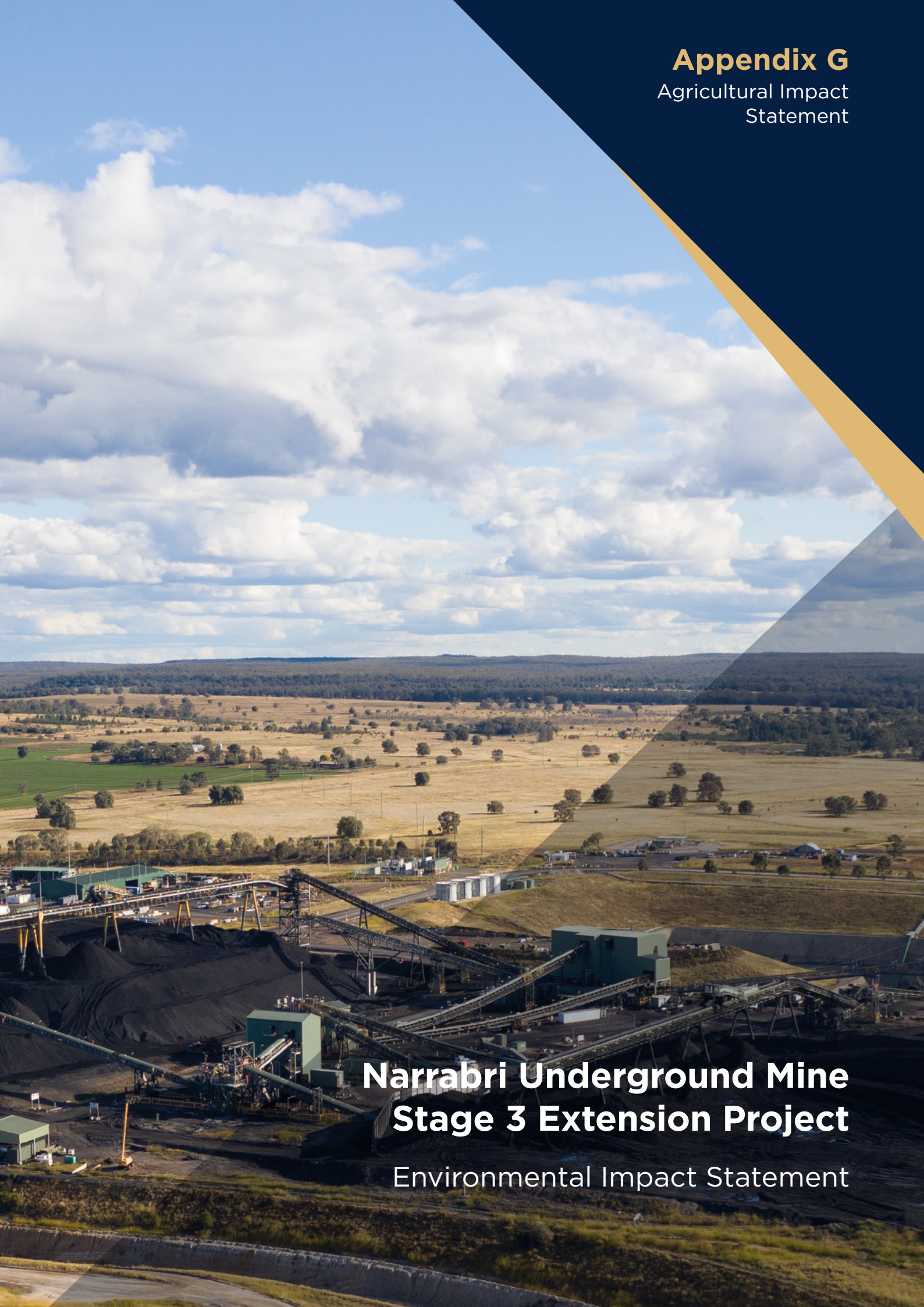

Appendix G
Agricultural Impact Statement

Narrabri Underground Mine Stage 3 Extension Project

Environmental Impact Statement

Narrabri Underground Mine Stage 3 Extension Project

Agricultural Impact Statement

August 2020

DOCUMENT CONTROL

Project name:	Narrabri Underground Mine Stage 3 Extension Project		
Report name	Narrabri Underground Mine Stage 3 Extension Project Agricultural Impact Statement		
Date	26/08/2020	Version Final	Status V3
Prepared by	Dr Bronwyn Cameron, Dr Paul Frazier		
Company	2rog Consulting		
Reviewed by	Dr Julian Wall		
Approved by	Dr Paul Frazier		

EXECUTIVE SUMMARY

Report Purpose

Narrabri Coal Operations Pty Limited (NCOPL) is seeking a new Development Consent under the State Significant Development provisions of Part 4 of the New South Wales (NSW) *Environmental Planning and Assessment Act 1979* (EP&A Act) for the Narrabri Underground Mine Stage 3 Extension Project (the Project). This Agricultural Impact Statement (AIS) forms part of an Environmental Impact Statement (EIS) which has been prepared to accompany the Development Application for the Project.

As the Project Area was found to contain areas of biophysical strategic agricultural land (BSAL), a Gateway Certificate for the Project was sought and a Conditional Gateway Certificate was issued by the NSW Mining and Petroleum Gateway Panel in 2019. This report specifically addresses the requirements stated in the Secretary's Environmental Assessment Requirements (SEARs) issued by the NSW Department of Planning, Industry and Environment (DPIE) and the recommendations of the Conditional Gateway Certificate.

This report should be read in conjunction with the Project EIS and the key findings of the associated specialist reports.

Proposed Project

The Project involves an extension to the south of the approved underground mining area to gain access to additional coal reserves within the Mining Lease Applications (MLAs) 1 and 2, an extension of the mine life to 2044 and development of supporting surface infrastructure. Run-of-mine (ROM) coal production would occur at a rate of up to 11 million tonnes per annum (Mtpa), consistent with the currently approved limit.

NCOPL has proposed the Project to provide continuity of mining with the existing Narrabri Mine. The Project includes the extension of the currently approved Longwalls (LW) 203 to 209 and an additional longwall (LW210) within MLA 1. Mining would continue to be carried out using longwall mining techniques with similar mine geometry, geology, landscape and land use as the existing Narrabri Mine.

Project Area

The Project Area includes the relevant portion within Mining Lease (ML) 1609 and MLAs 1 and 2 (excluding the Uambi property). The Uambi property is within MLA 1 but would not be subject to surface disturbance or material subsidence impacts and has therefore been excluded from the Project Area. Longwall mining impacts in ML1609 are approved, however, additional surface infrastructure is required to facilitate the Project.

Land use and land production capability was assessed through: field inspections; interviews with property managers within the Project Area; interviews with local agricultural consultants/suppliers; review and analysis of NSW Government agricultural resource mapping data; and assessment of local and regional agricultural data.

Land use within the Project Area consists of a combination of grazing (cattle and sheep), small areas of cropping, a small olive grove and a State Forest with selective silvicultural harvesting (predominantly white cypress). Cropping is generally restricted to fodder crops for livestock and is opportunistic, based on favourable soil moisture conditions and weather forecasts. There is no irrigated agriculture in the Project Area. Surface water is the main water source for stock and domestic use. Groundwater is seldom, if ever, used for agricultural production and is generally of poor quality.

The land surface is moderately to gently undulating with slopes generally less than 10 degrees. Land capability is generally moderate (Land and Soil Capability Classes 3, 4 or greater) with small areas of higher land capability (Classes 2). Detailed soil investigation, including extensive field sampling, conducted by Soil Management Designs (2019) and GT Environmental (2020), has mapped 215 hectares (ha) BSAL within MLAs 1 and 2. An additional area of approximately 172 ha of BSAL is located within the relevant portion of ML 1609, based on regional mapping.

Potential Impacts

Project surface infrastructure development would require the disturbance of approximately 639 ha, 399 ha within MLAs 1 and 2 and 240 ha in ML 1609.

Potential Impacts – MLAs 1 and 2

In general, surface infrastructure would be developed progressively over the life of the mine and decommissioned and rehabilitated where no further beneficial use is identified.

Within MLAs 1 and 2 subsidence of up to approximately 2.8 metres (m) is expected for each longwall panel. The main expected surface impact from subsidence would be small areas of ponding along existing creek lines including an increased ponding area of 1.45 ha on BSAL. Based on experience drawn from the existing Narrabri Mine, there is expected to be minimal to no impact on other agricultural resources if routine maintenance is undertaken as required through the Land Management Plan (Eco Logical Australia 2017) (or its latest approved version).

Surface development would occur on approximately 399 ha in MLAs 1 and 2, although some areas would only be required for a temporary period. An area of approximately 18 ha of BSAL would be used for surface development. All areas used for surface mining infrastructure would be rehabilitated to the pre-existing land use prior to mine closure.

Groundwater assessment and modelling by Australasian Groundwater and Environmental Consultants (2020) found no significant groundwater resources within the Project Area. The ‘highly productive’ Namoi Alluvium to the east of the Project Area is not expected to be significantly impacted by the Project.

Potential Impacts – ML 1609

This AIS considers the impacts additional to those approved under PA 08_0144 within ML 1609. The additional impacts from the Project primarily relate to the indicative surface development footprint that would be required above LWs 203 to 209 within ML 1609. Surface development would occur on approximately 240 ha in ML 1609, although some areas would only be required for a temporary period. An area of 4 ha of BSAL would be used for mine infrastructure development. All areas used for surface mining infrastructure would be rehabilitated to the pre-existing land use prior to mine closure.

Impacts to Agricultural production and BSAL

With appropriate management and rehabilitation, no significant impacts on BSAL or local or regional agricultural production are likely as a result of the Project.

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ABBREVIATIONS

Abbreviation	Description
AIP	Aquifer Interference Policy
ASC	Australian Soil Classification
BSAL	Biophysical Strategic Agricultural Land
CHPP	Coal Handling and Preparation Plant
DPI	NSW Department of Primary Industries
DPIE	NSW Department of Planning, Infrastructure and Environment
DP&E	NSW Department of Planning and Environment (now DPIE)
DP&I	NSW Department of Planning and Infrastructure
EIS	Environmental Impact Statement
EL	Exploration Licence
ha	Hectare
km	Kilometre
LGA	Local Government Area
LSC	Land and Soil Capability
Mining SEPP	*State Environmental Planning Policy (Mining, Petroleum Production and Extractive Industries) 2007*
ML	Mining Lease
NSW	New South Wales
PAC	Planning Assessment Commission (now the Independent Planning Commission)
Project Area	Narrabri Underground Mine Stage 3 Extension Project Area
ROM	Run-of-mine
SEARs	Secretary's Environmental Assessment Requirements
The Project	Narrabri Underground Mine Stage 3 Extension Project

01 INTRODUCTION

The Narrabri Mine is located approximately 25 kilometres (km) south-east of Narrabri and approximately 60 km north-west of Gunnedah within the Narrabri Shire Council Local Government Area (LGA) of New South Wales (NSW) (Figure 01-1). The Narrabri Mine is operated by Narrabri Coal Operations Pty Limited (NCOPL).

NCOPL is seeking a new Development Consent under the State Significant Development provisions of Part 4 of the NSW *Environmental Planning and Assessment Act 1979* (EP&A Act) for the Narrabri Underground Mine Stage 3 Extension Project (the Project). This Agricultural Impact Statement (AIS) forms part of the Environmental Impact Statement (EIS) which has been prepared to accompany the Development Application for the Project. The Secretary's Environmental Assessment Requirements (SEARs) states the following requirements in regard to the agricultural impact assessment:

- *an assessment of the likely agricultural impacts of the development including preparation of an Agricultural Impact Statement, prepared in accordance with DPI's Agricultural Impact Statement: Technical Notes;*
- *an assessment of the likely impacts of the development on the soils and land capability of the site and surrounds, paying particular attention to any Biophysical Strategic Agricultural Land (BSAL) and having regard to the Mining & Petroleum Gateway Panel's requirements (see Attachment 4);*
- *an assessment of the compatibility of the development with other land uses in the vicinity of the development in accordance with the requirements of Clause 12 of State Environmental Planning Policy (Mining, Petroleum Production and Extractive Industries) 2007.*

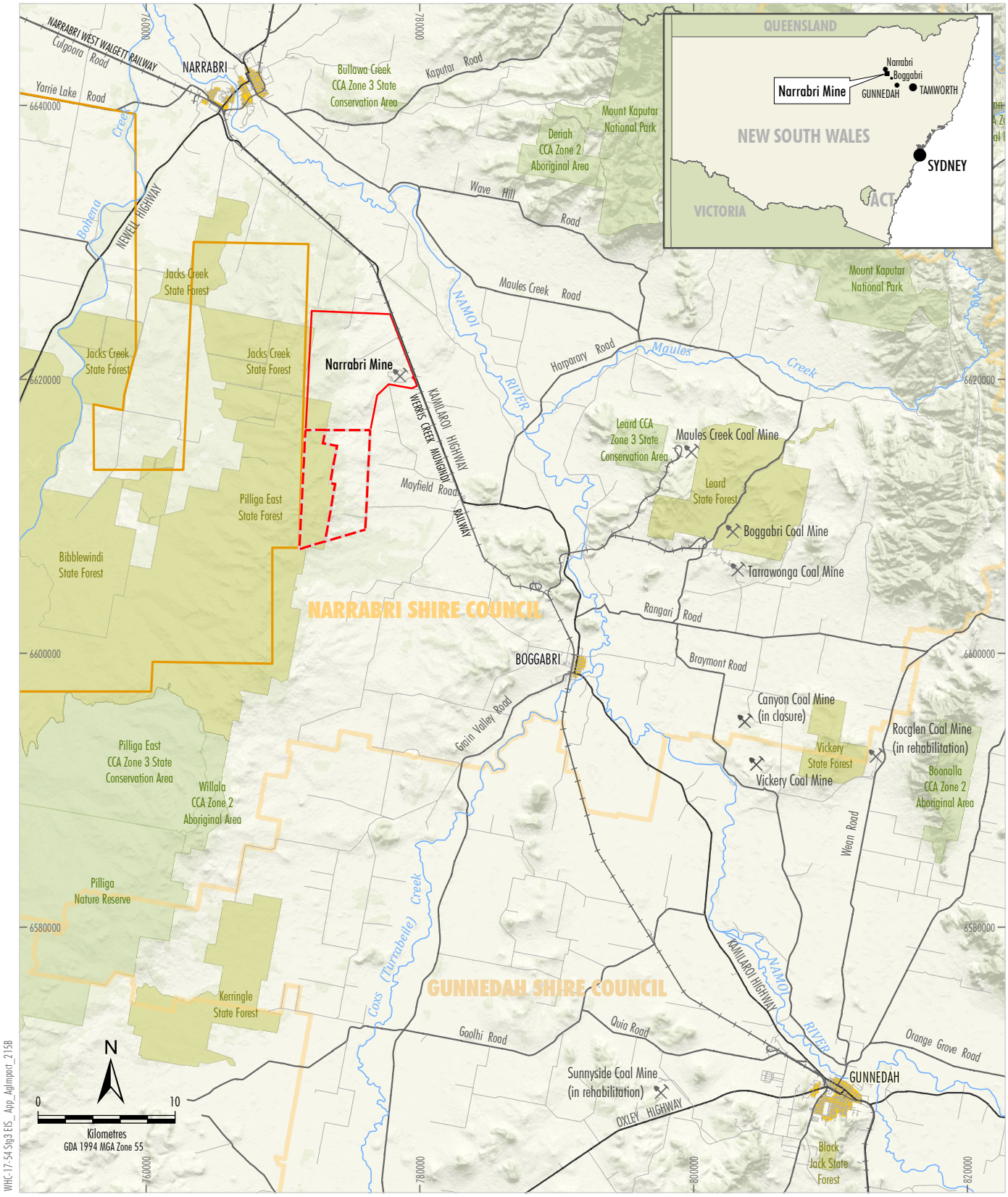
Section 01.2.1 provides relevant extracts from the SEARs and where these issues are addressed within the EIS.

01.1 Requirements for an Agricultural Impact Statement

Following receipt of a Conditional Gateway Certificate issued by the NSW Mining and Petroleum Gateway Panel (Gateway Panel) in June, 2019, NCOPL is seeking consent for the Project under the State Significant Development provisions of Part 4 of the NSW EP&A Act.

This assessment builds upon the assessment of potential impacts to agriculture described and assessed in the Application for a Gateway Certificate (Eco Logical Australia 2019) and has been prepared in accordance with:

- The SEARs issued by the NSW Department of Planning, Industry and Environment (DPIE) (20 November 2019);
- The recommendations attached to the Conditional Gateway Certificate (June 2019);
- Agricultural Impact Statement technical notes (Department of Primary Industries [DPI] 2013);
- Interim protocol for site verification and mapping biophysical strategic agricultural land (BSAL) (Office of Environment and Heritage [OEH] [now within the DPIE – Biodiversity Conservation Division {BCD}] and Office of Agricultural Sustainability and Food Security 2013).
- Strategic Regional Land Use Policy, Guideline for Gateway Applicants, Fact Sheet (Department of Planning and Infrastructure [DP&I] 2013).
- *New England North West Strategic Regional Land Use Plan*, September 2012 by DP&I (DP&I 2012).



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LEGEND

- Mine Site
- Mining Lease (ML 1609)
- Provisional Mining Lease Application Area
- Local Government Boundary
- State Forest
- State Conservation Area, Aboriginal Area
- Narrabri Gas Project (Santos NSW [Eastern] Pty Ltd)

Source: Geoscience Australia (2011); NSW Spatial Services (2019)

WHITEHAVEN COAL

NARRABRI STAGE 3 PROJECT

Regional Location

Figure 1-1

- *NSW Aquifer Interference Policy: NSW Government policy for the licensing and assessment of aquifer interference activities* (the AIP) (DPI 2012).
- The NSW *Environmental Planning and Assessment Regulation 2000* and *State Environment Planning Policy (Mining, Petroleum Production and Extractive Industries) 2007* (The Mining SEPP).

These policies and processes require that an AIS be developed that contains the following general information:

- detailed assessment of the agricultural resources and production within the Project Area and surrounds, including identification of the current agricultural enterprises;
- identification and assessment of potential impacts of the Project on agricultural resources or industries;
- consideration of any changes in agricultural water resource availability;
- assessment of socio-economic impacts;
- development of mitigation measures to minimise adverse impacts on agricultural resources; and
- consultation with adjoining land users and Government Departments.

01.2 Addressing Regulatory Requirements, Policies and Guidelines

This section describes the regulatory framework for this AIS including project-specific requirements.

01.2.1 Secretary's Environmental Assessment Requirements

The SEARs for the Project were issued on 20 November 2019. Table 01-1 details the general requirements of the SEARs, including key issues that relate to agricultural resources and production, and also highlights where each issue is addressed in this AIS.

Table 01-1 Secretary's Environmental Assessment Requirements Relevant to this AIS

Assessment Requirement	EIS Reference	Reference within this Document
Subsidence *including:* • *an assessment of the likely conventional and non-conventional subsidence effects and impacts of the development and the potential consequences of these effects and impacts on the natural and built environment, paying particular attention to those features that are considered to have significant economic, social, cultural or environmental value, taking into consideration:* – *recorded regional and historic subsidence levels, impacts and environmental consequences;* – *the potential extent of fracturing of the strata above the longwall panels* – *the implementation of a comprehensive subsidence monitoring program which is capable of detecting vertical, horizontal and far-field subsidence movements;*	**Appendix A**	**Section 7** Impact Assessment

Assessment Requirement	EIS Reference	Reference within this Document
Land *including:* • *an assessment of the likely agricultural impacts of the development including preparation of an Agricultural Impact Statement, prepared in accordance with DPI's Agricultural Impact Statement: Technical Notes;* • *an assessment of the likely impacts of the development on the soils and land capability of the site and surrounds, paying particular attention to any Biophysical Strategic Agricultural Land (BSAL) and having regard to the Mining & Petroleum Gateway Panel's requirements (see Attachment 4);* • *an assessment of the compatibility of the development with other land uses in the vicinity of the development in accordance with the requirements of Clause 12 of State Environmental Planning Policy (Mining, Petroleum Production and Extractive Industries) 2007*	**This AIS**	**Section 5** Agricultural Resource Analysis **Section 7** Impact Assessment
Water *including:* • *an assessment of the likely impacts of the development on the quantity and quality of the region's surface and groundwater resources, having regard to the Mining & Petroleum Gateway Panel's requirements (see Attachment 4) and (Commonwealth) Department of Environment and Energy requirements under the Environment Protection and Biodiversity Conservation Act 1999 (see Attachment 3);* • *an assessment of the likely impacts of the development on aquifers, watercourses, riparian land, groundwater dependent ecosystems, water-related infrastructure, and other water users;* • *an assessment of potential flooding and ponding impacts of the development;*	**Appendices A, B and C**	**Section 5** Agricultural Resource Analysis **Section 7** Impact Assessment
Noise and Vibration *including:* • *an assessment of the likely noise impacts of the development under the NSW Noise Policy for Industry and the Voluntary Land Acquisition and Mitigation Policy (DP&E);* • *an assessment of the likely road noise impacts of the development under the NSW Road Noise Policy;* • *an assessment of the likely rail noise impacts of the project under the Rail Infrastructure Noise Guidelines;* • *an assessment of the potential vibration and low frequency noise impacts of the development;*	**Appendix H**	**Section 7** Impact Assessment
Air *including:* • *an assessment of the likely air quality impacts of the development in accordance with the Approved Methods and Guidance for the Modelling and Assessment of Air Pollutants in NSW; and*	**Appendix I**	**Section 7** Impact Assessment
Transport *including:* • *an assessment of the likely transport impacts of the development on the capacity, condition, safety and efficiency of the local and State road network and the rail network;*	**Appendix J**	**Section 7** Impact Assessment
Visual and Light *including:* • *an assessment of the likely visual impacts of the development on private landowners in the vicinity of the development and key vantage points in the public domain, paying particular attention to the creation of any new landforms and minimising the lighting impacts of the development, with particular consideration of the impacts on the Siding Springs Observatory;*	**Section 6**	**Section 7** Impact Assessment

Assessment Requirement	EIS Reference	Reference within this Document
Rehabilitation and Final Landform *including* • *a conceptual final landform design;* • *an assessment of the likely impacts of the development on existing landforms and topography, including justification of the final landform design and its long-term geotechnical stability;* • *a detailed description of the progressive rehabilitation measures that would be implemented for the development and how this rehabilitation would integrate with the final landform of the mine;* • *a detailed description of the proposed rehabilitation and mine closure strategies for the development, including rehabilitation objectives, performance standards and completion criteria;* • *nominated final land uses, having regard to any relevant strategic land use planning or resource management plans or policies*	**This AIS and Attachment 5 of the EIS**	**Section 8** Landscape Management Plan
Consultation: • *During the preparation of the EIS, you must consult with relevant local, State or Commonwealth Government authorities, service providers, community groups and affected landowners. The EIS must describe the consultation that was carried out, identify the issues raised during this consultation, and explain how these issues have been addressed in the EIS.*	**Section 5**	**Section 3** Consultation
DoI - Water • *Assessment of impacts on surface and ground water sources (both quality and quantity), related infrastructure, adjacent licensed water users, basic landholder rights, watercourses, riparian land, and groundwater dependent ecosystems, and measures proposed to reduce and mitigate these impacts.* • *Consideration of relevant legislation, policies and guidelines, including the NSW Aquifer Interference Policy (2012), the DPI Water Guidelines for Controlled Activities on Waterfront Land (2018) and the relevant Water Sharing Plans.*	**Appendices B and C**	**Section 7** Impact Assessment
DPI Agriculture • *DPI Agriculture Notes the Draft SEARs request "an Agricultural Impact Statement, prepared in accordance with DPI's Agricultural Impact Statement: Technical Notes, to assess the likely impacts of the development on the soils and land capability of the site and surrounds, paying particular attention to any Biophysical Strategic Agricultural Land (BSAL)", this is supported and will cover issues related to Agricultural land and industries.*	**This AIS**	**This AIS**

01.2.2 Conditional Gateway Certificate Recommendations

As the Project Area contains an area of BSAL, a Gateway Assessment Application was submitted for assessment by the Gateway Panel (Eco Logical Australia 2019). The Gateway Panel provided a Conditional Gateway Certificate and provided a set of recommendations for further consideration. Those recommendations that relate specifically to this AIS are detailed in Table 01-2.

Table 01-2 Conditional Gateway Certificate Recommendations

Relevant Criteria	Recommendation	EIS Reference	Reference within this document
17H4(a)(i)	*The panel requires a landscape management plan to be prepared as part of the EIS detailing how surface cracking and altered drainage patterns will be managed as subsidence occurs. This plan must include detailed mapping of potential BSAL currently not verified.*	**This AIS**	**Section 8** Landscape Management Plan
17H4(a)(ii)	*The panel requires a landscape management plan to be prepared as part of the EIS detailing how altered drainage patterns resulting in soil saturation for extended periods will be managed as subsidence occurs.*	**This AIS**	**Section 8** Landscape Management Plan
17H4(a)(iii)	*The panel requires within the EIS landscape management plan a documented procedure for managing the altered micro-relief resulting from subsidence within the current agricultural production systems.*	**This AIS**	**Section 8** Landscape Management Plan
17H4(a)(iv)	*The Panel requires more geological detail and baseline data acquisition in any upgraded groundwater model that is to be used in an EIS. Also, any future groundwater flow modelling should include cumulative impact studies of the nearby (proposed) Santos Coal Seam Gas Project. Additional studies are required to more fully identify and evaluate cracking formed from the effects of mining and the possible loss of water in ephemeral streams due to surface cracking.*	**Appendix B**	**Section 7** Impact Assessment
17H4(a)(vi)	*The panel requires a detailed plan for the storage of BSAL topsoil removed for surface infrastructure development and its subsequent re-establishment in the mine rehabilitation process at the end of mine life.*	**This AIS**	**Section 8** Landscape Management Plan, Appendix B

It is worth noting that there are no Critical Industry Clusters in the region, therefore this aspect is not considered in this report.

01.3 Supporting Studies

The studies undertaken for the EIS, to be read in conjunction with this AIS, include:

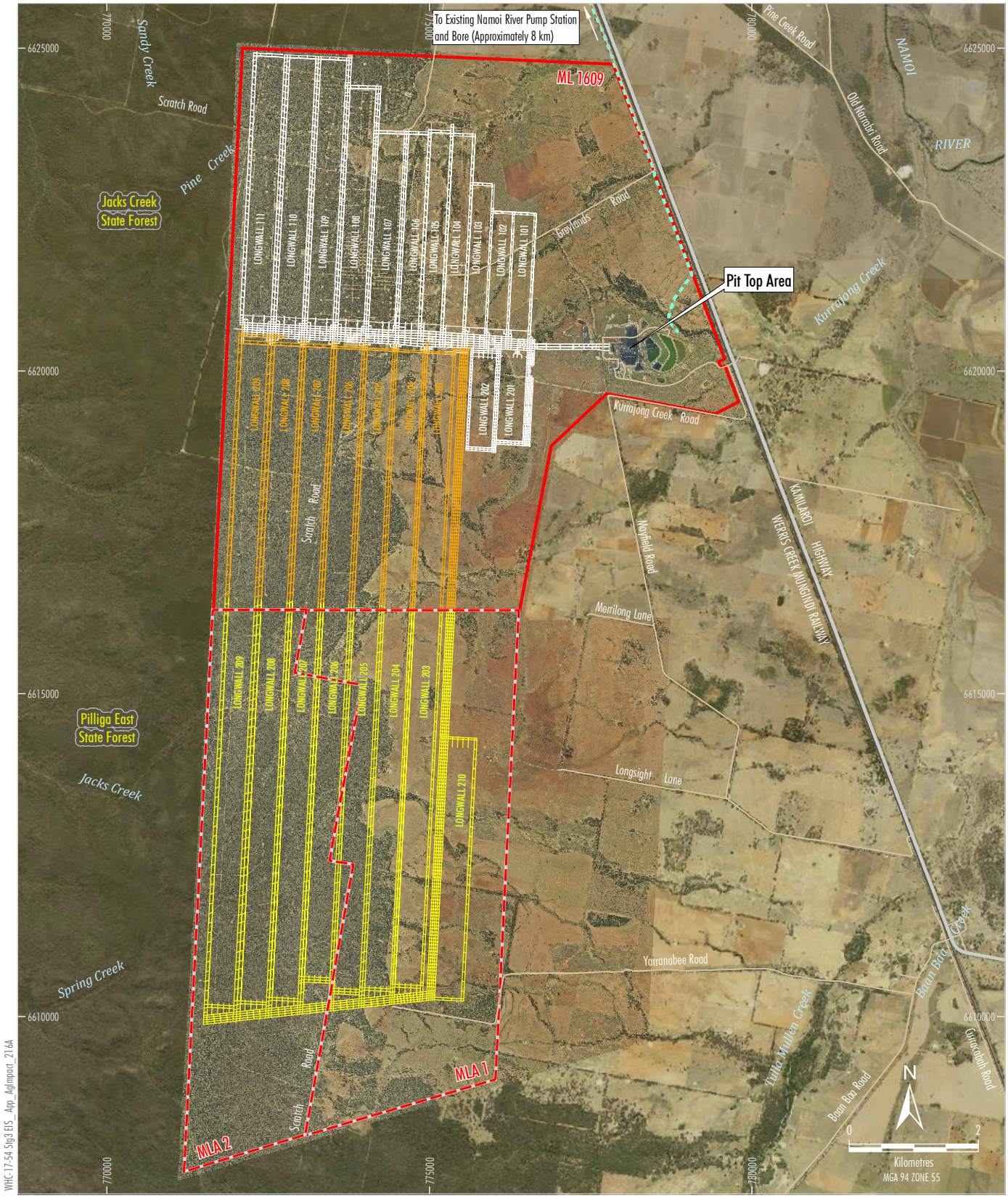
- **Appendix A:** Mine subsidence assessment in support of the EIS for Narrabri Underground Mine Stage 3 Extension Project (Ditton Geotechnical Services 2020).
- **Appendix B:** Narrabri Underground Mine Stage 3 Extension Project – Groundwater Assessment (Australasian Groundwater and Environmental Consultants [AGE] 2020).
- **Appendix C:** Narrabri Underground Mine Stage 3 Extension Project Surface Water Assessment (WRM Water & Environment [WRM] 2020).
- **Appendix H:** Narrabri Underground Mine Stage 3 Extension Project Noise Assessment (Wilkinson Murray 2020).
- **Appendix I:** Narrabri Underground Mine Stage 3 Extension Project Air Quality and Greenhouse Gas Assessment (Jacobs 2020).
- **Appendix J:** Narrabri Underground Mine Stage 3 Extension Project: Road Transport Assessment (The Transport Planning Partnership [TTPP] 2020).

02 PROJECT DESCRIPTION

02.1 Project Overview

The Project involves an extension to the south of the approved underground mining area to gain access to additional coal reserves within Mining Lease Applications (MLAs) 1 and 2 (Figure 02-1), an extension of the mine life to 2044 and development of supporting surface infrastructure. Run-of-mine (ROM) coal production would occur at a rate of up to 11 million tonnes per annum (Mtpa), consistent with the currently approved limit.

A detailed description of the Project is provided in Section 2 in the Main Report of the EIS.



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LEGEND

- Mining Lease (ML 1609)
- Provisional Mining Lease Application Area
- Existing Namoi River Pipeline (Buried)
- Approved Underground Mining Layout
- Indicative Underground Mining Layout to be Extended for Project
- Indicative Underground Project Mining Layout

Source: NCOPL (2019); NSW Spatial Services (2019)

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NARRABRI STAGE 3 PROJECT

Project General Arrangement - Indicative Underground Mining Layout

Figure 2-1

03 CONSULTATION

03.1 General Consultation

The existing Narrabri Mine has been operating since 2007. In this time, considerable community and stakeholder consultation has been undertaken. Community engagement is undertaken through the following mechanisms:

- a dedicated website (https://whitehavencoal.com.au/our-business/our-assets/narrabri-mine/);
- Community Consultative Committee (CCC) quarterly meetings (with meeting minutes provided on the website and emailed direct to interested stakeholders);
- Narrabri Mine CCC quarterly meeting Environmental Monitoring Reports;
- occasional community information sheets and letterbox drops;
- media releases and other media activities;
- general community surveys and reports;
- landholder relations program; and
- information days and mine open days.

NCOPL has undertaken a number of engagement activities in relation to the Project including opportunities for direct stakeholder feedback. Key consultation activities of particular relevance to this AIS include:

- Consultation with a wide range of government agencies and documentation of relevant assessment considerations identified by key government agencies in the SEARs (Section 01.2.1) and Gateway Certificate (Section 01.2.2).
- Consultation with neighbouring landholders, including Santos (proponents of the Narrabri Gas Project), which has included meetings and discussions regarding cumulative assessment considerations.
- Community consultation, including (but not limited to) distributing community newsletters to local residents and other stakeholders, conducting community information sessions, providing briefings to the CCC and proactively providing information through local media.
- Community and landholder engagement as part of the Social Impact Assessment (CDM Smith 2020) in accordance with the NSW Government's *Social Impact Assessment Guidelines* (Department of Planning and Environment 2017) (Appendix K of the EIS).

Further details of the consultation program conducted for the Project are provided in Section 5 in the Main Report of the EIS.

03.2 Consultation Specific to this AIS

Consultation with land managers in MLAs 1 and 2 was undertaken for the Gateway Certificate Application Agricultural Impact Assessment (Eco Logical Australia 2019). Since the Gateway Certificate application an additional two land managers operating within the Project Area were consulted.

Landholders/managers within the Project Area were contacted for interview/survey (Table 03-1). Of these landholders/managers, six agreed to consult regarding their agricultural/silvicultural systems and production. Email and phone contact were made with Forestry Corporation of NSW. Where an interview was not granted, Geographic Information System (GIS)-based and regional assessment information were used to estimate agricultural land use and productivity.

Table 03-1 Landholdings, landowners and interview status

Landholding	Land Owner	Interviewed/Surveyed
Merrilong	NCOPL	Yes
Longsight	NCOPL	Yes
Yarranabee	NCOPL	Yes
Karinda	NCOPL	No
The Bulga	Private Landholder	No
Mayfield	NCOPL	Yes
Private Landholding	Private Landholder	Yes
Westhaven	NCOPL	N/A
Kurrajong	NCOPL	N/A
Barton Hedge	NCOPL	N/A
Claremont	NCOPL	N/A
State Forest	NSW Govt.	Yes

Consultation generally covered the following aspects:

- Property history.
- Land manager local experience.
- Key agricultural systems.
- Typical yield/production.
- Major suppliers of materials and services.
- Number of employees.
- Property limitations.
- Water sources.
- Main markets.
- Key agricultural infrastructure.

In addition, consultation with agricultural consultants and service providers was conducted to further describe the key production systems and production levels in the Project Area and within the region. Consultation included:

- Dr Guy Roth, Roth Regional and Rural and Director of Northern Farm Systems (University of Sydney, Narrabri). Active researcher, adviser and program leader for agriculture application and research in the Narrabri region for over 15 years. Specialist in irrigation, water, soil and natural resource management.

- Robert Tumbers, Pursehouse Rural Boggabri. Robert has managed Boggabri Pursehouse Rural, a local agricultural supply company, for approximately 11 years and has approximately 16 years of locally relevant experience. Pursehouse Rural supplies chemical, seed and materials to land managers in the Project Area, including some of those interviewed.

The outcomes of this consultation are presented in Sections 05.1, 05.2 and Appendix A.

04 OVERVIEW OF REGIONAL AGRICULTURE

The Project is located in the Narrabri Shire Council LGA, which lies within the New England North West Region of NSW. Information relating to agricultural resources and production within the New England North West Region is summarised below, with more detail focused on the Narrabri LGA.

04.1 New England North West Region

The New England North West Region comprises an area of 9.9 million ha and includes the Northern Tablelands to the east, and the North West Slopes and Plains to the west. The region includes the LGAs of Armidale Regional, Glen Innes Severn, Gunnedah, Gwydir, Inverell, Liverpool Plains, Narrabri, Tamworth Regional, Tenterfield, Uralla and Walcha (DP&I 2012). The New England North West Region is split into four agricultural-geographical subregions:

1. Southern Plains (Liverpool Plains and Gunnedah LGAs).
2. Northern Plains (Moree Plains and Narrabri LGAs).
3. Slopes (Tamworth Regional, Gwydir and Inverell LGAs).
4. Tablelands (Armidale Regional, Uralla, Walcha, Glen Innes Severn and Tenterfield LGAs).

The New England North West Region generates more than $2 billion per annum of agricultural product. Almost a quarter of the gross value of all crops in NSW is produced in the region (NSW Trade & Investment 2015). The agricultural sector is the region's largest industry, with a 15 per cent (%) share of both regional output and employment (NSW Trade & Investment 2015). Main contributors are sheep and cattle grazing, broadacre cereal crops, irrigated cotton, intensive livestock and plant agriculture, and poultry production (DP&I 2012).

Australian Bureau of Statistics (2020) shows agricultural production for major cereal cropping and livestock production in the New England North West Region for the period 2016-17 (Table 04-1). This table indicates that there were approximately 6.2 million ha under agricultural production with 2,918 agricultural businesses. Broadacres crops including hay, silage and horticulture occupied 2.1 million ha. Sheep production was carried out on 869 properties and carried approximately 1.2 million head. Cattle production was mainly for meat production and was carried out on 2,202 properties with approximately 900,000 head. Average cereal crop yields per hectare are within industry normal ranges with wheat at 3.4 tonnes per hectare (t/ha) and barley at 3.0 t/ha (Table 04-2).

Almost half the regional production (about 45%) occurs in the Northern Plains; however, on a per unit of area of agricultural land basis, the Northern and Southern Plains contribute similar values of $312 and $310 per ha each to agricultural production (Short and Thomson 2014). Production in the Northern Plains is dominated by irrigation on predominantly grey cracking clay soils along the Namoi, Gwydir, and Macintyre Rivers. Irrigated agriculture, of which cotton is the major crop, is possible due to water availability from Pindari, Copeton, Keepit and Split Rock Dams and highly productive aquifers. The cattle industry is supported by artesian bores (DP&I 2012).

The Project is located in the Northern Plains subregion of the New England North West Region.

EL 6243 (encompassing the existing Narrabri Mine and the Project) is identified in the *Strategic Regional Land Use Plan: New England North West* as an area with the potential for future coal resource development (DP&I 2012).

Table 04-1 Agricultural commodities and production New England North West region 2016-17 (Australian Bureau of Statistics 2020a)

Commodity description	Estimate	Number of agricultural businesses
Area of holding - Total area (ha) (a)	6,229,510	2,918
Crops - Total crops (including broadacre, hay, silage and horticulture) - Area (ha)	2,144,118	1,935
Broadacre crops - Total area (ha)	2,093,309	1,717
Broadacre crops - Cereal crops - Wheat for grain - Area (ha)	776,220	1,144
Broadacre crops - Cereal crops - Wheat for grain - Production (t)	2,606,300	1,144
Broadacre crops - Cereal crops - Oats for grain - Area (ha)	39,509	370
Broadacre crops - Cereal crops - Oats for grain - Production (t)	42,729	370
Broadacre crops - Cereal crops - Barley for grain - Area (ha)	274,193	695
Broadacre crops - Cereal crops - Barley for grain - Production (t)	823,640	695
Broadacre crops - Cereal crops - Triticale for grain - Area (ha)	3,157	31
Broadacre crops - Cereal crops - Triticale for grain - Production (t)	12,479	31
Broadacre crops - Cereal crops - Sorghum for grain - Area (ha)	101,351	280
Broadacre crops - Cereal crops - Sorghum for grain - Production (t)	336,989	280
Broadacre crops - Cereal crops - Maize for grain - Area (ha)	4,221	32
Broadacre crops - Cereal crops - Maize for grain - Production (t)	26,354	32
Livestock - Sheep and lambs - Total (no.)	1,192,202	869
Livestock - Cattle - Total cattle (no.)	899,222	2,202
Livestock - Meat cattle - Total (no.)	889,107	2,167

Table 04-2 Average regional cereal crop yield (Australian Bureau of Statistics 2020)

Cereal crop type	Average yield (t/ha)
Wheat	3.4
Oats	1.1
Barley	3.0
Triticale	4.0
Sorghum	3.3
Maize	6.2

04.2 New England North West Strategic Regional Land Use Plan

The New England North West Strategic Regional Land Use Plan (DP&I 2012) was developed specifically to describe and help manage Strategic Agricultural Land in the New England North West region. The New England North West Strategic Regional Land Use Plan estimated the population of the region to be approximately 183,200 with the major regional centres of Armidale and Tamworth and the five major towns of Glen Innes, Inverell, Moree, Narrabri and Gunnedah making up approximately 50% of the population.

Agriculture and agribusiness within the regional economy generates an annual $1.8 billion (or around 20% of the state's gross value for agriculture and agribusiness), making the region one of the richest agriculture production areas in NSW. The main contributors are irrigated cotton, broadacre cereal crops, sheep and cattle grazing, intensive livestock, plant agriculture and poultry production (DP&I 2012).

The region has four agricultural-geographical regions (Section 04.1):

- The Southern Plains area (Liverpool Plains and Gunnedah LGAs) contains some of the most fertile soils in Australia and has the highest agricultural productivity in NSW. The Liverpool Plains LGA alone produces 20% of NSW sorghum from just 0.6% of the land area in NSW. The area is reliant on maintaining groundwater access for irrigation and stock and domestic water supplies for continued high production.

- The Northern Plains most significant crop is cotton, while beef cattle and wheat production are the other main industries. Moree and Narrabri LGAs produce around 66% of NSW cotton from around 4% of the land area in NSW. These same LGAs also produce 5% of the gross value of NSW beef cattle and the area known as the Golden Triangle (350,000 ha generally considered to be between Croppa Creek, North Star and Yallaroi) produces consistently high yields of prime hard (high protein) wheat.

- The Slopes contain some highly productive land used for dryland cropping as well as producing lucerne and pasture for dairy and hay production. Making up only 1% of the land area of NSW, this region produces around 10% of NSW beef, 84% of NSW peanuts, 8% of NSW eggs and 12% of NSW chicken meat. There is potential for growth of intensive livestock industries in this region, particularly in beef cattle, chicken meat and egg production, due to the availability of land away from urban growth areas, the location of existing processors and the local availability of grain.

- The Tablelands area is a major producer of beef, wool and lamb for NSW. The Tablelands makes up around 4% of NSW by area and produces 9% of the state's wool, 9% of beef and 8% of lamb. These high production rates for meat (beef and lamb) and wool are predominantly due to the high rainfall and improved pastures. The Tablelands also produces a range of horticultural crops including nuts, grapes, apples, stone fruit and vegetable crops such as potatoes. The Tablelands is also experiencing an expansion of the dairy industry and is proving to be well suited to glasshouse horticulture.

04.3 Narrabri Shire LGA

The Narrabri Shire covers an area of 13,056 square kilometres (km^2) and supports a population of approximately 14,000 people (NSC 2016). Narrabri is the largest town in the Narrabri Shire and is the administrative centre. Other towns and villages include Boggabri, Wee Waa, Baan Baa, Bellata, Edgeroi, Gwabegar and Pilliga. The landscape of the shire consists of flat open plains to the west and steep land that is associated with Mount Kaputar and the accompanying ranges to the east (EDGE Land Planning 2009).

The Narrabri Shire forms part of the Namoi River catchment, bounded by the Nandewar Range in the north, the New England Plateau in the north-east, the Liverpool Plains in the south-east and the Warrumbungle Range in the south-west (DPI Water 2017). The Namoi River system is subject to extensive flooding and is regulated with several dams, the largest being Lake Keepit, which provides major water storage for the catchment. The associated Namoi alluvium is a key source of water, in addition to the Great Artesian Basin (Askland et al. 2016).

Within the Narrabri Shire agricultural production accounted for $260.5 million as estimated by the Australian Bureau of Statistics (2010) for the year ending 2006 (Table 04-3). Cereal crops were estimated to cover 156,917 ha. There were an estimated 180,265 sheep and lambs produced and 105,351 meat cattle.

Table 04-3 Gross value of agricultural production Narrabri LGA year ended 30 June 2006 (Australian Bureau of Statistics 2010)

Gross Value of Agricultural Production	Item
Gross value of crops ($m)	215.1
Gross value of livestock slaughtering ($m)	41.4
Gross value of livestock products ($m)	4.0
Total gross value of agricultural production ($m)	260.5
Agricultural Commodities year ended 30 June 2006	
Total area	
Area of holding (ha)	790,855.2
Cereals for grain (ha)	156,916.7
Vegetables for human consumption (ha)	141.0
Orchard trees (including nuts) (ha)	106.8
All fruit (excluding grapes) (ha)	106.8
Non-cereal broadacre crops (ha)	70,894.8
Total number	
Sheep and lambs (no.)	180,265
Milk cattle (excluding house cows) (no.)	299
Meat cattle (no.)	105,351
Pigs (no.)	17,897

04.4 Project Area

04.4.1 Location

The Narrabri Mine is located approximately 25 km south-east of Narrabri and approximately 60 km north-west of Gunnedah within the Narrabri Shire Council LGA of NSW (Figure 01-1). The Narrabri Mine (and the Project) is located wholly within the Namoi River catchment.

04.4.2 Climate

The Namoi subregion is characterised by hotter and drier climate in the west and by cooler and wetter climate in the east. Köppen Key Climate Groups for the region, show subtropical areas west of Narrabri with temperate areas to the east and south (Figure 04-1) (Australian Government 2019a). The subtropical zone extends south-east along the main Namoi River channel to Gunnedah.

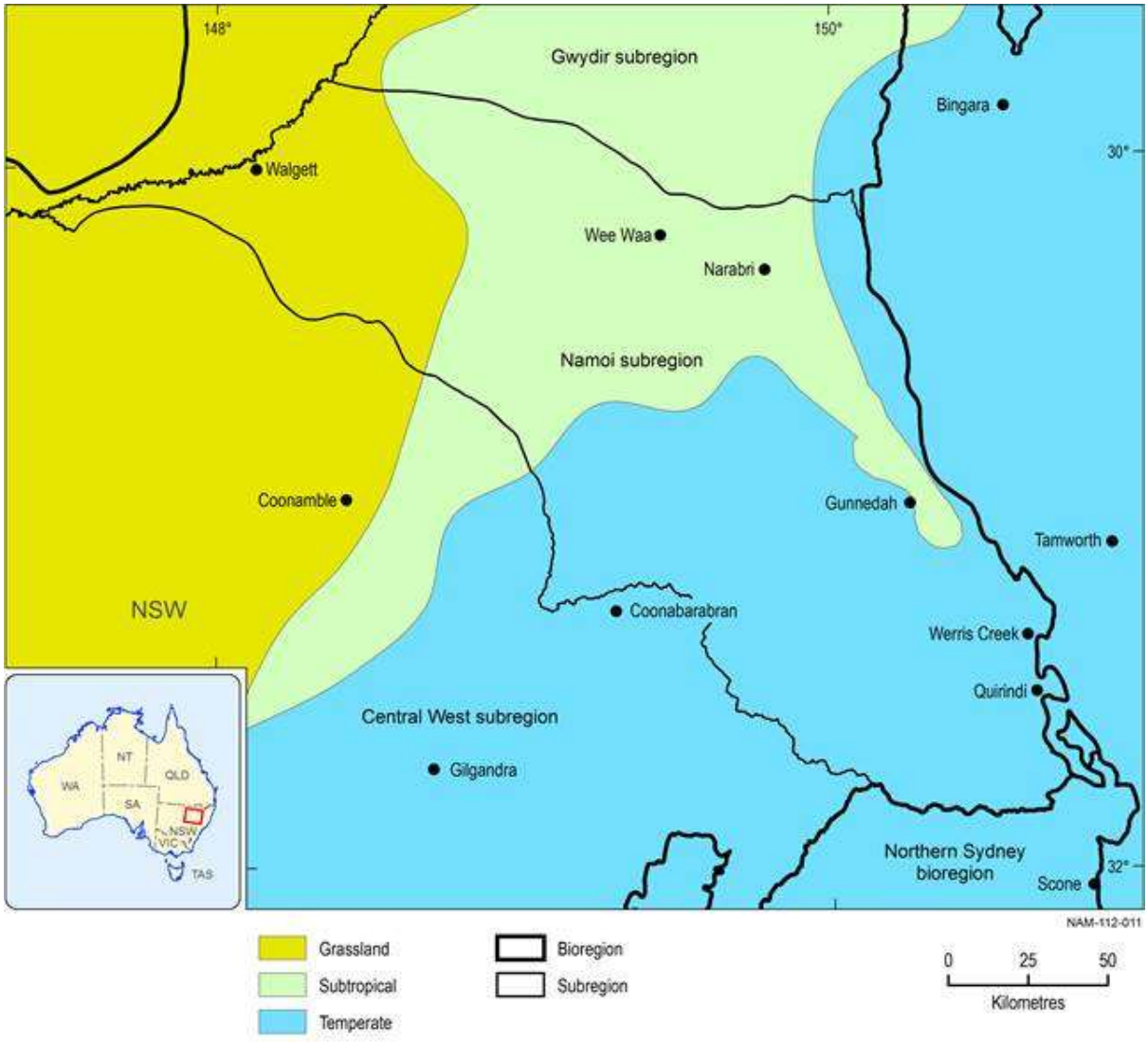


Figure 04-1 Köppen Key climate groupings in the Namoi subregion (Australian Government 2019a)

Narrabri has a mean annual rainfall of 658.5 millimetres (mm) and rainfall is summer dominant. Maximum mean temperature is 26.5 degrees Celsius (°C) and mean minimum is 11.7°C (BOM 2020). The rainfall in Narrabri is summer-dominant, with precipitation even during the driest month. These data have been compiled by the Bureau of Meteorology (BOM) to produce the following statistics (BOM 2020):

Mean maximum temperature of hottest month (January)	33.8°C
Mean minimum temperature of hottest month (January)	19.3°C
Highest recorded temperature (January 1979)	43.4°C
Mean maximum temperature of coolest month (July)	18.0°C
Mean minimum temperature of coolest month (July)	3.7°C
Lowest recorded temperature (June 1971)	-5.6°C
Mean annual rainfall (summer-dominant)	658.5 mm
Mean number of rain days (> 1mm)	38

The monthly distribution of temperature and rainfall is recorded at Narrabri West Post Office (053030) (Figure 04-2 and Figure 04-3).

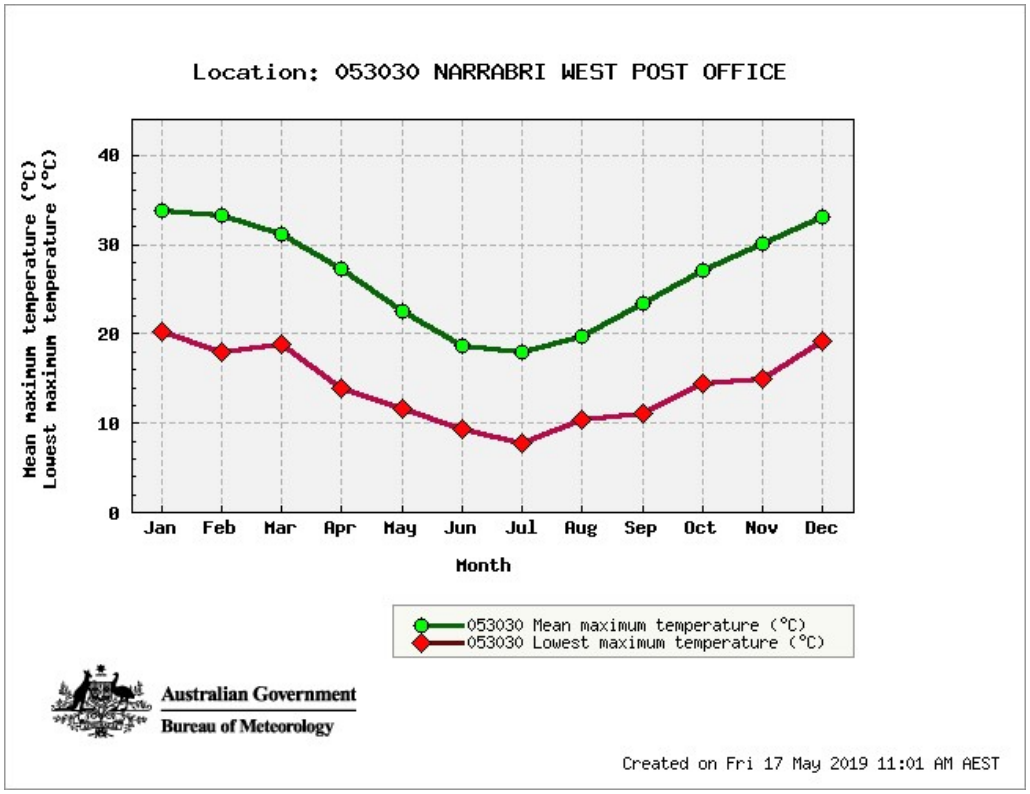


Figure 04-2 Mean monthly temperatures (maximum and minimum) recorded at Narrabri West Post Office (BOM 2020)

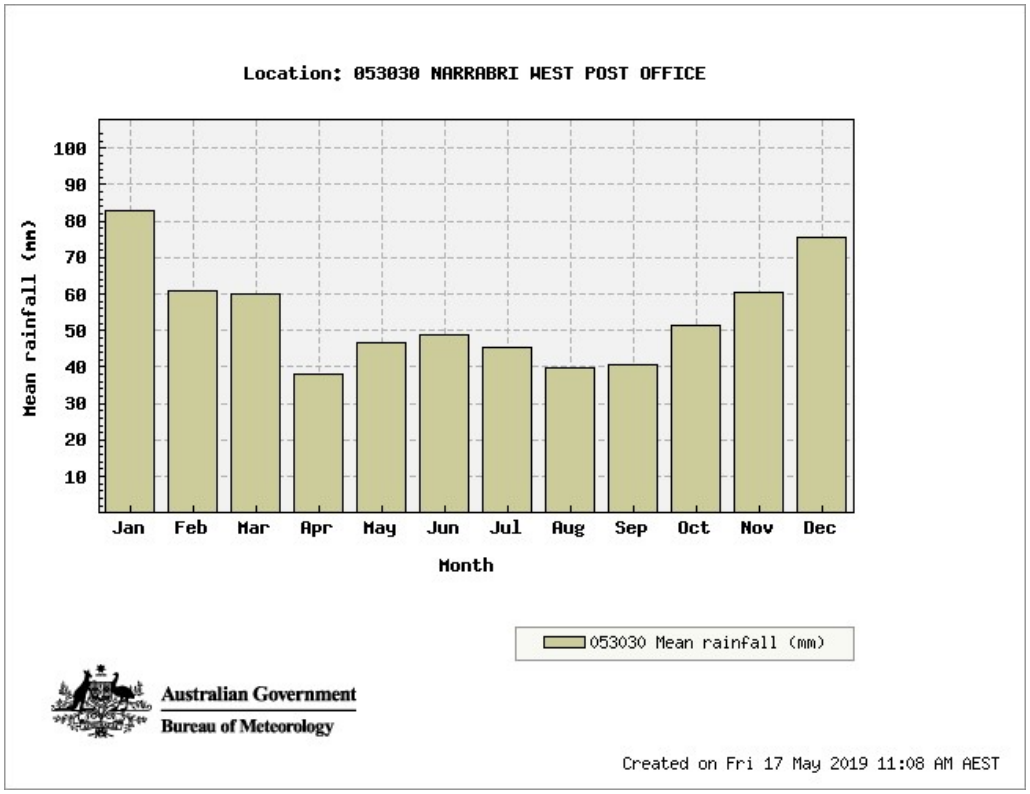


Figure 04-3 Mean monthly rainfall recorded at Narrabri West Post Office (BOM 2020)

04.4.3 Geology and Landform

The Project Area is located within the Mullaley Sub-basin, which forms part of the larger Gunnedah Basin (AGE 2020).

The geology has been described in GHD (2007), Aquaterra (2009), Hydrosimulations (2019) and AGE (2020). The main stratigraphic units in the Project Area are:

- Surat Basin Units of Jurassic age, including the Pilliga Sandstone, Purlawaugh Formation and Garrawilla Volcanics; and
- The Gunnedah Basin Units:
  - Napperby and Digby Formations of Triassic age; and
  - Permian coal measures within the Black Jack Group, including the Hoskissons Seam, the Arkarula Formation and the Pamboola Formation.

In addition to the stratigraphic units above, quaternary alluvium comprising unconsolidated clays, silts, sands and gravels associated with the Namoi River is located approximately 2 km to the east of the Project Area.

Geological features identified in the target underground mining area and surrounds include the Digby Formation Conglomerate, a dolerite sill intruding into the Napperby Formation and the Boggabri Ridge.

The Digby Conglomerate is generally less than 20 metres (m) thick within MLAs 1 and 2. Sandstone palaeochannels present in the north-west of ML 1609 thicken the Digby Conglomerate to greater than 20 m.

The coal resource of the Project is contained within the Hoskissons Seam which strikes generally north-south, and dips gently to the west. The seam is 7 to 10 m thick within the Project Area (AGE 2020).

The Namoi subregion is characterised by a broad floodplain in the west and highlands in the east and south. Figure 04-4 is a digital elevation model of the subregion. The Liverpool Ranges (in the south-east) and the Warrumbungle Ranges (north of Coonabarabran) contain the steepest slopes (>20°) of the subregion. The highest elevation of 1,400 m occurs in the Nandewar Range (Mount Kaputar is 1,508 metres Australian Height Datum (mAHD) but lies just outside of the subregion) while the lowest point of 95 mAHD lies west of Walgett. The Namoi River basin generally slopes toward the west and the north (Australian Government 2019b).

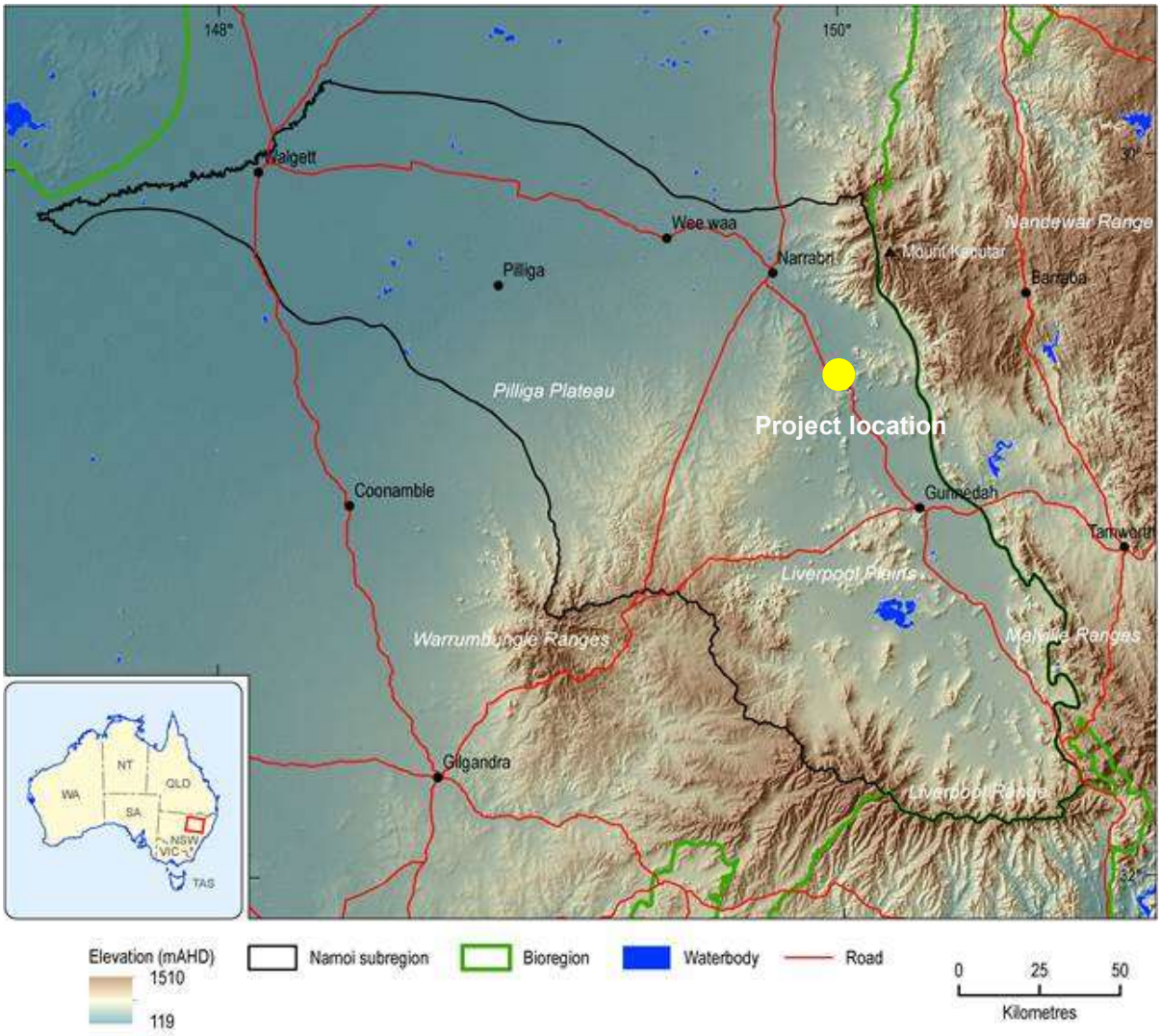


Figure 04-4 Digital Elevation Model showing topography and mountains of the Namoi subregion (Australian Government 2019b)

04.4.4 Vegetation

The Project Area has been used for a combination of grazing (cattle and sheep), occasional fodder crop, a small olive grove and a State Forest with selective silvicultural harvesting (predominantly white cypress). Native vegetation communities across the Project Area include the following (AMBS Ecology and Heritage 2020):

- Belah Woodland.
- Pilliga Box – Buloke Woodland.
- Broombush – Wattle Tall Shrubland.
- Dirty Gum – White Cypress Woodland on Sand Monkeys.
- Poplar Box Grassy Woodland.
- Red Gum – Tea Tree Creek Woodland.
- Rough-barked Apple Sand Flat Woodland.
- Red Ironbark – White Bloodwood.

- White Bloodwood – Red Ironbark – Black Cypress Woodland.
- White Bloodwood – Motherumbah – Red Ironbark Shrubby Woodland.
- Dirty Gum Shrubby Woodland.
- Dwyer's Red Gum Shrubby Woodland.
- White Box – White Cypress Woodland.

04.4.5 Surrounding Land Use

Typical land use in the vicinity of the Project includes grazing and the occasional fodder crop. The Jacks Creek State Forest and Pilliga East State Forest with selective silvicultural harvesting (predominantly white cypress) is situated on the western margin. This land use has remained the same since the 1830s when it was settled, therefore much of the more accessible land has been cleared for agricultural production (Askland et al. 2016).

Current agricultural uses in the Narrabri LGA include sheep and cattle grazing, grain crops, cotton, piggeries, feedlots, vineyards and forestry. The open flat floodplains located in the west of the LGA provide areas which are used for irrigated agriculture, particularly cotton. These crops rely heavily on water from the Namoi River and groundwater. Grazing of sheep and cattle is the primary form of agriculture to the south-east of the Narrabri Shire (EDGE Land Planning 2009).

A land use survey carried out by EDGE Land Planning (2009) found that extensive agriculture made up 54.7% of primary land use, irrigated plants (11.1%), and intensive animal keeping (0.2%) in the Narrabri LGA – a total of 66% of the LGA devoted to agriculture.

Coal mining is a growth industry in the Narrabri LGA. The Gunnedah Basin, in which the LGA is located, is estimated to contain 12% of NSW's available coal reserves. Extraction of coal seam gas is an emerging industry (Askland et al. 2016).

The major agricultural industries in the Namoi region include, livestock production, cotton, poultry, horticulture, grain and hay and forestry. These combined industries produce an economic output of over $1 billion with dry land and irrigated agriculture being responsible for over half of this output (Green et al. 2011). Sheep and cattle grazing are the major land use, making up over 61% of the total land use in the river basin. Broadacre crops are grown on alluvial floodplains, where over 800 km^2 is irrigated for cotton and over 300 km^2 is irrigated pasture and fodder crops (Green et al. 2011). The middle of river basin to the south of Narrabri is extensively covered by native forest and woodland (the Pilliga Forest), which make up around 18% of the river basin. Major land use statistics for the Namoi region are shown in Table 04-4.

Table 04-4 Land use statistics for the Namoi River basin

Land use type	Extent (km^2)	Proportion of river basin (%)
Grazing	25,727	61.2%
Dryland cropping and horticulture	6,810	16.2%
Forestry	4,339	10.3%
Native landscapes	2,136	5.1%
Conservation	1,351	3.2%
Irrigation	1,259	3.0%
Residential	256	0.6%
Lakes, rivers, dams	139	0.3%
Wetland	12	<0.1%
Mining	7	<0.1%

Source data: Green et al. (2011) https://www.bioregionalassessments.gov.au/assessments/11-context-statement-namoi-subregion/1171-namoi-river-basin-setting

05 AGRICULTURAL RESOURCE ANALYSIS OF PROJECT AREA

Agricultural resource analysis comprised: literature review, site inspections; land manager interviews/surveys; review of expert studies in soil resources (Soil Management Designs 2019, Appendix B - GT Environmental 2020); analysis of NSW Government land capability and soil mapping and water resource assessment (Australian Groundwater and Environmental Consultants 2020 [Appendix B of the EIS], WRM 2020 [Appendix C of the EIS]).

The Project Area includes the majority of MLAs 1 and 2 and a portion of ML 1609 (Figure 05-1). Within ML 1609, potential impacts are approved under PA 11_0047. The Project is seeking authorisation for minor changes to the approved impacts within ML 1609, which mainly include changes to the proposed surface development footprint within this area. The portion of the Project Area within ML 1609 captures these additional impacts.

Within MLAs 1 and 2 new impacts (predominantly direct surface disturbance and subsidence effects) are proposed for the Project. The Project Area does not include the Uambi property to the south-east within MLA 1 as no impacts are anticipated in this area (i.e. the Project would not result in surface disturbance or material subsidence impacts on this property).

Given the differences between the ML 1609 and MLAs 1 and 2 in terms of approved impacts, the property scale agricultural resource analysis and subsequent impact assessment has considered these areas as separate land parcels.

Regionally mapped BSAL within and in the vicinity of the Project can be found on Figure 05-2.

05.1 Property Scale Assessment – Project Area within MLAs 1 and 2

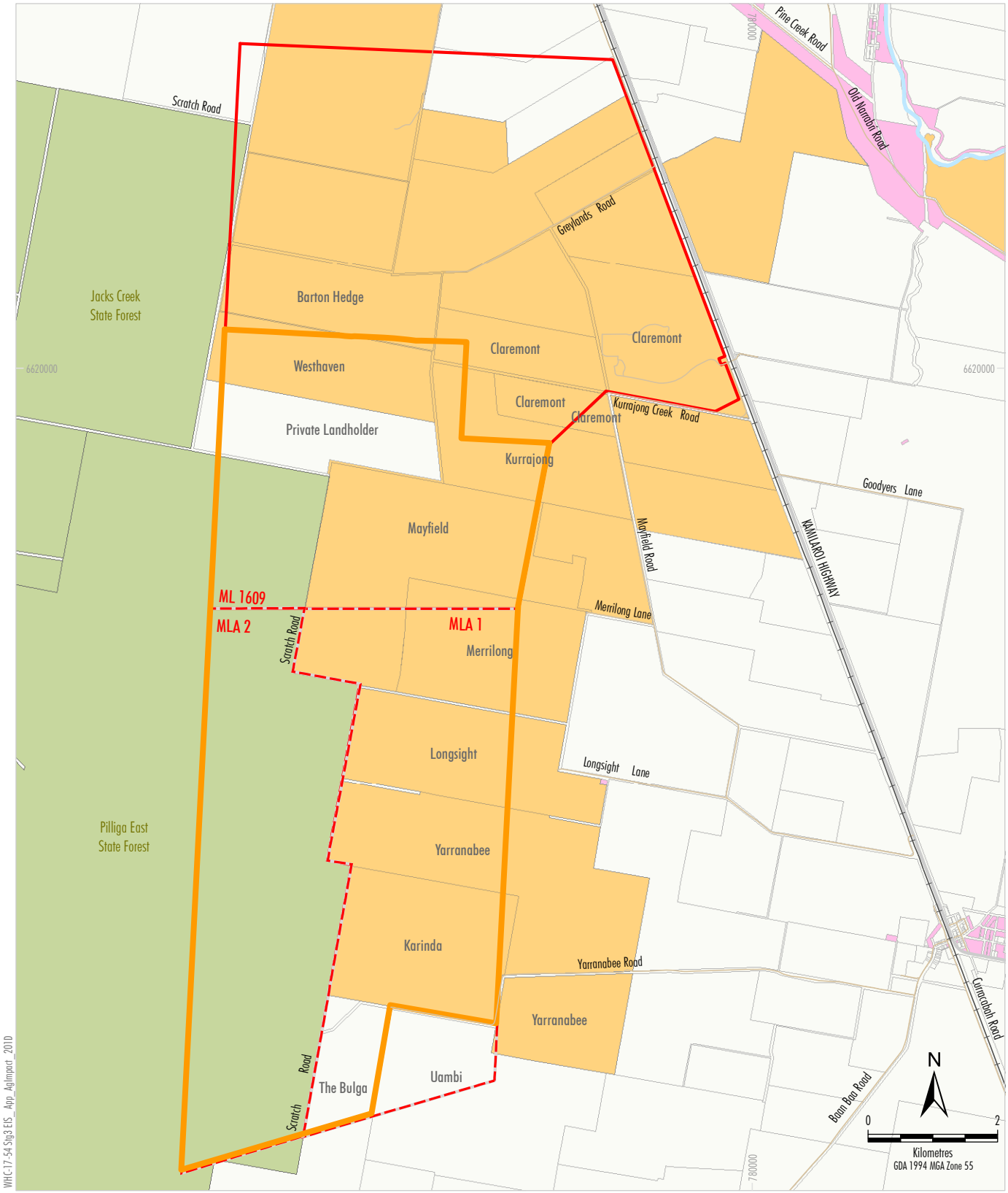
05.1.1 Site Inspection and Interviews

There are six potentially impacted landholdings that fall within the Project Area within MLAs 1 and 2 (Figure 05-1). In addition, the Pilliga East State Forest covers all of MLA 2, which is located on the western edge of the Project Area. The Pilliga East State Forest supplies native timbers that are routinely harvested by Forestry Corporation of NSW. A summary of these landholdings, including total area (ha) within the Project Area within MLAs 1 and 2 is provided in Table 05-1.

Eco Logical Australia (2019) provides a detailed report concerning the agricultural resources, productions systems and productivity within MLAs 1 and 2, including the outcomes of inspections and interviews.

Table 05-1 Landholdings/owners within the Project Area in MLAs 1 and 2

Landholding	Area (ha)	Area within Project Area (MLAs 1 and 2) (ha)
Mayfield	842	180
Merrilong	470	251
Longsight	515	357
Yarranabee	1,044	350
Karinda	527	509
The Bulga	735	193
Pilliga East State Forest	16,950	1,711



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LEGEND
- Mining Lease (ML 1609)
- Provisional Mining Lease Application Area
- Project Area
- State Forest
- Crown Land
- NCOPL Owned Land
- Privately Owned Land and Other Land

Source: NSW Spatial Services (2019); NCOPL (2019)

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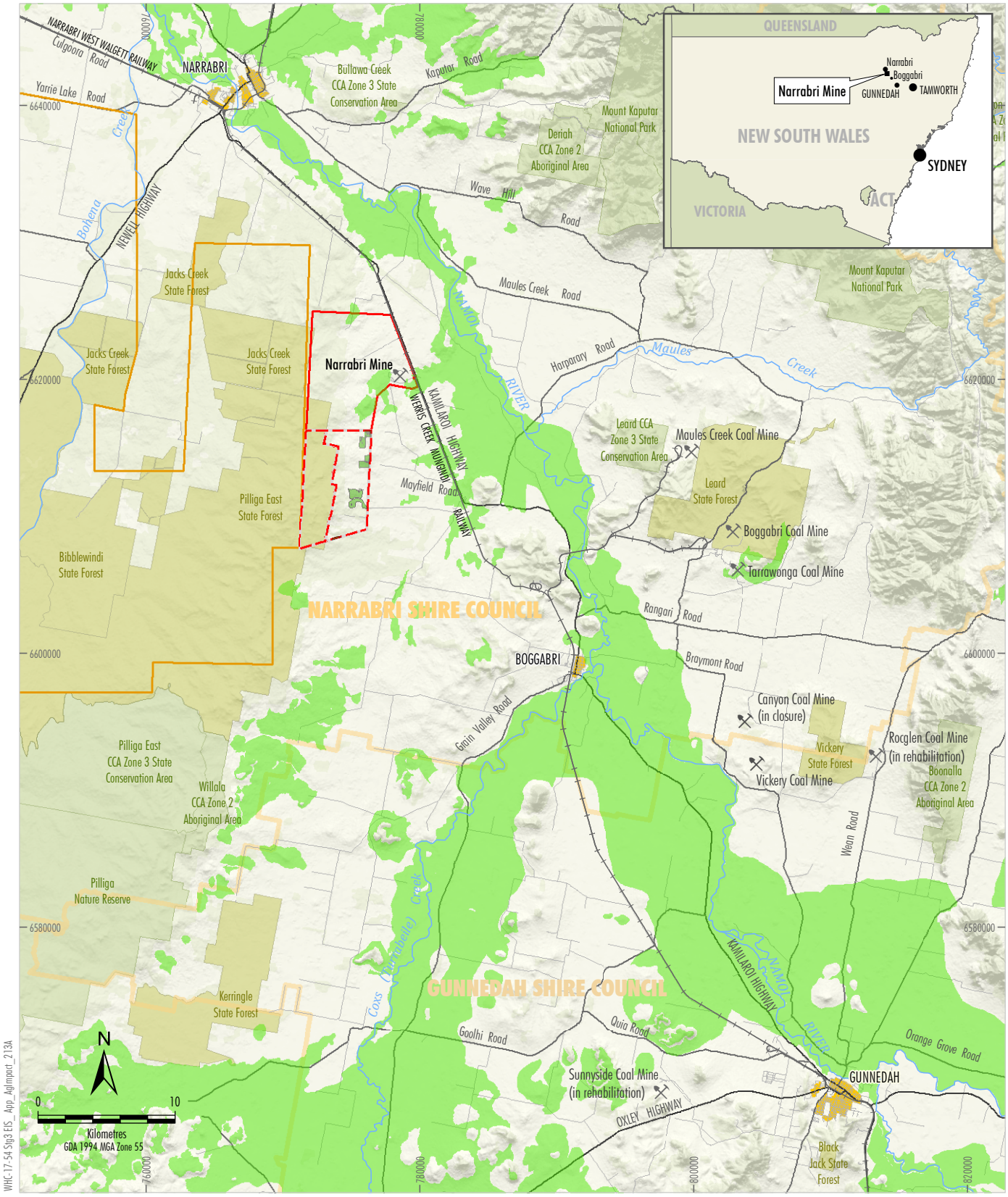
Land Holdings Within the Project Area

Figure 5-1



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LEGEND

- Mine Site
- Mining Lease (ML 1609)
- Provisional Mining Lease Application Area
- Proposed Narrabri Gas Project (Santos NSW [Eastern] Pty Ltd)
- Local Government Boundary
- State Forest
- State Conservation Area, Aboriginal Area
- Regionally Mapped BSAL
- Interim Protocol Verified BSAL

Source: Geoscience Australia (2011); NSW Spatial Services (2019) DPIE (2020); MacKenzie Soil Management (2019); GT Environmental (2020)

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Biophysical Strategic Agricultural Land (BSAL)

Figure 5-2

Agricultural land uses and productivity within MLAs 1 and 2 can be summarised as:

- Grazing for beef cattle and sheep is the dominant land use (Plate 1).
- Some dryland cropping of cereal crops is undertaken generally to support grazing production. Yields can reach 2 to 2.5 t/ha (personal communication [Yarranabee land manager]).
- Water for livestock is sourced from overland flow. Bores were reported by land managers to have provided poor quality water and to be currently disused and not maintained.
- There is no irrigated land use.
- Pilliga East State Forest supports limited commercial harvesting. The area has not been subject to recent harvesting, but adjacent areas have been selectively harvested for: white cypress and iron bark sawlog; iron bark residue; and *Melaleuca* spp. fencing brush.

A summary of the agricultural resources within MLAs 1 and 2 can be found in Table 05-2.

These observations are echoed by the Gateway Panel (Gateway Panel 2019), which states:

> *The land use near the existing Narrabri Mine and the proposed Extension Project is dominantly devoted to sheep and cattle grazing, some cereal production and horticulture. The Pilliga and Jacks Creek State Forests adjoins the western extent of the EL 6243.*

Plate 1: Yarranabee Grazing, View South from Yarranabee Road East of the Homestead (Source: Eco Logical Australia 2019).

Table 05-2 Summary of agricultural resources within the Project Area within MLAs 1 and 2

Landholding	Area (ha)	Primary land use	Other land use
Mayfield	180	Grazing – Sheep and Cattle	Forage cropping
Merrilong	251	Grazing – Cattle	Forage cropping
Longsight	357	Grazing – Cattle	Forage cropping
Yarranabee	350	Grazing - Sheep	Forage/hay cropping
Karinda*	509	Grazing - Cattle	None
The Bulga*	193	Grazing – Sheep and Cattle	None
Pilliga East State Forest	1,711	Selective logging	None

* Based on assessment of NSW Government mapping data, aerial image inspection and visual inspection. No landholder surveys were undertaken.

05.1.2 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 in Table 05-3.

Table 05-3 Land and Soil Capability Classes (OEH 2012)

LSC Class	Definition
Land capable of a wide variety of land uses (cropping, grazing, horticulture, forestry, nature conservation)	
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.
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.
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)	
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.
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)	
6	Low capability land: Land has very high limitations for high-impact land uses. Land use restricted to 6 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)	
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.
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.

LSC Class has been mapped across the Project Area within MLAs 1 and 2 (Soil Management and Designs 2019, Appendix B - GT Environmental 2020). LSC assessment found that Class 5 or greater (low to moderate land capability) dominates the western side of MLAs 1 and 2 (Figure 05-3). In the north-eastern portion Class 4 land (moderate capability) occupies the largest land area with smaller regions of classes 2 and 3 (very high and high capability). In the south-eastern portion Class 3 land dominates with smaller regions of Classes 2, 4, 5 and >5 (Figure 05-3). A breakdown of the LSC classes within each property in the Project Area within MLAs 1 and 2 is provided in Table 05-4.

Consistent with the current and historical land use practices (Table 05-2), the land is capable of supporting grazing land use with small areas capable of opportunistic cropping and a smaller area capable of supporting a more frequent cropping regime.

05.1.3 Land Slope

Surface topography in the Project Area within MLAs 1 and 2 is gently to moderately undulating and generally <15 degrees (°) (Figure 05-4). There is extremely low likelihood of mass movement or landslips. In areas with dispersive soils and slope >10°, any soil exposure is likely to increase erosion. Areas with slopes <10° are anticipated to have low erosion rates, except for creek channels which may undergo re-adjustment following subsidence.

05.1.4 Soil Survey and BSAL Assessment

Detailed soil mapping and assessment was undertaken to verify the soil landscape units within the Project Area within MLAs 1 and 2 and verify the area of BSAL (Soil Management Designs 2019, Appendix B - GT Environmental 2020)[1]. Soil survey and assessment was undertaken in accordance with standards and guidelines for BSAL mapping identified in the Interim Protocol (DPI 2013).

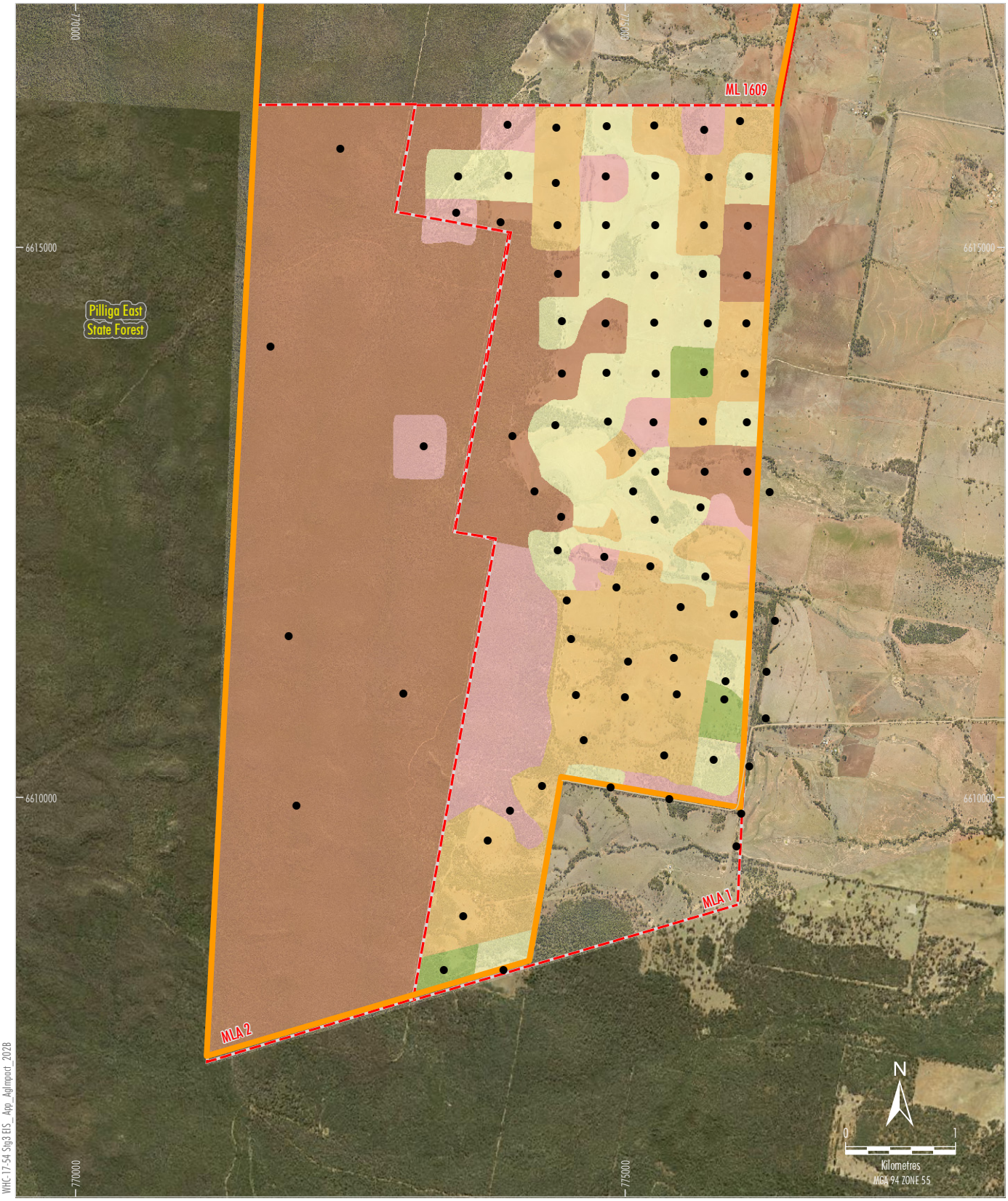
Soil mapping identified six soil landscape units within the Project Area within MLAs 1 and 2 (Table 05-5, Figure 05-5). BSAL was verified to occupy 215 ha of the Project Area within MLAs 1 and 2 and was found within the Dermosol and Vertosol soil types within the Garrawilla Volcanic – Intermediate and Calcic soil landscape units (Figure 05-6).

State-wide mapping of Strategic Agricultural Land shows significant BSAL areas in the New England North West. There are no areas that meet the criteria for Critical Industry Clusters so there are no Critical Industry Clusters in the region.

Table 05-4 LSC Classes within the Project Area within MLAs 1 and 2

Landholding	Land capability class within the Project Area within MLAs 1 and 2 (ha)					
	2 (high)	3 (high)	4 (moderate)	5 (moderate)	>5 (low)	Unknown
Merrilong	0.00	83.33	105.05	33.96	29.10	0.00
Longsight	17.66	54.92	153.41	8.33	120.70	0.00
Yarranabee	0.00	21.29	104.85	13.77	136.76	73.21
Karinda	19.37	264.87	62.66	159.60	0.67	0.76
The Bulga	19.66	124.29	17.81	31.15	0.54	0.00
Mayfield	0.00	52.36	44.50	30.79	52.53	0.00
Pilliga East State Forest	0.07	0.20	0.00	26.62	1,667.48	0.00
TOTAL	**56.76**	**601.26**	**488.28**	**304.22**	**2,007.78**	**73.97**

[1] Additional BSAL mapping within MLA 1 was undertaken in accordance with the SEARs and Schedule 2 of the Gateway Panel's conditional Gateway Certificate (reference criteria 17H4(a)(i)).



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LEGEND

Mining Lease (ML 1609)

Provisional Mining Lease Application Area

Project Area

Soil Test Pit

Land and Soil Capability

2 Slight but Significant Limitations

3 Moderate Limitations

4 Moderate to Severe Limitations

5 Severe Limitations

>5 Very Severe Limitations

Source: NCOPL (2019); NSW Spatial Services (2019); Soil Management Designs (2018); GT Environmental (2020)

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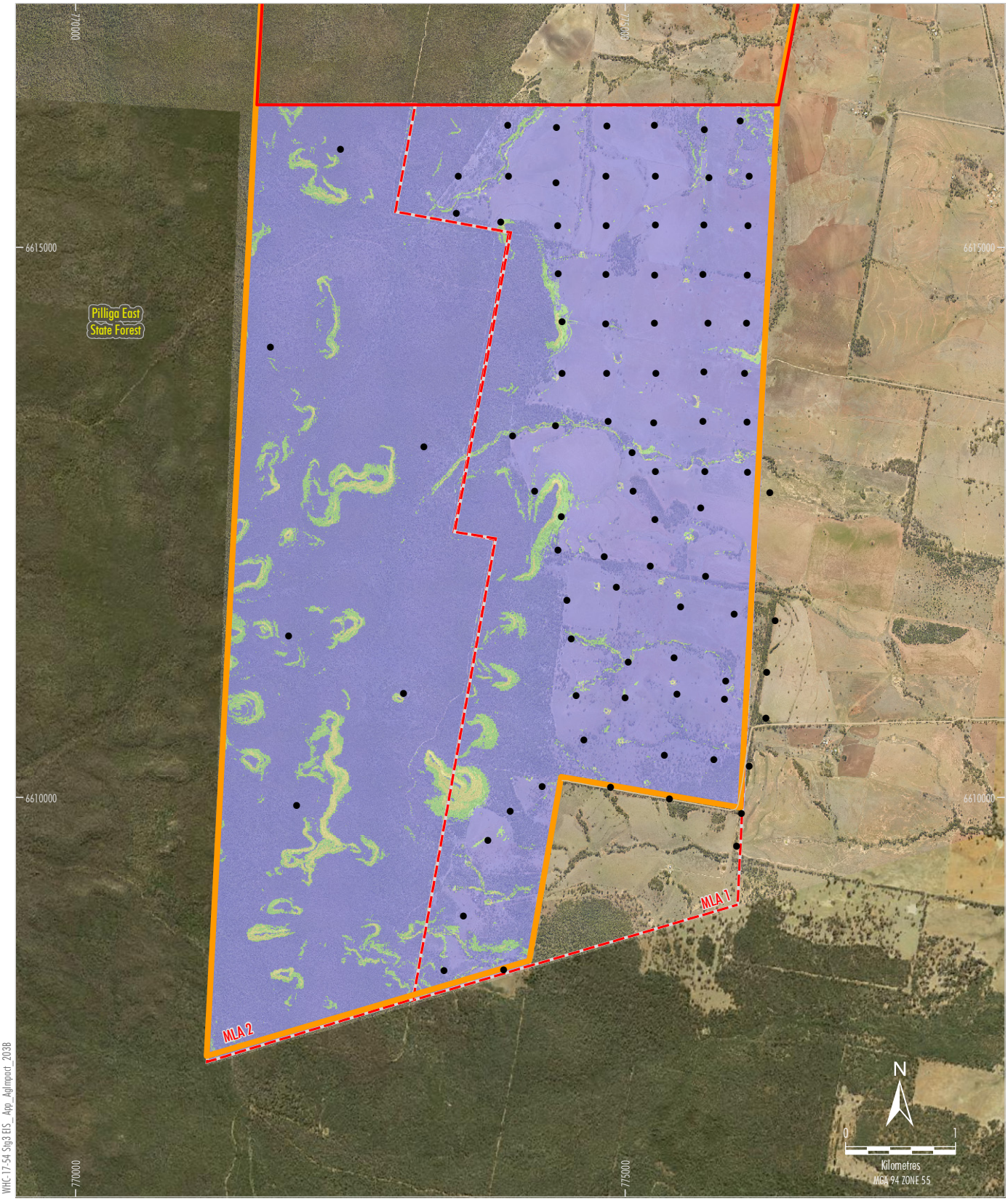
Project Area Within MLAs 1 and 2 - Land and Soil Capability

Figure 5-3



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LEGEND

Mining Lease (ML 1609)

Provisional Mining Lease Application Area

Project Area

Soil Test Pit

Slope Mapping

Slope 0 - 10 %

Slope 10 - 20%

Slope >20%

Source: NCOPL (2019); NSW Spatial Services (2019)

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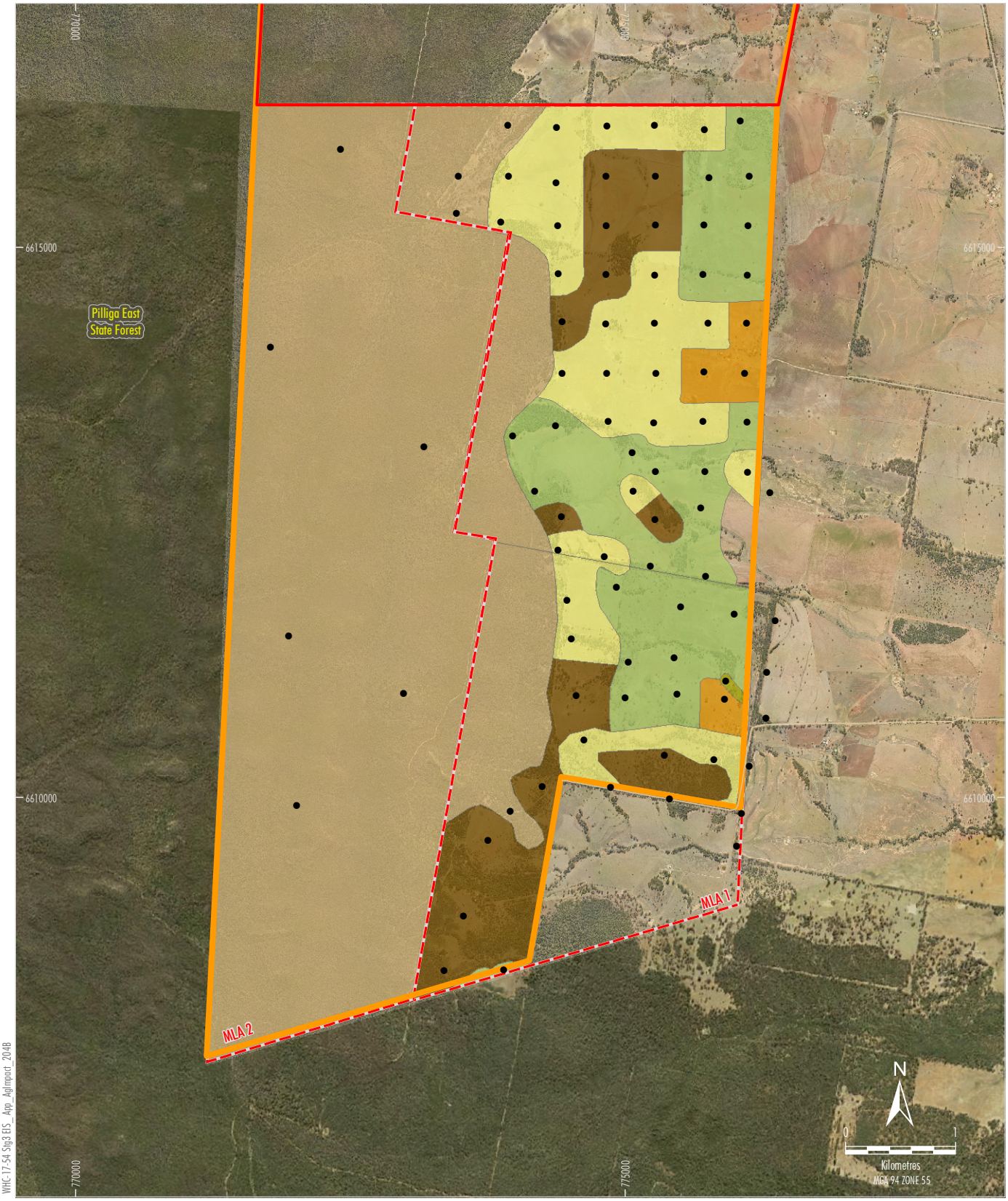
Project Area Within MLAs 1 and 2 - Land Surface Slope

Figure 5-4



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LEGEND

Mining Lease (ML 1609)

Provisional Mining Lease Application Area

Project Area

Soil Test Pit

Soil Units

Pilliga Sandstone (P)

Garawilla Volcanics - Calcic (GVC)

Garawilla Volcanics - Intermediate (GV-I)

Garawilla Volcanics - Sodic (GV-S)

Garawilla Volcanics - Sodic/Vertosols (GV-S/V)

Napperby Siltstone (N)

Source: NCOPL (2019); NSW Spatial Services (2019); McKenzie Soil Management (2018); GT Environmental (2020)

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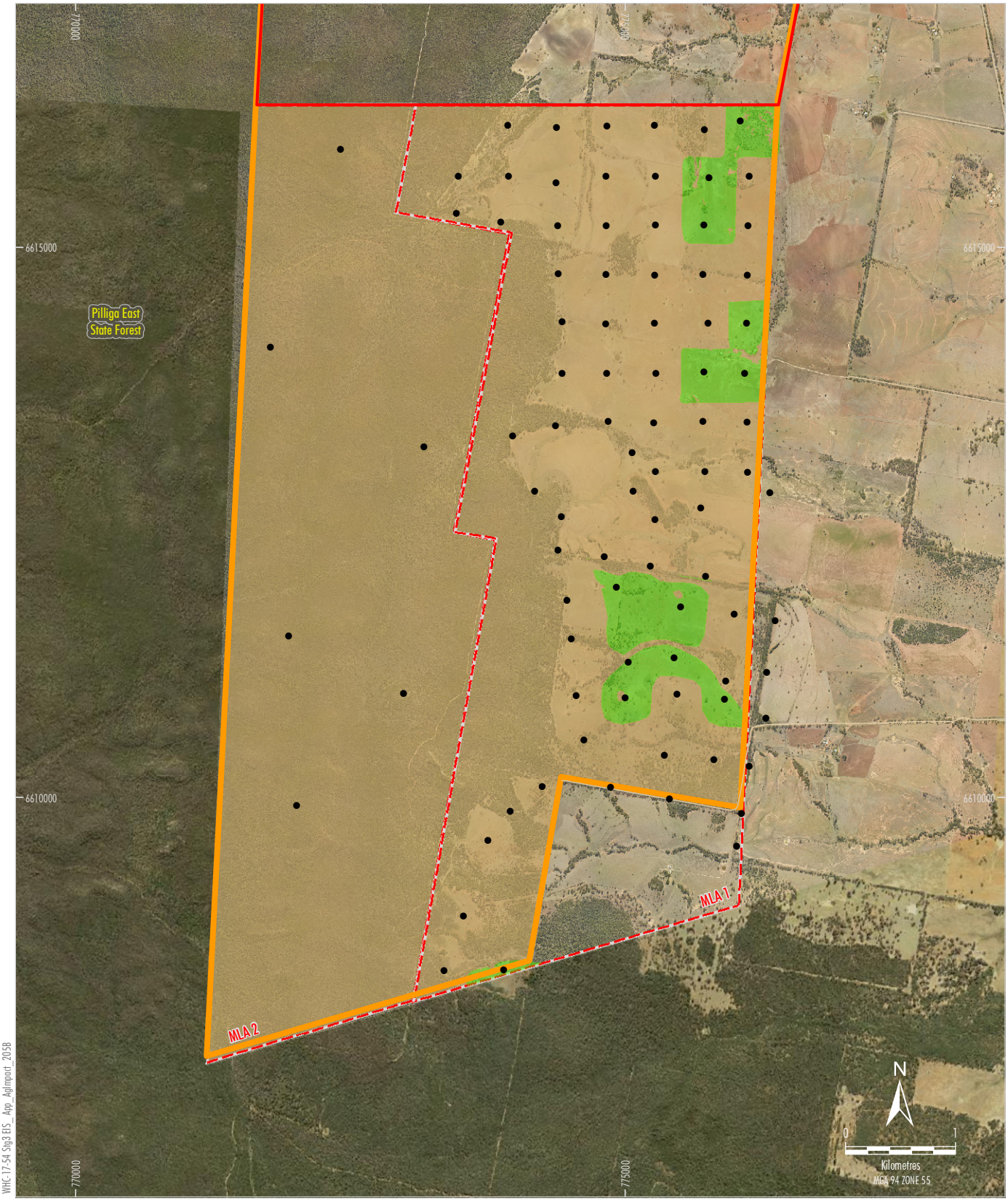
Project Area Within MLAs 1 and 2 - Soil Landscape Units

Figure 5-5



WHC-17-54 Stg3 EIS_App_Agimpact_2058

LEGEND

- Mining Lease (ML 1609)
- Provisional Mining Lease Application Area
- Project Area
- Soil Test Pit
- Verified BSAL
- Verified Non-BSAL

Source: NCOPL (2019); NSW Spatial Services (2019); Soil Management Designs (2018); GT Environmental (2020)

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NARRABRI STAGE 3 PROJECT

Project Area Within MLAs 1 and 2 - Verified Biophysical Strategic Agricultural Land

Figure 5-6

Table 05-5 Summary of soil types (Soil Management Designs 2019, Appendix B - GT Environmental 2020)

Soil Landscape Unit	Dominant or Co-dominant Soil Types	Sub-Dominant Soil Types	Additional Comments
Pilliga Sandstone	Orthic Tenosol	Sodosol, Dermosol, Rudosol	Acidic sandy soil – poor fertility for agricultural crops.
Garawilla Volcanics – Calcic*	Vertosol	Dermosol	High quality clay-rich soil that is suitable for a broad range of agricultural crops and pasture.
Garawilla Volcanics – Intermediate*	Dermosol	Chromosol, Kandosol, Rudosol	High quality soil that is suitable for a broad range of agricultural crops and pasture following amelioration.
Garawilla Volcanics – Sodic	Sodosol	Dermosol, Kandosol, Leptic Tenosol, Calcarosol	Poor root growth in subsoil due to sodicity.
Garawilla Volcanics – Sodic/Vertosols	Vertosol	N/A	Poor root growth in subsoil due to sodicity, but a favourable ability to regenerate soil structural form through shrink-swell processes.
Napperby Siltstone	Sodosol	Rudosol	Poor root growth in subsoil due to sodicity.

* Contains some areas of verified BSAL.

05.2 Property Scale Assessment – Project Area within ML 1609

05.2.1 Site Inspection and Interviews

There are seven (7) potentially impacted landholdings that fall within ML 1609 (Figure 05-1, Appendix A). In addition, there is an area of Pilliga East State Forest on the western edge of ML 1609. The Pilliga East State Forest supplies native timbers that are routinely harvested by Forestry Corporation of NSW. A summary of these landholdings, including total area (ha) in the Project Area within ML 1609 is provided in Table 05-6.

Table 05-6 Landholdings/owners within the Project Area (ML 1609)

Land Holding	Area (ha)	Area within Project Area (ML 1609) (ha)
Mayfield	842	594
Private Landholding	365	328
Westhaven	366	318
Kurrajong	405	184
Claremont	714	17
Merrilong	470	56
Barton Hedge	702	10
Pilliga East State Forest	16,950	350

In ML 1609, land manager surveys, GIS-based assessment of NSW Government datasets and high-resolution imagery and field inspection were used to assess agricultural resources (Appendix A).

Agricultural land uses and productivity within the Project Area in ML 1609 can be summarised as:

- Grazing for beef cattle and sheep is the dominant land use.
- 400 tree olive grove harvesting about 2 tonnes per year in reasonable years.
- Some dryland cropping of cereal crops is undertaken generally to support grazing production. Yields can reach 2.5 t/ha (personal communication with the Mayfield lessee).

- Water for livestock is sourced from overland flow.
- There is no irrigated land use.
- Pilliga East State Forest supports limited commercial harvesting. The area has not been subject to recent harvesting, but adjacent areas have been selectively harvested for: white cypress and iron bark sawlog; iron bark residue; and *Melaleuca* spp. fencing brush.

A summary of the agricultural resources within the Project Area in ML 1609 is provided in Table 05-7.

Table 05-7 Summary of agricultural resources within the Project Area (ML 1609)

Landholding	Primary land use	Other land use
Mayfield	Grazing – Sheep and Cattle	Forage cropping
Private Landholding	Olive production	None
Westhaven*	Grazing	Forage cropping
Kurrajong*	Grazing	Forage cropping
Claremont*	Grazing	Forage cropping
Merrilong	Grazing - cattle	Forage cropping
Barton Hedge*	Grazing	Forage cropping
Pilliga East State Forest	Selective logging	None

* Based on assessment of NSW Government mapping data, aerial image inspection and visual inspection. No landholder surveys were undertaken.

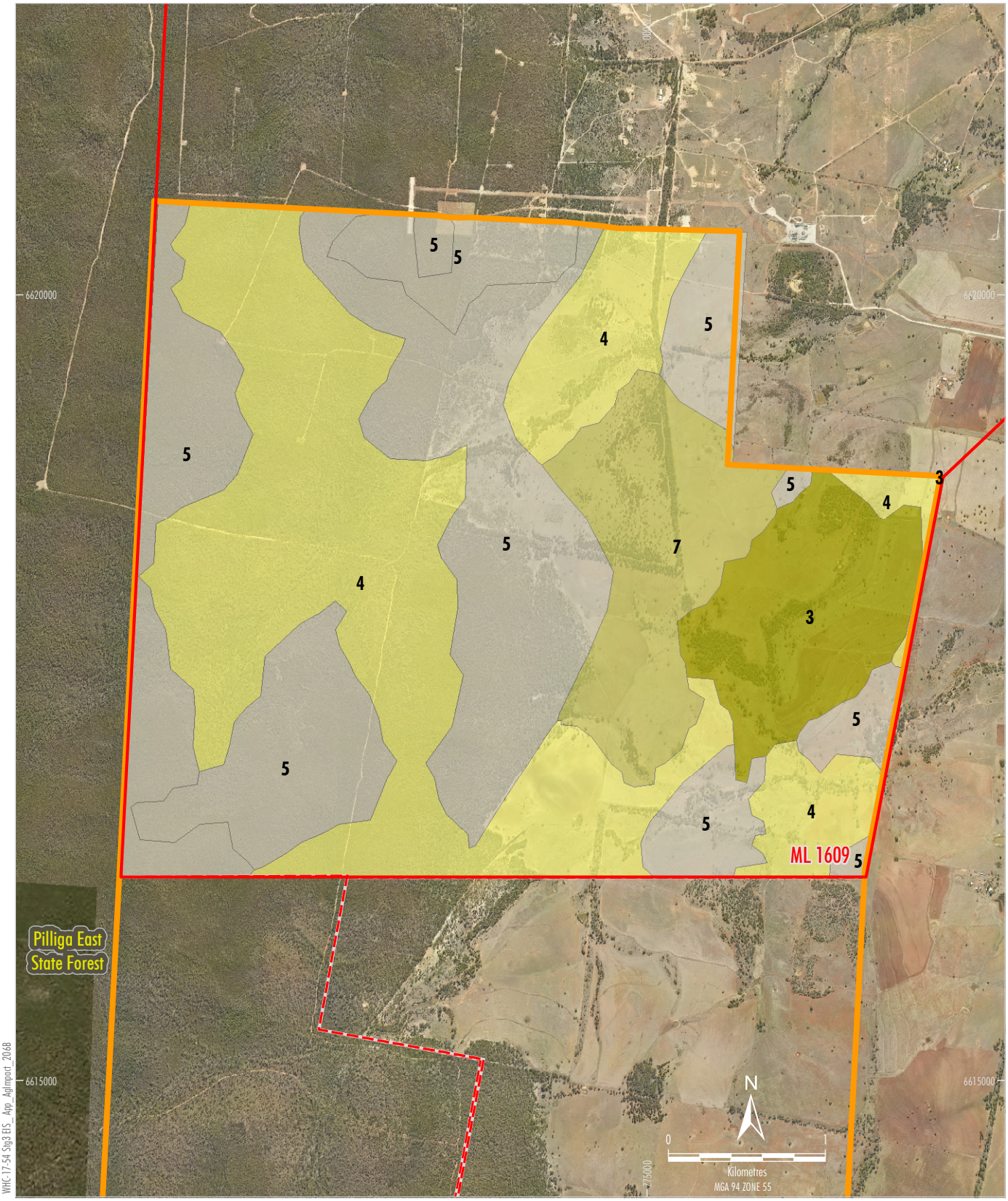
05.2.2 Land and Soil Capability

LSC Class has been mapped across the Project Area within ML 1609 by the NSW Government (NSW OEH 2017a) (Table 05-8, Figure 05-7). LSC assessment found that Classes 4 and 5 (moderate land capability) is found on the majority of the Project Area within ML 1609. There is a smaller region of Class 3 (high land capability) on the eastern portion of the Project Area within ML 1609.

Consistent with the current and historical land use practices (Table 05-7), the land is capable of supporting grazing land use with small areas capable of opportunistic cropping and a smaller area capable of supporting a more frequent cropping regime.

Table 05-8 LSC Classes within the Project Area (ML 1609)

Landholding	Land and soil capability class within the Project Area (ML 1609) (ha)			
	3	4	5	6 & 7
Mayfield	100.23	220.32	189.83	83.17
Private Landholding	0.00	136.72	138.66	52.8
Westhaven	0.00	153.73	156.95	7.67
Kurrajong	71.85	19.56	41.77	50.78
Claremont	0.00	6.24	10.97	0.00
Merrilong	0.00	27.41	28.57	0.00
Barton Hedge	0.00	4.65	5.13	0.00
Pilliga East State Forest	0.00	154.65	195.19	0.00
TOTAL	**172.08**	**723.28**	**767.07**	**194.42**



LEGEND

Mining Lease (ML 1609)

Provisional Mining Lease Application Area

Project Area

LSC Classes

3

4

5

7

Source: NCOPL (2019); NSW Spatial Services (2019)

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Project Area Within ML 1609 - Land and Soil Capability

Figure 5-7

05.2.3 Land Slope

Surface topography in the ML 1609 is similar to that described in MLAs 1 and 2 (Section 05.1.3). The area is gently to moderately undulating and generally <8° (Figure 05-8). There is extremely low likelihood of mass movement or landslips. In areas with dispersive soils and slope >10°, any soil exposure is likely to increase erosion. Areas with slopes <10° are anticipated to have low erosion rates, except for creek channels which are expected to undergo re-adjustment following subsidence.

05.2.4 Soil Survey and BSAL Assessment

NSW Government soil and BSAL mapping was used to assess the soil resources within the Project Area in ML 1609. Data assessed included:

- BSAL - Department of Planning, Industry and Environment (2020); and
- Soil Fertility - Inherent Fertility classes of Great Soil Groups (NSW OEH 2017b).

Soil mapping identified five soil fertility classes within the Project Area in ML 1609 (Table 05-9, Figure 05-9). The Project Area within ML 1609 is dominated by low to moderately low soil fertility classes, with smaller regions of moderate and high fertility classes in the eastern portion. Approximately 172 ha of BSAL is located within the Project Area within ML 1609 (Table 05-9, Figure 05-10).

Table 05-9 Summary of inherent soil fertility classes

Soil fertility class	Area (ha)	BSAL status	Capability
High	172.1	BSAL	Cropping, grazing, horticulture, forestry, nature conservation
Moderately high	0	Non-BSAL	
Moderate	78.2	Non-BSAL	Pasture cropping, grazing, some horticulture, forestry, nature conservation, limited cropping and cultivation
Moderately low	1,239.6	Non-BSAL	
Low	392.9	Non-BSAL	Grazing, forestry and nature conservation

05.3 Groundwater Resources and Use

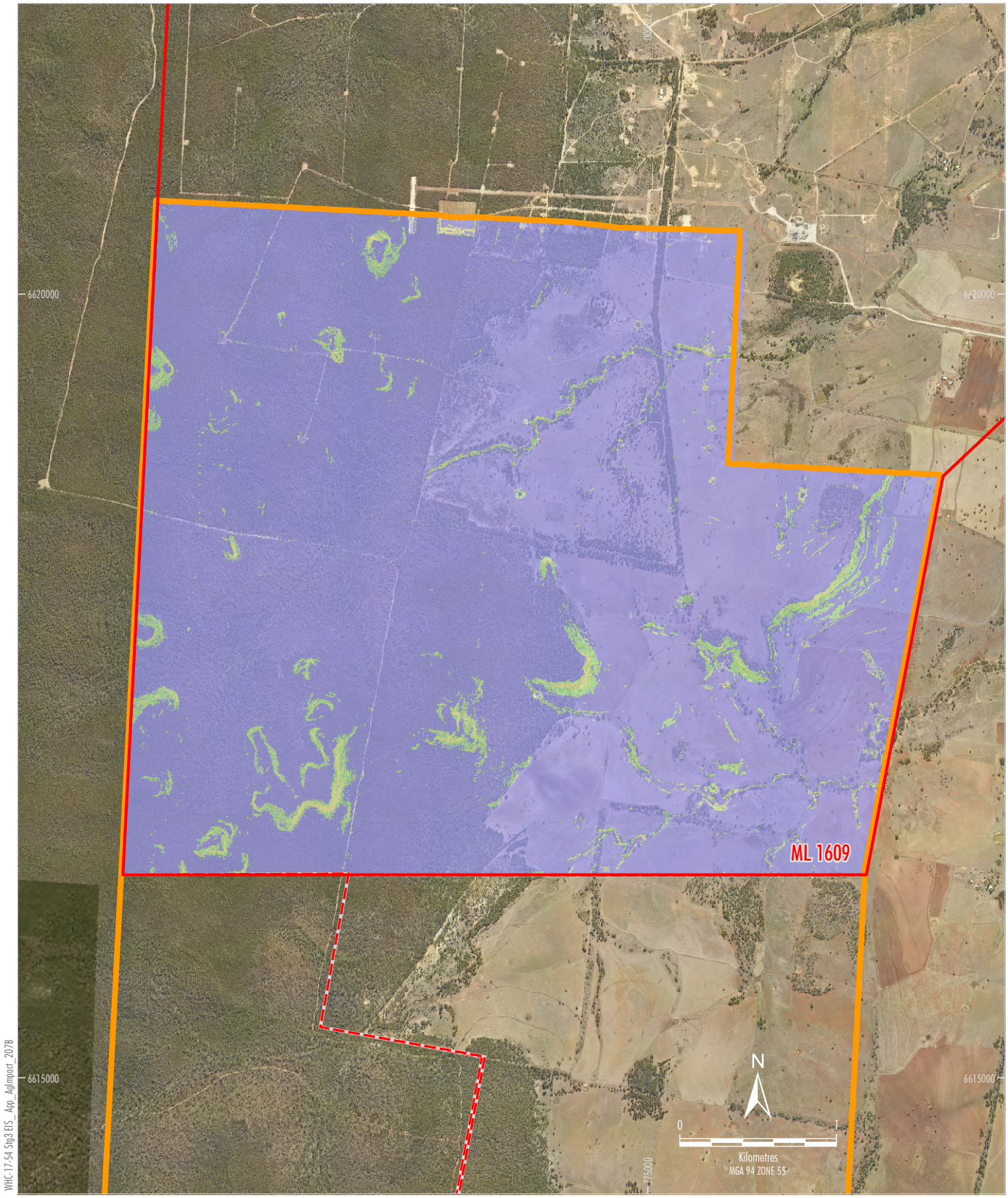
The Project Area is within the Mullaley Sub-basin, which forms part of the larger Gunnedah Basin (AGE 2020).

The geology has been described in GHD (2007), Aquaterra (2009), Hydrosimulations (2019) and AGE (2020).

A conceptual model of the existing groundwater regime was developed by AGE (2020), based on the geology and a review of the available baseline groundwater data and relevant water sharing plans under the *Water Management Act 2000*.

The geology has been described in GHD (2007), Aquaterra (2009), Hydrosimulations (2019) and AGE (2020). The main stratigraphic units in the Project Area are:

- Surat Basin Units of Jurassic age, including the Pilliga Sandstone, Purlawaugh Formation and Garrawilla Volcanics; and
- The Gunnedah Basin Units:
  - Napperby and Digby Formations of Triassic age; and
  - Permian coal measures within the Black Jack Group, including the Hoskissons Seam, the Arkarula Formation and the Pamboola Formation.



WHC-17-54 Stg3 EIS_App_AgImpact_207B

LEGEND

Mining Lease (ML 1609)

Provisional Mining Lease Application Area

Project Area

Slope Mapping

Slope 0 - 10 %

Slope 10 - 20%

Slope >20%

Source: NCOPL (2019); NSW Spatial Services (2019)

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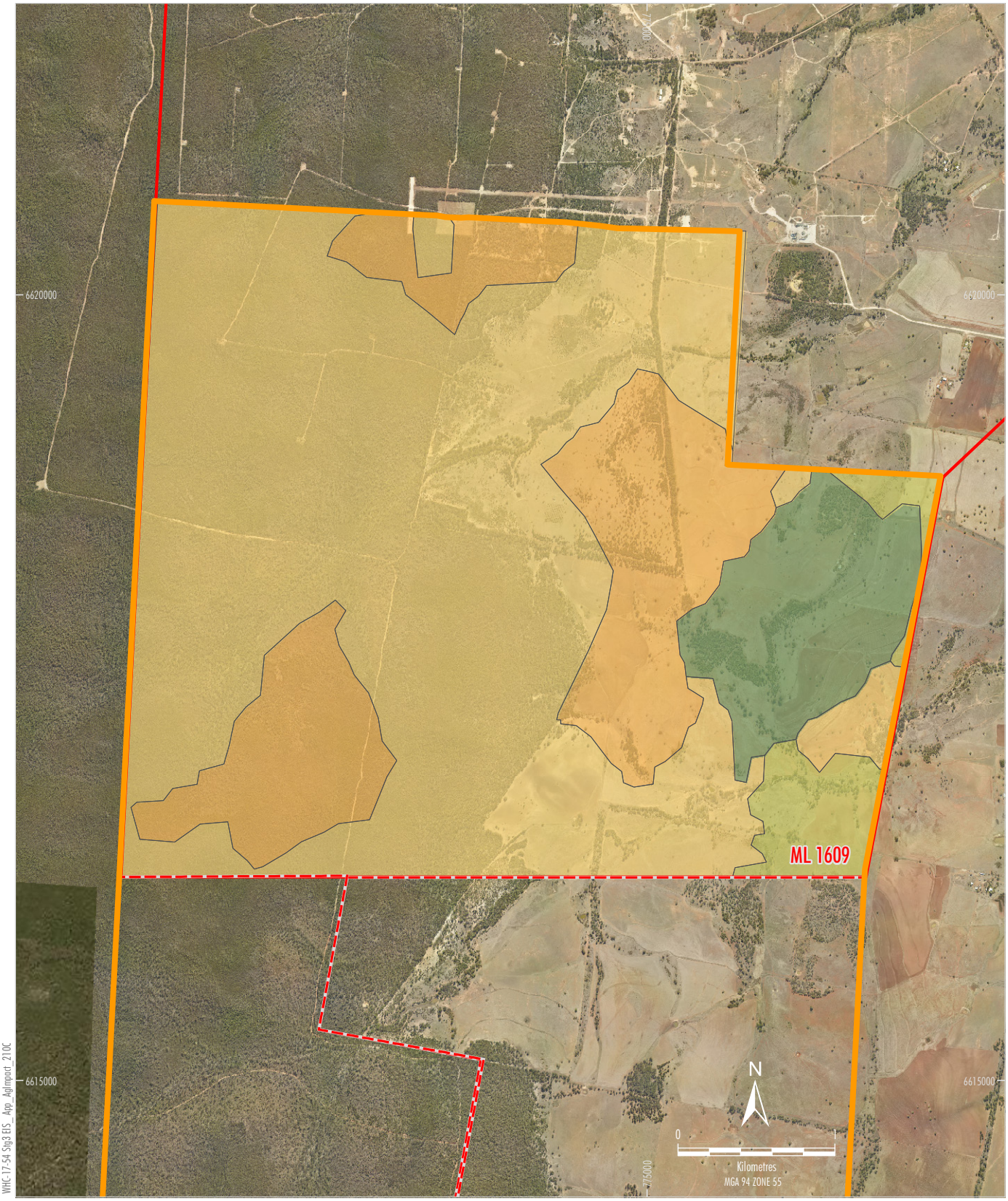
NARRABRI STAGE 3 PROJECT

Project Area Within ML1609 - Land Surface Slope

Figure 5-8



WHC-17-54 Stg3 EIS_App_AgImpact_210C

LEGEND

Mining Lease (ML 1609)

Provisional Mining Lease Application Area

Project Area

Soil Fertility

Low

Moderately low

Moderate

High

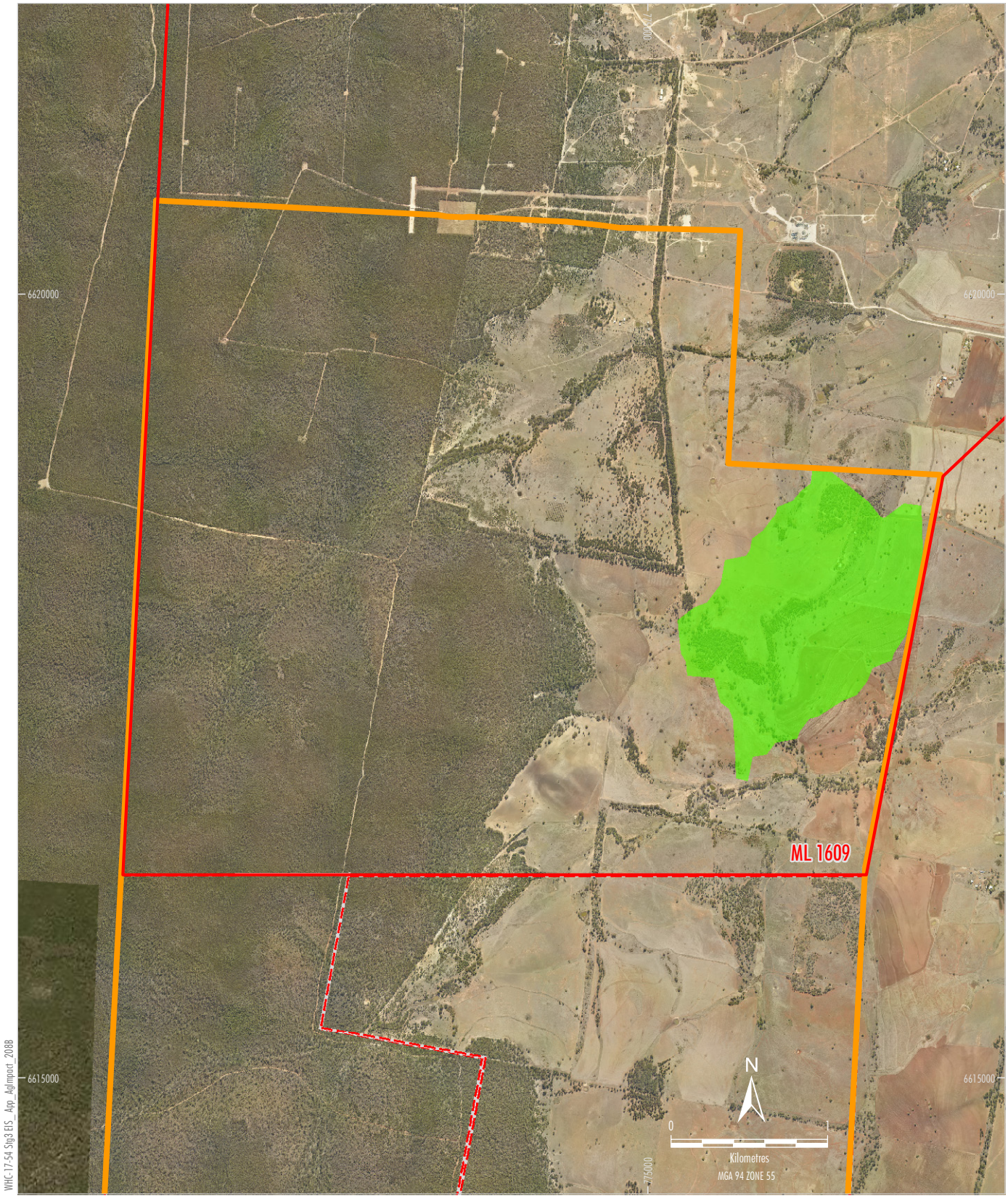
Source: NCOPL (2019); NSW Spatial Services (2019)

WHITEHAVEN COAL

NARRABRI STAGE 3 PROJECT

Project Area Within ML 1609 - Inherent Soil Fertility

Figure 5-9



LEGEND

Mining Lease (ML 1609)

Provisional Mining Lease Application Area

Project Area

Mining SEPP Potential BSAL

Source: NCOPL (2019); NSW Spatial Services (2019;2020)

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NARRABRI STAGE 3 PROJECT

Project Area Within ML 1609 - Regionally Mapped BSAL

Figure 5-10

In addition to the stratigraphic units above, quaternary alluvium comprising unconsolidated clays, silts, sands and gravels associated with the Namoi River is located approximately 5 km to the east of the Project underground mining area.

The Quaternary alluvium east of the Project, associated with the Namoi River and its major tributaries, forms the most important aquifer in the region and is considered 'highly productive' under the AIP. The alluvium is generally thickest (greater than 100 m) to the east of the current path of the Namoi River, thinning towards the edges of the mapped alluvium and along the tributaries (McNeilage 2006). The alluvium to the east of the Project forms part of the Upper Namoi Zone 5 within the Water Sharing Plan for the Namoi Alluvial Groundwater Sources 2020.

The alluvium-derived Narrabri and Gunnedah formations that form the Quaternary alluvium are the most important to agriculture in the region. The Narrabri formation, where present, is typically above the Gunnedah formation. Deeper aquifers rapidly trend to highly saline conditions making them unsuitable for irrigation or other agricultural use.

The Gunnedah Formation is the primary (highest yielding, most utilised) aquifer in the region. Groundwater from the Gunnedah Formation is used extensively for irrigation, stock and domestic use and for the town water supply.

The Pilliga Sandstone is present at, or close to, outcrop across the majority of the Project Area and can attain thicknesses of up to around 300 m in places (AGE 2020). The Pilliga Sandstone is another important regional aquifer dominated by well-sorted, fine- to coarse-grained sandstones which are typically highly porous and permeable and producing high yields of good quality groundwater (Radke *et al*. 2000). It also forms part of the Southern Recharge Groundwater Source under the NSW Great Artesian Basin Water Sharing Plan. The Pilliga Sandstone is the only Jurassic formation that is considered 'highly productive' under the AIP in the vicinity of the Project.

No Permian formations are considered 'highly productive' under the AIP in the vicinity of the Project.

06 LITERATURE REVIEW OF MINE SUBSIDENCE IMPACTS ON AGRICULTURAL LANDSCAPES

06.1 Review of Impacts of Mine Subsidence on Agricultural Landscapes

A literature review was undertaken to describe the documented impacts of planned mine subsidence on agricultural production. Particular attention was given to papers that presented measured impacts in agricultural regions with landscapes (topography and soils) and climatic regimes similar to those in the vicinity of the Project Area.

06.2 Physical Effects of Planned Mine Subsidence

This section describes the key features of mine subsidence with a particular focus on impacts that may affect agricultural activities and production.

The primary and secondary impacts of mine subsidence are well studied and described by multiple authors (e.g. Bell & Genske 2001; Bell *et al*. 2000; Palamara *et al.* 2006). Following extraction of the selected coal seam, subsidence can form a shallow depression (i.e. trough), generally within days of mining, settling over weeks to months (Bell *et al*. 2000).

With alteration to surface topography it follows that surface runoff patterns and soil moisture patterns may also be altered. Areas of increased surface slope can increase erosion risk, especially along areas of concentrated water flow, including pre-existing drainage lines. Likewise, areas of decreased slope may retain water and form temporary ponds following rainfall. In areas with shallow water tables, ponding from groundwater can also occur.

Depending on the nature of the underground mine, surface cracking can result from planned subsidence. Surface cracks generally appear in tensile zones parallel to longwall edges or the longwall end. Bedrock with fractures and joints can also influence the pattern of cracking. As the extraction face progresses, transient cracks can develop, opening and closing as the area moves from tensile to compressive phases. Larger cracks that may require remediation are usually located around the perimeters of the longwall. Large, isolated cracks can also develop along steep slopes.

Cracking at the surface or sub-surface can alter or create new flow paths, altering surface and groundwater flow. Cracking can also provide erosion initiation points. The amount of change in surface and sub-surface water flows will be dependent on the overlying strata and nature of the subsidence (Booth 2006; Sidle *et al*. 2000). In a landscape which is undulating and of high relief, subsidence impacts may be harder to recognise, whereas in flatter landscapes of low relief and higher water tables, the impacts of subsidence can be more obvious (Asadi *et al*. 2004).

06.3 Impacts on Agricultural Landscapes and Production

Worldwide there have been a few studies that have sought to quantify the impacts of mine subsidence on agricultural landscapes and production. There has been an ongoing program of research undertaken by the Illinois Mine Subsidence Research Program (e.g. Darmody *et al*. 1989; Darmody 1995; Darmody 1998), and these studies conclude that soil erosion and surface ponding are key factors that may impact productivity. The Illinois Mine Subsidence Research Program studies landscapes which are very flat with rich agricultural soil. Soil erosion has been found to be negligible with surface ponding considered the most important potential impact to productivity. However, land forming mitigation through ditch creation (drainage) or fill have been shown to successfully ameliorate any negative impacts.

In Australia, the Beltana No. 1 Underground Mine in the lower Hunter Valley and the Kestrel Mine in central Queensland have been subject to several studies that sought to quantify the impact of longwall mine subsidence on agricultural crop and pasture production and soil parameters (Trotter and Frazier 2009; Thompson *et al.* 2010; Frazier *et al*. 2010; Frazier 2015). Erosion control structures such as contour banks have been used as part of historical agricultural management and soils range from sandy alluvial soils to black cracking clays (vertosols).

06.3.1 Beltana No. 1 Underground Mine

The Beltana No. 1 Underground Mine has been the subject of several key studies to examine the impacts of subsidence on agricultural/viticultural production (Trotter and Frazier 2009; Thompson *et al.* 2010).

The Beltana No. 1 Underground Mine is located approximately 16 km south-west of Singleton in the Hunter Valley, NSW. Agricultural land use consists of cattle grazing (native and improved pasture), lucerne cropping, viticulture and olive farming (Frazier *et al.* 2010). The landform is gentle to undulating, with vineyards and other cropping located mainly on alluvium and toe-slopes. Soils include alluvial soils, yellow podzols and chocolate soils with the alluvial soils occupying lower parts of the landscape (Kovac and Lawrie 1991). The climate is warm-temperate with hot wet summers and cool mild winters. For Singleton, the mean maximum temperature is 30°C in December to January and 18°C in June to July. The mean annual rainfall is 722 mm. Following extraction of the coal seam, subsidence of up to 2 m was measured (Thompson *et al.* 2010) with associated changes in surface slope and cracking recorded.

Trotter and Frazier (2009) studied the impact of subsidence on irrigated lucerne and native pasture production above the Beltana No. 1 Underground Mine. They sampled total biomass using traditional field sampling methods, proximal crop sensing and remote sensing methods. In addition, soils were sampled via cores and EM38 soil conductivity surveys. Sampling was conducted across longwall panels and in control areas to cover a range of likely impacts. No significant impacts in production or soil characteristics were found that could be associated with longwall mine subsidence.

Thompson *et al*. (2010) conducted a detailed study of the impact of longwall mine subsidence on wine grape production from 2003 to 2008. Sampling included key grape and vine parameters to capture quality and quantity parameters at scales from individual vines to the vineyard block and vineyard region scale. Sampling was undertaken prior to subsidence and following subsidence and across longwall panels to examine changes in potential impacts over time or across the vineyard. Key changes in yield were found to be more associated with changes in seasonal climatic conditions rather than subsidence and they concluded that any impacts were likely to be highly localised rather than affecting productivity more broadly.

MSEC (2019) details the mining conditions at the Beltana No. 1 Underground Mine and suggests that this mine and resulting surface impacts represent a reasonable indication of surface impacts and surface cracking in particular that may occur at the Project. Cracking at Beltana No. 1 Underground Mine was mapped in detail with a total cracking length of 494 m over a total area of 17.7 square metres (m^2) found. Most cracks were less than 25 mm in width (62%), 26% of cracks were between 25-50 mm and 12% of cracks were between 50-100 mm. Out of a total survey area of 112,476 m^2, cracking was found to affect 0.02% of the total area. Pit excavations showed that cracks were shallow and generally less than 0.5 m in depth, with some wider cracks reaching below 1 m in depth.

06.3.2 Kestrel Mine

The Kestrel Mine has also been subject to several studies that aimed to quantify the impact of subsidence on agricultural production.

The Kestrel Mine is located approximately 50 km north-east of Emerald in central Queensland. The site is very gently to gently sloping with maximum gradients of 5%. The vertosol topsoil varies in depth from 0.5 to 2 m and is underlain by a highly dispersible sub-soil which is prone to erosion. Numerous erosion control measures including contour banks and grassed waterways were implemented prior to any mining activity (Trotter and Frazier 2009).

The agricultural land use at the site is primarily pastoral and cropping. Kestrel leased the property ‘Gordon Downs’ to the Northern Australian Pastoral Company as a background grazing property. There are areas of permanent pastures, both improved and unimproved and forage crops which were used for grazing purposes. The area has also been used for cereal crop production.

The climate of the area has characteristics intermediate between those of tropical and temperate climatic types. It is also transitional between humid and semi-arid, and is regarded as subhumid (Winders, Barlow & Morrison 1985). The mean annual rainfall for the area is 536 mm (data obtained for Emerald, Queensland). The area experiences an average of 60 days of rain per year, with the highest recorded annual rainfall being 883 mm and the lowest recorded annual rainfall being 284 mm. The mean maximum daily temperature for the area is 30°C and the mean minimum daily temperature for the area is 16°C (data obtained for Emerald, Queensland). The area experiences extremes in temperature, with the highest temperature of 47°C and low temperatures of 10°C.

Hinchliffe *et al.* (2003) studied the impact of longwall mine subsidence on wheat and soybean crops at the Kestrel Mine in 2000 and 2001. They compared subsided areas with unsubsided areas using measures of plant germination and yield as well as soil parameters. There was no apparent difference in crop or soil parameters that implied a negative impact from longwall mine subsidence. They concluded that, while impacts such as soil cracking and change in slope are apparent, these impacts are highly localised and ameliorated through normal agricultural management practices.

Further study over the site was undertaken across the 2007 and 2008 seasons (Trotter and Frazier 2009). Sampling was undertaken to assess forage sorghum, sown pasture and soil parameters at subsided and unsubsided (control) sites. Field sampling examined plant biomass, species composition, plant height, soil electrical conductivity, soil pH and soil moisture. Techniques commonly used in precision agriculture including EM38 conductivity survey, hand/machine-mounted crop sensors and satellite remote sensing were used to provide a broader, landscape view. The study concluded there were no negative impacts on plant or soil parameters that could be attributed to subsidence.

Frazier (2015) examined an established pasture paddock over the Kestrel Mine. The paddock had been subject to several years of conservation grazing practices that aimed to re-establish Queensland Bluegrass (*Dichanthium sericium*). This study targeted several longwall areas to determine if patterns of impact with time could be found; that is, if there was a recovery following subsidence or any impacts that compound over time. Samples were taken for plant cover and diversity using field samples and satellite imagery. No significant negative impact was found across any of the zones above any of the longwall panels in comparison to a control area. Further, it was found that conservative grazing practices had substantially increased the presence of Bluegrass.

06.3.3 Narrabri Mine

Longwalls at the existing Narrabri Mine underlie agricultural land comprising grazing, dryland crops, contour banks and ephemeral streams.

Whitehaven has prepared End of Panel Reports for LW101 to LW105 at the existing Narrabri Mine describing subsidence impacts, including surface cracking and monitoring results following the completion of mining each longwall (Whitehaven 2013, 2014, 2015a, 2015b, 2016).

With respect to impacts to agricultural production, the End of Panel Reports describe:

- The only area affected by subsidence, with regards to agricultural suitability, was where water ponded at an ephemeral creek. The ponded water is currently pumped downstream when required. The ephemeral nature of the creek system is such that any ponding that does occur is for relatively short periods only and, on this basis, has negligible effect on agricultural use or agricultural suitability.

- Contour banks, or parts thereof, were undermined during the extraction of LW101 to LW105. The subsidence impacts to the contour banks did not affect their structural stability or functionality.

- Ploughing of the land overlying LW103 was undertaken during the extraction of LW103, however, the ploughing was limited due to poor climatic conditions.

- Several farm dams have been undermined during extraction of LW101 to LW105. No structural damage to these dams has been noted at any site following subsidence.

06.3.4 Conclusions from Literature Review

Planned mine subsidence has an impact on the surface landscape with lowering of the surface above the underground mining areas. Secondary impacts, including surface cracking, altered surface flow patterns with potential ponding or increased erosion risk, can be predicted with a high degree of certainty at the paddock scale.

Several studies from within Australia and worldwide have demonstrated that localised impacts occur as a result of underground coal mining, such as those caused by an individual crack. However, none of the studies have shown widespread impacts that have significantly reduced agricultural productivity over the short or long-term during or following mining. Further, common agricultural maintenance practices such as cultivation, ripping or minor landforming (e.g. restoring contour banks or small channel formation) have proven effective in managing short-term impacts.

07 IMPACT ASSESSMENT

The Project Area has been separated into the area with impacts approved under PA 08_0144 (i.e. within ML 1609), where additional surface infrastructure is required, and the area where new mining leases are being sought (i.e. MLAs 1 and 2) (Figure 05-1).

It is important to note that subsidence effects within ML 1609 are approved via PA 08_0144. Incremental changes to these subsidence effects due to the Project are considered to be acceptable in relation to their potential impact on agricultural production. Therefore, presented below is a discussion of predicted Project subsidence, with a focus on new subsidence effects in the MLAs 1 and 2.

07.1 Nature of Proposed Mining Activities

The Project proposes to continue using longwall coal mining methods. The conceptual mine layout includes the extension of seven longwall panels (LW203 to LW209) from the existing Narrabri Mine (within ML 1609) into MLAs 1 and 2, plus the addition of a new longwall panel (LW210) within MLA 1 (Figure 02-1). With longwall mining, subsidence is the primary factor that may affect agricultural productivity. Smaller areas would also be needed for infrastructure development such as roads, gas drainage and mine ventilation. Some of these areas would be required only for relatively short periods (1 to 2 years) before the area is rehabilitated and infrastructure is moved elsewhere throughout the mine life.

By specifically using underground mining techniques, the Project is designed to minimise visual, noise and dust impacts within the region.

07.2 Predicted Subsidence Effects

The extent and nature of subsidence is related to: extracted panel thickness; depth of cover; overlying geology and surface topography (Ditton Geotechnical Services 2020). Ditton Geotechnical Services (2020) modelled the likely extent and nature of subsidence associated with the Project and assessed related secondary impacts on other land resources. This section provides a summary of the findings presented in Ditton Geotechnical Services (2020).

Ditton Geotechnical Services (2020) modelled the likely surface subsidence (horizontal and vertical movement along with associated stresses and strains) and assessed the likely subsidence-related consequences on the landscape and land use. Ditton Geotechnical Services (2020) used several modelling approaches along with the current mine design information to predict the likely (mean) subsidence and also estimated the upper 95% confidence limit (U95%CL) to provide a likely upper estimate of subsidence and related impacts. For this report, the U95%CL information has been used to assess impacts as it provides a likely maximum impact scenario. It should be noted that the U95%CL limit by definition may be exceeded 5% of the time. The data modelled by Ditton Geotechnical Services (2020) was also supported by measured observations in the existing Narrabri Mine LW101 to LW108a. These observations are particularly relevant as they are nearby, have similar mine design and overlying geology, have similar land use and are at the existing mine. Ditton Geotechnical Services (2020) also assessed the likely impacts based on their previous experiences of measured impacts in the Hunter Valley and Southern Coalfields of NSW.

Surface subsidence above the panels is expected to reach a maximum of 2.8 m (vertical change) for all panels (Table 07-1, Figure 07-1). Total depth of cover increases from approximately 180 m above LW210 to approximately 400 m above LW209. The predicted maximum tilt varies from 58 mm/m over LW210 to 25 mm/m over LW209. Subsidence above the chain pillar areas is expected to be much lower, ranging from 0.20 to 0.75 m. As a result of the uneven subsidence, the post-mining landform would contain a series of broad undulations. The angle of draw (AoD), which helps define the likely extent of subsidence beyond the mine footprint, ranges from 22° to 50° (Ditton Geotechnical Services 2020).

As a result of subsidence, a range of likely consequences on the surface landscape and land use have been predicted by Ditton Geotechnical Services (2020).

Table 07-1 Summary of predicted subsidence

Panel no.	Depth of cover (m)	Mining height (m)	Predicted max subsidence (m)	Maximum tilt (mm/m)
203	199-224	4.3	2.80	53
204	222-260	4.3	2.80	47
205	250-289	4.3	2.80	40
206	285-312	4.3	2.80	33
207	318-330	4.3	2.80	28
208	323-356	4.3	2.80	27
209	346-400	4.3	2.80	25
210	180-184	4.3	2.79	58

Source: Ditton Geotechnical Service (2020).

07.2.1 Surface Cracking in Mildly Undulating Terrain

Surface cracking usually develops within several days of longwall face retreat. Some compressive cracks would close once the subsidence trough is fully developed. New cracks in the tensile zone may develop along and inside the panels two to three weeks later. Tensile zone cracks would probably be tapered and range from 5 to 10 m in depth. Cracks in the compressive zone are generally low-angle shear cracks.

In areas of mildly undulating terrain, Ditton Geotechnical Services (2020) predicts cracks of 100 mm to 200 mm with occasional (<5% probability) of cracks up to approximately 350 mm in sandy soils and up to approximately 700 mm in cohesive soils or shallow rock.

Surface cracking over LW 101 to LW 105 of the Narrabri Mine were typically 50 mm to 100 mm wide, with some crack widths up to 200 mm (Whitehaven 2013, 2014, 2015a, 2015b, 2016). Surface cracking over LW 108a have been found at up to 400 mm in width (Ditton Geotechnical Services, 2020). All cracks in the cleared areas of LWs 101 to 107 have been remediated via filling, ploughing and, where possible, reseeding.

Management and remediation strategies for cracking include:

- restricting access by livestock and unauthorised personnel to areas of active subsidence;
- visual monitoring of the surface following subsidence to identify larger cracks that could lead to safety, access or erosion issues;
- ripping or tyning of larger surface cracks where soils and slopes allow;
- infilling with soil or other suitable materials or erosion protection works and revegetation of some larger cracks that don't self-heal; and
- development of site-specific management plans for areas that require broader remediation.

With the implementation of these measures, limited impacts on agricultural land use practices would occur. Impacts associated with the temporary cessation of agricultural use during mining and remediation is discussed in Section 7.2.6.

07.2.2 Sub-surface Cracking

Ditton Geotechnical Services (2020) predicted sub-surface fracturing heights of 133 m above LW210 to 282 m above LW209. The Geology and Geometry Pi-Term models predict that discontinuous sub-surface cracks are likely to interact with surface cracks where the depth of cover is <300 m (above 306 m wide longwall panels) and where the depth of cover is <390 m (above the wider longwall panels). In these areas, creeks could be re-routed to below surface pathways and re-surface downstream.

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LEGEND

Mining Lease (ML 1609)

Provisional Mining Lease Application Area

Project Area

-0.02 -0.1 -0.2 -0.5 -1 -1.5 -2 -2.5 -2.75 -3

Subsidence (m)

Source: NCOPL (2020); NSW Spatial Services (2019); Ditton Geotechnical Services (2020)

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Predicted Subsidence Contours

Figure 7-1

Observed tree stress in LW101 to LW103 indicated B-Zone interaction with tree roots. Direct impacts to tree roots are expected to decrease as cover above the longwall increases in thickness (i.e. in the western section of the Project Area). As predicted, the lighter soils (less clay) and thicker cover above LW104 to LW106 reduced likely shear stress on tree roots and tree health has remained unaffected. The potential impacts on harvesting have been considered. Since the Pilliga East State Forest is located in areas with thicker cover and lighter soils than those found over LW101 to LW103, it is expected that there will be no significant impact on harvestable timber.

Sub-surface crack management strategies include repairing cracks when they occur.

With the implementation of these measures, limited impacts on agricultural land use practices would occur. Impacts associated with the temporary cessation of agricultural use during mining and remediation is discussed in Section 7.2.6.

07.2.3 Surface Drainage and Potential Ponding

07.2.3.1 Creek network

WRM (2020) assessed the current condition of the creek network in MLAs 1 and 2 and the potential impacts of subsidence on creek condition. Kurrajong Creek and the Tulla Mullen tributary are the primary watercourses, which drain the area and flow in a primarily easterly direction towards the Namoi River (WRM 2020) (Figure 07-2). In addition, there are numerous first (1st) and second order streams that drain the area. All creeks in the area are ephemeral. WRM (2020) advised that the incremental change in catchment area due to the Project is minor and would not have a measurable impact on catchment flows. In addition, they found the existing creeks had several areas of head-cut erosion, in-stream dam structures and steep channel banks present, prior to any mining taking place. WRM (2020) concluded that:

- major change in creek alignment through avulsion is unlikely;
- minor change in 1st order stream alignment may occur;
- there may be increased erosion in reaches downstream of pillars following subsidence;
- the Project is unlikely to have a negative impact on water quality. There is less than 1% chance of uncontrolled water leaving the site and flowing into the Namoi system; and
- some contour bank structures may have reduced effectiveness following subsidence.

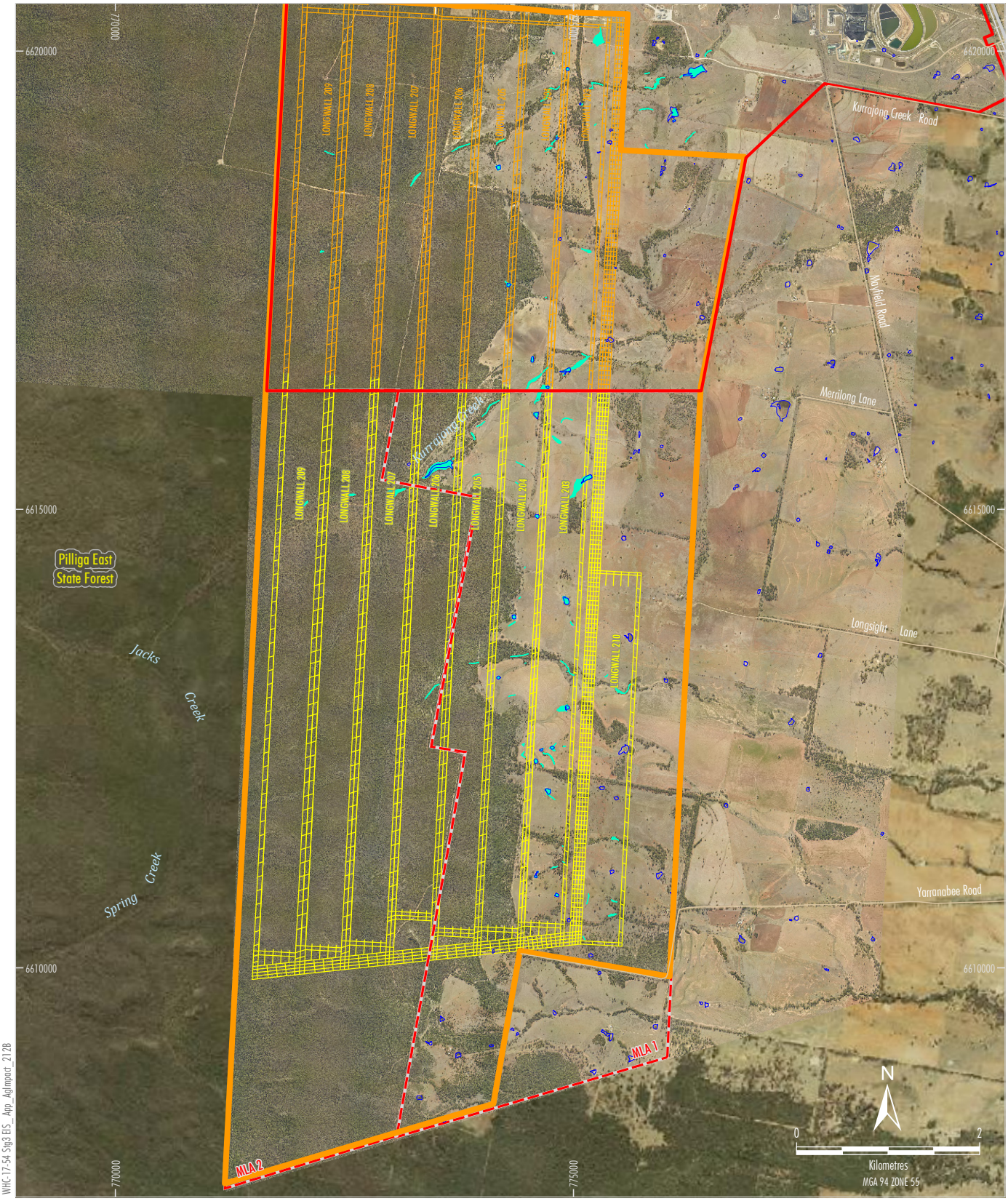
Management and remediation strategies for stream realignment include:

- visual monitoring of drainage lines following subsidence to identify regions of larger topographic change that could lead to realignment;
- site-specific management plans to either ameliorate the landscape through minor works or enhance the altered landscape to benefit the ongoing agricultural management; and
- ongoing monitoring of water quality in accordance with the Water Management Plan and site water management system (WRM 2017) (or its latest approved version).

With the implementation of these measures, limited impacts on agricultural land use practices would occur. Impacts associated with the temporary cessation of agricultural use during mining and remediation is discussed in Section 7.2.6.

07.2.3.2 Potential ponding

Surface slopes in the elevated areas between creeks range between 0.5° to 4° and indicate a net fall across the panels of 2.5 m to 10 m prior to mining (Ditton Geotechnical Services 2020). With predicted maximum subsidence at 2.8 m (Ditton Geotechnical Services 2020), closed depressions could form, especially across panels with flatter surface topography, altering natural drainage pathways to watercourses and farm dams (Figure 07-2).



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LEGEND

- Mining Lease (ML 1609)
- Provisional Mining Lease Application Area
- Project Area
- Indicative Underground Mining Layout to be Extended for Project
- Indicative Underground Project Mining Layout
- Farm Dam
- Potential Ponding Areas

Source: NCOPL (2020); NSW Spatial Services (2019); Ditton Geotechnical Services (2020); WRM (2020)

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Project Area Creek Network and Predicted Areas of Ponding

Figure 7-2

There are 18 potential ponding areas predicted within the Project Area. Four of these ponds are predicted within the verified BSAL area. There are nine existing surface dams that may have their inflow affected (Ditton Geotechnical Services 2020).

The majority of potential ponding areas exist along existing watercourses and are likely to remain in-channel (Ditton Geotechnical Services 2020). Existing (pre-mining) pond depths range from 0.2 m to 3.2 m. Post-mining pond depths are estimated to range from 0.25 m to 3.2 m with changes in individual ponds estimated from -0.1m to 0.9 m (average of 0.6 m).

Ponding on BSAL areas is predicted to occur at locations of existing ponds. At these locations ponding is predicted to increase by a maximum of 0.6 m. The net increase in ponding on BSAL areas is estimated to:

- reach a maximum depth of 0.6 m;
- increase the combined ponding area by up to 1.45 ha; and
- increase the combined ponding volume by 7.23 ML.

Management and remediation strategies for areas with increased ponding include:

- visual monitoring of drainage lines following subsidence to identify regions of larger topographic change that could lead to ponding or other water capture issues;
- site-specific management plans to ameliorate the landscape through minor works; and
- minor works to re-establish drainage lines adversely impacted by ponding, where needed.

With the implementation of these measures, limited impacts on agricultural land use practices would occur. Impacts associated with the temporary cessation of agricultural use during mining and remediation is discussed in Section 7.2.6

07.2.4 Slope Stability and Erosion

Surface topography in MLAs 1 and 2 is generally gently to moderately undulating and generally <10° (Figure 05-4). There is extremely low likelihood of mass movement or landslips. In areas with dispersive soils and slope >10°, any soil exposure is likely to increase erosion. Areas with slopes <10° are anticipated to have low erosion rates, except for creek channels, which are expected to undergo re-adjustment following subsidence.

Ongoing monitoring of any areas of potential enhanced erosion should be implemented as per the Landscape Management Plan (Eco Logical Australia 2017) (or its latest approved version).

With the implementation of these measures, limited impacts on agricultural land use practices would occur. Impacts associated with the temporary cessation of agricultural use during mining and remediation is discussed in Section 7.2.6.

07.2.5 Built Infrastructure

Water storage dams and soil conservation banks

A total of 36 dams that currently exist in MLAs 1 and 2 were assessed in the Project Area by Ditton Geotechnical Services (2020) (Figure 07-2). There are also nine dams which may have their inflows affected by upstream ponding due to the proposed longwalls (Ditton Geotechnical Services 2020). At the Narrabri Mine, several dams above LW101 to LW105 have already been undermined and subjected to subsidence. These dams did not require any remedial work following subsidence and have remained as functioning farm dams. It could be expected that phases of tensile and compressive strain may result in damage to a dam wall or floor with related water loss. Dam storage areas may be increased or decreased due to tilting of the land surface.

Impact management strategies include:

- dam-specific appraisal prior to subsidence;
- suitable works pre-mining if required; and
- ongoing monitoring during and following mining with remedial works if required.

With the implementation of these measures, limited impacts on agricultural land use practices would occur. Impacts associated with the temporary cessation of agricultural use during mining and remediation is discussed in Section 7.2.6.

Property fences and livestock

It is possible that some farm infrastructure may be affected by subsidence and cracking. Ongoing monitoring during and after subsidence should be undertaken with appropriate repair work for infrastructure as required. Livestock should be removed from the mining area until subsidence is complete, and any required amelioration of the surface or infrastructure is undertaken (Section 7.2.6).

Dwellings and sheds

There is a privately-owned dwelling within the MLA 1 which is located outside of the AoD. It is unlikely that this dwelling would be impacted by mine subsidence effects. One NCOPL-owned dwelling is located above LW210 which would likely to be 'moderately' to 'significantly' impacted by mine subsidence from the Project (Ditton Geotechnical Services 2020).

Existing buildings should be assessed prior to subsidence and preventative measures put in place if required. All buildings should be vacant during subsidence and then checked by a qualified inspector. Once inspected, the building should either be declared safe or made safe through works prior to being re-used or re-inhabited. Some structures may need to be demolished and reinstated if required.

Since these structures are not integral to ongoing agricultural practices in the area, it is not expected that the impacts on these buildings, or their potential demolition (if needed) would materially impact agricultural land uses post-mining (and remediation of the area).

07.2.6 Changes in Agricultural Productivity

For the period of active mining and remediation it may be necessary to remove small areas from agricultural production to ensure the safety of people and livestock. During this time, it is recommended that high levels of ground cover vegetation are maintained and cultivation avoided to improve surface soil stability and minimise erosion risk. In addition, the continuation of land management practices (e.g. weed control) would minimise potential impacts to agricultural productivity.

In general, it is expected that impacts to agricultural land use in MLAs 1 and 2 from subsidence would be short-term, with minimal to no impacts to production, including over areas identified as BSAL.

In addition, it is expected that subsidence as a result of the Project would not result in significant changes to LSC classes.

07.3 Changes in Availability and Productivity of Land for Agricultural Use

Changes in land available for agricultural use may result from:

- development of surface infrastructure in support of the Project that would remove some areas temporarily from agricultural land use;
- rehabilitation of the Project surface development areas to a combination of agricultural and woodland land uses; and
- conservation of the potential biodiversity offset areas that would reduce the agricultural productivity of these areas.

Each of these changes is addressed below.

07.3.1 Surface Disturbance for Infrastructure Development

Within the Project Area, approximately 639 ha would be required for the development of surface infrastructure including roads, mine ventilation and gas drainage (Figure 07-3, Table 07-2). Surface disturbance would be undertaken sequentially as the mining development expands and, where possible, areas would be rehabilitated progressively.

Table 07-2 Indicative surface development footprint

Project Area	Area (ha)	Surface Development Footprint (ha)	% Disturbed
ML 1609	1,883	240	12.8%
MLAs 1 and 2	3,790	399	10.5%
Total	5,673	639	11.3%

Approximately 80 ha of mapped (potential) cropping land, 180 ha of mapped (potential) grazing land, 240 ha of State Forest and 138 ha of mapped minimal use areas are predicted to be impacted by surface infrastructure development (Table 07-3). These areas represent relatively smaller sections of the Project Area and the broader agricultural region. A large proportion of the disturbance footprint would be rehabilitated soon after mining in that area is complete, hence the actual surface disturbance area lost to production would be less than the totals shown in Table 07-3 at any one time. These areas are small compared with the Narrabri LGA (790,855 ha of agricultural land held [Table 04-3]).

Table 07-3 Land use areas potentially impacted by the indicative surface development footprint (Department of Planning, Industry and Environment [2020b]).

Land Use	Surface Development footprint (ha)		
	ML 1609	MLAs 1 and 2	Total
Cropping	31	49	80
Grazing	71	111	183
Forestry	57	183	240
Other minimal use*	81	56	137
Total	**240**	**399**	**639**

* Other minimal use includes areas of land that are largely unused (in the context of the prime use) but may have ancillary uses.

07.3.1.1 Project Area within MLAs 1 and 2

The proposed surface disturbance within each property in the Project Area within MLAs 1 and 2 is shown in Table 07-4. Surface disturbance ranges from approximately 3.1% at Mayfield to 15.2% at Karinda. Disturbance is generally on soils with low or moderate land capability with only 0.88 ha of land capability class 2 and 65.9 ha of land capability Class 3 being impacted. Surface disturbance is shown to impact 0.67 ha of BSAL within the Longsight property and 17.60 ha of BSAL within the Karinda property.

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LEGEND

Mining Lease (ML 1609)

Provisional Mining Lease Application Area

Project Area

Indicative Surface Development Footprint

Source: NCOPL (2019); NSW Spatial Services (2019)

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Indicative Surface Development Footprint

Figure 7-3

Table 07-4 Project Area (MLAs 1 and 2) indicative surface development footprint – property breakdowns

Properties	Land capability class (ha)							Property Area (ha)	% Impacted by Surface Disturbance
	2	3	4	5	6 and higher	Unmapped	Total (ha)		
Karinda	0	48.49	6.70	24.76	0.07	0	80.02	527	15%
Longsight	0.88	1.98	18.30	1.89	15.71	0	38.76	515	7.53%
Mayfield	0	6.30	5.81	5.12	8.75	0	25.98	842	3.09%
Merrilong	0	5.52	16.47	0.75	0	0	22.74	470	4.84%
Pilliga East State Forest	0	0	0	4.46	178.18	0	182.65	16,950	1.08%
Yarranabee	0	3.65	14.63	2.87	18.89	6.34	46.37	1044	4.44%
Total	**0.88**	**65.93**	**61.90**	**39.86**	**221.60**	**6.34**	**396.52**		

07.3.1.2 Project Area within ML 1609

The proposed surface disturbance within each property in ML 1609 is shown in Table 07-5. Surface disturbance ranges from <1% at Claremont and Barton Hedge, to 8.02 to 9.02% at Westhaven, Private Landholding and Mayfield. Disturbance is generally on soils with low or moderately low fertility with only 4 ha of mapped high-fertility soils being affected. Mapped BSAL within the Project Area in ML 1609 is consistent with the high-fertility soil mapping, therefore only 4 ha of BSAL would be impacted by surface disturbance, all within the Mayfield property.

Table 07-5 ML 1609 indicative surface development footprint – property breakdowns

Property	Disturbance within soil fertility class						Property Area (ha)	% Impacted by Surface Disturbance
	Low	Mod. low	Mod.	Mod. high	High	Total (ha)		
Westhaven	8.30	24.73	0	0	0	33.03	366	9.02%
Private Landholding	4.54	24.75	0	0	0	29.29	365	8.02%
Pilliga East State Forest	20.93	39.17	0	0	0	60.10	16,950.00	0.35%
Claremont	0	3.08	0	0	0	3.08	714	0.43%
Kurrajong	8.03	8.17	0	0	0	16.20	405	4.00%
Mayfield	16.40	62.11	0	0	4.00	82.51	842	9.80%
Merrilong	0	15.57	0	0	0	15.57	470	3.31%
Barton Hedge	0.24	0	0	0	0	0.24	702	0.03%
Total	58.44	177.58	0	0	4	240.02		

* Area also mapped as BSAL

07.3.2 Silvicultural production

NSW Forestry Corporation manage the regional state forest reserve for selective harvesting of sawlogs, iron bark residue and fencing brush over a long time frame, years to decades, as is typical in silvicultural operations. Surface disturbance would disturb approximately 243 ha within the Pilliga East State Forest until the area is rehabilitated. The Pilliga East State Forest has a total area of approximately 131,899 ha.

The silviculture management plan for the broader State Forest area would be developed by Forestry NSW in consultation with NCOPL so that there is limited impact on silvicultural production or impact on milling operations (i.e. NCOPL would consult with Forestry NSW so that management of the overall forest resources can be conducted to ensure that the limited commercial harvesting operation can proceed unimpeded by the Project by prioritising other areas for production until after cessation of the Project).

07.3.3 Surface disturbance rehabilitation

During mining, the surface disturbance areas would be temporarily taken out of agricultural production. Once no further beneficial use is identified, the area would be rehabilitated to the pre-mining land use (e.g. agriculture or forestry). Certain areas such as major access roads would be required for the entire period of the Project and would be rehabilitated following the cessation of mining operations (i.e. in 2044).

Topsoil resources and management are outlined in Appendix B, Chapter 5 of this report (Appendix B, GT Environmental 2020). The objectives of soil resource management include (Appendix B, GT Environmental 2020):

- identify and quantify potential topsoil resources for rehabilitation;
- optimise the recovery of useable topsoil and subsoil during stripping operations;
- manage topsoil and subsoil reserves so as not to degrade the resource when stockpiled;
- establish effective soil amelioration procedures to maximise the availability of soil reserves for future rehabilitation works; and
- consider the need to provide soil conditions that minimise the risk of soil loss via wind and water erosion during and after rehabilitation.

Appendix B of this report outlines recommended stripping depths, soil and stockpile management and the application of soil on rehabilitated landforms.

With appropriate topsoil stripping and soil management (stockpile and application) it is expected that all areas of surface disturbance would be returned to the pre-mining land capability and productivity.

07.3.4 Biodiversity Offset Areas

NCOPL is considering potential biodiversity offset areas, which would be conserved to offset biodiversity impacts associated with the Project. At this stage, the precise areas are yet to be determined, with the areas to be conserved on a staged basis finalised prior to disturbance impact occurring. Biodiversity offset areas for the Project would be managed in accordance with a Biodiversity Stewardship Site Agreement. The key objective for the long-term security of offsets would be provided by entering into an in-perpetuity agreement with the NSW Biodiversity Conservation Trust that would safeguard the long-term restoration and protection of the areas. The creation and function of biodiversity offset areas would likely result in a reduction in current agricultural production within the offset areas.

07.4 Groundwater

The AIP (NSW Government 2012) establishes minimal impact considerations for ‘highly productive groundwater’ and ‘less productive groundwater’. Highly productive groundwater is defined in the AIP as a groundwater source that is declared in the NSW *Water Management (General) Regulation 2018* and would be based on the following criteria:

- has total dissolved solids of less than 1,500 milligrams per litre; and
- contains water supply works that can yield water at a rate greater than 5 litres per second.

The alluvial sediments associated with the Namoi Unregulated and Alluvial Water Sources are considered ‘highly productive’ in accordance with the AIP (AGE 2020). The Pilliga Sandstone is the only Jurassic formation that is considered ‘highly productive’ under the AIP in the vicinity of the Project.

Numerical modelling of potential drawdown due to the Project has been undertaken by AGE (2020) for the Groundwater Assessment. The results of the modelling show:

- minimal impact as defined in the AIP (i.e. less than 2 m drawdown) is predicted in the ‘highly productive’ Namoi River alluvium;

- minimal impact (i.e. less than 2 m drawdown) is predicted at all privately-owned bores in 'highly productive' aquifers (including Namoi River alluvium and Pilliga Sandstone); and
- the Project is anticipated to have negligible adverse impact on groundwater quality.

Eight privately-owned bores in 'less productive' aquifers are predicted to experience drawdowns exceeding the AIP minimal harm impact criterion (i.e. greater than 2 m drawdown). NCOPL would provide 'make good provisions' for impacts to these bores, such as deepening or replacing the bore and/or providing an alternative water supply of suitable quality and quantity.

With the implementation of 'make good provisions' for potential impacts to the bores in the 'less productive' aquifers, no ongoing impact to agricultural practices associated with the use of these bores is expected.

Drawdown is also predicted at a number of bores on NCOPL-owned land. Groundwater is seldom, if ever, used for agricultural production within the Project Area, and is generally of poor quality. Therefore, drawdown at bores on NCOPL-owned land would not affect ongoing use of these properties (i.e. predominately for grazing) during operations or post-mining.

The Narrabri Mine operates an extensive existing groundwater monitoring network to monitor the response of mining operations in nearby aquifers. Ongoing monitoring of groundwater levels and quality would be used to assess the extent and rate of groundwater impacts associated with the Project. In addition, monitoring of shallow groundwater and surface water levels and quality in the vicinity of Pine, Kurrajong and Tulla Mullen Creeks and of underground mine water quality is recommended by AGE (2020) for the Project.

07.5 Agricultural Impacts on Neighbouring Land

The Project involves an extension to the south of the approved underground mining area to gain access to additional coal reserves within MLAs 1 and 2 (Figure 02-1), an increase in the mine life to 2044, and development of supporting surface infrastructure.

The following subsections provide a summary of the key environmental assessment conclusions related to visual sensitivity, dust, noise and road traffic applicable to neighbouring properties.

07.5.1 Visibility and Visual Sensitivity

Section 6 of the main text of the EIS assessed the visual impact of the Project on surrounding properties. This section concluded that views of the Project would remain largely unchanged from the existing approved Narrabri Mine, and that residents in the vicinity of the Project would have minor impacts relating to visibility and visual sensitivity. Accordingly, it is not expected that changes to visual impacts would lead to concern regarding increased industrialisation of the predominantly agricultural landscape.

07.5.2 Air Quality

Jacobs (2020) made the following conclusions following assessment of potential impacts on air quality:

- 24-hour and annual average particulate matter 10 micrometres or less concentrations would not exceed the NSW Environment Protection Authority (EPA) or NSW Voluntary Land Acquisition and Mitigation Policy (VLAMP) criteria at any private sensitive receptor.
- 24-hour and annual average particulate matter 2.5 micrometres or less concentrations would not exceed EPA or VLAMP criteria at any private sensitive receptor.
- Annual average total suspended particulates (TSP) concentrations and dust deposition levels would not exceed EPA or VLAMP criteria at any private sensitive receptor.

Jacobs (2020) concluded that the Project can proceed without causing adverse air quality impacts at private sensitive receptors. This conclusion was informed by monitoring data which show that activities at the existing approved Narrabri Mine are generally not causing adverse off-site air quality impacts and predicted compliance with relevant criteria. Accordingly, continuation of current air quality mitigation and management measures is proposed.

Given the above, it is not expected the air quality emissions associated with the Project would materially impact agricultural land uses.

07.5.3 Noise

An assessment of predicted noise levels from the Project and potential changes in acoustic amenity was undertaken by Wilkinson Murray (2020).

Wilkinson Murray (2020) found that noise contributions from the Project would generally be less than the EPA's noise criteria, except at four privately owned properties.

There would be no exceedances of the relevant criteria predicted due to rail noise on the Werris Creek Mungindi Railway Line.

Given the above, it is not expected the noise emissions associated with the Project would materially impact agricultural land uses.

07.5.4 Road Transport Assessment

TTPP (2020) examined the likely road transport implications of the Project. TTPP (2020) found that no specific measures or upgrades to the existing road network were required and the Project would not impact significantly on the capacity, safety or efficiency of the current road network. Accordingly, it is not expected that traffic associated with the Project would be in volumes which would potentially impact use of local roads for agricultural activities (i.e. transportation or farm owners and employees and access to markets, etc.).

07.6 Summary of Agricultural Impact Assessment

Evidence from modelling and assessment undertaken for the Project (AGE 2020, Ditton Geotechnical Services 2020, GT Environmental 2020, Jacobs 2020, Soil Management Designs 2019, TTPP 2020, WRM 2020) and from assessment of similar projects in Australia and worldwide, shows that there is likely to be insignificant impacts to agricultural resources and agricultural production as a result of the Project, given appropriate management and rehabilitation (Table 07-6).

It is expected that the Project would require an Extraction Plan that incorporates a Land Management Plan, Built Features Management Plan and a Rehabilitation Management Plan. With appropriate development and implementation of these plans it is expected that there would be no significant long-term impact on the agricultural resources within the Project Area.

07.7 Potential Socio-Economic Impacts

Development of the Project is likely to have negligible impact on agricultural productivity within the Project Area. The Project proposes the continuation of underground mining to minimise surface impacts and agricultural land uses can be maintained during the life of the Project, with relatively small areas of active subsidence temporarily excluded from grazing to maintain staff and livestock safety. A relatively small net area of agricultural land and hence production would also be required for surface infrastructure over the life of the Project (i.e. approximately 80 ha cropping and approximately 180 ha grazing [Table 07-3]). These areas are small compared with the Narrabri LGA (790,855 ha of agricultural land held [Table 04-3]) and are significantly offset by the progressive re-establishment of agricultural production within the Project Area (i.e. via progressive rehabilitation of these areas).

With no material change in agricultural production from within the Project Area (with the implementation of appropriate management measures), it follows there would be negligible impacts for the regional agricultural industry and related services and employment.

07.7.1 Consideration of Critical Mass Thresholds

The DPI (2013) defines a critical mass as 'Where a project is expected to significantly reduce the portion of agricultural enterprises within a region (that is a reduction greater than 5%) within aggregate or within a specific enterprise (such as dairy, thoroughbred breeding or apple production etc)'.

With no material change in agricultural production from within the Project Area (with the implementation of appropriate management measures), it follows there would be negligible outcomes for the regional agricultural industry and related services and employment. Therefore, the Project does not create a risk to critical mass thresholds for the agricultural industry in the region.

07.8 Cumulative Impact Assessment

With no material change in agricultural production from within the Project Area (with the implementation of appropriate management measures), it is unlikely that there would be a loss of agricultural production in the region. Therefore, the Project would not materially contribute to potential cumulative impacts on the regional agricultural industry.

Table 07-6 Summary of agricultural impacts

Agricultural Resource, Practice or Infrastructure	Potential Impact	Management or Mitigation	Consequence to Agricultural Productivity
Resource			
Soil	Increased ponding is predicted at twelve existing pond locations with increased depth up to 0.9 m.	Draining or incorporation of ponded areas into land management.	No significant impact
	Erosion or degradation.	Land management planning and action to minimise erosion through retention of high levels of ground cover, minimising cultivation, repairing residual soil cracks and managing areas of poor drainage. Land management actions to ameliorate erosion should it occur.	No significant impact
	ML 1609 - Temporary loss through infrastructure development.	Rehabilitation of surface disturbance areas to agricultural land use.	No significant impact
	MLAs 1 and 2 - Temporary loss through infrastructure development.	Rehabilitation of surface disturbance areas to agricultural land use.	No significant impact
BSAL	Increased ponding is predicted at four existing pond locations located on BSAL with a total area of 1.45 ha.	Draining or incorporation of ponded areas into land management.	No significant impact
	Erosion or degradation.	Land management planning and action to minimise erosion through retention of high levels of ground cover, minimising cultivation, repairing residual soil cracks and managing areas or poor drainage. Land management actions to ameliorate erosion should it occur.	No significant impact
	ML 1609 - Temporary loss of 4.0 ha through infrastructure development.	Rehabilitation of surface disturbance areas to agricultural land use.	No significant impact
	MLAs 1 and 2 - Temporary loss of 18.27 ha through infrastructure development.	Rehabilitation of surface disturbance areas to agricultural land use.	No significant impact
Surface Water	Altered topography/catchment through subsidence. Ponding along creek lines. Altered dam storage or damage to dam wall or floor.	Catchment area would remain the same for all water courses. Draining or incorporation of ponded areas into land management. Inspect dams before and after subsidence to ensure no damage or change to productivity. Dams repaired as required.	No significant impact
Groundwater	No highly productive groundwater associated with the Namoi alluvium aquifer exists within the Project Area. Highly productive groundwater associated with the Namoi alluvium aquifer would not be impacted significantly.	N/A	No significant impact

Agricultural Resource, Practice or Infrastructure	Potential Impact	Management or Mitigation	Consequence to Agricultural Productivity
Weeds	Weeds decrease agricultural productivity (no significant risk anticipated with appropriate management).	Weed management procedures included in Land Management Plan to minimise potential risk of weed establishment and spread. Incorporate weed management into routine property management practices.	No significant impact
Practice			
Grazing	Small areas unavailable to grazing in the area of current mining until made safe for livestock and personnel. Loss of pasture areas potentially resulting from: • ponding; and • soil degradation.	Temporary exclusion of livestock and personnel. Minimal ponding expected along existing creek lines. Land management planning and action to minimise erosion through retention of high levels of ground cover, minimising cultivation, repairing residual soil cracks and managing areas or poor drainage. Weed management procedures included in Land Management Plan to minimise potential risk of weed establishment and spread. Incorporate weed management into routine property management practices.	No significant impact
	Loss of up to 180 ha of grazing land until mine closure through surface infrastructure development.	Progressive land rehabilitation as surface infrastructure is no longer required for mine function. Soil stripping, management and replacement in-line with Topsoil Management Plan.	No significant impact
Fodder cropping	Cropping areas unavailable in the area of current mining until made safe for vehicles and personnel. Loss of cropping area potentially resulting from: • ponding; and • soil degradation.	Temporary exclusion of personnel. Minimal ponding expected along existing creek lines. Land management planning and action to minimise erosion through retention of high levels of ground cover, minimising cultivation, repairing residual soil cracks and managing areas or poor drainage. Weed management procedures included in Land Management Plan to minimise potential risk of weed establishment and spread. Incorporate weed management into routine property management practices.	No significant impact
	Loss of up to 80 ha of cropping land until mine closure through surface infrastructure development.	Progressive land rehabilitation as surface infrastructure is no longer required for mine function. Soil stripping, management and replacement in-line with Topsoil Management Plan.	No significant impact
Olive grove	Subsidence impacts on grove.	Exclude personnel during active subsidence. Inspect following subsidence to determine any impacts. Replace trees and rehabilitate landscape if required and in consultation with the landholder.	No significant impact
State Forest – timber harvesting	Silviculture area unavailable in area of current mining.	Temporary exclusion of personnel. Schedule any silviculture operations for when active mining has ceased (in consultation with Forestry NSW). Land management planning and action to minimise erosion through repairing residual soil cracks and managing areas or poor drainage.	No significant impact

Agricultural Resource, Practice or Infrastructure	Potential Impact	Management or Mitigation	Consequence to Agricultural Productivity
	Loss of up to 240 ha of timber harvesting land until mine closure through surface infrastructure development.	Progressive land rehabilitation as surface infrastructure is no longer required for mine function. Soil stripping, management and replacement in-line with Topsoil Management Plan.	No significant impact
Infrastructure			
Fences and gates	Damage to fences and gates.	Monitor and repair as required.	No significant impact
Buildings and shed	Damage to buildings and sheds.	Exclude personnel during active subsidence. Inspect following subsidence to determine any safety concerns. Determine required action in consultation with landowner.	No significant impact
Dams	Loss of dam volume. Damage to dam wall or floor.	Inspect dams before and after subsidence to monitor for damage or change to productivity. Reduce water level in larger dams prior to active subsidence. Dam repairs or augmentation made as required.	No significant impact
Contour banks and other erosion control works	Damage to banks or alteration to function.	Monitor post-subsidence to determine any impacts. Repair banks if required.	No significant impact
Neighbouring Agricultural Impacts			
Visual Sensitivity	Low impacts on visual amenity.	Mitigated through Project design (e.g. continuation of underground mining).	No significant impact
Air Quality	No adverse air quality impacts at privately-owned properties used for agricultural production.	Mitigated through Project design (e.g. continuation of underground mining).	No significant impact
Noise	Impacts on three properties nearby. No material noise impacts at receiving privately-owned properties used for agricultural production.	Mitigated through Project design (e.g. continuation of underground mining).	No significant impact
Road Transport	No significant impact on the capacity, safety or efficiency of the current road network as a result of the Project.	Ongoing traffic management in-line with current practice.	No significant impact

08 LANDSCAPE MANAGEMENT PLAN

A Landscape Management Plan (Eco Logical Australia 2017) (or its latest approved version) has been prepared for the existing Narrabri Mine in accordance with Condition 3, Schedule 5 of Project Approval 08_0144. The Landscape Management Plan includes subsidence management and remediation measures for the following potential subsidence impacts:

- surface cracking;
- sub-surface cracking;
- slope instability and erosion;
- valley closure and uplift; and
- ponding and altered drainage patterns.

A summary of the subsidence management and remediation measures outlined in the Landscape Management Plan is provided in Table 08-1.

Table 08-1 Summary of existing subsidence management and remediation measures

Potential Subsidence Impact	Subsidence Management and Remediation Measures
Surface Cracking	• Conduct regular inspections of the surface during subsidence development above a given panel and map the crack locations. • Where natural processes have not completely filled each crack, rip or grade to infill the crack where necessary. • Repair large surface cracks, usually after subsidence development for a given longwall. Significant surface cracks that cannot be filled by surface ripping or grading will be filled using subsoil stockpile material from stockpiles maintained at nearby gas drainage or ventilation sites or material from within the footprint of the Reject Emplacement Area. Temporary fencing may be required before repairs can be made. • Leave a barrier pillar beneath a sensitive area or limit mining to first workings (e.g. Bulga Hill bat colony, which is currently protected from subsidence impact with a 26.5^{o} set-back distance from LW205 and 206 finishing points).
Sub-surface Cracking	• Repair surface cracks when they occur (refer above). • Leave a barrier pillar beneath sensitive areas or limit mining to first workings (e.g. Bulga Hill bat colony, which is currently protected from subsidence impact with a 26.5^{o} set-back distance from LW205 and 206 finishing points).
Slope Instability and Erosion	• Monitor surface slope displacement along subsidence cross-lines. • Infill surface cracking to prevent excessive ingress of runoff into the slopes. • Conduct mitigation works such as re-grading, installation of new contour banks and revegetation of exposed areas in areas that are significantly affected by erosion after mining. • Regularly review and appraise any significant changes to surface slopes after each longwall is extracted. • In the unlikely event of large-scale slope instability and erosion stabilisation remediation actions will be undertaken. Such actions would include: – infilling of surface cracking to prevent excessive ingress of runoff into the slopes; – installation of deep sub-surface drainage trenches and the construction of catch drains along slope crests so that surface run-off is controlled; and – stabilisation works undertaken along sections of bank which are damaged or steeply eroded.

Potential Subsidence Impact	Subsidence Management and Remediation Measures
Ponding and Altered Drainage Patterns	• Where ponding or flow re-direction occurs, the following actions will be undertaken, including: – if ponding occurs, no further work will be undertaken unless the ponding significantly affects downstream flows and vegetation; – to restore natural flow patterns, channel earthworks may be required; – should ponding significantly affect flow or vegetation, advice will be sought from a suitably qualified person specialist (e.g. hydrologist, geomorphologist) so that the most effective way of re-establishing more natural flow patterns is identified; – if overbank ponding occurs, advice will be sought from a suitably qualified specialist (e.g. hydrologist, ecologist) on potential mitigation options to reduce the impacts of ponding on vegetation within the ponds, vegetation on the boundary of the ponds and downstream riparian vegetation.

Source: Eco Logical Australia (2017).

Subsidence management and remediation measures similar to those outlined in Table 08-1 would continue to be implemented for the Project (including areas mapped as BSAL – Sections 5.1.4 and 5.2.4). Appropriate topsoil stripping and soil management measures (stockpile and application) would continue to be implemented in areas of surface disturbance. These areas would be returned to the pre-mining land capability and productivity. In addition, weed management procedures would be included in Land Management Plan to minimise the potential risk of weed establishment and spread.

The Landscape Management Plan (including the subsidence management and remediation measures) would be updated to include the Project and the recommendations of the Subsidence Assessment (Ditton Geotechnical Services 2020) and the Surface Water Assessment (WRM 2020) to incorporate the Project.

09 CONCLUSIONS AND RECOMMENDATIONS

Detailed assessment of potential impacts of the Project has forecast no significant impact on agricultural production and BSAL.

The Project involves an extension to the south of the approved underground mining area to gain access to additional coal reserves within MLAs 1 and 2. The additional impacts from the Project within ML 1609 would predominantly include additional surface development. All impacts within the MLAs 1 and 2 have been assessed in the AIS.

Within the Project Area, Ditton Geotechnical Services (2020) modelled the potential subsidence and undertook an impact assessment for the potential consequences of subsidence in the area. They also drew upon experience from measured subsidence and associated impacts from other mines in Australia, including the existing Narrabri Mine. As the Project is an extension of the existing Narrabri Mine, they have very similar mine geometry, geology, landscape and land use and measured impacts are highly likely to be similar to those that might be experienced by the Project. Subsidence modelling showed a likely maximum subsidence of approximately 2.8 m for each of the proposed panels with resulting consequences of soil cracking, ponding, increased erosion risk, infrastructure disturbance and changes to farm dams. Based on the modelling and experience from the existing Narrabri Mine, Ditton Geotechnical Services (2020) found that there was little to no significant risk of detrimental consequences to agricultural resources if land management and rehabilitation was applied in a similar manner to that undertaken at the existing Narrabri Mine. Creek line ponding is the most likely potentially detrimental consequence, however, ponding can be drained through channel creation and/or creek channel works or incorporated into the working agricultural landscape.

Groundwater assessment and modelling by AGE (2020) found no significant groundwater resources within the Project Area. The 'highly productive' Namoi Alluvium to the east of the Project Area is not expected to be significantly impacted by the Project.

The Project Area is in a region of moderate agricultural production. Grazing of cattle and sheep is the dominant land use with small areas of opportunistic fodder cropping and an olive grove. There is no irrigation land use in the Project Area. Approximately 215 ha of BSAL was verified by Soil Management Designs (2019) and GT Environmental (2020) within MLAs 1 and 2, of which approximately 18 ha would be subject to surface development and rehabilitated progressively over the life of the mine. Given the nature of the production systems and the nature of the impacts predicted for the Project, it is likely that agricultural production can continue throughout the Project's operation, with small areas being excluded temporarily while subsidence and rehabilitation are taking place. It is estimated that 638 ha of land (240 ha within ML 1609 and 399 ha within MLAs 1 and 2), including 22 ha of BSAL, would be required for infrastructure development. Surface infrastructure required for the Project is largely temporary and would be rehabilitated to agricultural or forestry land use, in a progressive manner, where no beneficial use for the area is identified. Non-temporary surface infrastructure would be either retained for beneficial use or rehabilitated to agricultural land use upon mine closure.

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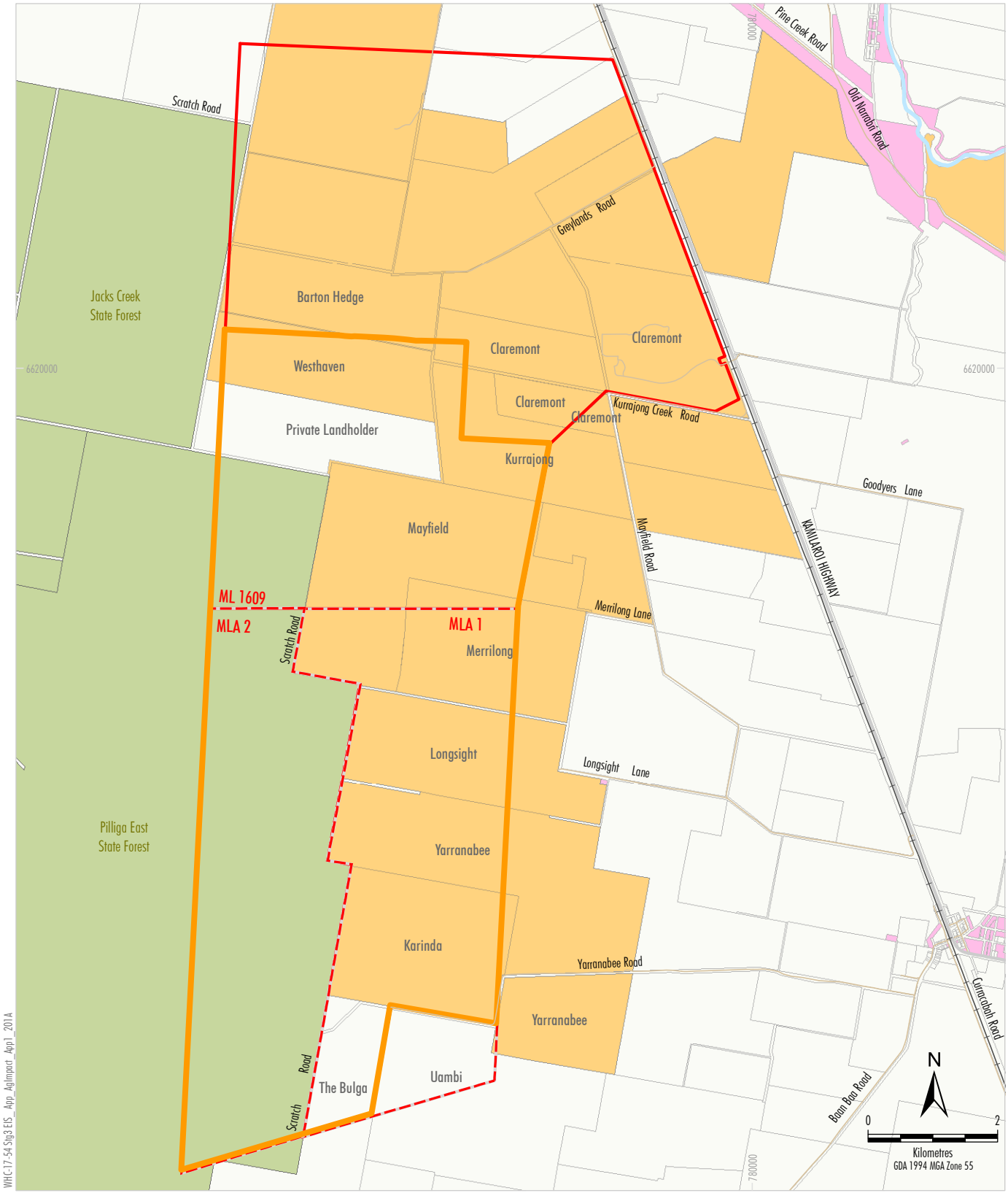
APPENDIX A: ADDITIONAL PROPERTY SURVEY AND ASSESSMENT

Eco Logical Australia (2019) describes the property scale agricultural resources for properties assessed for the Gateway Certificate Application. The area assessed for the Gateway Application is the same as that covered by Mining Lease Applications (MLAs) 1 and 2 (Appendix Figure 1). Longwall mining impacts in the Mining Lease (ML) 1609 are approved, however additional surface infrastructure is required to facilitate the Project (Appendix Figure 1). This property scale agricultural assessment considers these impacts within ML 1609.



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LEGEND
- Mining Lease (ML 1609)
- Provisional Mining Lease Application Area
- Project Area
- State Forest
- Crown Land
- NCOPL Owned Land
- Privately Owned Land and Other Land

Source: NSW Spatial Services (2019); NCOPL (2019)

WHITEHAVEN COAL

NARRABRI STAGE 3 PROJECT

Land Holdings Within the Project Area

Appendix Figure 1

A.1: Methods

GIS-based analysis supported by field survey and land holder/manager interview were used to describe agricultural resources and production systems within each property in ML 1609. GIS data were compiled from the NSW Government databases (Appendix Table 1). These datasets were overlaid with the Project Area and landholding boundaries, allowing the area of mapped resources to be determined. High-resolution imagery from both aerial and satellite sources were also used to assess land use and verify other findings.

Appendix Table 1: GIS Data Layers

Data	Source
BSAL	Department of Planning, Industry and Environment (2020a)
Cropping	Land Use Mapping (Department of Planning, Industry and Environment 2020b)
Grazing	Land Use Mapping (Department of Planning, Industry and Environment 2020b)
Soil Fertility	Inherent Fertility classes of Great Soil Groups (NSW OEH 2017b)
Land Capability	Department of Planning, Industry and Environment (NSW OEH 2017a)

All seven landholders/managers within the Project Area in ML 1609 were contacted by Narrabri Mine representatives to assess the nature of the agricultural resources, markets and infrastructure for each holding. Questions put to the landholders/managers included:

- How long have you lived on the property?
- Describe the property history (e.g. ownership, land use, produce).
- What is your experience in agriculture?
- What water sources do you have access to on this property?
- What do you consider to be the main limitations of your property?
- How many people do you employ?
- Describe the key agricultural infrastructure on your property.
- Typical yield/production - what commodities does the property typically produce (and production rate)? What could it produce opportunistically in ideal weather conditions?
- What are your key agricultural systems?
- What / who are your main markets?
- Who / where are your major suppliers of goods and services?

Field survey including note-taking and photographs, was conducted on 15 January 2020.

Not all properties were able to be surveyed on 15 January 2020 and not all landholders responded to the questions. The Merrilong property was surveyed and the land manager was interviewed as part of the process for the preparation of the Gateway Certificate Application (Eco Logical Australia 2019).

A.2: Property Scale Agricultural Assessments

Mayfield

Date: 6 February 2020

Time: 1:00pm-1:30pm

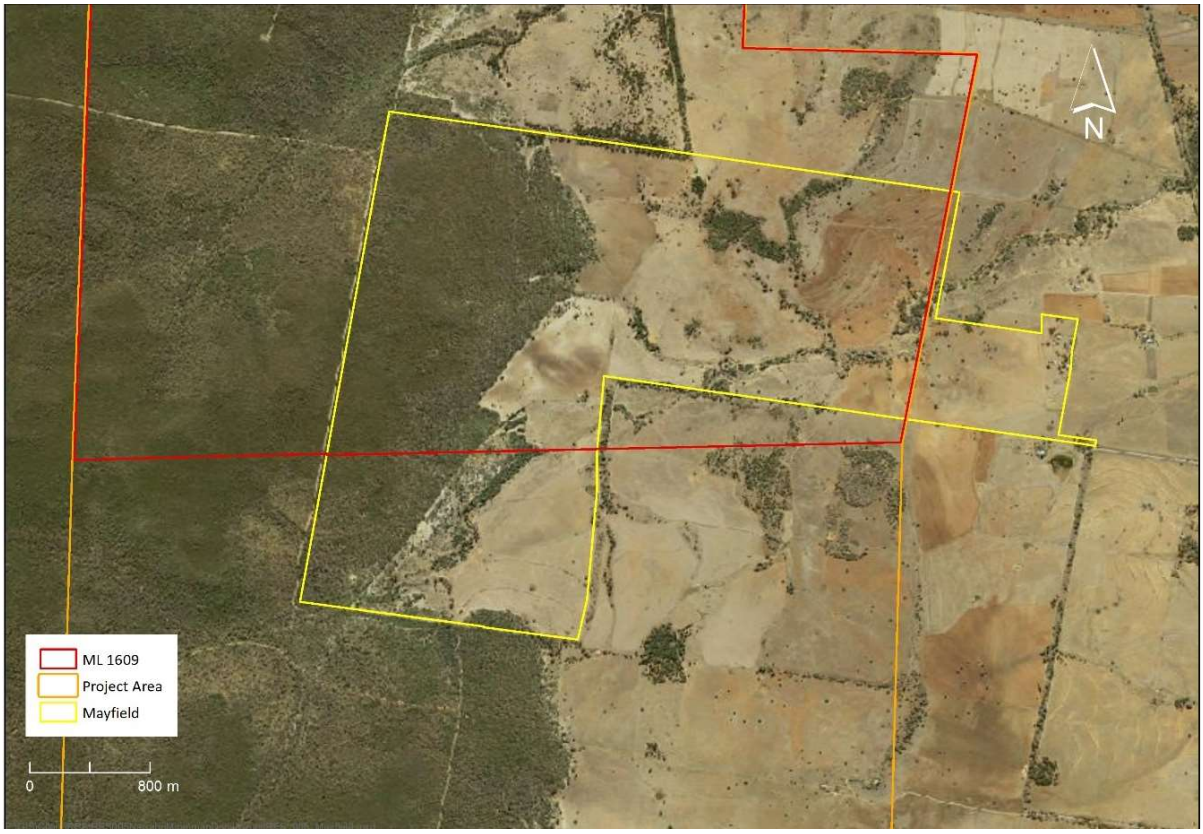
Mayfield contains 100.22 ha of BSAL and generally has a land capability in the moderate range that is considered suitable for grazing with opportunistic cropping (Appendix Table 2). Comments from the land manager confirm that grazing sheep and cattle is the primary land use, with opportunistic fodder cropping (Appendix Table 2). Appendix Figure 2 shows the extent of the Mayfield landholding in comparison to the Project Area in ML 1609. Appendix Figure 3 shows a photograph of the Mayfield property taken during the 15 January 2020 field survey.

Appendix Table 2 Mayfield GIS-based agricultural resource assessment

GIS data	Total on property (ha)	Total within Project Area (ML 1609) (ha)
BSAL	100.22	100.22
Cropping	298.51	193.63
Grazing	252.09	179.13
Soil Fertility (moderate to high)	193.71	145.21
Land Capability Classes 1-3 (high)		
1	0	0
2	0	0
3	109.0	100.23
Classes 4-5 (moderate)		
4	249.66	220.32
5	189.83	189.83
Classes 6-7 (low)		
6	0	0
7	83.17	83.17

Appendix Table 3 Mayfield responses

Question	Response
How long have you lived on or managed the property?	Has been managing for 14 years. Purchased 14 years ago, sold to NCOPL 10 years ago and leased since. Property is 2,000 acres (809.4 ha), with 1,700 acres (688.0 ha) available for grazing or cropping. The current properties Haylin Views and Matilda were part of Mayfield, but the Mayfield lessee subdivided them off.
Describe the property history (e.g. ownership, land use, produce)	Prior to the Mayfield lessee purchasing it was mainly cropped (winter cereals). With some of the rocky outcrops used for grazing. Now about 200-300 acres (81.0-121.4 ha) per year is cropped for feed (oats or barley) and used to feed his cattle and sheep. Average season can carry 800 ewes, and 40-50 cattle.
What is your experience in agriculture?	The Mayfield lessee has been a farmer his whole life, born in Brewarrina, and then moved to Narrabri as an adult.
What water sources do you have access to on this property?	Farm dams. During exploration he was told there was some good groundwater, but he never accessed this water.
What do you consider to be the main limitations of your property?	Rainfall.
How many people do you employ?	2 people full time.
Describe the key agricultural infrastructure on your property.	3 stand shearing shed, house with storage shed, and a concrete grain shed (capacity around 500 tonnes).
Typical yield/production - what commodities does the property typically produce (and production rate)? What could it produce opportunistically in ideal weather conditions?	Oats or barley – averages about 1 tonne per acre (2.47 tonne per ha). In good conditions he would put more livestock on or keep lambs longer.
What are your key agricultural systems?	Rotational grazing of each paddock for livestock and rotates oats and barley for cropping. Fertilises every year.
What / who are your main markets?	Sheep go to Tamworth saleyards. Cattle go to Narrabri saleyards.
Who / where are your major suppliers of goods and services?	Narrabri.



Appendix Figure 2 Mayfield landholding

Appendix Figure 3 Mayfield (15 January 2020)

Private Landholding

Date: 29 January 2020

Time: 9:30 am-10:00 am

The Private landholder contains no mapped areas of BSAL and generally has a land capability in the moderate range that is considered suitable for grazing with opportunistic cropping (Appendix Table 4). Comments from the land manager indicate that olive growing is the primary land use (400 trees) with no secondary land use at present (Appendix Table 5). Appendix Figure 4 shows the extent of the Private landholding in comparison to the Project Area in ML 1609. Appendix Figure 5 shows a photograph of the Private landholding taken during the 15 January 2020 field survey.

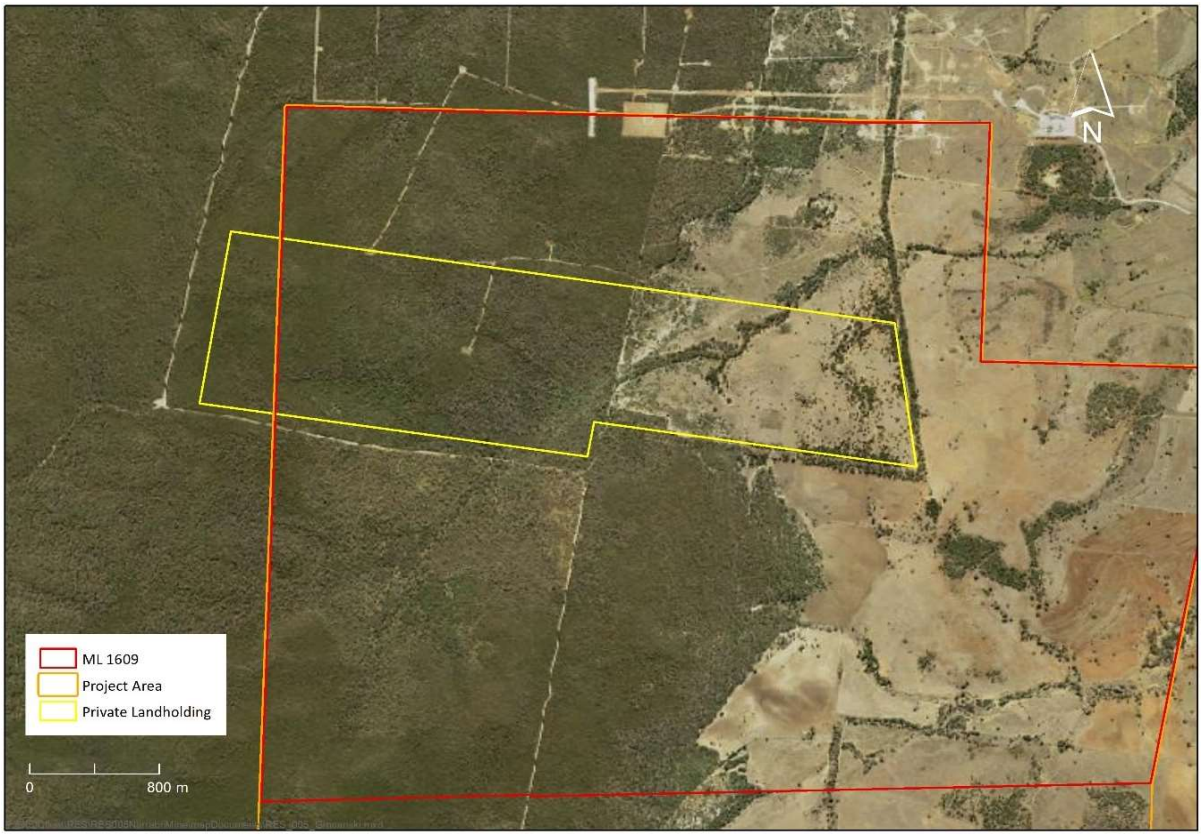
Appendix Table 4 Private Landholding GIS-based agricultural resource assessment

GIS data	Total on property (ha)	Total within Project Area (ML 1609) (ha)
BSAL	0	0
Cropping	2.73	2.73
Grazing	362.48	325.46
Soil Fertility (moderate to high)	0	0
Land Capability Classes 1-3 (high)		
1	0	0
2	0	0
3	0	0
Classes 4-5 (moderate)		
4	136.72	136.72
5	175.68	138.66
Classes 6-7 (low)		
6	0	0
7	52.8	52.8

Appendix Table 5 Private Landholder survey responses

Question	Response
How long have you lived on or managed the property?	About 20-25 years, purchased in late 1990s (could not remember year).
Describe the property history (e.g. ownership, land use, produce).	Does not know history before purchase. Currently has olive grove with table and oil olives (400 trees). No cattle or sheep as he does not live there to look after them. Part built house.
What is your experience in agriculture?	This property is the only agricultural enterprise he owns and operates. Previous experience working on his uncle's tomato farm in Gosford.
What water sources do you have access to on this property?	Three farm dams. No bores.
What do you consider to be the main limitations of your property?	Soil has been tested and "can grow anything". Lack of water is the main constraint. Plans to put in a bore at some stage and build a larger dam.
How many people do you employ?	None.

Question	Response
Describe the key agricultural infrastructure on your property.	No sheds. Only partly built house.
Typical yield/production - what commodities does the property typically produce (and production rate)? What could it produce opportunistically in ideal weather conditions?	Current production is none due to drought and damage from goats. Previous years he has harvested about 2 tonnes per year of olives from 400 trees.
What are your key agricultural systems?	Olive production. Wants to diversify to have continuity in production of produce.
What / who are your main markets?	Sells pickled olives to individuals in Sydney.
Who / where are your major suppliers of goods and services?	Transports all materials from Sydney.



Appendix Figure 4 Private landholding

Appendix Figure 5 Private Landholding (15 January 2020)

Westhaven

Westhaven contains no mapped areas of BSAL and generally has a land capability in the moderate range that is considered suitable for grazing with opportunistic cropping (Appendix Table 6). Land capability included 358.44 ha of class 4 and 5 (moderate) productivity land. Land capability would generally be suitable for grazing with opportunistic cropping (Appendix Table 6). Appendix Figure 6 shows the extent of the Westhaven landholding in comparison to the Project Area within ML 1609. Appendix Figure 7 shows a photograph of the Westhaven property taken during the 15 January 2020 field survey.

Appendix Table 6 Westhaven GIS-based agricultural resource assessment

GIS data	Total on property (ha)	Total within Project Area (ML 1609) (ha)
BSAL	0	0
Cropping	0	0
Grazing	103.33	6.32
Soil Fertility (moderate to high)	0	0
Land Capability Classes 1-3 (high)		
1	0	0
2	0	0
3	0	0
Classes 4-5 (moderate)		
4	169.05	153.73
5	189.39	156.95
Classes 6-7 (low)		
6	0	0
7	7.67	7.67

Appendix Figure 6 Westhaven landholding

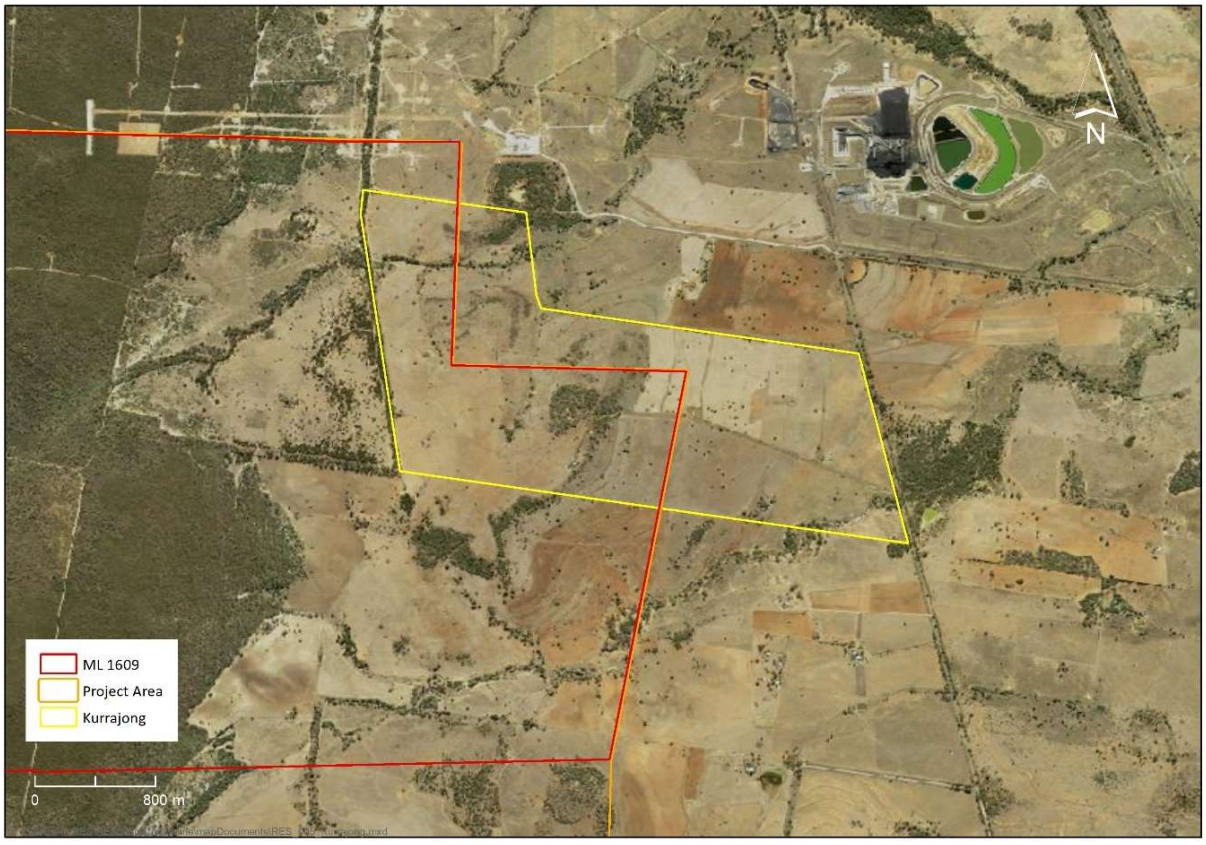
Appendix Figure 7 Westhaven (15 January 2020)

Kurrajong

Kurrajong contains 71.71 ha of unverified state mapped BSAL within the Project Area in ML 1609. Land capability included 168.64 ha class 3 (high), 182.71 ha of class 4 and 5 (moderate) and 53.71 ha of class 7 (low) productivity land. Land capability would be suitable for cropping in the class 3 areas and grazing with opportunistic cropping in class 4-5 areas (Appendix Table 7). Appendix Figure 8 shows the extent of the Kurrajong landholding in comparison to the Project Area within ML 1609. Appendix Figure 9 shows a photograph of the Kurrajong property taken during the 15 January 2020 field survey.

Appendix Table 7 Kurrajong GIS-based agricultural resource assessment

GIS data	Total on property (ha)	Total within Project Area (ML 1609) (ha)
BSAL	142.18	71.71
Cropping	274.72	120.64
Grazing	130.34	63.32
Soil Fertility (moderate to high)	257.79	88.41
Land Capability Classes 1-3 (high)		
1	0	0
2	0	0
3	168.64	71.85
Classes 4-5 (moderate)		
4	92.14	19.56
5	90.57	41.77
Classes 6-7 (low)		
6	0	0
7	53.71	50.78



Appendix Figure 8 Kurrajong landholding

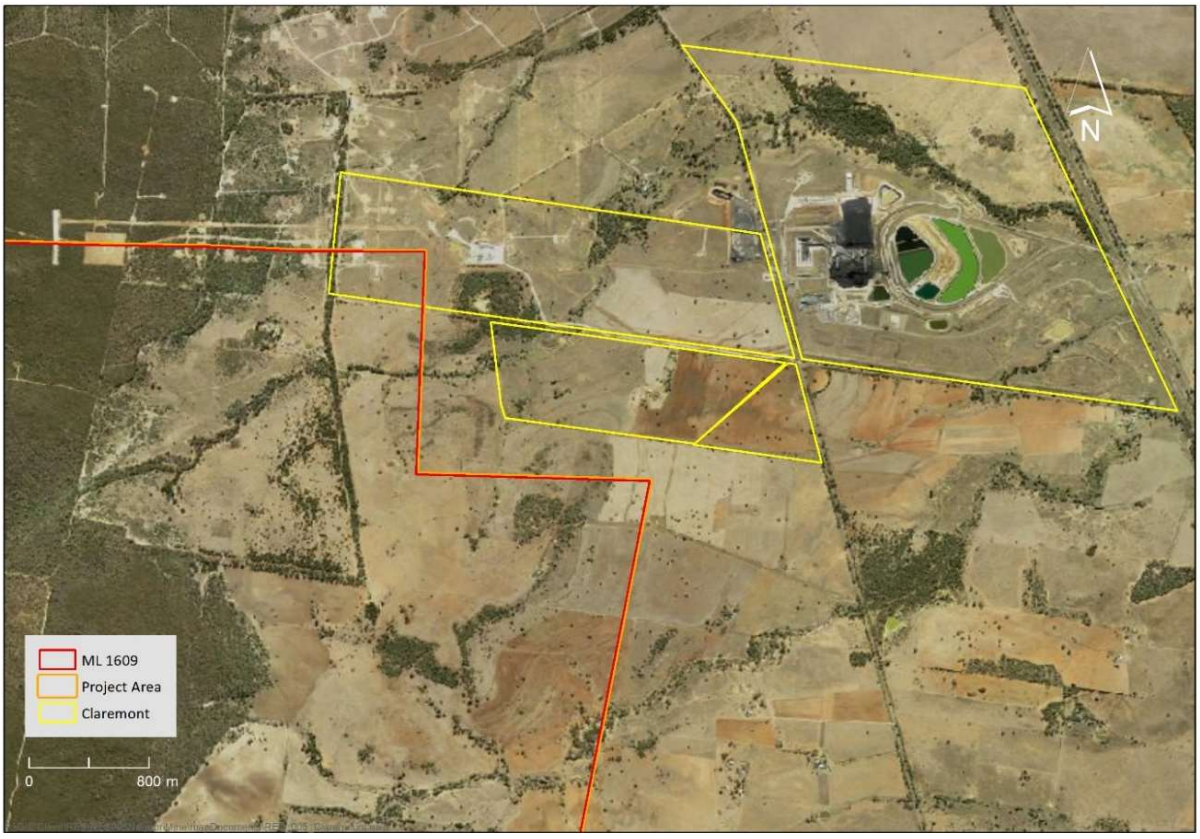
Appendix Figure 9 Kurrajong (15 January 2020)

Claremont

Claremont contains no areas of mapped BSAL within the Project Area in ML 1609. Land capability included 416.81 ha class 3 (high) and 297.53 ha of class 4 and 5 (moderate) productivity land. Land capability would be suitable for cropping in the class 3 areas and grazing with opportunistic cropping in class 4-5 areas (Appendix Table 8). Appendix Figure 10 shows the extent of the Claremont landholding in comparison to the Project Area within ML 1609.

Appendix Table 8 Claremont GIS-based agricultural resource assessment

GIS data	Total on property (ha)	Total within Project Area (ML 1609) (ha)
BSAL	236.0	0
Cropping	155.90	0
Grazing	283.38	17.22
Soil Fertility (moderate to high)	487.02	0
Land Capability Classes 1-3 (high)		
1	0	0
2	0	0
3	416.81	0
Classes 4-5 (moderate)		
4	94.90	6.24
5	202.63	10.97
Classes 6-7 (low)		
6	0	0
7	0	0



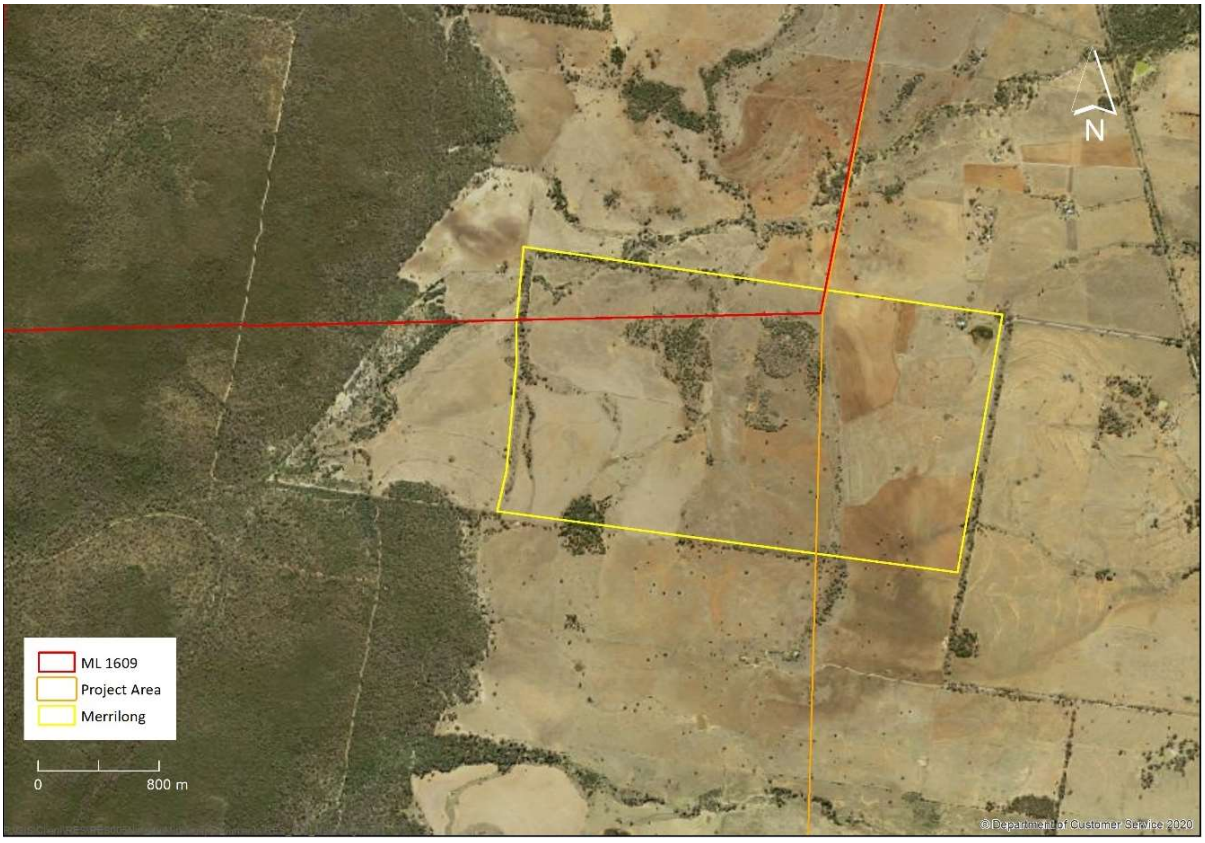
Appendix Figure 10 Claremont landholding

Merrilong

Merrilong contains no mapped BSAL within the Project Area in ML 1609. Land capability included 49.89 ha class 3 (high), 238.74 ha of class 4 and 5 (moderate) and 181.22 ha of class 7 (low) productivity land. Land capability would be suitable for cropping in the class 3 areas and grazing with opportunistic cropping in class 4-5 areas (Appendix Table 9). Appendix Figure 11 shows the extent of the Merrilong landholding in comparison to the Project Area within ML 1609.

Appendix Table 9 Merrilong GIS-based agricultural resource assessment

GIS data	Total on property (ha)	Total within Project Area (ML 1609) (ha)
BSAL	49.89	0
Cropping	285.23	0.26
Grazing	180.34	55.71
Soil Fertility (moderate to high)	199.96	46.19
Land Capability Classes 1-3 (high)		
1	0	0
2	0	0
3	49.89	0
Classes 4-5 (moderate)		
4	57.08	27.41
5	181.66	28.57
Classes 6-7 (low)		
6	0	0
7	181.22	0



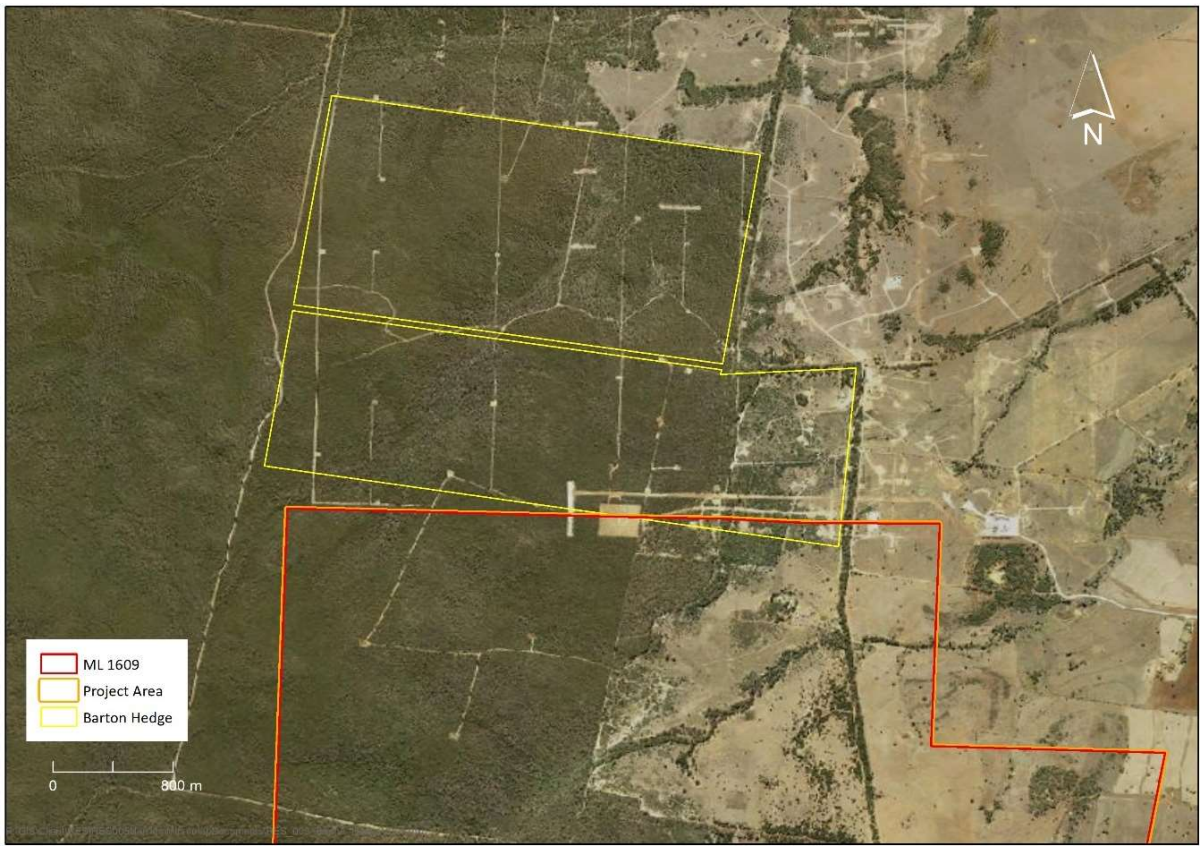
Appendix Figure 11 Merrilong landholding

Barton Hedge

Barton Hedge contains no mapped BSAL within the Project Area in ML 1609. Land capability included 701.65 ha of class 4 and 5 (moderate) productivity land. Land capability would be suitable for grazing with opportunistic cropping (Appendix Table 10). Appendix Figure 12 shows the extent of the Barton Hedge landholding in comparison to the Project Area within ML 1609.

Appendix Table 10 Barton Hedge GIS-based agricultural resource assessment

GIS data	Total on property (ha)	Total within Extension Area (ha)
BSAL	0	0
Cropping	4.61	0
Grazing	70.46	6.2
Soil Fertility (moderate to high)	0	0
Land Capability Classes 1-3 (high)		
1	0	0
2	0	0
3	0	0
Classes 4-5 (moderate)		
4	248.76	4.65
5	452.89	5.13
Classes 6-7 (low)		
6	0	0
7	0	0



Appendix Figure 12 Barton Hedge landholding

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APPENDIX B: LAND RESOURCES ASSESSMENT

Land Resources Assessment

Narrabri Underground Mine Stage 3 Extension Project

Final
25 August 2020

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Name of document:	Land Resources Assessment Narrabri Underground Mine Stage 3 Extension Project

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1 INTRODUCTION

1.1 Project Details

The Narrabri Mine is located approximately 25 kilometres (km) south-east of Narrabri and approximately 60 km north-west of Gunnedah within the Narrabri Shire Council Local Government Area of New South Wales (NSW) (Figure 1). The Narrabri Mine is operated by Narrabri Coal Operations Pty Limited (NCOPL).

NCOPL is seeking a new Development Consent under the State Significant Development provisions of Part 4 of the NSW *Environmental Planning and Assessment Act 1979* (EP&A Act) for the Narrabri Underground Mine Stage 3 Extension Project (the Project). GT Environmental Pty Ltd (GTE) was commissioned by NCOPL (Client) to conduct a Land Resources Assessment to form part of an Environmental Impact Statement (EIS) prepared to accompany the Development Application for the Project.

1.2 Background

NCOPL lodged an application for a Gateway Certificate to the Mining and Petroleum Gateway Panel in relation to the Project on 6 February 2019. The Gateway Certificate application was supported by *Agricultural Resource Assessment for Gateway Certificate Application: Narrabri Underground Mine Stage 3 Extension Project, Narrabri, NSW* (Soil Management Designs, 2019). Soil Management Designs (2019) assessed all relevant areas of the Project site except for approximately 700 hectares (ha) where land access was not available at the time (Figure 2).

A Conditional Gateway Certificate was issued on 4 June 2019. The Mining and Petroleum Gateway Panel recommended that the Project EIS include assessment of the land resources in the area of the Project site that was not able to be assessed by Soil Management Designs (2019).

1.3 Scope

This report addresses the Mining and Petroleum Gateway Panel's recommendation for further assessment of the land resources in the area of the Project site that were not able to be assessed by Soil Management Designs (2019) (herein referred to as the Area of Interest – Figure 2). The Area of Interest is approximately 700 ha (Figure 2).

The scope of this report includes the following:

- Identification of areas of biophysical strategic agricultural land (BSAL) within the Area of Interest (excluding the appropriate buffer) in accordance with the *Interim protocol for site verification and mapping of biophysical strategic agricultural land* (NSW Government, 2013) (the Interim Protocol) (Sections 2 and 3);
- Assessment of land and soil capability (LSC) classes within the Area of Interest in accordance with *The Land and Soil Capability Assessment Scheme – Second Approximation* (NSW Office of Environment and Heritage [OEH], 2012) (Section 4); and
- Development of topsoil management of existing soil resources within the Area of Interest (Section 5).

This report is to be read in conjunction with Soil Management Designs (2019) and further information regarding the Project site is available within the Soil Management Designs (2019).

2 BSAL VERIFICATION METHODOLOGY

The Interim Protocol provides a methodology for verifying whether land mapped as BSAL meets the BSAL criteria. The initial steps for verifying BSAL and how they apply to the Area of Interest is outlined in Section 2.1 and the detailed soil and landscape verification criteria are described in Section 2.2.

2.1 BSAL Desktop Review

2.1.1 Step 1 – Identify the project area which will be assessed for BSAL

The Area of Interest is approximately 700 ha (Figure 2) and consists of two land use categories; cleared agricultural land (400 ha) and woodland (300 ha).

In accordance with the Interim Protocol, an additional 100 metre (m) buffer area has been added to the Area of Interest in areas not assessed by Soil Management Designs (2019) for the purposes of the BSAL assessment (refer Figure 3). The Area of Interest and the added buffer areas covers an area of approximately 730 ha. References to the Area of Interest in relation to the BSAL assessment includes the buffer area.

The *State Environmental Planning Policy (Mining, Petroleum Production and Extractive Industries) 2007* (Mining SEPP) includes mapping of lands identified as BSAL. There is regionally mapped BSAL in the Mining SEPP within the Area of Interest (Figure 3).

2.1.2 Step 2 – Confirm access to a reliable water supply

For the Area of Interest to be considered BSAL, the land must have access to a 'reliable water supply'. The Interim Protocol outlines that all the area in the *New England North West Strategic Regional Land Use Plan* (Department of Planning and Infrastructure, 2012) is considered to have access to a 'reliable water supply'. This is due to either rainfall of 350 millimetres (mm) or more per annum in 9 out of 10 years, or the land is underlain by a groundwater aquifer with a bore yield rate greater than 5 litres per second and total dissolved solid of less than 1,500 milligrams per litre.

As the Area of Interest is in the *New England North West Strategic Regional Land Use Plan* (Department of Planning and Infrastructure, 2012) area, the Area of Interest is considered to have access to a reliable water supply.

2.1.3 Step 3 – Appropriate approach to map soils information

NCOPL has obtained access to the Area of Interest for the purposes of the soil survey. An on-site soil assessment for BSAL verification in accordance with Section 6 and 9 of the Interim Protocol has therefore been undertaken in the Area of Interest.

2.1.4 Step 4 – Risk assessment for site density

In order to identify the potential impact on agricultural resources and the appropriate level of soil survey required, Soil Management Designs (2019) conducted an evaluation of potential risks to agricultural resources and enterprises for the Project site (including the Area of Interest). This risk assessment was based on the process outlined in Appendix 3 of the Interim Protocol.

The risk assessment concluded the following (Soil Management Designs, 2019):

- Western vegetated areas – considered to be a low risk to agricultural resources and enterprises (in the context of the Interim Protocol) and a sampling density of 1 site per 400 ha was considered appropriate; and
- Eastern cleared areas – considered to be a high risk to agricultural resources and enterprises (in the context of the Interim Protocol) and a sampling density of 1 site per 20 ha was considered appropriate.

GTE has used the above sampling densities and applied these to the Area of Interest field survey.

2.2 BSAL Field Survey

2.2.1 Field survey timing

A detailed field survey was undertaken between 8 and 11 August 2019, which encompassed the Area of Interest (Figure 3). The field survey was undertaken by Associate Environmental Scientist Reece McCann and Environmental Consultant Greg Tuck with assistance from client staff and equipment operators.

2.2.2 Field survey techniques

Field survey techniques were based on identifying sampling locations derived from the desktop review of background information, existing available soils information, Soil Management Designs (2019) and an examination of satellite imagery.

The specific locations of the survey sites were further refined in the field based on available site access and the location being a sound representation of the soil type being described and their location as identified within the isolated polygon (herein known as 'map unit'). Soil type unit size and density of observation sites are shown in Table 2-1. The locations of the detailed and check sites are shown on Figure 3.

Table 2-1: Soil Type Unit Size and Density of Observation Sites

Observation Sites/Map Unit	Unit
Minimum area for BSAL verification	20 ha
Minimum density or sites in a map unit	1 site per 20 ha for the eastern area[1] 1 site per 400 ha for the western area / low risk[1]
Detailed (Analysed) sites per soil type	3[1]
Check sites per soil type	Density not stipulated; check sites complement detailed sites
Exclusion sites per excluded area	2

1 – Detailed/analysed total sites include Soil Management Designs (2019) sites.

Test pit locations were selected on the Area of Interest by desktop review of available information, satellite imagery, previous BSAL assessment work and refined on-site. Detailed sites were undertaken using a backhoe to excavate test pits to approximately 1.2 m below ground level (mbgl). Check sites were undertaken by 50 mm hand auger with exclusion sites consisting of surface observations.

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' (McKenzie et al., 2008). The soil profiles have been classified according to the 'Australian Soil Classification' [ASC] (Isbell, 2002).

The following characteristics were assessed for the layers identified in each of the detailed and check 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 Color [2009] reference colours) and mottle characteristics;
- Pedality of the soil aggregates;
- Amount and type of coarse fragments (gravel, rock, nodules);
- Texture (proportions of sand, silt and clay), estimated by hand;
- Root frequency; and
- Dispersibility and the degree of slaking in deionised water (after 10 minutes).

Site factors noted included current land use, landform, slope (measured with a handheld clinometer), aspect and surface rock (measured in four 1.0 m quadrants where required).

2.2.3 Laboratory analysis

Soil samples were collected from test pit sites for laboratory analysis. The sampling intervals for laboratory analysis were guided per the Interim Protocol, i.e. 0 to 5 centimetres (cm); 5 to 15 cm; 15 to 30 cm; 30 to 60 cm; and 60 to 100 cm.

Where soil horizons do not coincide with these depth intervals, allowance was made to avoid cross sampling of horizon depths. Additionally, the final sample interval of 60 to 100 cm was amended to 60 to 75 cm to accurately assess the chemical barrier BSAL criterion.

The soil was analysed by Environmental Analysis Laboratory at Southern Cross University with laboratory methods compatible with key components of the Interim Protocol.

The detailed sites were analysed with the following:

- pH (1:5 soil water);
- Salinity (electrical conductivity [EC] 1:5); and
- Exchangeable sodium percentage (ESP) and cation exchange capacity.

Laboratory results are presented in Appendix D which includes conversion of EC to saturated soil extract EC (ECe) and base status calculations undertaken by GTE.

2.3 BSAL Soil and Landscape Verification Criteria

There are twelve BSAL site verification criteria used to identify BSAL at each representative site. Assessment techniques for each criterion are summarised within Table 2-2 below and based on *Figure 2: Flow chart for site assessment of BSAL* within the Interim Protocol.

The specific assessment techniques for each criterion are referenced in *Appendix 1: Measuring BSAL Criteria* within the Interim Protocol. The following sub-sections summarise the BSAL assessment criteria and justification for analysis, as outlined within the Interim Protocol.

Table 2-2: Overview of Site Assessment of BSAL

Step	Site Assessment		Assessment	
1	Is slope less than or equal to 10%?		Yes – continue to next step	No – This site is not BSAL
2	Is there <30% rock outcrop?		Yes – continue to next step	No – This site is not BSAL
3	Does ≤20% of area have unattached rock fragments >60 mm diameter?		Yes – continue to next step	No – This site is not BSAL
4	Does ≤50% of the area have gilgais >500 mm deep?		Yes – continue to next step	No – This site is not BSAL
5	Is slope <5%?		Yes – continue to step 6	No – continue to step 7, part 2
6	Are there nil rock outcrops?		Yes – continue to step 7, part 1	No – continue to step 7, part 2
7	Part 1 - Does soil have moderate fertility?	Part 2 - Does soil have moderately high or high fertility?	Yes – continue to next step	No – This site is not BSAL
8	Is effective rooting depth (ERD) to a physical barrier ≥750 mm?		Yes – continue to next step	No – This site is not BSAL
9	Is soil drainage better than poor?		Yes – continue to next step	No – This site is not BSAL
10	Does the pH range from 5 – 8.9 if measured in water or 4.5 – 8.1 if measured in calcium chloride, within the uppermost 600 mm of the soil profile?		Yes – continue to next step	No – This site is not BSAL
11	Is salinity (ECe) ≤4 deciSiemens per metre (dS/m) or are chlorides <800 milligrams per kilogram when gypsum is present, within the upper most 600 mm of the soil profile?		Yes – continue to next step	No – This site is not BSAL
12	Is ERD to a chemical barrier ≥75 mm?		Yes – continue to next step	No – This site is not BSAL
The site is BSAL (if contiguous area is ≥20 ha).				

2.3.1 Slope – Steps 1 and 5

Slope is considered an impediment to farming as erosion potential rapidly increases once slope increases beyond 10%. Increased slope is also an impediment to the safe operation of machinery. Soil Management Designs (2019) included slope mapping which has been reproduced on Figure 4.

2.3.2 Rock outcrop – Steps 2 and 6

Rocks and rocky outcrops hinder cultivation operations (e.g. damage to machinery). BSAL must have less than 30% rock outcrop.

2.3.3 Surface rockiness – Step 3

Rockiness refers to the presence of unattached coarse rock fragments on the soil surface and to rock outcrops at the soils surface. BSAL soils must have surface rockiness where no more than 20% of area has unattached rock fragments greater than 60 mm diameter.

2.3.4 Gilgai – Step 4

Gilgai microrelief is a natural soil feature of mounds and depressions commonly associated with cracking clays or Vertosols. If the average depth of gilgai depressions is deeper than 500 mm, and if the depressions occupy more than 50% of a mapped area of gilgai, then the area is not BSAL.

2.3.5 Soil Type – Step 7

BSAL must have a soil type which has naturally high, moderately high or moderate fertility. Soils with moderately high or high fertility can sustain high levels of productivity and soils with moderate fertility capable of moderate levels of productivity. Soils below moderate levels are not considered BSAL.

2.3.6 Effective rooting depth to physical barrier – Step 8

ERD refers to the depth of soil over which plant roots can function effectively. Physical barriers include bedrock, weathered rock, hard pans and continuous gravel layers. BSAL soils must have an ERD to a physical barrier greater than, or equal to, 750 mm.

2.3.7 Drainage – Step 9

Areas that have poor drainage severely reduce crop and pasture productivity and root growth is inhibited due to poor aeration. Waterlogged, poorly drained or very poorly drained soils are not BSAL soils.

2.3.8 Soil pH – Step 10

BSAL soils range from acidic to alkaline soil conditions within the range of 5.0 – 8.9 when measured in water or 4.5 – 8.1 when measured in calcium chloride, within the uppermost 600 mm of the soil profile. The above is an acceptable range for most crop and pasture species.

2.3.9 Soil Salinity – Step 11

Salinity affects the ability of plants to extract nutrients and water and affects root development. Soil salinity will need to be measured in the laboratory as this is more accurate.

BSAL soils have a level of soil salinity where electrical conductivity in a saturated extract (ECe) is less than or equal to 4 dS/m. This applies to the uppermost 600 mm of the soil profile.

2.3.10 Effective rooting depth to chemical barrier – Step 12

Chemical barriers include pH, electrical conductivity, chloride content, exchangeable sodium percentage and the calcium to magnesium ratio. BSAL soils must have an ERD to a chemical barrier greater than or equal to 750 mm.

2.3.11 Non-site criteria: Minimum area

BSAL soils must have a contiguous area of greater than or equal to 20 ha. The minimum area refers to the extent of the biophysical resource rather than the lot or holding size. This is the minimum area considered necessary to commercially produce a high value agricultural crop.

3 BSAL VERIFICATION RESULTS

3.1 Soil Types

Regional ASC mapping available from the OEH identified vertosols, sodosols, rudosols, tenosols, ferrosols and chromosols.

Six soil landscape units were identified by Soil Management Designs (2019) and were associations of soils described and delineated by means of landform. These soil landscape units included dominant and subdominant soil types and were named with terminology recorded on the geology map.

GTE identified six dominant soil types separated within nine polygons. These meet the minimum map sizes for the Area of Interest and are summarised in Table 3-1. The soil types have been grouped according to basic soil morphology, position in the landscape, and parent material and based on 30 observation sites, consisting of 21 detailed sites (Appendix B), 7 check sites (Appendix C) and 2 exclusion sites (Appendix C) (Figure 5). The soil types and terminology are consistent with the Soil Management Designs (2019).

Figure 5 illustrates the spatial distribution of soil types and major dominant soils within the Area of Interest and detailed descriptions of each soil type are provided in the following sections. This assessment includes review of existing soils data (McKenzie et al., 2008) adjacent to the Area of Interest.

Table 3-1: Summary of Soil Types

Soil Type	Detailed Sites[1]	Map Code	Dominant Soil Type[2]	Subdominant Soil Type[2]	Additional Comments
Pilliga Sandstone	21	P	Orthic Tenosol	Sodosol, Dermosol Rudosol	Acidic sandy soil – poor fertility for agricultural crops.
Garawilla Volcanics – Calcic	12	GV-C	Vertosol	Dermosol	High quality clay-rich soil that is suitable for a broad range of agricultural crops and pasture.
Garawilla Volcanics – Intermediate	2, 3, 4, 6, 7, 10, 11, 20	GV-I	Dermosol	Chromosol, Kandosol, Rudosol	High quality soil that is suitable for a broad range of agricultural crops and pasture following amelioration.
Garawilla Volcanics – Sodic	1, 5, 13, 15	GV-S	Sodosol	Dermosol, Kandosol, Leptic Tenosol, Calcarosol	Poor root growth in subsoil due to sodicity.
Garawilla Volcanics – Sodic/Vertosols	9, 14, 16, 17, 18, 19	GV-S/V	Vertosol	-	Poor root growth in subsoil due to sodicity, but a favourable ability to regenerate soil structural form through shrink-swell processes.
Napperby Siltstone	8	N	Sodosol	Rudosol	Poor root growth in subsoil due to sodicity.

1 - Detailed sites refers to GTE sites only, not including sites from Soil Management Designs (2019).

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

3.2 Verified Non-BSAL Sites

The following sites below were assessed as verified non-BSAL areas. The assessment for BSAL is presented in Appendix A and detailed site descriptions in Appendix B.

3.2.1 Site 1 – Fertility, pH and effective rooting depth to chemical barrier

Site 1 test pit assessment indicated the following three limitations:

- Fertility status of moderately low, due to the ASC assessed as subnatric brown sodosol;
- pH laboratory result was analysed at 0.30-0.60 mbgl at 9.51 above 8.90; and
- ESP laboratory result was analysed at 0.60-0.75 at 15.48 indicating a chemical barrier.

3.2.2 Site 4 – pH, ECe and effective rooting depth to chemical barrier

Site 4 test pit assessment indicated the following three limitations:

- pH laboratory result was analysed at 0.30-0.60 mbgl at 8.93 above 8.90;
- ECe laboratory result was analysed at 0.30-0.60 mbgl at 9.91 above 4 dS/m; and
- ESP laboratory result was analysed at 0.60-0.75 at 16.66 indicating a chemical barrier within 0.75 mbgl.

3.2.3 Site 5 – Fertility, pH and effective rooting depth to chemical barrier

Site 5 test pit assessment indicated the following four limitations:

- Fertility status of moderately low, due to the ASC assessed as eutrophic brown sodosol;
- Marginal physical ERD with a rock layer observed between 0.75 mbgl and 0.77 mbgl. Visual inspection of the layer throughout the test pit did not indicate rock within 0.75 mbgl;
- pH laboratory result was analysed at 0.60-0.75 mbgl at 9.06 above 8.90; and
- ECe laboratory result was analysed at 0.60-0.75 mbgl at 4.94 above 4 dS/m.

3.2.4 Site 8 – Fertility

Site 8 test pit assessment indicated the following limitation:

- Fertility status of moderately low, due to the ASC assessed as stratic rudosol.

3.2.5 Site 9 – Effective rooting depth to chemical barrier

Site 9 test pit assessment indicated the following limitation:

- ESP laboratory result was analysed at 0.30-0.60 at 18.07 indicating a chemical barrier within 0.75 mbgl.

3.2.6 Site 11 – pH

Site 11 test pit assessment indicated the following limitation:

- pH laboratory result was analysed at 0.30-0.60 mbgl at 9.09 above 8.90.

3.2.7 Site 13 – Fertility and pH

Site 13 test pit assessment indicated the following two limitations:

- Fertility status of moderately low, due to the ASC assessed as subnatric red sodosol; and
- pH laboratory result was analysed at 0.30-0.60 mbgl at 8.99 above 8.90.

3.2.8 Site 14 – pH and ECe

Site 14 test pit assessment indicated the following two limitations:

- pH laboratory result was analysed at 0.30-0.60 mbgl at 8.90 equal to 8.90; and
- ECe laboratory result was analysed at 0.05-0.15 mbgl at 4.95 above 4 dS/m.

3.2.9 Site 15 – Fertility and pH

Site 15 test pit assessment indicated the following two limitations:

- Fertility status of moderately low, due to the ASC assessed as hypocalcic brown sodosol; and
- pH laboratory result was analysed at 0.15-0.30 mbgl at 8.96 above 8.90.

3.2.10 Site 16 – ECe and effective rooting depth to chemical barrier

Site 16 test pit assessment indicated the following two limitations:

- ECe laboratory result was analysed at 0.30-0.60 mbgl at 4.18 above 4 dS/m; and
- ESP laboratory result was analysed at 0.15-0.30 at 15.78 indicating a chemical barrier within 0.75 mbgl.

3.2.11 Site 17 – ECe and effective rooting depth to chemical barrier

Site 17 test pit assessment indicated the following two limitations:

- ECe laboratory result was analysed at 0.30-0.60 mbgl at 6.99 above 4 dS/m; and
- ESP laboratory result was analysed at 0.30-0.60 at 16.25 indicating a chemical barrier within 0.75 mbgl.

3.2.12 Site 18 – ECe and effective rooting depth to chemical barrier

Site 18 test pit assessment indicated the following two limitations:

- ECe laboratory result was analysed at 0.30-0.60 mbgl at 6.19 above 4 dS/m; and
- ESP laboratory result was analysed at 0.60-0.75 at 18.34 indicating a chemical barrier within 0.75 mbgl.

3.2.13 Site 19 – Non-site criteria

Site 19 test pit assessment does not indicate any limitation except for marginal physical depth to a weathered rock layer at 0.75 mbgl, the site passes BSAL criteria.

However, when the BSAL status is assessed on the dominant soil type and the sites within the soil map unit, as noted in Section 9.6.3 of the Interim Protocol the dominant soil type fails for the entire map unit. In this instance, the BSAL status is based on the dominant soil type and therefore the site fails.

3.2.14 Site 21 – Fertility

Site 21 test pit assessment indicated one limitation:

- Fertility status of moderately low, due to the ASC assessed as stratic rudosol.

3.3 Verified BSAL Sites

The following sites were assessed as verified BSAL areas. The assessment for BSAL is presented in Appendix A and detailed site descriptions in Appendix B.

3.3.1 Sites 2, 3, 6, 7, 10, 12 and 20

Sites 2, 3, 6, 7, 10, 12 and 20 were assessed as passing the soils and landscape verification criteria and are part of a contiguous area larger than 20 ha.

Site 20 BSAL verification area extends outside the Area of Interest and buffer area. GTE have mapped the estimated boundary assessing the minimum area and is included on Figure 6.

3.4 BSAL Assessment Summary

Overall BSAL verification status of detailed sites is shown in Appendix A and summarised in Table 3-2 below. Figure 6 shows areas assessed as verified BSAL and verified non-BSAL.

3.5 Verified BSAL Areas

The verified BSAL area within the Area of Interest was determined by assessing the following:

- LIDAR metadata used to determine slope/s greater than 10%;
- Detailed sites that were verified as BSAL or non-BSAL;
- Exclusion and check sites identifying landscape criteria fails such as slope and physical barriers (unattached rock fragments on the surface);
- BSAL verification mapping of Soil Management Designs (2019) assessment; and
- Satellite imagery.

The verified BSAL polygon boundaries were placed in order to follow patterns of sites that are individually assessed as verified BSAL while being part of a contiguous area larger than 20 ha. These polygons were also based on the landforms between sites, soil types, areas above 10% slope (Section 2.3) and BSAL verification mapping of Soil Management Designs (2019) assessment. During the field survey an existing drainage line was identified to the north of Sites 6 and 7 that was considered non-BSAL as the slope was generally greater than 10% along the drainage line banks (Figure 6).

Based on the above, approximately 106 ha of verified BSAL and 594 ha of verified non-BSAL were identified in the Area of Interest.

Table 3-2: BSAL Verification Assessment

Site	BSAL Status	Non-BSAL Criteria
1	Non-BSAL	Fertility, pH and ERD to chemical barrier
2	BSAL	-
3	BSAL	-
4	Non-BSAL	pH, ECe and ERD to chemical barrier
5	Non-BSAL	Fertility, pH and ERD to chemical barrier
6	BSAL	-
7	BSAL	-
8	Non-BSAL	Fertility
9	Non-BSAL	ERD to chemical barrier
10	BSAL	-
11	Non-BSAL	pH
12	BSAL	-
13	Non-BSAL	Fertility and pH
14	Non-BSAL	pH and ECe
15	Non-BSAL	Fertility and pH
16	Non-BSAL	ECe and ERD to chemical barrier
17	Non-BSAL	ECe and ERD to chemical barrier
18	Non-BSAL	ECe and ERD to chemical barrier
19	Non-BSAL	Non-site criteria, the BSAL status is based on the dominant soil type and therefore the site fails
20	BSAL	-
21	Non-BSAL	Fertility

4 LAND AND SOIL CAPABILITY CLASS ASSESSMENT

4.1 Land and Soil Capability Methodology

The Land and Soil Capability Assessment Scheme – Second Approximation OEH (2012) aims to provide a reliable assessment of the potential of the land to support a range of sustainable land uses and land management practices.

LSC mapping has been prepared for the Area of Interest based on the results of the BSAL assessment (Sections 2 and 3) consistent with the methodology adopted by Soil Management Designs (2019) and in accordance with *The Land and Soil Capability Assessment Scheme – Second Approximation* (OEH, 2012).

4.1.1 Water erosion

Water erosion class was determined by slope (%) class figures using the Eastern and Central division as per OEH (2012) scheme criterion, refer to Table 4-1.

Table 4-1: Water Erosion Assessment

Slope % (Field Assessment)	Slope (LSC) Class
<1	1
1 to <3	2
3 to <10	3
10 to <20	4

4.1.2 Wind erosion

Factors used to assess wind erosion include surface soil texture, site exposure to prevailing winds, wind erosive power and average annual rainfall across the test site (OEH, 2012).

Soil Management Designs (2019) indicated that exposure to prevailing winds and wind erosive power is assumed to be moderate across all test sites due to a lack of consistent information for all test site positions. The long term mean annual rainfall at the nearby meteorological station of Narrabri West Post Office is 658.5 millimetres (mm) (Bureau of Meteorology [BOM], 2018).

The Soil Management Designs (2019) assessment conclusion has been adopted for the Area of Interest.

4.1.3 Soil structure decline

Poor soil structure limits plant growth through poor germination and root growth, low infiltration and impeding mechanical processes. The LSC classification assesses the nature of the surface soil using surface texture, degree of sodicity and degree of self-mulching (OEH, 2012).

The assessment of soil structure decline has been undertaken in accordance with Table 7 of OEH (2012) and assesses the field texture against a modifier (such as sodicity).

4.1.4 Soil acidification hazard

Soil Management Designs (2019) indicated that soil acidification is determined by firstly estimating buffering capacity. For the purpose of this report, buffering capacity was determined by surface soil texture as outlined in Table 4-2. Buffering capacity is then used to determine soil acidification hazard in Table 4-3.

Table 4-2: Soil Texture and Buffering Capacity

Surface Soil Texture	Buffering Capacity
Sands and sandy loams – no calcium carbonate	Very low
Sands and sandy loams – with calcium carbonate	Moderate
Fine sandy loams – no calcium carbonate	Low
Fine sandy loams – with calcium carbonate	Moderate
Loams and clay loams – no calcium carbonate	Moderate
Loams and clay loams – with calcium carbonate	High
Dark loams and clay loams	High
Clays – no calcium carbonate	High
Clays – with calcium carbonate	Very High
Clays – with high shrink–swell	Very High

Table 4-3: Soil pH and Buffering Capacity

Texture/ Buffering Capacity	pH (1:5 water) of soil surface				
	<4.7	4.7-5.5	5.5-6.7	6.7-8.0	>8.0
Very low	6	5	5	4	n/a
Low	5	5	4	3	n/a
Moderate	5	4	3	3	1
High	n/a	n/a	2	2	1
Very High	n/a	n/a	1	1	1

4.1.5 Salinity hazard

Assessment of salinity hazard within OEH (2012) is a simple initial evaluation. The methodology is based on Native Vegetation Regulation 2005 Environmental Outcomes Assessment Methodology (Department of Environment, Climate Change and Water, 2011) and requires three inputs; recharge potential, discharge potential and salt stores.

Review of the average annual rainfall of approximately 658.5 mm and average annual evaporation of approximately 1800 to 2000 mm (BOM, 2018) indicates low recharge potential. Discharge potential is based on annual average rainfall and average annual evapotranspiration of approximately 600 to 700 mm (BOM, 2018). This indicates minor to negligible discharge potential for the site. Recharge and discharge potential also relate to attributes such as landform position, vegetation cover, soil permeability, however no further guidance within OEH (2012) is given to assessing these attributes.

The study area according to the Salt Store Map of NSW (Figure 7 within OEH [2012]) is in a low-moderate salt store. Assessment using this mapping indicates a LSC Class of 3 across the site.

It is recommended that the Soil Management Designs (2019) thresholds for salt-sensitive crops and pastures outlined in Table 4-4 be included in place of the regional approach to salinity assessment presented in OEH (2012). This allows direct assessment of each soil type and the actual soil salinity. The Soil Management Designs (2019) assessment approach has been adopted for the Area of Interest.

Table 4-4: Soil Salinity Hazard

LSC Class	ECe dS/m
1	<1
2	1-2
3	2.1-4
4	4.1-8
5	8.1-12
6	12.1-16
7	16.1-30
8	>30

4.1.6 Waterlogging

Soil Management Designs (2019) indicates LSC waterlogging class was determined using site-specific information about depth to a layer with mottling and/or presence of a manganic layer (manganiferous nodules/segregations >20%), refer to Table 4-5. The Soil Management Designs (2019) assessment approach has been adopted for the Area of Interest.

Table 4-5: Depth to Waterlogging

LSC Class	Depth to Waterlogging (cm)
1	None
2	>=100
3	75-<100
4	50-<75
6	25-<50
7	<25

4.1.7 Shallow soils and rockiness

Soil Management Designs (2019) indicated rock outcrop presence was negligible. Therefore, the rating was based entirely on the following depths of soil to a layer with >90% rock, refer to Table 4-6. The Soil Management Designs (2019) assessment approach has been adopted for the Area of Interest.

Table 4-6: Soil Depth to Physical Barrier

LSC Class	Soil Depth (cm)
1	No rock encountered
2	>100
3	75-<100
4	50-<75
6	25-<50
7	<25

4.1.8 Mass movement

Soil Management Designs (2019) indicated soil pit sites within the Area of Interest which did not exhibit evidence of mass movement. An LSC class of 1 was therefore given for each site.

4.2 Land and Soil Capability Assessment

4.2.1 Initial assessment and review

Reviewing the methodology outlined in Section 4.1, each detailed site was initially assessed. Table 4-7 summarises this assessment.

Table 4-7: Initial LSC Assessment Matrix

Map ID	Hazards and LSC Score								
	Water Erosion	Wind Erosion	Structural Decline Class	Soil Acidification	Salinity	Water Logging	Shallow Soil	Mass Movement	LSC Class
1	2	3	1	5	1	1	1	1	**5**
2	2	2	3	3	1	1	1	1	**3**
3	2	2	3	3	1	2	1	1	**3**
4	2	2	3	3	1	2	1	1	**3**
5	3	3	3	5	1	1	3	1	**5**
6	3	3	3	5	2	2	1	1	**5**
7	2	3	3	5	2	2	1	1	**5**
8	1	3	3	5	3	4	1	1	**5**
9	3	2	1	2	2	1	1	1	**3**
10	3	2	3	3	1	2	1	1	**3**
11	2	2	3	3	2	2	1	1	**3**
12	2	2	1	2	1	2	1	1	**2**
13	3	2	3	3	2	2	1	1	**3**
14	3	2	1	2	1	1	1	1	**3**
15	3	3	3	4	2	2	2	1	**4**
16	3	2	3	2	1	1	1	1	**3**
17	3	2	1	2	1	1	1	1	**3**
18	3	2	1	2	1	1	1	1	**3**
19	2	2	1	-	2	2	1	1	**2**
20	3	2	1	3	1	4	1	1	**4**
21	3	4	1	5	1	1	1	1	**5**

1 – Orange highlighted cells indicate most limiting hazard.

The major limiting hazard impacting on most of the sites is soil acidification. Section 4.3 of the OEH (2012) outlines that soil acidity logic/decision tables tend to rank the soil acidity too severely and may require manual override, so it doesn't unrealistically affect the final LSC.

GTE propose a review of the sites 1, 5, 6, 7, 8, 15 and 21 as this hazard was considered an outlier. This includes reviewing the surface and subsurface soil textures and pH to a depth of approximately 0.30 mbgl.

Re-assessment of the soil acidity of these sites is below:

- Site 1 is a thin clayey sand horizon on clay loam sandy soils with alkaline pH. Reassessment of texture/buffering capacity is of surface soils is low with an increased pH for a revised hazard level of 3;
- Site 5 is a sandy loam horizon on sandy clay loam soils with alkaline pH.

  Reassessment of texture/buffering capacity of surface soils is low with an increased pH for a revised hazard level of 3;
- Site 6 is a thin sandy loam horizon on sandy clay loam soils with alkaline pH. Reassessment of texture/buffering capacity of surface soils is low with an increased pH for a revised hazard level of 3;
- Site 7 is a clayey sand horizon on sandy clay loam soils with alkaline pH.

  Reassessment of texture/buffering capacity of surface soils is low with an increased pH for a revised hazard level of 3;
- Site 8 is a loamy sand horizon on sandy loam soils with alkaline pH.

  Reassessment of texture/buffering capacity of surface soils is low with an increased pH for a revised hazard level of 4;
- Site 15 is a sandy loam horizon on sandy clay loam soils with alkaline pH.

  Reassessment of texture/buffering capacity of surface soils is low for a revised hazard level of 3; and
- Site 21 textures and pH are consistent throughout the soil profile. No re-assessment of the soil acidity levels is required.

All remaining site's soil acidity levels are considered suitable on review of the other hazards.

4.2.2 Final assessment

Table 4-8 summaries the final assessment and the results shown on Figure 7. This final assessment includes review of existing land and soil capability soils data (McKenzie et al, 2008) adjacent to the Area of Interest.

Table 4-8: Final LSC Assessment Matrix

Map ID	Hazards and LSC Score								
	Water Erosion	Wind Erosion	Structural Decline Class	Soil Acidification	Salinity	Water Logging	Shallow Soil	Mass Movement	LSC Class
1	2	3	1	3	1	1	1	1	**3**
2	2	2	3	3	1	1	1	1	**3**
3	2	2	3	3	1	2	1	1	**3**
4	2	2	3	3	1	2	1	1	**3**
5	3	3	3	3	1	1	3	1	**3**
6	3	3	3	3	2	2	1	1	**3**
7	2	3	3	3	2	2	1	1	**3**
8	1	3	3	3	3	4	1	1	**4**
9	3	2	1	2	2	1	1	1	**3**
10	3	2	3	3	1	2	1	1	**3**
11	2	2	3	3	2	2	1	1	**3**
12	2	2	1	2	1	2	1	1	**2**
13	3	2	3	3	2	2	1	1	**3**
14	3	2	1	2	1	1	1	1	**3**
15	3	3	3	4	2	2	2	1	**4**
16	3	2	3	2	1	1	1	1	**3**
17	3	2	1	2	1	1	1	1	**3**
18	3	2	1	2	1	1	1	1	**3**
19	2	2	1	-	2	2	1	1	**2**
20	3	2	1	3	1	4	1	1	**4**
21	3	4	1	5	1	1	1	1	**5**

1 – Orange highlighted cells indicate most limiting hazard.

Sites 12, 19 (LSC class 2) and 1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 13, 14, 16, 17 and 18 (LSC class 3) are capable of a wide variety of land uses, including cropping, grazing, horticulture, forestry and nature conservation (OEH, 2012).

Sites 8, 15 and 20 (LSC class 4) are considered 'moderate capability land'. They have moderate to high hazards for high-impact land uses such as cropping, high-intensity grazing and horticulture. These hazards may be managed by specialised management practices with a high level of knowledge, expertise, inputs, investment and technology (OEH, 2012).

Site 21 (LSC class 5) is considered to have limited agricultural potential because of topsoil with acidity and poor buffering capacity (OEH, 2012).

5 TOPSOIL RESOURCES AND MANAGEMENT

5.1 Topsoil Resources and Stripping Depth

Areas to be disturbed as a result of mining activities may require stripping of the topsoil (primary growth media) for reuse in the rehabilitation of these areas. Therefore, all detailed sites in the Area of Interest have been assessed with their suitability for stripping and reuse for rehabilitation purposes.

5.1.1 Soil stripping assessment

Soil resources in the Area of Interest has been assessed against stripping suitability criteria, Elliot and Veness, (1981). This methodology includes assessing topsoil with the nominated criteria. These are summarised in Table 5-1.

Table 5-1: Soil Stripping Assessment Criteria

Attribute	Criteria
Structure grade	>30% peds
Coherence	Coherent (wet and dry)
Mottling	Absent
Macrostructure	>10 cm
Force to disrupt peds	=<3 force
Texture	Finer than a fine sandy loam
Gravel and Sand Content	<60%
pH	4.5 to 8.4
Salt Content	<1.5 dS/m

Table 5-2 presents the soil types, limitations (Elliot and Veness, 1981) and topsoil stripping assessment with not suitable criterion results highlighted in orange. Soil types identified with one criterion assessed as not suitable for texture or force to disrupt peds is considered marginal. Soil types identified with greater than one criteria limitation is assessed as not suitable.

Assessment of soil types with one unsuitable criterion, generally force to disrupt peds and field texture may be considered marginal. These soil types and stripping depths may be ameliorated, as outlined in Table 5-2. Soil types with two criteria may be unsuitable for topsoil.

Further assessment has also included review against BSAL results and LSC classes for each site including associated hazards. This assessment is provided in Table 5-3 includes the topsoil stripping depth and recommended amelioration management.

Table 5-2: Soil type, Elliot and Veness, (1981) Limitations and Topsoil Stripping Depths and Suitability

Soil Type	Criteria									Initial Suitability Assessment
	Structure grade	Coherence	Mottling	Macro-structure	Force to disrupt peds[2]	Texture (Field)	Gravel and Sand Content (%)	pH	Salt Content	
1	>30% peds	Pass	Absent	<10cm	=<3 force	Not suitable	<60	4.5-8.4[3]	<1.5 dS/m	Marginal
2	>30% peds	Pass	Absent	<10cm	Not suitable	<FSL	<60	4.5-8.4[3]	<1.5 dS/m	Marginal
3	>30% peds	Pass	Absent	<10cm	Not suitable	<FSL	<60	4.5-8.4[3]	<1.5 dS/m	Marginal
4	>30% peds	Pass	Absent	<10cm	Not suitable	<FSL	<60	4.5-8.4[3]	<1.5 dS/m	Marginal
5	>30% peds	Pass	Absent	<10cm	=<3 force	Not suitable	<60	4.5-8.4[3]	<1.5 dS/m	Marginal
6	>30% peds	Pass	Absent	<10cm	=<3 force	Not suitable	<60	4.5-8.4[3]	<1.5 dS/m	Marginal
7	>30% peds	Pass	Absent	<10cm	=<3 force	Not suitable	<60	4.5-8.4[3]	<1.5 dS/m	Marginal
8	Not suitable	Pass	Absent	<10cm	=<3 force	Not suitable	<60	4.5-8.4[3]	<1.5 dS/m	Not suitable
9	>30% peds	Pass	Absent	<10cm	Not suitable	<FSL	<60	4.5-8.4[3]	<1.5 dS/m	Marginal
10	>30% peds	Pass	Absent	<10cm	=<3 force	<FSL	<60	4.5-8.4[3]	<1.5 dS/m	Suitable
11	>30% peds	Pass	Absent	<10cm	=<3 force	<FSL	<60	4.5-8.4[3]	<1.5 dS/m	Suitable
12	>30% peds	Pass	Absent	<10cm	=<3 force	<FSL	<60	4.5-8.4[3]	<1.5 dS/m	Suitable
13	>30% peds	Pass	Absent	<10cm	Not suitable	<FSL	<60	4.5-8.4[3]	<1.5 dS/m	Marginal
14	>30% peds	Pass	Absent	<10cm	=<3 force	<FSL	<60	4.5-8.4[3]	<1.5 dS/m	Suitable
15	>30% peds	Pass	Absent	<10cm	=<3 force	Not suitable	<60	4.5-8.4[3]	<1.5 dS/m	Marginal
16	>30% peds	Pass	Absent	<10cm	=<3 force	<FSL	<60	4.5-8.4[3]	<1.5 dS/m	Suitable
17	>30% peds	Pass	Absent	<10cm	=<3 force	<FSL	<60	4.5-8.4[3]	<1.5 dS/m	Suitable
18	>30% peds	Pass	Absent	<10cm	=<3 force	<FSL	<60	4.5-8.4[3]	<1.5 dS/m	Suitable
19	>30% peds	Pass	Absent	<10cm	=<3 force	<FSL	<60	4.5-8.4[3]	<1.5 dS/m	Suitable
20	>30% peds	Pass	Absent	<10cm	=<3 force	<FSL	<60	4.5-8.4[3]	<1.5 dS/m	Suitable
21	Not suitable	Pass	Absent	<10cm	=<3 force	Not suitable	<60	4.5-8.4[3]	<1.5 dS/m	Not suitable

Table 5-3: Map ID, Limitations, Topsoil Stripping Depths and Amelioration Management

Map Code	Map ID	BSAL Criteria Observed	LSC Hazard Observed[1]	Elliot and Veness, 1981 Limitations	Topsoil Stripping Depth (m)	Recommended Amelioration Management
GV-S	1	Moderately low fertility	Acidic topsoil horizon	Texture	0.0-0.10	Marginal - May improve slightly with input of soil conditioners such as lime or dolomite. Recommended for level plain application.
GV-I	2	-	Slight acidic topsoil horizon Surface structure	Force to disrupt peds	0.0-0.10	Marginal - pH may be detrimental to plant growth, however if plant growth is showing undesirable signs, lime or dolomite may be applied. Surface structure may be improved by reducing the time the stripped soil is exposed by planting native grasses and encouraging organic matter horizon.
GV-I	3	-	Slight acidic topsoil horizon Surface structure	Force to disrupt peds	0.0-0.10	Marginal - May improve slightly with input of soil conditioners such as lime or dolomite. Surface structure may be improved by reducing the time the stripped soil is exposed by planting native grasses and encouraging organic matter horizon.
GV-I	4	-	Slight acidic topsoil horizon Surface structure	Force to disrupt peds	0.0-0.10	Marginal - May improve slightly with input of soil conditioners such as lime or dolomite. Surface structure may be improved by reducing the time the stripped soil is exposed by planting native grasses and encouraging organic matter horizon.
GV-S	5	Moderately low fertility	Water / wind erosion Acidic topsoil horizon Surface structure	Texture	0.0-0.14	Marginal - Input of soil conditioners such as lime or dolomite will increase surface pH levels. Surface structure may be improved by reducing the time the stripped soil is exposed by planting native grasses and encouraging organic matter horizon. Recommended for level plain application.
GV-I	6	-	Water / wind erosion Acidic topsoil horizon Surface structure	Texture	0.0-0.05	Marginal - Input of soil conditioners such as lime or dolomite. Surface structure may be improved by reducing the time the stripped soil is exposed by planting native grasses and encouraging organic matter horizon. Recommended for level plain application.

Map Code	Map ID	BSAL Criteria Observed	LSC Hazard Observed[1]	Elliot and Veness, 1981 Limitations	Topsoil Stripping Depth (m)	Recommended Amelioration Management
GV-I	7	-	Wind erosion Acidic topsoil horizon Surface structure	Texture	0.0-0.10	Marginal - May improve slightly with input of soil conditioners such as lime or dolomite. Surface structure may be improved by reducing the time the stripped soil is exposed by planting native grasses and encouraging organic matter horizon. Recommended for level plain application.
N	8	Moderately low fertility	Water logging	Structure, Texture	0.0	Not recommended - Due to limitations presented with potential water logging, structure grade and texture. Soils may improve with input of soil conditioners such as lime, dolomite and/or organic material and fertilisers for level plain application or subsoil material supporting topsoils of 0.0-0.30 mbgl
GV-S/V	9	-	Water erosion	Force to disrupt peds	0.0-0.10	Marginal - Gypsum organic or polymers may be used to overcome dispersion attributes associated with sodic topsoil. Surface structure may be improved by reducing the time the stripped soil is exposed by planting native grasses and encouraging organic matter horizon. Recommended for level plain application.
GV-I	10	-	Water erosion	None	0.0-0.10	Suitable - Surface structure may be improved by reducing the time the stripped soil is exposed by planting native grasses and encouraging organic matter horizon. Recommended for level plain application.
GV-C	11	-	Slight acidic topsoil horizon Surface structure	None	0.0-0.40	Suitable - Input of soil conditioners such as lime or dolomite will increase surface pH levels. Surface structure may be improved by reducing the time the stripped soil is exposed by planting native grasses and encouraging organic matter horizon. Recommended for slope and level plain application.
GV-C	12	-	Minimal hazards	None	0.0-0.10	Suitable - Recommended for slope and level plain application.
GV-S	13	Moderately low fertility	Water erosion Slight acidic topsoil horizon Surface structure	Force to disrupt peds	0.0-0.15	Marginal - Input of soil conditioners such as lime or dolomite will increase surface pH levels. Surface structure may be improved by reducing the time the stripped soil is exposed by planting native grasses and encouraging organic matter horizon. Recommended for slope and level plain application.

Map Code	Map ID	BSAL Criteria Observed	LSC Hazard Observed[1]	Elliot and Veness, 1981 Limitations	Topsoil Stripping Depth (m)	Recommended Amelioration Management
GV-S/V	14	Salty below 0.05 mbgl	Water Erosion	None	0.0-0.05	Suitable - Care is to be taken when stripping due to increase in salinity attributes below 0.05 m. Surface structure may be improved by reducing the time the stripped soil is exposed by planting native grasses and encouraging organic matter horizon. Recommended for level plain application.
GV-S	15	Moderately low fertility	Acidic topsoil horizon	Texture	0.0-0.15	Marginal - pH may not consider detrimental to plant growth, however if plant growth is showing undesirable signs, lime or dolomite may be applied. Recommended for level plain application.
GV-S/V	16	-	Water erosion Surface structure	None	0.0-0.10	Suitable - Surface structure may be improved by reducing the time the stripped soil is exposed by planting native grasses and encouraging organic matter horizon.
GV-S/V	17	-	Water erosion	None	0.0-0.10	Suitable - Surface structure may be improved by reducing the time the stripped soil is exposed by planting native grasses and encouraging organic matter horizon.
GV-S/V	18	-	Water erosion	None	0.0-0.10	Suitable - Surface structure may be improved by reducing the time the stripped soil is exposed by planting native grasses and encouraging organic matter horizon.
GV-S/V	19	-	Minimal hazards	None	0.0-0.10	Suitable - Recommended for slope and level plain application.
GV-I	20	-	Water logging	None	0.0-0.10	Suitable - May improve slightly with input of soil conditioners such as lime, dolomite, organic material and fertilisers.
P	21	Moderately low fertility	Acidic topsoil horizon	Structure, Texture	0.0	Not recommended - Input of soil conditioners such as lime, dolomite, organic material and fertilisers may improve soils for level plain application or subsoil material supporting topsoils of 0.0-0.40 mbgl

1 – pH scale assessed using Bruce and Rayment (1982).

5.1.2 Topsoil resources volumes

Topsoil volumes are presented in Table 5-4 and are based on the six recommended depths across the Area of Interest, presented in Figure 8. These volumes are based on the nominated stripping depth provided in Table 5-3 and the expected surface disturbance area and provide an upper estimate of volumes that may be available. Individual sites should be reviewed in Table 5-3 to ensure an understanding of the limitations in the area. Further topsoil management of these is outlined within Section 5.2.

Table 5-4: Recommended Topsoil Stripping Depth and Resource Volumes

Topsoil Stripping Depth (mbgl)	Volume (cubic metres [m^3])
0.0-0.05	28,500
0.0-0.10	390,000
0.0-0.14	29,400
0.0-0.15	85,500
0.0-0.40	84,000
Upper Estimate Total	617,400

5.2 Topsoil Resource Management

Soil resource management has been outlined in Soil Management Designs (2019). It covers soil resource management measures in stripping, stockpile management, application of soil on rehabilitation landforms, remediation of potential soil contamination, review of the existing Rehabilitation Management Plan and remediation strategies for subsidence impacts.

Review of these topsoil resource managements strategies are considered suitable for the Area of Interest, soil types encountered and topsoil resource management. Where applicable, they are summarised in the sections below with additional strategies implemented.

5.2.1 General soil resource management

The objectives of soil resource management for the Area of Interest shall include:

- Identify and quantify potential topsoil resources for rehabilitation;
- Optimise the recovery of useable topsoil and subsoil during stripping operations;
- Manage topsoil and subsoil reserves so as not to degrade the resource when stockpiled;
- Establish effective soil amelioration procedures to maximise the availability of soil reserves for future rehabilitation works; and
- Consider the need to provide soil conditions that minimise the risk of soil loss via wind and water erosion during and after rehabilitation.

5.2.2 Soil stripping management

The following are recommended general management procedures for soil stripping activities. These also include handling measures to retain soil attributes for future rehabilitation reuse, which are presented below:

- Supervisors and competent operators should be familiar with the areas to be stripped based upon existing soils mapping and recommended topsoil and subsoil reuse and depth;
- Vegetation removal should occur prior to stripping which will reduce loss of stripped topsoil and mixing with unsuitable soils. Vegetation removed may be stockpiled and reused as whole limbs or mulch if handled is appropriate; and
- Inspections of the stripped areas should be undertaken to observe any unexpected changes in soils. Areas of land downgradient, low-lying areas or areas of observed runoff should have suitable erosion and sediment control measures in place such as sediment fence prior to construction commencing.

5.2.3 Soil stockpiling management

It is important to stockpile topsoil and any excavated subsoil materials separately and maintain records of the materials origin in order to keep topsoil and subsoil in its original state.

Topsoil and subsoil stockpiles should be in areas based on the following recommendations:

- Stockpile locations shall be placed on the perimeter of surface development areas and away from current drainage lines;
- Where possible, stockpile locations should be placed against existing vegetated areas to act as a buffer, or adjacent to any rise in landscape to provide protection from wind erosion;
- Adequate erosion and sediment control including but not limited to sediment fencing, shall be placed on the downslope area of stockpiles;
- Locations are to be designated off limits by machinery and vehicles; and
- Locations should be placed in areas where it may assist future rehabilitation reuse, i.e. reduce movement of materials where possible.

Stockpile design may consider the following management recommendations for the Area of Interest soil resources:

- Topsoil and subsoils should be kept separate to prevent mixing of soils;
- Topsoil and subsoil stockpiles should be retained at a height of no more than 2 m, with slopes no greater than 1:2 (vertical to horizontal) and a slightly roughened surface to minimise erosion;
- Surface of the stockpile is recommended to be flat;
- Where amendments such as lime, gypsum and fertiliser are needed to improve the condition of cut soil, they should be spread on the soil prior to scraping;
- Wherever practicable, soil should not be trafficked, deeply ripped or removed in wet conditions to avoid breakdown in soil structure;

- All topsoil and subsoil stockpiles should be seeded 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 (e.g. with a straw/vegetative mulch/cleared vegetation/geomesh) to improve stability;
- There should be no vehicle access on soil stockpiles, except when soil quality monitoring is required;
- If unacceptable weed generation is observed on soil stockpiles, a weed eradication program should be implemented;
- If a stockpile is scheduled to remain in place for more than 24 months, additional management measures may be considered where required such as:
    - Catch drains or runoff areas may be excavated along the surface edge, ideally plastic lined with plastic lined runoff sloped areas to minimise erosion of the batter edges;
    - Revegetation of the stockpiles with native or suitable grasses will minimise erosion and soil loss, minimise the establishment of weeds, assist in maintaining organic matter, nutrients and microbial activity and rejuvenate native vegetation through existing seedbank; and
- Inspection of the stockpiles (once completed) with scheduled ongoing maintenance either as required or recommended every three months.

5.2.4 Application of soil on rehabilitated landforms

The following management measure is recommended during the application of soils on rehabilitated landforms in the Area of Interest:

- Spread topsoil/subsoil profile thickness and quality is to be evaluated prior to sowing.

6 CONCLUSION

The following conclusions have been made:

- Six soil types were identified from previous BSAL assessment with an additional major subdominant soil type within the Area of Interest based upon recent fieldworks;
- BSAL assessment identified approximately 106 ha verified BSAL within the Area of Interest;
- The Area of Interest contains LSC classes of class 2, 3, 4 and 5; and
- Topsoil resources are shallow across most of the eastern portion of the Area of Interest with additional resources available in the western portion, if stripping is deemed required. Soil stripping, stockpiling, handling and amelioration management measures are recommended so that topsoil resources are suitable for rehabilitation reuse.

7 REFERENCES

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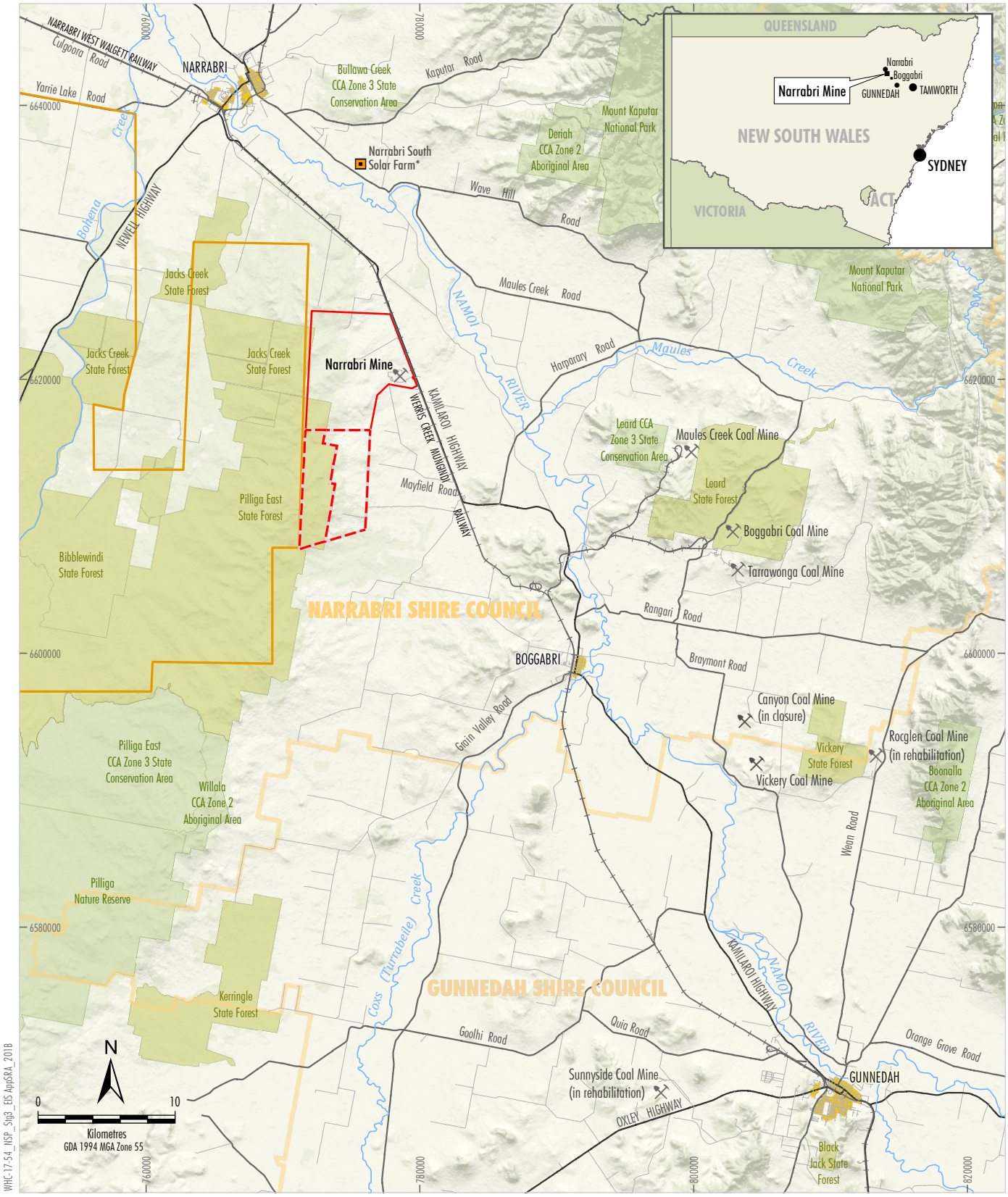
8 FIGURES



LEGEND

- Mine Site
- Mining Lease (ML 1609)
- Provisional Mining Lease Application Area
- Local Government Boundary
- State Forest
- State Conservation Area, Aboriginal Area
- Narrabri Gas Project (Santos NSW [Eastern] Pty Ltd)

Source: Geoscience Australia (2011); NSW Spatial Services (2019)

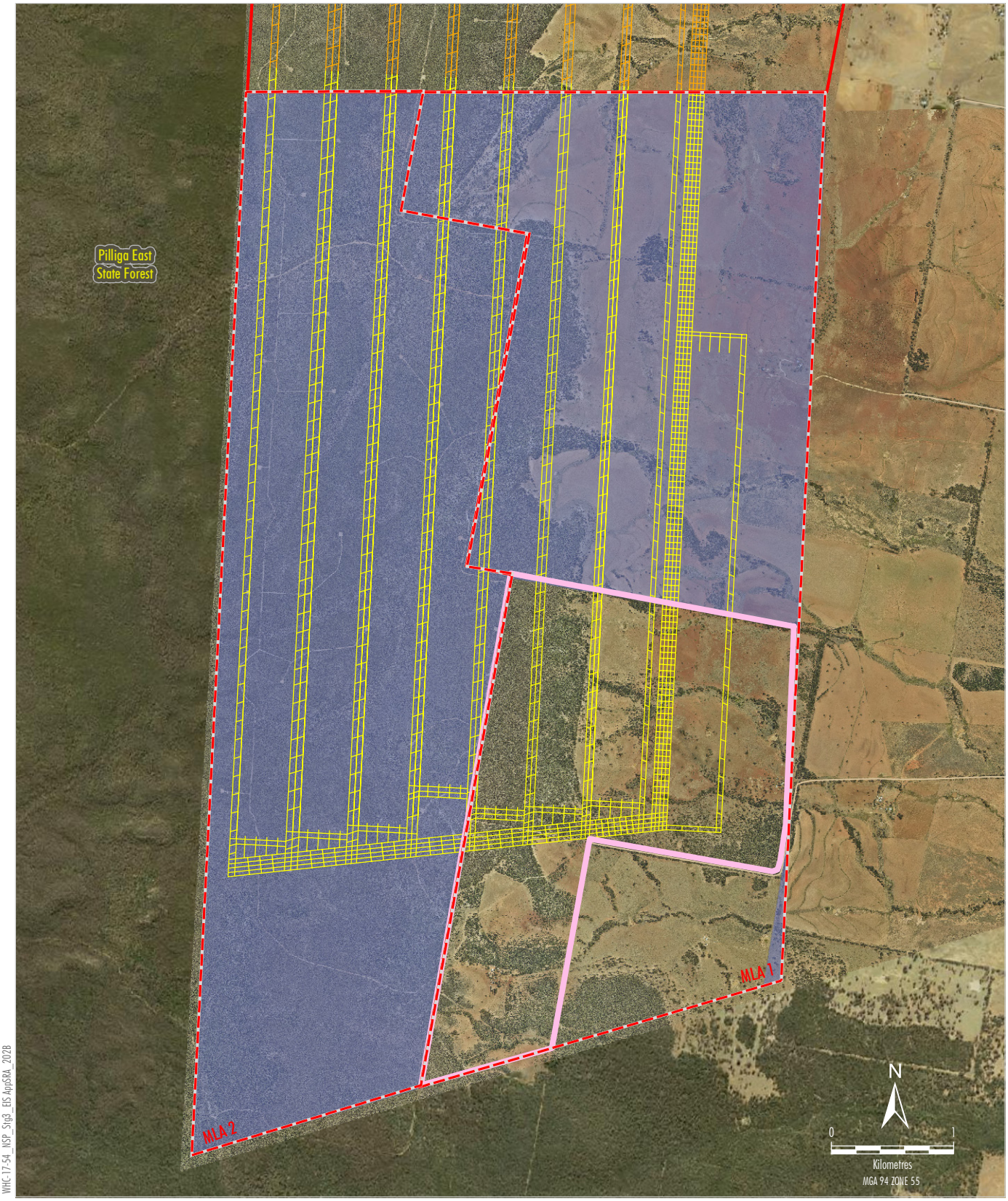
*Note: * Approved but not yet constructed*

WHITEHAVEN COAL

NARRABRI STAGE 3 PROJECT

Regional Location

Figure 1



WHC-17-54_NSP_Stg3_EIS AppSRA_202B

LEGEND

Mining Lease (ML 1609)

Provisional Mining Lease Application Area

Indicative Underground Mining Layout to be Extended for Project

Indicative Underground Project Mining Layout

Area of Interest

Soil Management Designs (2019) Survey Area

Source: NCOPL (2019); Soil Management Designs (2019)

WHITEHAVEN COAL

NARRABRI STAGE 3 PROJECT

Area of Interest

Figure 2

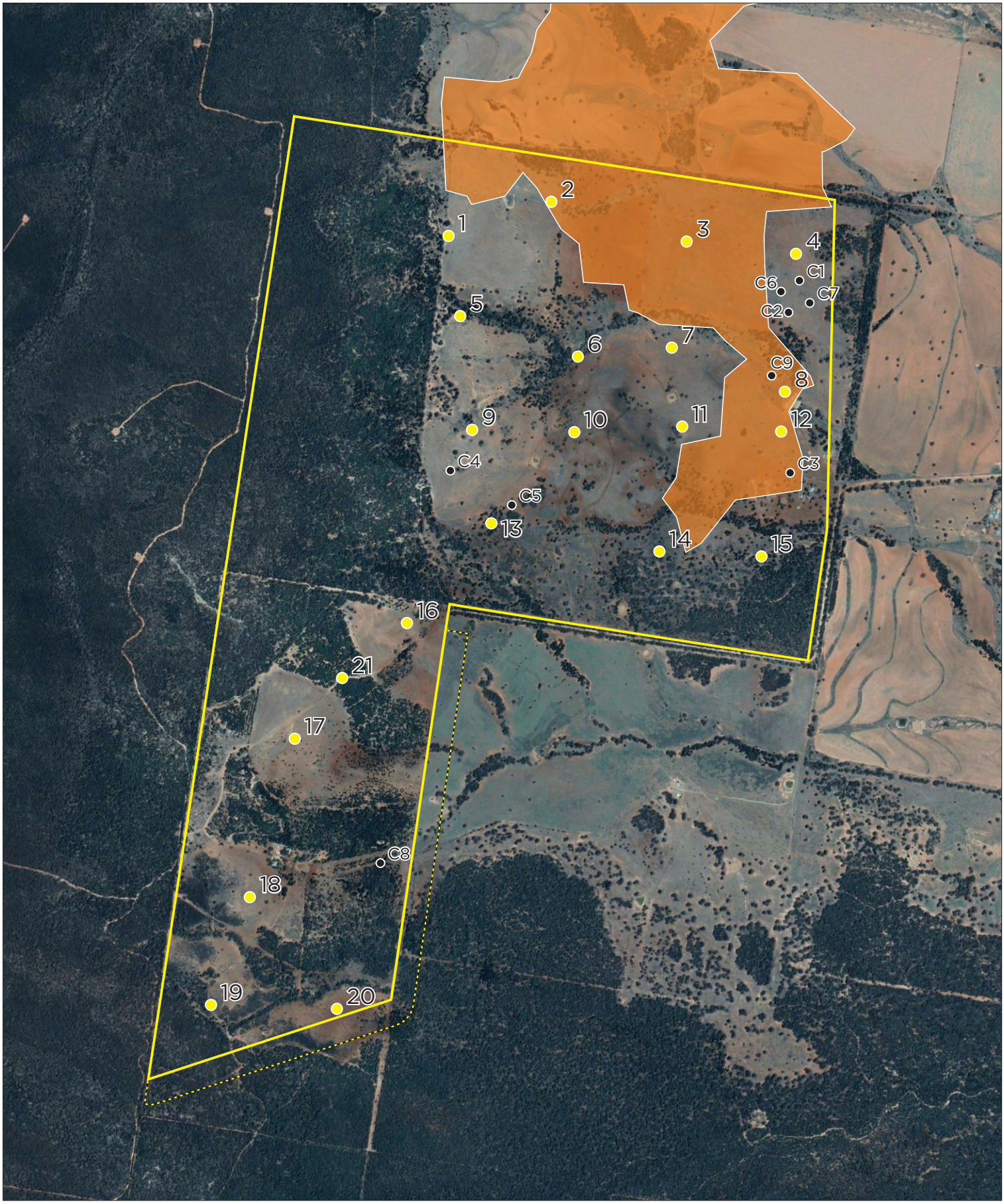


Figure 3: BSAL Regional Mapping

Version 3 02/11/2019

Land Resources Assessment
NARRABRI UNDERGROUND MINE
STAGE 3 EXTENSION PROJECT

Legend

- Area of Interest
- Buffer area
- Detailed site
- Check site
- BSAL Regional Mapping

0 1000

Metres

GTenvironmental

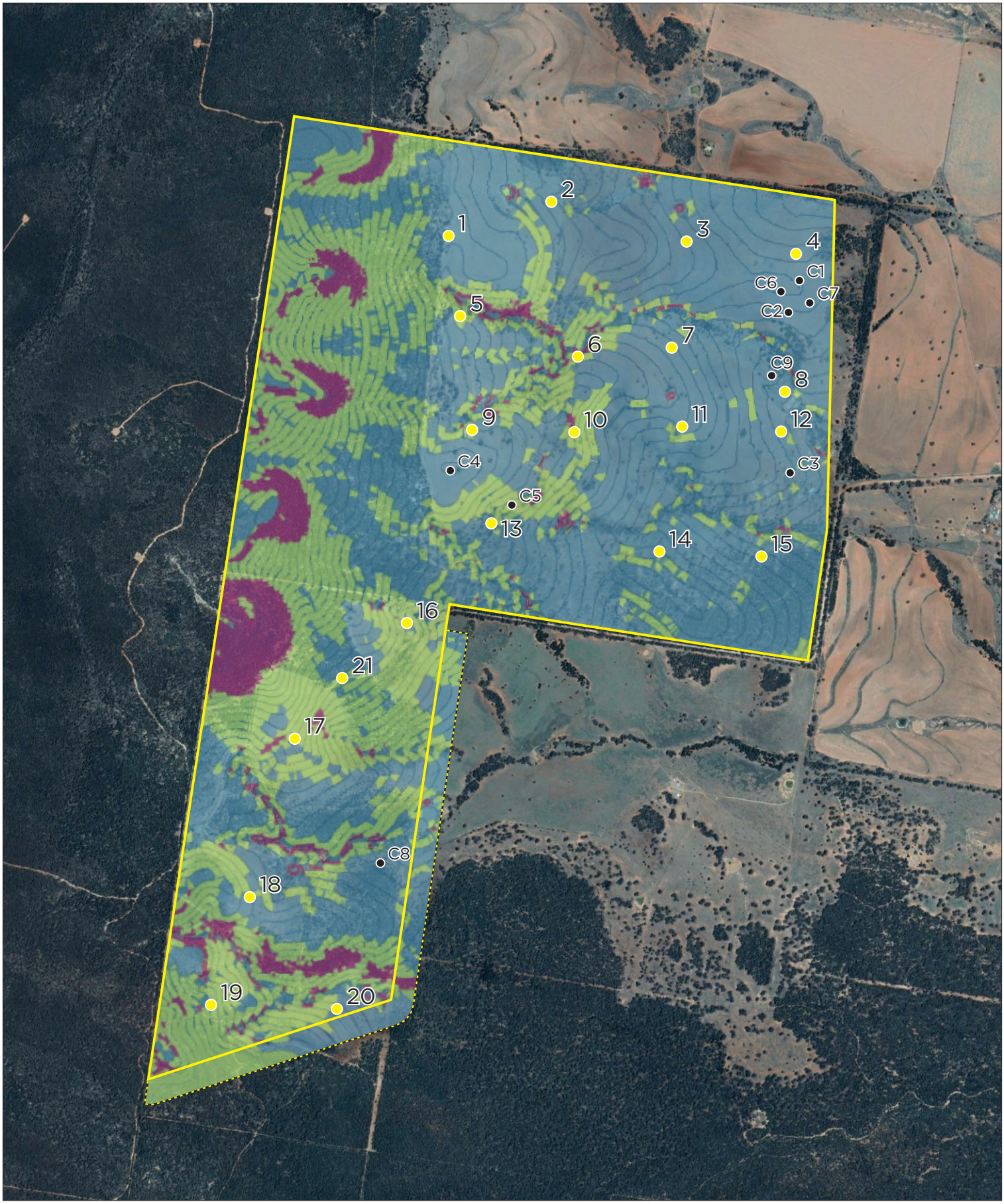


Figure 4: Lidar Slope Assessment

Version 3 02/11/2019

Land Resources Assessment
NARRABRI UNDERGROUND MINE
STAGE 3 EXTENSION PROJECT

0 1000
Metres

Legend

- Area of Interest
- Buffer area
- Detailed site
- Check site
- Slope over 10%
- Slope 2% to 10%
- Slope <2%

GTenvironmental

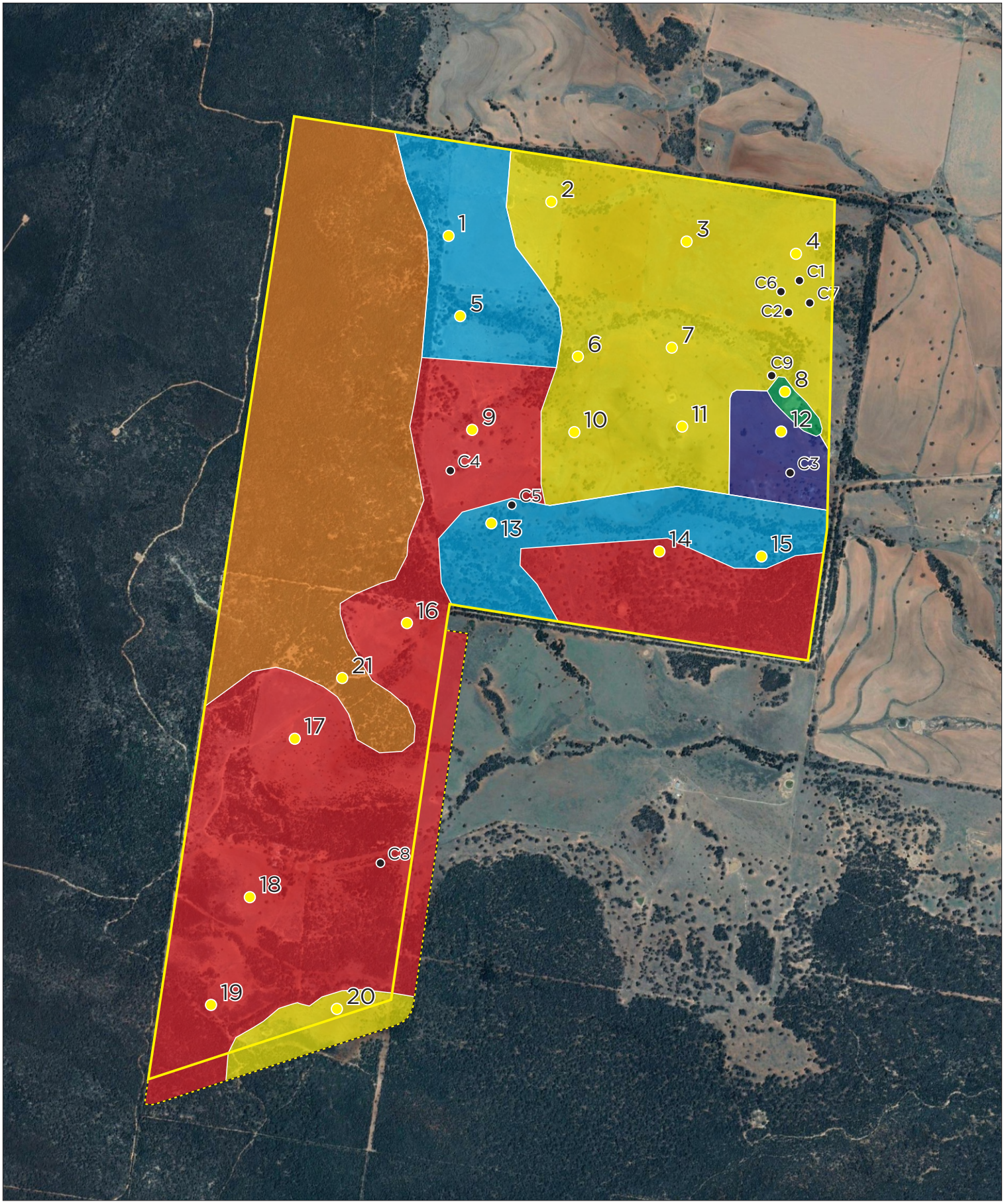


Figure 5: Soil Types and Observation Sites

Version 3 02/11/2019

Land Resources Assessment
NARRABRI UNDERGROUND MINE
STAGE 3 EXTENSION PROJECT

0 1000
Metres

N

Legend

- Area of Interest
- Buffer area
- Detailed site
- Check site
- GV-S (Dominant ASC: Sodosol)
- GV-I (Dominant ASC: Dermosol)
- GV-C (Dominant ASC: Vertosol)
- GV-S/V (Dominant ASC: Vertosol)
- P (Dominant ASC: Orthic Tenosol)
- N (Dominant ASC: Sodosol)

GTenvironmental

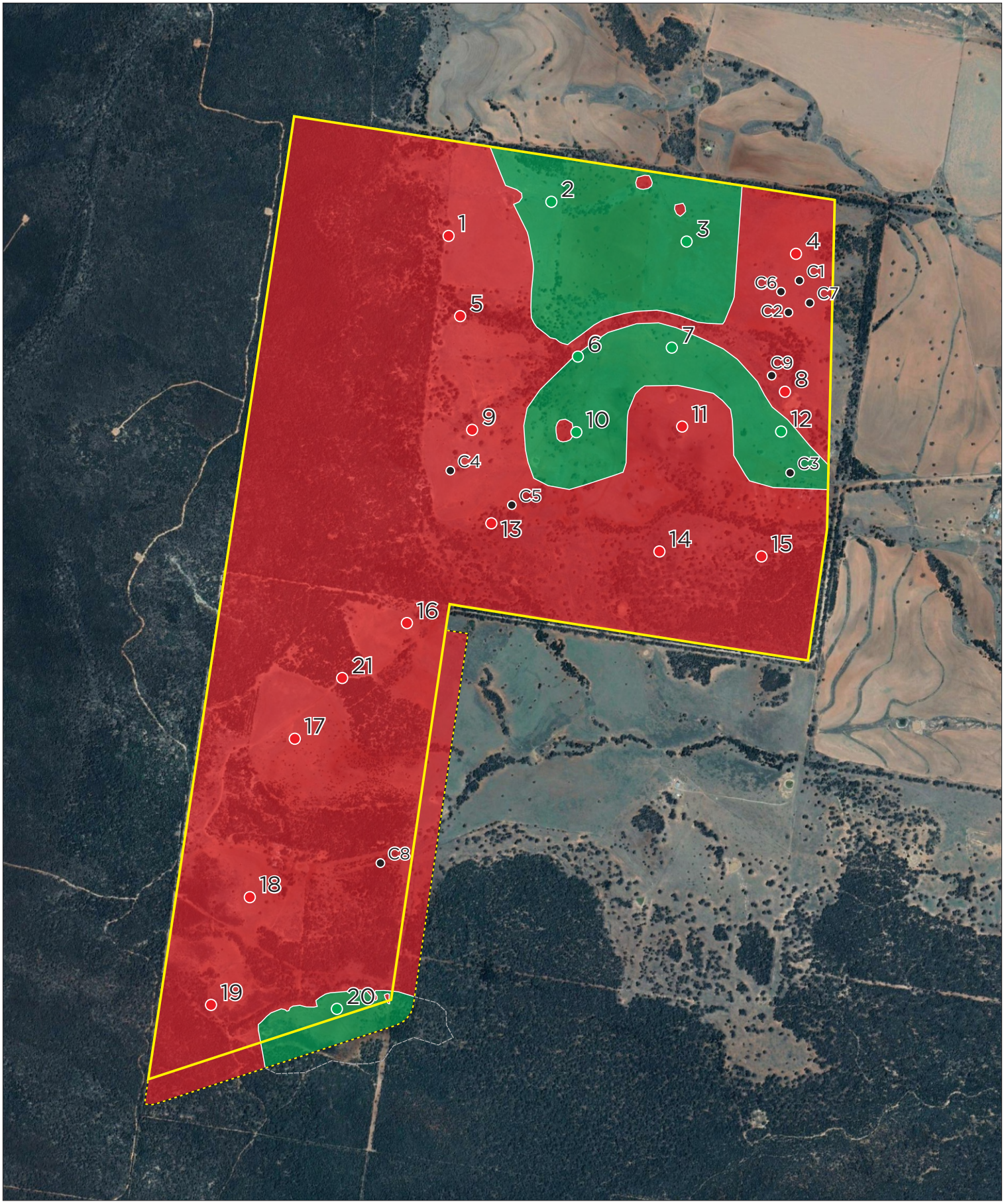


Figure 6: BSAL Verification

Version 3 02/11/2019

Land Resources Assessment
NARRABRI UNDERGROUND MINE
STAGE 3 EXTENSION PROJECT

0 1000
Metres

Legend

- Area of Interest
- Buffer area
- Verified BSAL
- Verified Non-BSAL
- Estimated boundary of BSAL soil map unit
- Detailed site (Verified BSAL)
- Detailed site (Verified Non-BSAL)
- Check site

GTenvironmental

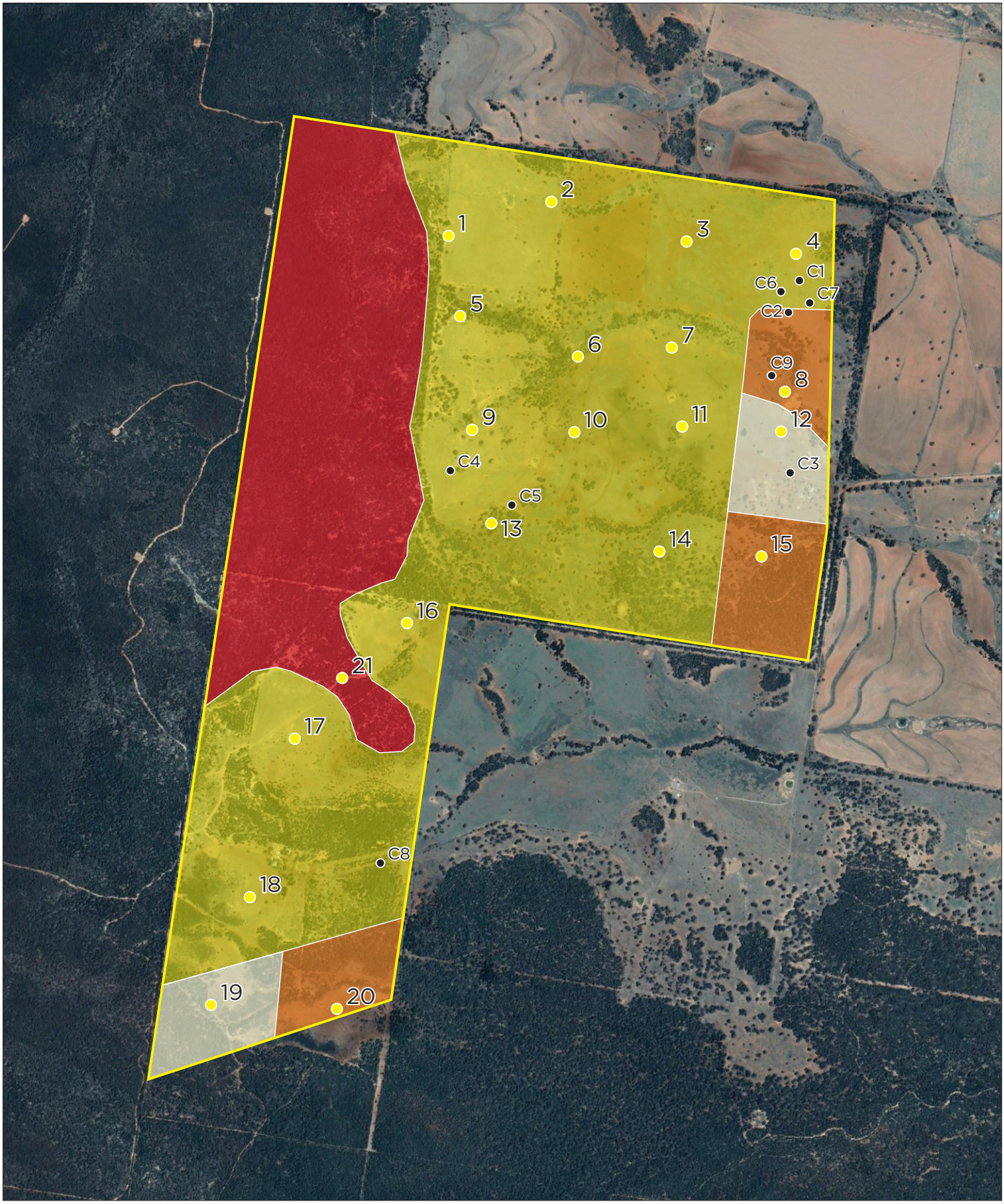


Figure 7: Land and Soil Capability

Version 3 02/11/2019

Land Resources Assessment
NARRABRI UNDERGROUND MINE
STAGE 3 EXTENSION PROJECT

0 1000
Metres

Legend

- Area of Interest
- Detailed site
- Check site
- Class 2
- Class 3
- Class 4
- Class 5

GTenvironmental

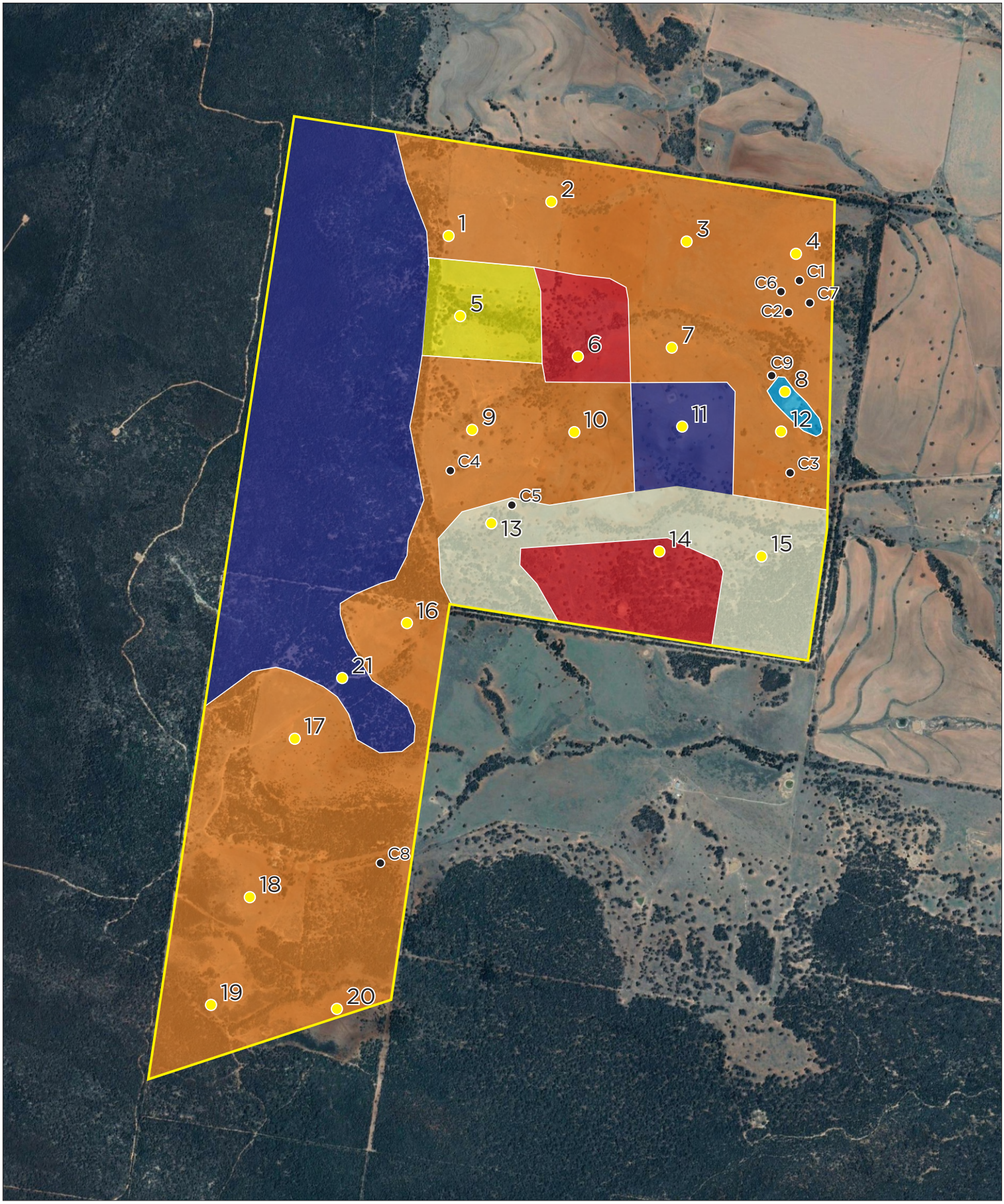


Figure 8: Topsoil Stripping Depths

Version 3 02/11/2019

Land Resources Assessment
NARRABRI UNDERGROUND MINE
STAGE 3 EXTENSION PROJECT

0 1000
Metres

N

Legend

- Area of Interest
- Detailed site
- Check site
- 0.05 metres
- 0.10 metres
- 0.14 metres
- 0.15 metres
- 0.30 metres
- 0.40 metres

GTenvironmental

APPENDICES

Appendix A
BSAL Assessment Table

Legend	
	Criteria Fail
	Criteria Marginal
	BSAL Verifed

BSAL Assessment Table

Site	Map Code	Slope (%)	Rock outcrop	Surface Rock		Gilgai	Australian Soil Classification			Fertility Status	Physical Barrier	Soil Drainage		Chemical barier. Sample depths are either as per horizon sampled or indicative of horizon sampled														Contiguous Area	BSAL Verified
														pH 1:5 Water <5.0 or >8.9.					Ece >4dS/m					ESP>15						
		>10%	≥30%	>20% of area	Rock fragments >60 mm dia.	>50% of >500mm deep	Great Group	Suborder	Order		Effective rooting depth <0.75 m	Depth to >10% mottles	Depth to water-logged layer	0.00-0.05	0.05-0.15	0.15-0.30	0.30-0.60	0.60-0.75	0.00-0.05	0.05-0.15	0.15-0.30	0.30-0.60	0.60-0.75	0.00-0.05	0.05-0.15	0.15-0.30	0.30-0.60	0.60-0.75	<20 Ha assessed as viable / BSAL status of dominant and subdominant sites in map unit	
1	GV-S	2	Nil	1	>60	0	Subnatric	Brown	Sodosol	Moderately low	1.00+	<1	Nil	6.23		7.91	9.51	9.38	0.76		0.52	2.06	5.61	1.57		6.15	12.07	15.48	No	No
2	GV-I	1	Nil	<1	>60	0	Eutrophic	Brown	Dermosol	Moderately high	1.00+	Nil	Nil	7.34	7.31	7.29	7.69	7.74	0.61	0.33	0.22	0.45	0.41	0.40	0.57	0.64	0.64	0.69	Yes	Yes
3	GV-I	3	Nil	<1	>60	0	Eutrophic	Red	Dermosol	Moderately high	1.05+	<4	Nil	6.34		7.14	7.5	8.02	0.78		0.32	0.29	0.34	0.46		0.99	1.53	2.16	Yes	Yes
4	GV-I	3	Nil	2	>60	0	Eutrophic	Red	Dermosol	Moderately high	1.10+	<4	Nil	6.29		8.14	8.93	8.81	0.83		1.57	9.91	12.75	0.96		10.87	14.63	16.66		No
5	GV-S	4	Nil	5	<10	0	Eutrophic	Brown	Sodosol	Moderately low	0.75-0.77	Nil	Nil	5.72	7.22	8.05	8.74	9.06	0.77	2.26	2.16	3.23	4.94	1.48	9.67	8.16	10.51	12.81		No
6	GV-I	8	Nil	10	>60	0	Eutrophic	Red	Dermosol	Moderately high	1.00+	Nil	Nil	6.55	6.89	7.08	7.24	7.61	1.07	0.25	0.25	0.26	0.33	0.54	0.63	0.40	0.79	2.66	Yes	Yes
7	GV-I	3	Nil	10	>60	0	Eutrophic	Red	Chromosol	Moderately high	1.00+	<5	Nil	6.5	7.64	8.39	8.42	8.46	1.34	0.59	0.96	0.75	0.85	0.25	0.15	0.67	0.64	0.71	Yes	Yes
8	N	1	Nil	0	Nil	0	-	Stratic	Rudosol	Moderately low	1.00+	Nil	Nil	6.39	6.83	7.21	7.24	7.32	2.27	0.18	0.37	0.31	0.28	0.61	0.38	0.43	0.44	0.39		No
9	GV-S/V	3	Nil	<1	20-40	0	Epipedal	Brown	Vertosol	Moderately high	1.00+	Nil	Nil	6.07		6.93	7.62	5.6	1.42		1.63	2.55	3.43	6.36		13.49	18.07	22.23		No
10	GV-I	10	Nil	10	>60	0	Eutrophic	Red	Dermosol	Moderately high	1.10+	<5	Nil	6.69	7.22	7.58	7.46	7.37	0.38	0.29	0.35	0.31	0.29	0.46	0.26	0.27	0.30	0.35	Yes	Yes
11	GV-I	2	Nil	<2	>60	0	Eutrophic	Red	Dermosol	Moderately high	1.20+	<5	Nil	5.85		8.68	9.09	9.21	1.61		1.20	1.51	2.02	1.03		0.91	2.66	4.65		No
12	GV-C	3	Nil	10	>60	0	Epipedal	Brown	Vertosol	Moderately high	1.00+	<5	Nil	7.32		7.57	8.04	8.43	0.35		0.46	1.29	3.08	0.84		2.61	3.78	5.46	Single site, adjecent BSAL verified sites	Yes
13	GV-S	4	Nil	<1	20-60	0	Subnatric	Red	Sodosol	Moderately low	1.00+	<1	Nil	5.92	6.98	8.57	8.99	9.07	1.35	0.52	1.62	3.44	3.64	1.47	6.00	10.33	10.14	11.12		No
14	GV-S/V	3	Nil	<20	30-60	0	Epipedal	Red	Vertosol	Moderately high	1.20+	Nil	Nil	6.59	8.54	8.74	8.9	8.95	0.36	4.95	6.70	6.65	6.71	2.09	10.90	10.40	8.92	10.10		No
15	GV-S	3	Nil	<2	2-6	0	Hypocalcic	Brown	Sodosol	Moderately low	1.2	<2	Nil	7.45	8.54	8.96	9.07	6.19	1.40	1.08	2.67	3.83	0.97	2.09	12.03	15.08	15.47	3.91		No
16	GV-S/V	7	Nil	1	30->60	0	Epipedal	Brown	Vertosol	Moderately high	1.00+	Nil	Nil	6.1	7.31	7.49	5.64	5.1	0.90	0.68	2.56	4.18	4.04	3.77	7.90	15.78	20.70	25.45		No
17	GV-S/V	5	Nil	1	10-30	0	Epipedal	Brown	Vertosol	Moderately high	1.40+	Nil	Nil	6.82		8.86	8.54	7.8	0.80		2.63	6.99	8.25	2.08		9.47	16.25	24.35		No
18	GV-S/V	4	Nil	2	>60	0	Epipedal	Brown	Vertosol	Moderately high	1.00+	Nil	Nil	6.64		7.89	8.89	8.73	0.38		1.39	6.19	9.31	2.70		9.50	12.46	18.34		No
19	GV-S/V	2	Nil	1	>60	0	Epipedal	Brown	Vertosol	Moderately high	0.75	5	Nil	5.42		5.65	6.16	5.22	1.62		0.61	1.54	1.91	2.78		6.69	8.18	9.57	Subdominant site in map unit, majority of dominant sites fail, therefore the map unit and site 20 fails	No
20	GV-I	5	Nil	<10	>60	0	Hypocalcic	Brown	Dermosol	Moderately high	1.10+	Nil	Nil	6.1		8.19	8.85	8.79	5.44		0.61	1.40	1.95	0.72		4.29	3.10	8.23	Single site / map unit. Extends beyond project site	Yes
21	P	5	Nil	0	Nil	0	-	Stratic	Rudosol	Moderately low	1.20+	Nil	Nil	5.8		5.46	5.27	5.8	0.36		0.40	0.25	0.09	0.52		0.99	1.76	0.45		No

Appendix B
Detailed site descriptions

SITE 1

Map Unit / Map Code:	Location (GDA94 ZONE 55):	Aust. Soil Class.:	Site Survey Type:	Survey Date:
GV-S	774471 mE 6611789 mN	Subnatic Brown Sodosol	Test Pit	August 2019

Land use Landform Pattern, Element, Slope	Vegetation	Microrelief Disturbance Erosion	Surface condition, surface rock	Soil Profile Description									
				Horizon Depth (m), Boundary	Field Texture	Structure, Strength	Inclusions Segregations	Colour, Mottle, Bleaching	Moisture, Drainage	Roots	Depth (m) / Field pH. Lab Sample, pH level and BSAL Assessment	Sample (m)	Observations
Grazing, Gently undulating plain, Upper slope 1% uphill / 2% downhill	Grass with adjacent tall woodlands (<100m away)	Nil microrelief, BSAL Pass Extensively disturbed Nil Erosion	Hard setting, 1% coverage of rock 60mm+ No rock outcrops BSAL Pass	A1 0.00-0.12 Abrupt	Clayey sand	Moderate, weak	Nil inclusions / segregations	10YR2/2 Very dark brown Nil mottles / bleach	Dry, well drained	Common	0.05 / 6.5 0.00-0.10 6.23 – BSAL Pass	0.00-0.10 0.15-0.35 0.40-0.60 0.60-0.75 0.80-1.00	Nil additional observations
				B21 0.12-0.38 Abrupt	Clay loam sandy	Moderate, weak	Nil inclusions / segregations	10YR2/2 Very dark brown Nil mottles / bleach	Dry, well drained	Few	0.30 / 7.5 0.15-0.35 7.91 – BSAL Pass		
				B22 0.38-0.78 Abrupt	Clay loam, sandy	Moderate, strong	<1% coarse fragments <1mm 10-20% calcium carbonate	10YR3/3 Dark brown Nil mottles / bleach BSAL Pass	Dry, moderately well drained BSAL Pass	Few	0.60 / 8.5 0.40-0.60 9.51 – Not BSAL ERD Not BSAL 0.60-0.75 9.38 – Not BSAL		
				B23 0.78-1.00 End of Borehole (EOBH)	Sandy clay loam	Moderate, strong	<2% calcium carbonate	10YR3/2 Very dark greyish brown Mottle: <1% 2.5YR3/6 Dark red Nil bleach	Dry, moderately well drained	Yes, very few very fine	0.90 / 7.5		

SITE 1 Plates

SITE 2

Map Unit / Map Code:	Location (GDA94 ZONE 55):	Aust. Soil Class.:	Site Survey Type:	Survey Date:
GV-I	774922 mE 6611911 mN	Eutrophic Brown Dermosol	Test Pit	August 2019

Land use Landform Pattern, Element, Slope	Vegetation	Microrelief Disturbance Erosion	Surface condition, surface rock	Soil Profile Description									
				Horizon Depth (m), Boundary	Field Texture	Structure, Strength	Inclusions Segregations	Colour, Mottle, Bleaching	Moisture, Drainage	Roots	Depth (m) / Field pH. Lab Sample, pH level and BSAL Assessment	Sample (m)	Observations
Grazing, Gently undulating plain, wide depression 1% / 1%	Grass, with tall trees in depression	Nil microrelief BSAL Pass Extensively disturbed Nil Erosion	Firm, cracking <2mm, rocks 60mm+ <1% No rock outcrops BSAL Pass	A1 0.00-0.10 Abrupt	Silty loam	Moderate, very firm	Nil inclusions / segregations	7.5YR3/2 Dark brown Nil mottles / bleach	Dry, moderately well drained	Common	0.05 / 6.5 0.00-0.05 7.34 – BSAL Pass 0.05-0.15 7.31– BSAL Pass	0.00-0.10 0.10-0.30 0.30-0.50 0.50-0.60 0.60-0.75 0.75-1.00	Nil additional observations
				B2 0.10-0.50 Abrupt	Silty clay loam	Moderate, subangular blocky, very firm	1% coarse fragments, 5-20mm	7.5YR5/2 Brown Nil mottles / bleach	Dry, moderately well drained	Few	0.30 / 7.0 0.10-0.30 7.29 – BSAL Pass		
				2D 0.50-1.00 EOBH ERD BSAL Pass	Sandy loam	Moderate, subangular blocky, very firm	1% rocks 100-200mm 5% coarse fragments 206mm	7.5YR3/2 Dark brown Nil mottles / bleach BSAL Pass	Dry, moderately well drained BSAL Pass	Very few to Nil roots	0.60 / 7.0 0.90 / 7.0 0.30-0.60 7.69 – BSAL Pass 0.60-0.75 7.74 – BSAL Pass		

SITE 2 Plates

SITE 3

Map Unit / Map Code:	Location (GDA94 ZONE 55):	Aust. Soil Class.:	Site Survey Type:	Survey Date:
GV-I	775506 mE 6611731 mN	Eutrophic Red Dermosol	Test Pit	August 2019

Land use Landform Pattern, Element, Slope	Vegetation	Microrelief Disturbance Erosion	Surface condition, surface rock	Soil Profile Description									
				Horizon Depth (m), Boundary	Field Texture	Structure, Strength	Inclusions Segregations	Colour, Mottle, Bleaching	Moisture, Drainage	Roots	Depth (m) / Field pH. Lab Sample, pH level and BSAL Assessment	Sample (m)	Observations
Grazing, Gently undulating plain, lower slope 1% / 3 %	Grass, 50% coverage	Nil microrelief BSAL Pass Extensively disturbed Nil Erosion	Self-mulching, minor cracks 6-8mm, <1% occasional rock 60-100mm, no coarse fragments No rock outcrops BSAL Pass	A1 0.00-0.10 Abrupt	Silty clay loam	Moderate, subangular blocky, peds 10-50mm, very firm	<1% coarse fragments <2mm	5YR3/4 Dark reddish brown Nil mottles / bleach	Dry, moderately well drained	Common	0.05 / 6.0 0.00-0.05 6.34 – BSAL Pass	0.00-0.10 0.15-0.30 0.30-0.60 0.60-0.75 0.85-1.00	Nil additional observations
				B21 0.10-0.50 Abrupt	Light clay	Moderate, subangular blocky, peds 30+mm, very firm	<1% coarse fragments <2mm	5YR3/4 Dark reddish brown Nil mottles / bleach	Dry, moderately well drained	Few	0.30 / 6.5 0.15-0.30 7.14 – BSAL Pass 0.30-0.60 7.5 – BSAL Pass		
				B22 0.50-0.85 Abrupt	Medium clay	Moderate, strong	<1% coarse fragments 2-6mm	5YR3/4 Dark reddish brown Nil mottles / bleach BSAL Pass	Dry, moderately well drained BSAL Pass	Few, very fine	0.60 / 7.5 0.60-0.75 8.02 – BSAL Pass		
				B23 0.85-1.05 EOBH ERD BSAL Pass	Medium clay	Moderate, strong	5% coarse fragments <1mm 2% calcium carbonate	5YR4/6 Yellowish red Mottles: 2% red 2% red brown Nil bleach	Dry, imperfectly drained	Nil roots	0.90 / 8.0		

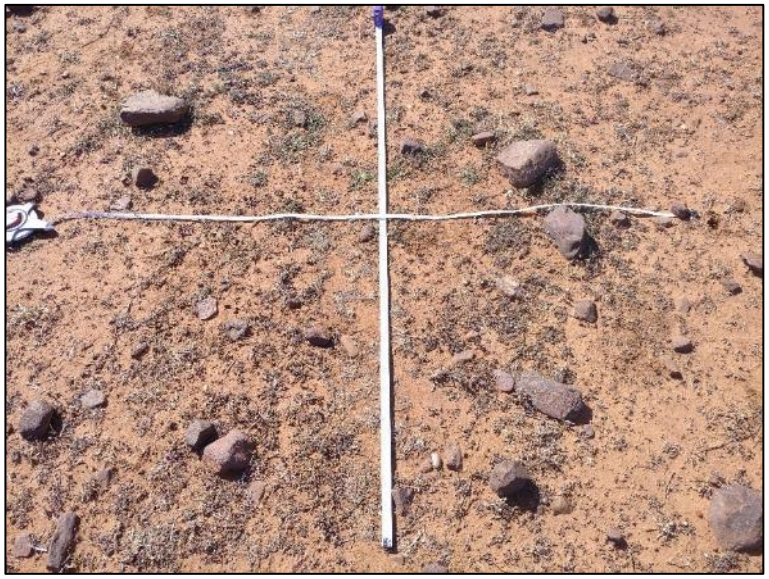
SITE 3 Plates

SITE 4

Map Unit / Map Code:	**Location (GDA94 ZONE 55):**	**Aust. Soil Class.:**	**Site Survey Type:**	**Survey Date:**
GV-I	775506 mE 6611731 mN	Eutrophic Red Dermosol	Test Pit	August 2019

Land use Landform Pattern, Element, Slope	**Vegetation**	**Microrelief Disturbance Erosion**	**Surface condition, surface rock**	**Soil Profile Description**									
				Horizon Depth (m), Boundary	**Field Texture**	**Structure, Strength**	**Inclusions Segregations**	**Colour, Mottle, Bleaching**	**Moisture, Drainage**	**Roots**	**Depth (m) / Field pH. Lab Sample, pH level and BSAL Assessment**	**Sample (m)**	**Observations**
Grazing, Gently undulating plain, mid slope 1% / 3 %	Grass, 50% coverage	Nil microrelief BSAL Pass Extensively disturbed Nil Erosion	Firm, cracking <2mm, occasional rocks 2% 60mm+ No coarse fragments No rock outcrops BSAL Pass	A1 0.00-0.10 Abrupt	Silty clay loam	Moderate, subangular blocky, peds 10-50mm, very firm	<1% coarse fragments <2mm	7.5YR2.5/3 Very dark brown Very dark brown Nil mottles / bleach	Dry, moderately well drained	Common, medium	0.05 / 6.0 0.00-0.05 6.29 – BSAL Pass	0.00-0.10 0.15-0.30 0.35-0.60 0.60-0.75 0.94-1.10	Nil additional observations
				B21 0.10-0.33 Abrupt	Light clay	Moderate, subangular blocky, peds 30+mm, very firm	<1% coarse fragments <2mm 1% Rocks 10-20mm	5YR4/4 Reddish brown Nil mottles / bleach	Dry, moderately well drained	Few	0.30 / 7.5 0.15-0.30 8.14 – BSAL Pass		
				B22 0.33-0.94 Abrupt	Light clay	Moderate, strong	<2% coarse fragments <5mm	5YR4/6 Yellowish red Nil mottles / bleach BSAL Pass	Dry, moderately well drained BSAL Pass	Very fine	0.60 / 8.0 0.30-0.60 8.93– ERD Not BSAL		
				B23 0.94-1.10 EOBH ERD Not BSAL	Light clay	Moderate, strong	5% coarse fragments <1mm 2% calcium carbonate	7.5YR4/4 Reddish brown Brown Mottles: 2% red 2% red brown Nil bleach	Dry, imperfectly drained	Nil roots	0.90 / 7.5		

SITE 4 Plates



SITE 5

Map Unit / Map Code/ Map Code	Location (GDA94 ZONE 55):	Aust. Soil Class.:	Site Survey Type:	Survey Date:
GV-S	774511 mE 6611439 mN	Eutrophoic Brown Sodosol	Test Pit	August 2019

Land use Landform Pattern, Element, Slope	Vegetation	Microrelief Disturbance Erosion	Surface condition, surface rock	Soil Profile Description									
				Horizon Depth (m), Boundary	Field Texture	Structure, Strength	Inclusions Segregations	Colour, Mottle, Bleaching	Moisture, Drainage	Roots	Depth (m) / Field pH. Lab Sample, pH level and BSAL Assessment	Sample (m)	Observations
Grazing, Lower slope, depression 3% / 4%	Grass	Nil microrelief BSAL Pass Extensively disturbed Nil Erosion	Hard setting, 2-5% coarse fragments <10mm No rock outcrops BSAL Pass	A1 0.00-0.14 Abrupt	Sandy loam	Moderate, firm	10% coarse fragments <2mm	7.5YR2.5/2 Very dark brown Nil mottles / bleach	Dry, well drained	Common	0.05 / 5.0 0.00-0.05 5.72 – BSAL Pass 0.05-0.15 7.22 – BSAL Pass	0.00-0.05 0.05-0.14 0.15-0.30 0.40-0.60 0.60-0.75	Nil additional observations
				B21 0.14-0.36 Abrupt	Sandy clay loam	Moderate, strong	10% coarse fragments <2mm	7.5YR3/2 Dark brown Nil mottles / bleach	Dry, well drained	Common	0.30 / 6.0 0.15-0.30 8.05 – BSAL Pass		
				B22 0.36-0.60 Abrupt	Clay loam	Moderate, very strong	<5% <5mm coarse fragments	7.5YR4/2 Brown Nil mottles / bleach	Dry, well drained	Few	0.60 / 6.5 0.30-0.60 8.74 – BSAL Pass		
				B23 0.60-0.75 Abrupt	Light clay	Moderate, subangular blocky, strong	<5% <5mm coarse fragments	10YR5/3 Brown Nil mottles / bleach BSAL Pass	Dry, well drained BSAL Pass	Nil roots	0.90 / 7.5 0.60-0.75 9.06 – ERD Not BSAL		
				R 0.75-0.77+ EOBH ERD Not BSAL	Bedrock	-	-	-	-	-	-		

SITE 5 Plates

SITE 6

Map Unit / Map Code:	Location (GDA94 ZONE 55):	Aust. Soil Class.:	Site Survey Type:	Survey Date:
GV-I	775029 mE 6611233 mN	Eutrophic Red Dermosol	Test Pit	August 2019

Land use Landform Pattern, Element, Slope	Vegetation	Microrelief Disturbance Erosion	Surface condition, surface rock	Soil Profile Description									
				Horizon Depth (m), Boundary	Field Texture	Structure, Strength	Inclusions Segregations	Colour, Mottle, Bleaching	Moisture, Drainage	Roots	Depth (m) / Field pH. Lab Sample, pH level and BSAL Assessment	Sample (m)	Observations
Grazing, undulating plain, slope 8% / 8%	Mixed woodland and grasses	Nil microrelief BSAL Pass Extensively disturbed Nil Erosion	Firm, cracking <2mm, rocks >60mm 2-10% coverage No rock outcrops BSAL Pass	A11 0.00-0.05 Abrupt	Sandy loam	Weak, weak	2% coarse fragments 2-6mm	7.5YR2.5/3 Very dark brown Nil mottles / bleach	Dry, well drained	Common	0.05 / 6.0 0.00-0.05 6.55 – BSAL Pass	0.00-0.05 0.05-0.15 0.15-0.28 0.30-0.60 0.65-0.75 0.75-1.00	Nil additional observations
				B21 0.05-0.28 Abrupt	Sandy clay loam	Weak, subangular blocky, firm	2% coarse fragments 2-6mm 2% <60mm rocks	5YR4/4 Reddish brown Nil mottles / bleach	Dry, well drained	Common	0.30 / 6.0 0.05-0.15 6.89 – BSAL Pass 0.15-0.30 7.08 – BSAL Pass		
				B22 0.28-0.65 Clear	Sandy clay loam	Moderate, subangular blocky, strong	1% rocks, incl. quartz 5-100mm	2.5YR3/4 Dark reddish brown Nil mottles / bleach	Dry, well drained	Few	0.60 / 6.5 0.30-0.60 7.24 – BSAL Pass		
				B23 0.65-1.00 EOBH ERD BSAL Pass	Sandy clay loam	Moderate, subangular blocky, very strong	10% coarse fragments 1-2mm	7.5YR4/4 Reddish brown Nil mottles / bleach BSAL Pass	Dry, well drained BSAL Pass	Nil roots	0.90 / 7.0 0.60-0.75 7.61 – BSAL Pass		

SITE 6 Plates

SITE 7

Map Unit / Map Code:	Location (GDA94 ZONE 55):	Aust. Soil Class.:	Site Survey Type:	Survey Date:
GV-I	775443 mE 6611270 mN	Eutrophic Red Chromosol	Test Pit	August 2019

Land use Landform Pattern, Element, Slope	Vegetation	Microrelief Disturbance Erosion	Surface condition, surface rock	Soil Profile Description									
				Horizon Depth (m), Boundary	Field Texture	Structure, Strength	Inclusions Segregations	Colour, Mottle, Bleaching	Moisture, Drainage	Roots	Depth (m) / Field pH. Lab Sample, pH level and BSAL Assessment	Sample (m)	Observations
Grazing, gently undulating plain 2% / 3 %	Grass	Nil microrelief BSAL Pass Extensively disturbed Nil Erosion	Firm, cracking 2-6mm, rocks >60mm 2-10% coverage No rock outcrops BSAL Pass	A1 0.00-0.10 Abrupt	Clayey sand	Weak, weak	Nil inclusions / segregations	7.5YR2.5/2 Very dark brown Nil mottles / bleach	Dry, well drained	Common	0.05 / 6.5 0.00-0.05 6.5 – BSAL Pass	0.00-0.10 0.10-0.30 0.30-0.50 0.53-0.60 0.60-0.75 0.75-1.00	Nil additional observations
				B21 0.10-0.53 Abrupt	Sandy clay loam	Moderate, subangular, weak	<1% black nodules	5YR3/4 Dark reddish brown Nil mottles / bleach	Dry, moderately well drained	Common	0.30 / 7.5 0.05-0.15 7.64 – BSAL Pass 0.15-0.30 8.39 – BSAL Pass 0.30-0.60 8.42 – BSAL Pass		
				B22 0.53-1.00 EOBH ERD BSAL Pass	Medium clay	Moderate, subangular, firm	<2% Mg nodules <1% calcium carbonate	2.5YR4/4 Reddish brown Yellowish brown <5% Mottle: Dark brown Nil bleach BSAL Pass	Dry, imperfectly drained BSAL Pass	Nil roots	0.60 / 7.0 0.90 / 7.0 0.60-0.75 8.46 – BSAL Pass		

SITE 7 Plates

SITE 8

Map Unit / Map Code:	Location (GDA94 ZONE 55):	Aust. Soil Class.:	Site Survey Type:	Survey Date:
N	775913 mE 6611057 mN	Stratic Rudosol	Test Pit	August 2019

Land use Landform Pattern, Element, Slope	Vegetation	Microrelief Disturbance Erosion	Surface condition, surface rock	Soil Profile Description									
				Horizon Depth (m), Boundary	Field Texture	Structure, Strength	Inclusions Segregations	Colour, Mottle, Bleaching	Moisture, Drainage	Roots	Depth (m) / Field pH. Lab Sample, pH level and BSAL Assessment	Sample (m)	Observations
Grazing, open depression slope 0% / 1%	Grass, 90% coverage	Nil microrelief BSAL Pass Extensively disturbed Nil Erosion	Hard setting. No rocks or coarse fragments No rock outcrops BSAL Pass	A11 0.00-0.12 Abrupt	Loamy sand	Massive, weak	<1% <1mm coarse fragments	7.5YR3/2 Dark brown Nil mottles / bleach	Dry, rapidly drained	Common	0.05 / 6.0 0.00-0.05 6.39 – BSAL Pass	0.00-0.10 0.15-0.30 0.35-0.50 0.35-0.50 0.50-0.60	Nil additional observations
				A21 0.12-0.32 Abrupt	Sandy loam	Massive to weak, weak	<10% black nodules <2mm	7.5YR3/4 Dark brown Nil mottles / bleach	Dry, well drained	Common	0.30 / 6.0 0.05-0.15 6.83 – BSAL Pass 0.15-0.30 7.21 – BSAL Pass		
				A22 0.32-0.50 Abrupt	Clayey sand	Massive to weak, weak	<2% <1mm coarse fragments	7.5YR3/4 Dark brown Nil mottles / bleach	Dry, rapidly drained	Few	0.60 / 6.5 0.30-0.60 7.24 – BSAL Pass		
				A23 0.50-1.00 EOBH ERD BSAL Pass	Loamy sand	Weak, loose	<30% <1mm coarse fragments	7.5YR3/4 Dark brown Nil mottles / bleach BSAL Pass	Dry, rapidly drained BSAL Pass	Few	0.90 / 6.5 0.60-0.75 7.32 – BSAL Pass		

SITE 8 Plates

SITE 9

Map Unit / Map Code:	Location (GDA94 ZONE 55):	Aust. Soil Class.:	Site Survey Type:	Survey Date:
GV-S/V	774556 mE 6610929 mN	Epipdeal Brown Vertosol	Test Pit	August 2019

Land use Landform Pattern, Element, Slope	Vegetation	Microrelief Disturbance Erosion	Surface condition, surface rock	Soil Profile Description									
				Horizon Depth (m), Boundary	Field Texture	Structure, Strength	Inclusions Segregations	Colour, Mottle, Bleaching	Moisture, Drainage	Roots	Depth (m) / Field pH. Lab Sample, pH level and BSAL Assessment	Sample (m)	Observations
Grazing, gently undulating plains, lower slope 3% / 3%	Grass, some tall woodlands	Nil microrelief BSAL Pass Extensively disturbed Nil Erosion	Firm, cracking 2mm, <1mm rocks 20-40mm No rock outcrops BSAL Pass	A1 0.00-0.13 Abrupt	Light clay	Moderate, strong	<2% coarse fragments <5mm	10YR3/2 Very dark greyish brown Nil mottles / bleach	Dry, well drained	Common	0.05 / 5.5 0.00-0.05 6.07 – BSAL Pass	0.00-0.10 0.15-0.30 0.30-0.60 0.60-0.75 0.80-1.00	Nil additional observations ERD Not BSAL Chemical barrier ESP 0.30-0.60 18.07
				B21 0.13-0.45 Abrupt	Medium clay	Moderate, strong	<2% coarse fragments <10mm <1% coarse fragments <50mm	10YR3/3 Dark brown Nil mottles / bleach	Dry, well drained	Few	0.30 / 5.5 0.15-0.30 7.21 – BSAL Pass 0.30-0.60 7.62 – BSAL Pass		
				B22 0.45-1.00 EOBH ERD Not BSAL	Medium clay	Moderate, subangular blocky, strong	<2% calcium carbonate	10YR3/3 Dark brown Nil mottles / bleach BSAL Pass	Dry, moderately well drained BSAL Pass	Very few	0.60 / 5.5 0.90 / 5.5 0.60-0.75 5.6 – BSAL Pass		

SITE 9 Plates

SITE 10

Map Unit / Map Code:	**Location (GDA94 ZONE 55):**	**Aust. Soil Class.:**	**Site Survey Type:**	**Survey Date:**
GV-I	775000 mE 6610910 mN	Eutrophic Red Dermosol	Test Pit	August 2019

Land use Landform Pattern, Element, Slope	**Vegetation**	**Microrelief Disturbance Erosion**	**Surface condition, surface rock**	**Soil Profile Description**									
				Horizon Depth (m), Boundary	**Field Texture**	**Structure, Strength**	**Inclusions Segregations**	**Colour, Mottle, Bleaching**	**Moisture, Drainage**	**Roots**	**Depth (m) / Field pH. Lab Sample, pH level and BSAL Assessment**	**Sample (m)**	**Observations**
Undulating plain, slope 10% / 8%	Grass and mixed woodlands	Nil microrelief BSAL Pass Extensively disturbed Nil Erosion	Firm, cracking 2-6mm, rocks >60mm 2-10% coverage No rock outcrops BSAL Pass	A1 0.00-0.10 Abrupt	Clay loam	Moderate, weak	<1% coarse fragments <2mm	7.5YR3/3 Dark brown Nil mottles / bleach	Dry, well drained	Common	0.05 / 6.5 0.00-0.05 6.69 – BSAL Pass 0.05-0.15 7.22 – BSAL Pass	0.00-0.10 0.15-0.30 0.32-0.47 0.50-0.60 0.60-0.75 0.80-1.00	Nil additional observations Area nearby to west of Site 10 is an area of over 10% slope, approximately 80 x 80m.
				B21 0.10-0.32 Abrupt	Clay loam sandy	Moderate, weak	<1% black nodules	5YR4/4 Reddish brown Nil mottles / bleach	Dry, well drained	Common	0.30 / 7.0 0.15-0.30 7.58 – BSAL Pass		
				B22 0.32-0.47 Abrupt	Sandy clay loam	Moderate, weak	<5% coarse fragments <10mm	5YR4/6 Yellowish red Nil mottles / bleach	Dry, well drained	Few	0.60 / 7.0 0.30-0.60 7.46 – BSAL Pass		
				B23 0.47-1.10 EOBH ERD BSAL Pass	Sandy clay loam	Moderate, subangular blocky, very strong	<10% coarse fragments <10mm <10% black nodules	7.5YR4/4 Reddish brown Mottle <5% red Nil bleach BSAL Pass	Dry, imperfectly drained BSAL Pass	Nil roots	0.90 / 7.0 0.60-0.75 7.37 – BSAL Pass		

SITE 10 Plates

SITE 11

Map Unit / Map Code:	Location (GDA94 ZONE 55):	Aust. Soil Class.:	Site Survey Type:	Survey Date:
GV - I	775471 mE 6610939 mN	Calcic Red Dermosol	Test Pit	August 2019

Land use Landform Pattern, Element, Slope	Vegetation	Microrelief Disturbance Erosion	Surface condition, surface rock	Soil Profile Description									
				Horizon Depth (m), Boundary	Field Texture	Structure, Strength	Inclusions Segregations	Colour, Mottle, Bleaching	Moisture, Drainage	Roots	Depth (m) / Field pH. Lab Sample, pH level and BSAL Assessment	Sample (m)	Observations
Grazing, Wide crest / upper slope 1% / 2%	Grass	Nil microrelief BSAL Pass Extensively disturbed Nil Erosion	Hard setting, minor cracking <2mm <2% >60mm No rock outcrops BSAL Pass	A11 0.00-0.10 Abrupt	Sandy clay loam	Moderate, peds 10-50mm weak	<5% coarse fragments <10mm	7.5YR2.5/2 Very dark brown Nil mottles / bleach	Dry, well drained	Common	0.05 / 6.0 0.00-0.05 5.85 – BSAL Pass	0.00-0.10 0.15-0.40 0.45-0.60 0.60-0.75 0.80-1.00	Nil additional observations
				A12 0.10-0.40 Abrupt	Sandy clay loam	Moderate, peds 30-50mm weak	<5% coarse fragments <20mm	5YR5/4 Reddish brown Nil mottles / bleach	Dry, well drained	Common	0.30 / 6.0 0.15-0.30 8.68 – BSAL Pass		
				B21 0.45-0.80 Abrupt	Light medium clay	Moderate, subangular blocky, peds 10-50mm, strong	<2% coarse fragments <50mm <2% coarse fragments <50-100mm <10% Calcium carbonate	7.5YR3/4 Dark brown Mottle <1% red Nil bleach BSAL Pass	Dry, well drained BSAL Pass	Very few	0.60 / 7.5 0.30-0.60 9.09 – ERD Not BSAL		
				B22 0.80-1.20 EOBH ERD Not BSAL	Light medium clay	Moderate, subangular blocky, peds 10-50mm, strong	<2% coarse fragments <50mm <2% coarse fragments <50-100mm <10-20% Calcium carbonate	7.5YR3/4 Dark brown Mottle 5% red Nil bleach	Dry, imperfectly drained	Nil roots	0.90 / 6.0		

SITE 11 Plates

SITE 12

Map Unit / Map Code:	Location (GDA94 ZONE 55):	Aust. Soil Class.:	Site Survey Type:	Survey Date:
GV-C	775903 mE 6610892 mN	Epipedal Brown Vertosol	Test Pit	August 2019

Land use Landform Pattern, Element, Slope	Vegetation	Microrelief Disturbance Erosion	Surface condition, surface rock	Soil Profile Description									
				Horizon Depth (m), Boundary	Field Texture	Structure, Strength	Inclusions Segregations	Colour, Mottle, Bleaching	Moisture, Drainage	Roots	Depth (m) / Field pH. Lab Sample, pH level and BSAL Assessment	Sample (m)	Observations
Grazing, gently undulating plain, simple slope 1% / 3%	Grass	Nil microrelief BSAL Pass Extensively disturbed Nil Erosion	Firm, cracking 2-6mm Rocks 2-10% >60mm No rock outcrops BSAL Pass	A1 0.00-0.10 Abrupt	Light clay	Moderate, firm	<5% rocks <50mm	7.5YR3/2 Dark brown Nil mottles / bleach	Dry, well drained	Common	0.05 / 6.0 0.00-0.05 7.32 – BSAL Pass	0.00-0.10 0.10-0.30 0.35-0.60 0.60-0.75 0.75-1.00	Nil additional observations
				B21 0.10-0.34 Abrupt	Light medium clay	Moderate, subangular blocky, very firm	<5% rocks <50mm	10YR3/2 Very dark greyish brown Nil mottles / bleach	Dry, well drained	Few	0.30 / 6.0 0.15-0.30 7.57 – BSAL Pass		
				B22 0.34-0.75 Abrupt	Light medium clay	Moderate, subangular blocky, very firm	2% rocks <20mm	10YR3/2 Very dark greyish brown Mottle: <1% Light brown Nil bleach BSAL Pass	Dry, moderately well drained BSAL Pass	Very few	0.60 / 7.5 0.30-0.60 8.04 – BSAL Pass 0.60-0.75 8.43 – BSAL Pass		
				B23 0.75-1.00 EOBH ERD BSAL Pass	Medium clay	Moderate, subangular blocky, very firm	<10% calcium carbonate	7.5YR3/4 Dark brown Mottle: <5% Pale brown and dark brown Nil bleach	Dry, imperfectly drained	Nil roots	0.90 / 6.0		

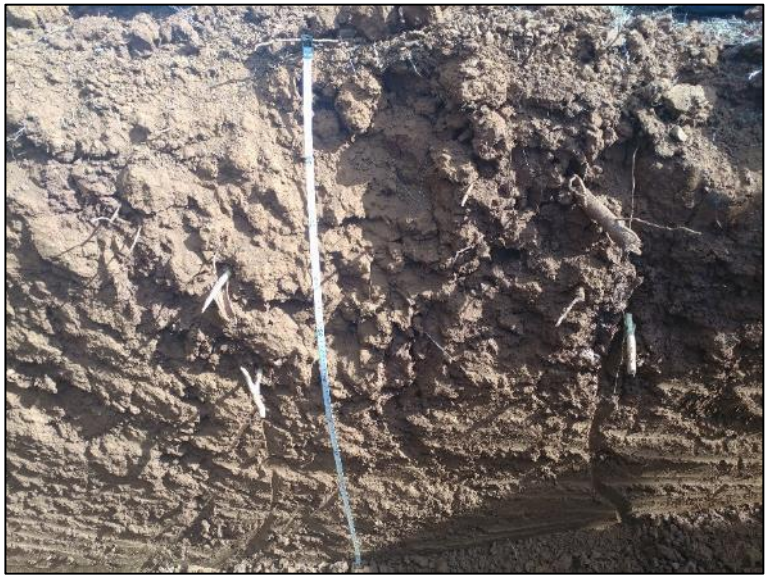
SITE 12 Plates

SITE 13

Map Unit / Map Code:	Location (GDA94 ZONE 55):	Aust. Soil Class.:	Site Survey Type:	Survey Date:
GV-S	774624 mE 6610526 mN	Subnatric Red Sodosol	Test Pit	August 2019

Land use Landform Pattern, Element, Slope	Vegetation	Microrelief Disturbance Erosion	Surface condition, surface rock	Soil Profile Description									
				Horizon Depth (m), Boundary	Field Texture	Structure, Strength	Inclusions Segregations	Colour, Mottle, Bleaching	Moisture, Drainage	Roots	Depth (m) / Field pH. Lab Sample, pH level and BSAL Assessment	Sample (m)	Observations
Grazing, gently undulating plain, mid slope 3% / 4%	Tall woodlands	Nil microrelief BSAL Pass Semi disturbed Nil Erosion	Firm, cracking 1-3mm, <1% rock 20-60mm No rock outcrops BSAL Pass	A1 0.00-0.15 Abrupt	Clay loam	Moderate, subangular blocky, very firm	<2% coarse fragments <5mm	5YR3/3 Dark reddish brown Nil mottles / bleach	Dry, well drained	Common	0.05 / 5.5 0.00-0.05 5.92 – BSAL Pass 0.05-0.15 6.98 – BSAL Pass	0.00-0.05 0.05-0.15 0.15-0.40 0.50-0.60 0.60-0.75	Nil additional observations
				B21 0.15-0.50 Abrupt	Medium clay	Moderate, subangular blocky, peds 30-50mm, strong	Nil inclusions / segregations	5YR3/4 Dark reddish brown Nil mottles / bleach	Dry, well drained	Few, fine	0.30 / 6.5 0.15-0.30 8.57 – BSAL Pass 0.30-0.60 8.99 – Not BSAL		
				B22 0.50-1.00 EOBH ERD Not BSAL	Medium clay	Moderate, subangular blocky, peds 30-50mm, very strong	<2% calcium carbonate	5YR3/4 Dark reddish brown Mottle: <1% 5YR6/6 Reddish yellow Nil bleach BSAL Pass	Dry, moderately well drained BSAL Pass	Nil roots	0.60 / 8.0 0.90 / 8.0		

SITE 13 Plates



SITE 14

Map Unit / Map Code:	Location (GDA94 ZONE 55):	Aust. Soil Class.:	Site Survey Type:	Survey Date:
GV-S/V	775358 mE 6610384 mN	Epipdeal Red Vertosol	Test Pit	August 2019

Land use Landform Pattern, Element, Slope	Vegetation	Microrelief Disturbance Erosion	Surface condition, surface rock	Soil Profile Description									
				Horizon Depth (m), Boundary	Field Texture	Structure, Strength	Inclusions Segregations	Colour, Mottle, Bleaching	Moisture, Drainage	Roots	Depth (m) / Field pH. Lab Sample, pH level and BSAL Assessment	Sample (m)	Observations
Grazing, ridge, Slope 3% / 3%	Tall woodland, gums	Nil microrelief BSAL Pass Semi disturbed Nil Erosion	Firm, cracking 1-3mm, <20% rock: 5-10mm and 30-60mm (50/50 split) No rock outcrops BSAL Pass	A11 0.00-0.15 Abrupt	Light clay	Moderate, subangular blocky, firm	5% rocks 20-40mm	7.5YR3/2 Dark brown Nil mottles / bleach	Dry, well drained	Common	0.05 / 6.5 0.00-0.05 6.59 – BSAL Pass 0.05-0.15 8.54 – BSAL Pass	0.00-0.10 0.15-0.30 0.30-0.54 0.54-0.60 0.60-0.75 0.80-1.00	Nil additional observations ERD Not BSAL Chemical barrier ECe 0.05-0.15 4..95
				B21 0.15-0.54 Abrupt	Light medium clay	Moderate, subangular blocky, very strong	2% rocks 20-40mm	5YR4/6 Yellowish red Nil mottles / bleach	Dry, well drained	Few	0.30 / 6.5 0.15-0.30 8.74 – BSAL Pass 0.30-0.60 8.9 – Not BSAL		
				B22 0.54-0.75 Abrupt	Light medium clay	Moderate, subangular blocky, strong	<2% calcium carbonate <2% black nodules	7.5YR3/3 Dark brown Nil mottles / bleach BSAL Pass	Dry, well drained BSAL Pass	Few	0.60 / 7.5		
				B23 0.75-1.20 EOBH ERD Not BSAL	Medium clay	Moderate, subangular blocky, very strong	Nil inclusions / segregations	7.5YR4/6 Strong brown Nil mottles / bleach	Dry, well drained	Nil roots	0.90 / 7.5		

SITE 14 Plates

SITE 15

Map Unit / Map Code:	Location (GDA94 ZONE 55):	Aust. Soil Class:	Site Survey Type:	Survey Date:
GV-S	775806 mE 6610344 mN	Hypocalcic Brown Sodosol	Test Pit	August 2019

Land use Landform Pattern, Element, Slope	Vegetation	Microrelief Disturbance Erosion	Surface condition, surface rock	Soil Profile Description									
				Horizon Depth (m), Boundary	Field Texture	Structure, Strength	Inclusions Segregations	Colour, Mottle, Bleaching	Moisture, Drainage	Roots	Depth (m) / Field pH. Lab Sample, pH level and BSAL Assessment	Sample (m)	Observations
Grazing, mid slope 3% / 3%	Tall woodlands	Nil microrelief BSAL Pass Semi disturbed Nil Erosion	Firm, <2% coarse fragments 2-6mm No rock outcrops BSAL Pass	A1 0.00-0.15 Abrupt	Sandy loam	Moderate, firm	<1% coarse fragments <10mm	10YR2/2 Very dark brown Nil mottles / bleach	Dry, rapidly drained	Common	0.05 / 5.5 0.00-0.05 7.45 – BSAL Pass 0.05-0.15 8.54 – BSAL Pass	0.00-0.10 0.10-0.25 0.25-0.50 0.50-0.60 0.60-0.75 0.75-0.95	Nil additional observations
				B21 0.15-0.45 Abrupt	Sandy clay loam	Moderate, firm	<1% calcium carbonate	10YR3/3 Dark brown Nil mottles / bleach	Dry, well drained	Common	0.30 / 6.5 0.15-0.30 8.96 – Not BSAL		
				B22 0.45-0.80 Abrupt	Sandy clay loam	Moderate, strong	<2% calcium carbonate	7.5YR4/3 Brown Nil mottles / bleach BSAL Pass	Dry, well drained BSAL Pass	Few	0.60 / 7.5		
				B23 0.80-1.20	Sandy clay loam	Moderate, strong	Nil inclusions / segregations	7.5YR4/2 Brown Mottle: <2% pale brown Nil bleach	Dry, moderately well drained	Nil roots	0.90 / 7.5		
				R 1.20+ EOBH ERD Not BSAL	Rock	-	-	-	-	-	-		

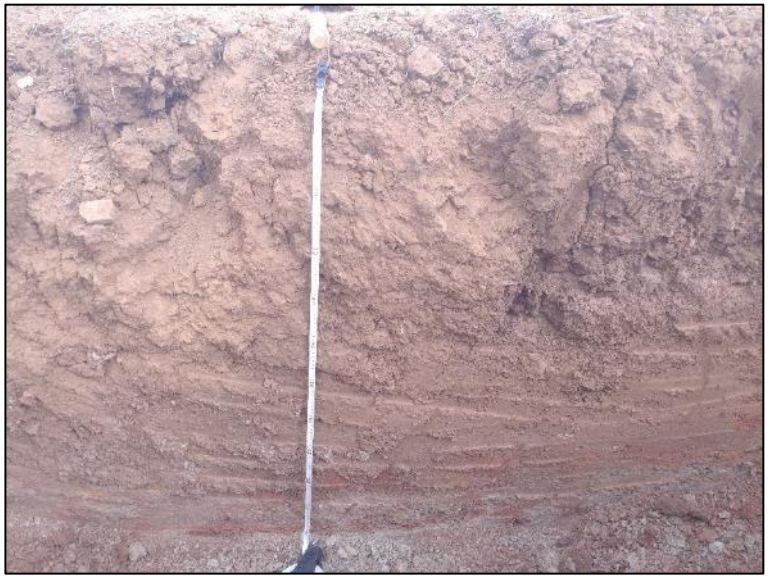
SITE 15 Plates

SITE 16

Map Unit / Map Code:	Location (GDA94 ZONE 55):	Aust. Soil Class:	Site Survey Type:	Survey Date:
GV-S/V	774247 mE 6610105 mN	Epipedal Brown Vertosol (Sodic)	Test Pit	August 2019

Land use Landform Pattern, Element, Slope	Vegetation	Microrelief Disturbance Erosion	Surface condition, surface rock	Soil Profile Description									
				Horizon Depth (m), Boundary	Field Texture	Structure, Strength	Inclusions Segregations	Colour, Mottle, Bleaching	Moisture, Drainage	Roots	Depth (m) / Field pH. Lab Sample, pH level and BSAL Assessment	Sample (m)	Observations
Grazing, Undulating plain, lower slope 7% / 3%	Grass	Nil microrelief Extensively disturbed Nil Erosion	Firm, cracking <2mm 1% rocks 30-200mm No rock outcrops BSAL Pass	A1 0.00-0.10 Abrupt	Light clay	Moderate, subangular blocky, firm	<2% coarse fragments <10mm	10YR3/2 Very dark greyish brown Nil mottles / bleach	Dry, well drained	Common	0.05 / 6.5 0.00-0.05 6.1 – BSAL Pass 0.05-0.15 7.31 – BSAL Pass	0.00-0.10 0.10-0.25 0.25-0.50 0.50-0.60 0.60-0.75 0.75-0.95	Nil additional observations ERD Not BSAL Chemical barrier ESP 0.15-0.30 15.78
				B21 0.10-0.25 Abrupt	Light clay	Moderate, subangular blocky, firm	<1% coarse fragments <10mm <1% rocks <100mm	7.5YR3/4 Dark brown Nil mottles / bleach	Dry, well drained	Common	0.30 / 6.5 0.15-0.30 7.49 – BSAL Pass		
				B22 0.25-0.60 Abrupt	Light clay	Moderate, subangular blocky, firm	Nil inclusions / segregations	7.5YR/4/3 Brown Nil mottles / bleach	Dry, well drained	Few	0.60 / 6.5 0.30-0.60 5.64 – Not BSAL		
				B23 0.60-0.95 Abrupt	Medium clay	Moderate, subangular blocky, firm	<2% coarse fragments <2mm	7.5YR/4/3 Brown Nil mottles / bleach BSAL Pass	Dry, well drained BSAL Pass	Nil roots	0.90 / 6.5 0.60-0.75 5.1 – BSAL Pass		
				B24 0.95-1.00 EOBH ERD Not BSAL	Medium clay	Moderate, subangular blocky, firm	Nil inclusions / segregations	7.5YR/4/4 Brown Nil mottles / bleach	Dry, well drained	Nil roots	0.95 / 7.0		

SITE 16 Plates



SITE 17

Map Unit / Map Code:	**Location (GDA94 ZONE 55):**	**Aust. Soil Class.:**	**Site Survey Type:**	**Survey Date:**
GV-S/V	773751 mE 6609610 mN	Epipedal Brown Vertosol (Sodic)	Test Pit	August 2019

Land use Landform Pattern, Element, Slope	**Vegetation**	**Microrelief Disturbance Erosion**	**Surface condition, surface rock**	**Soil Profile Description**									
				Horizon Depth (m), Boundary	**Field Texture**	**Structure, Strength**	**Inclusions Segregations**	**Colour, Mottle, Bleaching**	**Moisture, Drainage**	**Roots**	**Depth (m) / Field pH. Lab Sample, pH level and BSAL Assessment**	**Sample (m)**	**Observations**
Grazing, Undulating plain, upper slope 4% / 5%	Grass	Nil microrelief BSAL Pass Extensively disturbed Nil Erosion	Firm, cracking 2mm Rocks 10-30mm 1% coverage No rock outcrops BSAL Pass	A1 0.00-0.10 Abrupt	Light clay	Moderate, subangular blocky, firm	<2% coarse fragments <10mm	10YR3/2 Very dark greyish brown Nil mottles / bleach	Dry, well drained	Common	0.05 / 6.5 0.00-0.05 6.82 – BSAL Pass 0.15-0.30 8.86 – BSAL Pass	0.00-0.10 0.10-0.30 0.30-0.60 0.60-0.75 0.80-1.00	Nil additional observations ERD Not BSAL Chemical barrier ESP 0.30-0.60 16.25 ECe 0.30-0.60 6.99
				B21 0.10-0.60 Abrupt	Light clay	Moderate, subangular blocky, firm	<1% coarse fragments <10mm <1% rocks <100mm	7.5YR3/4 Dark brown Nil mottles / bleach	Dry, well drained	Common/few	0.30 / 6.5 0.30-0.60 8.54 – BSAL Pass		
				B22 0.60-1.20 Abrupt	Light clay	Moderate, subangular blocky, firm	Nil inclusions / segregations	7.5YR4/3 Brown Nil mottles / bleach BSAL Pass	Dry, well drained BSAL Pass	Nil roots	0.70 / 6.5 0.60-0.75 7.8 – BSAL Pass		
				B23 1.20-1.40 EOBH ERD Not BSAL	Medium clay	Moderate, subangular blocky, firm	Nil inclusions / segregations	7.5YR4/4 Brown Nil mottles / bleach	Dry, well drained	Nil roots	1.00 / 7.0		

SITE 17 Plates

SITE 18

Map Unit / Map Code:	Location (GDA94 ZONE 55):	Aust. Soil Class:	Site Survey Type:	Survey Date:
GV-S/V	773527 mE 6608926 mN	Epipedal Brown Vertosol (Sodic)	Test Pit	August 2019

Land use Landform Pattern, Element, Slope	Vegetation	Microrelief Disturbance Erosion	Surface condition, surface rock	Soil Profile Description									
				Horizon Depth (m), Boundary	Field Texture	Structure, Strength	Inclusions Segregations	Colour, Mottle, Bleaching	Moisture, Drainage	Roots	Depth (m) / Field pH. Lab Sample, pH level and BSAL Assessment	Sample (m)	Observations
Grazing, upper slope 4% / 3%	Grass - 50% cover	Nil microrelief BSAL Pass Extensively disturbed Nil Erosion	Firm, with some crusting, Minor cracking <2mm 2% >60mm rock fragments No rock outcrops BSAL Pass	A1 0.00-0.11 Abrupt	Light clay	Moderate, subangular blocky, strong	<2% coarse fragments <10mm	10YR3/2 Very dark greyish brown Nil mottles / bleach	Dry, well drained	Common	0.05 / 6.5 0.00-0.05 6.64 – BSAL Pass 0.15-0.30 7.89 – BSAL Pass	0.00-0.10 0.15-0.30 0.40-0.60 0.60-0.75 0.80-1.00	Nil additional observations ERD Not BSAL Chemical barrier ECe 0.30-0.60 6.19
				B21 0.11-0.40 Abrupt	Light clay	Moderate, subangular blocky, strong	<1% coarse fragments <5mm	7.5YR3/4 Dark brown Nil mottles / bleach	Dry, well drained	Common/few	0.30 / 6.5 0.30-0.60 8.89 – BSAL Pass		
				B22 0.40-0.75 Abrupt	Light clay	Moderate, subangular blocky, strong	<2% calcium carbonate	7.5YR4/3 Brown Nil mottles / bleach BSAL Pass	Dry, well drained BSAL Pass	Nil roots	0.60 / 7.0 0.60-0.75 8.73 – BSAL Pass		
				B23 0.75-1.00 EOBH ERD Not BSAL	Medium clay	Moderate, subangular blocky, strong	Nil inclusions / segregations	7.5YR4/4 Brown Nil mottles / bleach	Dry, well drained	Nil roots	0.95 / 7.0		

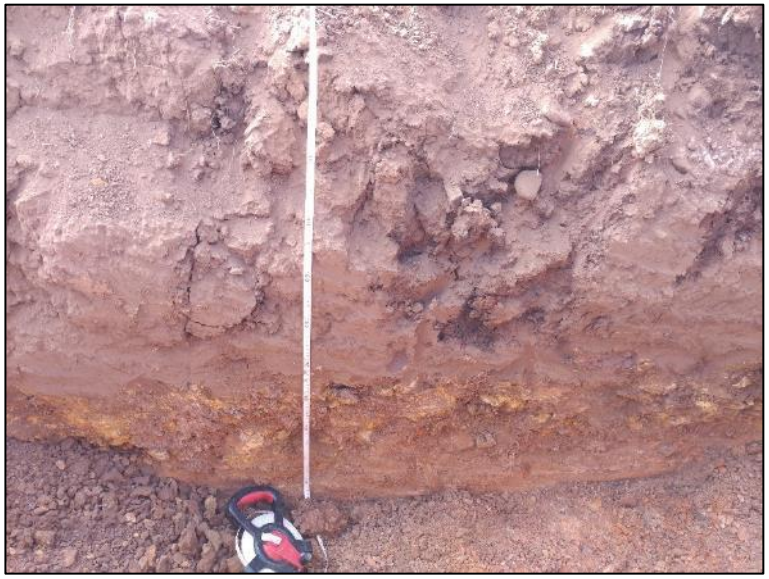
SITE 18 Plates

SITE 19

Map Unit / Map Code:	Location (GDA94 ZONE 55):	Aust. Soil Class.:	Site Survey Type:	Survey Date:
GV-S/V	773527 mE 6608926 mN	Epipedal Brown Vertosol (Sodic)	Test Pit	August 2019

Land use Landform Pattern, Element, Slope	Vegetation	Microrelief Disturbance Erosion	Surface condition, surface rock	Soil Profile Description									
				Horizon Depth (m), Boundary	Field Texture	Structure, Strength	Inclusions Segregations	Colour, Mottle, Bleaching	Moisture, Drainage	Roots	Depth (m) / Field pH. Lab Sample, pH level and BSAL Assessment	Sample (m)	Observations
Grazing, upper slope 2% / 2%	Grass - 50% cover	Nil microrelief BSAL Pass Extensively disturbed Nil Erosion	Firm, with some crusting, Minor cracking <2mm 1% >60mm rock fragments No rock outcrops BSAL Pass	A1 0.00-0.10 Abrupt	Light clay	Moderate, subangular blocky, firm	<2% coarse fragments <10mm	10YR3/2 Very dark greyish brown Nil mottles / bleach	Dry, well drained	Common	0.05 / 6.5 0.00-0.05 5.42 – BSAL Pass	0.00-0.10 0.15-0.30 0.40-0.60 0.60-0.75 0.80-1.00	Nil additional observations
				B21 0.10-0.75 Abrupt	Medium clay	Moderate, subangular blocky, strong	<2% coarse fragments <10mm	7.5YR3/4 Dark brown Nil mottles / bleach BSAL Pass	Dry, well drained BSAL Pass	Common/few	0.30 / 6.5 0.15-0.30 5.65 – BSAL Pass 0.30-0.60 6.16 – BSAL Pass 0.60-0.75 5.22 – BSAL Pass		
				B22 0.75-1.00 EOBH ERD BSAL Pass	Weathered rock	Moderate, subangular blocky, strong	5% rocks 10-50mm	7.5YR4/3 Brown Mottle: 5% orange and pale brown Nil bleach	Dry, imperfectly drained	Nil roots	0.60 / 7.0 0.95 / 7.5		

SITE 19 Plates



SITE 20

Map Unit / Map Code:	Location (GDA94 ZONE 55):	Aust. Soil Class.:	Site Survey Type:	Survey Date:
GV-I	773527 mE 6608926 mN	Hypocalcic Brown Dermosol	Test Pit	August 2019

Land use Landform Pattern, Element, Slope	Vegetation	Microrelief Disturbance Erosion	Surface condition, surface rock	Soil Profile Description									
				Horizon Depth (m), Boundary	Field Texture	Structure, Strength	Inclusions Segregations	Colour, Mottle, Bleaching	Moisture, Drainage	Roots	Depth (m) / Field pH. Lab Sample, pH level and BSAL Assessment	Sample (m)	Observations
Grazing, Mid-lower slope 4% / 5%	Grass - 40% cover	Nil microrelief BSAL Pass Extensively disturbed Nil Erosion	Firm, with some crusting, Minor cracking <2mm 5-10% >60 rock fragments No rock outcrops BSAL Pass	A1 0.00-0.12 Abrupt	Silty clay loam	Moderate, subangular blocky, firm	10% rock <60mm	10YR3/2 Very dark greyish brown Nil mottles / bleach	Dry, well drained	Common	0.05 / 6.5 0.00-0.05 6.1 – BSAL Pass	0.00-0.10 0.15-0.35 0.42-0.60 0.60-0.75 0.80-0.94	Nil additional observations
				B21 0.12-0.42 Abrupt	Light clay	Moderate, subangular blocky, firm	10% rock 30-100mm	7.5YR3/4 Dark brown Nil mottles / bleach	Dry, well drained	Common/few	0.30 / 6.5 0.15-0.30 8.19 – BSAL Pass		
				B22 0.42-0.77 Abrupt	Medium clay	Moderate, subangular blocky, strong	30% <60mm rocks 2% calcium carbonate	7.5YR3/4 Dark brown Nil mottles / bleach BSAL Pass	Dry, well drained BSAL Pass	Few	0.60 / 6.5 0.30-0.60 8.85 – BSAL Pass 0.60-0.75 8.79 – BSAL Pass		
				B23 0.77-0.94 Clear	Medium clay	Moderate, subangular blocky, strong	Nil inclusions / segregations	7.5YR4/3 Brown Nil mottles / bleach	Dry, well drained	Nil roots	0.80 / 7.0		
				B24 0.94-1.10 EOBH ERD BSAL Pass	Medium clay	Moderate, subangular blocky, strong	Nil inclusions / segregations	7.5YR4/3 Brown Nil mottles / bleach	Dry, well drained	Nil roots	1.00 / 7.0		

SITE 20 Plates

SITE 21

Map Unit / Map Code:	Location (GDA94 ZONE 55):	Aust. Soil Class.:	Site Survey Type:	Survey Date:
P	773527 mE 6608926 mN	Stratic Rudosol	Test Pit	August 2019

Land use Landform Pattern, Element, Slope	Vegetation	Microrelief Disturbance Erosion	Surface condition, surface rock	Soil Profile Description									
				Horizon Depth (m), Boundary	Field Texture	Structure, Strength	Inclusions Segregations	Colour, Mottle, Bleaching	Moisture, Drainage	Roots	Depth (m) / Field pH. Lab Sample, pH level and BSAL Assessment	Sample (m)	Observations
Grazing, gently undulating plain, upper slope, 5% / 3%	Tall woodlands	Nil microrelief BSAL Pass Nil disturbance Nil Erosion	Soft, loose, no coarse fragments No rock outcrops BSAL Pass	A11 0.00-0.40 Abrupt	Loamy sand	Single grain, loose	Nil inclusions / segregations	10YR6/1 Grey Nil mottles / bleach	Dry, rapidly drained	Common	0.10 / 5.5 0.00-0.05 5.8 – BSAL Pass 0.15-0.30 5.46 – BSAL Pass	0.00-0.10 0.15-0.30 0.40-0.60 0.60-0.75 0.85-1.00	Nil additional observations
				A12 0.40-0.85 Abrupt	Loamy sand	Single grain, loose	Nil inclusions / segregations	10YR6/2 Light brownish grey Nil mottles / bleach BSAL Pass	Dry, rapidly drained BSAL Pass	Nil roots	0.50 / 6.0 0.30-0.60 5.27 – BSAL Pass 0.60-0.75 5.8 – BSAL Pass		
				A2 0.85-1.20 EOBH ERD BSAL Pass	Loamy sand	Massive, loose	Nil inclusions / segregations	10YR6/2 Light brownish grey Nil mottles / bleach	Dry, rapidly drained	Nil roots	1.00 / 6.0		

SITE 21 Plates

Appendix C
Check and Exclusion site descriptions

SITE C1

Map Unit:	Location (GDA94 ZONE 55):	Aust. Soil Class:	Site Survey Type:	Survey Date:
GV-I	776003 mE 6611496 mN	-	Exclusion Site	9 August 2019

Land use Landform Pattern, Element, Slope	Vegetation	Microrelief Disturbance Erosion	Surface condition, surface rock	Soil Profile Description									
				Horizon Depth (m), Boundary	Texture	Structure, Strength	Inclusions Segregations	Colour, Mottle, Bleaching	Moisture, Drainage	Roots	Depth (m) / Field pH	Sample (m)	Observations
Grazing, Undulating plain, Ridge	Grasses	Nil microrelief Extensively disturbed Nil Erosion	Hard setting, Unattached rock assessment >60mm	-	-	-	-	-	-	-	-	-	Four quadrants of 1.0m x 1.0m assessed for unattached rock fragments >60mm Quadrant 1 - >20% Quadrant 2 - >20% Quadrant 3 - 20% Quadrant 4 – 15-20% Assessed exclusion site, Fail BSAL

SITE C1 Plates

SITE C2

Map Unit:	Location (GDA94 ZONE 55):	Aust. Soil Class:	Site Survey Type:	Survey Date:
GV-I	775958 mE 6611404 mN	-	Exclusion Site	9 August 2019

Land use Landform Pattern, Element, Slope	Vegetation	Microrelief Disturbance Erosion	Surface condition, surface rock	Soil Profile Description									
				Horizon Depth (m), Boundary	Texture	Structure, Strength	Inclusions Segregations	Colour, Mottle, Bleaching	Moisture, Drainage	Roots	Depth (m) / Field pH	Sample (m)	Observations
Grazing, Undulating plain, Ridge, upper slope	Grasses	Nil microrelief Extensively disturbed Nil Erosion	Hard setting, Unattached rock assessment >60mm	-	-	-	-	-	-	-	-	-	Four quadrants of 1.0m x 1.0m assessed for unattached rock fragments >60mm Quadrant 1 - >10% Quadrant 2 - >10% Quadrant 3 - >5% Quadrant 4 – >2% Passes BSAL criterion for surface rock

SITE C2 Plates

SITE C3

Map Unit:	Location (GDA94 ZONE 55):	Aust. Soil Class:	Site Survey Type:	Survey Date:
GV-C	775954 mE 6610684 mN	-	Check Site	9 August 2019

Land use Landform Pattern, Element, Slope	Vegetation	Microrelief Disturbance Erosion	Surface condition, surface rock	Soil Profile Description									
				Horizon Depth (m), Boundary	Texture	Structure, Strength	Inclusions Segregations	Colour, Mottle, Bleaching	Moisture, Drainage	Roots	Depth (m) / Field pH	Sample (m)	Observations
Grazing, Gently undulating plain, Lower slope	Sparse woodlands	Nil microrelief Extensively disturbed Nil Erosion	Unattached rock fragments is <20%	-	-	-	-	-	-	-	-	-	Four quadrants of 1.0m x 1.0m assessed for unattached rock fragments >60mm Quadrant 1 - >10% Quadrant 2 - >10% Quadrant 3 - >10% Quadrant 4 – >2% Passes BSAL criterion for surface rock

SITE C3 Plates

SITE C4

Map Unit:	Location (GDA94 ZONE 55):	Aust. Soil Class:	Site Survey Type:	Survey Date:
GV-SV	774447 mE 6610756 mN	-	Check Site	9 August 2019

Land use Landform Pattern, Element, Slope	Vegetation	Microrelief Disturbance Erosion	Surface condition, surface rock	Soil Profile Description									
				Horizon Depth (m), Boundary	Texture	Structure, Strength	Inclusions Segregations	Colour, Mottle, Bleaching	Moisture, Drainage	Roots	Depth (m) / Field pH	Sample (m)	Observations
Grazing, Undulating plain, Ridge	Grasses	Nil microrelief Extensively disturbed Nil Erosion	Minor crust, firm, no cracking Unattached rock fragments is <20%	-	-	-	-	-	-	-	-	-	Four quadrants of 1.0m x 1.0m assessed for unattached rock fragments >60mm Quadrant 1 - 15% Quadrant 2 - 10% Quadrant 3 – deemed not required Quadrant 4 – deemed not required Passes BSAL criterion for surface rock

SITE C4 Plates

SITE C5

Map Unit:	Location (GDA94 ZONE 55):	Aust. Soil Class:	Site Survey Type:	Survey Date:
GV-S	774704 mE 6610600 mN	-	Check Site	9 August 2019

Land use Landform Pattern, Element, Slope	Vegetation	Microrelief Disturbance Erosion	Surface condition, surface rock	Soil Profile Description									
				Horizon Depth (m), Boundary	Texture	Structure, Strength	Inclusions Segregations	Colour, Mottle, Bleaching	Moisture, Drainage	Roots	Depth (m) / Field pH	Sample (m)	Observations
Grazing, Undulating plain, Lower slope 5.0%	Grasses	Nil microrelief Extensively disturbed Nil Erosion	Cracking 2mm No coarse fragments	-	-	-	-	-	-	-	-	-	Passes BSAL criterion for surface rock

SITE C5 Picture

SITE C6

Map Unit:	Location (GDA94 ZONE 55):	Aust. Soil Class:	Site Survey Type:	Survey Date:
GV-I	775918 mE 6611462 mN	-	Check Site	9 August 2019

Land use Landform Pattern, Element, Slope	Vegetation	Microrelief Disturbance Erosion	Surface condition, surface rock	Soil Profile Description									
				Horizon Depth (m), Boundary	Texture	Structure, Strength	Inclusions Segregations	Colour, Mottle, Bleaching	Moisture, Drainage	Roots	Depth (m) / Field pH	Sample (m)	Observations
Grazing, Undulating plain, Upper slope	Grasses	Nil microrelief Extensively disturbed Nil Erosion	-	-	-	-	-	-	-	-	-	-	Four quadrants of 1.0m x 1.0m assessed for unattached rock fragments >60mm Quadrant 1 - <20% Quadrant 2 - <20% Quadrant 3 – <20% Quadrant 4 – <20% Passes BSAL criterion for surface rock

SITE C6 Plates

SITE C7

Map Unit:	Location (GDA94 ZONE 55):	Aust. Soil Class:	Site Survey Type:	Survey Date:
GV-I	776019 mE 6611436 mN	-	Check Site	9 August 2019

Land use Landform Pattern, Element, Slope	Vegetation	Microrelief Disturbance Erosion	Surface condition, surface rock	Soil Profile Description									
				Horizon Depth (m), Boundary	Texture	Structure, Strength	Inclusions Segregations	Colour, Mottle, Bleaching	Moisture, Drainage	Roots	Depth (m) / Field pH	Sample (m)	Observations
Grazing, Undulating plain, Upper slope	Grasses	Nil microrelief Extensively disturbed Nil Erosion	-	-	-	-	-	-	-	-	-	-	Four quadrants of 1.0m x 1.0m assessed for unattached rock fragments >60mm Quadrant 1 - <20% Quadrant 2 - <20% Quadrant 3 – <20% Quadrant 4 – <20% Passes BSAL criterion for surface rock

SITE C7 Plates

SITE C8

Map Unit:	Location (GDA94 ZONE 55):	Aust. Soil Class:	Site Survey Type:	Survey Date:
GV-SV	774114 mE 6609050 mN	Brown Vertosol	Check Site	9 August 2019

Land use Landform Pattern, Element, Slope	Vegetation	Microrelief Disturbance Erosion	Surface condition, surface rock	Soil Profile Description									
				Horizon Depth (m), Boundary	Texture	Structure, Strength	Inclusions Segregations	Colour, Mottle, Bleaching	Moisture, Drainage	Roots	Depth (m) / Field pH	Sample (m)	Observations
Grazing, Gently undulating plain, Lower slope 3% / 1%	Tall woodland	Nil microrelief Nil disturbed Nil Erosion	Cracking, soft	A1 0.00-0.10 Abrupt	Light clay	Weak, firm	Nil inclusions / segregations	10YR4/3 Brown Nil mottles / bleaching	Dry, well drained	Common	0.05 / 6.5	-	Nil additional observations
				B21 0.10-0.50 EOBH	Light clay	Moderate, firm	Nil inclusions / segregations	10YR3/3 Dark brown Nil mottles / bleaching	Dry, well drained	Few	0.30 / 7.5		

SITE C8 Plates

SITE C9

Map Unit:	Location (GDA94 ZONE 55):	Aust. Soil Class:	Site Survey Type:	Survey Date:
GV-I	775854 mE 6611119 mN	Red Dermosol	Check Site	9 August 2019

Land use Landform Pattern, Element, Slope	Vegetation	Microrelief Disturbance Erosion	Surface condition, surface rock	Soil Profile Description									
				Horizon Depth (m), Boundary	Texture	Structure, Strength	Inclusions Segregations	Colour, Mottle, Bleaching	Moisture, Drainage	Roots	Depth (m) / Field pH	Sample (m)	Observations
Grazing, Gently undulating plain, Wide depression	Mixed sparse vegetation	Nil microrelief Semi disturbed Nil Erosion	Firm, minor cracking	A11 0.00-0.15 Abrupt	Clayey sand	Loose, massive	Nil inclusions / segregations	2.5YR3/3 Dark reddish-brown Nil mottles / bleaching	Dry, rapid	Common	-	-	Nil additional observations
				B21 0.15-0.40 Abrupt	Sandy loam	Weak, soft	Nil inclusions / segregations	2.5YR3/4 Dark reddish-brown Nil mottles / bleaching	Dry, well drained	Few	-		
				B22 0.40-0.80 EOBH	Sandy clay loam	Weak, firm	Nil inclusions / segregations	2.5YR3/4 Dark reddish-brown Nil mottles / bleaching	Dry, well drained	Few	-		

SITE C9 Plates

Appendix D
Laboratory Data

ESSA Pty Ltd /EAL NATA (ASPAC certified)

For Info Refer ESSA Pty Ltd
PO Box 442 Sunnybank Q 4109

Phone: 0403245560

email: e.s.s.a@bigpond.net.au

References: I4919

Date Received: 19/08/2019
Date Completed: 04/09/2019

FINAL REPORT

Project:

Project -Narrabri (19NA)

All results in this report relate only to the items tested. Results are expressed on an "as received basis".

Client Name: GT Environmental

Contact: Mr Reece Mc Cann

Sample Type: Soil

Number of sample 94

ESSA /EAL Pty Ltd

Soil Analysis Report
Batch Number: I4919

Date Received: 19/08/2019
Date Completed:04/09/2019

Client: GTE Narrabri 19NA- Results Page 1 of 2

ESSA Ref	field ref	Soil pH	Soil EC	Exch.Ca	Exch. Mg	Exch.K	Exch. Na	Exch. Al	CEC	ESP	Al Satn	Ca/Mg	Cation
	depth (m)		dS/m	meq/100g	meq/100g	meq/100g	meq/100g	meq/100g	meq/100g	%Na/CEC	Al/CEC%	Ratio	Method
i4919/1	1-0.00-0.10	6.23	0.034	5.12	2.86	0.59	0.14	..	8.7	1.6	..	1.8	15D3
i4919/2	1-0.15-0.35	7.91	0.060	13.53	10.59	0.56	1.62	..	26.3	6.2	..	1.3	15D3
i4919/3	1-0.40-0.60	9.51	0.240	5.78	9.22	0.48	2.12	..	17.6	12.1	..	0.6	15C1
i4919/4	1-0.60-0.75	9.38	0.590	4.61	9.17	0.19	2.56	..	16.5	15.5	..	0.5	15C1
i4919/5	2-0.00-0.10	7.34	0.064	15.91	9.08	1.19	0.10	..	26.3	0.4	..	1.8	15D3
i4919/6	2-0.10-0.30	7.31	0.038	11.02	5.71	0.50	0.10	..	17.3	0.6	..	1.9	15D3
i4919/7	2-0.30-0.50	7.29	0.025	11.88	5.20	0.48	0.11	..	17.7	0.6	..	2.3	15D3
i4919/8	2-0.50-0.60	7.69	0.032	16.22	5.66	0.36	0.14	..	22.4	0.6	..	2.9	15D3
i4919/9	2-0.60-0.75	7.74	0.030	15.41	5.04	0.29	0.14	..	20.9	0.7	..	3.1	15D3
i4919/10	3-0.00-0.10	6.34	0.091	18.34	14.65	1.43	0.16	..	34.6	0.5	..	1.3	15D3
i4919/11	3-0.15-0.35	7.14	0.037	21.25	16.29	0.38	0.38	..	38.3	1.0	..	1.3	15D3
i4919/12	3-0.30-0.60	7.50	0.034	20.52	16.99	0.33	0.59	..	38.4	1.5	..	1.2	15D3
i4919/13	3-0.60-0.75	8.02	0.045	14.82	11.83	<0.12	0.59	..	27.3	2.2	..	1.3	15C1
i4919/14	4-0.00-0.10	6.29	0.087	6.37	5.32	1.39	0.13	..	13.2	1.0	..	1.2	15D3
i4919/15	4-0.15-0.30	8.14	0.183	6.33	9.45	0.39	1.97	..	18.1	10.9	..	0.7	15C1
i4919/16	4-0.30-0.60	8.93	1.152	4.38	9.46	<0.12	2.38	..	16.3	14.6	..	0.5	15C1
i4919/17	4-0.60-0.75	8.81	1.482	3.85	10.37	0.18	2.88	..	17.3	16.7	..	0.4	15C1
i4919/18	5-0.00-0.05	5.72	0.056	5.14	2.32	0.37	0.12	..	8.0	1.5	..	2.2	15D3
i4919/19	5-0.05-0.14	7.22	0.238	8.10	10.03	0.20	1.96	..	20.3	9.7	..	0.8	15D3
i4919/20	5-0.15-0.30	8.05	0.227	7.28	9.58	0.36	1.53	..	18.8	8.2	..	0.8	15C1
i4919/21	5-0.30-0.60	8.74	0.375	5.14	9.42	0.26	1.74	..	16.6	10.5	..	0.5	15C1
i4919/22	5-0.60-0.75	9.06	0.574	2.63	6.05	0.18	1.30	..	10.2	12.8	..	0.4	15C1
i4919/23	6-0.00-0.05	6.55	0.078	18.09	6.03	0.56	0.13	..	24.8	0.5	..	3.0	15D3
i4919/24	6-0.05-0.15	6.89	0.026	16.53	6.25	0.32	0.15	..	23.3	0.6	..	2.6	15D3
i4919/25	6-0.15-0.28	7.08	0.026	16.71	6.76	0.27	0.09	..	23.8	0.4	..	2.5	15D3
i4919/26	6-0.30-0.60	7.24	0.028	12.72	8.27	0.18	0.17	..	21.3	0.8	..	1.5	15D3
i4919/27	6-0.60-0.75	7.61	0.035	12.80	13.77	0.17	0.73	..	27.5	2.7	..	0.9	15D3
i4919/28	7-0.00-0.10	6.50	0.059	8.57	2.82	0.96	<0.065	..	12.4	0.3	..	3.0	15D3
i4919/29	7-0.10-0.30	7.64	0.062	14.12	2.34	0.64	<0.065	..	17.1	0.2	..	6.0	15D3
i4919/30	7-0.30-0.50	8.39	0.101	12.49	4.24	0.64	0.12	..	17.5	0.7	..	2.9	15C1
i4919/31	7-0.53-0.60	8.42	0.100	10.44	4.91	0.67	0.10	..	16.1	0.6	..	2.1	15C1
i4919/32	7-0.60-0.75	8.46	0.113	12.03	5.18	0.77	0.13	..	18.1	0.7	..	2.3	15C1
i4919/33	8-0.00-0.10	6.39	0.100	15.56	7.55	1.65	0.15	..	24.9	0.6	..	2.1	15D3
i4919/34	8-0.15-0.30	6.83	0.019	11.83	5.27	0.64	0.07	..	17.8	0.4	..	2.2	15D3
i4919/35	8-0.30-0.50	7.21	0.016	13.90	5.49	0.41	0.09	..	19.9	0.4	..	2.5	15D3
i4919/36	8-0.50-0.60	7.24	0.014	10.19	3.91	0.27	<0.065	..	14.4	0.4	..	2.6	15D3
i4919/37	8-0.60-0.75	7.32	0.012	11.66	3.79	0.26	<0.065	..	15.8	0.4	..	3.1	15D3
i4919/38	9-0.00-0.10	6.07	0.166	6.11	11.02	0.66	1.21	..	19.0	6.4	..	0.6	15D3
i4919/39	9-0.15-0.30	6.93	0.217	6.27	15.56	0.26	3.44	..	25.5	13.5	..	0.4	15D3
i4919/40	9-0.30-0.60	7.62	0.340	5.34	16.44	0.22	4.85	..	26.8	18.1	..	0.3	15D3
i4919/41	9-0.60-0.75	5.60	0.457	2.83	13.62	0.28	4.78	..	21.5	22.2	..	0.2	15D3
i4919/42	10-0.00-0.10	6.69	0.045	25.92	8.93	1.14	0.17	..	36.2	0.5	..	2.9	15D3
i4919/43	10-0.15-0.30	7.22	0.033	27.12	13.03	0.35	0.10	..	40.6	0.3	..	2.1	15D3
i4919/44	10-0.32-0.47	7.58	0.037	36.73	20.17	0.21	0.15	..	57.3	0.3	..	1.8	15D3
i4919/45	10-0.50-0.60	7.46	0.033	43.60	25.28	0.20	0.21	..	69.3	0.3	..	1.7	15D3
i4919/46	10-0.60-0.75	7.37	0.030	50.49	32.31	0.26	0.29	..	83.4	0.3	..	1.6	15D3
i4919/47	11-0.00-0.10	5.85	0.169	7.63	9.01	0.54	0.18	..	17.4	1.0	..	0.8	15D3
i4919/48	11-0.10-0.40	8.68	0.126	11.47	12.55	0.32	0.22	..	24.6	0.9	..	0.9	15C1
i4919/49	11-0.40-0.60	9.09	0.175	7.86	14.56	0.25	0.62	..	23.3	2.7	..	0.5	15C1
i4919/50	11-0.60-0.75	9.21	0.235	5.73	17.26	0.26	1.13	..	24.4	4.7	..	0.3	15C1

ESSA Ref	field ref	Soil pH	Soil EC	Exch.Ca	Exch. Mg	Exch.K	Exch. Na	Exch. Al	CEC	ESP	Al Satn	Ca/Mg	Cation
	depth (m)		dS/m	meq/100g	meq/100g	meq/100g	meq/100g	meq/100g	meq/100g	%Na/CEC	Al/CEC%	Ratio	Method
i4919/51	**12-0.00-0.10**	7.32	0.040	21.43	13.75	0.60	0.30	..	36.1	0.8	..	1.6	**15D3**
i4919/52	**12-0.10-0.30**	7.57	0.053	22.78	17.86	0.36	1.10	..	42.1	2.6	..	1.3	**15D3**
i4919/53	**12-0.35-0.60**	8.04	0.150	17.96	16.75	0.31	1.37	..	36.4	3.8	..	1.1	**15C1**
i4919/54	**12-0.60-0.75**	8.43	0.358	10.67	11.98	0.22	1.32	..	24.2	5.5	..	0.9	**15C1**
i4919/55	**13-0.00-0.05**	5.92	0.157	10.13	5.98	0.89	0.25	..	17.2	1.5	..	1.7	**15D3**
i4919/56	**13-0.05-0.15**	6.98	0.070	9.48	11.12	0.39	1.34	..	22.3	6.0	..	0.9	**15D3**
i4919/57	**13-0.15-0.40**	8.57	0.216	5.27	7.97	0.21	1.55	..	15.0	10.3	..	0.7	**15C1**
i4919/58	**13-0.50-0.60**	8.99	0.458	3.20	5.63	<0.12	1.01	..	10.0	10.1	..	0.6	**15C1**
i4919/59	**13-0.60-0.75**	9.07	0.485	2.99	5.74	0.13	1.11	..	10.0	11.1	..	0.5	**15C1**
i4919/60	**14-0.00-0.10**	6.59	0.042	11.19	14.75	0.25	0.56	..	26.8	2.1	..	0.8	**15D3**
i4919/61	**14-0.15-0.30**	8.54	0.575	4.97	23.67	0.24	3.53	..	32.4	10.9	..	0.2	**15C1**
i4919/62	**14-0.30-0.54**	8.74	0.779	6.60	28.48	0.21	4.10	..	39.4	10.4	..	0.2	**15C1**
i4919/63	**14-0.54-0.60**	8.90	0.774	5.17	21.39	0.19	2.62	..	29.4	8.9	..	0.2	**15C1**
i4919/64	**14-0.60-0.75**	8.95	0.781	3.81	16.74	0.26	2.34	..	23.1	10.1	..	0.2	**15C1**
i4919/65	**15-0.00-0.10**	7.45	0.102	5.53	4.31	0.20	0.21	..	10.3	2.1	..	1.3	**15D3**
i4919/66	**15-0.15-0.30**	8.54	0.113	4.90	6.92	0.32	1.66	..	13.8	12.0	..	0.7	**15C1**
i4919/67	**15-0.30-0.45**	8.96	0.281	5.12	9.01	0.38	2.58	..	17.1	15.1	..	0.6	**15C1**
i4919/68	**15-0.45-0.60**	9.07	0.403	6.10	11.51	0.44	3.30	..	21.4	15.5	..	0.5	**15C1**
i4919/69	**15-0.60-0.75**	6.19	0.102	7.47	12.05	0.64	0.82	..	21.0	3.9	..	0.6	**15D3**
i4919/70	**16-0.00-0.10**	6.10	0.104	7.04	11.77	0.63	0.76	..	20.2	3.8	..	0.6	**15D3**
i4919/71	**16-0.10-0.25**	7.31	0.079	8.23	15.11	0.19	2.02	..	25.5	7.9	..	0.5	**15D3**
i4919/72	**16-0.25-0.50**	7.49	0.297	4.28	16.12	0.15	3.85	..	24.4	15.8	..	0.3	**15D3**
i4919/73	**16-0.50-0.60**	5.64	0.486	2.67	14.67	0.14	4.56	..	22.0	20.7	..	0.2	**15D3**
i4919/74	**16-0.60-0.75**	5.10	0.538	1.36	12.02	0.14	4.88	0.51	19.2	25.5	2.7	0.1	**15E3**
i4919/75	**17-0.00-0.10**	6.82	0.093	13.14	14.25	1.39	0.61	..	29.4	2.1	..	0.9	**15D3**
i4919/76	**17-0.10-0.30**	8.86	0.306	4.17	7.42	0.62	1.28	..	13.5	9.5	..	0.6	**15C1**
i4919/77	**17-0.30-0.60**	8.54	0.813	2.23	5.57	0.58	1.63	..	10.0	16.3	..	0.4	**15C1**
i4919/78	**17-0.60-0.75**	7.80	0.960	5.46	16.52	0.59	7.26	..	29.8	24.3	..	0.3	**15D3**
i4919/79	**19-0.00-0.10**	6.64	0.044	9.59	9.85	0.71	0.56	..	20.7	2.7	..	1.0	**15D3**
i4919/80	**19-0.15-0.30**	7.89	0.161	11.39	15.50	0.34	2.86	..	30.1	9.5	..	0.7	**15D3**
i4919/81	**19-0.40-0.60**	8.89	0.719	5.02	8.86	0.52	2.05	..	16.5	12.5	..	0.6	**15C1**
i4919/82	**19-0.60-0.75**	8.73	1.083	5.12	12.75	0.54	4.14	..	22.6	18.3	..	0.4	**15C1**
i4919/83	**20-0.00-0.10**	5.42	0.188	7.77	10.94	1.26	0.57	..	20.5	2.8	..	0.7	**15D3**
i4919/84	**20-0.15-0.30**	5.65	0.082	5.59	17.65	0.57	1.71	..	25.5	6.7	..	0.3	**15D3**
i4919/85	**20-0.40-0.60**	6.16	0.205	9.23	24.14	0.60	3.03	..	37.0	8.2	..	0.4	**15D3**
i4919/86	**20-0.60-0.75**	5.22	0.254	6.53	24.27	0.59	3.32	..	34.7	9.6	..	0.3	**15D3**
i4919/87	**21-0.00-0.10**	6.10	0.061	13.21	10.56	0.68	0.18	..	24.6	0.7	..	1.3	**15D3**
i4919/88	**21-0.15-0.35**	8.19	0.071	12.43	17.53	0.70	1.37	..	32.0	4.3	..	0.7	**15C1**
i4919/89	**21-0.42-0.60**	8.85	0.186	11.68	15.11	0.76	0.88	..	28.4	3.1	..	0.8	**15C1**
i4919/90	**21-0.60-0.75**	8.79	0.260	10.57	17.25	0.89	2.58	..	31.3	8.2	..	0.6	**15C1**
i4919/91	**22-0.00-0.10**	5.80	0.016	2.01	0.61	<0.12	<0.065	..	2.7	0.5	..	3.3	**15D3**
i4919/92	**22-0.15-0.30**	5.46	0.018	0.78	0.41	<0.12	<0.065	..	1.3	1.0	..	1.9	**15D3**
i4919/93	**22-0.40-0.60**	5.27	0.011	0.32	0.25	<0.12	<0.065	..	0.6	1.8	..	1.3	**15D3**
i4919/94	**22-0.60-0.75**	5.80	0.004	0.18	0.16	<0.12	<0.065	..	0.4	0.5	..	1.2	**15D3**

1. All results presented as a 40°C oven dried weight. Soil sieved and lightly crushed to < 2 mm.
2. Methods from Rayment and Lyons, 2011. *Soil Chemical Methods - Australasia.* CSIRO Publishing: Collingwood.
3.Symbol .. In cell = Not Analysed - Cation Method 15C1 = Alcoholic with prewash

Soil Analysis Report
Batch Number: I4919

Date Received: 19/08/2019
Date Completed:04/09/2019

Client: GTE Narrabri 19NA- Results Page 2 of 2

Lab No	Sample No			Tot Org C	Org Matter	P	N as NH4	N as NO3	Tot N
	Depth (m)			%	%	mg/kg	mg/kg	mg/kg	%
I4919/91	**22-0.00-0.10**			1.37	3.0	5.6	1.6	0.10	138

ESSA / EAL Pty Ltd (Nata ASPAC Approved)

METHOD DESCRIPTIONS

Soil

Methods used to Analyse Samples

Analyte	ALHS*	Uncertainty %	LOQ	Unit	Name	Method Description
pH	4A1	1.1	0.1	pH	pH	1:5 water extr, pH meter
EC	3A1	5.4	0.01	dS/m	Electrical conductivity	1:5 water extr, EC meter
Cl	5A2	10.0	10.0	mg/kg	Chloride	1:5 water extr, (AA) colorimetric
NO3-N	7C2	6.7	1.0	mg/kg	Nitrate-nitrogen	1:5 water extr, (AA) colorimetric
NH4-N	7C2	7.8	0.6	mg/kg	Ammonium-nitrogen	1M KCl extr, (AA) colorimetric
Bicarb.P	9B2	16.8	1.0	mg/kg	Bicarb.ext.phosphorus	0.5M NaHCO3 @ pH 8.5, (AA) colorimetric
Exch.Ca	15B/C1	7.2	0.18	meq/100g	Exchangeable calcium	1M NH4OAc @ pH 7.0/8.5 leach, AAS
Exch.Mg	15B/C1	4.7	0.31	meq/100g	Exchangeable magnesium	1M NH4OAc @ pH 7.0/8.5 leach, AAS
Exch.Na	15B/C1	9.6	0.09	meq/100g	Exchangeable calcium	1M NH4OAc @ pH 7.0/8.5 leach, AAS
Exch.K	15B/C1	4.8	0.02	meq/100g	Exchangeable calcium	1M NH4OAc @ pH 7.0/8.5 leach, AAS
CEC	15I3	5.7	1.0	meq/100g	Cation Exchange Capacity	KNO3 + Ca(NO3)2 extr, (AA) colorimetric
ADMC	2A1	11.9	0.4	%	Air Dried Moisture Content	Gravimetric oven dry @ 105C
R1	NA	20.2	NA		Dispersion Ratio	Ratio [Aqueous dispersible (Silt + Clay):Total (Silt + Clay)]
SO4-S	10B3	11.5	0.6	mg/kg	Sulfate sulfur	Ca(H2PO4)2 @ pH 4.0 extractable sulfate-sulfur, ICPOES
Sand	no ref	22.1	1.0	%	Particle size, sand	Hydrometer, gravimetric & Sieve
Silt	no ref	16.6	1.0	%	Particle size, silt	Hydrometer, gravimetric
Clay	no ref	12.7	1.0	%	Particle size, clay	Hydrometer, gravimetric

*** Australian Laboratory Handbook of Soil and Water Chemical Methods (1992)**

For Manager Analytical Services: **D E Baker BSc MASSSI**

Methods from Rayment and Lyons, 2011. *Soil Chemical Methods - Australasia.* CSIRO Publishing: Collingwood.
Soluble Salts included in Exchangeable Cations - Except PRE-WASHED (if EC>0.3dS/m) as 15C1.

ESSA / EAL Pty Ltd(NATA ASPAC Approved)

QUALITY CONTROL DATA

Soil

Reference: I4919
Page: 4 of 4

*** Australian Laboratory Handbook of Soil and Water Chemical Methods (1992)**

Test Method	Units		Actual Value	Acceptance Criteria [Range]
pH	pH	B		5.0 - 5.3
EC	dS/m	B		0.27 - 0.32
Cl	mg/kg	B		10 - 35
NO3-N	mg/kg	B		10 - 16
NH4-N	mg/kg	NA		NA
Bicarb.P	mg/kg	B		51 -75
Total Kjeldahl N	%	ASPAC 34	0.110	.100 - .120
Total P	%	ASPAC 34	0.02	.019 - .021
Organic Carbon	%	B		1.82 - 2.3
Ca (Exch. cations)pH7	meq/100g	B		6.96 - 8.04
Mg (Exch. cations)pH7	meq/100g	B		1.88 - 2.22
Na (Exch. cations)pH7	meq/100g	B		.057 - .182
K (Exch. cations)pH7	meq/100g	B		1.209 - 1.411
Exch. Acidity	meq/100g			NA
ECEC	meq/100g	A		NA
CEC	meq/100g	S12		58 - 73
ESP	%	A		NA
Coarse sand	%	B	17.0	17.3 - 22.4
Fine Sand	%	B	22.0	20.0 - 25.7
Silt	%	B	16.0	10.5 - 19.8
Clay	%	B	44.0	37.9 - 48.9
R1		B		0.23 - 0.38

Test Method	Units	Test Soil	Actual Value	Acceptance Criteria [Range]
DTPA-Cu	mg/kg	SB		2.37 - 3.25
DTPA-Zn	mg/kg	SB		3.15 - 3.81
DTPA-Mn	mg/kg	SB		97.7 - 149.0
DTPA-Fe	mg/kg	SB		24.3 - 32.6
0.33 Bar	%	G		32 - 51
15 Bar	%	G		23 - 30
Ca (Exch. cations)pH8.5	meq/100g	S12		27.7 - 35.4
Mg (Exch. cations)pH8.5	meq/100g	S12		22.88 - 24.5
Na (Exch. cations)pH8.5	meq/100g	S12		2.0 - 2.28
K (Exch. cations)pH8.5	meq/100g	S12		1.64 - 2.09

GT Environmental
ECe and Base status / class calulations

ESSA Ref	field ref	Soil EC	ConV Fac	ECe		Exch.Ca	Exch. Mg	Exch.K	Exch. Na	Sum	x 100	/ Clay %	Base Status	Base Class
	depth (m)	dS/m				meq/100g	meq/100g	meq/100g	meq/100g		100			
i4919/1	**1-0.00-0.10**	0.034	22.7	0.761		5.12	2.86	0.59	0.14	8.71	871.03	25.00	34.84	Euro
i4919/2	**1-0.15-0.35**	0.060	8.6	0.517		13.53	10.59	0.56	1.62	26.29	2629.39	25.00	105.18	Euro
i4919/3	**1-0.40-0.60**	0.240	8.6	2.065		5.78	9.22	0.48	2.12	17.60	1760.37	25.00	70.41	Euro
i4919/4	**1-0.60-0.75**	0.590	9.5	5.609		4.61	9.17	0.19	2.56	16.53	1653.39	25.00	66.14	Euro
i4919/5	**2-0.00-0.10**	0.064	9.5	0.612		15.91	9.08	1.19	0.10	26.29	2629.24	25.00	105.17	Euro
i4919/6	**2-0.10-0.30**	0.038	8.6	0.326		11.02	5.71	0.50	0.10	17.33	1732.92	35.00	49.51	Euro
i4919/7	**2-0.30-0.50**	0.025	8.6	0.217		11.88	5.20	0.48	0.11	17.68	1767.92	35.00	50.51	Euro
i4919/8	**2-0.50-0.60**	0.032	13.8	0.446		16.22	5.66	0.36	0.14	22.38	2237.65	35.00	63.93	Euro
i4919/9	**2-0.60-0.75**	0.030	13.8	0.408		15.41	5.04	0.29	0.14	20.89	2088.60	35.00	59.67	Euro
i4919/10	**3-0.00-0.10**	0.091	8.6	0.782		18.34	14.65	1.43	0.16	34.58	3458.35	30.00	115.28	Euro
i4919/11	**3-0.15-0.35**	0.037	8.6	0.315		21.25	16.29	0.38	0.38	38.30	3829.83	40.00	95.75	Euro
i4919/12	**3-0.30-0.60**	0.034	8.6	0.293		20.52	16.99	0.33	0.59	38.43	3843.07	47.00	81.77	Euro
i4919/13	**3-0.60-0.75**	0.045	7.5	0.336		14.82	11.83	<0.12	0.59	27.24	2724.10	47.00	57.96	Euro
i4919/14	**4-0.00-0.10**	0.087	9.5	0.825		6.37	5.32	1.39	0.13	13.20	1319.92	35.00	37.71	Euro
i4919/15	**4-0.15-0.30**	0.183	8.6	1.573		6.33	9.45	0.39	1.97	18.14	1814.05	35.00	51.83	Euro
i4919/16	**4-0.30-0.60**	1.152	8.6	9.905		4.38	9.46	<0.12	2.38	16.22	1621.96	40.00	40.55	Euro
i4919/17	**4-0.60-0.75**	1.482	8.6	12.748		3.85	10.37	0.18	2.88	17.28	1728.08	40.00	43.20	Euro
i4919/18	**5-0.00-0.05**	0.056	13.8	0.772		5.14	2.32	0.37	0.12					
i4919/19	**5-0.05-0.14**	0.238	9.5	2.262		8.10	10.03	0.20	1.96					
i4919/20	**5-0.15-0.30**	0.227	9.5	2.157		7.28	9.58	0.36	1.53					
i4919/21	**5-0.30-0.60**	0.375	8.6	3.227		5.14	9.42	0.26	1.74					
i4919/22	**5-0.60-0.75**	0.574	8.6	4.939		2.63	6.05	0.18	1.30					
i4919/23	**6-0.00-0.05**	0.078	13.8	1.070		18.09	6.03	0.56	0.13	24.81	2481.05	15.00	165.40	Euro
i4919/24	**6-0.05-0.15**	0.026	9.5	0.247		16.53	6.25	0.32	0.15	23.25	2325.42	25.00	93.02	Euro
i4919/25	**6-0.15-0.28**	0.026	9.5	0.247		16.71	6.76	0.27	0.09	23.84	2383.70	25.00	95.35	Euro
i4919/26	**6-0.30-0.60**	0.028	9.5	0.263		12.72	8.27	0.18	0.17	21.34	2134.35	25.00	85.37	Euro
i4919/27	**6-0.60-0.75**	0.035	9.5	0.334		12.80	13.77	0.17	0.73	27.48	2747.55	25.00	109.90	Euro
i4919/28	**7-0.00-0.10**	0.059	22.7	1.336		8.57	2.82	0.96	<0.065	12.34	1234.41	25.00	49.38	Euro
i4919/29	**7-0.10-0.30**	0.062	9.5	0.586		14.12	2.34	0.64	<0.065	17.10	1710.43	25.00	68.42	Euro
i4919/30	**7-0.30-0.50**	0.101	9.5	0.956		12.49	4.24	0.64	0.12	17.49	1748.59	25.00	69.94	Euro
i4919/31	**7-0.53-0.60**	0.100	7.5	0.747		10.44	4.91	0.67	0.10	16.12	1612.33	25.00	64.49	Euro
i4919/32	**7-0.60-0.75**	0.113	7.5	0.851		12.03	5.18	0.77	0.13	18.11	1810.92	25.00	72.44	Euro
i4919/33	**8-0.00-0.10**	0.100	22.7	2.268		15.56	7.55	1.65	0.15					
i4919/34	**8-0.15-0.30**	0.019	9.5	0.180		11.83	5.27	0.64	0.07					
i4919/35	**8-0.30-0.50**	0.016	22.7	0.370		13.90	5.49	0.41	0.09					
i4919/36	**8-0.50-0.60**	0.014	22.7	0.308		10.19	3.91	0.27	<0.065					
i4919/37	**8-0.60-0.75**	0.012	22.7	0.276		11.66	3.79	0.26	<0.065					
i4919/38	**9-0.00-0.10**	0.166	8.6	1.425		6.11	11.02	0.66	1.21					
i4919/39	**9-0.15-0.30**	0.217	7.5	1.628		6.27	15.56	0.26	3.44					
i4919/40	**9-0.30-0.60**	0.340	7.5	2.551		5.34	16.44	0.22	4.85					
i4919/41	**9-0.60-0.75**	0.457	7.5	3.429		2.83	13.62	0.28	4.78					
i4919/42	**10-0.00-0.10**	0.045	8.6	0.385		25.92	8.93	1.14	0.17	36.16	3615.80	25.00	144.63	Euro
i4919/43	**10-0.15-0.30**	0.033	8.6	0.286		27.12	13.03	0.35	0.10	40.60	4059.56	25.00	162.38	Euro
i4919/44	**10-0.32-0.47**	0.037	9.5	0.348		36.73	20.17	0.21	0.15	57.27	5726.65	25.00	229.07	Euro
i4919/45	**10-0.50-0.60**	0.033	9.5	0.313		43.60	25.28	0.20	0.21	69.28	6927.75	25.00	277.11	Euro
i4919/46	**10-0.60-0.75**	0.030	9.5	0.285		50.49	32.31	0.26	0.29	83.35	8335.36	25.00	333.41	Euro
i4919/47	**11-0.00-0.10**	0.169	9.5	1.606		7.63	9.01	0.54	0.18	17.36	1736.04	25.00	69.44	Euro
i4919/48	**11-0.10-0.40**	0.126	9.5	1.196		11.47	12.55	0.32	0.22	24.57	2456.51	25.00	98.26	Euro
i4919/49	**11-0.40-0.60**	0.175	8.6	1.506		7.86	14.56	0.25	0.62	23.29	2328.76	42.00	55.45	Euro
i4919/50	**11-0.60-0.75**	0.235	8.6	2.022		5.73	17.26	0.26	1.13	24.39	2438.99	42.00	58.07	Euro

i4919/51	**12-0.00-0.10**	0.040	8.6	0.348		21.43	13.75	0.60	0.30					
i4919/52	**12-0.10-0.30**	0.053	8.6	0.455		22.78	17.86	0.36	1.10					
i4919/53	**12-0.35-0.60**	0.150	8.6	1.294		17.96	16.75	0.31	1.37					
i4919/54	**12-0.60-0.75**	0.358	8.6	3.080		10.67	11.98	0.22	1.32					
i4919/55	**13-0.00-0.05**	0.157	8.6	1.352		10.13	5.98	0.89	0.25					
i4919/56	**13-0.05-0.15**	0.070	7.5	0.525		9.48	11.12	0.39	1.34					
i4919/57	**13-0.15-0.40**	0.216	7.5	1.621		5.27	7.97	0.21	1.55					
i4919/58	**13-0.50-0.60**	0.458	7.5	3.437		3.20	5.63	<0.12	1.01					
i4919/59	**13-0.60-0.75**	0.485	7.5	3.640		2.99	5.74	0.13	1.11					
i4919/60	**14-0.00-0.10**	0.042	8.6	0.359		11.19	14.75	0.25	0.56					
i4919/61	**14-0.15-0.30**	0.575	8.6	4.948		4.97	23.67	0.24	3.53					
i4919/62	**14-0.30-0.54**	0.779	8.6	6.695		6.60	28.48	0.21	4.10					
i4919/63	**14-0.54-0.60**	0.774	8.6	6.652		5.17	21.39	0.19	2.62					
i4919/64	**14-0.60-0.75**	0.781	8.6	6.712		3.81	16.74	0.26	2.34					
i4919/65	**15-0.00-0.10**	0.102	13.8	1.402		5.53	4.31	0.20	0.21	10.26	1026.01	42.00	24.43	Euro
i4919/66	**15-0.15-0.30**	0.113	9.5	1.075		4.90	6.92	0.32	1.66	13.79	1379.40	42.00	32.84	Euro
i4919/67	**15-0.30-0.45**	0.281	9.5	2.671		5.12	9.01	0.38	2.58	17.09	1709.20	42.00	40.70	Euro
i4919/68	**15-0.45-0.60**	0.403	9.5	3.831		6.10	11.51	0.44	3.30	21.36	2135.76	42.00	50.85	Euro
i4919/69	**15-0.60-0.75**	0.102	9.5	0.966		7.47	12.05	0.64	0.82	20.99	2098.50	42.00	49.96	Euro
i4919/70	**16-0.00-0.10**	0.104	8.6	0.897		7.04	11.77	0.63	0.76					
i4919/71	**16-0.10-0.25**	0.079	8.6	0.682		8.23	15.11	0.19	2.02					
i4919/72	**16-0.25-0.50**	0.297	8.6	2.555		4.28	16.12	0.15	3.85					
i4919/73	**16-0.50-0.60**	0.486	8.6	4.182		2.67	14.67	0.14	4.56					
i4919/74	**16-0.60-0.75**	0.538	7.5	4.037		1.36	12.02	0.14	4.88					
i4919/75	**17-0.00-0.10**	0.093	8.6	0.800		13.14	14.25	1.39	0.61					
i4919/76	**17-0.10-0.30**	0.306	8.6	2.633		4.17	7.42	0.62	1.28					
i4919/77	**17-0.30-0.60**	0.813	8.6	6.988		2.23	5.57	0.58	1.63					
i4919/78	**17-0.60-0.75**	0.960	8.6	8.253		5.46	16.52	0.59	7.26					
i4919/79	**19-0.00-0.10**	0.044	8.6	0.380		9.59	9.85	0.71	0.56					
i4919/80	**19-0.15-0.30**	0.161	8.6	1.386		11.39	15.50	0.34	2.86					
i4919/81	**19-0.40-0.60**	0.719	8.6	6.187		5.02	8.86	0.52	2.05					
i4919/82	**19-0.60-0.75**	1.083	8.6	9.312		5.12	12.75	0.54	4.14					
i4919/83	**20-0.00-0.10**	0.188	8.6	1.617		7.77	10.94	1.26	0.57					
i4919/84	**20-0.15-0.30**	0.082	7.5	0.613		5.59	17.65	0.57	1.71					
i4919/85	**20-0.40-0.60**	0.205	7.5	1.538		9.23	24.14	0.60	3.03					
i4919/86	**20-0.60-0.75**	0.254	7.5	1.906		6.53	24.27	0.59	3.32					
i4919/87	**21-0.00-0.10**	0.061	88.6	5.436		13.21	10.56	0.68	0.18					
i4919/88	**21-0.15-0.35**	0.071	8.6	0.609		12.43	17.53	0.70	1.37					
i4919/89	**21-0.42-0.60**	0.186	7.5	1.398		11.68	15.11	0.76	0.88					
i4919/90	**21-0.60-0.75**	0.260	7.5	1.951		10.57	17.25	0.89	2.58					
i4919/91	**22-0.00-0.10**	0.016	22.7	0.359		2.01	0.61	<0.12	<0.065					
i4919/92	**22-0.15-0.30**	0.018	22.7	0.399		0.78	0.41	<0.12	<0.065					
i4919/93	**22-0.40-0.60**	0.011	22.7	0.250		0.32	0.25	<0.12	<0.065					
i4919/94	**22-0.60-0.75**	0.004	22.7	0.088		0.18	0.16	<0.12	<0.065					

1. All results presented as a 40°C oven dried weight. Soil sieved and lightly crushed to < 2 mm.
2. Methods from Rayment and Lyons, 2011. *Soil Chemical Methods - Australasia.* CSIRO Publishing: Collingwood.
3.Symbol .. In cell = Not Analysed - Cation Method 15C1 = Alcoholic with prewash