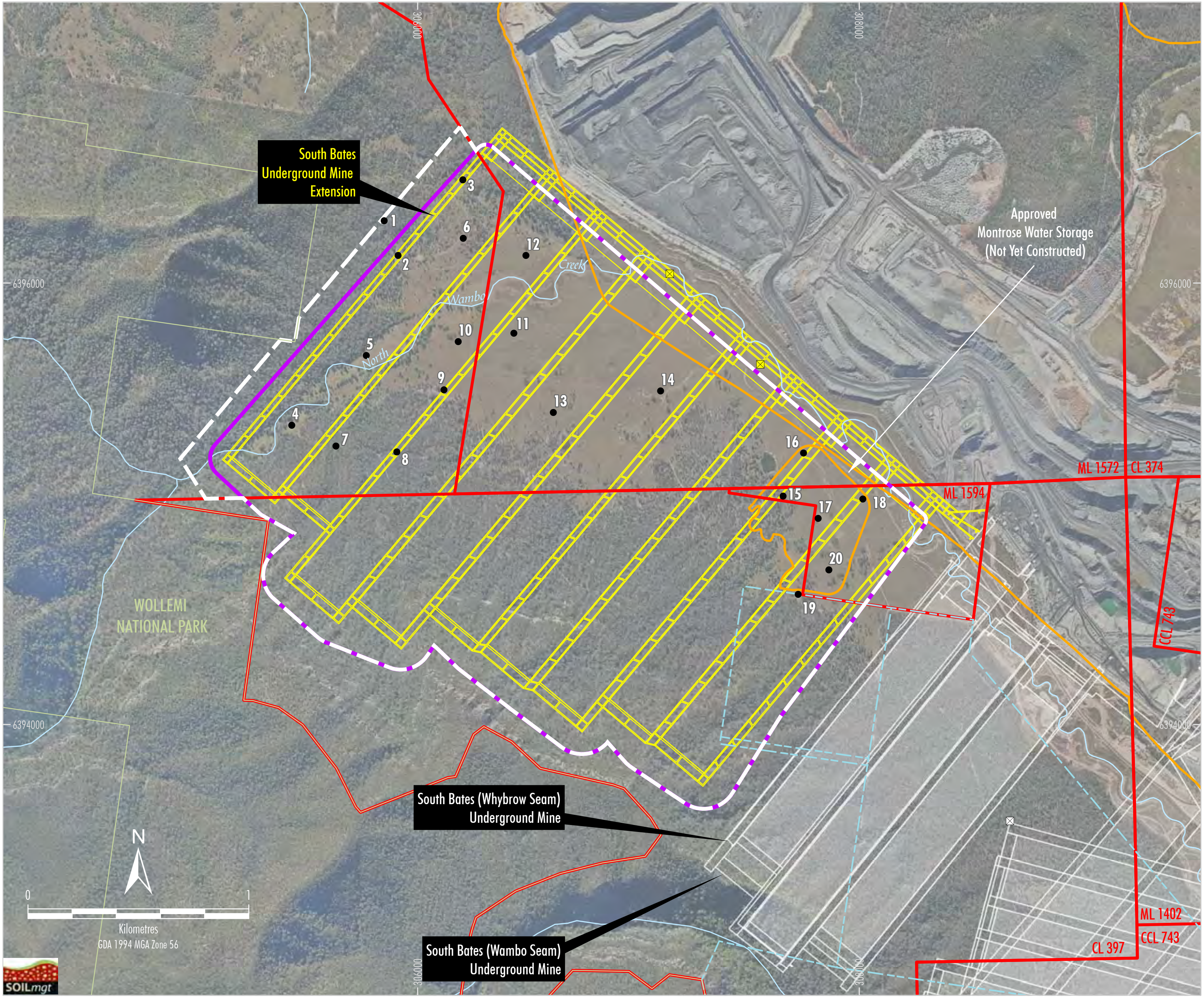
The Modification involves an extension of mining in the Whybrow Seam to the north-west of the approved South Bates Underground Mine to include nine additional longwall panels. The Modification would primarily involve use of the existing approved infrastructure at the South Bates Underground Mine, however the Modification would also involve the construction of new ventilation shafts, gas drainage infrastructure and other ancillary infrastructure.

There are no proposed changes to the approved ROM coal production rate from the underground operations, or overall ROM coal processing rate through the Coal Handling and Preparation Plant. The Modification would not change the open cut mining operations.

Additional details of the Modification are provided in Section 3 of the Environmental Assessment.

The "Modification Area" comprises the extent of conventional subsidence resulting from the modified longwall layout (Figure 3).

The "Study Area" is a larger area that incorporates the Modification Area and all the soil test pits surveyed for this Agricultural Resources Assessment (Figure 3). The Study Area is approximately 550 hectares (ha).



LEGEND

- Mining and Coal Lease Boundary
- National Park Boundary
- Existing/Approved Surface Development Area
- Approved Underground Development
- Modified Underground Development
- Extent of Conventional Subsidence from the Modified Underground Development
- Study Area
- Approved Ventilation Shaft
- Modified Ventilation Shaft
- Remnant Woodland Enhancement Program (RWEP) Area
- Soil Test Pit

Source: *Department of Lands (July 2009); WCPL (2016); WCPL Orthophoto (July 2016)*

Peabody ENERGY

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

Soil Pit Locations

Figure 3

WAM-09-15_SBEM_ARA_202E

3. DESCRIPTION OF THE WAMBO AREA

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. 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 (Figure 2).

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 Study Area from the south-west to north-east (Figure 2).

Elevations in the broader area range from approximately 60 metres (m) Australian Height Datum (AHD) near Wollombi Brook to approximately 320 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 at Mount Wambo within the Wollemi National Park (Figure 2). Elevations within the Study Area range from approximately 100 m AHD in the north-east to 320 m AHD in the south-east (Map 1a).

Land use in the vicinity of Wambo is characterised by a combination of coal mining operations, Remnant Woodland Enhancement Programme (RWEP) areas, agricultural land use and WCPL-owned lands that are not subject to mining operations (Figure 2). The latter areas are 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).

Land uses in the Study Area include coal mining operations, RWEP Area D, 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 Bulga and Doyles Creek are 692 millimetres (mm) and 647 mm, respectively (Bureau of Meteorology, 2016).

4. SOIL RESOURCES

4.1. Review of Existing Soil Survey Information

The following existing soil resource information relevant to the Study Area was reviewed for this report:

- *Hunter Coalfield Regional 1:100,000 Geology Map* (Glen and Beckett 1993);
- Soil Profile Attribute Data Environment (eSPADE) soil profiles (part of the NSW Natural Resource Atlas [2016]);
- Regional soil type and landscape mapping (Kovac and Lawrie 1991);
- *Agricultural Resource Assessment: "Montrose Water Storage"*, Wambo NSW (McKenzie Soil Management 2012); and
- Acid sulfate soil risk map data (part of the NSW Natural Resource Atlas).

A 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 Study 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 Study Area with soil conditions significantly better than those derived from conglomerate and sandstone.

eSPADE Soil Profile Database

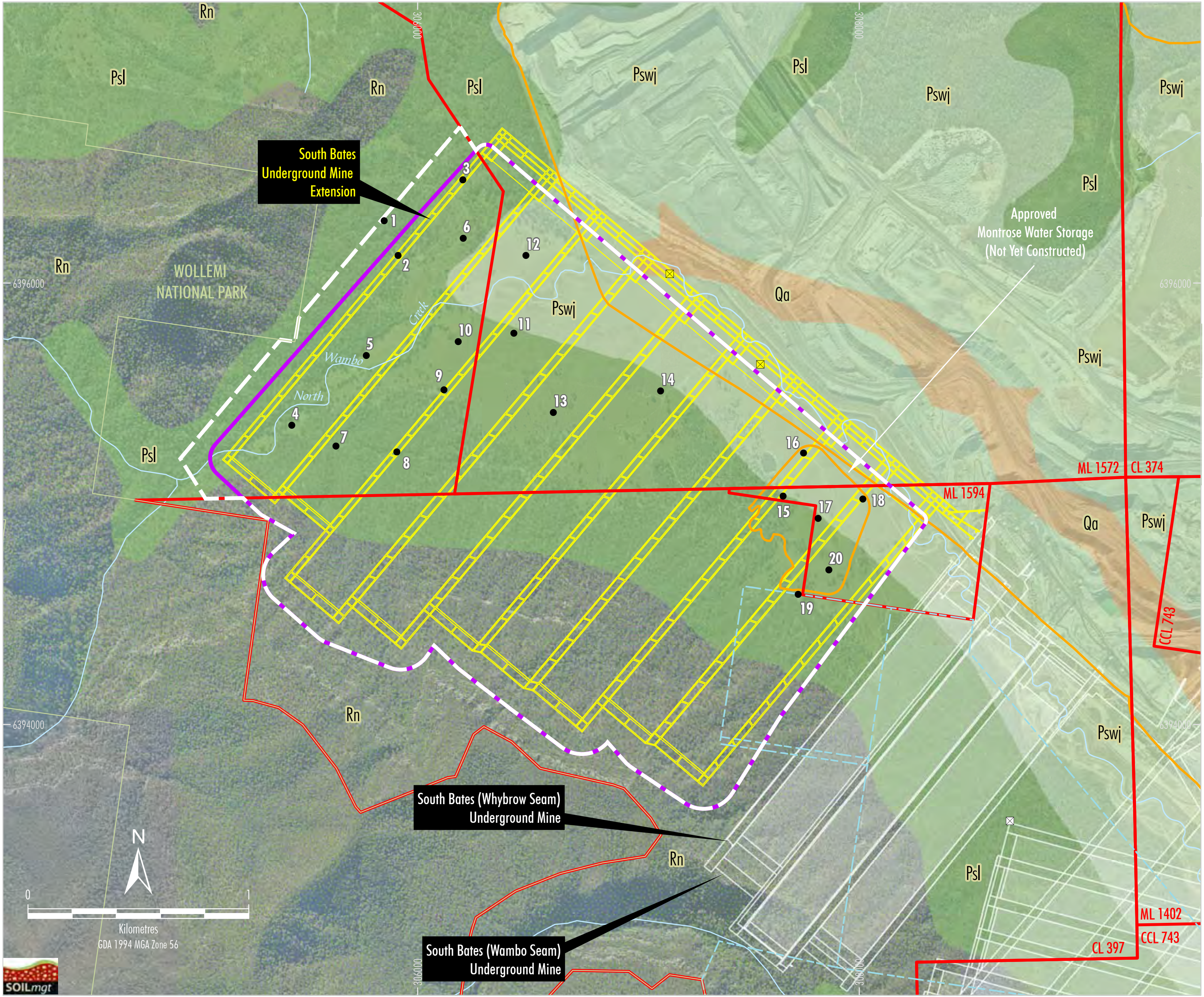
A search of the NSW Government's 'eSPADE' website (part of the NSW Natural Resource Atlas) was conducted to identify any existing soil profile information in the Study Area. No eSPADE soil profiles could be found in the Study Area.

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 Study Area.

Two soil landscape units were identified within the Study Area (i.e. Bulga Soloths and Lees Pinch Shallow) (Figure 5). Five soil landscape units were identified in the vicinity of the Study Area (i.e. Benjang Solodic, Jerrys Plains Soloths and Ogilvie Shallow [shown on Figure 5] as well as, Wollombi Alluvial and Branxton Yellow Podzolic[1] [described in Table 1]).

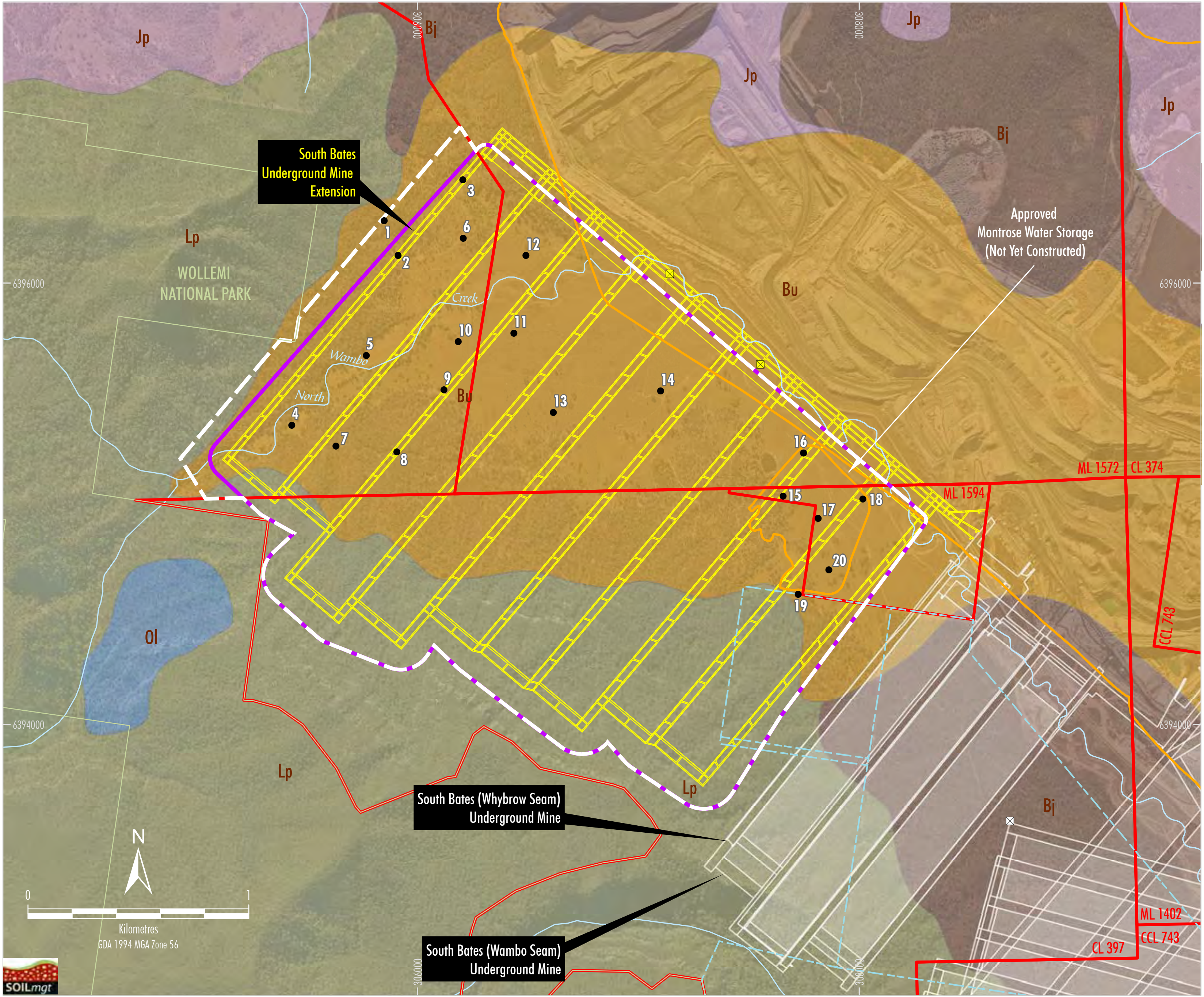
[1] Wollombi Alluvial and Branxton Yellow Podzolic Soils were identified within the vicinity of Wambo, but outside the extent shown on Figure 5.



Regional Geology Mapping

Figure 4

WAM-09-15_SBEM_ARA_204E



WAM-09-15_SBEM_ARA_205C

LEGEND
Mining and Coal Lease Boundary
National Park Boundary
Existing/Approved Surface Development Area
Approved Underground Development
Modified Underground Development
Extent of Conventional Subsidence from the Modified Underground Development
Study Area
Approved Ventilation Shaft
Modified Ventilation Shaft
Remnant Woodland Enhancement Program (RWEP) 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 (July 2016)*

Peabody ENERGY

WAMBO COAL MINE

Regional Soil Landscape Mapping

Figure 5

All seven soil landscape units are described in Table 1 (Kovac and Lawrie 1991). The descriptions of these units indicate the presence of soil conditions that generally are poor for plant growth (Table 1).

Table 1. Soil Landscape Units (Kovac and Lawrie 1991) Mapped in the vicinity of the Study 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.
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.
Jerrys Plains Soloths (**Jp**)	Soloths on crests to midslopes with Solodic Soils on lower slopes and in drainage lines. Red Earths on some upper slopes, Brown Clays in midslope depressions and some Solodised Solonetz on poorly drained slopes.	Poor aeration in subsoils when wet, very hard when dry. Prone to water erosion when bare.
Ogilvie Shallow Soils (**Ol**)	Lithosols associated with steep hills and escarpments, and Brown Solodic Soils on the lower slopes.	Very poor water holding capacity, and prone to water erosion when bare.
Wollombi Alluvial Soils (**Wo**)	Layered alluvial soils (sands and earthy sands).	Poor water holding capacity, acidity and a lack of nutrients. Prone to wind erosion.
Branxton Yellow Podzolic Soils (**Bx**)	Yellow Podzolic Soils on midslopes with Red Podzolic Soils on crests; Yellow Soloths on lower slopes.	Poor aeration in subsoils when wet, very hard when dry. Prone to water erosion when bare.

Agricultural Resource Assessment: "Montrose Water Storage"

McKenzie Soil Management (2012) prepared *Agricultural Resource Assessment: "Montrose Water Storage"* which included six soil pits in the footprint of the Montrose Water Storage (approximately 24 ha) (Figure 3).

The site inspection and soil survey was carried out on 29 to 30 May 2012 (the 2012 survey). Six backhoe pits (approximately 1.4 m deep; shallower where hard rock was encountered) were assessed across the Montrose Water Storage area. The pits were located in a way that covered as many of the major variations in elevation and landforms as possible.
As these soil pits are also located within the Study Area, they have been included in this Agricultural Resource Assessment.

Acid Sulfate Soil Mapping

The acid sulfate soil risk map data (part of the NSW Natural Resource Atlas) were reviewed for the Modification. No acid sulfate soils are mapped within the vicinity of the Study Area and therefore mapping has not been reproduced in this report.

No acid sulfate soils were observed during the soil survey.

Given the above, the *Acid Sulfate Soils Manual* (Stone *et al.* 1998) and the *Acid Sulfate Soils Laboratory Methods Guidelines* (Ahern *et al*. 2004) have not been considered further.

4.2. Soil Survey Methodology

This section provides a description of the soil survey conducted by Soil Management Designs in the Study Area in August 2016 (the 2016 survey). This section also includes details of the 2012 survey where relevant.

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.

In addition, the 2016 survey considered the requirements of the *Interim protocol for site verification and mapping of biophysical strategic agricultural land* (Interim Protocol).

Soil Survey

The 2016 survey was conducted on 1 and 2 August 2016 and involved survey of 14 soil pit profiles excavated 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 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.

The soil depth intervals sampled in this survey were 0 to 5 centimetres (cm), 5 to 15 cm, 15 to 30 cm, 30 to 60 cm, and 60 to 100 cm, as per the Interim Protocol (NSW Government 2013).

The same method was adopted for the 2012 survey, with the exception of the soil depth intervals (refer to McKenzie Soil Management [2012] for more detail if required). The soil depth intervals sampled in the 2012 survey were 0 to 15 cm, 15 to 30 cm, 30 to 60 cm and 60 to 90 cm.

Soil Pit Locations

Surface contour and slope information (Maps 1a and 1b) interpreted from detailed LiDAR data obtained by WCPL was used to assist with locating sampling sites.

Soil pit locations selected for the 2016 survey were mainly in the western part of the Study Area as there had been no previous surveys in this area. The soil pits were located in a way that covered as many of the major variations in elevation and landforms as possible and focussed on existing agricultural areas.

Field Soil Observations/Testing

The 1.4 m deep pit profiles were excavated with a backhoe 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).

Factors noted at each soil pit included current land use, landform (landscape position and element), slope (measured with a SUUNTO clinometer), aspect, and surface rock. The occurrence of outcropping bedrock was negligible[2] and no gilgai features were observed in the Study 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) for each horizon. 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. Where the soil depth intervals shown in Attachment C included two horizons, the smallest (i.e. the most limiting for root growth) of the two SOILpak scores was used for mapping (see Map 8).

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).

---

[2] No rock outcropping was observed at the Soil Pits 1 to 20.

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

The field methods used for the 2016 survey were very similar to those used for the 2012 survey (refer to McKenzie Soil Management [2012] for more detail if required).

Laboratory Soil Testing

All soil pits were sampled for laboratory analysis. The sampling soil depth intervals for laboratory analysis of Soil Pits 1 to 14 (2016 survey) were as per the Interim Protocol (i.e. 0 to 5 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.

Soil Pits 15 to 20 (2012 survey) had data for the soil depth intervals 0 to 15 cm, 15 to 30 cm, 30 to 60 cm and 60 to 90 cm.

To allow a standardised and clear approach for mapping of all 20 soil pits (Maps 7a to 13), the laboratory data recorded for the 0 to 5 cm and 5 to 15 cm soil intervals for Soil Pits 1 to 14 (2016 survey) were combined to provide values for one soil interval (i.e. 0 to 15 cm) through a weighted averaging procedure[3].

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).

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.

The laboratory results are presented in Attachment D.

[3] The original laboratory data for Soil Pits 1 to 14 are presented in Attachment D.

The laboratory methods used for the 2016 survey were very similar to those used for the 2012 survey (refer to McKenzie Soil Management [2012] for more detail if required).

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

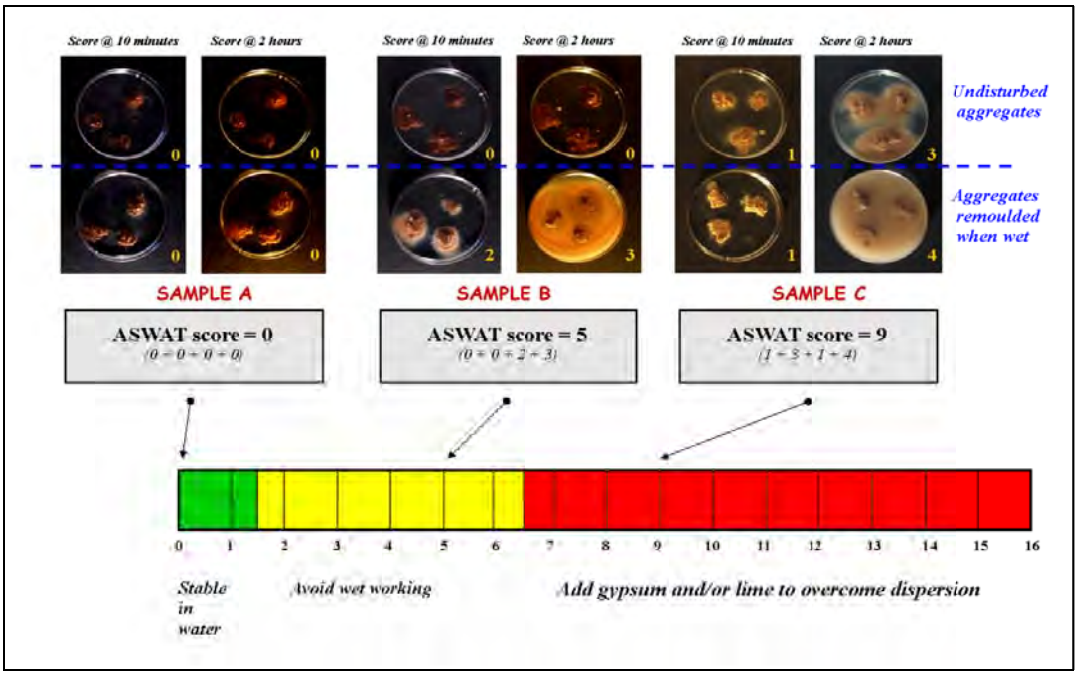


Figure 6. The Link between ASWAT Results and Soil Management Options

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.
Map 10. Salinity (Electrical Conductivity - ECe).
Map 11. pH ($CaCl_2$).
Map 12. Phosphorus (Colwell P).
Map 13. Organic Carbon.

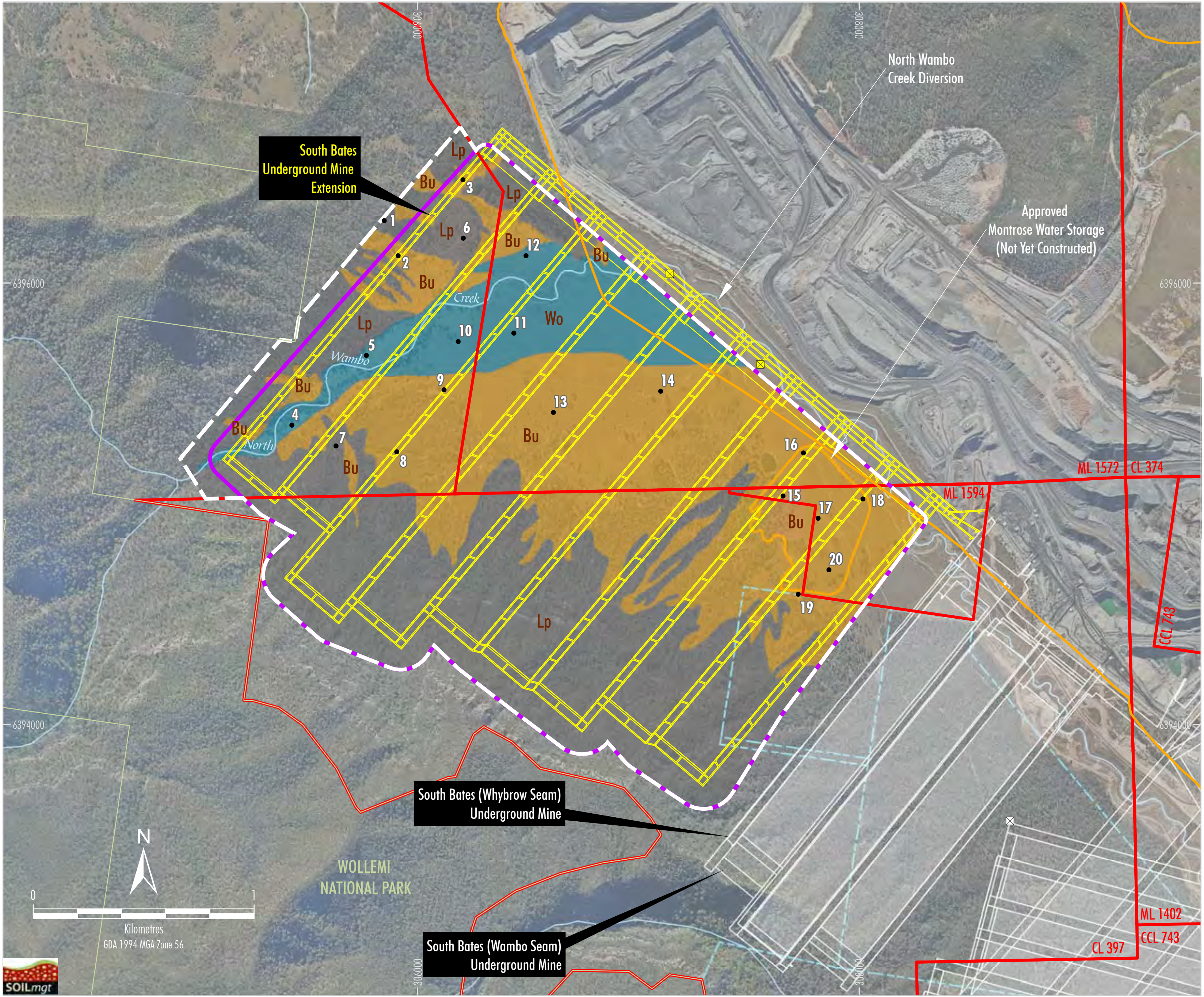
4.3. Soil Types and Mapping

Soil Landscape Units

Soil Landscape Units identified in the Study Area that host the soil types described in the next section are shown 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).

Table 3. Soil Types Associated with the Soil Landscape Units

Soil Landscape Unit	Number of Described Sites	Map Code	Dominant or Co-dominant Soil Types	Additional Comments
Wollombi Alluvial Soil (**Wo**)	5	Wo	Stratic Rudosol (5 of 5 soil pits)	Deep young soil with favourable physical subsoil conditions for root growth; derived from alluvium associated with North Wambo Creek.
Bulga Soloths (**Bu**)	12	Bu	Sodosol (7 of 12 soil pits)	Poor root growth in much of the subsoil due to sodicity.
Lees Pinch Shallow Soils (**Lp**)	3	Lp	Sodosol, Chromosol, Kandosol	Soil that is mostly shallow/stony and with restricted water holding capacity; generally in areas with slope >10%.



LEGEND

- Mining and Coal Lease Boundary
- National Park Boundary
- Existing/Approved Surface Development Area
- Approved Underground Development
- Modified Underground Development
- Extent of Conventional Subsidence from the Modified Underground Development
- Study Area
- Approved Ventilation Shaft
- Modified Ventilation Shaft
- Remnant Woodland Enhancement Program (RWEP) Area
- Soil Test Pit

Soil Landscape Units

- Bu Bulga Soloths
- Lp Lees Pinch Shallow
- Wo Wollombi Alluvial

Source: Department of Lands (July 2009); WCPL (2016); WCPL Orthophoto (July 2016)

WAM-09-15_SBEM_ARA_207F

Peabody ENERGY

WAMBO COAL MINE

Soil Landscape Units

Figure 7

At least three detailed soil pits were undertaken for all of the Soil Landscape Units recorded in the Study Area.

ASC Soil Types

The ASC (Isbell 2002) has been used to determine soil types at each of the 20 observation soil pits (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 soil pits 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 soil pits are shown in Attachment E.

Soil profile photographs for the 20 soil pits are presented 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	8	Soloths and Solodic Soils
Rudosol	7	Alluvial Soils
Kandosol	3	Calcareous Red Earths
Chromosol	1	Red-Brown Earths, Non-calcic brown soils
Tenosol	1	Lithosols

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.
- Kandosols lack strong textural contrast and have a massive or only weakly structured B horizon.
- 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.
- Tenosols at this location are shallow and have only weak pedological development.

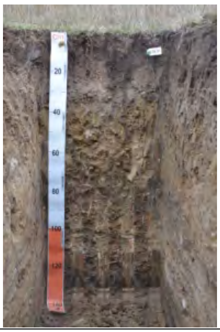
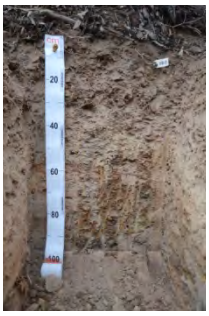
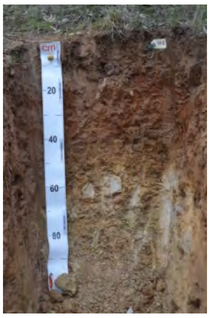
Soil Landscape Unit	Dominant or Co-dominant Soil Types	Landscape View
Wollombi Alluvial Soil	Pit 11: Stratic Rudosol 	Site 11 
Bulga Soloths	Pit 14: Sodosol 	Site 14 
Lees Pinch Shallow Soils	Pit 7: Sodosol  Pit 1: Chromosol  Pit 6: Kandosol 	Site 7  Site 1  Site 6 

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

4.4. Soil Conditions for Plant Growth

Soil Depth, Texture and Waterholding Capacity

The impact across the Study 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 Study Area, the lack of water holding capacity in shallow/stony soils is a significant constraint to agricultural productivity.

The deeper (i.e. greater depth to rock) alluvial soil present in the Wollombi Alluvial soil landscape unit (see Map 3) tended to have very good water holding capacity (Map 4) because of a combination of minimal coarse fragments and favourable soil structure.

Waterlogging Hazard

Much of the sodic subsoil (ESP>6) in non-alluvial sections of the Study 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. All soil pits recorded an absence of lime in the upper 140 cm, except for Soil Pit 3.

Soil Stability in Water – Dispersion and Slaking

Poor soil structure in the Study 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 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 top soil (0-15 cm), sub-surface (15-30 cm) and subsoil (30-60 cm) across the Study Area (Map 7a). 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 (ESP in the range 3 to 6), aggravated by low electrolyte concentrations (Levy 2000). Map 7b shows that non-alluvial soils had higher ESP values than alluvial soils.

The Electrochemical Stability Index [ESI]; EC÷ESP for the Modification Area is presented on Map 7c. The ESI values in the deeper soil (i.e. 60 to 90 cm and 60 to 100 cm intervals) and non-alluvial soils were generally lower than alluvial soils (Map 7c).

Compaction Status

Compaction was assessed using the SOILpak scoring system. Most of the alluvial soil (Stratic Rudosols) in the Study Area had a favourable soil structural form (i.e. high SOILpak score) (Soil Pits 4, 5, 10, 11 and 12) (Map 8). 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 (McKenzie 1998). The CEC values greater than 15 milliequivalents per 100 grams (meq/100 g) tend to be associated with significant shrinkage. Much of the non-alluvial soil in the Study Area had a moderately favourable capacity for self-repair capacity via shrink-swell processes (Map 9), but the benefits are short-lived when the soil develops poor structural form because of dispersion in water.

Salt Concentrations

Subsoil salinity was an important constraint to plant growth in Sodosols associated with the 'Bulga' soil landscape unit in the Study Area (i.e. Soil Pits 2, 3, 9, 13, 15 and 19) (Map 10).

pH Imbalance

Most soil pits in the Study Area had favourable near-neutral pH (Map 11), but Soil Pits 2, 8, 15 and 19 had near-surface acidity that is likely to respond well to the application of agricultural lime.

Nutrients

The topsoil and subsoil in the Study 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 Attachment D generally 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 Study 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 most of the non-alluvial sections of the Study Area:

- poor waterholding capacity in shallow/stony soils;
- waterlogging in subsoil;
- dispersive top soil, sub-surface soil and subsoil;
- compaction in subsoil;
- subsoil salinity at six soil pits;
- near-surface acidity at four soil pits;
- nutrient deficiency in topsoil and subsoil; and
- poor organic content in deeper layers of soil.

The alluvial soil in the Study 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.

5. AGRICULTURAL RESOURCES

Strategic Agricultural Land

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 Study Area (Figure 9).

The Study Area is not located within mapped Viticulture Critical Industry Clusters (Figure 9). The closest Viticulture Critical Industry Cluster is located approximately 7.5 km to the south-east of the Study Area (Figure 9).

A Site Verification Report (Soil Management Designs 2016) was prepared to support a Site Verification Certificate Application for the component of the Study Area outside existing mining tenements (which includes Soil Pits 1 to 10). The Site Verification Report was prepared in accordance with the Interim Protocol (NSW Government 2013). The Site Verification Certificate Application was submitted on 19 October 2016 and subsequently granted on 23 November 2016. The Site Verification Certificate confirmed there was no BSAL within the Site Verification Certificate Application Area.

Land and Soil Capability

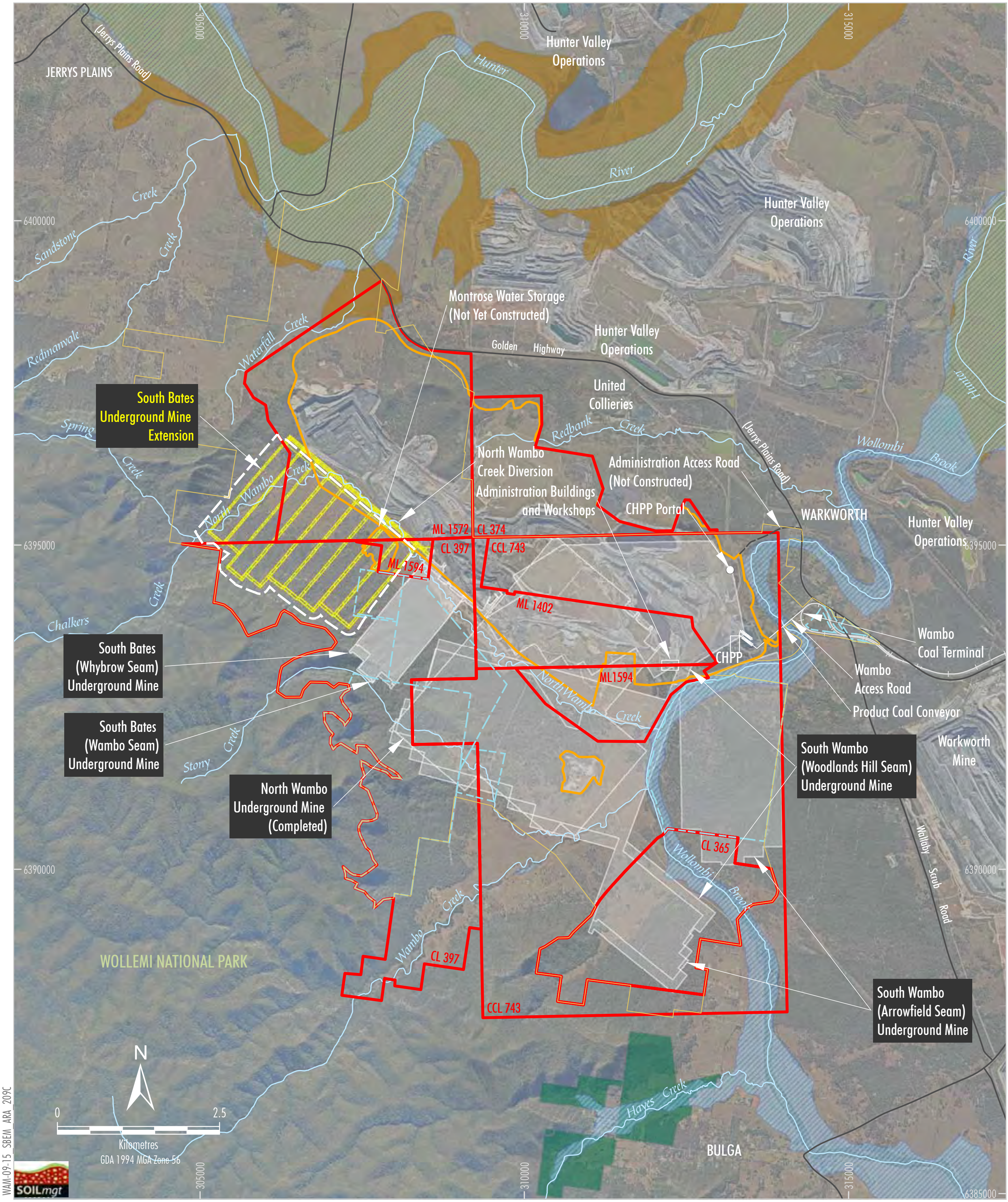
The *Land and Soil Capability Assessment Scheme – Second Approximation* (Office of Environment and Heritage [OEH] 2012) uses the biophysical features of the land and soil including landform position, slope gradient, drainage, climate, soil type and soil characteristics to derive detailed rating tables for a range of land and soil hazards (OEH 2012). The Land and Soil Capability (LSC) class gives an indication of the land management practices that can be applied to a parcel of land (OEH 2012). The LSC classes are outlined below.

Land capable of a wide variety of land uses (cropping, grazing, horticulture, forestry, nature conservation)

Class 1: Extremely high capability land: Land has no limitations. No special land management practices required. Land capable of all rural land uses and land management practices.

Class 2: Very high capability land: Land has slight limitations. These can be managed by readily available, easily implemented management practices. Land is capable of most land uses and land management practices, including intensive cropping with cultivation.

Class 3: High capability land: Land has moderate limitations and is capable of sustaining high-impact land uses, such as cropping with cultivation, using more intensive, readily available and widely accepted management practices. However, careful management of limitations is required for cropping and intensive grazing to avoid land and environmental degradation.



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
- Study 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: DP&I (January 2014); Department of Lands (July 2009); WCPL (2016); WCPL Orthophoto (July 2016)

Figure 9

Land capable of a variety of land uses (cropping with restricted cultivation, pasture cropping, grazing, some horticulture, forestry, nature conservation)

Class 4: Moderate capability land: Land has moderate to high limitations for high-impact land uses. Will restrict land management options for regular high-impact land uses such as cropping, high-intensity grazing and horticulture. These limitations can only be managed by specialised management practices with a high level of knowledge, expertise, inputs, investment and technology.

Class 5: Moderate–low capability land: Land has high limitations for high-impact land uses. Will largely restrict land use to grazing, some horticulture (orchards), forestry and nature conservation. The limitations need to be carefully managed to prevent long-term degradation.

Land capable for a limited set of land uses (grazing, forestry and nature conservation, some horticulture)

Class 6: Low capability land: Land has very high limitations for high-impact land uses. Land use restricted to low-impact land uses such as grazing, forestry and nature conservation. Careful management of limitations is required to prevent severe land and environmental degradation.

Land generally incapable of agricultural land use (selective forestry and nature conservation)

Class 7: Very low capability land: Land has severe limitations that restrict most land uses and generally cannot be overcome. On-site and off-site impacts of land management practices can be extremely severe if limitations not managed. There should be minimal disturbance of native vegetation.

Class 8: Extremely low capability land: Limitations are so severe that the land is incapable of sustaining any land use apart from nature conservation. There should be no disturbance of native vegetation.

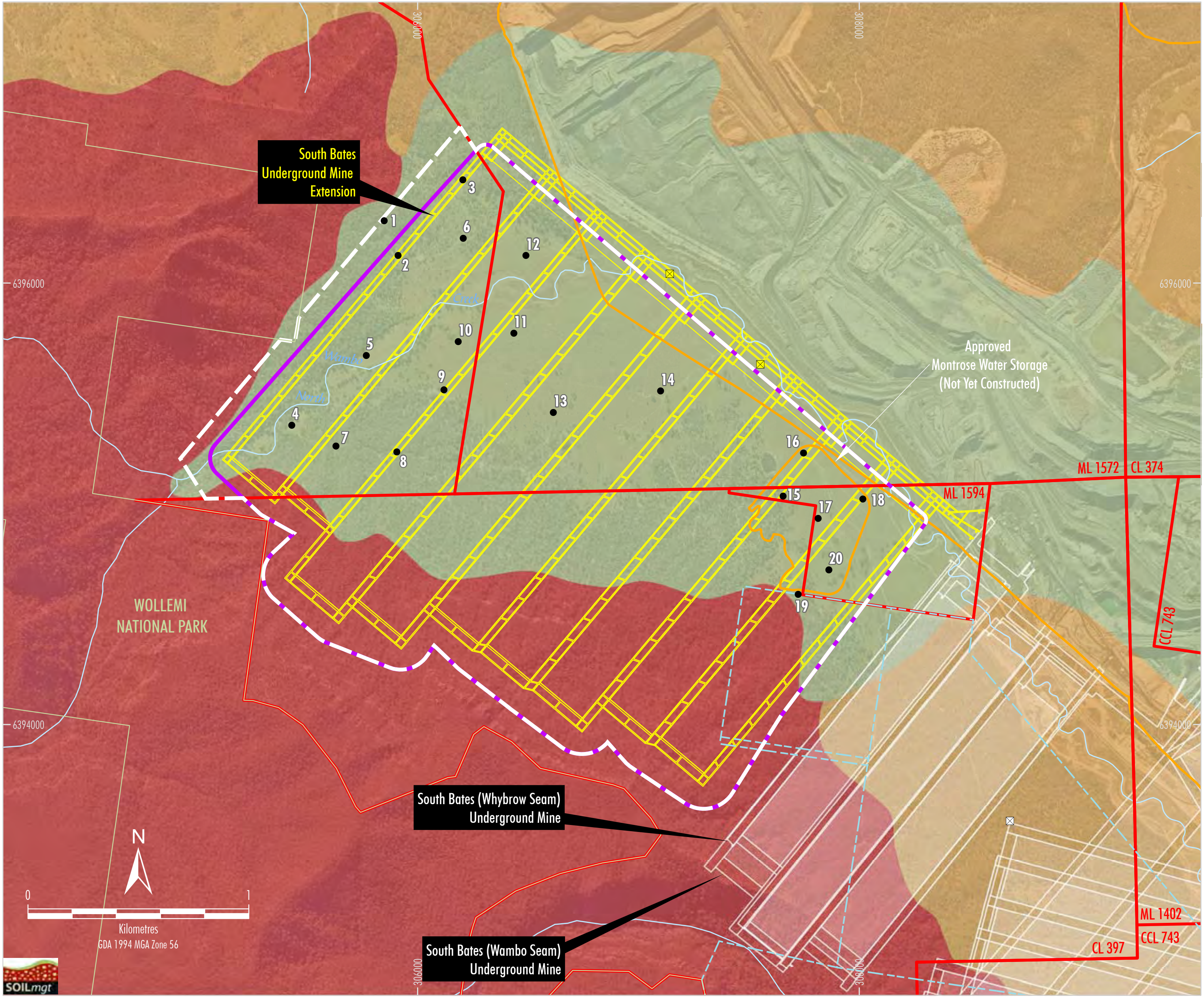
Regional LSC mapping prepared by the OEH (2012) is presented in Figure 10. The Study Area is mapped primarily as LSC Class 4 and a small portion of Class 7 in the south.

Agricultural Land Uses

The Study Area consists of cleared agricultural land, approved mining areas and remnant vegetation (Figure 3). The cleared agricultural areas include both native and introduced pasture species. Pasture productivity was greater on the deep well-drained alluvial soil (Stratic Rudosols) than on the upslope sodic areas.

Agricultural Productivity

The main agricultural land uses in the vicinity of Wambo include dairy and beef cattle and pasture production, horse breeding, viticulture and wine making (NSW Government, 2012).



LEGEND
- Mining and Coal Lease Boundary
- National Park Boundary
- Existing/Approved Surface Development Area
- Approved Underground Development
- Modified Underground Development
- Extent of Conventional Subsidence from the Modified Underground Development
- Study Area
- Approved Ventilation Shaft
- Modified Ventilation Shaft
- Remnant Woodland Enhancement Program (RWEP) Area
- Soil Test Pit

Regional LSC Mapping
- Class 4
- Class 5
- Class 7

Source: *Department of Lands (July 2009); WCPL (2016); WCPL Orthophoto (July 2016); Office of Environment and Heritage (2012)*

Peabody ENERGY

WAMBO COAL MINE

Land and Soil Capability Mapping

Figure 10

WAM-09-15_SBEM_ARA_210C

Agricultural enterprises known to have been conducted on the Study Area include cattle grazing for beef production on rain-fed pastures. The Department of Primary Industries (DPI) Beef Gross Margin Budget for Coastal Weaners on Native and Improved Pasture (DPI 2016) (www.dpi.nsw.gov.au/agriculture/budgets/livestock) provides up-to-date estimates of productivity in pastures across the Study Area. The productivity of these agricultural enterprises is summarised in Table 5.

Table 5. Approximate Productivity of the Agricultural Enterprises on the Study 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 of agricultural areas within the Modification	4	117.39
Beef cattle grazing (weaners) on medium productivity "improved" pastures; alluvial zones ('Wollombi Alluvial Soils')	8	346.72

It was observed during the field work in 2012 and 2016 that the alluvial zone ('Wollombi Alluvial Soils'; LSC Class 4) had much better growth of native and introduced pasture species than the shallower sodic soil. This occurred despite the alluvial zone nutritional limitations noted in Section 4.4. Therefore, two categories have been included in Table 5.

6. AGRICULTURAL RESOURCES IMPACT ASSESSMENT

6.1. Potential Impacts

Potential impact mechanisms on agricultural resources as a result of the Modification are likely to be associated with:

- loss of productive agricultural land due to additional minor surface development in the Study Area; and
- subsidence-related impacts.

Surface Development

The proposed ventilation infrastructure for the Modification would be located within the approved surface development area and therefore would result in no additional impacts on agricultural resources beyond the approved operations.

The Modification would result in additional minor surface development (approximately 2 ha) to allow for construction of gas drainage infrastructure and other ancillary infrastructure. The surface development areas would mostly consist of derived grassland (FloraSearch 2016), suitable for agricultural uses (i.e. grazing). The remainder of the surface development areas are vegetated (FloraSearch 2016) (i.e. trees) and would not be suitable for agricultural uses. Agricultural land in the surface development areas consist primarily of LSC Class 4 (Figure 10).

Following the cessation of mining, surface infrastructure would be decommissioned and the disturbed land would be rehabilitated to woodland or agricultural areas suitable for grazing. As such, disturbance associated with the Modification surface infrastructure would result in either temporary or permanent impacts to potential agricultural production on WCPL owned land depending on the selected final land use.

Additional surface development for gas drainage infrastructure and other ancillary infrastructure would occur progressively over the life of Wambo. The locations of gas drainage infrastructure are flexible and would be located in order to minimise potential impacts on agricultural productivity (e.g. by avoiding fence lines and farm dams). Any surface development associated with gas drainage infrastructure would be progressively rehabilitated over the life of Wambo.

These potentially impacted agricultural lands are not BSAL mapped in the Mining SEPP (Section 5). 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 Study Area (Figure 9).

The additional minor surface development at Wambo would result in the following potential impacts to soil resources:

- disturbance of *in situ* soil resources;
- alteration of soil structure beneath infrastructure items;

- increased erosion and sediment movement due to exposure of soils during construction; and
- alteration of physical and chemical soil properties (e.g. structure, permeability, nutrient status and microbial activity) due to soil stripping and stockpiling operations.

Subsidence

Subsidence is the vertical and horizontal movement of the overburden and land surface as a result of the extraction of underlying coal. These land surface movements are generically referred to as subsidence effects. The type and magnitude of the subsidence effects is dependent on a range of variables (e.g. mine geometry, topography and geology).

Mine Subsidence Engineering Consultants (MSEC) (2016) has assessed the potential subsidence impacts of the Modification (i.e. inclusion of nine additional longwall panels [Longwalls 17 to 25] in the Whybrow Seam) within the Study Area. These longwalls are considered the 'additional mining layout' as they are located adjacent to Longwalls 11 to 16 at the existing South Bates Underground Mine (Figure 2) (MSEC 2016).

Table 6 presents the predicted subsidence effects from the additional mining layout (Whybrow Seam).

Table 6. Predicted Subsidence Effects for the Additional Mining Layout

Layout	Maximum Predicted Total Conventional Subsidence (mm)	Maximum Predicted Total Conventional Tilt (mm/m)	Maximum Predicted Total Conventional Hogging Curvature (km^{-1})	Maximum Predicted Total Conventional Sagging Curvature (km^{-1})
Additional Mining Layout (Whybrow Seam)	1,950	90	> 3.0	> 3.0

Source: MSEC (2016).
mm = millimetre.
mm/m = millimetre per metre.
km^{-1} = per kilometre.

The type and magnitude of predicted subsidence effects for the additional mining layout are generally similar to or less than the previously approved underground developments at Wambo.

Subsidence may impact the integrity of agricultural infrastructure (e.g. fences) and potential impacts on soils and agricultural productivity would be associated with the following potential subsidence impacts:

- surface cracking;
- slope instability;
- ponding and changes in stream alignment; and
- ponding in poorly drained areas.

Notwithstanding, it is 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, there is a low potential for material impact to agricultural productivity in the Study Area.

The closest mapped BSAL is located approximately 2 km to the north of the Study Area and would not be impacted by subsidence associated with the Modification.

WCPL would implement mitigation and management measures to minimise potential risks to land uses as described in Section 6.2.

Given the above, it is considered that the Modification would not have any significant adverse impacts on agricultural production in the Study Area.

6.2. Management Measures

Agricultural land resource management should include the following key components:

- minimisation of disturbance to agricultural lands, where practicable;
- continued use of adjoining WCPL-owned land for agricultural uses, where practicable;
- management of soil resources so that they can be used for rehabilitation; and
- inclusion of agricultural lands in the Wambo rehabilitation strategy.

The area of agricultural land disturbed at any one time should be minimised so that beneficial agricultural uses can continue to be undertaken on available WCPL grazing lands. As demonstrated by WCPL at Wambo, grazing agricultural activities can be readily undertaken in conjunction with the operation of a mine.

To minimise the potential direct impacts of the Modification on agricultural production, WCPL-owned agricultural lands that adjoin Wambo should continue to be subject to agricultural use.

Soil resource management measures that should be used are described below.

Following the cessation of mining, surface infrastructure should be decommissioned and the disturbed land should be rehabilitated to woodland or agricultural areas suitable for grazing.

Subsidence Impact Management

The existing South Bates Underground Mine Extraction Plan (WCPL 2016) includes the following management measures in relation to potential land resource impacts:

- Notification to agistees of areas of longwall mining and active subsidence, and exclusion of agistment grazing from areas where surface cracking presents a reasonable risk to people and/or livestock.

- Remediation of surface cracks[4] where practicable using conventional earthmoving equipment (e.g. a backhoe) including:
  - infilling of surface cracks with soil or other suitable materials; or
  - locally re-grading and re-compacting the surface where hill steepness and water erosion hazard has increased.
- Stabilisation of any areas of surface cracking using erosion protection measures (e.g. vegetation planting or gypsum application in erosion-prone sodic areas).
- Drainage works and rehabilitation of subsidence troughs (i.e. areas of induced ponding) as necessary. Where new ponds are useful as stock watering points, however, consideration will be given to their retention.
- Repair of fences prior to allowing access for agistment grazing.
- Measures to stabilise/mitigate impacts to rock faces/cliffs if considered beneficial and practicable in consultation with the Department of Planning and Environment and the Department of Industry – Division of Resources and Energy (e.g. artificial rock support, standing supports, dislodgement of remaining loose rock etc.).
- Management measures in accordance with the Erosion and Sediment Control Plan.

An Extraction Plan should be developed for the Modification Area with similar management measures.

Soil Resource Management

General soil management practices for the Modification surface development areas should include the stripping and stockpiling of soil resources for use in rehabilitation. The objectives of soil resource management at Wambo should be to:

- identify and quantify potential soil resources for rehabilitation;
- optimise the recovery of usable soil reserves during soil stripping operations;
- preferentially replace stripped soil directly on completed sections of the final landform;
- manage soil reserves so as not to degrade the resource when stockpiled; and
- establish effective soil amelioration procedures to maximise the availability and suitability of soil reserves for future rehabilitation works.

The following management measures should be implemented during the stripping of soils at Wambo:

- Areas of disturbance requiring soil stripping should be clearly defined following vegetation clearing.
- Areas of disturbance should be stripped progressively, as required, to reduce potential erosion and sediment generation, and to minimise the extent of topsoil stockpiles and the period of soil storage.

[4] Minor cracks that develop are not expected to require remediation as geomorphologic processes will result in the natural filling of these cracks over time.

- Topsoil and subsoil stripping during periods of high soil moisture content (i.e. following heavy rain) should be avoided to reduce the likelihood of damage to soil structure.
- In preference to stockpiling, wherever practicable, stripped soil should be directly replaced on completed sections of the final landforms.

Any long-term soil stockpiles should be managed to maintain long-term soil viability through the implementation of the following management practices:

- Soil stockpiles should be retained at a height of 2 m, with slopes no greater than 1:2 (vertical:horizontal) and a slightly roughened surface to minimise erosion.
- Topsoil stockpiles should be constructed to minimise erosion, encourage drainage, and promote revegetation.
- Wherever practicable, soil should not be trafficked, deep ripped or removed in wet conditions to avoid breakdown in soil structure.
- All topsoil and subsoil stockpiles should be protected with a non-persistent cover crop to reduce erosion potential as soon as practicable after completion of stockpiling. Where seasonal conditions preclude adequate development of a cover crop, stockpiles should be treated with a straw/vegetative mulch to improve stability.
- Soil stockpiles should be located in positions to avoid surface water flows. Silt stop fencing should be placed immediately down-slope of stockpiles until stable vegetation cover is established.
- An inventory of soil resources (available and stripped) at Wambo should be maintained and regularly reconciled with rehabilitation requirements.
- Weed control programmes should be implemented on soil stockpiles if required.

The Mining Operations Plan should be updated to describe the soil resource management measures that would be used for the Modification.

7. REFERENCES

Ahern CR, McElnea AE, Sullivan LA (2004) *Acid Sulfate Soils Laboratory Methods Guidelines* (Queensland Department of Natural Resources, Mines and Energy: Brisbane).

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

Bureau of Meteorology (2016) *Weather Station Directory,* Bureau of Meteorology Website, available at: http://www.bom.gov.au/climate/data/stations/.

Dent D, Young A (1981) *Soil Survey and Land Evaluation* (George Allen and Unwin: London).

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).

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

FloraSearch (2016) *South Bates Underground Mine Extension Flora Assessment.*

Frazier P, Jenkins R, Trotter T (2010) *Monitoring the effect of longwall mine subsidence on native vegetation and agricultural environments: ACARP project C15013* (Australian Coal Association Research Program: Brisbane).

Glen RA, Beckett J (1993) *Hunter Coalfield Regional Geology 1:100 000 (2nd ed.)* (Department of Industry, Resources and Energy: Sydney).

Hazelton P, Murphy B (2007) *Interpreting Soil Test Results: What Do All the Numbers Mean?* (New South Wales Department of Infrastructure, Natural Resources and Planning: Sydney).

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

Kovac M, Lawrie JM (1991) *Soil Landscapes of the Singleton 1:250 000 Sheet* (Soil Conservation Service of New South Wales: Sydney).

Levy GJ (2000) Sodicity. In M.E Sumner, *Handbook of Soil Science* (pp. G27-G63). Boca Raton, Florida: CRC Press.

McKenzie DC (ed.) (1998) *SOILpak for Cotton Growers, 3rd Edition* (New South Wales Agriculture: Orange).

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 (2013) *Visual soil examination techniques as part of a soil appraisal framework for farm evaluation in Australia*. *Soil and Tillage Research* **127**, 26-33.

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).

McKenzie Soil Management (2012) *Agricultural Resource Assessment: "Montrose Water Storage".*

Mine Subsidence Engineering Consultants (2016) *South Bates Extension Underground Mine Modification Subsidence Assessment*.

National Committee on Soil and Terrain (2009) *Australian Soil and Land Survey Field Handbook (3rd ed.)* (CSIRO Publishing: Collingwood).

New South Wales Department of Primary Industries (2016) *Livestock gross margin budgets*, available at: http://www.dpi.nsw.gov.au/agriculture/budgets/livestock.

New South Wales Government (2012) *Upper Hunter Strategic Regional Land Use Plan.* (Department of Planning and Infrastructure: Australia).

New South Wales Government (2013) *Interim protocol for site verification and mapping of biophysical strategic agricultural land* (Office of Environment and Heritage: Australia).

New South Wales Government (2016) NSW Natural Resource Atlas website. http://www.nratlas.nsw.gov.au.

Office of Environment and Heritage (2012) *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, Alymore AG (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: Melbourne).

Soil Management Designs (2016) *Site Verification Report: Wambo Coal Mine; Singleton, NSW.*

Stace HCT, Hubble GD, Brewer R, Northcote KH, Sleeman JR, Mulcahy MJ, Hallsworth EG (1968) *A Handbook of Australian Soils* (Rellim Technical Publications: Glenside SA).

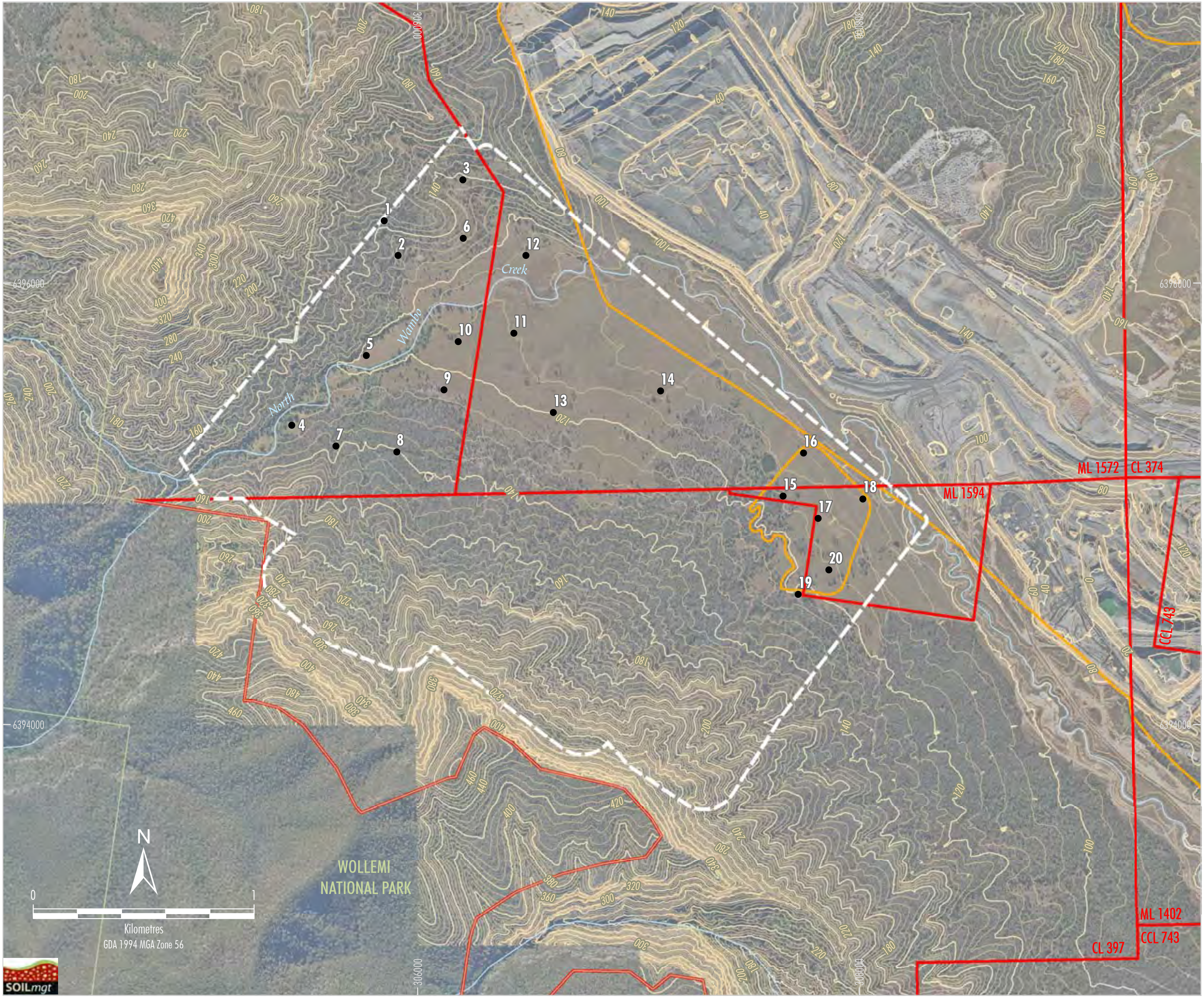
Stone Y, Ahern CR, Blunden B (1998) *Acid Sulfate Souls Manual 1998* (Acid Sulfate Soil Management Advisory Committee: Wollongbar).

Wambo Coal Pty Limited (2016) *Wambo Coal Mine South Bates (Whybrow Seam) Underground Mine Extraction Plan Longwalls 11 to 13.*

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

White RE (2006) *Principles and Practice of Soil Science: The Soil as a Natural Resource (4th ed.)* (Wiley-Blackwell: Carlton).

SOIL MAPS 1 TO 13



LEGEND
- Mining and Coal Lease Boundary
- National Park Boundary
- Existing/Approved Surface Development Area
- Study Area
- Surface Contour (5 m AHD)
- Soil Test Pit

Source: Department of Lands (July 2009); WCPL (2016); WCPL Orthophoto (July 2016)

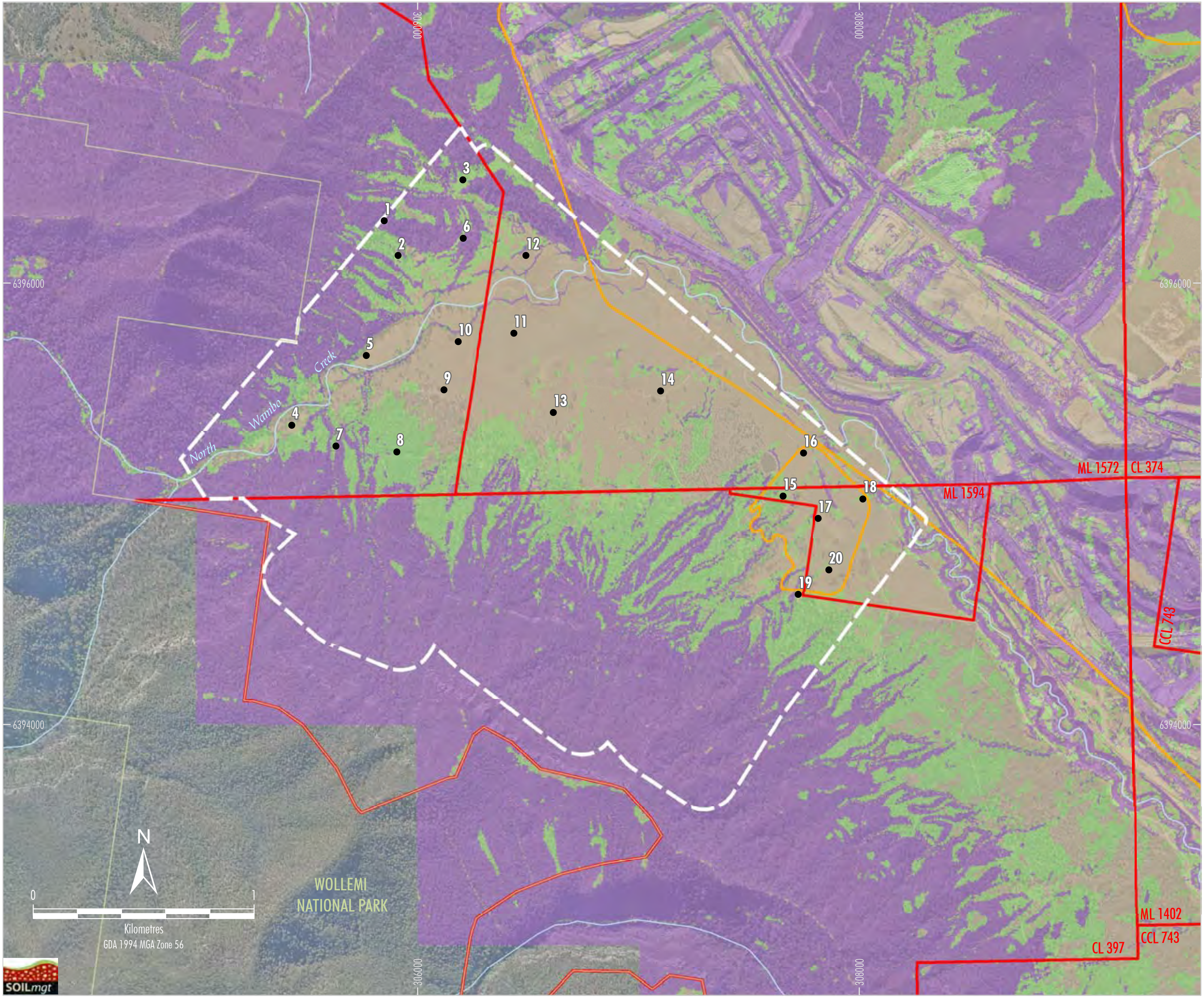
Peabody ENERGY

WAMBO COAL MINE

Surface Contours

Map 1a

WAM-09-15_SBEM_ARA_SM_215B



LEGEND

- Mining and Coal Lease Boundary
- National Park Boundary
- Existing/Approved Surface Development Area
- Study Area
- Soil Test Pit

Slope Categories

- Slopes < 5%
- Slopes 5% to 10%
- Slopes > 10%

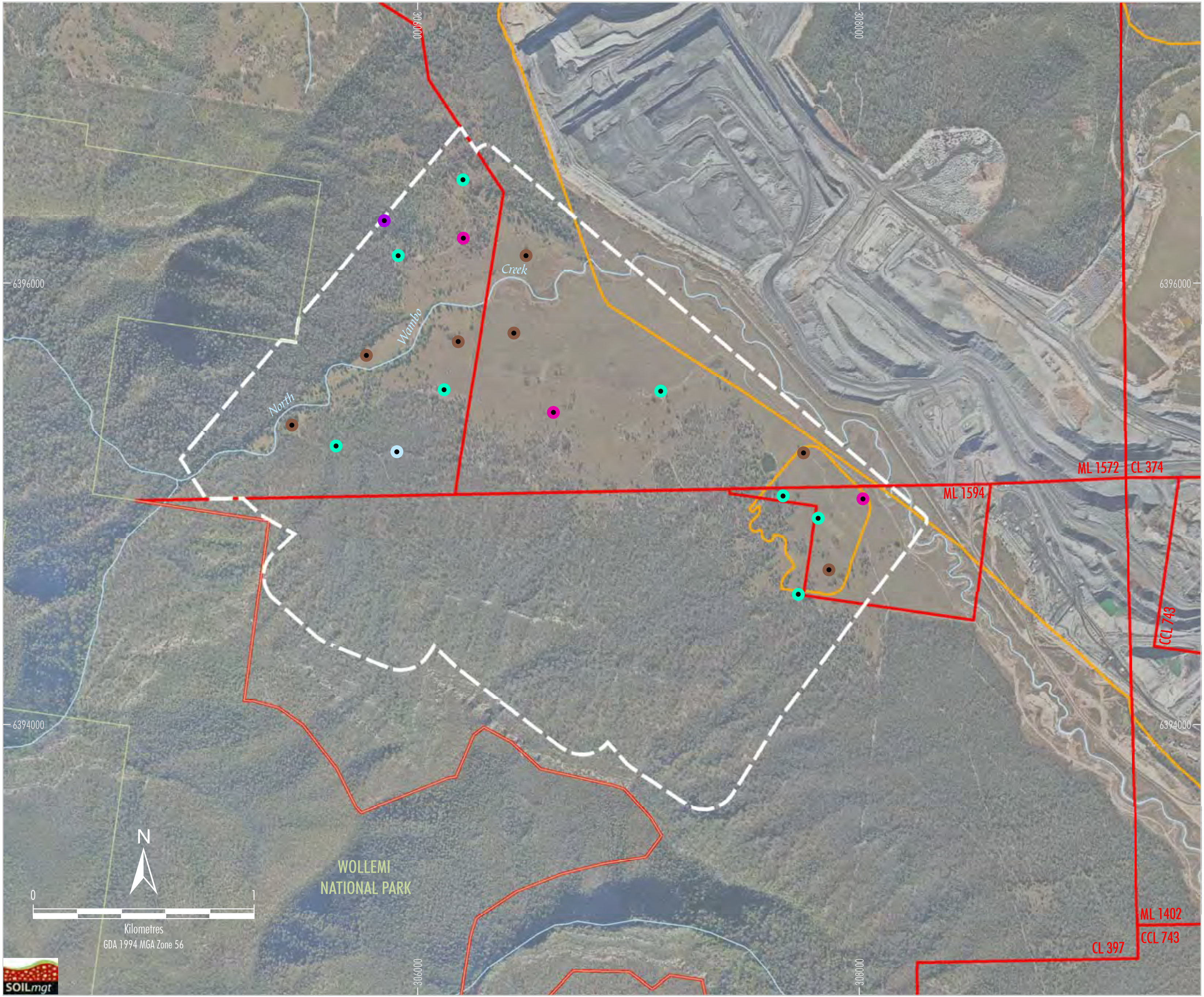
Source: Department of Lands (July 2009); WCPL (2016); WCPL Orthophoto (July 2016)

WAMBO COAL MINE

Slope Categories

Map 1b

WAM-09-15_SBEM_ARA_SM_216B



LEGEND

Mining and Coal Lease Boundary

National Park Boundary

Existing/Approved Surface Development Area

Study Area

Soil Test Pit

Soil Types

Chromosol

Kandosol

Rudosol

Sodosol

Tenosol

Source: Department of Lands (July 2009); WCPL (2016); WCPL Orthophoto (July 2016)

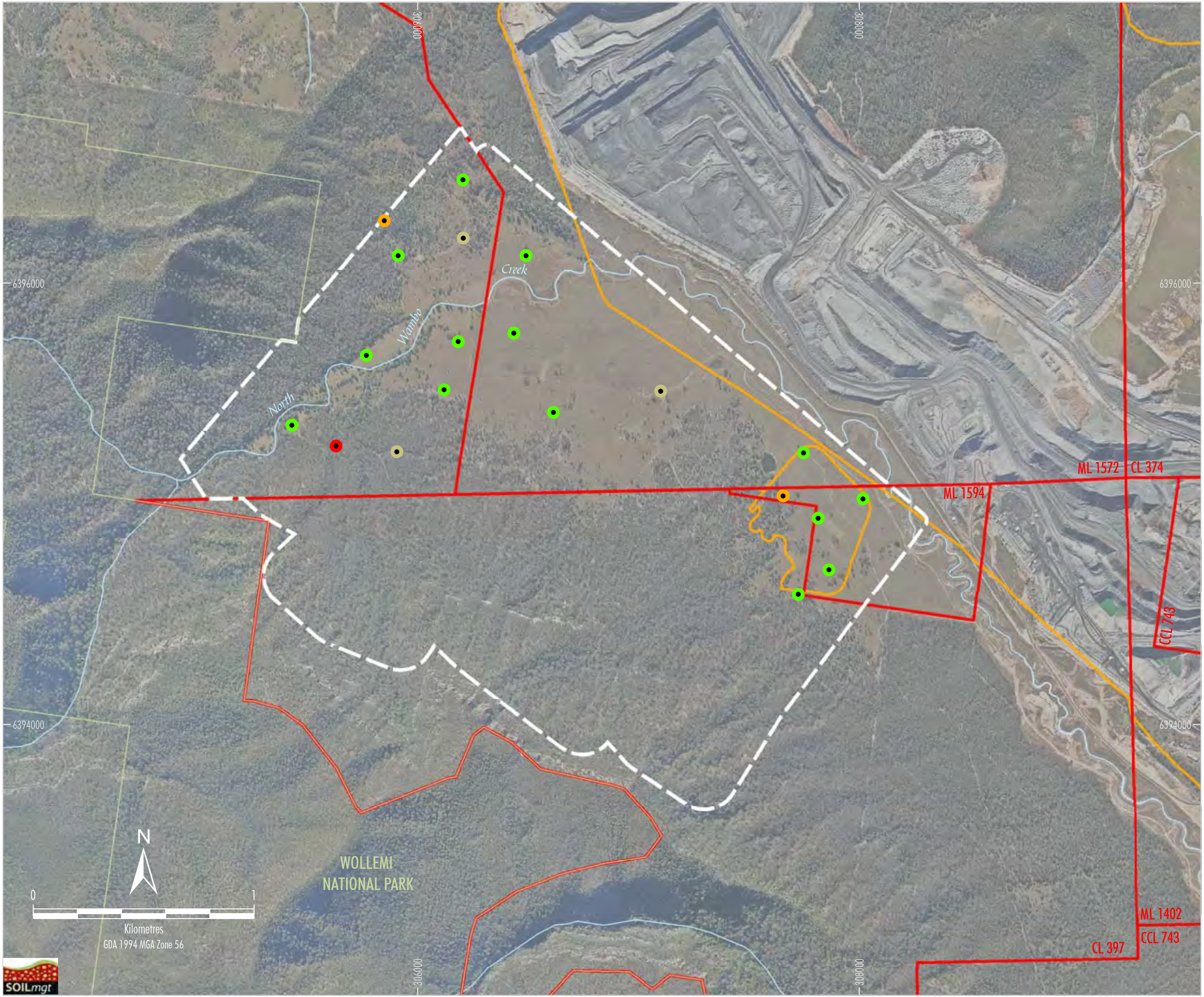
Peabody ENERGY

WAMBO COAL MINE

Soil Types - Australian Soil Classification

Map 2

WAM-09-15_SBEM_ARA_SM_201C



WAM-09-15_SBEM_ARA_SM_202B

LEGEND

- Mining and Coal Lease Boundary
- National Park Boundary
- Existing/Approved Surface Development Area
- Study Area
- Soil Test Pit

Depth to Rock (cm)

- < 50 cm
- 50 - 75 cm
- 76 - 100 cm
- > 100 cm

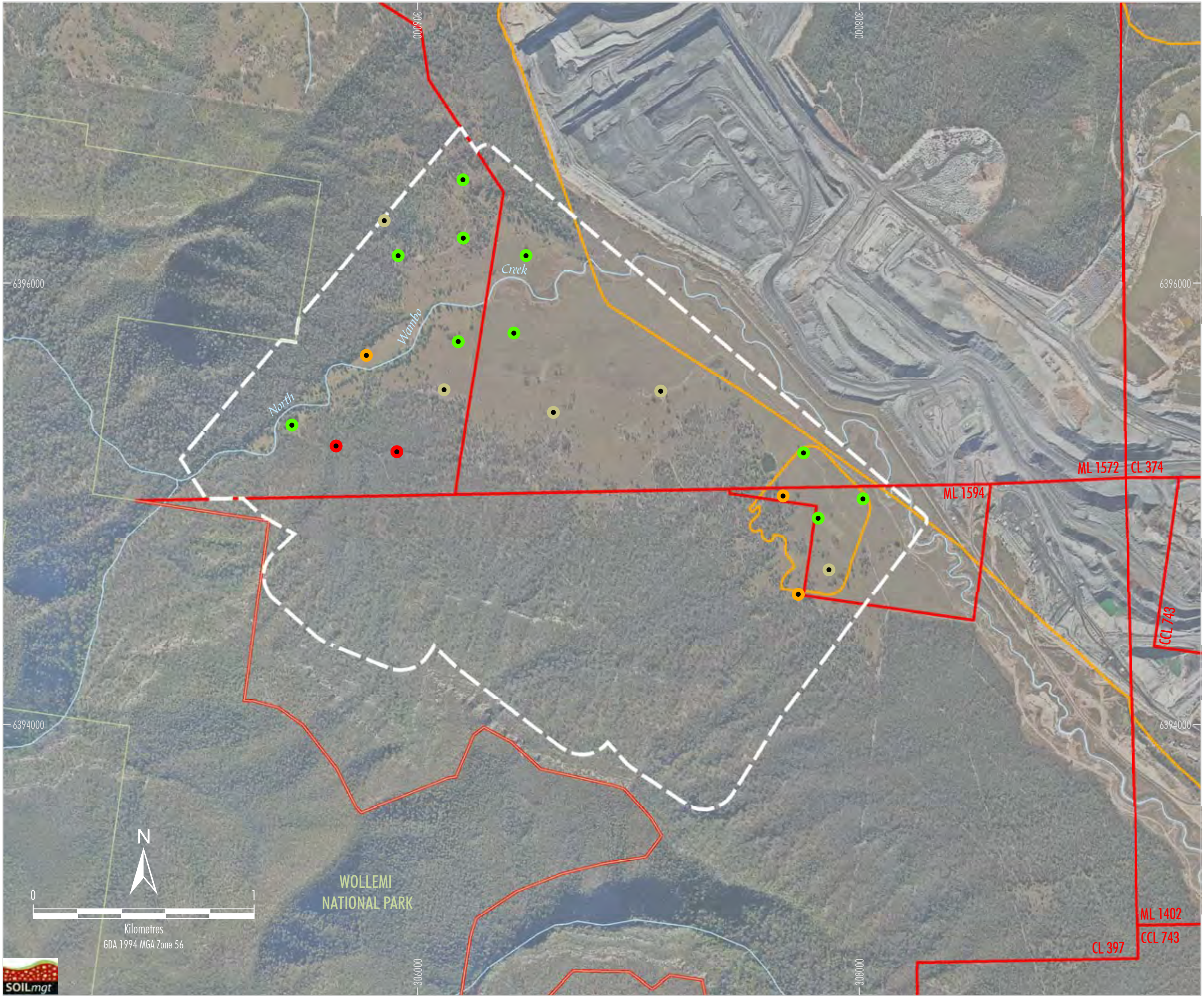
Source: Department of Lands (July 2009); WCPL (2016); WCPL Orthophoto (July 2016)

Peabody ENERGY

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

Depth to Rock

Map 3



LEGEND

Mining and Coal Lease Boundary

National Park Boundary

Existing/Approved Surface Development Area

Study Area

Soil Test Pit

Plant Available Water (TAW)

< 50 mm/m

50 - 75 mm/m

76 - 100 mm/m

> 100 mm/m

Source: Department of Lands (July 2009); WCPL (2016); WCPL Orthophoto (July 2016)

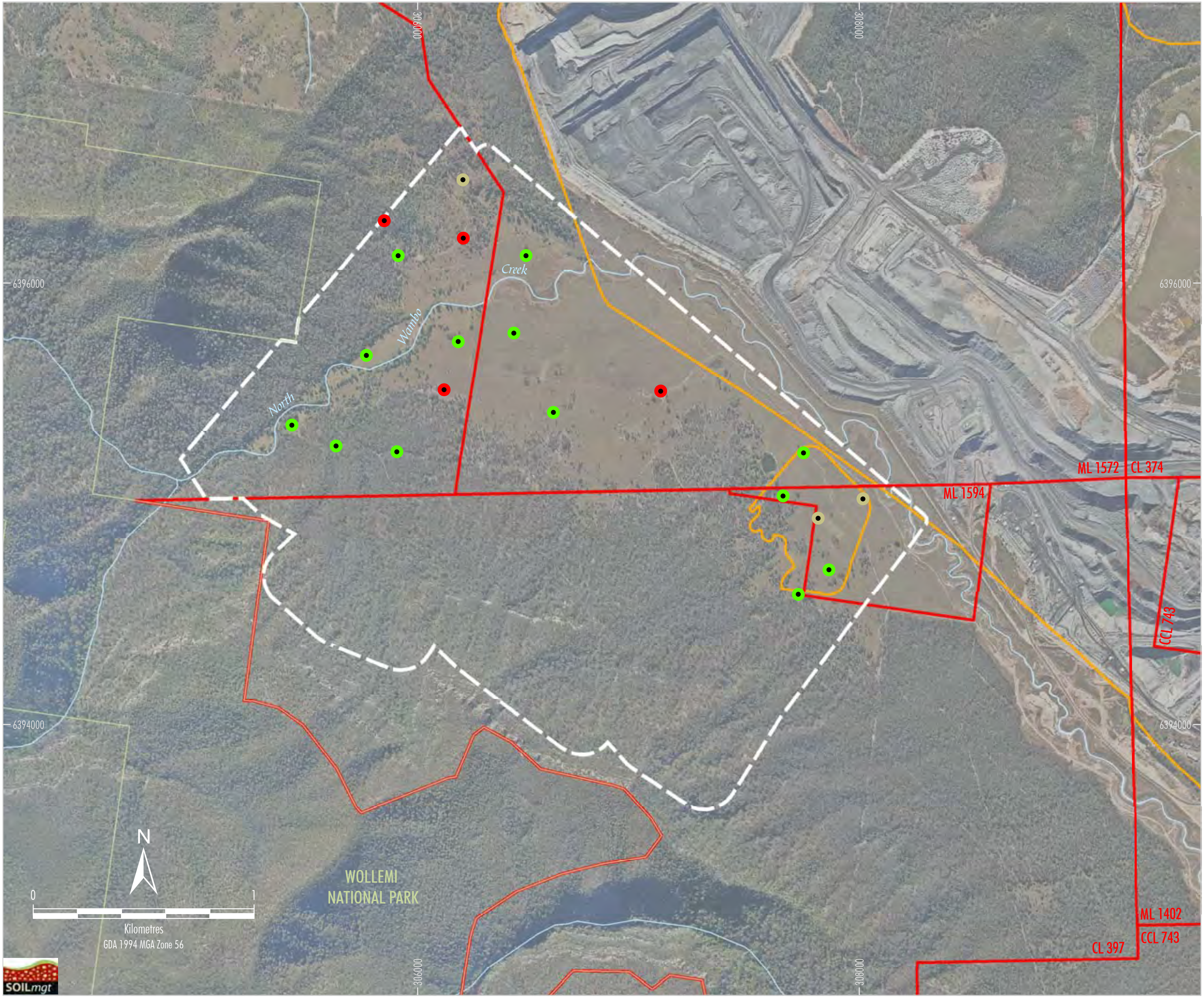
Peabody ENERGY

WAMBO COAL MINE

Plant Available Water (TAW)

Map 4

WAM-09-15_SBEM_ARA_SM_203B



LEGEND

Mining and Coal Lease Boundary
National Park Boundary
Existing/Approved Surface Development Area
Study Area
Soil Test Pit

Depth to Mottled Layer (cm)

< 50 cm
50 - 100 cm
> 100 cm

Source: Department of Lands (July 2009); WCPL (2016); WCPL Orthophoto (July 2016)

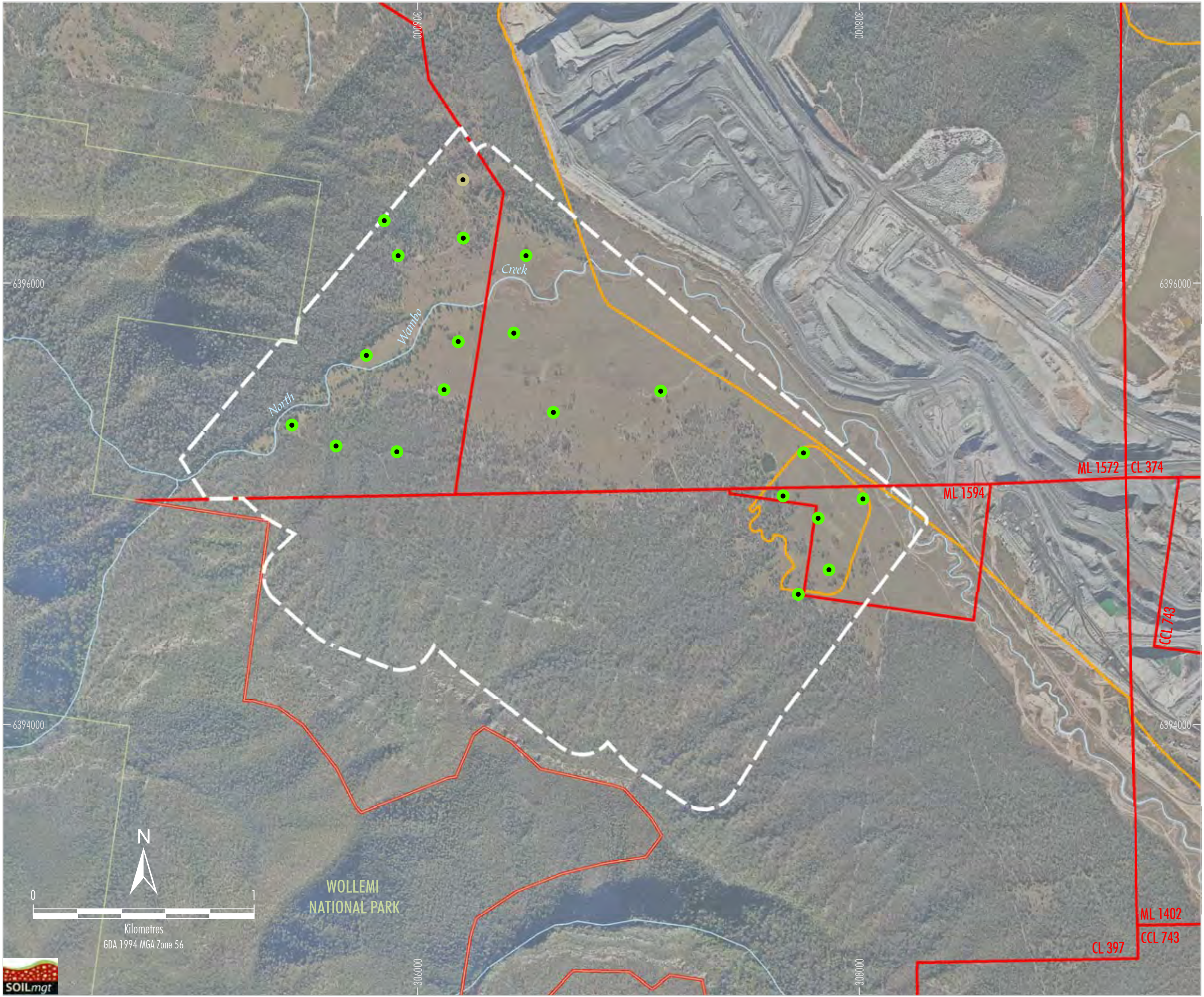
Peabody ENERGY

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

Depth to Mottled Layer

Map 5

WAM-09-15_SBEM_ARA_SM_204B



LEGEND
Mining and Coal Lease Boundary
National Park Boundary
Existing/Approved Surface Development Area
Study Area
Soil Test Pit
Depth to Layer with Lime (cm)
< 60 cm
60 - 140 cm
> 140 cm

Source: Department of Lands (July 2009); WCPL (2016); WCPL Orthophoto (July 2016)

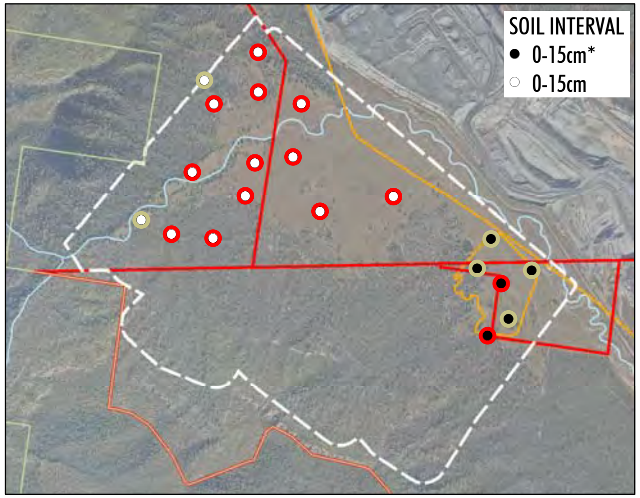
Peabody ENERGY

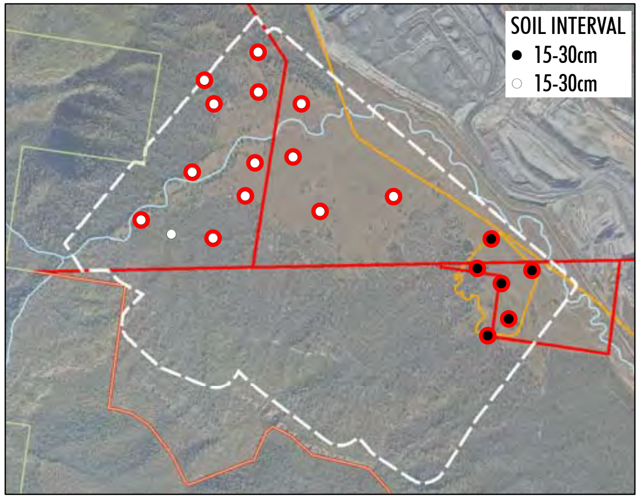
WAMBO COAL MINE

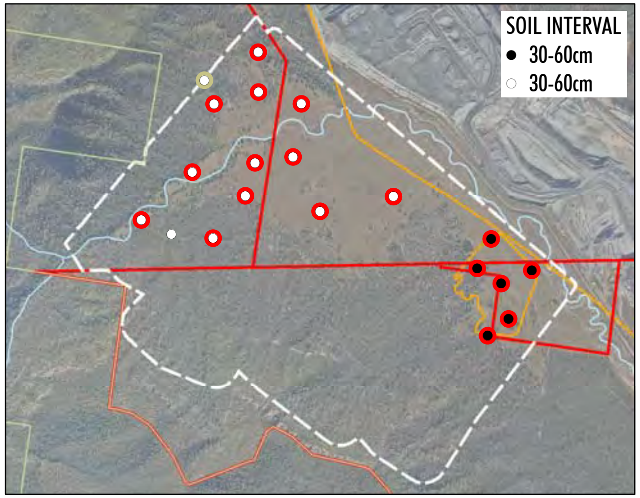
Depth to Layer with Lime

Map 6

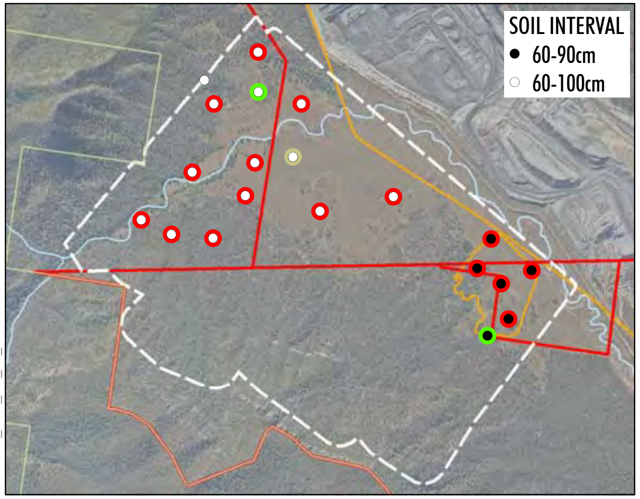
WAM-09-15_SBEM_ARA_SM_205B







** Data is based on a weighted average of the 0 - 5 cm and 5 -15 cm soil interval samples (refer to Section 4).*

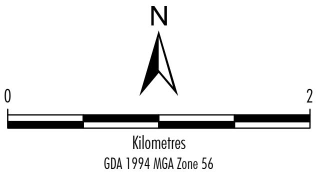


WAM-09-15_SBEM_ARA_SM_206B

LEGEND
- Mining and Coal Lease Boundary
- Existing/Approved Surface Development Area
- Study Area

Soil Test Pit
- 2012 Survey
- 2016 Survey

Dispersion (ASWAT)
- > 6
- 2 - 6
- < 2



SOILmgt

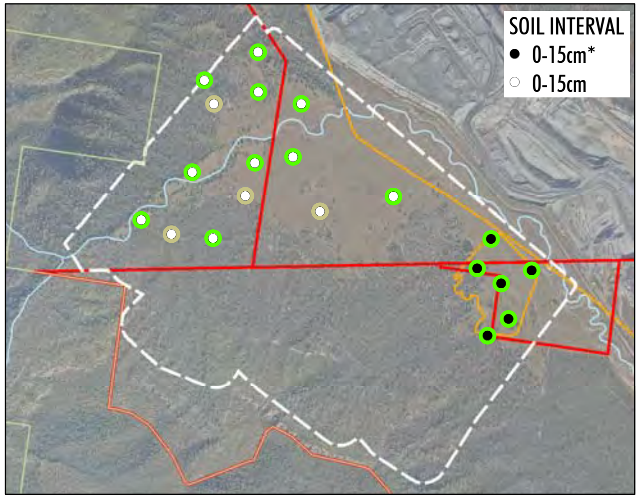
Source: Department of Lands (July 2009); WCPL (2016); WCPL Orthophoto (July 2016)

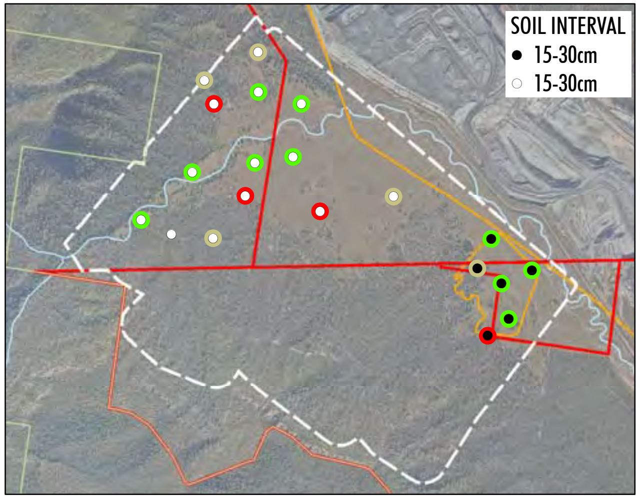
Peabody ENERGY

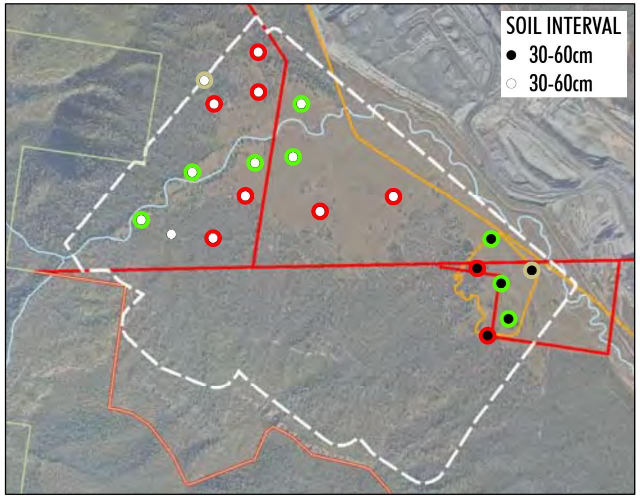
W A M B O C O A L M I N E

Dispersion (ASWAT Score)

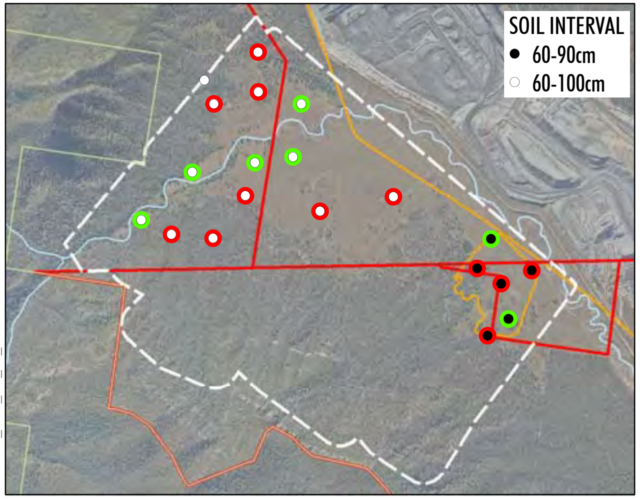
Map 7a







** Data is based on a weighted average of the 0 - 5 cm and 5 -15 cm soil interval samples (refer to Section 4).*



WAM-09-15_SBEM_ARA_SM_207B

LEGEND
Mining and Coal Lease Boundary
Existing/Approved Surface Development Area
Study Area

Soil Test Pit
2012 Survey
2016 Survey

Dispersion (ESP)
> 6
3 - 6
< 3

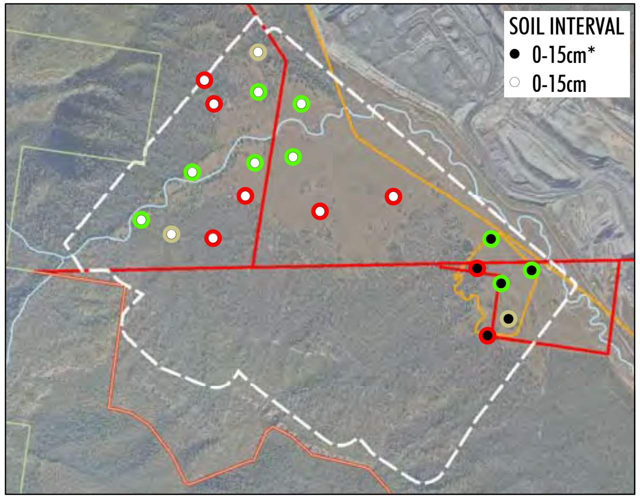
N
0 2
Kilometres
GDA 1994 MGA Zone 56

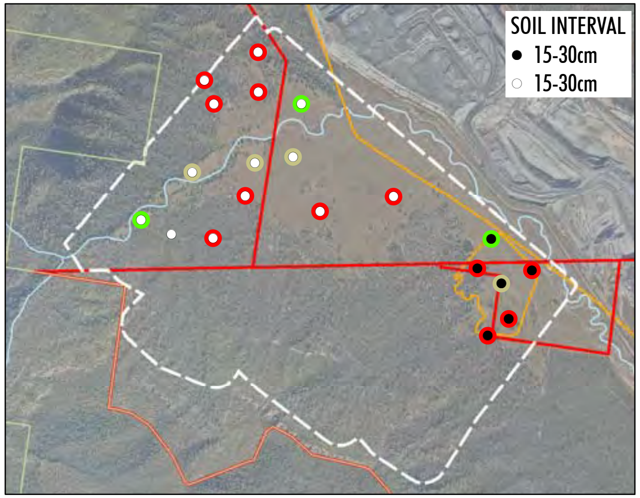
Peabody ENERGY
W A M B O C O A L M I N E
Dispersion (ESP Value)

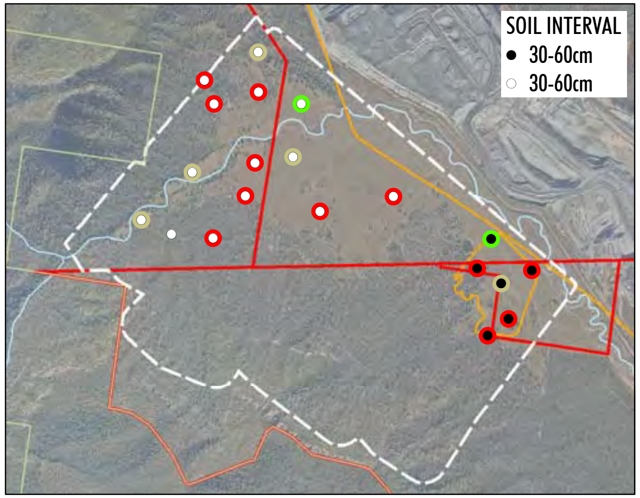
SOILmgt

Source: Department of Lands (July 2009); WCPL (2016); WCPL Orthophoto (July 2016)

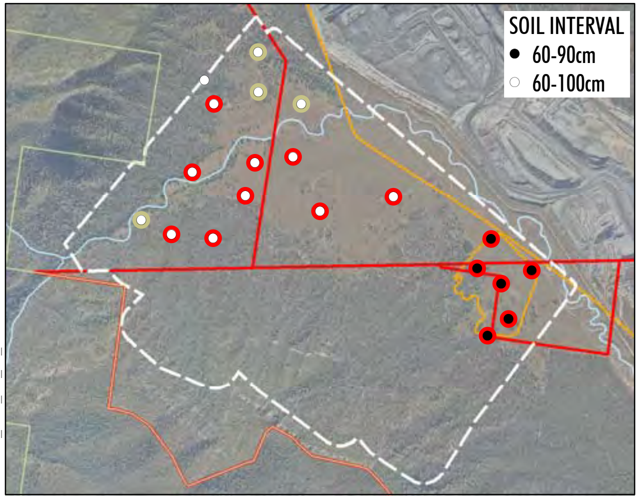
Map 7b







** Data is based on a weighted average of the 0 - 5 cm and 5 -15 cm soil interval samples (refer to Section 4).*



WAM-09-15_SBEM_ARA_SM_208C

LEGEND
Mining and Coal Lease Boundary
Existing/Approved Surface Development Area
Study Area

Soil Test Pit
2012 Survey
2016 Survey

Dispersion (ESI)
< 0.03
0.03 - 0.05
> 0.05

SOILmgt

Source: Department of Lands (July 2009); WCPL (2016); WCPL Orthophoto (July 2016)

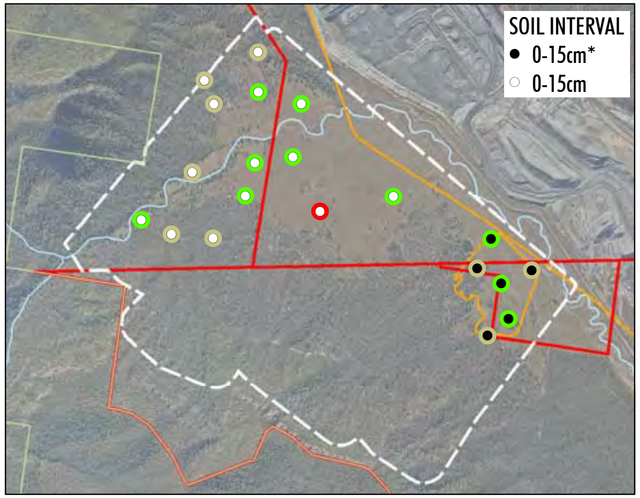
N
0 2
Kilometres
GDA 1994 MGA Zone 56

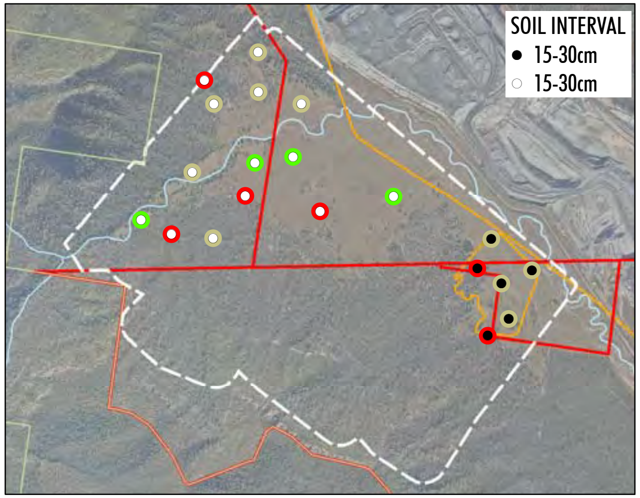
Peabody ENERGY

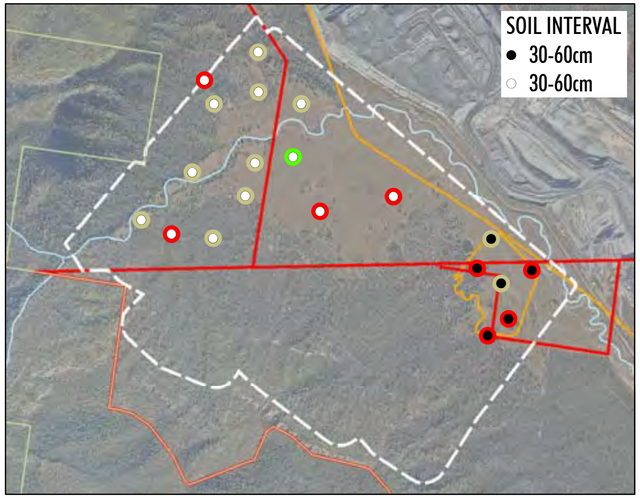
W A M B O C O A L M I N E

Dispersion (ESI Value)

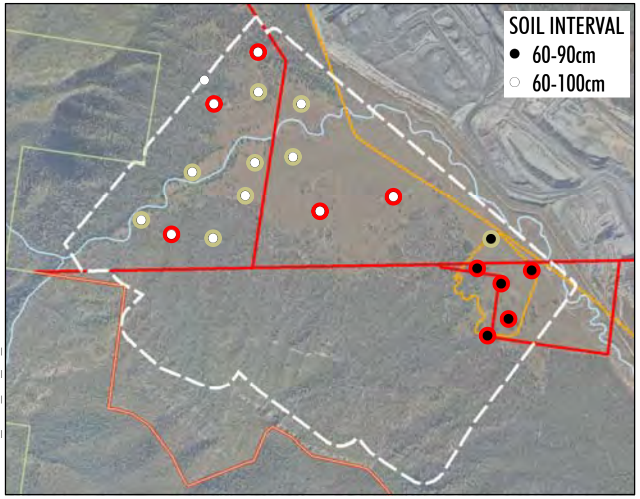
Map 7c







** Data is based on 0 - 5 cm and 5 -15 cm soil interval samples.*



WAM-09-15_SBEM_ARA_SM_209C

LEGEND

Mining and Coal Lease Boundary

Existing/Approved Surface Development Area

Study Area

Soil Test Pit

2012 Survey

2016 Survey

Compaction Severity

< 1.0

1.0 - 1.5

> 1.5

Note: The SOILpak score adopted for each soil interval is based on the SOILpak score of the dominant soil horizon or where there is no dominant soil horizon, the limiting soil horizon SOILpak score in the soil interval (Section 4.2).

SOILmgt

Source: Department of Lands (July 2009); WCPL (2016); WCPL Orthophoto (July 2016)

N

0 2

Kilometres

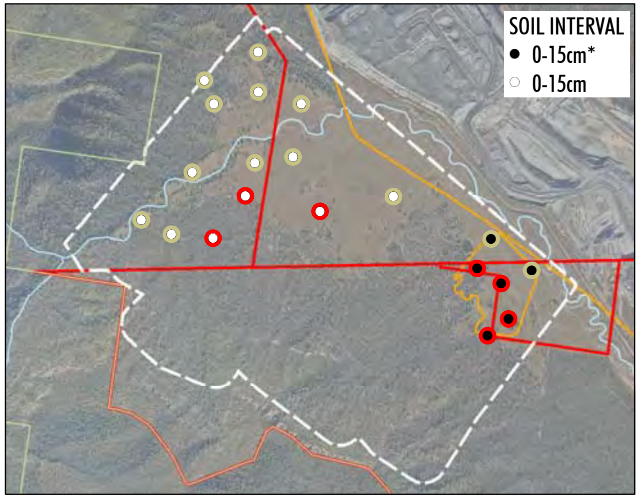
GDA 1994 MGA Zone 56

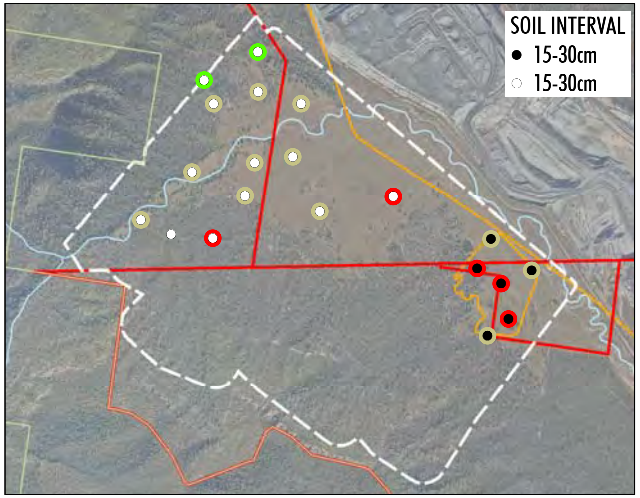
Peabody ENERGY

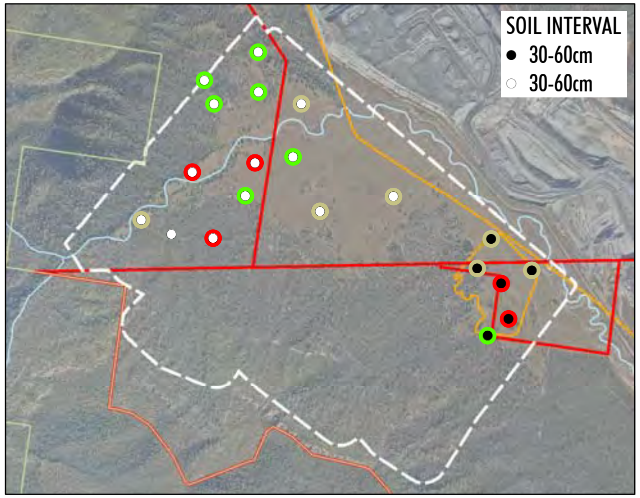
WAMBO COAL MINE

Compaction Severity (SOILpak Score)

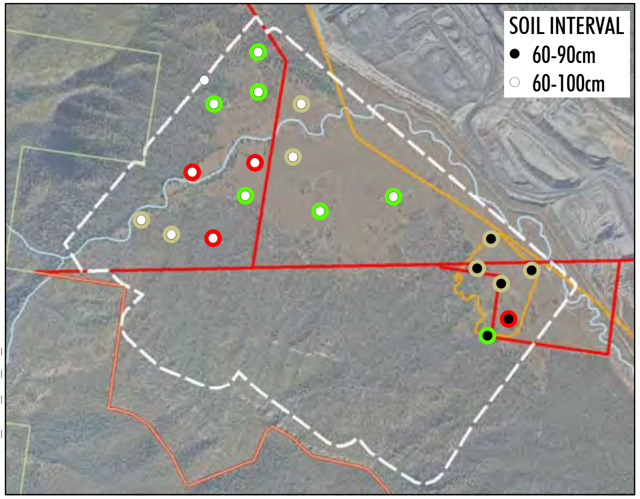
Map 8







* Data is based on a weighted average of the 0 - 5 cm and 5 -15 cm soil interval samples (refer to Section 4).



WAM-09-15_SBEM_ARA_SM_210C

LEGEND
- Mining and Coal Lease Boundary
- Existing/Approved Surface Development Area
- Study Area

Soil Test Pit
- ● 2012 Survey
- ○ 2016 Survey

Cation Exchange Capacity
- < 5 meq/100g
- 5 - 15 meq/100g
- >15 meq/100g

N

0 2
Kilometres
GDA 1994 MGA Zone 56

SOILmgt

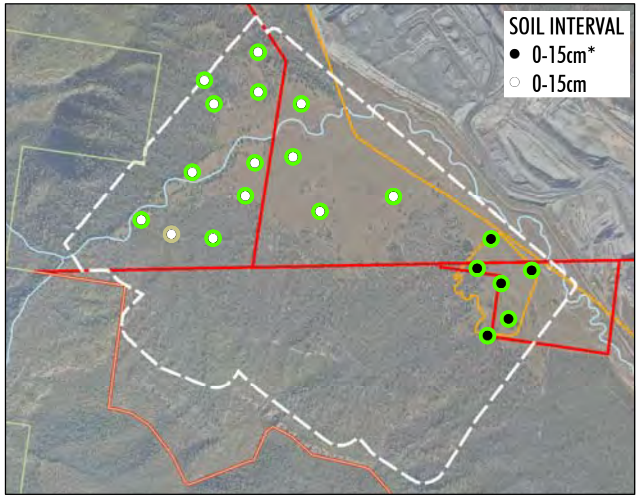
Source: Department of Lands (July 2009); WCPL (2016); WCPL Orthophoto (July 2016)

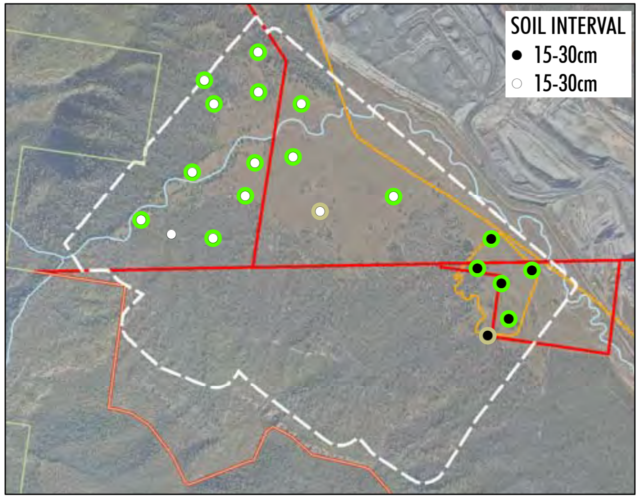
Peabody ENERGY

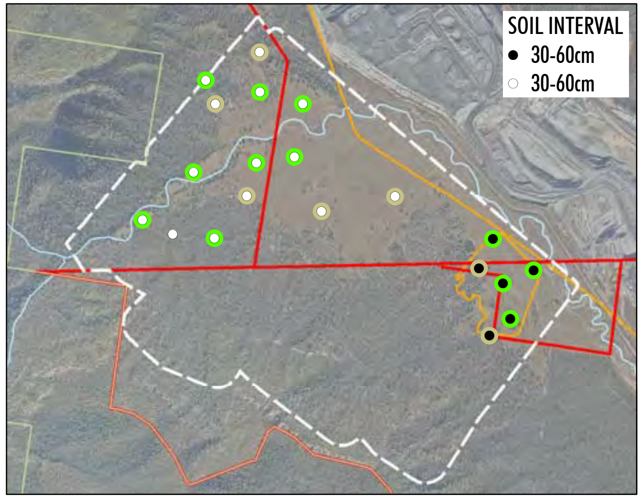
WAMBO COAL MINE

Cation Exchange Capacity

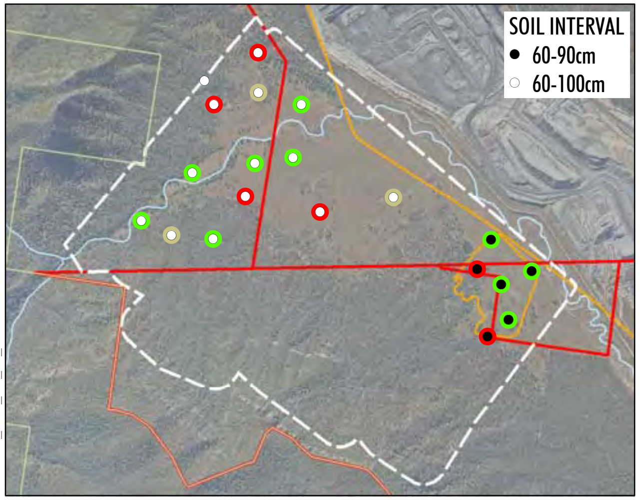
Map 9







** Data is based on a weighted average of the 0 - 5 cm and 5 -15 cm soil interval samples (refer to Section 4).*



WAM-09-15_SBEM_ARA_SM_211B

LEGEND
- Mining and Coal Lease Boundary
- Existing/Approved Surface Development Area
- Study Area

Soil Test Pit
- 2012 Survey
- 2016 Survey

Salinity
- > 4.0 dS/m
- 1.5 - 4.0 dS/m
- < 1.5 dS/m

N

0 — 2
Kilometres
GDA 1994 MGA Zone 56

SOILmgt

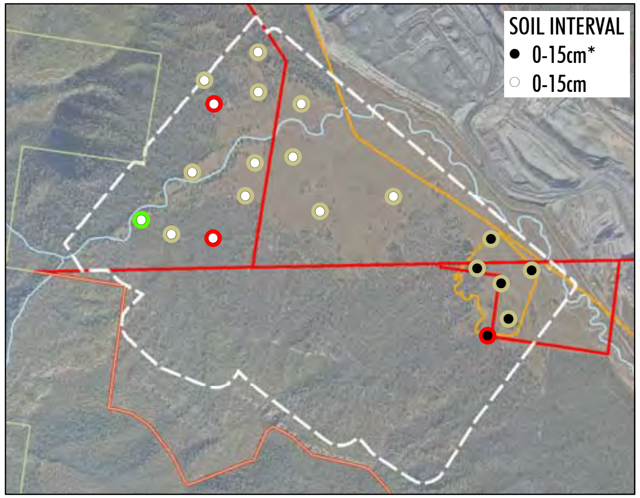
Source: Department of Lands (July 2009); WCPL (2016); WCPL Orthophoto (July 2016)

Peabody ENERGY

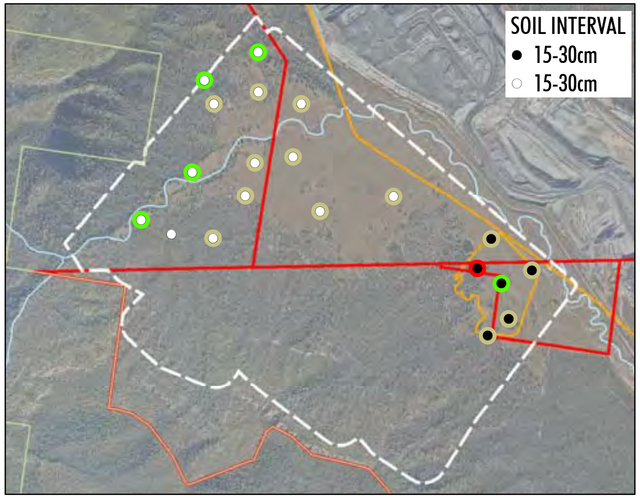
W A M B O C O A L M I N E

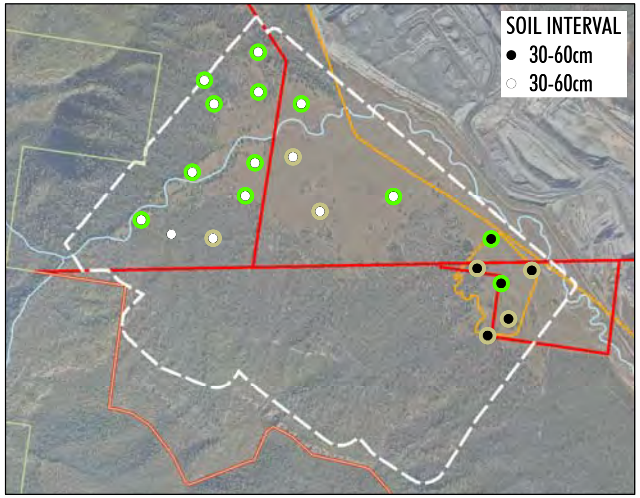
Salinity (Electrical Conductivity - ECe)

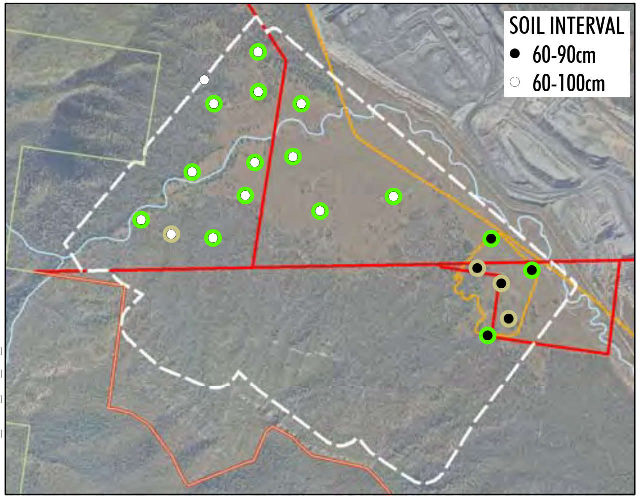
Map 10



* Data is based on a weighted average of the 0 - 5 cm and 5 -15 cm soil interval samples (refer to Section 4).





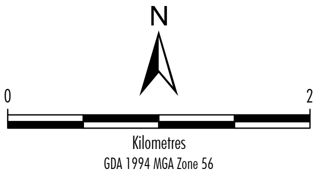


WAM-09-15_SBEM_ARA_SM_212B

LEGEND
Mining and Coal Lease Boundary
Existing/Approved Surface Development Area
Study Area

Soil Test Pit
2012 Survey
2016 Survey

pH
< 4.5
4.5 - 5.5
> 5.5



SOILmgt

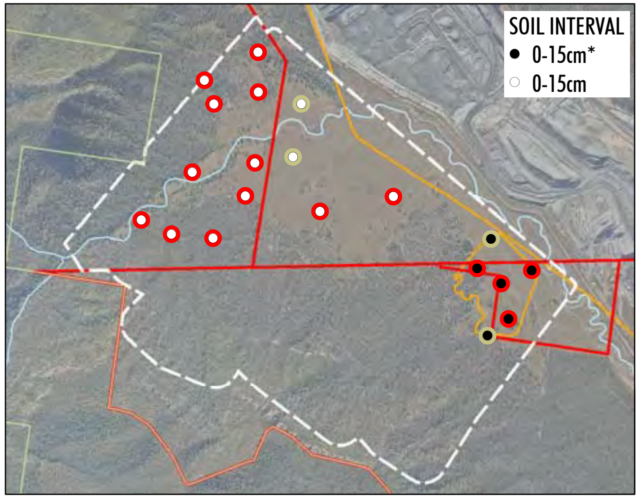
Source: Department of Lands (July 2009); WCPL (2016); WCPL Orthophoto (July 2016)

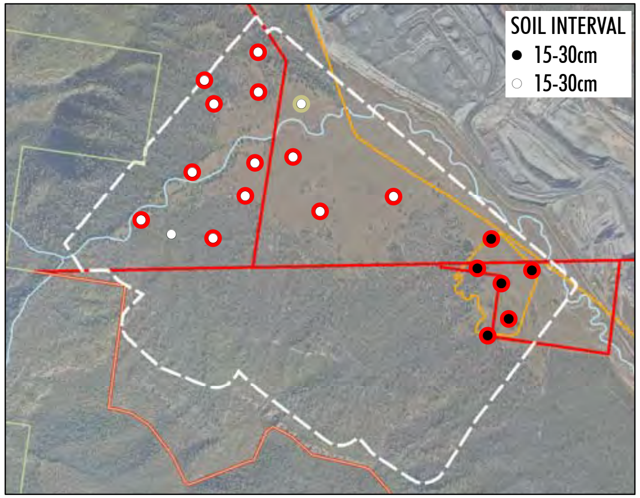
Peabody ENERGY

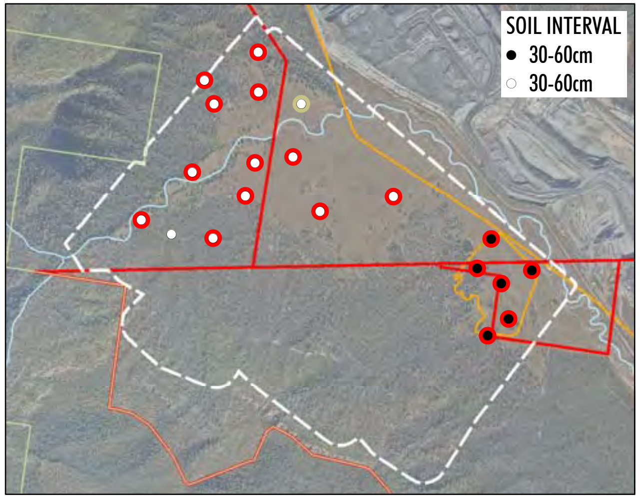
W A M B O C O A L M I N E

pH ($CaCl_2$)

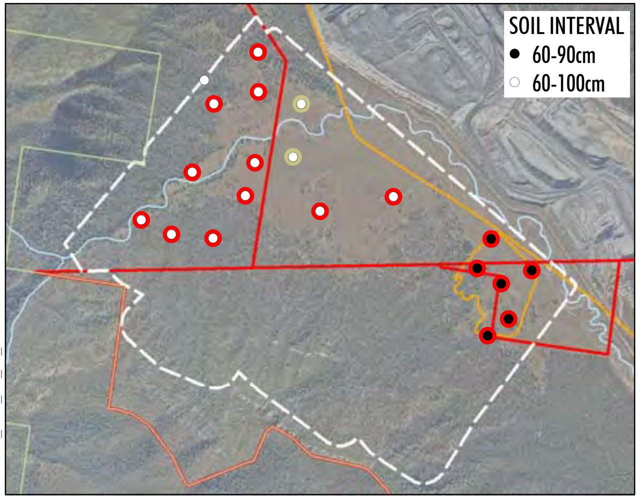
Map 11







** Data is based on a weighted average of the 0 - 5 cm and 5 -15 cm soil interval samples (refer to Section 4).*



WAM-09-15_SBEM_ARA_SM_213B

LEGEND
Mining and Coal Lease Boundary
Existing/Approved Surface Development Area
Study Area

Soil Test Pit
2012 Survey
2016 Survey

Phosphorus
< 10 mg/kg
10 - 30 mg/kg
> 30 mg/kg

N
0 2
Kilometres
GDA 1994 MGA Zone 56

SOILmgt

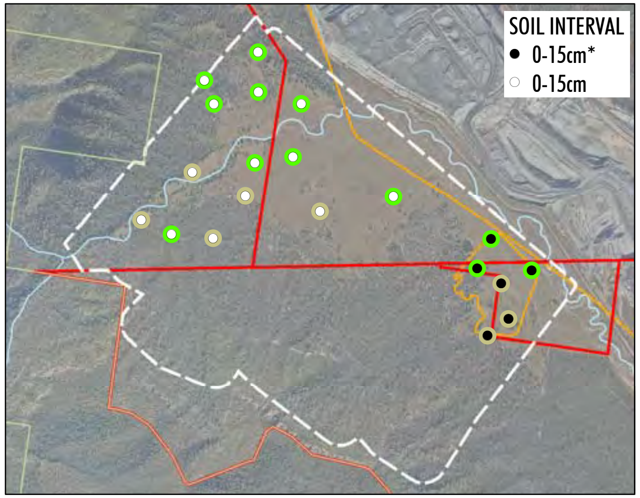
Source: Department of Lands (July 2009); WCPL (2016); WCPL Orthophoto (July 2016)

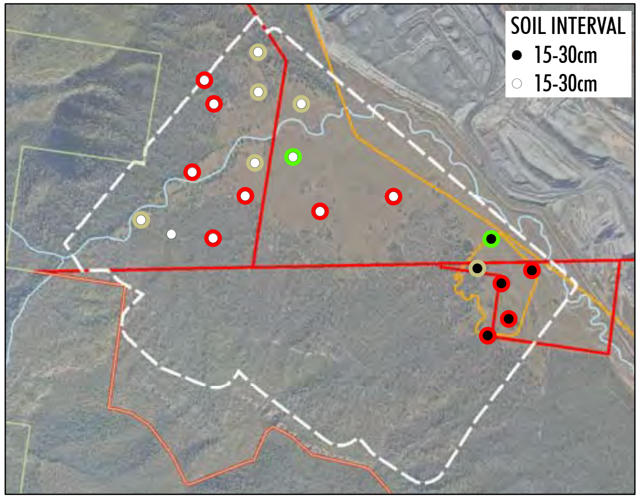
Peabody ENERGY

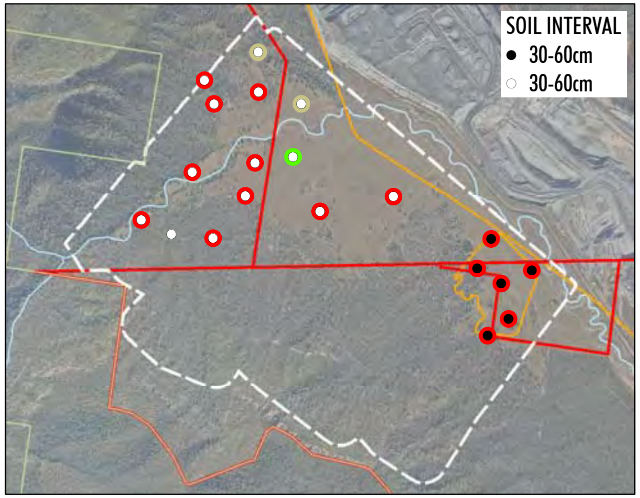
WAMBO COAL MINE

Phosphorus (Colwell P)

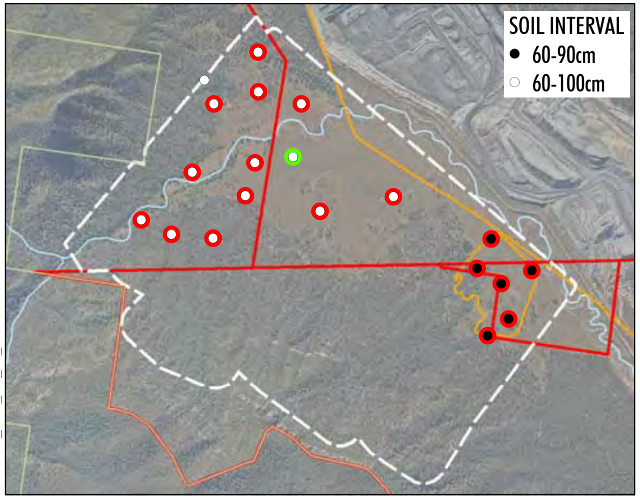
Map 12







** Data is based on a weighted average of the 0 - 5 cm and 5 -15 cm soil interval samples (refer to Section 4).*



WAM-09-15_SBEM_ARA_SM_214B

LEGEND
- Mining and Coal Lease Boundary
- Existing/Approved Surface Development Area
- Study Area

Soil Test Pit
- ● 2012 Survey
- ○ 2016 Survey

Organic Carbon
- < 0.8 %
- 0.8 - 1.5 %
- > 1.5 %

N

0 2

Kilometres
GDA 1994 MGA Zone 56

SOILmgt

Source: Department of Lands (July 2009); WCPL (2016); WCPL Orthophoto (July 2016)

Peabody ENERGY

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

Organic Carbon

Map 13

ATTACHMENTS A TO E

Attachment A. Overview Data

Map ID	Easting, m WGS84	Northing, m WGS84	ASC	BSAL	Slope %	Aspect	Landscape position	Landscape element	Depth to rock >90% cm	Depth to mottles>10% cm *	Depth to Lime cm	TAW (0-100 cm) mm	Surface rock %	Surface condition	Surface Cover %	Land use	Other comments
1	305849	6396283	Red Chromosol CD AH	No	15	S	midslope	straight	55	40	>140	82	0	soft	80	forest	
2	305912	6396125	Red Sodosol DP AH	No	7	E	midslope	straight	>140	>140	>140	128	0	firm	60	forest	
3	306205	6396468	Yellow Sodosol DP AH	No	8	S	midslope	straight	120	80	60	154	0	soft	100	native pasture	
4	305431	6395357	Stratic Rudosol AR	No	4	NW	plain	convex	>140	>140	>140	115	0	soft	100	native pasture	
5	305768	6395673	Stratic Rudosol AR	No	2	SE	plain	straight	>140	>140	>140	75	0	soft	100	native pasture	
6	306207	6396204	Red Kandosol HB AH	No	12	SE	lower slope	straight	90	45	>140	189	0	soft	100	native pasture	
7	305631	6395262	Red Sodosol DSP AH	No	14	NW	midslope	straight	15	>140	>140	31	0	soft	90	forest	
8	305906	6395236	Brown-Orthic Tenosol AR CZ	No	6	NE	midslope	straight	90	>140	>140	39	0	soft	60	forest	A1 water repellent
9	306120	6395517	Brown Sodosol FO AH	No	4	NE	lower slope	straight	>140	32	>140	95	0	soft	100	native pasture	
10	306184	6395735	Stratic Rudosol AR	No	1	N	plain	straight	>140	>140	>140	113	0	soft	100	native pasture	
11	306436	6395774	Stratic Rudosol AR	No	1	NE	plain	straight	>140	>140	>140	182	0	soft	100	native pasture	
12	306491	6396125	Stratic Rudosol AR	No	2	SE	plain	straight	>140	>140	>140	37	0	soft	100	native pasture	
13	306615	6395414	Brown Kandosol EO AH	No	4	N	midslope	straight	>140	>140	>140	97	0	firm	100	native pasture	
14	307101	6395511	Brown Sodosol FO AH	No	3	NE	lower slope	convex	80	33	>140	88	0	firm	100	native pasture	
15	307655	6395036	Grey Sodosol FO AH	No	4	NE	upper midslope	convex	75	>140	>140	70	0	firm	100	native pasture / woodland	
16	307748	6395231	Stratic Rudosol AR	No	3	NE	lower slope	straight	>140	>140	>140	129	0	soft	100	native pasture	
17	307814	6394935	Brown Sodosol FN AH	No	4	NE	midslope	straight	>140	65	>140	134	0	soft	100	native pasture	A3 water repellent

Map ID	Easting, m WGS84	Northing, m WGS84	ASC	BSAL	Slope %	Aspect	Landscape position	Landscape element	Depth to rock >90% cm	Depth to mottles>10% cm *	Depth to Lime cm	TAW (0-100 cm) mm	Surface rock %	Surface condition	Surface Cover %	Land use	Other comments
18	308017	6395023	Red Kandosol HB AH	No	2	NE	lower slope	straight	>140	50	>140	123	0	firm	100	native pasture	
19	307724	6394590	Grey Sodosol DP AH	No	4	N	upper slope	convex	>140	>140	>140	73	0	firm	100	native pasture / woodland	
20	307863	6394701	Stratic Rudosol AR	No	3	N	lower slope	straight	>140	>140	>140	87	0	firm	100	native pasture	

***** ‘Depth to mottles >10%’ is equivalent, at this site, to ‘Depth to waterlogged layer’ because there were no layers with ‘>20% Mn’

Attachment B. Layer Data

Map ID	Horizon	Lower depth cm	Boundary Distinctness	Texture	pH water	Moist soil colour (Munsell)	Colour from Munsell sheet	Mottles	Mn	SOILpak compaction score	Coarse fragments %	Dispersion 10 minutes	Moisture	Lime		Root score
														%	Type	
1	A11	10	Abrupt	FSCL	5.5	7.5YR3/3	Dark brown	–	–	1.8	–	0	S	–	–	4
1	A12	20	Abrupt	FSCL	5.5	7.5YR4/3	Brown	–	–	1.4	5	1	S	–	–	3
1	B21	40	Abrupt	MC	6.0	5YR4/6	Yellowish red	–	–	0.8	–	1	S	–	–	3
1	B22	55	Abrupt	LMC	7.0	7.5YR4/6	Strong brown	grey 20%	–	1	–	0	M	–	–	2
1	BC	90+	–	–	–	–	–	–	–	–	–	–	–	–	–	1
2	A11	5	Abrupt	SCL	5.0	7.5YR3/3	Dark brown	–	–	1.2	–	0	S	–	–	3
2	A12	20	Sharp	SCL	5.5	7.5YR4/3	Brown	–	–	1.3	–	1	S	–	–	2
2	B21	60	Clear	MC	7.5	5YR4/4	Reddish brown	–	–	1	10	0	S/M	–	–	1
2	B22	130+	–	LMC	8.0	5YR4/3	Reddish brown	–	–	0.8	10	2	S/M	–	–	1(100)
3	A1	10	Sharp	FSCL	5.5	10YR4/2	Dark greyish brown	–	–	1.8	20	2	M	–	–	3
3	B1	35	Abrupt	MHC	6.5	10YR4/2	Dark greyish brown	–	–	1.3	–	3	M	–	–	2
3	B21	60	Clear	MHC	8.0	10YR6/4	Light yellowish brown	–	–	1.4	–	0	M	–	–	2
3	B22	80	Clear	HC	9.5	10YR6/4	Light yellowish brown	–	–	0.8	–	0	M	10	D	1
3	B23	120	Sharp	HC	9.5	10YR6/4	Light yellowish brown	grey 20%	–	1.1	–	0	M	20	P/D	0
3	C	125+	–	HC	–	–	–	–	–	–	–	–	–	–	–	–
4	A1	25	Sharp	CS	5.5	5YR3/2	Dark reddish brown	–	–	1.8	–	0	M	–	–	4
4	2A	55	Sharp	LS (coarse)	5.5	5YR3/3	Dark reddish brown	–	–	1.5	70	0	M	–	–	3
4	3A	80	Clear	LC	6.0	5YR3/3	Dark reddish brown	–	–	1.6	–	1	M	–	–	3
4	3B	140+	–	LC	6.0	7.5YR4/4	Brown	–	–	1.4	–	1	S/M	–	–	1

Map ID	Horizon	Lower depth cm	Boundary Distinctness	Texture	pH water	Moist soil colour (Munsell)	Colour from Munsell sheet	Mottles	Mn	SOILpak compaction score	Coarse fragments %	Dispersion 10 minutes	Moisture	Lime %	Lime Type	Root score
5	A11	15	Clear	LS	5.5	5YR3/2	Dark reddish brown	–	–	1.5	–	0	M	–	–	4
5	A12	35	Clear	LS	6.0	5YR3/3	Dark reddish brown	–	–	1.5	–	0	M	–	–	3
5	A3	115	Sharp	LS	6.0	5YR4/3	Reddish brown	–	–	1.5	–	1	M	–	–	4
5	2A	140+	–	S (coarse)	–	–	–	–	–	–	90	–	–	–	–	2
6	A11	15	Abrupt	LC	5.5	7.5YR3/3	Dark brown	–	–	1.7	–	2	M	–	–	3
6	A12	30	Sharp	LC	5.5	7.5YR4/3	Brown	–	–	1.5	–	1	M	–	–	3
6	B21	45	Clear	MHC	6.0	5YR4/6	Yellowish red	–	–	1	–	3	M	–	–	2
6	B22	90	Sharp	HC	7.0	10YR5/4	Yellowish brown	grey 15%	–	1.2	–	0	M	–	–	1
6	C	140+	–	–	–	–	–	–	–	–	–	–	–	–	–	–
7	A1	15	Abrupt	CS	5.0	7.5YR3/2	Dark brown	–	–	1.5	70	0	S	–	–	3
7	A3	50	Sharp	CS	–	–	–	–	–	0.3	95	–	–	–	–	1
7	B2	100+	–	SLC	5.0	7.5YR4/6	Strong brown	–	–	0.7	40	3	M	–	–	1
8	A1	20	Abrupt	LS	5.5	7.5YR4/4	Brown	–	–	–	5	0	S	–	–	3
8	A3	60	Abrupt	LS	5.5	10YR5/3	Brown	–	–	–	70	2	S	–	–	2
8	B1	90	Sharp	LS	6.0	7.5YR6/4	Light brown	–	–	–	30	2	S	–	–	1
8	C	95+	–	HC (fine)	–	–	–	–	–	–	–	–	–	–	–	–
9	A1	13	Sharp	SCL	5.5	7.5YR3/3	Dark brown	–	–	1.7	–	3	M	–	–	2
9	B21	32	Sharp	HC	6.0	10YR5/6	Yellowish brown	grey 5%	–	0.7	–	3	M	–	–	1
9	B22	60	Sharp	HC	6.5	10YR5/6	Yellowish brown	grey 20%	–	1	–	2	M	–	–	1
9	BC	130+	–	–	–	–	–	–	–	–	20-90	–	–	–	–	1(80)

Map ID	Horizon	Lower depth cm	Boundary Distinctness	Texture	pH water	Moist soil colour (Munsell)	Colour from Munsell sheet	Mottles	Mn	SOILpak compaction score	Coarse fragments %	Dispersion 10 minutes	Moisture	Lime		Root score
														%	Type	
10	A1	15	Sharp	SLC	5.5	7.5YR3/2	Dark brown	–	–	1.8	–	0	M	–	–	3
10	A3	50	Sharp	LC	6.0	7.5YR3/2	Dark brown	–	–	1.6	–	0	M	–	–	3
10	2A	60	Sharp	S	6.0	7.5YR3/3	Dark brown	–	–	1.5	15	1	M	–	–	4
10	3A	73	Sharp	CS	6.0	7.5YR3/2	Dark brown	–	–	1.5	10	1	M	–	–	3
10	4A	100	Sharp	LS	6.0	7.5YR3/3	Dark brown	–	–	1.5	80	0	M	–	–	4
10	5A	140+	–	CS	6.0	7.5YR3/2	Dark brown	–	–	1.5	–	0	M	–	–	2
11	A1	15	Abrupt	SCL	5.0	7.5YR3/2	Dark brown	–	–	1.9	–	0	M	–	–	3
11	B1	70	Sharp	ZLC	5.5	7.5YR2.5/1	Black	–	–	1.6	–	0	M	–	–	3
11	2A	125	Sharp	FSL	6.0	5YR3/2	Dark reddish brown	–	–	1.4	–	0	S	–	–	3
11	3A - 6A	140+	–	sand & loam banding	–	–	–	–	–	–	–	–	–	–	–	–
12	A1	15	Abrupt	SLC	5.5	7.5YR3/2	Dark brown	–	–	1.8	–	1	M	–	–	4
12	A3	70	Sharp	SLC	6.0	7.5YR3/2	Dark brown	–	–	1.4	1	2	M	–	–	3
12	2A	95	Sharp	LS	6.0	7.5YR3/3	Dark brown	–	–	1.5	10	0	M	–	–	2
12	3A	140+	–	SCL	6.0	7.5YR3/2	Dark brown	–	–	1.3	10	0	M	–	–	2
13	A1	10	Sharp	SCL	5.0	5YR4/2	Dark reddish grey	–	–	1.5	–	2	M	–	–	2
13	B21	70	Clear	SLC	5.5	7.5YR4/4	Brown	–	–	0.4	–	3	S	–	–	1
13	B22	140+	–	SLC	7.5	7.5YR4/4	Brown	–	–	0.6	–	0	S	–	–	1(120)
14	A1	12	Abrupt	FSCL	5.0	5YR3/3	Dark reddish brown	–	–	1.6	–	0	M	–	–	2
14	A2	33	Sharp	FSCL	5.5	10YR5/3	Brown	–	–	1.6	15	2	M	–	–	2
14	B2	80	Abrupt	HC	6.5	10YR5/4	Yellowish brown	grey 15%	–	0.8	–	1	S	–	–	1(60)
14	BC	140+	–	–	–	–	–	–	–	–	90	–	–	–	–	–

Map ID	Horizon	Lower depth cm	Boundary Distinctness	Texture	pH water	Moist soil colour (Munsell)	Colour from Munsell sheet	Mottles	Mn	SOILpak compaction score	Coarse fragments %	Dispersion 10 minutes	Moisture	Lime		Root score
														%	Type	
15	A1	15	Abrupt	SL	5.5	7.5YR4/2	Brown	–	–	1.4	3	0	S/M	–	–	1
15	A2	30	Sharp	SL	5.0	10YR5/2	Greyish brown	–	–	0.7	10	1	S	–	–	1
15	B2	75	Clear	SLC	6.0	10YR4/2	Dark greyish brown	yellow 30%	–	0.4	5	3	S	–	–	1
15	C	125+	–	–	–	–	–	–	–	–	98	–	–	–	–	–
16	A1	20	Clear	SCL	5.0	7.5YR2.5/2	Very dark brown	–	–	1.7	2	0	S/M	–	–	3
16	2A	50	Clear	SCL	5.5	7.5YR3/2	Dark brown	–	–	1.4	4	0	S	–	–	3
16	3A	75	Abrupt	SL	6.0	7.5YR4/4	Brown	–	–	1.4	4	0	S	–	–	3
16	4A	140+	–	LS	6.0	7.5YR3/3	Dark brown	–	–	1.3	3	1	S	–	–	1
17	A1	15	Abrupt	SCL	6.0	7.5YR3/3	Dark brown	–	–	1.6	1	0	S/M	–	–	3
17	A3	75	Sharp	FSL	5.5	7.5YR4/4	Brown	–	–	1.4	3	0	S	–	–	3
17	B2	140+	–	LC	5.5	10YR4/3	Brown	grey & orange 15%	–	0.8	0	0	S/M	–	–	1
18	A11	12	Abrupt	ZCL	5.5	7.5YR4/3	Brown	–	–	1.3	0	1	S/M	–	–	2
18	A12	25	Sharp	ZCL	5.5	7.5YR5/4	Brown	–	–	1.1	0	2	S	–	–	2
18	B21	50	Clear	LC	5.5	5YR4/3	Reddish brown	–	–	1.1	0	0	S	–	–	2
18	B22	140+	–	LC	6.0	5YR4/6	Yellowish red	grey 15%	–	0.7	3	1	S	–	–	1
19	A1	3	Abrupt	SCL	5.0	7.5YR4/2	Brown	–	–	1.5	2	0	S/M	–	–	2
19	A2	12	Sharp	SCL	4.5	7.5YR3/2	Dark brown	–	–	1.2	5	0	S	–	–	1
19	B21	50	Clear	LC	5.5	7.5YR4/2	Brown	–	–	0.7	15	3	S	–	–	0.5
19	B22	80	Clear	LC	5.5	7.5YR4/2	Brown	–	–	0.7	70	3	S	–	–	0.5
19	2B	140+	–	LC	7.0	7.5YR4/1	Dark grey	–	–	1.0	0	0	S	–	–	1

Map ID	Horizon	Lower depth cm	Boundary Distinctness	Texture	pH water	Moist soil colour (Munsell)	Colour from Munsell sheet	Mottles	Mn	SOILpak compaction score	Coarse fragments %	Dispersion 10 minutes	Moisture	Lime %	Lime Type	Root score
20	A1	15	Sharp	SL	5.5	7.5YR3/3	Dark brown	–	–	1.6	2	0	S/M	–	–	2
20	2A	35	Abrupt	SL	5.5	7.5YR4/4	Brown	–	–	1.1	5	2	S	–	–	2
20	3A	75	Abrupt	CS	6.0	7.5YR4/4	Brown	–	–	0.8	60	2	S	–	–	2
20	4A	140+	–	SL	6.0	5YR5/3	Reddish brown	–	–	1.1	20	3	S	–	–	1

Attachment C. Soil Structure Details

Map ID	Lower depth, cm	Grade	Type	Size	Fabric	Consistence	SOILpak score
1	10	S	SB	5	E	1	1.8
1	20	S	PO	8	E	3	1.4
1	40	S	LE/PO	15	RP	4	0.8
1	55	S	LE/PO	12	RP	4	1.0
1	90+	–	–	–	–	–	–
2	5	W	B	10	E	2	1.2
2	20	M	LE/PO	8	E	2	1.3
2	60	M	LE/B	8	RP	3	1.0
2	130+	M	PO/B	10	RP	4	0.8
3	10	S	SB	5	E	1	1.8
3	35	S	PO	10	RP	3	1.3
3	60	M	PO	8	RP	3	1.4
3	80	S	LE/PO	15	RP	5	0.8
3	120	M	LE/PO	10	RP	4	1.1
3	125+	–	–	–	–	–	–
4	25	S	SB	3	E	1	1.8
4	55	apedal	–	–	–	–	1.5
4	80	M	PO	7	RP	2	1.6
4	140+	M	O	10	RP	2	1.4
5	15	apedal	–	–	–	–	1.5
5	35	apedal	–	–	–	–	1.5
5	115	apedal	–	–	–	–	1.5
5	140+	–	–	–	–	–	–
6	15	M	PO	5	RP	2	1.7
6	30	M	PO	10	RP	2	1.5
6	45	W	B	15	RP	3	1.0
6	90	W	B	12	RP	3	1.2
6	140+	–	–	–	–	–	–
7	15	apedal	–	–	–	–	1.5
7	50	apedal	–	–	–	–	0.3
7	100+	W	LE	10	RP	4	0.7
8	20	apedal	–	–	–	–	1.5
8	60	apedal	–	–	–	–	1.5
8	90	apedal	–	–	–	–	1.5
8	95+	–	–	–	–	–	–
9	13	S	SB	7	E	2	1.7
9	32	W	LE/B	15	RP	3	0.7
9	60	W	LE	12	RP	2	1.0
9	130+	–	–	–	–	–	–
10	15	S	SB	5	E	1	1.8
10	50	S	SB	7	RP	2	1.6
10	60	apedal	–	–	–	–	1.5
10	73	apedal	–	–	–	–	1.5
10	100	apedal	–	–	–	–	1.5
10	140+	apedal	–	–	–	–	1.5

Map ID	Lower depth, cm	Grade	Type	Size	Fabric	Consistence	SOILpak score
11	15	S	SB	5	E	1	1.9
11	70	M	PO	7	RP	2	1.6
11	125	M	PO/LE	10	RP	2	1.4
11	140+	–	–	–	–	–	1.5
12	15	S	SB	3	E	1	1.8
12	70	M	PO	8	E	2	1.4
12	95	apedal	–	–	–	–	1.5
12	140+	M	PO	10	E	2	1.3
13	10	M	PO	10	E	2	1.5
13	70	M	LE	15	RP	5	0.4
13	140+	M	LE	15	RP	4	0.6
14	12	M	PO	86	E	2	1.6
14	33	M	PL/PO	8	E	2	1.6
14	80	M	CO/LE	15	RP	4	0.8
14	140+	–	–	–	–	–	–
15	15	M	PO	8	E	2	1.4
15	30	W	LE	12	E	3	0.7
15	75	W	LE	12	RP	6	0.4
15	125+	–	–	–	–	–	–
16	20	M	SB	7	E	2	1.7
16	50	M	SB	10	E	3	1.4
16	75	W	PO	8	E	2	1.4
16	140+	W	LE	8	E	2	1.3
17	15	W	PO	7	E	1	1.6
17	65	W	PO	9	E	2	1.4
17	140+	M	LE	15	RP	3	0.8
18	12	M	PO	8	E	2	1.3
18	25	M	LE	10	E	3	1.1
18	50	M	LE	10	RP	3	1.1
18	140+	M	LE	15	RP	5	0.7
19	3	M	PO	7	E	2	1.5
19	12	W	LE	10	E	3	1.2
19	50	S	LE	15	RP	6	0.7
19	80	S	B	10	RP	6	0.7
19	140+	–	–	–	–	–	1
20	15	W	PO	7	E	1	1.6
20	35	W	LE	10	E	2	1.1
20	75	W	LE	8	E	3	0.8
20	140+	W	po	8	E	2	1.1

Attachment D. Laboratory Data

Map	Depth,	pH	pH	EC 1:5	ECe	Chloride	Exchangeable cations, meq/100g					CEC	ESP	ESI	Ca/Mg	ASWAT	NO3-N	Colwell-P	PBI	SO4-S	DTPA-Zn	DTPA-Cu	Boron	Org. C
ID	cm	water	$CaCl_2$	dS/m	dS/m	mg/kg	Ca	Mg	K	Na	Al					score	mg/kg	mg/kg		mg/kg	mg/kg	mg/kg	mg/kg	%
1	0-5	6.1	5.0	0.05	0.69	5	7.4	3.0	0.6	0.2	0.0	11.2	2.1	0.02	2.5	6	0.9	8	67	4	6.2	0.6	0.5	3.4
1	5-15	6.3	5.1	0.04	0.55	5	6.5	3.1	0.4	0.3	0.0	10.3	2.6	0.02	2.1	6	0.3	5	60	3	1.0	0.9	0.5	1.7
1	15-30	6.9	5.7	0.06	0.45	15	10.0	8.5	0.7	0.6	0.0	19.8	3.0	0.02	1.2	12	0.3	3	100	4	0.2	1.2	0.8	0.6
1	30-60	7.6	6.5	0.07	0.6	31	9.1	7.9	0.6	0.7	0.0	18.3	3.8	0.02	1.2	5	0.3	3	110	7	0.3	0.9	1.1	0.4
2	0-5	5.9	4.5	0.02	0.19	5	2.6	1.9	0.8	0.1	0.2	5.7	2.5	0.01	1.4	6	0.3	7	60	2	4.3	0.2	0.4	2.6
2	5-15	5.7	4.2	0.03	0.29	11	1.6	1.8	0.5	0.3	0.8	5.0	5.6	0.01	0.9	10	0.6	3	91	3	2.0	0.3	0.2	1.4
2	15-30	6.4	5.0	0.11	0.83	62	1.7	6.1	0.5	1.4	0.2	9.9	14.2	0.01	0.3	14	0.3	3	62	3	0.5	0.4	0.5	0.6
2	30-60	7.3	6.4	0.36	2.7	320	2.2	9.2	0.6	3.5	0.0	15.5	22.6	0.02	0.2	14	0.3	3	76	17	0.8	0.5	1.3	0.5
2	60-100	8.9	8.1	0.74	6.36	600	2.4	10.0	0.8	6.2	0.0	19.4	31.9	0.02	0.2	13	0.3	33	62	90	0.5	0.5	1.5	0.4
3	0-5	6.2	5.0	0.06	0.52	17	4.6	3.2	1.3	0.2	0.0	9.3	2.5	0.02	1.4	6	2.5	7	84	6	6.4	0.8	0.5	2.7
3	5-15	6.4	5.2	0.05	0.43	5	5.7	3.7	1.1	0.2	0.0	10.7	1.5	0.03	1.5	11	1.2	3	84	4	3.0	1.4	0.6	2.3
3	15-30	6.9	5.6	0.05	0.34	5	7.2	8.8	1.1	0.8	0.0	17.9	4.5	0.01	0.8	14	0.3	3	110	2	0.4	1.2	1.0	1.5
3	30-60	9.1	8.3	0.54	3.62	400	10.0	15.0	0.6	3.9	0.0	29.5	13.2	0.04	0.7	12	0.3	3	170	17	0.2	1.0	2.0	0.8
3	60-100	9.5	8.7	0.76	4.41	570	10.0	14.0	0.6	6.0	0.0	30.6	19.6	0.04	0.7	12	0.3	3	140	50	0.3	0.8	1.5	0.3
4	0-5	6.6	6.0	0.07	1.59	11	5.7	1.4	0.7	0.1	0.0	7.8	0.9	0.08	4.1	5	5.2	7	37	4	6.2	0.4	0.3	1.6
4	5-15	6.7	5.9	0.04	0.91	5	5.6	1.1	0.7	0.0	0.0	7.4	0.5	0.07	5.1	6	2.6	3	38	2	1.4	0.4	0.2	1.2
4	15-30	7.3	6.1	0.03	0.68	5	5.5	0.9	0.8	0.0	0.0	7.2	0.4	0.07	5.9	13	1.2	3	31	1	0.4	0.3	0.2	0.8
4	30-60	7.5	6.4	0.03	0.68	5	3.9	0.9	0.6	0.0	0.0	5.4	0.6	0.05	4.3	10	1.3	3	36	1	0.2	0.3	0.2	0.5
4	60-100	7.6	6.5	0.03	0.26	5	5.2	2.1	0.7	0.1	0.0	8.1	0.7	0.04	2.5	13	0.3	3	57	1	1.1	0.5	0.3	0.5

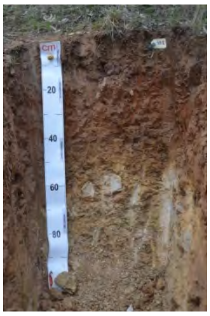
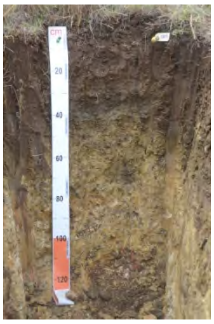
Map	Depth,	pH	pH	EC 1:5	ECe	Chloride	Exchangeable cations, meq/100g					CEC	ESP	ESI	Ca/Mg	ASWAT	NO3-N	Colwell-P	PBI	SO4-S	DTPA-Zn	DTPA-Cu	Boron	Org. C
ID	cm	water	$CaCl_2$	dS/m	dS/m	mg/kg	Ca	Mg	K	Na	Al					score	mg/kg	mg/kg		mg/kg	mg/kg	mg/kg	mg/kg	%
5	0-5	6.5	5.3	0.03	0.68	5	4.1	1.0	0.6	0.0	0.0	5.7	0.2	0.17	4.3	5	5.5	8	36	2	2.5	0.3	0.3	1.0
5	5-15	6.8	5.5	0.03	0.68	5	4.0	1.0	0.8	0.0	0.0	5.8	0.2	0.17	4.0	10	5.7	5	32	2	2.0	0.3	0.2	1.1
5	15-30	7.2	5.6	0.02	0.45	5	3.5	0.6	0.8	0.0	0.0	5.0	0.8	0.03	5.5	10	2.3	3	30	1	0.7	0.3	0.2	0.5
5	30-60	7.6	6.0	0.01	0.23	5	2.2	0.3	0.5	0.0	0.0	3.1	0.3	0.03	6.9	12	0.7	3	25	1	0.1	0.2	0.1	0.2
5	60-100	7.5	6.2	0.02	0.45	5	2.0	0.3	0.4	0.0	0.0	2.7	1.1	0.02	6.3	12	0.9	3	29	2	0.2	0.2	0.1	0.2
6	0-5	6.3	5.3	0.07	0.6	15	7.9	5.1	1.4	0.1	0.0	14.5	0.8	0.08	1.5	4	3.4	6	86	7	8.0	1.9	0.6	3.2
6	5-15	6.3	5.3	0.05	0.43	16	7.2	5.0	1.1	0.1	0.0	13.4	1.0	0.05	1.4	11	0.3	3	100	4	3.2	2.1	0.4	2.3
6	15-30	6.5	5.3	0.03	0.26	11	6.0	4.0	0.6	0.2	0.0	10.8	1.9	0.02	1.5	13	0.3	3	68	2	1.8	1.1	0.4	1.5
6	30-60	7.5	6.2	0.09	0.6	46	7.2	10.0	0.5	1.9	0.0	19.6	9.7	0.01	0.7	15	0.3	3	110	2	0.2	1.0	0.8	0.6
6	60-100	9.2	8.3	0.59	3.42	520	20.0	12.0	0.4	4.4	0.0	36.8	12.0	0.05	1.7	0	0.3	3	120	12	0.1	0.6	1.5	0.4
7	0-5	6.4	5.8	0.12	2.72	35	9.8	3.8	0.8	0.3	0.0	14.7	2.0	0.06	2.6	5	4.0	6	40	9	1.9	0.2	0.8	4.1
7	5-15	6.1	4.8	0.04	0.91	18	1.8	1.3	0.6	0.2	0.2	4.0	4.2	0.01	1.4	8	1.1	3	21	4	0.5	0.1	0.4	1.0
7	15-30	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
7	30-60	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
7	60-100	5.8	4.9	0.29	2.49	290	0.3	7.7	0.5	2.0	0.1	10.6	18.9	0.02	0.0	14	0.3	3	31	24	0.4	0.2	0.2	0.1
8	0-5	5.9	4.5	0.01	0.23	5	1.9	0.5	0.3	0.0	0.3	3.1	1.0	0.01	3.6	6	0.0	5	25	2	0.5	0.1	0.1	1.3
8	5-15	5.7	4.2	0.01	0.23	5	0.5	0.3	0.2	0.1	0.7	1.9	2.7	0.00	1.6	11	0.3	3	40	2	0.2	0.0	0.1	0.5
8	15-30	6.3	4.6	0.01	0.23	5	0.8	0.6	0.2	0.1	0.2	1.8	5.0	0.00	1.5	13	0.3	3	15	2	0.1	0.0	0.1	0.2
8	30-60	6.0	4.7	0.04	0.91	44	0.3	1.1	0.2	0.2	0.1	1.8	9.2	0.00	0.2	13	0.3	3	12	2	0.1	0.0	0.1	0.2
8	60-100	7.4	6.0	0.02	0.45	5	0.1	1.5	0.1	0.2	0.0	1.8	8.3	0.00	0.0	13	0.3	3	3	1	0.0	0.1	0.1	0.1

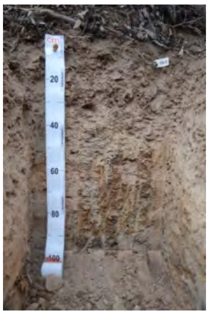
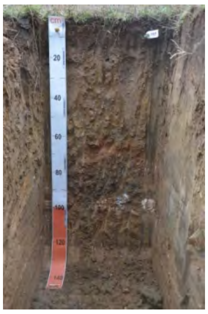
Map	Depth,	pH	pH	EC 1:5	ECe	Chloride	Exchangeable cations, meq/100g					CEC	ESP	ESI	Ca/Mg	ASWAT	NO3-N	Colwell-P	PBI	SO4-S	DTPA-Zn	DTPA-Cu	Boron	Org. C
ID	cm	water	$CaCl_2$	dS/m	dS/m	mg/kg	Ca	Mg	K	Na	Al					score	mg/kg	mg/kg		mg/kg	mg/kg	mg/kg	mg/kg	%
9	0-5	5.9	4.5	0.03	0.29	5	2.2	0.9	0.9	0.1	0.2	4.2	1.4	0.02	2.5	11	2.6	8	45	2	2.8	0.2	0.2	1.5
9	5-15	6.3	4.7	0.03	0.29	10	2.0	0.8	0.6	0.2	0.1	3.8	6.1	0.00	2.4	13	1.3	3	38	3	0.7	0.1	0.3	0.8
9	15-30	6.7	5.5	0.18	1.04	78	3.5	7.5	0.5	2.4	0.0	13.9	17.3	0.01	0.5	15	0.3	3	39	7	0.1	0.3	0.6	0.4
9	30-60	7.1	6.1	0.42	2.44	420	2.5	8.0	0.4	4.7	0.0	15.6	30.2	0.01	0.3	14	0.3	3	52	25	0.1	0.3	1.2	0.3
9	60-100	8.3	7.5	0.87	5.05	1000	2.1	8.6	0.5	7.4	0.0	18.6	39.7	0.02	0.2	11	0.3	3	49	82	0.6	0.4	1.2	0.2
10	0-5	6.3	5.1	0.05	0.69	5	5.9	1.6	1.0	0.0	0.0	8.5	0.5	0.11	3.7	5	6.2	8	38	4	5.6	0.4	0.4	1.9
10	5-15	6.2	4.9	0.03	0.41	5	6.2	1.2	0.7	0.0	0.0	8.1	0.4	0.08	5.2	10	3.2	6	38	2	3.7	0.5	0.3	1.4
10	15-30	6.8	5.5	0.02	0.17	5	7.8	1.7	0.6	0.1	0.0	10.2	0.5	0.04	4.6	12	0.7	5	31	2	1.3	1.7	0.3	1.0
10	30-60	7.2	5.8	0.01	0.23	5	2.8	1.0	0.2	0.0	0.0	4.0	1.0	0.01	2.8	13	0.3	3	23	1	0.1	0.2	0.2	0.3
10	60-100	7.3	5.8	0.01	0.23	5	3.1	1.5	0.1	0.1	0.0	4.8	1.0	0.01	2.1	10	0.7	8	23	2	0.3	0.3	0.1	0.4
11	0-5	6.4	5.2	0.05	0.48	5	7.7	2.5	1.5	0.0	0.0	11.7	0.3	0.20	3.1	7	5.4	15	50	3.8	5.4	0.47	0.4	2.4
11	5-15	6.6	5.3	0.03	0.29	5	8.2	2.2	1.2	0.1	0.0	11.7	0.4	0.07	3.7	10	2.8	9	41	2.1	2.1	0.39	0.36	1.7
11	15-30	6.5	5.0	0.03	0.26	5	7.6	1.9	1.1	0.1	0.0	10.7	0.6	0.05	4.0	12	1.6	7	52	2	1.4	0.41	0.36	1.6
11	30-60	6.8	5.5	0.02	0.17	5	12.0	3.8	0.7	0.1	0.0	16.6	0.5	0.04	3.2	13	0.3	8	69	1.6	0.5	0.6	0.57	1.9
11	60-100	7.4	6.1	0.02	0.19	5	10.0	4.4	0.2	0.2	0.0	14.8	1.0	0.02	2.3	6	0.3	12	65	1.9	0.79	0.44	0.37	1.6
12	0-5	6.4	5.3	0.06	0.83	5	7.9	2.0	1.2	0.0	0.0	11.1	0.3	0.22	4.0	5	9.1	22	31	3.8	11	0.45	0.41	2.6
12	5-15	6.7	5.2	0.03	0.41	5	6.0	1.2	1.2	0.0	0.0	8.4	0.5	0.06	5.0	11	3.8	13	25	1.4	2.6	0.31	0.24	1.3
12	15-30	6.9	5.4	0.03	0.41	5	6.3	1.2	1.0	0.0	0.0	8.5	0.4	0.09	5.3	13	2.9	10	19	1.1	0.97	0.35	0.26	1
12	30-60	7.5	6.2	0.03	0.41	5	10.0	3.3	1.3	0.1	0.0	14.7	0.5	0.06	3.0	15	0.8	16	57	1.1	0.43	0.49	0.52	1.3
12	60-100	7.8	6.5	0.02	0.45	5	5.8	2.6	0.6	0.1	0.0	9.0	0.7	0.03	2.2	13	0.3	16	36	1	0.32	0.25	0.39	0.59

Map	Depth,	pH	pH	EC 1:5	ECe	Chloride	Exchangeable cations, meq/100g					CEC	ESP	ESI	Ca/Mg	ASWAT	NO3-N	Colwell-P	PBI	SO4-S	DTPA-Zn	DTPA-Cu	Boron	Org. C
ID	cm	water	$CaCl_2$	dS/m	dS/m	mg/kg	Ca	Mg	K	Na	Al					score	mg/kg	mg/kg		mg/kg	mg/kg	mg/kg	mg/kg	%
13	0-5	6.0	4.7	0.04	0.38	<10.0	2.1	1.1	0.6	0.1	0.1	4.1	2.7	0.01	1.9	6	4.4	6	49	3.3	2.4	0.24	0.4	1.7
13	5-15	6.4	4.9	0.04	0.34	14	1.5	1.5	0.4	0.3	0.0	3.6	7.7	0.01	1.0	11	<0.5	<5	46	2.9	0.27	0.09	0.29	0.69
13	15-30	6.2	5.1	0.25	2.15	200	1.3	7.3	0.4	2.4	0.2	11.6	20.8	0.01	0.2	13	<0.5	<5	66	11	0.15	0.16	0.86	0.45
13	30-60	6.1	5.1	0.41	3.53	420	0.7	7.3	0.4	3.7	0.0	12.0	30.7	0.01	0.1	15	<0.5	<5	54	30	0.17	0.18	0.93	0.29
13	60-100	8.0	7.1	0.6	5.16	570	0.6	9.6	0.6	5.9	0.0	16.7	35.4	0.02	0.1	11	<0.5	<5	34	67	0.58	0.25	1	0.18
14	0-5	6.1	4.9	0.07	0.6	<10.0	3.3	1.4	1.3	0.1	0.0	6.1	2.1	0.03	2.4	4	14	12	53	5.1	4.9	0.4	0.64	2.1
14	5-15	6.0	4.6	0.05	0.43	<10.0	2.7	0.9	1.3	0.1	0.2	5.2	2.1	0.02	3.0	10	5.6	6	69	3.6	2.2	0.53	0.61	1.4
14	15-30	6.6	5.0	0.03	0.26	<10.0	2.3	0.8	0.8	0.2	0.0	4.0	4.2	0.01	3.0	11	1.7	<5	49	1.9	<0.02	0.17	0.36	0.55
14	30-60	7.5	6.5	0.29	1.68	230	2.9	8.1	0.3	3.6	0.0	14.9	24.2	0.01	0.4	14	<0.5	<5	83	13	<0.02	0.37	1.9	0.32
14	60-100	8.0	6.8	0.44	2.55	410	2.7	8.5	0.3	4.9	0.0	16.4	29.9	0.01	0.3	12	<0.5	<5	77	28	0.06	0.49	3.1	0.35
15	0-15	5.6	4.5	0.04	0.55	16	1.6	1.2	0.7	0.1	0.4	3.9	1.8	0.02	1.33	5	2	9	–	6	0.12	2.40	0.23	1.70
15	15-30	5.9	4.4	0.03	0.41	11	0.7	1.0	0.5	0.1	0.6	2.9	3.8	0.01	0.71	10	1	7	–	3	0.06	0.22	0.15	0.83
15	30-60	6.3	5.4	0.30	2.58	250	0.4	8.2	0.6	2.7	0.1	12.0	22.5	0.01	0.05	15	1	5	–	40	0.13	0.19	0.53	0.45
15	60-100	6.2	5.4	0.48	4.13	410	0.2	9.9	0.7	3.4	0.1	14.3	23.9	0.02	0.02	13	1	5	–	85	0.21	0.27	0.61	0.34
16	0-15	6.1	5.1	0.08	0.76	24	7.5	1.8	1.5	0.1	0.1	11.0	0.5	0.18	4.17	4	6	10	–	9	0.34	4.70	0.61	2.40
16	15-30	6.6	5.5	0.04	0.38	10	9.5	1.6	0.8	0.0	0.0	12.0	0.3	0.12	5.94	7	2	6	–	4	0.34	0.98	0.83	2.70
16	30-60	7.6	6.5	0.03	0.29	12	6.0	1.2	0.3	0.0	0.0	7.6	0.5	0.06	5.00	11	1	5	–	3	0.29	0.39	0.50	0.65
16	60-90	7.7	6.6	0.02	0.28	10	4.0	2.1	0.2	0.1	0.0	6.4	0.9	0.02	1.90	11	1	5	–	2	0.31	0.15	0.38	0.38
17	0-15	6.4	5.4	0.03	0.29	10	2.9	0.9	0.6	0.0	0.1	4.6	0.4	0.07	3.19	10	3	7	–	4	0.16	1.60	0.31	0.97
17	15-30	6.7	5.6	0.02	0.28	10	2.1	0.8	0.5	0.0	0.0	3.4	0.6	0.03	2.59	12	2	5	–	2	0.11	0.17	0.22	0.42
17	30-60	7.0	5.8	0.02	0.28	10	2.1	1.2	0.4	0.0	0.0	3.7	0.5	0.04	1.75	13	1	6	–	2	0.40	0.03	0.24	0.29
17	60-90	6.5	5.0	0.04	0.34	22	2.6	5.1	0.3	0.6	0.1	8.7	6.6	0.01	0.51	15	1	5	–	5	1.00	0.35	0.64	0.39

Map ID	Depth, cm	pH water	pH $CaCl_2$	EC 1:5 dS/m	ECe dS/m	Chloride mg/kg	Exchangeable cations, meq/100g Ca	Mg	K	Na	Al	CEC	ESP	ESI	Ca/Mg	ASWAT score	NO3-N mg/kg	Colwell-P mg/kg	PBI	SO4-S mg/kg	DTPA-Zn mg/kg	DTPA-Cu mg/kg	Boron mg/kg	Org. C %
18	0-15	5.9	4.8	0.05	0.43	24	4.1	1.1	1.1	0.0	0.1	6.4	0.5	0.11	3.73	4	4	6	–	4	0.54	2.20	0.60	1.60
18	15-30	6.5	5.3	0.02	0.19	10	3.6	1.5	0.5	0.1	0.1	5.7	0.9	0.02	2.40	12	1	5	–	3	0.45	0.20	0.48	0.68
18	30-60	6.6	5.4	0.03	0.26	10	3.5	3.5	0.3	0.3	0.1	7.7	3.6	0.01	1.00	11	1	5	–	8	0.40	0.06	0.76	0.32
18	60-90	7.2	5.9	0.06	0.52	18	4.6	4.4	0.4	0.7	0.0	10.0	6.5	0.01	1.05	13	1	5	–	12	0.30	0.04	1.50	0.32
19	0-15	5.6	4.4	0.03	0.29	11	1.3	0.9	0.6	0.1	0.4	3.3	2.1	0.01	1.43	7	2	29	–	3	0.11	2.10	0.23	1.30
19	15-30	5.8	4.8	0.19	1.63	100	2.6	9.1	1.2	1.6	0.3	14.8	10.8	0.02	0.29	14	1	5	–	13	0.11	0.17	0.95	0.58
19	30-60	5.7	4.9	0.41	3.53	330	2.0	9.9	1.2	3.0	0.2	16.3	18.4	0.02	0.20	12	1	7	–	58	0.11	0.08	1.50	0.55
19	60-90	7.7	7.0	0.77	6.62	910	1.1	9.1	0.6	5.7	0.0	16.5	34.6	0.02	0.12	0	1	5	–	90	0.19	0.22	1.20	0.22
20	0-15	5.9	4.8	0.03	0.41	10	2.1	0.9	0.6	0.0	0.1	3.7	0.8	0.04	2.31	4	1	7	–	5	0.11	0.48	0.29	1.20
20	15-30	5.8	4.6	0.02	0.28	10	1.0	0.5	0.4	0.0	0.4	2.2	0.9	0.02	1.94	12	1	7	–	2	0.03	0.03	0.18	0.37
20	30-60	6.0	4.7	0.01	0.23	10	0.4	1.2	0.3	0.0	0.2	2.1	0.9	0.01	0.36	12	1	5	–	2	0.03	0.02	0.13	0.15
20	60-90	6.6	5.4	0.01	0.14	10	0.7	1.4	0.1	0.1	0.1	2.4	2.5	0.00	0.50	12	1	6	–	2	0.03	0.02	0.12	0.15

Attachment E. Photographs of Soil Profiles and Associated Landscapes

Site	Soil Profile	Associated Landscape
1		
2		
3		
4		
5		

6		
7		
8		
9		
10		

11		
12		
13		
14		
15		

16		
17		
18		
19		
20