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V3

Marulan South Limestone Mine Continued Operations
State Significant Development Application

ENVIRONMENTAL IMPACT STATEMENT

Prepared for Boral Cement Limited | March 2019

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Groundwater assessment

VOLUME 3

Australasian Groundwater and
Environmental Consultants Pty Ltd

Report on

Marulan South Limestone Mine Continued Operations Groundwater Technical Study

Prepared for
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Executive summary

Boral Cement Limited (Boral) owns and operates the Marulan South Limestone Mine (the Mine). It is a long standing open cut mine that has produced up to 3.38 million tonnes of limestone and lime based products per year for the cement, steel, agricultural, construction and commercial markets. The mine is located in Marulan South, 10 kilometres (km) southeast of Marulan village and 35 km east of Goulburn, within the Goulburn Mulwaree Local Government Area (LGA) in the Southern Tablelands of NSW.

Due to changes between the NSW *Mining Act 1992* and the *Environmental Planning & Assessment Act 1979* (EP&A Act), when mining moves beyond the area covered by the current Mining Operations Plan (MOP), a development consent under the EP&A Act will need to be in place.

Boral is seeking approval including a 30 year mine plan, associated overburden emplacement areas and a mine water supply dam. The Project is a State Significant Development (SSD) for which an environmental assessment is required in accordance with NSW Government policies and the Department of Planning and Environment (DP&E) Secretary's Environmental Assessment Requirements (SEARs), and the Aquifer Interference Policy (AIP). The SEARs specify a groundwater impact assessment is required. Therefore, an assessment of the potential groundwater impact of the proposed mining activities is the focus of this document. The assessment addresses water licensing requirements, including consideration of proposed activities to operate within relevant Water Sharing Plan (WSP) rules and available allocations.

Aims

Australasian Groundwater and Environmental Consultants Pty Ltd (AGE) was commissioned by Boral to undertake an impact assessment of groundwater in support of the Environmental Impact Assessment (EIS) for the proposed development. Specifically, this report assesses whether the proposed development is likely to have a significant impact on the groundwater system surrounding and under the proposed Project area. It assesses the predicted take of groundwater from alluvial and consolidated strata water sources, potential impact to water users including groundwater dependent ecosystems (GDEs) and identifies the impact to the groundwater regime at the end of mining and post mining.

Results

The Marulan South Limestone deposit lies within the Lachlan Geosynclinal Province. The formations include Ordovician age turbidities and shales, Siluro-Devonian marine limestone, shale and sandstones; and Early Devonian intrusive/extrusive volcanics and intrusive granitoids. There are two sources of groundwater within the Project area which include shallow, unconsolidated aquifers and deep, consolidated aquifers. The shallow unconsolidated aquifer is mainly within the weathered zone where the groundwater exists in the pore spaces within the sediment or regolith. Groundwater within the deep, bedrock aquifer exists mainly in rock fractures caused by geologic and structural movement, associated with intrusive volcanic or dissolution of limestone. The assessment has identified that groundwater:

- Is used as a rural water supply for livestock and domestic purposes in the neighbouring areas surrounding the Project site.
- Water levels are typically buffered by the weathered, regolith layer, except within the pit where responses to rainfall are more pronounced.
- Groundwater quality is typically neutral to slightly alkaline and fresh to slightly brackish.
- The ionic composition of the groundwater identifies three distinct groundwater types that are dominated by magnesium-potassium-sodium-bicarbonate, magnesium-potassium-sodium-chloride, and calcium-bicarbonate dominant waters.

- Age dating indicates the groundwater from the limestone at the mine is young water less than 100 years old, and the dominant recharge source is from direct rainfall and overland flow from up-gradient catchments.
- Isotopes were not collected from within the deep aquifer of the limestone bearing zone.
- The relatively high permeability of the pit floor between 0.5 m/day and 1.25 m/day is likely to be enhanced by the steep dip of the limestone strata in most of the Project area.
- Groundwater levels indicate the regional groundwater flow direction being to the east-south-east towards Bungonia and Barber's Creeks. Locally, groundwater movement is dominated by flow into Marulan South Limestone Mine, which then flows southwards into Bungonia Creek.
- A conceptual groundwater model was developed for the Project which was then used to inform development of the numerical groundwater flow model.

Assessment of impacts

The numerical model was developed to assess the impacts of the Project on the surrounding groundwater environment, including the groundwater take from the alluvial and fractured/sedimentary rock water sources, baseflow reduction, influence on GDEs and groundwater licensing requirements. A Class 2, MODFLOW-USG groundwater flow model was used to assess impacts from the Project. The numerical model assessed the limestone is mostly pre-drained from the various interconnected fracture systems with predicted inflows during the Project ranging from 7 ML/year to 22 ML/year.

The numerical model predicts only a slight increase in pit inflows from the larger Project mine pit as mining occurs in essentially 'dry' limestone from which groundwater is only removed from groundwater contained in the porous spaces of the limestone.

The predicted groundwater drawdown extent at the end of mining is more extensive within the upper North Pit area and along the eastern edge of the pit. The 1 m drawdown contour extends approximately 620 m to the northeast from the northern edge of the pit and approximately 290 m from the eastern edge of the current mine pit. None of the identified groundwater users are predicted to be impacted by the Project. The post mining equilibrium drawdown predicts impact will continue to expand away from the void up to 1.2 km to the northeast into the granodiorite and approximately 600 m to the east and west into the sediments and metamorphics.

The eastern slopes towards Barbers Creek and southern slopes towards Bungonia gorge are classified as having high potential for groundwater interactions, while the plateau zone west of the existing pit is classified as having low potential for interaction with groundwater. Based on the field survey undertaken by Niche (2015), predicted groundwater drawdown from the Project is unlikely to impact on mapped GDEs along Bungonia Creek and Barbers Creek. Similarly, springs identified at the base of the steep slopes of Bungonia Gorge are unlikely to be impacted as the recharge through the pit floor will continue to recharge the limestone and the springs.

Impacts to groundwater quality are not anticipated as the recharge mechanism to the limestone will not be altered significantly suggesting groundwater quality will remain unchanged. Geochemical assessment indicates that the overburden rock and limestone mined at the site will have a minimal, if not negligible, impact on the downstream groundwater quality.

An option for obtaining a groundwater supply from the area between Marulan Mine and Peppertree Quarry was explored using six pumping wells. The numerical model predicts an initial pumping rate at the start of groundwater abstraction around 80 ML/year, declining to 15 ML/year towards the end of mining activities. The net decline in groundwater abstraction suggests that a usable groundwater supply (which was tested at 300 ML/year), would not necessarily be available from a borefield located within the granodiorite aquifer.

Cumulative impacts resulting from groundwater abstraction from the Peppertree borefield and mining for the Project identified no groundwater users are predicted to be impacted.

The groundwater model predicts the impact from mining will be spatially constrained to the mined limestone body and the adjoining geological units that immediately surround the mine.

Management and mitigation measures

During the life of the mine, Boral will monitor groundwater to measure the potential extent and rate of depressurisation against model predictions. Recommendation is also provided for monitoring seepage from the overburden emplacements using the existing groundwater monitoring network. Groundwater monitoring is to include the following:

- water level monitoring;
- water quality monitoring;
- seepage from overburden emplacements;
- mine water seepage monitoring; and
- data management and reporting.

Management and mitigation strategies should include a robust surface and groundwater level and quality monitoring program, for all groundwater and surface water sources. Where monitoring indicates changes in groundwater levels and quality, and surface water discharge and quality deviate significantly from that predicted, mitigation measures will be implemented through design and operation of the water management system for the Project. Mitigation options should be addressed primarily through the design and operation of the water management system developed for the Project. The key objective is to minimise discharge into 'sensitive' environments. Depressurisation of groundwater surrounding the mine pits will result in groundwater gradients being directed towards the mine pit(s). Any seepage water reporting to the pit would be managed in accordance with the Surface Water Assessment which requires 'dirty' water to be *"retained in the sediment dams"* and *"transferred to one of the water storage dams"* for reuse in either limestone processing or dust suppression.

'Make good' arrangements with surrounding landholders are not considered necessary as the groundwater impact assessment does not predict any private bores will be impacted by drawdown greater than 1 m during the lifetime of the mine.

The implementation of the above mitigation strategies is expected to minimise the potential for groundwater impacts resulting from the Project.

Glossary of terms

Alluvium - sediment (gravel, sand, silt, clay) transported by water (i.e. deposits in a stream channel or floodplain).

Aquiclude - a low-permeability unit that forms either the upper or lower boundary of a ground-water flow system.

Aquifer - rock or sediment in a formation, group of formations, or part of a formation which is saturated and sufficiently permeable to transmit economic quantities of water to wells and springs.

Aquifer - confined - an aquifer that is overlain by a confining bed. The confining bed has a significantly lower hydraulic conductivity than the aquifer. The water level in a bore that penetrates a confined aquifer will rise to a level that is higher than the top of the aquifer.

Aquifer - perched - a region in the unsaturated zone where the soil may be locally saturated because it overlies a low-permeability unit.

Aquifer - semi-confined - an aquifer confined by a low-permeability layer that permits water to slowly flow through it. During pumping of the aquifer, recharge to the aquifer can occur across the confining layer. Also known as a leaky artesian or leaky confined aquifer.

Aquifer - unconfined - an aquifer in which there are no confining beds between the zone of saturation and the surface. There will be a water table in an unconfined aquifer. Water-table aquifer is a synonym.

Aquitard - a low-permeability unit than can store ground water and also transmit it slowly from one aquifer to another.

Anisotropy - having a physical hydraulic property which has a different value when measured in different directions

Artesian conditions - an aquifer is said to be artesian if the hydraulic head is so high that the water level rises above the elevation of the land surface

Barrier boundary - an aquifer-system boundary represented by a rock mass that is not a source of water.

Baseflow - part of stream flow that originates from ground water seeping into the stream.

Colluvium - sediment (gravel, sand, silt, clay) transported by gravity (i.e. deposits at the base of a slope).

Cone of depression - the depression in the water table around a well or excavation defining the area of influence of the well. Also known as cone of influence.

Discharge - the volume of water flowing in a stream or through an aquifer past a specific point in a given period of time.

Discharge Area - an area in which there are upward components of hydraulic head in the aquifer. Groundwater is flowing toward the surface in a discharge area and may escape as a spring, seep, or baseflow or by evaporation and transpiration.

Drawdown - a lowering of the water table of an unconfined aquifer or the potentiometric surface of a confined aquifer caused by pumping of ground water from wells or excavations.

Falling/rising head (slug) test - a test made by the instantaneous addition, or removal, of a known volume of water to or from a well. The subsequent well recovery is measured and analysed to provide a permeability value.

Groundwater - the water contained in interconnected pores or fractures located below the water table in an unconfined aquifer or located in a confined aquifer.

Groundwater flow - the movement of water through openings in sediment and rock; occurs in the zone of saturation.

Glossary of terms (continued)

Groundwater, perched - the water in an isolated, saturated zone located in the zone of aeration. It is the result of the presence of a layer of material of low hydraulic conductivity, called a perching bed. Perched ground water will have a perched water table.

Groundwater, unconfined - the water in an aquifer where there is a water table.

Heterogeneous - pertaining to a substance having different characteristics in different locations. A synonym is non-uniform.

Hydraulic conductivity - a measure of the rate at which water moves through a soil/rock mass. It is the volume of water that moves within a unit of time under a unit hydraulic gradient through a unit cross-sectional area that is perpendicular to the direction of flow.

Hydraulic gradient - the change in total head with a change in distance in a given direction. The direction is that which yields a maximum rate of decrease in head.

Hydrogeology - the study of the interrelationships of geologic materials and processes with water, especially ground water.

Infiltration - the flow of water downward from the land surface into and through the upper soil layers.

Limit of reporting - the lowest concentration (or amount) of analyte, that can be reported by a laboratory.

Model calibration - the process by which the independent variables of a digital computer model (such as hydraulic parameters) are varied in order to match values of modelled and measured dependent variable (such as a head).

Monitoring bore (piezometer) - a non-pumping well (bore), generally of small diameter that is used to measure the elevation of the water table or potentiometric surface. A piezometer generally has a short well screen through which water can enter.

Packer test - an aquifer test performed in an open borehole to determine rock permeability; the segment of the borehole to be tested is sealed off from the rest of the borehole by inflating seals, called packers, both above and below the segment.

Porosity - the ratio of the volume of void spaces in a rock or sediment to the total volume of the rock or sediment.

Potentiometric surface - a surface that represents the level to which water will rise in tightly cased wells. If the head varies significantly with depth in the aquifer, then there may be more than one potentiometric surface. The water table is a particular potentiometric surface for an unconfined aquifer.

Pumping test - a test made by pumping a well for a period of time and observing the response/change in hydraulic head in the aquifer in order to determine aquifer hydraulic characteristics.

Recharge area - an area in which there are downward components of hydraulic head in the aquifer. Infiltration moves downward into the deeper parts of an aquifer in a recharge area.

Recharge basin - a basin or pit excavated to provide a means of allowing water to soak into the ground at rates exceeding those that would occur naturally.

Recharge boundary - an aquifer system boundary that adds water to the aquifer. Streams and lakes are typically recharge boundaries.

Recharge well - a well specifically designed so that water can be pumped into an aquifer in order to recharge the ground-water reservoir.

Recovery - the rate at which the water level in a well rises after the pump has been shut off. It is the inverse of drawdown.

Glossary of terms (continued)

Rock, volcanic - An igneous rock formed when molten rock called lava cools on the earth's surface.

Specific yield - the ratio of the volume of water a rock or soil will yield by gravity drainage to the volume of the rock or soil. Gravity drainage may take many months to occur.

Storativity - the volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head. It is equal to the product of specific storage and aquifer thickness. In an unconfined aquifer, the storativity is equivalent to the specific yield. Also called storage coefficient.

Transmissivity - the rate at which water of a prevailing density and viscosity is transmitted through a unit width of an aquifer or confining bed under a unit hydraulic gradient. It is a function of properties of the liquid, the porous media, and the thickness of the porous media.

Unsaturated zone - the zone between the land surface and the water table. It includes the root zone, intermediate zone, and capillary fringe. The pore spaces contain water at less than atmospheric pressure, as well as air and other gases. Saturated bodies, such as perched ground water, may exist in the unsaturated zone. Also called zone of aeration and vadose zone.

Water budget - an evaluation of all the sources of supply and the corresponding discharges with respect to an aquifer or a drainage basin.

Well development - the process whereby a well (bore) is pumped or surged to remove any fine material that may be blocking the well screen or the aquifer outside the well screen.

Well screen - a tubular device with either slots, holes, gauze, or continuous-wire wrap; used at the end of a well casing to complete a well. The water enters the well through the well screen.

List of abbreviations

AGE	Australasian Groundwater and Environmental Consultants Pty Ltd
ALS	ALS Environmental Laboratories
BoM	Bureau of Meteorology
CAP	Catchment Action Plan
CRD	Cumulative Rainfall Departure
DEM	Digital elevation model
DP&E	NSW Department of Planning and Environment
EC	electrical conductivity
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency
DPI	Department of Primary Industries
GIA	Groundwater Impact Assessment
L/s	litres per second
LIDAR	Light detection and ranging
m	metres
m/day	metres per day
mE	Easting
mN	Northing
mg/L	milligram per litre
ML	megalitres
ML/yr	Megalitres per annum
ML/day	Megalitres per day
NATA	National Association of Testing Authorities
No.	number
NSW	New South Wales
NOW	NSW Office of Water
RMS	root mean square
SEARs	Secretary's Environmental Assessment Requirements
SRTM	Shuttle Radar Topography Mission
USG	Un-structured grid
VWP	Vibrating Wire Piezometer
WSP	Water Sharing Plan
%	percentage

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Report on

Marulan South Limestone Mine Continued Operations Groundwater Technical Study

1 Introduction

Boral Cement Limited (Boral) owns and operates the Marulan South Limestone Mine (the mine). It is a long-standing open cut mine that has produced up to 3.38 million tonnes of limestone based products per year for the cement, steel, agricultural, construction and commercial markets.

The mine is a strategically important asset for Boral, as it supplies the main ingredient for the manufacture of cement at Boral's Berrima Cement Works. This is also a strategically important operation for Sydney based consumers of these products as this represents around 60% of the cement sold in NSW and feeds into more than 30% of concrete sold in Sydney.

The mine operates under Consolidated Mining Lease No. 16 (CML 16), Mining Lease No. 1716, Environment Protection Licence (EPL) 944 and a combination of development consents issued by Goulburn Mulwaree Council and continuing use rights.

Due to changes between the Mining Act 1992 and the Environmental Planning & Assessment Act 1979 (EP&A Act), when mining moves beyond the area covered by the current Mining Operations Plan, a development consent under the EP&A Act will need to be in place.

An Environmental Impact Statement has been prepared by Element Environment Pty Ltd on behalf of Boral for submission to the Department of Planning and Environment to satisfy the provisions of Part 4 of the EP&A Act. Boral is seeking approval for continued operations at the site through a development application for a State Significant Development including a 30 year mine plan, associated overburden emplacement areas and a mine water supply dam (hereafter referred to as 'the Project').

2 Study objectives and scope

The objective of this study is to assess the potential groundwater impacts of the proposed mining activities as defined in the Project description (Section 3) against NSW Government policies and the Department of Planning and Environment (DP&E) Secretary's Environmental Assessment Requirements (SEARs). Section 4 introduces government legislation framework, relevant policies and guidelines, including SEARs issued by NSW DP&E and references to further information provided in Appendix A. Appendix A contains tables that present the requirements for the groundwater study requested from each government department to DP&E for consideration in SEARs issued for the Project and shows where each requirement was addressed within this report.

In order to achieve the groundwater study objectives, the following scope of services was undertaken:

- review and collate existing groundwater information and identify data gaps;
- review of relevant statutory requirements and development of impact assessment criteria;
- field work to gather additional data to support the assessment;
- identify and describe existing environment in the context of groundwater levels and quality (baseline conditions), relevant groundwater sources, groundwater dependent ecosystems (GDE's) and water users;
- develop a conceptual model of the groundwater system and interconnected surface water systems;
- develop a numerical model reflecting the conceptual model to assess the potential impacts including estimating:
    - groundwater takes from alluvial and consolidated strata water sources;
    - potential changes to baseflow in connected streams;
    - potential influence on water users including groundwater dependent ecosystems (GDEs);
    - predictions of during and post mining groundwater conditions;
    - predictions for potential cumulative impacts; and
    - water licensing requirements, including consideration of proposed activities to operate within relevant Water Sharing Plan (WSP) rules and available allocations.
- identify and recommend avoidance, mitigation and adaptive management and monitoring strategies to minimise potential groundwater impacts; and
- document the outcomes of the study in a technical report addressing the SEARs and the Aquifer Interference Policy (AIP) as part of the EIS.

3 Project

3.1 Site location

The mine is located in Marulan South, 10 km southeast of Marulan village and 35 km east of Goulburn, within the Goulburn Mulwaree Local Government Area in the Southern Tablelands of NSW (refer to Figure 3-1). Access is via Marulan South Road, which connects the mine and Boral's Peppertree Hard Rock Quarry (Peppertree Quarry) with the Hume Highway approximately 9 km to the northwest (Figure 3-2). Boral's private rail line connects the mine and Peppertree Quarry with the Main Southern Railway approximately 6 km to the north (Figure 3-2).

3.2 Land use and ownership

CML 16 (which encompasses ML 1716) covers an area of 616.5 hectares (ha), which includes land owned by Boral (approximately 475 ha), Crown Land (adjoining to the south and east) and five privately owned titles (Figure 3-3). There is also Boral owned land surrounding the mine that does not fall within CML 16.

Land use surrounding the mine is a mixture of extractive industry, grazing, rural residential, commercial/industrial and conservation.

The mine is separated from the Bungonia State Conservation Area to the south by Bungonia Creek and is separated from the Shoalhaven River and Morton National Park to the east by Barbers Creek.

Peppertree Quarry, owned by Boral Resources (NSW) Pty Limited, borders the mine to the north. The site of the former village of Marulan South is between the mine and Peppertree Quarry on land owned by Boral. The village was established principally to service the mine but has been uninhabited since the late 1990's. The majority of the village's infrastructure has been removed and only a village hall and former bowling club remains. The bowling club has been converted into administration offices for the mine and the hall is used by the mine services team.

A small number of rural landholdings surround the Boral properties to the north and west, including an agricultural lime manufacturing facility, fireworks storage facility, turkey farm and rural residential (a number of these properties are actively grazed). The main access for these properties is via Marulan South Road. Rural residential properties are also located to the northeast of the mine along Long Point Road. These properties are separated from the mine by the deep Barbers Creek gorge. Sensitive receivers are shown in Figure 3-3.

3.3 Zoning

The majority of the site is zoned RU1 - Primary Production zone under the Goulburn Mulwaree Local Environmental Plan (LEP) 2009 (Figure 3-4). Mining and extractive industries are permissible in this zone with consent.

The remaining area is zoned E3 - Environmental Management. Under this zone mining and extractive industries are prohibited development, although historically mining has occurred within these areas under "existing use rights" as mining and processing operations commenced well before the commencement of the Mulwaree Planning Scheme Ordinance (PSO) on 15 May 1970. Notwithstanding that both mining and extractive industries are prohibited in the E3 zone these activities are permissible pursuant to State Environmental Planning Policy (Mining, Petroleum Production and Extractive Industries) 2007 (SEPP). In accordance with Clause 7(1)(b)(i) of this SEPP mining can be carried out with consent in any zone which has agriculture as a permissible land use (with or without consent). Agriculture is permitted with consent in the E3 - Environmental Management zone under the Goulburn Mulwaree LEP 2009. Similarly, Clause 7(3)(a) of this SEPP makes it clear that extractive industries can be carried out with consent in any zone which has agriculture as a permissible land use (with or without consent). Therefore, both mining and extractive industries are land uses which can be carried out provided development consent is granted.

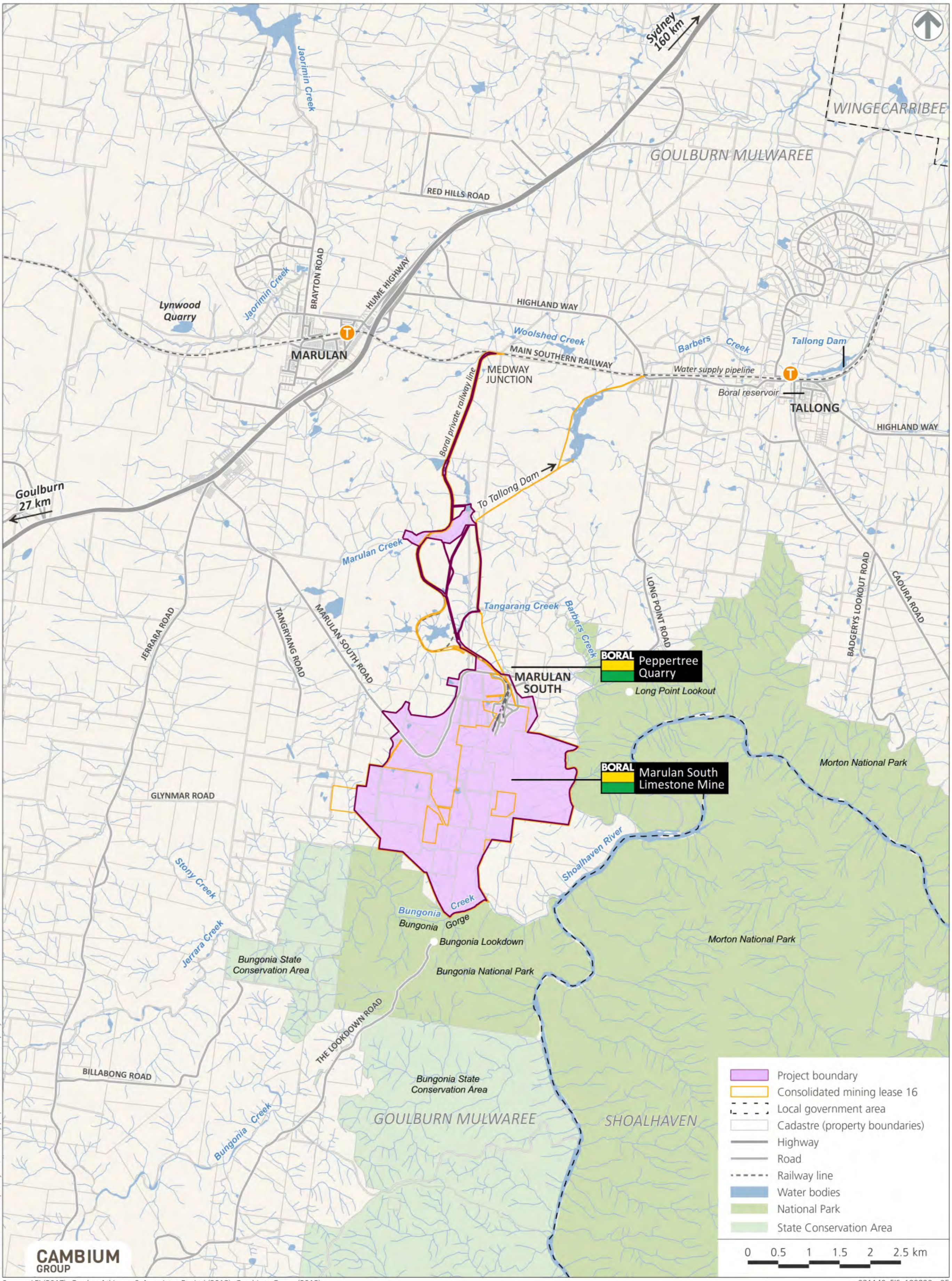
Boral operates the mine pursuant to Part 4, Division 4.11, Section 4.68 of the EP&A Act and the continuance of an existing use and its expansion is possible provided the necessary approvals are in place. Therefore, there are no environmental planning issues that would prohibit approval of expanded operations at the mine.

Importantly, the Project aims to improve the stability of existing overburden emplacements and improve rehabilitation outcomes over the entire site.

Figure 3-1

Regional context

MARULAN SOUTH LIMESTONE MINE CONTINUED OPERATIONS - SSD APPLICATION
ENVIRONMENTAL IMPACT STATEMENT



Source: LPI (2017), Gordon Atkinson & Associates Pty Ltd (2018), Cambium Group (2018).

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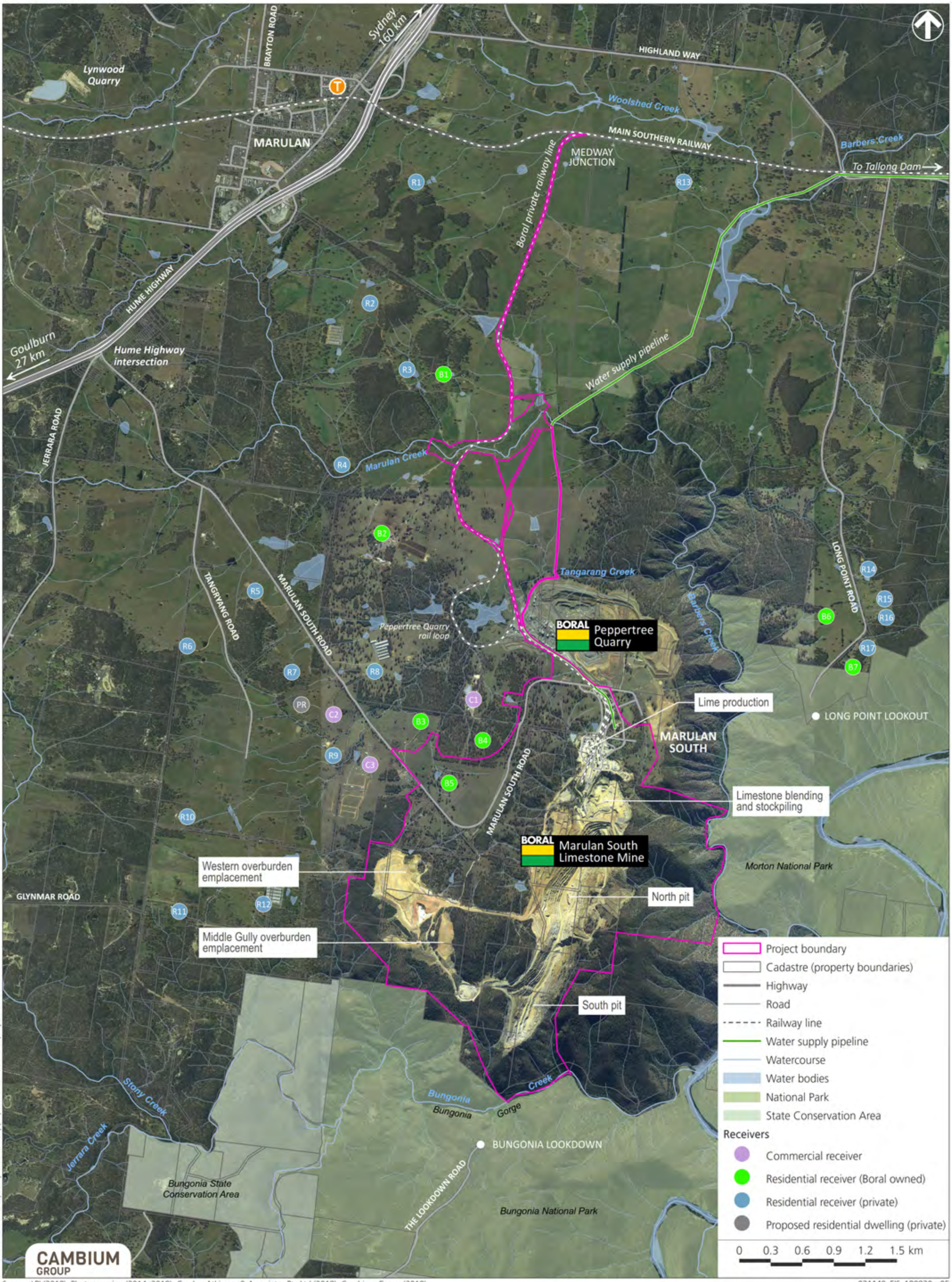
Figure 3-2

Local context

MARULAN SOUTH LIMESTONE MINE CONTINUED OPERATIONS - SSD APPLICATION
ENVIRONMENTAL IMPACT STATEMENT



Source: LPI (2018), Photomapping (2014, 2018), Gordon Atkinson & Associates Pty Ltd (2018), Cambium Group (2018).

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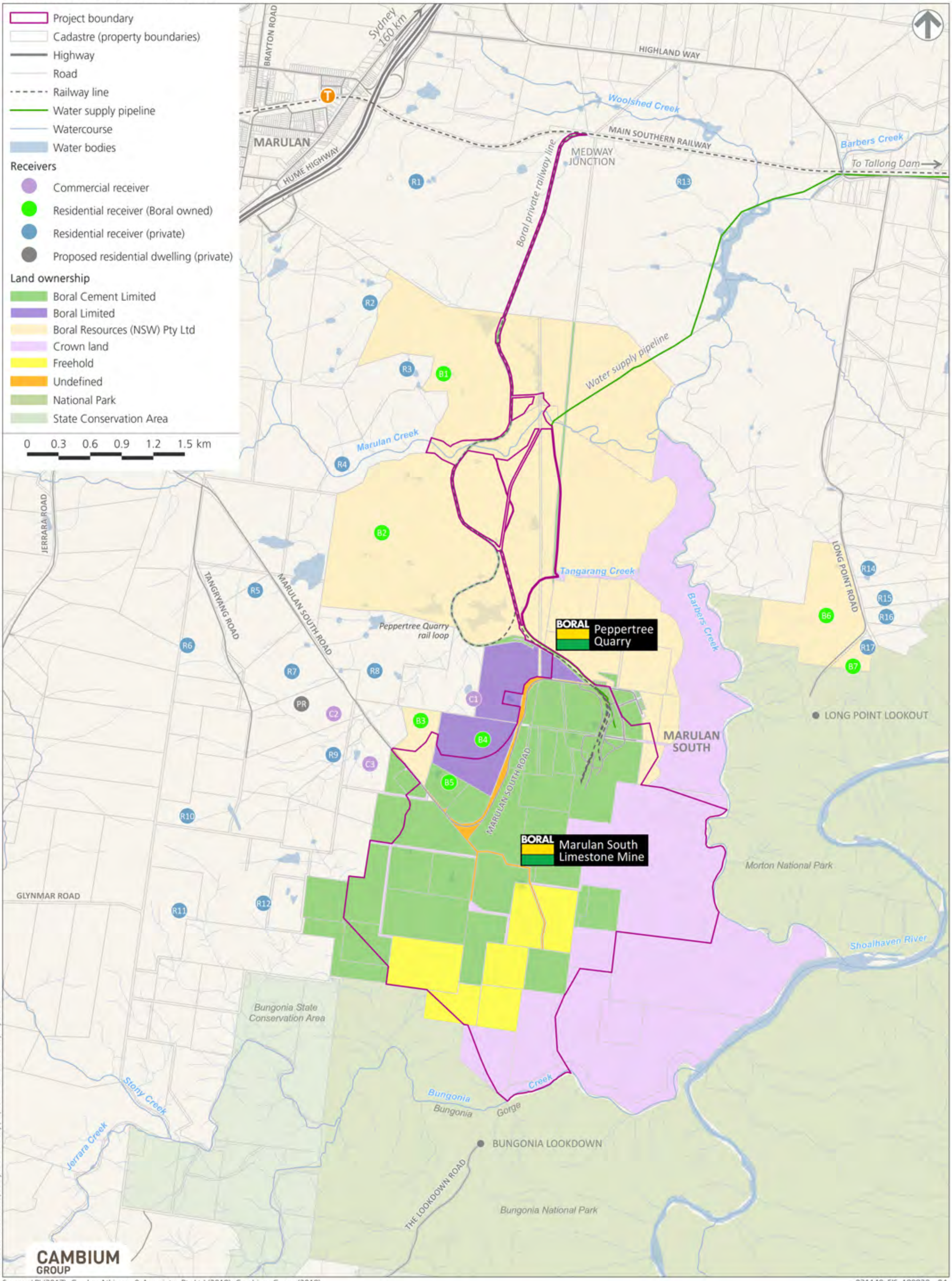
Figure 3-3

Land ownership

MARULAN SOUTH LIMESTONE MINE CONTINUED OPERATIONS - SSD APPLICATION
ENVIRONMENTAL IMPACT STATEMENT



Source: LPI (2017), Gordon Atkinson & Associates Pty Ltd (2018), Cambium Group (2018).

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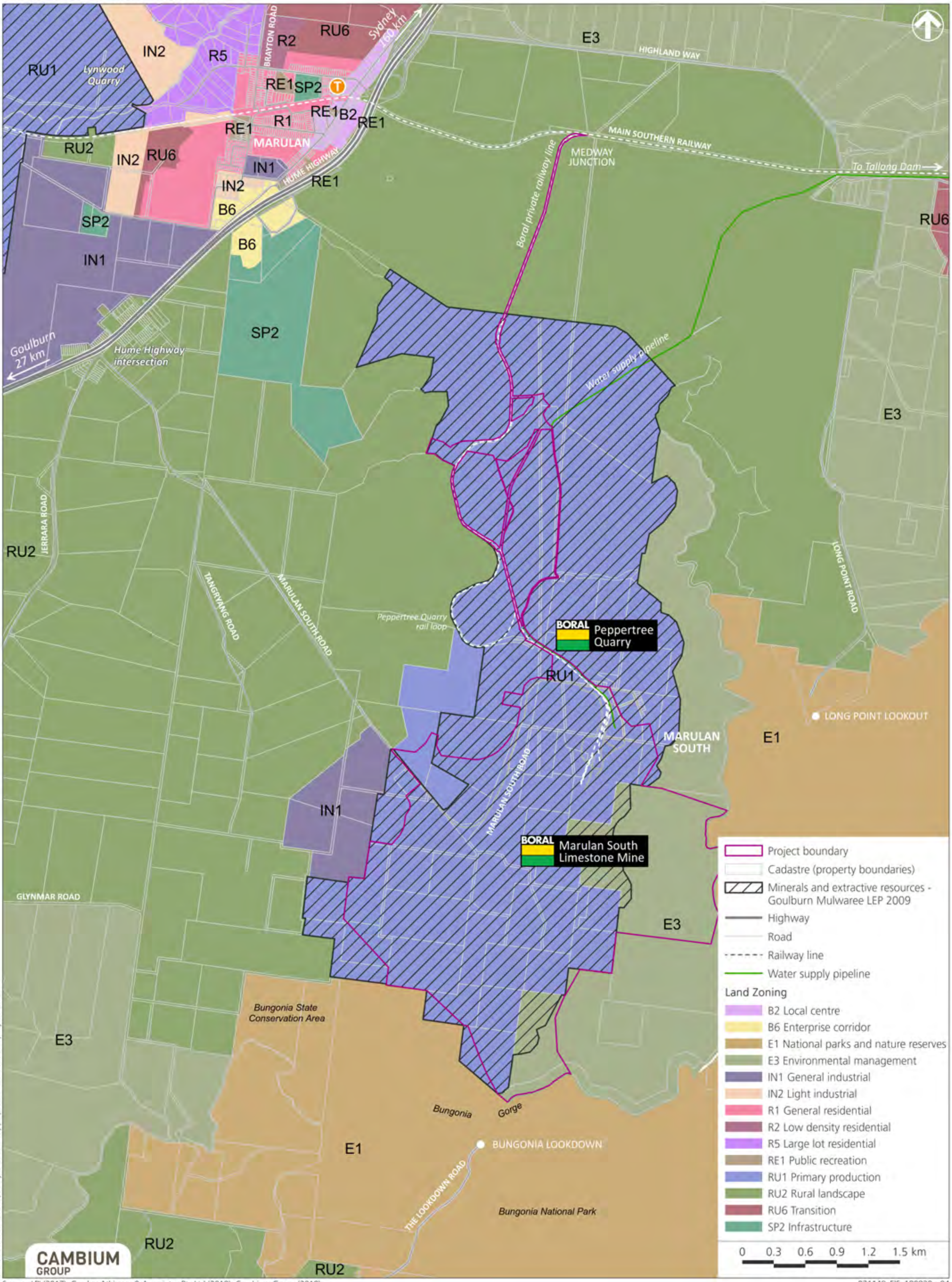
Figure 3-4

Land zoning

MARULAN SOUTH LIMESTONE MINE CONTINUED OPERATIONS - SSD APPLICATION
ENVIRONMENTAL IMPACT STATEMENT



Source: LPI (2017), Gordon Atkinson & Associates Pty Ltd (2018), Cambium Group (2018).

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3.4 Topography and drainage

The Southern Highlands, similar to the Blue Mountains to the north-west, are predominantly comprised of a level plateau with the occasional high intrusive volcanic remnant mountains, such as Mount Jellore, Mount Gibraltar and Mount Gingenbullen. On the seaward side they decline into a steep escarpment that is heavily divided by the headwaters of the Shoalhaven River.

The Project site and surrounds is characterised by the rolling hills of pasture and grazing lands (Figure 3-5) interspersed with woodland to the west, contrasting with the heavily wooded, deep gorges that begin abruptly to the east of the mine, forming part of the Great Escarpment and catchment of the Shoalhaven River (Figure 3-6). As such, local relief of Marulan South ranges from around 130 m Australian Height Datum (AHD) to over 630 m AHD.

The Project site is drained by a number of minor ephemeral drainage lines into Barbers Creek to the east and Bungonia Creek to the south. These creeks are tributaries of the Shoalhaven River, which is 1.5 km from the mine (at its closest point) and flows eastwards into Lake Yarrunga, approximately 20 km downstream and enters the Pacific Ocean approximately 15 km east of Nowra (approximately 100 km downstream).

3.5 Climate

The mine is in Australia's cool temperate climatic region, which is characterised by mild to warm summers and cold winters, with common frost and occasional snow fall.

Long term climatic data was obtained from the Bureau of Meteorology (BoM) automatic weather station at Goulburn Airport, approximately 25 km west-southwest of the mine. The BoM weather station shows that January is the hottest month with a mean maximum temperature of 27.9 degrees Celsius (ºC) and July is the coldest month with a mean minimum temperature of 0.3ºC.

Average annual rainfall is 551.9 mm. Rainfall peaks during the summer and the month of June. June is the wettest month with an average rainfall of 60.9 mm over 7.0 days and April is the driest month with an average rainfall of 25.6 mm over 4.0 days.

Relative humidity levels exhibit variability and seasonal flux across the year. Mean 9am relative humidity levels range from 65% in October and December to 88% in June. Mean 3pm relative humidity levels vary from 39% in December to 63% in June. Wind direction is predominantly from the west in winter and from the east in summer.

Wind speeds have a generally similar spread between the 9am and 3pm conditions. The mean 9am wind speeds range from 12.2 km/h in March to 19.8km/h in September. The mean 3pm wind speeds vary from 19.8km/h in April to 26.5km/h in August.

The climate, especially rainfall and evapotranspiration, is discussed in context of its contribution to hydraulic processes in more detail in Section 6.

3.6 Existing on-site operations

The mine is sited on a high grade limestone resource. Subject to market demand the mine has typically produced 3 million to 3.38 million tonnes of limestone and 120,000 tonnes to 200,000 tonnes of shale per annum.

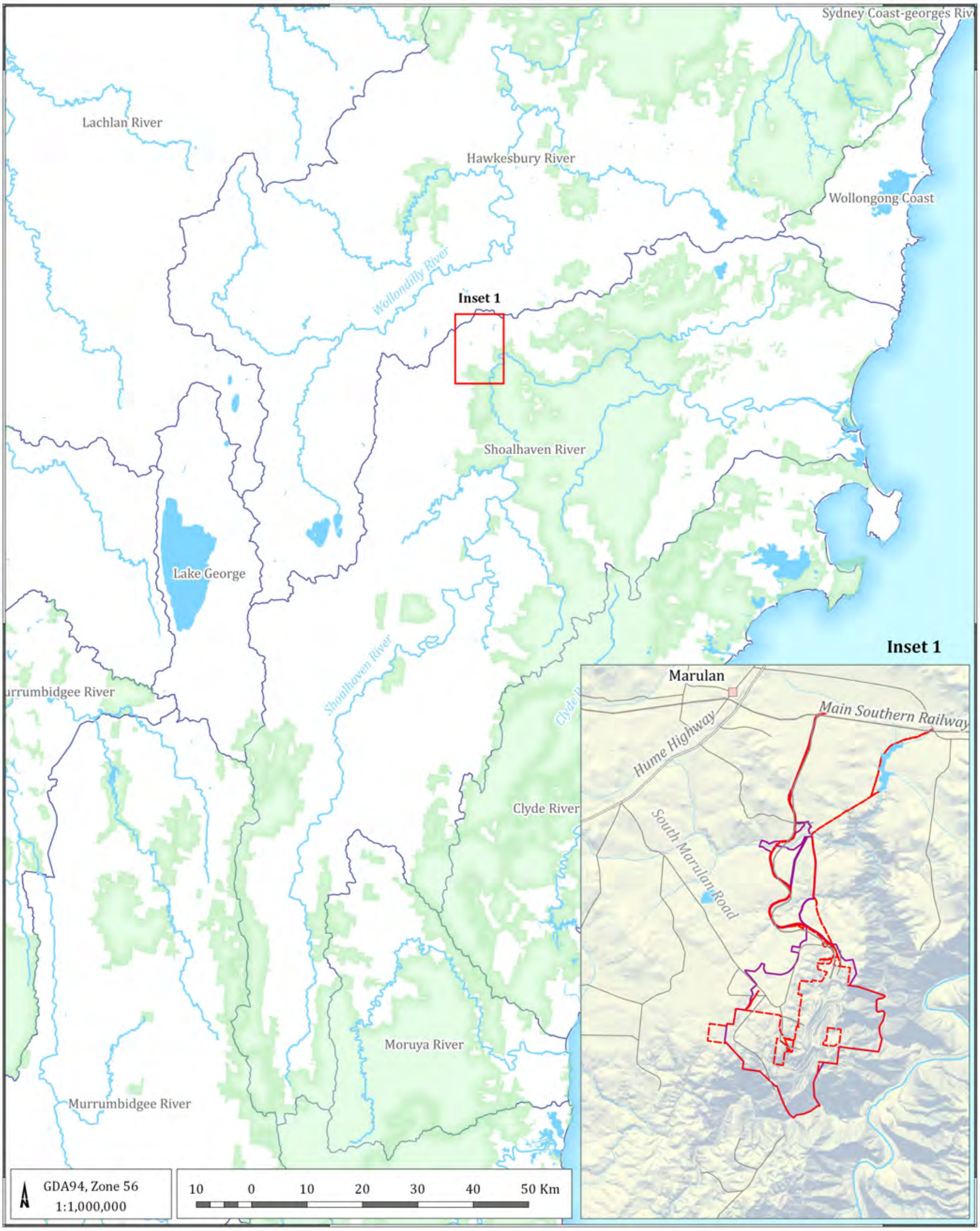
The mine currently produces a range of limestone products for internal and external customers in the Southern Highlands/Tablelands, the Illawarra and Metropolitan Sydney markets for use primarily in cement and lime manufacture, steel making, agriculture and other commercial uses. Products produced at the mine are despatched by road and rail, with the majority despatched by rail.

Historically limestone mining was focused on the approximately 200 m to 300 m wide Eastern Limestone and was split between a North Pit and a South Pit. A limestone wall (referred to by the mine as the 'centre ridge') rising almost to the original land surface, divided the two pits. The North and South Pits were recently joined in 2016/2017 by mining the centre ridge to form a single contiguous pit, approximately 2 km in length. However, the North Pit/South Pit nomenclature remains important as current mining operation locations continue to be reported with respect to one or other of the old pits.

Limestone and shale are extracted using open-cut hard rock drill and blast techniques. Material is loaded using front end loaders and hauled to either stockpiles or the processing plant using haul trucks. Oversized material is stockpiled and reduced in size using a hydraulic hammer attached to an excavator.

Limestone processing facilities including primary and secondary crushing, screening, conveying and stockpiling plant and equipment are in the northern end of the North Pit. Kiln stone grade limestone is also processed on site through the existing lime plant comprising kiln stone stockpiles, rotary lime kiln, hydration plant and associated auxiliary conveying, processing, storage, despatch plant and equipment. Overburden from stripping operations is emplaced in the Western Overburden Emplacement, west of the open cut pits.

The current operations are 24 hour, 7 days per week with personnel employed on a series of 8 hour, 10 hour and 12 hour shifts to cover the different operational aspects of the mine. Blasting is restricted to daylight hours and on weekdays, excluding public holidays.



LEGEND

- Populated place
- Project boundary
- CML16
- River basin
- Nature reserve
- Water area
- Road
- Rail
- Watercourse, drainage

Marulan South COP (G1714C)

Shoalhaven River catchment

AGE

DATE

23/03/2018 **3-5**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:/Projects/G1714C.Marulan South COP/3_GIS/Workspaces/001_Deliverable1/03.05 G1714C Shoalhaven River catchment.qgs

Figure 3-6 View of relatively flat grazing land west of the Project site.

3.7 Proposed mine expansion

3.7.1 Mining operations

Boral proposes to continue mining limestone from the mine at a rate of up to 4 million tonnes per annum (mtpa) for a period of up to 30 years. This represents an increase in extraction rate from historic levels (peak of 3.38 mtpa) due to forecast increased demand from the construction industry. Shale will continue to be extracted at a rate of up to 200,000 tonnes per annum (tpa).

The proposed 30 year mine plan accesses approximately 120 million tonnes of limestone down to a depth of 335 m AHD. The mine footprint focuses on an expansion of the North Pit westwards to mine the Middle Limestone and to mine deeper into the Eastern Limestone. As the Middle Limestone lies approximately 70 m to 150 m west of the Eastern Limestone, the 30 year mine plan avoids mining where practical the interburden between these two limestone units thereby creating a smaller second, north-south oriented West Pit with a ridge remaining between. The North Pit will also be expanded southwards, encompassing part of the South Pit, leaving the remainder of the South Pit for overburden emplacement and a visual barrier (Figure 3-7).

In addition to mining approximately 5 million tonnes of shale, the extraction of the limestone requires the removal of approximately 108 million tonnes of overburden over the 30 year period. This material will be emplaced within existing and proposed overburden emplacement areas (Figure 3-7).

Limestone will continue to be mined using drilling and blasting methods. Shale will continue to be mined by excavator/front end loader. Limestone, shale and overburden will be transported to the primary crusher, stockpile areas and overburden emplacements respectively, using the load and haul fleet of trucks. Products produced at the mine will continue to be despatched by road and rail, with the majority despatched by rail.

The limestone sand plant produces a crushed and air classified limestone sand for use in concrete. The mine currently produces 500,000 tpa for Peppertree Quarry and propose to increase production of manufactured sand to approximately 1 million tpa.

Boral's adjoining Peppertree Quarry currently has approval to emplace some of its overburden in the South Pit mine void. As the South Pit is required for the emplacement of over 30 million tonnes of overburden from the mine after the removal of accessible limestone, Boral proposes to emplace up to 15 million tonnes of overburden from Peppertree Quarry within the Northern Overburden Emplacement (Figure 3-7).

3.7.2 Associated infrastructure

Processing

The existing facilities for processing limestone will continue to be utilised to produce a series of graded and blended limestone products that are despatched from site for use primarily in cement manufacture, steel making, commercial and agricultural applications.

Limestone processing facilities (Figure 3-7) include primary and secondary crushing, screening, conveying and stockpiling plant and equipment located north-west of the North Pit and extending to the tertiary crushing, screening, bin storage and despatch (rail and road) systems that form part of the main processing facilities.

Kiln stone grade limestone will also continue to be processed on site through the existing lime plant comprising kiln stone stockpiles, rotary lime kiln, hydration plant and associated auxiliary conveying, processing, storage, despatch plant and equipment.

Processing infrastructure and the reclaim and stockpile area at the northern end of the North Pit will be relocated during the life of the 30 year pit to enable full development of the mine plan. The timing and location of this is presented in the EIS.

Shale and white clay will not be processed and will be stockpiled directly from the pit, ready for dispatch by road to the Berrima and Maldon cement operations.

Water supply

Water supply for the Project, including dust suppression, processing activities and some non-potable amenities will be from existing and new on-site dams and a proposed new water supply dam on Marulan Creek (Figure 3-7 and Figure 3-8). This dam would be located on Boral owned land north of Peppertree Quarry and utilises Boral's adjoining Tallong water pipeline to transfer water to the mine. This dam would require the purchase of water entitlements.

Mine water demand will also be supplemented by Tallong Weir via the Tallong water pipeline.

Rail

No changes are proposed to the existing rail infrastructure. A 1.2 km long passing line was constructed at Medway Junction during construction of the Peppertree Quarry, which will also be used by the mine to enhance access to the Main Southern Railway.

Road

Road access from the mine to the Hume Highway is via Marulan South Road. The proposed Western Overburden Emplacement extends northwards over Marulan South Road. Boral propose to realign a section of Marulan South Road, to accommodate the northern portion of the proposed Western Overburden Emplacement (Figure 3-7).

All public roads within the former village of Marulan South as well as the section of Marulan South Road between Boral's operations and the entrance to the agricultural lime manufacturing facility will be de-proclaimed.

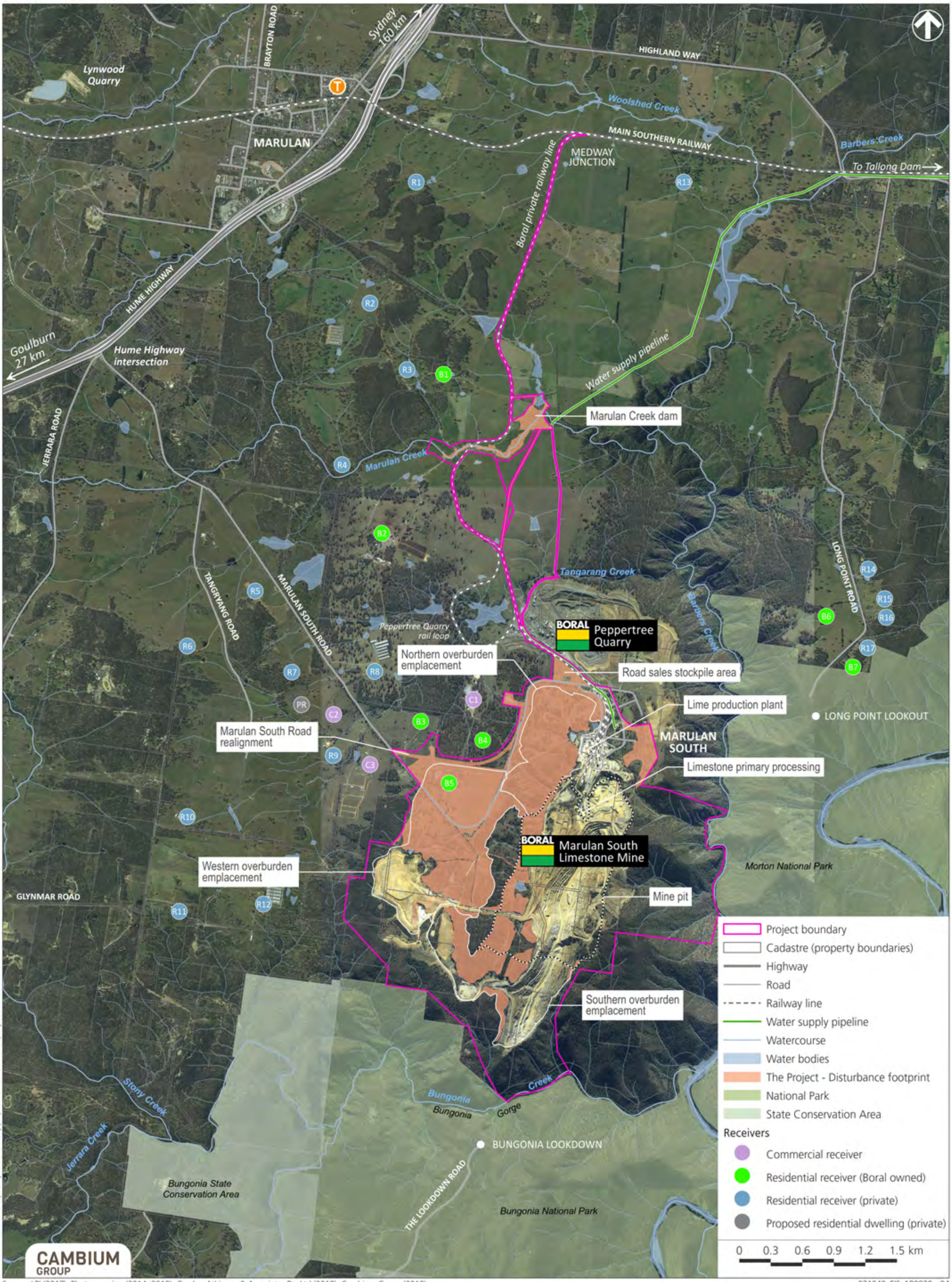
Power

Power supply to the mine is via a high voltage power line that commences at a sub-station on the southern side of Marulan South Road, immediately west of the Project boundary. A section of this power line will be relocated to accommodate the proposed Northern Overburden Emplacement (Figure 3-7).

Figure 3-7

The Project - Disturbance footprint

MARULAN SOUTH LIMESTONE MINE CONTINUED OPERATIONS - SSD APPLICATION
ENVIRONMENTAL IMPACT STATEMENT



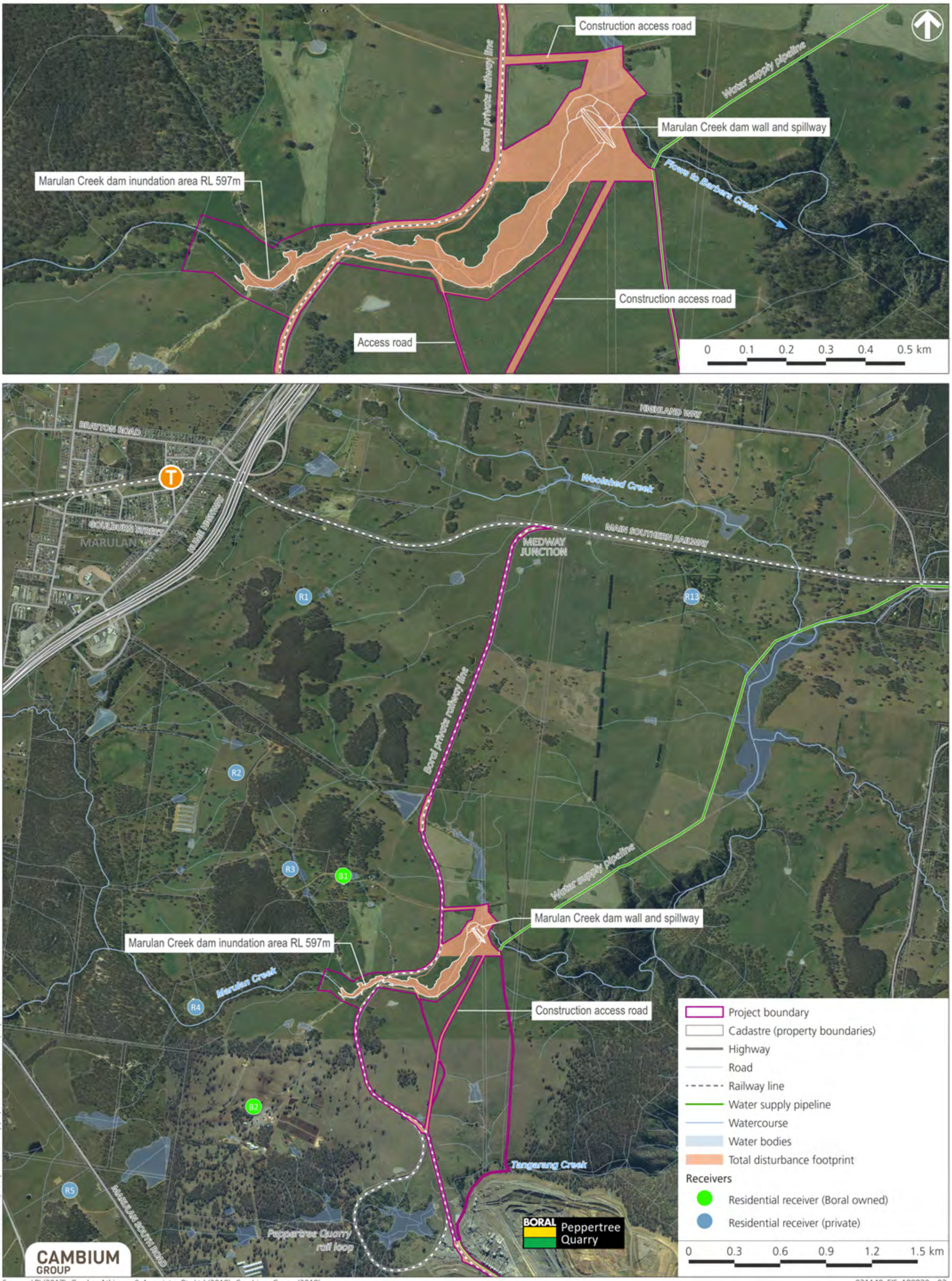
Source: LPI (2017), Photomapping (2014, 2018), Gordon Atkinson & Associates Pty Ltd (2018), Cambium Group (2018).

031040_EIS_180830_v04

Figure 3-8

Marulan Creek Dam - Disturbance footprint

MARULAN SOUTH LIMESTONE MINE CONTINUED OPERATIONS - SSD APPLICATION
ENVIRONMENTAL IMPACT STATEMENT



Source: LPI (2017), Gordon Atkinson & Associates Pty Ltd (2018), Cambium Group (2018).

031140_EIS_180830_v03

3.7.3 Transport

The majority of limestone products will continue to be transported to customers by rail for cement, steel, commercial and agricultural uses. Boral seeks no limitation on the volume of products transported by rail. Manufactured sand will continue to be transported by truck along a dedicated internal road, across Marulan South Road and into Peppertree Quarry for blending and dispatch by rail.

Agricultural lime, quick lime and fine limestone products will continue to be transported by powder tanker, bulk bags on trucks or open tipper trucks along Marulan South Road. Shale, limestone aggregates, sand and tertiary crushed products will be transported by predominantly truck and dog along Marulan South Road.

The adjoining Peppertree Quarry is currently approved to transport all products by rail. Boral will seek to transport approximately 150,000 tpa of Peppertree Quarry's products from the mine to customers via Marulan South Road. This could be achieved by back loading to a new shared road sales product stockpile area by the trucks carrying the limestone sand to Peppertree Quarry. A new shared road sales product stockpile area is proposed on the northern side of Marulan South Road, immediately west of the mine and Peppertree Quarry entrances (Figure 3-7). This shared finished product stockpile area, includes a weighbridge and wheel wash and will service both the mine and Peppertree Quarry.

In total, Boral is seeking to transport up to 600,000 tpa of limestone and hard rock products along Marulan South Road to the Hume Highway, as well as 120,000 tpa of limestone products to the agricultural lime manufacturing facility.

4 Regulatory framework, relevant policies and guidelines

4.1 NSW regulatory framework

4.1.1 Environmental Planning and Assessment Act (EP&A Act), 1979

The EP&A Act is administered by the NSW Department of Planning and Environment (DP&E) and provides the primary statutory framework in NSW for integrated planning and development under which development proposals are assessed and approved. The Project is a State Significant Development (SSD) listed under Schedule 1, Clause 5 of the State Environmental Planning Policy (State and Regional Development) 2011.

This report provides the results of a groundwater impact assessment in accordance with the environmental impact considerations under Part 4, Division 4.3, Section 4.12 of the EP&A Act.

4.1.2 Water Management Act 2000

The objectives of the NSW *Water Management Act 2000* (WM Act) include the sustainable and integrated management of the State's water for the benefit of both present and future generations. The WM Act provides clear arrangements for controlling land based activities that affect the quality and quantity of the State's water resources. Under the Act, without a licence it is an offence to take, remove or divert water from a water source, or relocate water from one part of an aquifer to another part of an aquifer, in the course of carrying out a mining activity (including exploration).

It provides for three types of approvals:

- management works approvals:
    - water supply work approval;
    - drainable work approval; and
    - flood work approval (Section 90 WM Act).
- water use approval – which authorises the use of water at a specified location for a particular purpose, for up to 10 years (Section 89 WM Act); and
- activity approvals comprising:
    - controlled activity approval; and
    - aquifer interference activity approval – which authorises the holder to conduct activities that affect an aquifer such as approval for activities that intersect groundwater, other than water supply bores and may be issued for up to 10 years (Section 91 WM Act).

The proposal to extend the existing mine footprint requires an 'aquifer interference activity approval'. This report addresses the items required for such an approval.

4.1.3 *Water NSW Act 2014*

The *Water NSW Act 2014* establishes and defines the objectives of Water NSW, as an amalgamation of the former Sydney Catchment Authority (SCA) and State Water. For this Project, the relevant objectives of the Act include:

- to ensure that declared catchment areas and water management works in such areas are managed and protected so as to promote water quality, the protection of public health and public safety, and the protection of the environment; and
- to conduct its operations in compliance with the principles of ecologically sustainable development.

Implementation of the Act to satisfy these objectives through related guidelines and water quality objectives for surface and groundwater is discussed further in Section 4.2.4.

4.2 Relevant policies, plans and guidelines

4.2.1 *Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources*

The main tool in the WM Act for managing the State's water resources are Water Sharing Plans (WSP). These are used to set out the rules for the sharing of water in a particular water source between water users and the environment and rules for the trading of water in a particular water source. Each source provides rules on access, managing water allocation, rules for the use and granting/amending of water supply works approvals, limitations to availability of water, and rules for trading of water.

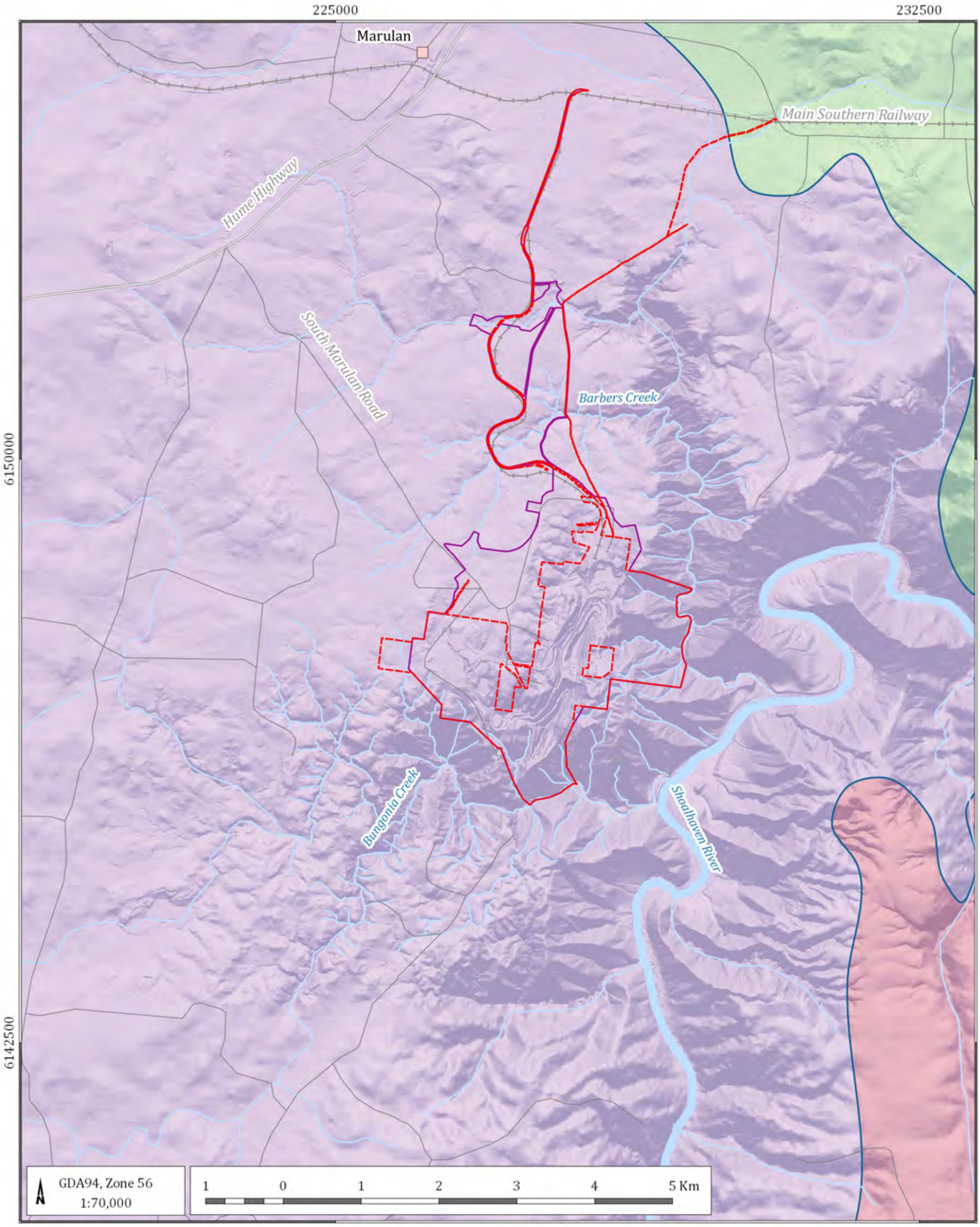
Groundwater in the Project area is managed under the Greater Metropolitan Region Groundwater Sources Water Sharing Plan (2011, referred to as 'the WSP'). The WSP covers 13 groundwater sources on the east coast of NSW, and divides the area into management zones based on geology and aquifer properties. The Project area is within the Goulburn Fractured Rock Groundwater Source (GFRGS, refer to Figure 4-1). The provisions in the plan are intended to provide water to support the ecological processes and environmental needs of high priority GDEs and rivers, and direct how the water available for extraction is to be shared. Water sharing is intended to protect the groundwater source and its dependent ecosystems through reserving portions of stored groundwater and recharge as planned environmental water, and establishing rules for the granting and amendment of water supply works approvals.

Under the WSP, groundwater extraction requires an authorisation under a water access licence or some form of exemption. This provision is exclusive of water extracted for basic landholder rights. Basic landholder rights include water for domestic and stock purposes extracted from a water source fronting a landholder's property or from any aquifer underlying the landholder's property, and for native title rights. Groundwater extracted for basic landholder rights does not require a licence; however, the bore must be approved by the NSW Office of Water (NOW).

Upon plan commencement, on 1 July 2011, the licensing provisions of the WM Act came into effect in the plan area. Licences issued under the NSW *Water Act 1912* (WA 1912) were converted to WM Act water access licences, and water supply works and use approvals.

Boral currently holds following licences for groundwater use on-site:

- *10WA116142* and *WAL24697* – for pumping from bores WP16 and WP17; allowed extraction of 12ML per annum for industrial purposes. DPI Water lists tenure type as continuing valid until 10 August 2024;
- bore monitoring licences *10BL605442-455* and *10BL605449-450* were obtained to facilitate installation and monitoring of 6 groundwater bores on 10 October 2013 in perpetuity; and
- bore monitoring licence *10BL605796* was obtained to facilitate installation and monitoring of a 7th groundwater bore on 26 August 2016 in perpetuity; and
- groundwater allocation of 838 ML granted on 27 September 2017 under licence *ROI17-1-061*.



LEGEND

- Populated place
- Project boundary
- CML16
- Road
- Rail
- Watercourse, drainage

Groundwater management areas

- Goulburn Fractured Rock Groundwater Source
- Sydney Basin - South Groundwater Source
- Sydney Basin Nepean Groundwater Source

Marulan South COP (G1714C)

Groundwater management areas, groundwater sources

AGE

DATE 23/03/2018

FIGURE No: **4-1**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:/Projects/G1714C.Marulan South COP/3_GIS/Workspaces/001_Deliverable1/04.01_G1714C Groundwater management areas, groundwater sources.qgs

4.2.2 Water Sharing Plan for the Greater Metropolitan Region Unregulated Water Sources

Surface water in the Project area is managed under the Water Sharing Plan for Greater Metropolitan Region Unregulated Water Sources (the plan) which commenced on 1 July 2012. The plan is broken down into zones with different rules, with the Project area within the Shoalhaven River Gorge Management Zone. The Shoalhaven River Gorge Management Zone includes the hydrological catchment of the Shoalhaven River between the confluence of the Shoalhaven River and the Mongarlowe River (26 km, NNW of Braidwood, NSW) and confluence of the Shoalhaven River and the Kangaroo River, including Tallowa Dam. The hydrological catchment of Barbers Creek is considered separate to that of the Shoalhaven River gorge, but managed under the same water sharing rules.

A licence holder's access to surface water is managed in the water sharing plan and management zone through the long-term average annual extraction limit which sets the total annual extraction rate through daily access rules. The long term limit is a management tool against which total extraction is monitored and managed over the 10-year life of the plan. The rules in the plan that determine when licence holders can and cannot pump on a daily basis are more specific. Basic landholder rights do not require a water access licence. Water access licences are required for mining activities where these activities intercept an unregulated river or connected aquifer water.

Currently, the site has following surface water use licences under the water sharing plan:

- Licences *10WA102352, WAL25352,* and *WAL25207* for extraction of 76ML from Tallong Weir (Barbers Creek) for mining and 1ML for domestic purposes; DPI Water lists tenure type as continuing valid until 30 June 2024; and
- Licences *10WA102377*, and *WAL25373* for extraction of 10ML for mining purposes from Barbers Creek; DPI Water lists tenure type as continuing valid until 25 April 2026.

4.2.3 Aquifer Interference Policy

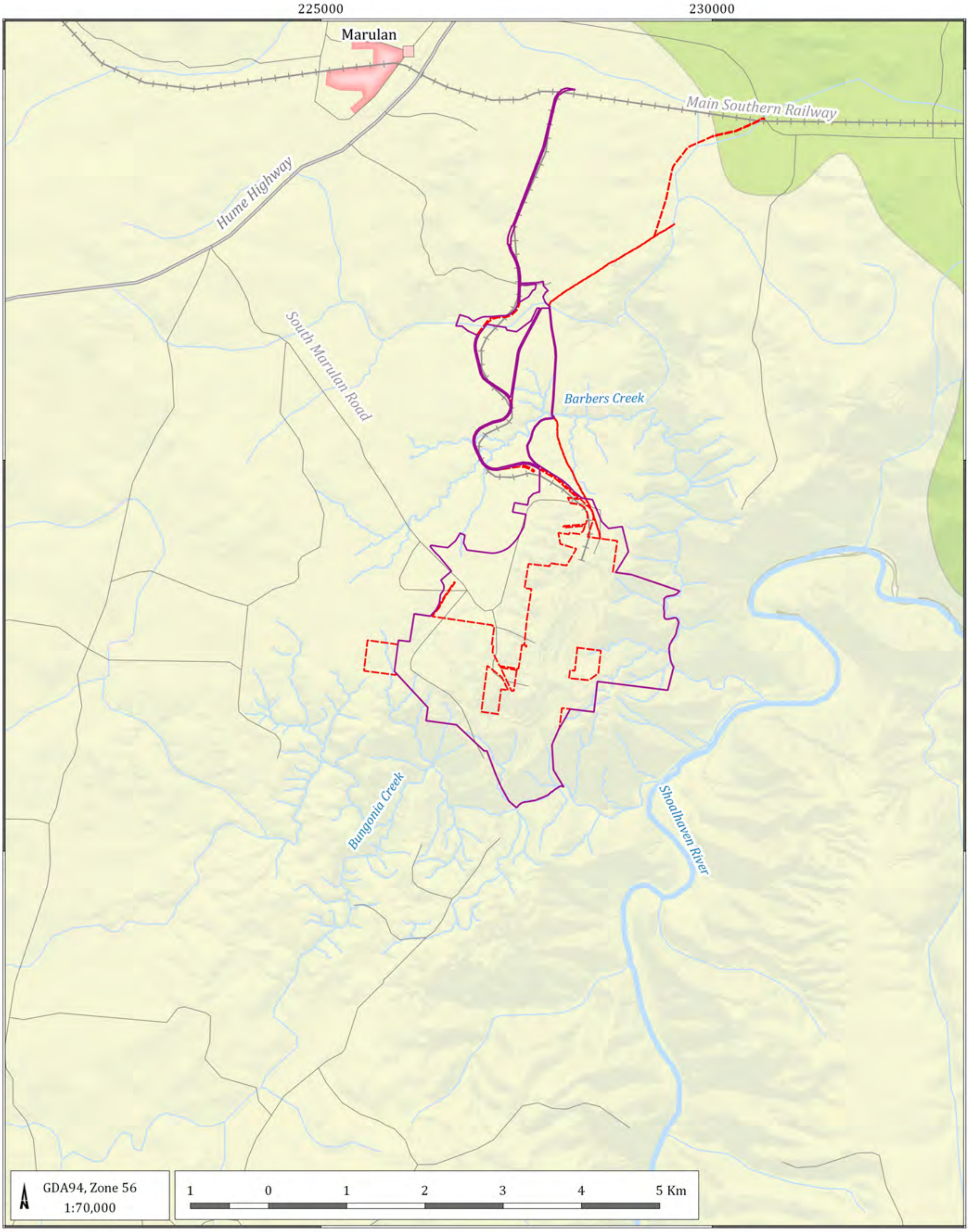
In September 2012, NOW (currently known as DPI Water) released the Aquifer Interference Policy (AIP) which covers water licensing and assessment processes for aquifer interference activities within NSW. The AIP was designed to address the 'incidental' take of groundwater from significant developments (i.e. including mines), which was not yet accounted for in the Water Act or WM Act. The AIP ensures that all groundwater is accounted for, in order for a water sharing plan to be implemented and function effectively and forms the basis for assessment of aquifer interference activities under the EP&A Act.

The AIP clarifies the need to hold water licences under the WM Act and establishes whether 'minimal impact' occurs. The policy addresses any activity which involves any of the following:

- penetration of an aquifer;
- interference with water in an aquifer;
- obstruction of the flow of water in an aquifer;
- taking of water from an aquifer in the course of carrying out mining or any other activity prescribed by the regulations; and
- disposal of water taken from an aquifer in the course of carrying out mining or any other activity prescribed by the regulations.

The AIP outlines highly productive and less productive groundwater sources, as well as high and minimal impact interference activities. As mentioned in Section 4.2.2, groundwater in the Project area forms part of the Goulburn Fractured Rock Groundwater Source (refer to Figure 4-1). The AIP classifies the Goulburn Fractured Rock as a less productive groundwater source (refer to Figure 4-2).

The closest highly productive aquifer is associated with Sydney Basin Nepean Groundwater Source and appears to comprise of talus, colluvium and weathered rock associated with the Permian-Triassic Sydney Basin units, including the Tallong Conglomerate and the Berry Siltstone. Due to the distance of the Project boundary to the highly productive aquifer/groundwater source (over 3 km to the east across highly varied and steep terrain), no impact on the highly productive aquifer is expected.



LEGEND

- Project boundary
- CML16
- Model boundary
- Road
- Rail

Groundwater productivity

- More productive
- Less productive

Marulan South COP (G1714C)

Regional AIP aquifer classification

AGE

DATE 23/03/2018

FIGURE No: **4-2**

4.2.4 SEPP (Sydney Drinking Water Catchment) 2011 and Water NSW NorBE Guidelines

Under the EP&A Act (Part 3, Division 3.2, Section 3.26), provision is to be made in a State Environmental Planning Policy (SEPP) requiring all development applications relating to any part of the Sydney drinking water catchment to have a neutral or beneficial effect on water quality (Water NSW, 2015).

SEPP (Sydney Drinking Water Catchment) 2011 was established to implement this obligation, and sets out the planning and assessment requirements for all new developments in the Sydney drinking water catchment to have a neutral or beneficial effect (NorBE) on water quality, incorporating Current Recommended Practices (CRPs) or performance standards relating to water quality endorsed/published by Water NSW (formerly Sydney Catchment Authority or SCA). Water NSW established guidelines defining NorBE for assessments of various classes of activities as discussed further below ("Neutral or Beneficial Effect on Water Quality Assessment Guideline", Water NSW, February 2015), supported by Current Recommended Practices.

A neutral or beneficial effect on water quality is satisfied if the development:

a) has no identifiable potential impact on water quality; or
b) will contain any water quality impact on the development site and prevent it from reaching any watercourse, water body or drainage depression on the site; or
c) will transfer any water quality impact outside the site where it is treated and disposed of to the standards approved by the consent authority.

Table A2 of the NorBE Guidelines (Water NSW, 2015) provides a checklist for identifying potential impact occurring to water quality for Project activities where:

- flow of water is concentrated on part of the site during construction or operation;
- flow of water is impeded on part of the site during construction or operation;
- proposed development during construction or operation will involve a discharge of effluent, dust, stormwater or other pollutants; and
- any other matter considered to result in an identifiable impact on water quality.

Minimum information requirements to assess development applications have been established by Water NSW (Developments in the Drinking Water Catchment – Water Quality Information Requirements, Feb 2015) which defines water quality as comprising both surface and groundwater in characterising the existing environment.

For the purposes of Water NSW and the above guidelines, the Project falls within Module 5, requiring referral to the Water NSW.

4.2.5 ANZECC Water Quality Guidelines (2000)

The Australian and New Zealand Environment Conservation Council (ANZECC) provides guidelines for fresh and marine water quality. The guidelines have been developed to assist government and the community with a framework for the conservation of water quality in our rivers, lakes, estuaries and marine waters. These guidelines are dependent on the catchment's environmental values or water quality objectives that form the long-term goals for assessing and managing impact from activities within the waterways. The preservation of these river and groundwater systems within the Shoalhaven catchment are therefore linked to the water sharing plans outlined in Section 4.2.2, which establish rules for sharing water between the environmental needs of the river or aquifer and water users.

4.2.6 Australian Groundwater Modelling Guidelines (2012)

The Australian Groundwater Modelling Guidelines were developed by the Natural Resource Commission (NRC) in 2012 to promote a consistent and sound approach to the development of groundwater flow and solute transport models in Australia. The guidelines seek to provide direction on the scope and approaches common to all modelling projects from conceptualization through calibration to evaluation of model performance. Australian Groundwater Modelling Guidelines were used as a reference during all phases of the Project groundwater flow model construction, calibration and prediction.

5 Geology

5.1 Regional geology

The Marulan South Limestone deposit lies within the Lachlan Geosynclinal Province. During the Palaeozoic Era (500 to 300 million years ago) thick sedimentary formations were laid down in the region. The formations include Ordovician age turbidities and shales, Siluro-Devonian marine limestone, shale and sandstones; and Early Devonian intrusive/extrusive volcanics and intrusive granitoids.

The Ordovician units are strongly deformed and dip steeply, with tight to isoclinal folds trending northeast–southwest. The overlying Siluro-Devonian and Devonian units consist of a number of generally parallel, north-south striking units which are dipping at 65 degrees to 85 degrees to the west. Table 5-1 below summarises the key stratigraphic units in the region. Figure 5-1 shows the Project site in context of regional geology.

The marine Bungonia Limestone Group was later folded and faulted by crustal collisions and then subsequently levelled by substantial erosion. About 65 million years ago the area was again uplifted, giving way to a rejuvenated river system leading to the landscape of today. The limestone formations around Marulan South consist of a number of generally parallel and north-south striking beds, including Mt. Frome limestone, sedimentary rocks, volcanic rocks and the Eastern Limestone.

The Eastern limestone has the highest grade and was therefore selected for the commencement of mining. The limestone is bound to the east by the older Tallong shale beds and to the west by the younger shales, volcanic tuff and the Mt. Frome limestone, the subject of the proposed mining expansion of the Project. A north-south and various east-west dolerite dykes intrude the limestone and the limestone bed is cut off in the north by the Glenrock Granodiorite intrusion, which is currently mined by Peppertree Quarry.

Table 5-1 Summary of regional geology

<table>
<tr><th>Age</th><th>Group</th><th>Formation</th><th>Member</th><th>Main rock type</th></tr>
<tr><td rowspan="10">Devonian</td><td rowspan="2">Arthursleigh Suite</td><td colspan="2">Marulan Granite</td><td>Granite</td></tr>
<tr><td colspan="2">Glenrock Granodiorite</td><td>Granodiorite</td></tr>
<tr><td rowspan="8">Bindook Group</td><td colspan="2">Barrallier Ignimbrite</td><td>Dacitic Ignimbrite</td></tr>
<tr><td rowspan="7">Tangarang Formation</td><td>Carne Dacite Member</td><td>Discrete bodies of dacite</td></tr>
<tr><td>Unnamed Member</td><td>Quartz rich sandstone tuffaceous locally</td></tr>
<tr><td>Kerrawarra Dacite Member</td><td>Dacite</td></tr>
<tr><td>Kerillon Tuff Member</td><td>Rhyolitic and dacitic volcanoclastics, tuffs and ignimbrites</td></tr>
<tr><td>Devil’s Pulpit Member</td><td>Volcanic breccia and sandstone</td></tr>
<tr><td>Unnamed Member</td><td>Silicic pyroclastic detritus</td></tr>
<tr><td></td><td></td></tr>
<tr><td rowspan="5">Siluro-Devonian</td><td rowspan="5">Bungonia Group</td><td rowspan="3">Frome Hill Formation</td><td>Sawtooth Ridge Limestone Member</td><td>Limestone – fossiliferous micrite</td></tr>
<tr><td>Efflux Siltstone Member</td><td>Siltstone and fine sandstones</td></tr>
<tr><td>Folly Point Limestone Member</td><td>Limestone – fossiliferous micrite</td></tr>
<tr><td colspan="2">Cardinal View Formation</td><td>Siltstone and fine sandstones</td></tr>
<tr><td colspan="2">Lookdown Limestone Formation</td><td>Limestone – fossiliferous</td></tr>
<tr><td rowspan="3">Ordovi-cian</td><td rowspan="2">Bendoc Group</td><td colspan="2">Warbisco Shale</td><td>Sandstone and siltstone with chert</td></tr>
<tr><td colspan="2">Bumbulla Formation</td><td>Quartose metasandstone and metasiltstone</td></tr>
<tr><td colspan="3">Adaminaby Group</td><td>Turbiditic siltstone and sandstone with chert</td></tr>
</table>

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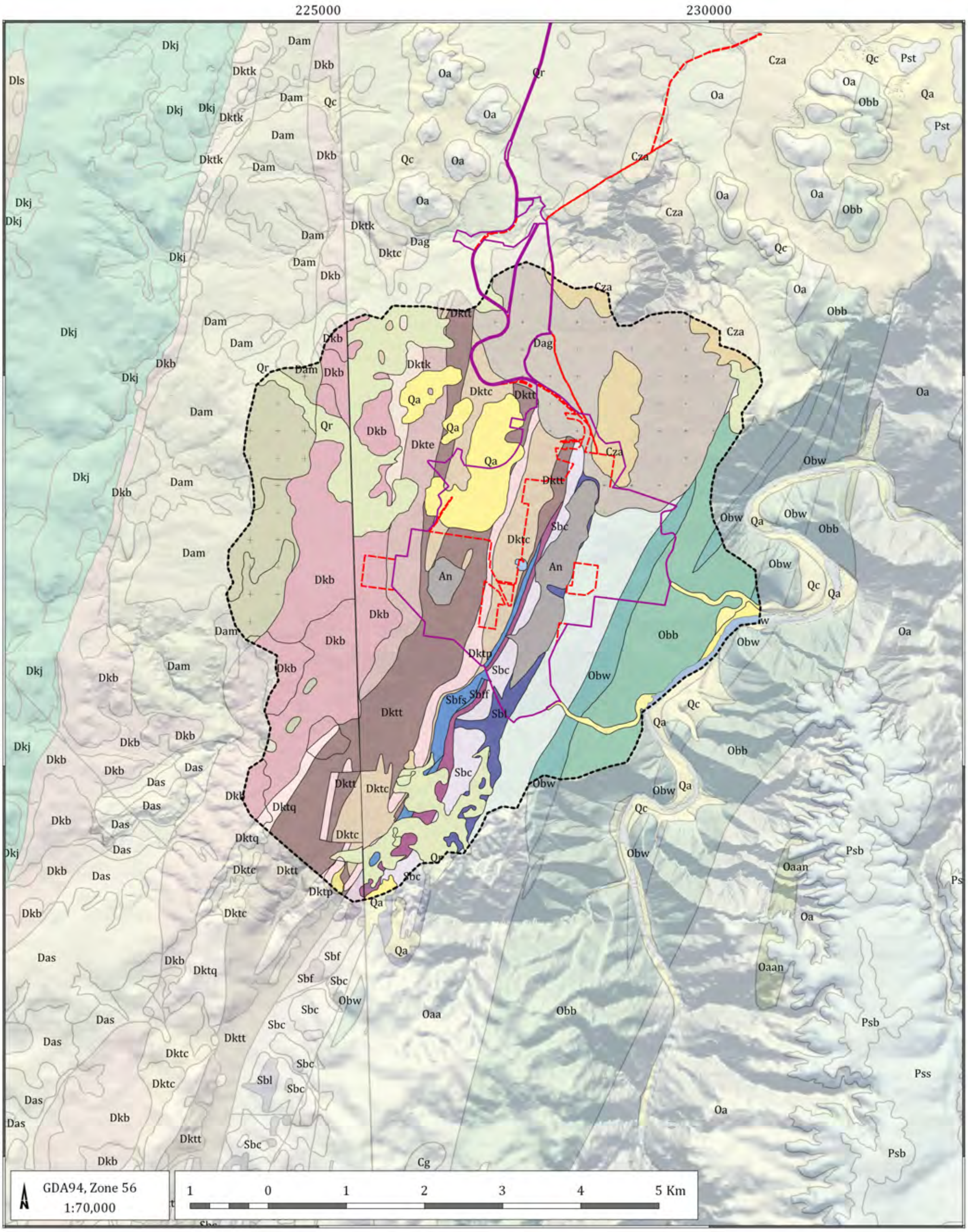


LEGEND

Regional geology

- An - Anthropogenic deposits
- Water
- Qa - Anthropogenic deposits
- Qc - Quaternary talus deposits
- Qr - Cenozoic pisolithic iron laterite
- Cza - Cenozoic alluvial and colluvial deposits of gravels, sands and clays
- Czr - Cainozoic regolith
- Psw - Wandrawandian Formation
- Dag - Glenrock Granodiorite
- Dam - Marulan Granite
- Das - Springponds Tonalite
- Dkb - Barrallier Ignimbrite
- Dktc - Carne Dacite Member
- Dkte - Kerillon Tuff Member
- Dktk - Kerrawarra Dacite Membe
- Dktp - Devils Pulpit Member
- Dktq - Bindook Group - not named
- Dktt - Tangerang Formation - unnamed tuffaceous member
- Sbc - Cardinal View Formation
- Sbf - Frome Hill Formation
- Sbfe - Efflux Siltstone Member
- Sbff - Folly Point Limestone Member
- Sbfs - Sawtooth Ridge Limestone Member
- Sbl - Lookdown Limestone
- Obw - Warbisco Shale
- Obb - Bumballa Formation
- Oa - Adaminaby Group
- Oaa - Adaminaby Group

- Project boundary
- CML16
- Model boundary

Marulan South COP (G1714C)

Geological map - regional geology

AGE

DATE 22/03/2018

FIGURE No: **5-1**

G:/Projects/G1714C.Marulan South COP/3_GIS/Workspaces/001_Deliverable1/05.01_G1714C Geological map - regional geology.qgs

5.2 Site geology

Figure 5-2 shows the Project area looking from the southern edge of Bungonia Gorge in the northerly direction and approximates the outcrop of key stratigraphic units.

GeoRes (2017, 2018) describes the limestone currently and historically mined at Marulan South as two sub-parallel and steeply west dipping members of the Bungonia Limestone Group. These include the upper 'Mt. Frome Limestone' (formally the 'Folly Point Limestone' member) and the lower 'Eastern Limestone' (formally the 'Lookdown Limestone' member). The Mt. Frome Limestone comprises three separate limestone units referred to as the Upper, Middle and Lower Limestone. Each limestone units is separated by fine grained sediments such as mudstones, siltstones and sandstones.

To the west, the limestone is overlain by series of volcanoclastic and intrusive units composed of dacites, tuffs and volcanic breccias. All geological units dip towards west-north-west with variable degree of steepness (GeoRes, 2018). To the south, the limestone units extend south beyond Bungonia Creek, whereas to the north, the limestone is truncated by the Glenrock Granodiorite intrusion. The granodiorite has also metamorphosed the limestone to varying degrees across the site. A number of intrusive dolerite dykes are present at the site.

The contact with the overlying siltstone and limestone units is known to be faulted within the mine area, becoming a conformable contact further south. Where the margins of the limestone are bounded by faults, the fault affected zones have been noted to be up to 50 metres thick, consisting of broken and shattered sidewall rock and limestone. The fracture planes are filled with assorted clays and other materials introduced following the removal of limestone by solution.

Figure 5-2 View north from Bungonia Gorge lookout – generalised geology and approximate geological boundaries

In terms of groundwater occurrence, two aquifer systems are known to exist west of the existing mine. These include a surficial aquifer associated with the weathered zone, and a deeper, fractured bedrock aquifer. These two aquifers appear to be vertically interconnected; however the magnitude of this connectivity is not well understood. Of the two, the more significant aquifer and potential source of groundwater seepage into the mine is the deeper bedrock aquifer.

5.2.1 Geological structures

The region and Project area has been subject to multiple phases of deformation creating a complex geological sequence. The Ordovician Adaminaby Group was deformed during the Silurian and the Siluro-Devonian Bungonia Group that includes the Eastern Limestone was deposited on the deformed Adaminaby Group. Both units were again deformed, most likely during the Devonian prior to the intrusion of the Arthursleigh Suite granitoids. Shear or fault zones that bound and cross-cut the Eastern Limestone are also expected to have been formed at this time.

A shear/fault zone occurs west of the active pit at the upper contact of the Eastern Limestone and is a regionally extensive feature. Figure 5-3 and Figure 5-4 show geological maps prepared by Carr and Jones (1984) and indicate the presence of major fault structures in plan view and section. Figure 5-3 also shows east-west oriented faulting, and a number of these faults have been noted at the Project area. A second shear/fault zone is also known within the pit at the lower contact of the Eastern Limestone.

Latest mapping of structural features was undertaken by Rankin (GeoRes, 2018; Figure 5-5) and identified multiple fracture zones intersecting the Eastern Limestone. The fractures are considered to connect the current floor of the pits with caverns in the limestone that naturally drain through springs in the northern slopes of the Bungonia Gorge. This process has been observed during and after heavy rainfall events, when it is believed the water that seeps from the pit floor discharges from these openings. Similar to the Eastern Limestone, the Mt. Frome Limestone units are probably also fractured and naturally drained. This is evidenced by groundwater level measurements in the exploration holes within the Mt. Frome Limestone units (see Section 7.4.2).

As noted previously the faults zones are filled with broken and shattered sidewall rock and limestone. The fracture planes are filled with assorted clays (in-situ decomposition product) and other materials introduced following the removal of limestone by solution.

The main deformational stresses were oriented in what is now east-west resulting in north-south oriented bedding cleavage in fine grained units and joint development. Figure 5-6 shows the Eastern Limestone in the Project area highlighting the cleavage and jointing oriented predominantly parallel to bedding. This uniformly oriented cleavage and jointing promotes north-south anisotropy in the groundwater systems. Refer to Section 7.10 for more detailed discussion of the impact of anisotropy of hydraulic properties to the groundwater flow regime.

In the active pit there are also a number of dykes that have been identified that are normal and sub-normal to strike. The dykes are generally less than 1 m thick and intersect the limestone units in both a north-south and east-west orientation. A large dolerite dyke ~25 m thick, intersects the limestone in the north of the mine area and pre-dates the Glenrock Granodiorite. This dyke has been described as a significant barrier to groundwater flow (GeoRes, 2018).

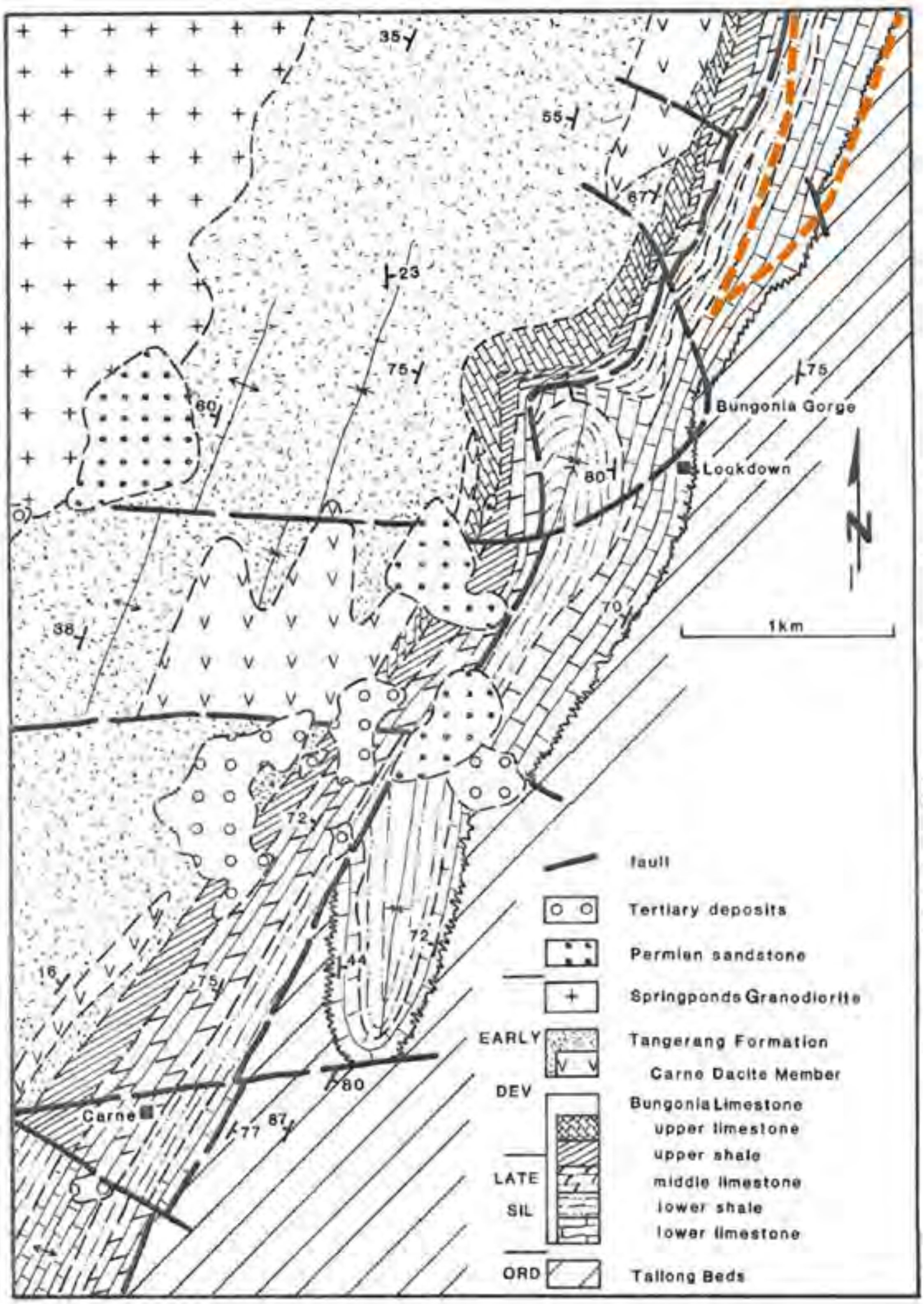


Figure 5-3 Geological map of the Marulan South-Bungonia gorge-Carne area with approximate mine crest location (Carr and Jones, 1984)

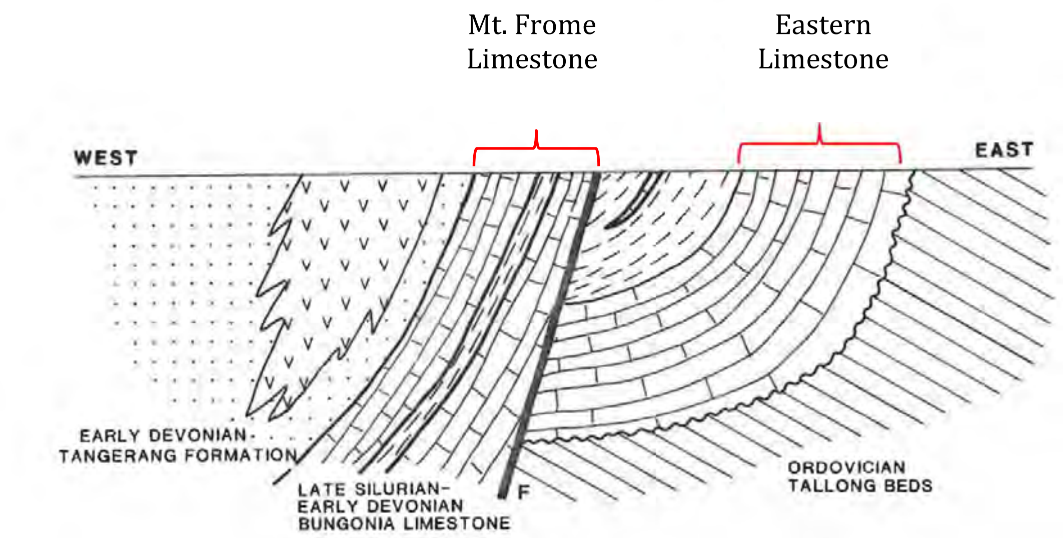


Figure 5-4 Cross-section of the Bungonia area (Carr and Jones, 1984)

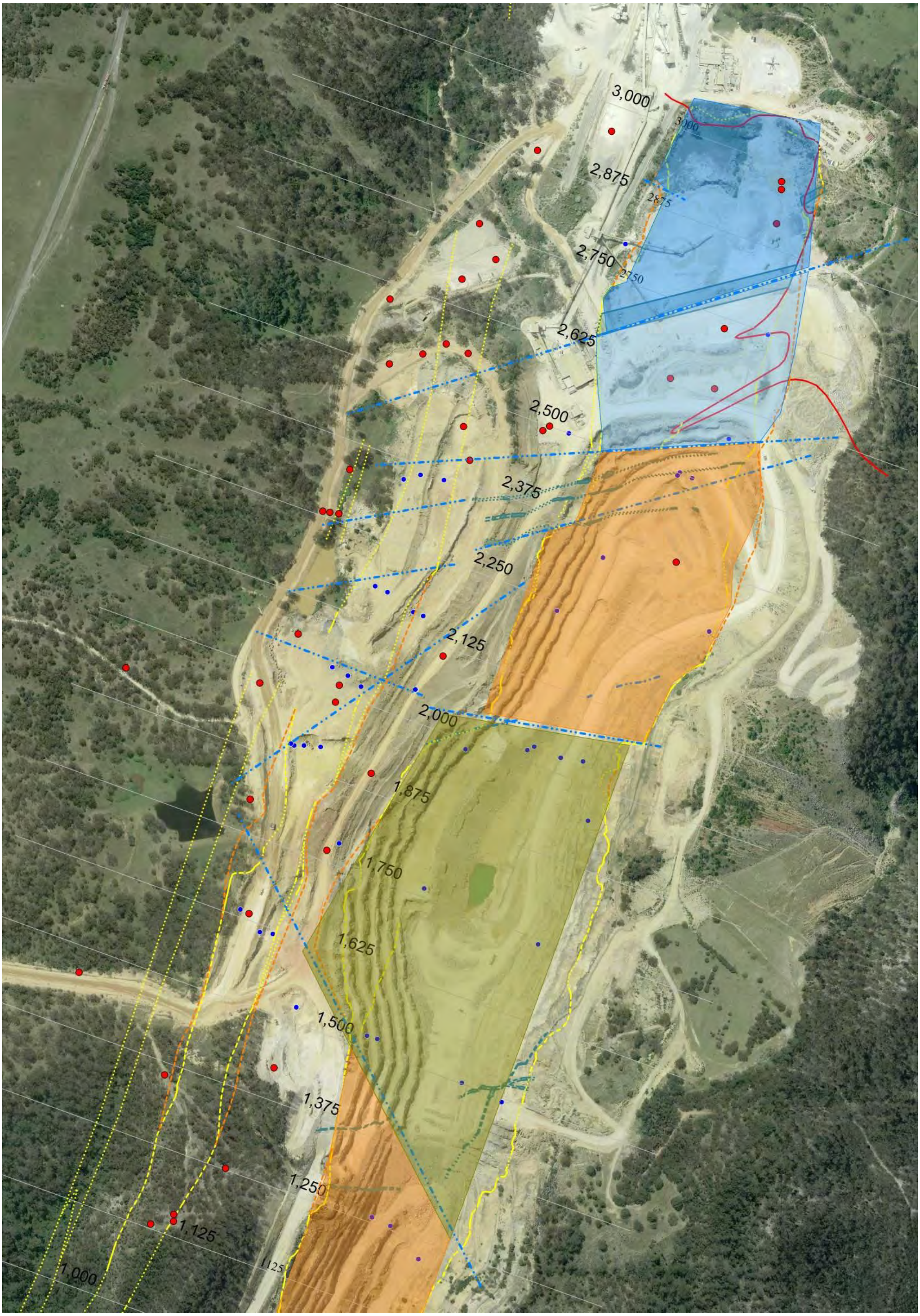


Figure 5-5 Recent mapping of faults, fractures, dykes and contact zones (GeoRes, 2018)

Figure 5-6 Jointing parallel to bedding in Eastern Limestone at base of Bungonia Gorge

5.2.2 Karst features

During mining, cavities were found throughout the limestone sediments, predominantly in the southern areas of the mine. These cavities can be of considerable size and sometimes are filled with material, including clay, gravel, fractured limestone, dolomite and limonite. Anecdotal information indicates a cavities with dimensions of approximately 40 m x 20 m x 40 m, described as “of moderate size compared to other cavities discovered previously” by Boral personnel (GeoRes, 2018), however the exact location of these voids is not known.

Furthermore, a set of two caves known as Main Gully Spring (B68) and Main Gully Spring Too (B128) are located within the northern escarpment of the Bungonia Gorge, south of the mine (Bauer J. and Bauer P., 1998). The Main Gully Spring Too (B128) cave is described as discharging a spring at the base of cliff line, approximately 50 m to the east from the Main Gully Spring cave (B68) which acts as an overflow during periods of high groundwater discharge. It is understood that the increased groundwater discharge has been recently observed (see Figure 5-7) by Boral personnel from the Main Gully Spring cave (B68 - locally referred to as the ‘Blowhole’). In August 2017, Boral engaged speleologist Peter Bauer to lead the Boral personnel and environmental consultant to the Main Gully Spring cave in order to document the cave itself and obtain water quality samples from the cave discharge during the dry period (see Figure 5-8).

The observed discharge from the ‘Blowhole’ implies that there could be an existence of a system of fractures, connecting the base of the pit with the discharge point in the Bungonia Gorge. The implication of hydraulic interconnectivity between the Mine and Bungonia Gorge (and Bungonia creek) is discussed in more detail in Section 7 as well as (from the pit water balance perspective) in Appendix E.

Figure 5-7 View north from Bungonia Gorge lookout – 'Blowhole' sediment-laden overflow after heavy rainfall, 7/6/2016

Figure 5-8 Main Gully Spring cave ('Blowhole') – opening and flowing water inside (August 2017)

5.2.3 Weathering

The volcanics, limestone and sedimentary units include a surface weathered zone of variable depth. Within designated areas, overburden material have been deposited over the weathered regolith zone throughout the life of the mine. Geochemical testing undertaken for this study (Section 5.2.4 and details in Appendix C) investigated potential for spoil/emplacement materials to act as a source of potential contamination for ground and surface waters through the process of leaching of metals and salts.

The steep terrain in the Project area is characterised by gullies and deep gorges formed by high runoff velocities. In the areas away from steep slopes, chemical and mechanical weathering has created a regolith and topsoil layer at the surface. The alternating rock units weather preferentially based on the composition, conditions and structural integrity, creating varied depths and degrees of weathering. Figure 5-9 shows the pit and the approximate depth of the regolith layer. PSM report the limestone is highly weathered to between 30 m and 40 m below the ground surface, whilst moderately weathered rock can extend to some 90 m depth.

Figure 5-9 Westerly view of hanging wall with weathering profile.

5.2.4 Overburden geochemistry

RGS Environmental Pty Ltd (RGS) assessed the geochemistry of 25 samples collected from the mine resource and overburden materials to investigate potential for these materials to generate acidity, salts and soluble metals/metalloids. The results of the investigations have been used to inform appropriate management and mitigation measures where required to avoid or minimise potential impacts to groundwater quality. The full RGS report is presented as Appendix C.

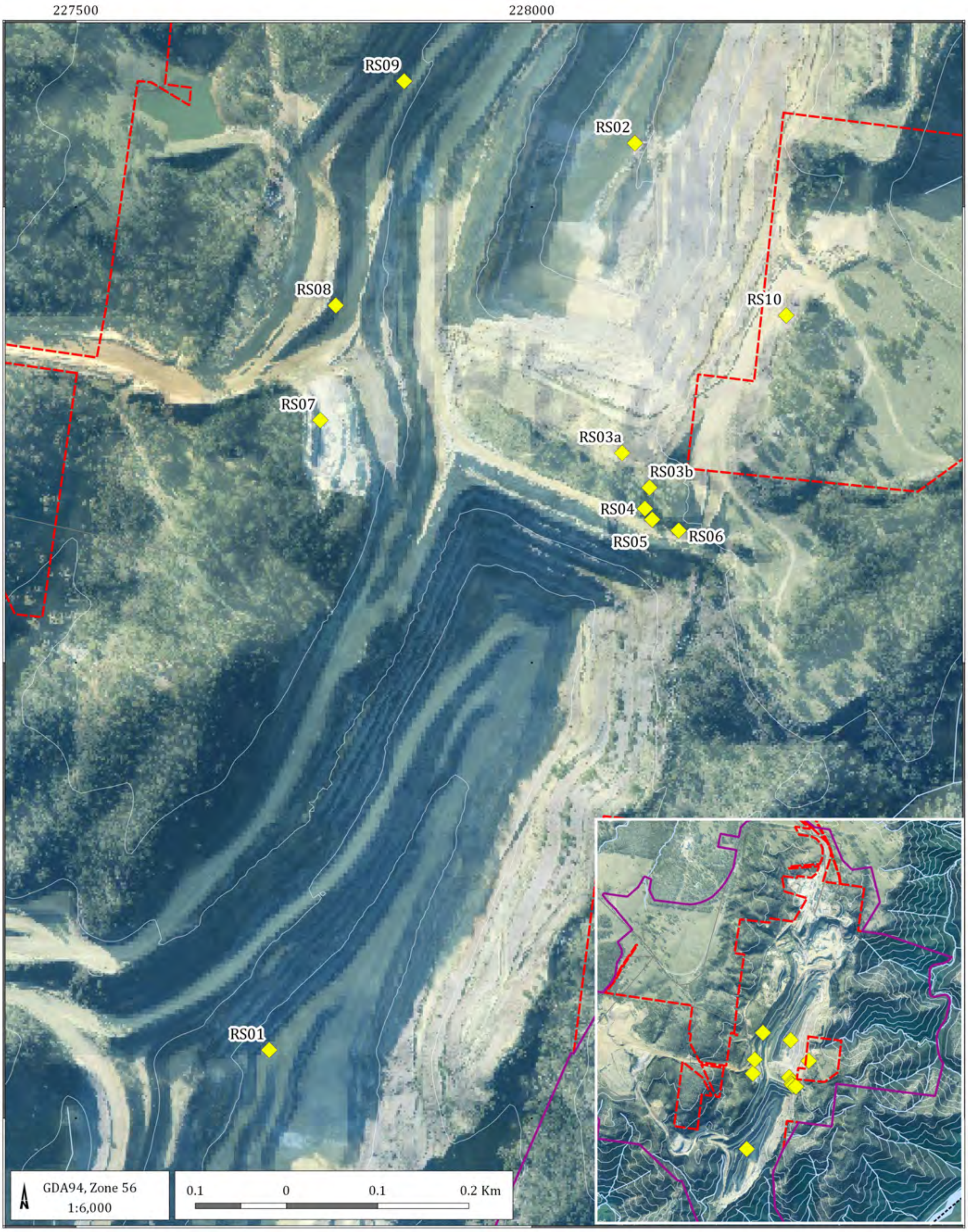
The results of the geochemical assessment for the Project indicated that:

- The overburden materials are classified as non-acid forming (NAF) and are essentially barren of sulphur. The overburden rock therefore has a high factor of safety with respect to potential acid generation.
- Surface runoff and seepage from overburden materials is likely to be slightly alkaline and contain low concentrations of dissolved salts.
- The overburden materials contain relatively low overall concentration of metals/metalloids in solids. While the concentration of arsenic, cobalt and manganese may be elevated compared to average crustal abundance in some of the contact material between limestone and shales, the solubility of these minerals in water is negligible and does not pose elevated risk of contamination.
- Most trace metal/metalloids in the overburden material are sparingly soluble in slightly alkaline contact water. Because of the low solubility, they are unlikely to impact upon the quality of surface and groundwater resources at the site.

Table 5-2 provides a summary of the location and of the nature of each of the overburden samples collected and tested. The locations where each sample was collected are also shown on Figure 5-10.

Table 5-2 Overburden material sampling locations.

Sample	Description	Easting (GDA94z56)	Northing (GDA94z56)	GPS Elevation (m AHD)
RS01-1	West wall - limestone - Mg rich(South Pit)	227712	6146575	390
RS01-2	West wall - limestone - Mg rich(South Pit)	227712	6146575	390
RS02-1	East wall – limestone (North Pit)	228113	6147570	450
RS02-2	East wall – limestone (North Pit)	228113	6147570	450
RS03a	East wall - extremely weathered dyke, material peeling by hand	228099	6147230	624
RS03b	East wall - mafic dyke	228129	6147192	536
RS04-1	East wall - contact between limestone and shales - ferruginised material	228124	6147169	530
RS04-2	East wall - contact between limestone and shales - ferruginised material	228124	6147169	538
RS05-1	East wall - transitional zone - in-situ weathered material - clays	228132	6147157	539
RS05-2	East wall - transitional zone - in-situ weathered material - clays	228132	6147157	539
RS06-1	East wall - shale, mudstone	228161	6147145	540
RS06-2	East wall - shale, mudstone	228161	6147145	540
RS07-1	West wall - white sandstone (tuff), brittle, feldspar, silica rich	227768	6147266	566
RS07-2	West wall - white sandstone (tuff), brittle, feldspar, silica rich	227768	6147266	566
RS08-1	West wall - red soil/clay, decomposed sandstone (tuff) with ferrous bands, nodules	227785	6147392	572
RS08-2	West wall - red soil/clay, decomposed sandstone (tuff) with ferrous bands, nodules	227785	6147392	572
RS09-1	West wall - brown sandstone, claystone, blocky, hard	227860	6147638	557
RS09-2	West wall - brown sandstone, claystone, blocky, hard	227860	6147638	557
RS10-1	East wall - unweathered shale	228279	6147381	568
RS10-2	East wall - unweathered shale	228279	6147381	568



LEGEND

- Project boundary
- CML16
- Rock sample location
- Watercourse, drainage

Marulan South COP (G1714C)

Overburden rock sample locations

AGE

DATE 22/03/2018

FIGURE No: 5-10

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006;
G:/Projects/G1714C.Marulan South COP/3_GIS/Workspaces/001_Deliverable1/05.10_G1714C Overburden rock sample locations.qgs

6 Climate

Climatic conditions – mainly rainfall and evapotranspiration – are the main drivers behind recharge of the groundwater system. The climate of the Project area is characterised as 'temperate without a dry season and warm summers' (Köppen-Geiger climatic classification - Peel *et al.* 2007). On average, more precipitation falls in summer, between October and March. The winters are generally drier with slight rainfall increase in June.

The daily rainfall data were obtained from Boral weather station (active 2014 - present). In order to obtain rainfall, evaporation and evapotranspiration data prior 2014, the SILO patched point dataset (QLD government, 2014) was interrogated. The SILO data drill point is located approximately 3.8 km north-west from the mine, atop the Southern Tablelands (latitude -34.75°, longitude: 150.0°; easting: 225370, northing: 6150580).

In order to confirm relevance of SILO dataset with respect to the actual on-site climatic data, the monthly rainfall values for SILO data drill point and Boral weather station were compared (see Figure 6-1) between January 2012 and August 2014. On average, the SILO algorithm slightly over-predicts rainfall (approximately 0.9 mm or 1.4% per month more) but this difference would not have any meaningful impact on groundwater recharge assessment. Based on this comparison, SILO dataset was adopted as a stand-in for the periods of missing on-site data and used for the long-term trend analysis of rainfall.

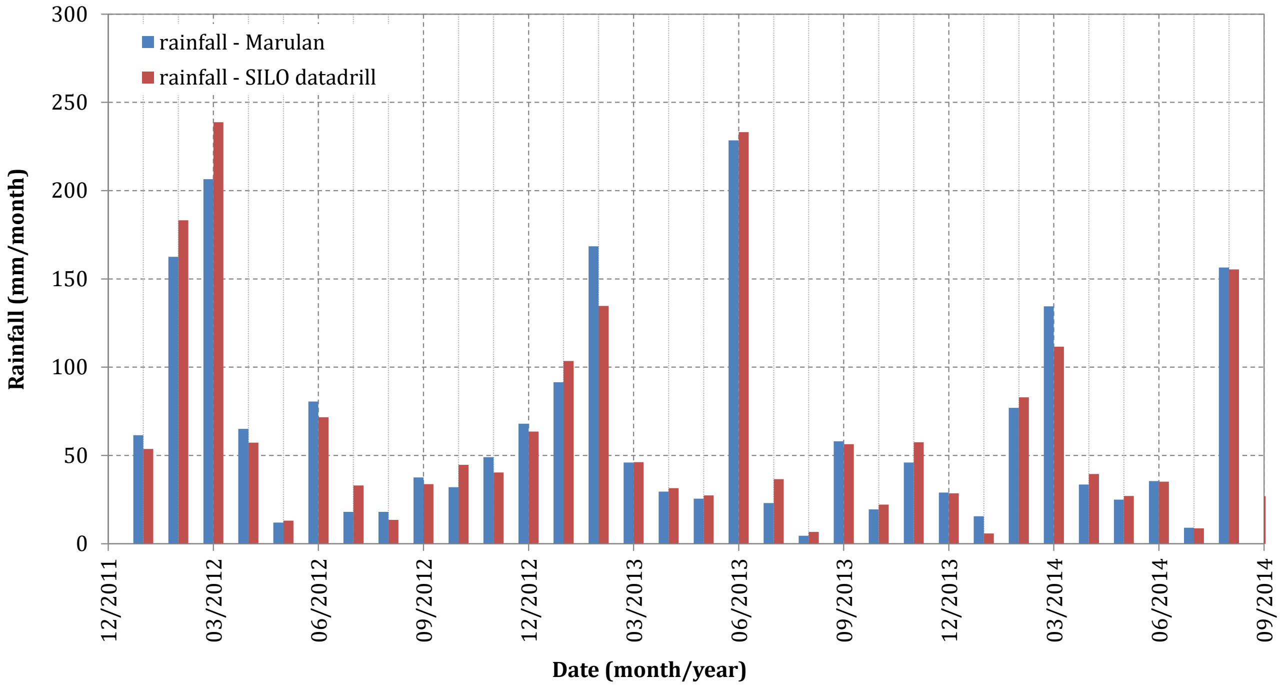


Figure 6-1 Comparison of on-site (Marulan office weather station) and SILO data drill monthly rainfall.

6.1 Rainfall

Table 6-1, Figure 6-2 and Figure 6-3 below summarise the monthly rainfall, pan evaporation and potential evapo-transpiration in the region. The data is based on long term SILO dataset - data from January 1889 to December 2017. On average, the precipitation rates oscillate between 69 mm/month in January and 46 mm/month in August. The long term annual average rainfall over 129 years is 694.1 mm/year. The long term rainfall data are nearly identical to the data derived from BoM weather station data analysed by Advisian (2018) presenting average annual rainfall of 696 mm.

Long term trends in rainfall are represented by the Cumulative Rainfall Departure (CRD, see Bredenkamp *et al.*, 1995) graph which is presented in Figure 6-3. The CRD shows trends in rainfall relative to the long term monthly average and provides a historical record of relatively wetter and drier periods. A rising trend in slope in the CRD plot indicates periods of above average rainfall, while a declining slope indicates periods when rainfall was below average. Groundwater levels can have a similar trend to the CRD, and therefore it is used to discuss climatic trends with regards to surface water flows, groundwater levels and water quality results.

Table 6-1 Average monthly rainfall, evaporation and evapotranspiration (SILO).

Month	Rainfall (mm)	Evaporation (pan) (mm)	Potential EVT *) (mm)
January	69.46	188.74	148.61
February	67.69	147.43	117.89
March	68.18	125.72	102.54
April	52.20	83.08	67.49
May	50.50	55.37	45.38
June	64.69	38.76	32.20
July	47.30	45.27	35.67
August	46.58	67.67	51.18
September	47.53	95.65	73.98
October	59.36	128.08	104.24
November	58.15	152.01	124.45
December	62.46	189.45	148.22
TOTAL	**694.10**	**1317.24**	**1051.84**

Note: **) Based on FAO56 potential evapotranspiration (EVT) calculations (Allen et al. 1998)*

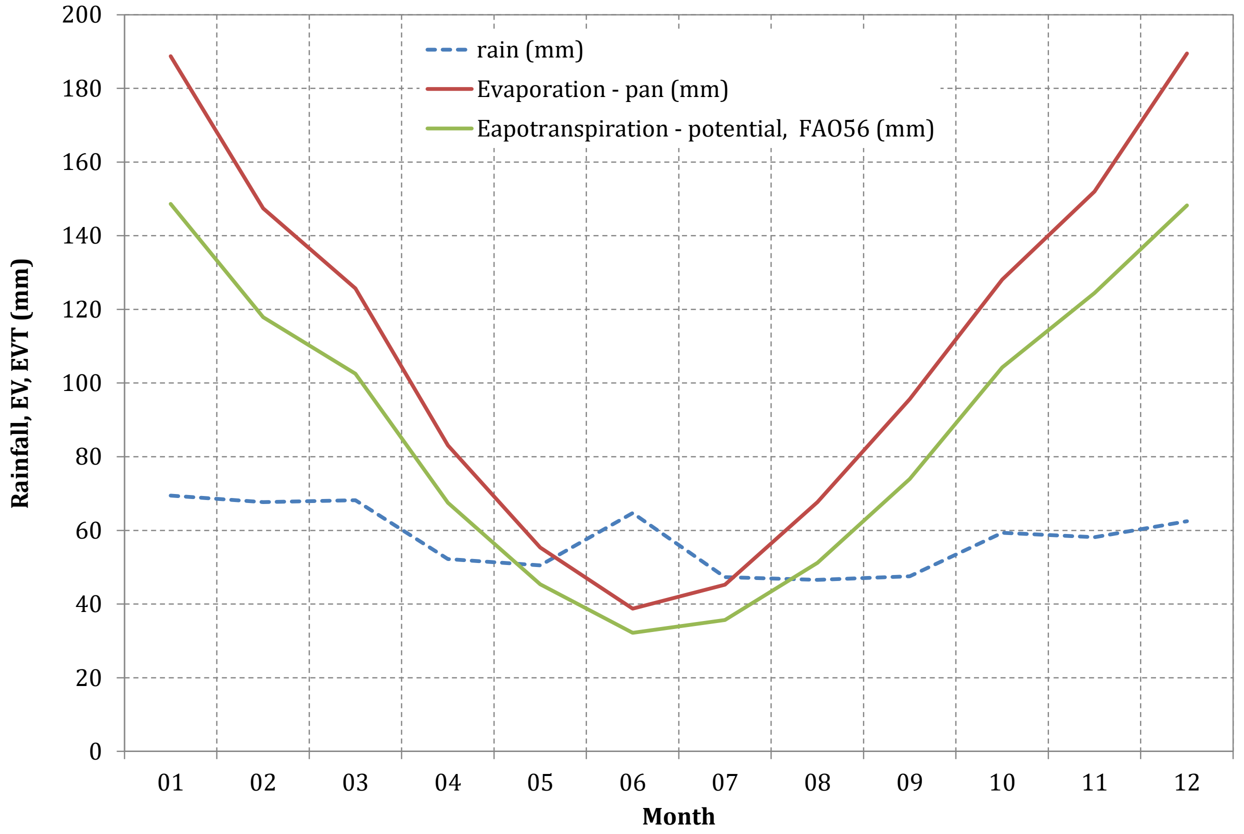


Figure 6-2 Long term average monthly rainfall, pan evaporation and potential EVT

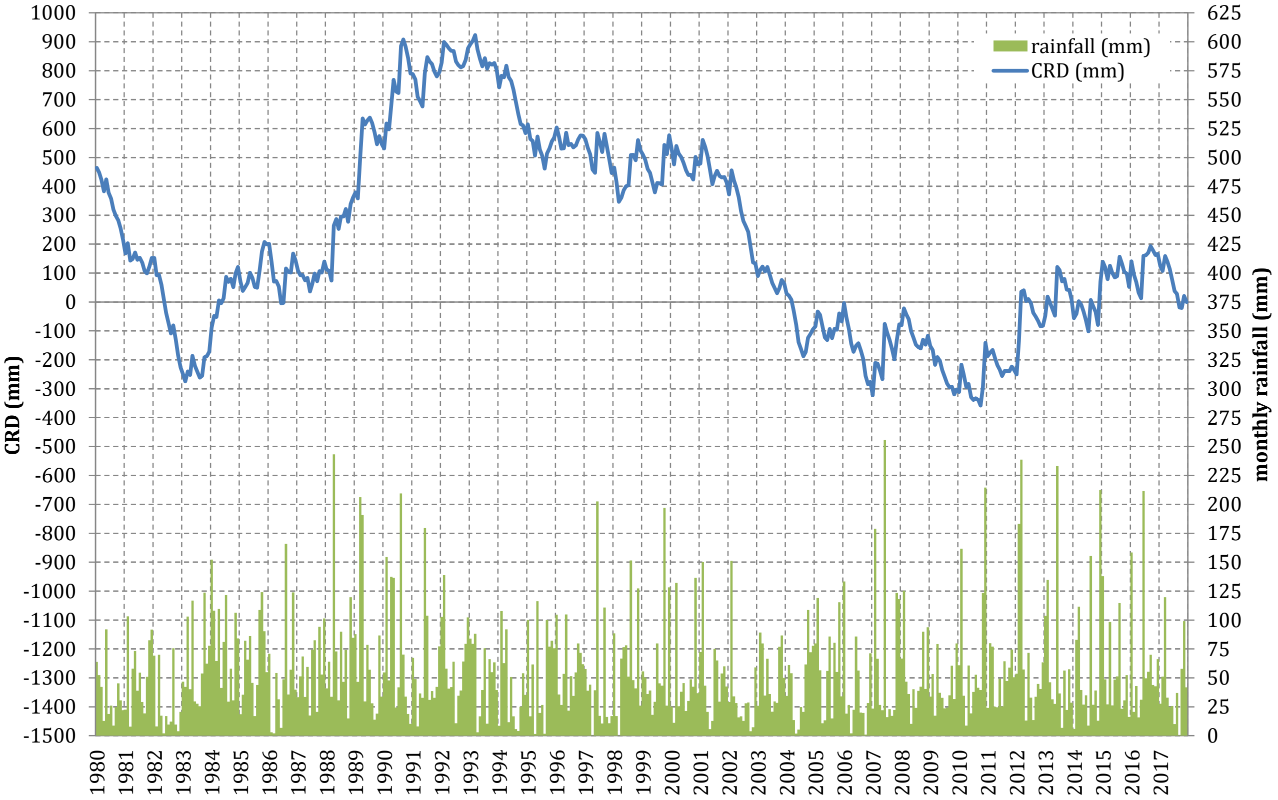


Figure 6-3 Comparison of average monthly rainfall and CRD – SILO datadrill.

The CRD indicates that the Project area experienced below average rainfall from early to mid-1980s and then 1993 until March 2010. The last lower-than average rainfall period is now known as the 'Millennium Drought'. This was followed by a period of above average rainfall between March 2010 and January 2017.

6.2 Evaporation

Compared to rainfall, the evapotranspiration distribution is strictly unimodal, with maximum of 148.6 mm/month in January and minimum of 32.2 mm/month in June. Potential monthly evapotranspiration is higher than rainfall, indicating recharge deficit in summer months.

The only time when the average rainfall exceeds evaporation is between May and August indicating higher potential for groundwater recharge to occur during winter. The long term average EV rate is 1317 mm/year while EVT rate is 1052 mm/year.

7 Hydrogeology

7.1 Groundwater sources

There are two basic sources of groundwater within the Project area: shallow, unconsolidated aquifers and deep, consolidated aquifers. The shallow unconsolidated aquifer is mainly within the weathered zone where the groundwater exists in the pore spaces within the sediment or regolith. Groundwater within the deep, bedrock aquifer exists mainly in rock fractures caused by geologic and structural movement, associated with intrusive volcanic or dissolution of limestone.

Groundwater sources in the Project area are managed under the 2011 Greater Metropolitan Region Groundwater Sources Water Sharing Plan*.* Under this particular WSP, the Project area falls fully within Goulburn Fractured Rock Groundwater Source (GFRGS) and based on Aquifer Interference Policy, the aquifer is classified as 'low-productivity' groundwater source. The relevant legislative framework concerning the water sources classification is overviewed earlier in Section 4.2.1and Section 4.2.3.

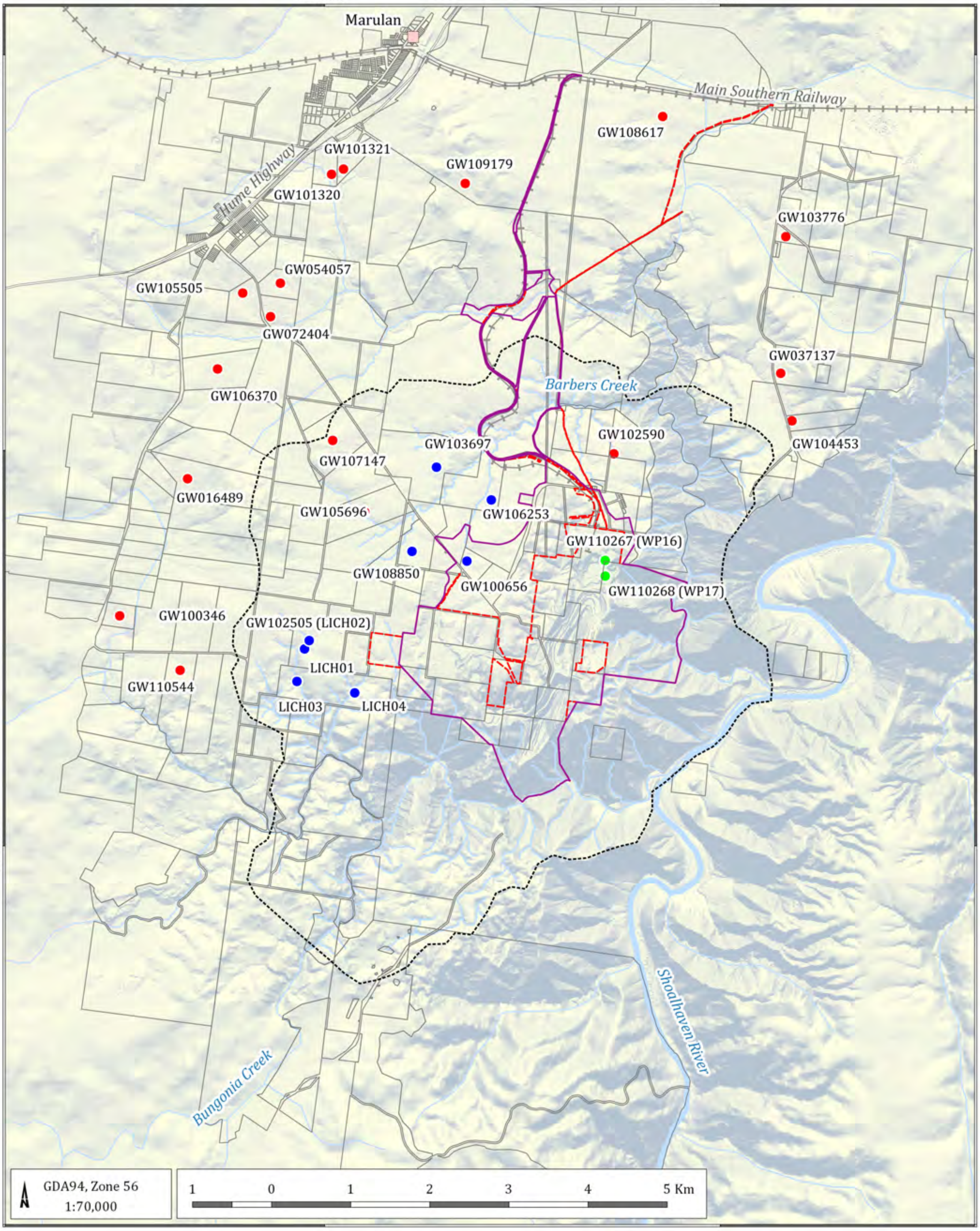
7.2 Groundwater users

There are a total of 22 water supply bores registered on the NSW government water bore database ('Pinneena' database) in the region surrounding the Project. Although most of the registered bores are used for domestic water supply, there are several industrial water users (poultry farmers) in the vicinity of the mine. As it is known to be common for the government database to be incomplete, a bore census was undertaken to identify any additional bores within the region surrounding the Project. In February 2015, properties adjacent to the Project were visited to determine if any other bores were present, and to collect relevant information. Two additional bores were inspected (LICH01, LICH04) on an adjacent poultry farm. The farm uses the water to supply water for cooling and watering the poultry. Table 7-1 summarises details for each bore with Figure 7-1 showing the bore locations.

Table 7-1 Project areas registered bores (Pinneena groundwater database 2013)

Bore ID	Easting (GDA94z56)	Northing (GDA94z56)	Depth (m)	Property lot no.	Source	Inspected
GW016489	223267.2	6149642.2	93	14/810374	1	No
GW037137	230763.1	6150975.3	33.2	1/588450	1	No
GW054057	224440.5	6152114.3	60	251/750029	1	No
GW072404	224315.6	6151691.2	48.8	252/657522	1	No
GW100346	222409.6	6147909.0	85	8/253177	1	No
GW100656	226797.5	6148600.8	90	112/830458	2	Yes
GW101320	225086.9	6153490.8	15.8	2/833561	1	No
GW101321	225237.7	6153557.0	15.7	1/804586	1	No
GW102505 (LICH02)	224804.4	6147596.8	70	1/1013487	2	Yes
LICH01	224745.6	6147490.5	-	1/1013487	2	Yes
GW111354 (LICH03)	224649.5	6147080.1	-	1/1013487	2	Yes
LICH04	225379.8	6146935.3	-	1/1013487	2	Yes
GW102590	228654.7	6149957.1	68	1/557562	1	No
GW103697	226412.9	6149788.1	31	1/1190667	2	Yes
GW103776	230827.4	6152702.9	54	3/233091	1	No
GW104453	230905.4	6150374.4	30	4/1010444	1	No
GW105505	223964.5	6151989.6	49	263/750029	1	No
GW105696	225506.3	6149221.6	76	9/1056566	1	No
GW106253	227106.0	6149374.3	78	21/867667	2	Yes
GW106370	223646.5	6151029.9	121	2/1056566	1	No
GW107147	225101.4	6150126.4	-	7/1056566	1	No
GW108617	229272.0	6154221.0	90	204/870194	1	No
GW108850	226103.6	6148723.7	24	11/1056566	2	Yes
GW109179	226776.1	6153375.2	54	203/870194	1	No
GW110544	223173.2	6147220.7	102	8/703477	1	No

Notes: *Source:* *1 – Pinneena data search; and*
2 – coordinates updated during AGE bore census.



LEGEND

- Populated place
- Project boundary
- CML16
- Cadastre
- Model boundary
- Rail
- Watercourse, drainage
- Old production bores
- Water users - AGE census
- Water users - Pinneena (2013)

Marulan South COP (G1714C)

Regional users of groundwater – registered bores

AGE

DATE 23/03/2018

FIGURE No: **7-1**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006;
G:/Projects/G1714C.Marulan South COP/3_GIS/Workspaces/001_Deliverable1/07.01_G1714C_Regional users of groundwater – registered bores.qgs

7.3 Groundwater dependent ecosystem (GDEs)

Based on the ecosystem classification (Bioregional Assessment Programme, 2012), the mine is situated within the NSW South Western Slopes bioregion. It comprises of both plateau and low-lying (gorge) landscapes with the vegetation ecosystems designated as 'Northeast Tableland Dry Shrub Forest', 'Shoalhaven Gorge Dry Shrub Forest' and 'Shoalhaven Gorge Forest'. The dry shrub forest ecosystems surround the site on north and west, while the 'Shoalhaven Gorge Forest' can be found on the southern (into Bungonia Gorge) and eastern slopes (towards Barbers Creek). The 'Shoalhaven Gorge Forest' ecosystem is the only one classified as *with high potential for groundwater interaction*.

Niche (2018) undertook a field GDE survey to determine the presence of stygofauna in groundwater and presence of ecologically high-value aquatic species on and around the mine site, especially in springs and pools along sections of the Bungonia Creek, Main Gully, Barbers Creek and the Shoalhaven River. The springs and pools detected during the survey are expected to occur where the steep topography along the incised drainage lines is cut below the level of the water table promoting drainage of groundwater. See Figure 7-2 and Figure 7-3 for examples of groundwater (spring) dependent zones.

While stygofauna was not found, aquatic fauna as well as spring dependent flora of high ecological value was found along the drainage lines, mainly along Barbers Creek and in Bungonia Gorge. Niche (2018) advises that there are currently no apparent adverse effects on the aquatic groundwater faunas in any of the receiving streams as a result of any activities arising from the operations of the Marulan Limestone Mine. The proposed development is expected to present low environmental risk of impacts.

The impact of proposed mining expansion on groundwater fed springs in Bungonia Gorge is further discussed in Sections 9.3 and 9.4.

Figure 7-2 Spring with fern community on cliff in Bungonia Creek gorge (Niche, 2018)

Figure 7-3 Spring head in the upper headwaters of Main Gully (Niche, 2018)

7.4 Groundwater monitoring network

7.4.1 Established monitoring bores

Boral maintains a network of nine groundwater monitoring bores within the Project area. RPS (2014) initially supervised the installation of the eight monitoring bores (MW1 - MW6) and undertook a series of hydraulic tests on each bore during April and May 2014. Over a period of more than three and a half years, water level and quality data have been collected as required by the AIP and will continue to be collected in the future.

In September 2016, Boral installed an additional monitoring bore (MW7) in the volcanics area west of the pit in order to establish and monitor groundwater levels in the zone proposed for the future expansion of the pit. The bore was drilled to the depth of 80 m and included into the AIP data collection program. The bore has been dry since it was installed.

The monitoring bores are located adjacent to and within the pit area. There were also historically two bores within the pit area in the early 1980s that have since been consumed and removed by operations. Table 7-2 summarises the key details for each of the current monitoring bores, with the locations shown on Figure 7-4. Details regarding water quality data collected from these monitoring bores are provided in Section 7.6.

EPL944 requires monitoring of groundwater quality at the 'North Pit bore' (WP16) for total suspended solids and pollutant oil and grease on a quarterly basis.

Table 7-2 Observation and pumping bores within the Project area

Monitoring bore ID	Co-ordinates (GDA94 Zone 56)		Elevation (m AHD)	Standpipe stick-up (m)	Bore screen depths (m bgl)		Screened formation	Purpose
	East	North			From	To		
MW1	228111	6147568	440.11	0.91	36.5	60.5	Limestone – north pit	Water quality and level monitoring
MW2	227722	6146555	380.22	0.6	41.4	59.4	Limestone – south pit	Water quality and level monitoring
MW3S	226618	6148365	618.37	0.75	39	48	Weathered regolith	Water quality and level monitoring
MW3D	226608	6148370	618.38	0.66	72	102	Weathered volcanics (dacite)	Water quality and level monitoring
MW4S	226718	6147140	596.33	0.88	26	38	Weathered regolith, volcanics (tuffs)	Water quality and level monitoring
MW4D	226717	6147129	595.46	0.87	83	123	Volcanics (tuffs)	Water quality and level monitoring
MW5	227826	6148352	574.41	0.7	73	97	Weathered regolith, weathered volcanics (dacite)	Water quality and level monitoring
MW6	228482	6147186	567.71	0.9	109.5	127.5	Sandstone	Water quality and level monitoring
MW7	227525	6147816	610.00	0.7	68.0	80.0	Volcanics (andesite)	Water quality and level monitoring
WP16 1)	228535	6148530	546.50	~1	Not known		Limestone	Water supply
WP17 2)	228555	6148492	546.50	~1	Not known		Limestone	Water supply

Notes: 1) *This bore has alternative identifiers: EPL944 identifies this bore as Licensed Discharge Point 13; the DPI Water registered number for this bore is 'GW110267'.*

2) *This bore has alternative identifiers – the DPI Water registered number for this bore is 'GW110268'.*

7.4.2 Temporary groundwater monitoring network (July 2016)

In July 2016, Boral took advantage of the drilling exploration program to further investigate groundwater occurrence within the northern Pit batters through establishment of a temporary groundwater monitoring network in this area. The purpose of this exercise was to measure (where accessible) the depth to groundwater at each location; and where possible, install 32 mm diameter Polypipe as temporary casing. Details of groundwater level data measurements from 20 exploration drill holes are summarised in Table 7-3.

Most bores were dry or collapsed at various depths above the groundwater surface following drilling, making it impossible to measure the groundwater level at these locations. However, groundwater levels were able to be measured in three bores. Continued groundwater level measurement was not possible in the temporary monitoring bores as none of the exploration holes inspected remained accessible, as they were either destroyed or remained dry, indicating the depth of the bores were shallower than the groundwater surface in these areas. Overall, the groundwater level along this northern portion of the mine Pit was assessed to be deeper than 150 m below ground surface in the two holes in which groundwater levels were measured, indicating that the western (Mt. Frome) limestone units are largely unsaturated.

Table 7-3 Exploration holes with groundwater level observations

Hole ID	Easting	Northing	Drilled length (m)	Water level (mbgl)	Comment
EL40	228008	6147854	204	n/a	Bore destroyed.
EL41	227747	6147219	204	n/a	Bore destroyed.
EL42	227672	6147063	234	Dry	Temporary polypipe casing installed.
EL43	227828	6147554	270	Dry	Top casing broken.
EL44	228268	6148664	156	n/a	Bore collapsed.
EL45	228519	6148519	78	35 m	Encountered at 4m, increased flow ~35m. Moderate flow visibly decreased after airlift 30min.
EL46	228419	6148268	156	120 m	Dry to ~120 m, then wet. Below the North Pit floor.
EL47	227897	6147676	180	Dry	Dry to bottom at 180 m (below base of pit).
EL49	228160	6148202	150	Dry	Dry to bottom.
ML20	227709	6147456	264	Dry	Temporary polypipe casing installed.
ML21	227710	6147633	186	Dry	Collapsed just below the PVC casing.
ML22	227864	6148142	204	Dry	Blocked by clay at 5.9 m.
ML23	227784	6147888	354	Dry	Moisture at 43.5 mbgl.
ML24	227578	6147208	228	Dry	n/a
ML25	227842	6147783	36	Dry	n/a
ML26	227848	6147809	288	Dry	n/a
ML27	227592	6146980	300	168 m	Wet from 168m.
ML28	227593	6146993	36	Dry	Dry to bottom.
ML29	227558	6146978	132	Dry	Dry to bottom.
ML30	227921	6148307	132	Dry	Dryish to bottom. Multiple weak/broken zones and at least 1 void.

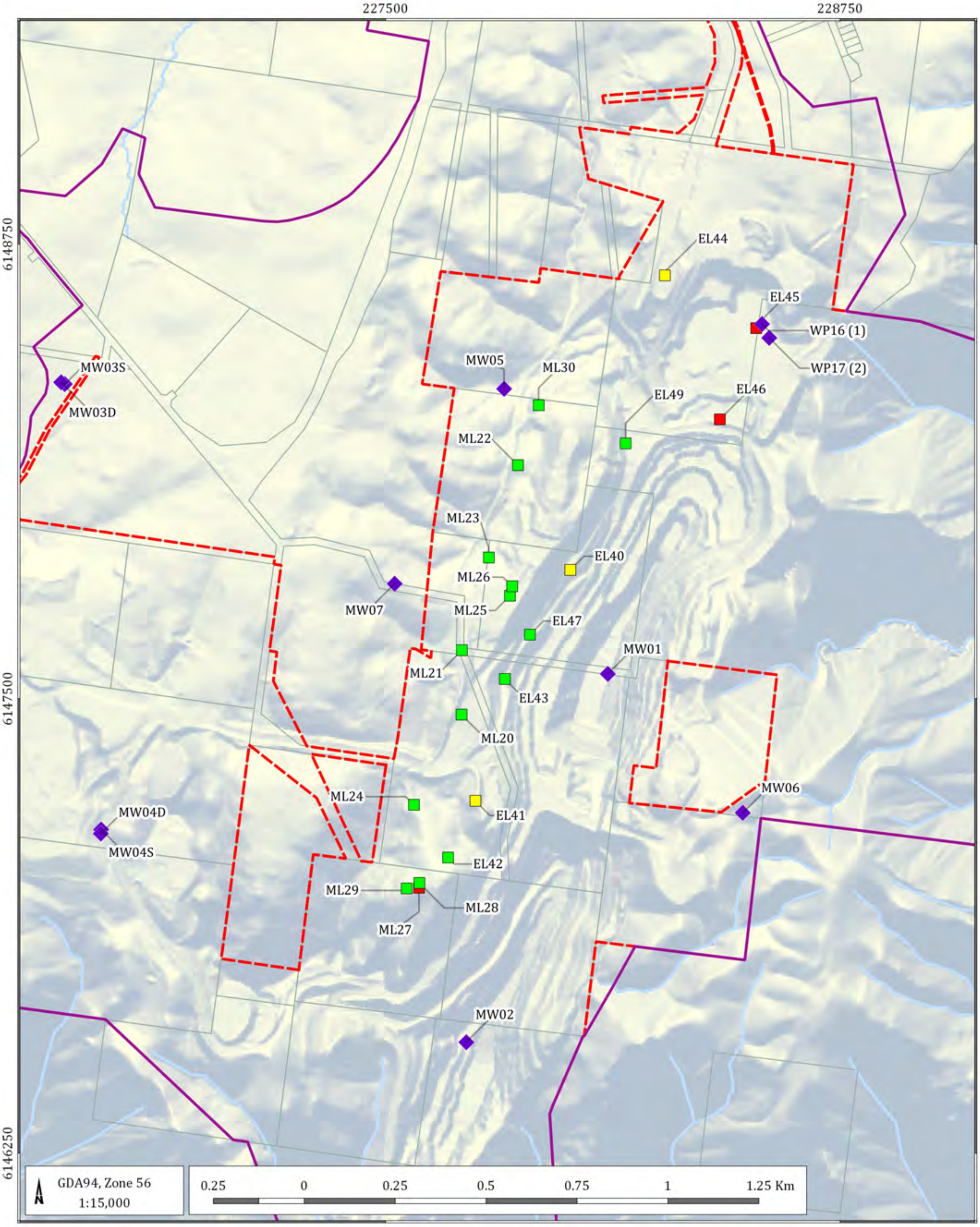
7.5 Surface water monitoring network

Boral monitors surface water quality in 12 locations within and around the mine. Refer to Table 7-4 for summary of surface water monitoring locations and Figure 7-5 for the map of the locations. The EIS Surface Water Study (Advisian, 2018) discusses these monitoring points, and monitoring points that are no longer utilised in more detail.

Main Gully Sample Point is downhill from Main Gully Spring (B68 – 'Blow Hole') and Main Gully Spring Too (B128 – refer to Section 5.2.2). Due to the very steep terrain, access to the 'Blow Hole' is impractical and difficult, therefore, the sampling at the Main Gully Sample Point and Blow Hole Sampling Point are considered to be representative of the seepage from these springs.

Historically, surface water sampling at Main Gully Sampling Point occurred approximately monthly during the period from March 2008 to June 2012. Sampling at this location recommenced in November 2014 and monthly sampling has been continuing to date.

Full details concerning the surface water monitoring network are provided in Surface Water Assessment (Advisian, 2018).



LEGEND

- Project boundary
- CML16
- Cadastre
- Watercourse, drainage

- Groundwater monitoring bores

Temporary groundwater observation bores

- Dry
- Groundwater found
- Not available

Marulan South COP (G1714C)

Groundwater monitoring locations

AGE

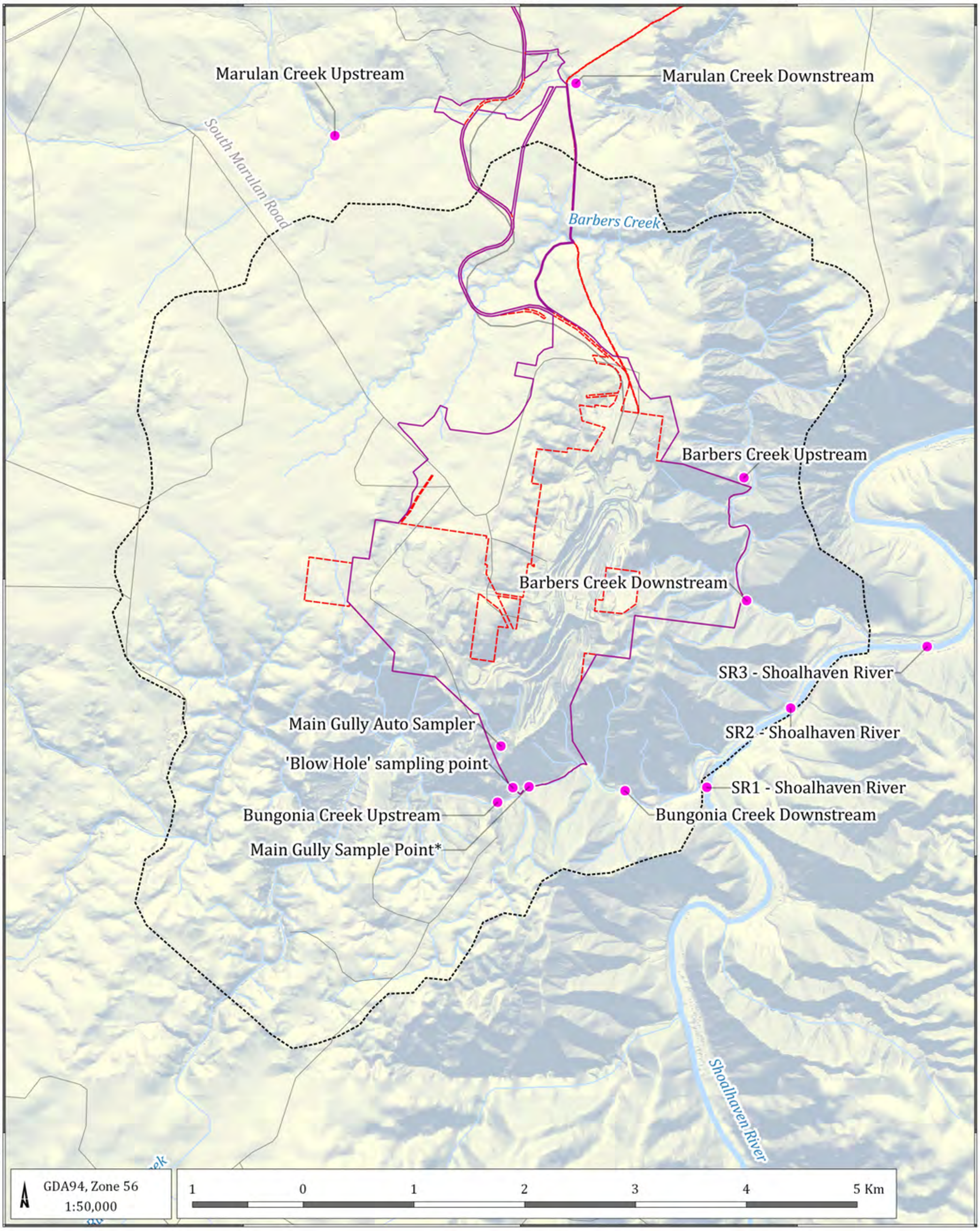
DATE 23/03/2018

FIGURE No: **7-4**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006;
G:/Projects/G1714C.Marulan South COP/3_GIS/Workspaces/001_Deliverable1/07.04_G1714C_Groundwater monitoring locations.qgs

Table 7-4 Surface water sampling locations

Monitoring location	Co-ordinates (GDA94 Zone 56)		Elevation (m AHD)
	Easting	Northing	
Marulan Creek Upstream	225825	6151504	603.00
Marulan Creek Downstream	228002	6151977	585.50
Barbers Creek Upstream	229518	6148416	250.50
Barbers Creek Downstream	229542	6147306	155.00
SR1 - Shoalhaven River	229183	6145620	120.00
SR2 - Shoalhaven River	229940	6146335	118.00
SR3 - Shoalhaven River	231172	6146891	115.00
Bungonia Creek Upstream	227294	6145485	173.00
Bungonia Creek Downstream	228445	6145589	135.00
Main Gully Sample Point*	227578	6145625	152.00
Main Gully Auto Sampler	227324	6145992	382.80
'Blow Hole' Sampling Point	227432	6145617	179.00



LEGEND

- Project boundary
- CML16
- Model boundary
- Road
- Watercourse, drainage
- Surface water monitoring locations

Marulan South COP (G1714C)

Surface water monitoring locations

AGE

DATE 23/03/2018

FIGURE No: **7-5**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006;
G:/Projects/G1714C.Marulan South COP/3_GIS/Workspaces/001_Deliverable1/07.05_G1714C_Surface water monitoring locations.qgs

7.6 Baseline monitoring

Mining activities commenced on site in 1869s and therefore true baseline data prior to mining is not available. However, Boral recognised the need for major projects to collect two years baseline data to comply with the Aquifer Interference Policy. The sections below outline data collection from the monitoring network that commenced in April/May 2014 to comply with this requirement for establishing a baseline dataset.

7.6.1 Groundwater levels

Boral manually measures groundwater levels in the monitoring bore network and periodically downloads electronic pressure transducers that record water levels on a daily basis. Groundwater levels were measured manually after installation of the bores in April/May 2014. Pressure transducers equipped with data loggers were installed in July 2014 to automatically monitor groundwater levels. There is now a data set that spans over three and a half years (as of December 2017), which therefore satisfies the minimum data requirements for the Aquifer Interference Policy (AIP).

Figure 7-6 shows groundwater level fluctuations recorded by pressure transducers installed within monitoring bores located in the mine pit, while Figure 7-7 and Figure 7-8 shows groundwater levels in monitoring bores surrounding the pit. The electronic data is cross checked with periodic manual measurements. Water level measurements preceding the deployment of the pressure transducers have also been plotted. Aspects of presented data are discussed further in this section.

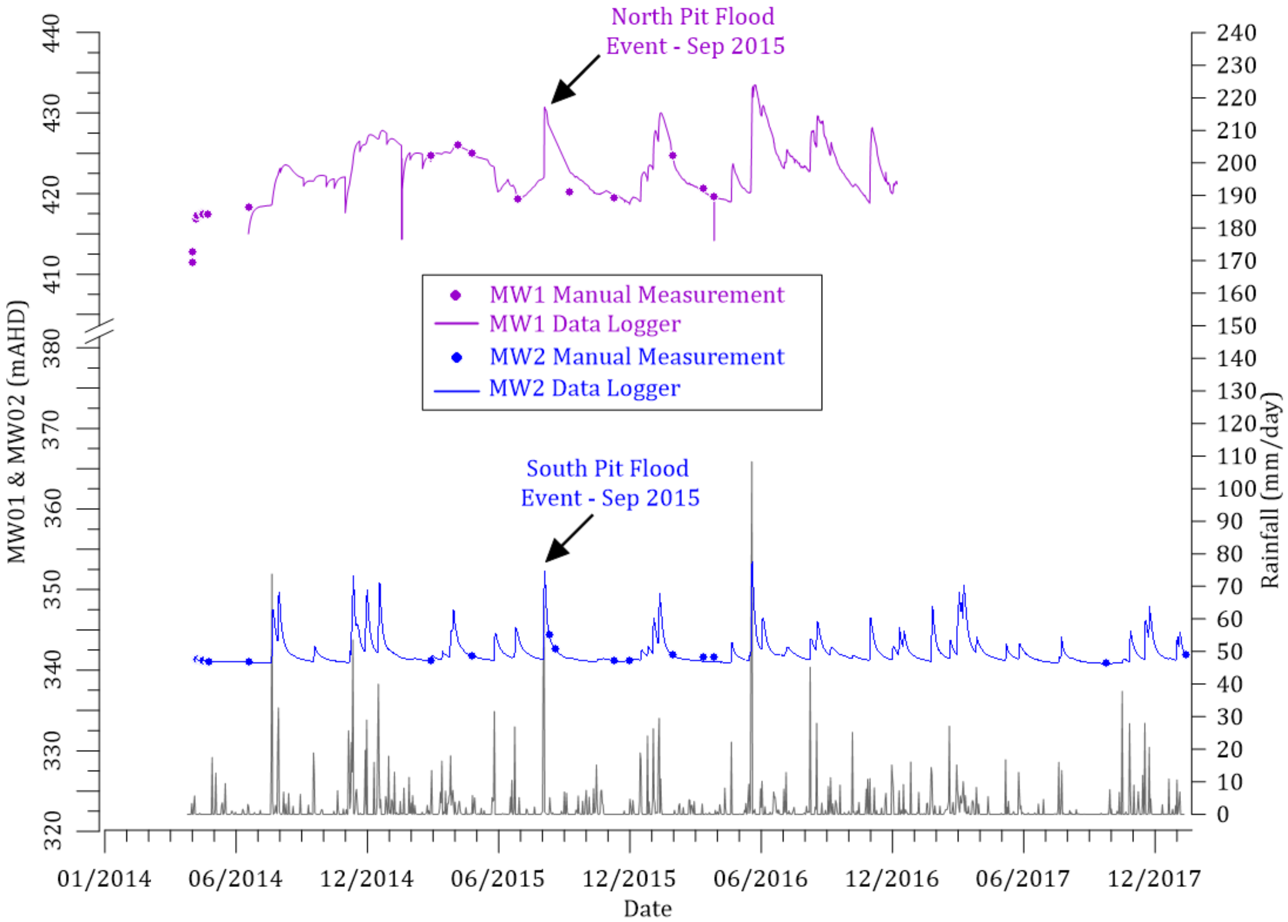


Figure 7-6 Hydrographs of in-pit monitoring bore water levels (MW1-MW2)

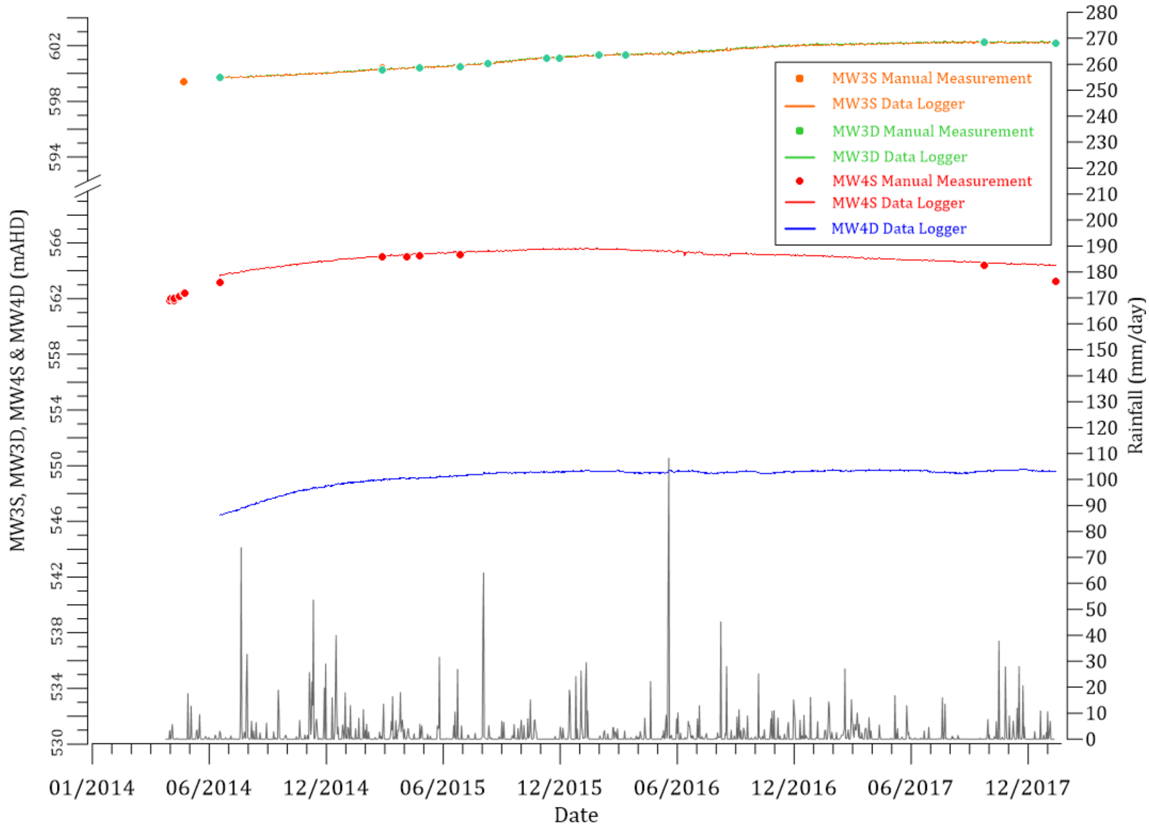


Figure 7-7 Hydrograph of water levels from monitoring bores adjacent to mine (MW3-MW4)

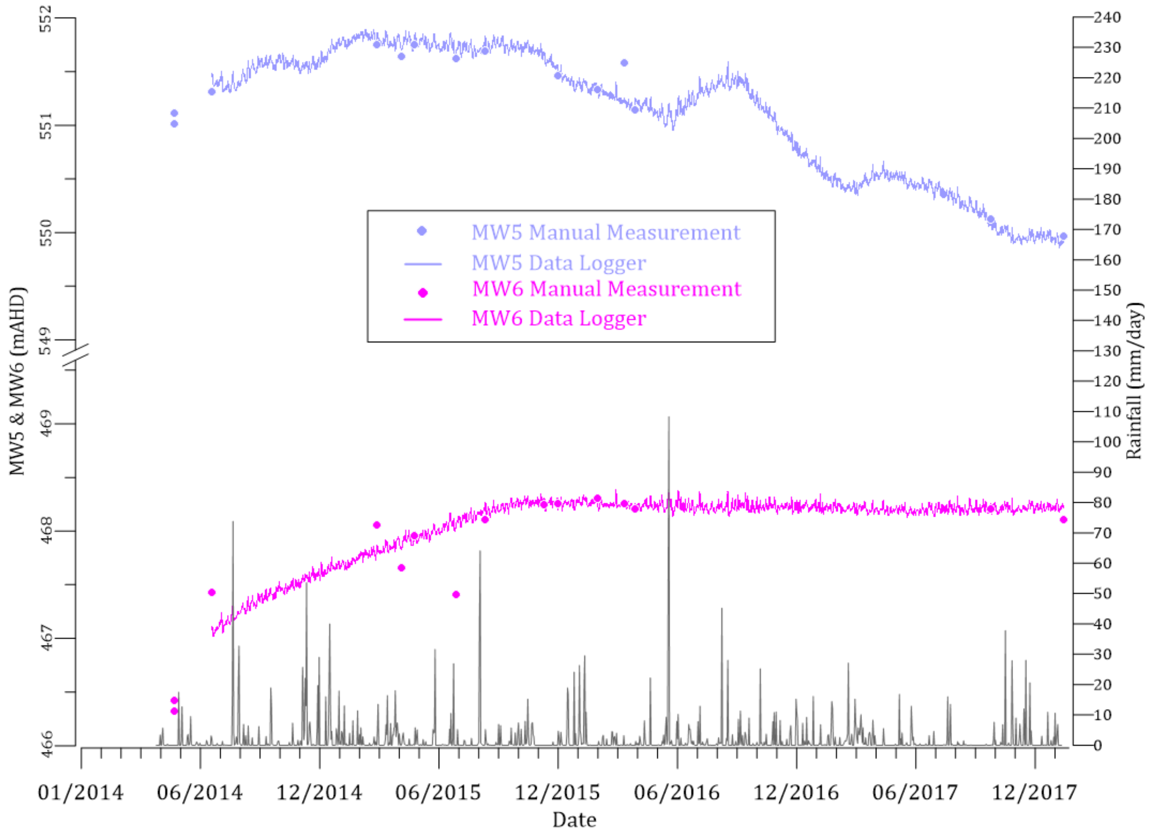


Figure 7-8 Hydrograph of water levels from monitoring bores adjacent to mine (MW5-MW6)

The water level fluctuations measured in the bores installed within the pit contrast strongly with the bores outside the pit. The water levels under the pit floor, particularly MW2 (located within the South pit) respond rapidly to rainfall events with groundwater levels rising over 10 m in some instances, and then slowly decline over a period of days/weeks back to the static water level. This response is due to the accumulated runoff that ponds on the pit floor which then seeps over a period of approximately two weeks into the underlying limestone. The low storage within the limestone results in rapidly rising groundwater levels following accumulation of runoff within the South Pit.

In contrast, MW1 (located within the North Pit) initially responds more gradually, rising and declining more slowly following responses to rainfall recharge events and accumulation of runoff within the North Pit. Water level fluctuations from sampling events are also evident on the MW1 hydrograph. The high rainfall event in September 2015 which resulted in water temporarily ponding within the pit, is visible on both MW1 and MW2 hydrographs. Although MW1 was entirely submerged, the bore hydrograph shows the maximum groundwater level at 430.75 mAHD, which is about 9.4 m below the level of the pit floor. This response suggests that runoff accumulated within the pit drained preferentially through larger fractures, and that the less permeable matrix which MW1 monitors was not fully recharged by the rainfall event. This would indicate poor hydraulic connection between the limestone matrix (in which the MW1 was placed) and surrounding fractured rock matrix.

The hydrograph response for MW1 to rainfall events changes in the latter half of 2015 to one similar to that for MW2, showing quicker water level rises and declines. One explanation for this change could be the development of blast induced fractures altering the hydraulic properties of the limestone matrix surrounding MW1, hydraulically connecting this block of limestone with the main fracture system within the floor of the North Pit.

The recharge of MW2 bore during the 2015 event where water ponded at the base of the pit was entirely consistent with previous observed recharge events and shows very good hydraulic connectivity with surrounding rock, indicating secondary (fracture related) porosity.

The water levels measured in the bores adjacent the pit do not show any significant response to individual rainfall events, but have recorded a slow increase (MW3S, MW3D, and MW4D) in the water levels over the baseline monitoring period. This indicates that a slight recharge to the aquifer occurs either by slow lateral flow from surrounding areas and/or from slow vertical seepage through the overlying weathered regolith layer to the underlying saturated zone. In contrast, the hydrographs for MW4S and MW5 show an overall slight decrease in groundwater levels.

This data suggests the regolith layer acts as a temporary store of recharging rainfall, buffering the fluctuations in groundwater levels below the regolith. In contrast, within the pit area where the regolith has been removed, the fluctuations are more rapid as this buffering layer is not present.

7.6.2 Groundwater quality

Groundwater quality data has been collected on a routine basis since Boral installed the monitoring bore network in April/May 2014. A longer record of water quality data exists for bore WP16, which was installed in 1983, and is monitored according to the requirements of EPL944.

The water quality analytical suite for the mine includes:

- pH, electrical conductivity and total dissolved solids (calc.);
- sodium adsorption ratio (SAR);
- total hardness;
- anions - fluoride, bromide, sulfate, chloride;
- alkalinity - hydroxide, carbonate bicarbonate and total alkalinity;
- cations – calcium, magnesium, sodium, potassium;
- total and dissolved metals - aluminium, arsenic, beryllium, barium, cadmium, chromium, cobalt, copper, lead, manganese, molybdenum, nickel, selenium, strontium, vanadium, zinc, boron, iron;
- dissolved and total recoverable mercury;
- dissolved silica; and
- suspended solids and oil and grease (WP16 only as required by EPL944).

Boral collected groundwater samples on a monthly basis from the monitoring bores and WP16, and have accumulated over two years of baseline data, which is a requirement of the AIP for aquifer interference activities. This sampling is now done on a quarterly basis. AGE also collected a round of water samples from the monitoring bore network and from surface water features during February 2015. The purpose of this round of sampling was to assist in developing the conceptual model and numerical model for the EIS.

pH and salinity (EC)

Table 7-5 summarises the average pH and EC measurements for each bore and the range in the available baseline data. The data indicates the groundwater is typically neutral to slightly alkaline (and alkaline in places), and fresh to slightly brackish. Generally, the groundwater samples from the limestone (MW1, MW2, and WP16) recorded lower electrical conductivity than the volcanics, ranging from 270 µS/cm to 1,060 µS/cm. Samples from the volcanics recorded higher electrical conductivity values which ranged as high as 3,870 µS/cm in MW5.

Ranges in pH values were also observable based on the host geology, ranging between 6.9 in sandstone up to 12 for the volcanics. Limestone pH values were all slight alkaline to alkaline ranging between 7.4 and 8. The highly alkaline value of 12 in water from MW5 is considered to be influenced by downward seepage of groundwater through the cement grout that is placed around the annulus of the PVC casing during bore installation. As such, samples from this bore are not considered to represent the in-situ groundwater quality.

The EC and pH of the sample from the 'Blow Hole' Sampling Point was within the range typical for the limestone.

The measured EC range (concentration of dissolved salts) in the groundwater samples generally indicates the groundwater is of marginal use for drinking water, but suitable for other uses such as stock water and aquatic ecosystems.

Table 7-5 Summary statistics of groundwater quality indicators – pH and EC

Bore ID	Geology	pH (-)				Electrical conductivity @ 25°C (µS/cm)			
		min	mean	max	# Samples	min	mean	max	# Samples
MW1	limestone	7.22	7.67	8.14	26	330	777	1020	26
MW2	limestone	7.23	7.75	8.02	30	566	662	796	30
MW3D	volcanics	7.29	7.69	8.18	29	1060	1252	1450	29
MW3S	regolith	7.34	7.67	7.89	29	1180	1358	1470	29
MW4D	volcanics	7.39	8.08	9.59	29	1070	1250	1450	29
MW4S	volcanics	7.16	7.47	7.77	29	1400	1631	1760	29
MW5	volcanics	7.03	10.21	12	30	765	1213	3870	30
MW6	sandstone	6.92	7.40	7.87	28	476	1763	2500	28
WP16 (North Pit Bore)	limestone	7.45	7.65	7.88	19	486	880	1060	19
'Blow Hole' Sampling Point*	n/a	7.61	8.00	8.22	26	524	619	690	26

***Note**:* ** Sample collected from cliff wall seepage under the B68 cave and is presumed to be representative of the water from B68 spring.*

Ionic composition

The ionic composition of the groundwater collected over the three and a half year baseline monitoring period from the bore network was plotted on Piper (Figure 7-9) and Durov (Figure 7-10) plots. These show three distinct groundwater types based on the major cation-anion ratios which can be grouped from the following host rock geological units:

- Tangerang Formation (Tuff) which is magnesium-potassium-sodium-bicarbonate dominant water;
- Tangerang Formation (Carne Dacite) which is magnesium-potassium-sodium-chloride dominant water; and
- Eastern Limestone and the Adaminaby Group sandstone which are calcium-bicarbonate dominant water.

The surface water sample collected from the location assumed to be downstream of the 'Blow Hole' plotted in a cluster with the limestone groundwater samples, suggesting the source of this water is from the limestone karst system and most likely associated with the fractured limestone aquifer.

The Durov plot shows that the groundwater from the non-limestone units has a higher electrical conductivity. The calcium-bicarbonate water type from the bores screened in the limestone is a reflection of the host geology and dissolution of limestone. The grouping of water quality data from the limestone, Tangerang Formation (Dacite/Tuff) and Adaminaby Sandstone suggests interconnectivity and mixing of groundwater between these units.

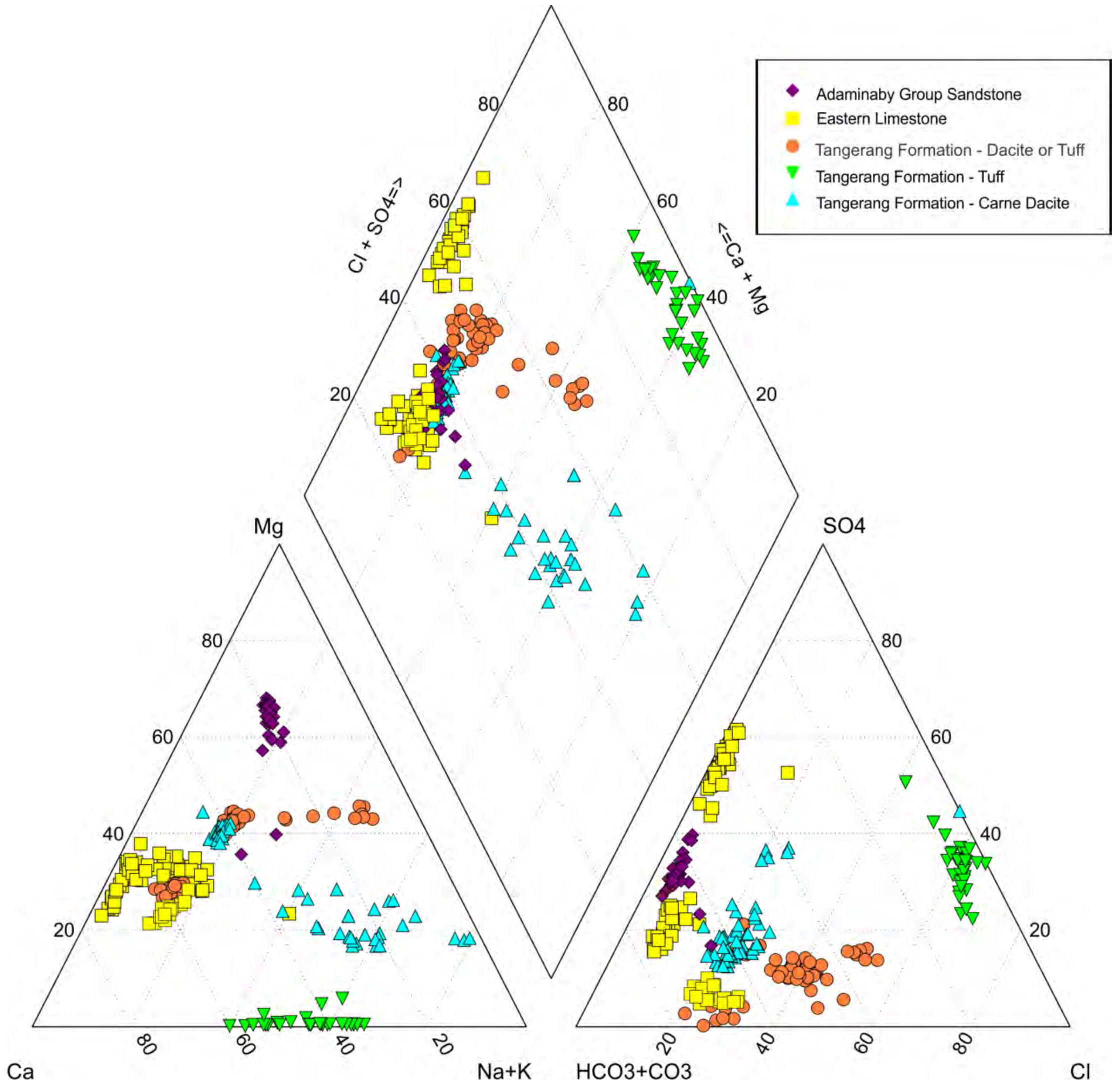


Figure 7-9 Groundwater composition grouped by source geology (Piper diagram)

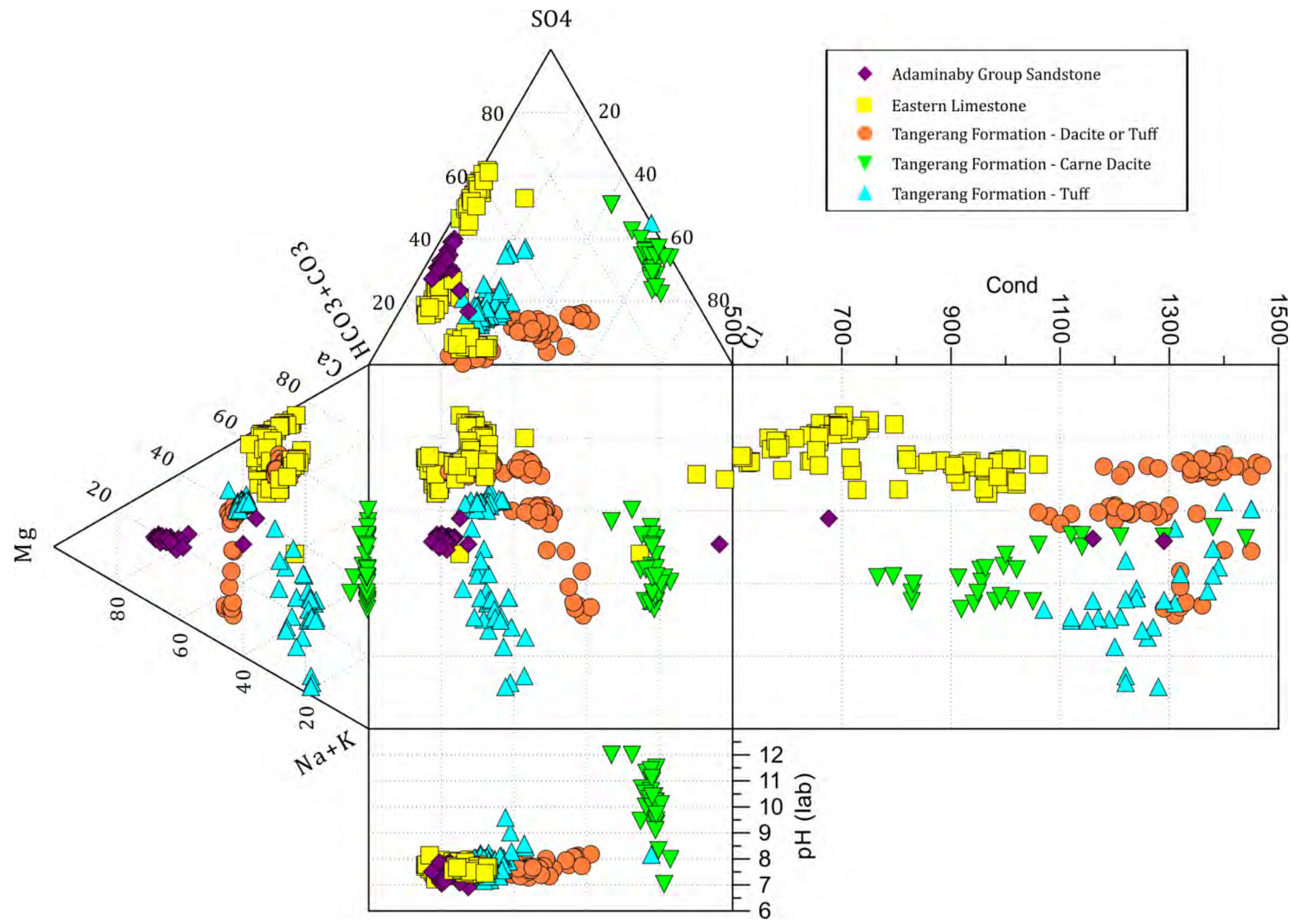


Figure 7-10 Groundwater composition grouped by source geology (extended Durov plot)

7.6.3 Surface water quality

The EIS Surface Water Report presents water quality statistics for surface water sampling sites based on historical pH, conductivity and suspended solids data. The data indicates:

- surface water samples from the Shoalhaven River have the lowest electrical conductivity (EC) and pH as the water is predominantly rainfall sourced;
- the EC of surface water samples from Bungonia Creek and Main Gully are representative of EC levels from the limestone aquifer; and
- the headwaters of Barbers Creek and Marulan Creek occur in areas of Glenrock Granodiorite and Tangerang Volcanics respectively, causing surface water samples to have a relatively higher EC.

The EIS Surface Water Report (Advisian, 2018) describes how the surface water monitoring program has been used to inform whether the existing and proposed future mining activities have, or are likely to have, an impact on surface water resources.

7.7 Isotope analysis summary

In February 2015, AGE collected four water samples for source assessment and dating through isotope analysis – Deuterium, Oxygen-18 Tritium and Carbon-14. The samples were collected from MW1, MW2, 'Blow Hole' Sampling Point and the 'Main Gully Sampling Point' within Bungonia Gorge. The analyses indicated that groundwater from the limestone at the mine is young water less than 100 years old, and the dominant recharge source is from direct rainfall and overland flow from up-gradient catchments.

The isotope analysis suggested the aquifer feeding the spring sampled is recharged relatively quickly. This would indicate that the recharge is likely to be the exposed limestone within the mine and outcrop, where higher permeability and exposure allows direct rainfall recharge. Tritium dating of the groundwater indicates that the groundwater is "modern" and that the groundwater residence time is in the order of 20 years.

The isotope analyses are discussed in more detail in Appendix B.

7.8 Hydraulic properties

7.8.1 Point testing and measurements

RPS (2014) measured hydraulic conductivity by conducting in-situ permeability "slug" tests within the limestone and the overburden geologic units through the monitoring bores installed in April and May 2014. Table 7-6 summarises the results of that in-situ hydraulic testing.

Table 7-6 Estimated hydraulic conductivity

Bore ID	Depth (m)	Geology	Estimated hydraulic conductivity (m/day)
MW1	61	Limestone – north pit	low (1)
MW2	61	Limestone – south pit	0.08
MW3S	49	Weathered regolith	3.2
MW3D	103	Weathered volcanics (dacite)	2.3
MW4S	40	Weathered regolith, volcanics (tuffs)	0.01
MW4D	124	Volcanics (tuffs)	0.03
MW5	98	Weathered regolith, weathered volcanics (dacite)	high (2)
MW6	128	Sandstone	low (3)

Notes: *(1) Hydraulic test undertaken by RPS deemed unreliable due to slow water recovery.*
(2) Rapid recovery restricted observations limiting reliability of hydraulic testing.
(3) Water level depth prevented hydraulic testing.

The initial slug test data highlights the variability in the hydraulic properties of the limestone and surrounding rock units. The data suggests that both highly permeable fracture networks and less permeable rock matrix zones are present at the site. The water level hydrographs shown in Section 7.4 support this conclusion.

Table 7-6 also identifies that a hydraulic conductivity value could not be estimated in three bores using the slug testing method. Slug tests are a cost effective method for estimating the hydraulic conductivity of the geologic material around a bore, however in very low or high hydraulic conductivity material they may not provide a definitive estimate of permeability. Despite this limitation, the tests indicate zones of both limited and high permeability which have assisted in developing a conceptual understanding of the groundwater system.

7.8.2 Bulk hydraulic properties

The bulk hydraulic conductivity of the limestone body in the pit floor was further investigated by analysing the seepage rate of runoff through the pit floor following temporary ponding of water in the North and South Pits following a substantial rainfall event (see Appendix E). In July 2013 and August 2015 water accumulated on the floor of both North and South Pits as a result of high rainfall and surface runoff inflow (that was contained within the pit floor). A pressure transducer was placed in the South Pit before the 2015 flooding event to monitor the rate of accumulated water seepage through the pit floor into the underlying limestone. The sensor was later moved and placed into the area where water accumulated within the North Pit so that the seepage of the runoff into the underlying limestone could be observed.

The pressure transducer data from both locations were combined with water level and volume estimates from direct observations on-site, and used to analyse the discharge rate through the floors of both North and South Pits. Based on this analysis, the bulk vertical saturated hydraulic conductivity of the North and South Pit floors was estimated at 0.5 m/day and 1.25 m/day respectively, indicating an overall, relatively high permeability value. The bulk hydraulic conductivity effectively represents an average value of the primary (pore) porosity and secondary (fracture) porosity of the pit floor. However, it is expected that the fracture network would largely be responsible for the relatively permeable pit floors.

The permeability of the pit floor is also likely to be enhanced by generally steeply dipping limestone strata in the Project area. This would be expected to be confined to the extraction area as less permeable geology units bound the formation to the east and west of the mine pits. The estimated bulk hydraulic conductivity was used to guide the more appropriate value that was adopted in the numerical model for the limestone within the pit floors. Appendix D describes the calibration of the model and adopted values for hydraulic conductivity.

Based on this historical evidence, it is expected that during continued operation of the mine, water that ponds within the pits during high rainfall events will seep through the limestone within the pit floor quickly (within days or a few weeks) and will discharge via the most permeable pathways within the underlying karst system, e.g. B68 - 'Blow Hole', B128, and possibly other unmapped springs that are the points of discharge to the Bungonia Gorge, Bungonia Creek and/or its associated tributaries. A routine monitoring program for the Bungonia Gorge surface water is in place and would be expected to detect any deterioration in water quality. The EIS Surface Water report (Advisian, 2018) details the surface water monitoring program and the likely surface water quality in the receiving water bodies during continued mining.

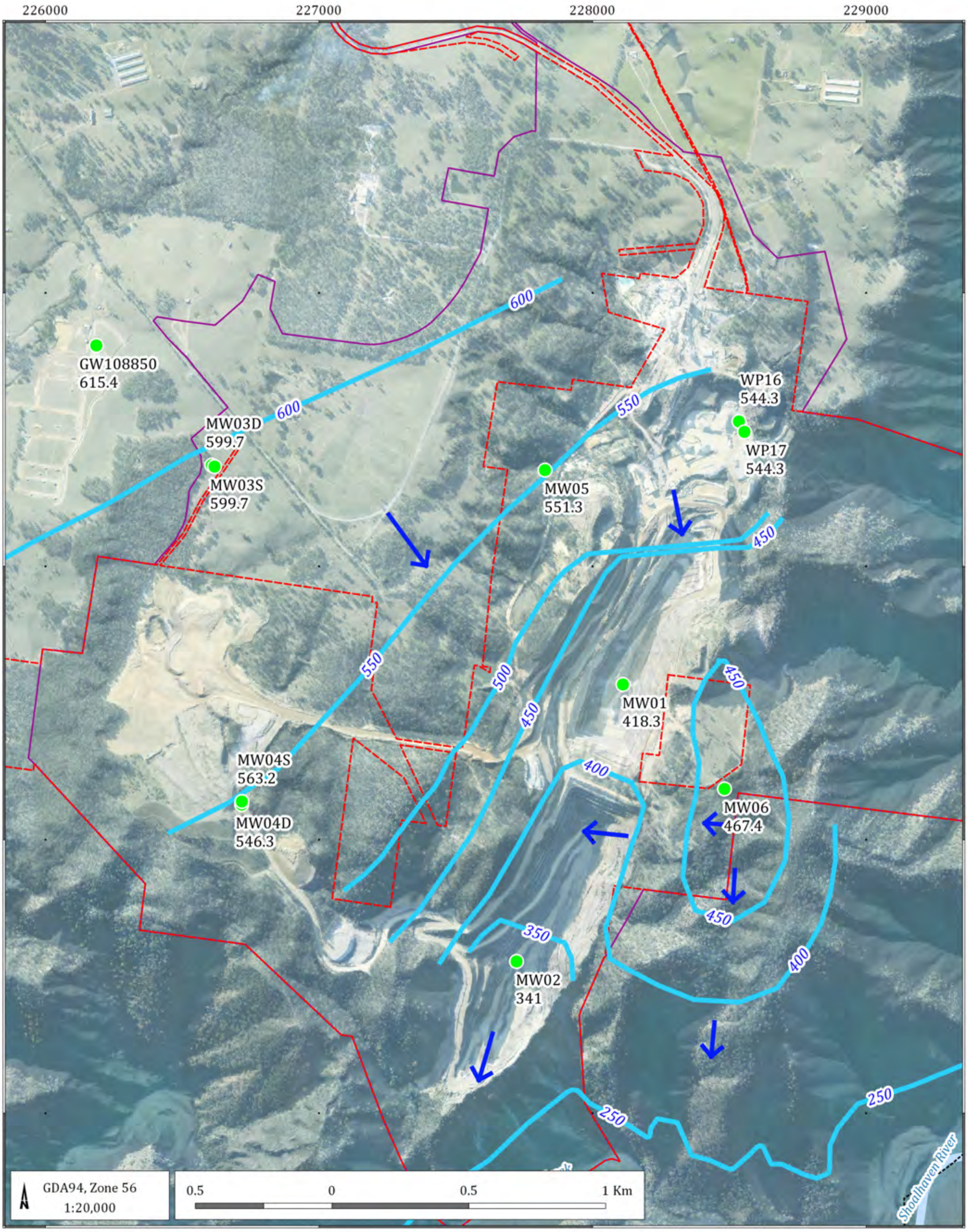
7.9 Hydraulic gradients and flow direction

Water levels for off-site bores where available were accessed from the NSW Government's 'Pinneena' Groundwater Database (2013), and supplemented with water levels measured during the bore census in February 2015 (as described in Section 7.2). Not all bores within the government database contain water level measurements and it was not possible to measure levels in all bores visited during the bore census. Despite this, sufficient information was obtained to prepare a groundwater level map around the Project.

Table 7-7 summarises groundwater levels available for bores in proximity to the Project. Figure 7-11 presents groundwater levels and interpolated water level contours which provide an overall indication of the regional groundwater flow direction being to the east-south-east towards Bungonia and Barber's Creeks. On a local scale around the Marulan South Limestone Mine, groundwater movement is dominated by flow into the mine pits, which is then predicted to seep through the floor of the mine pit and flow southwards into Bungonia Creek.

Table 7-7 Groundwater levels – off-site bores

Registered bore	SWL (mbgl)	Approx. elevation (mAHD)	Date measured
GW102505	18	607	-
GW104453	18	589	3/10/2002
GW105505	12	622	4/12/2003
GW105696	25	595	12/01/2004
GW107145	49	596	30/05/2004
GW108850	10.03	615.38	12/02/2015
GW109179	22	616	7/08/2008
GW109921	10	623	5/02/2009
LICH03	19.35	603.24	12/02/2015
LICH04	23.66	584.22	12/02/2015



LEGEND

- Project_boundary
- CML16
- Head contours (mAHD)
- Flow direction
- Observation bores

Marulan South COP (G1714C)

Regional groundwater flow direction (Feb 2015)

AGE

DATE 23/03/2018

FIGURE No: **7-11**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006;
G:/Projects/G1714C.Marulan South COP/3_GIS/Workspaces/001_Deliverable1/07.11_G1714C_Regional groundwater flow direction (February 2015).qgs

7.10 Conceptual hydrogeological model

The Project site has a unique groundwater regime controlled by a range of factors including the steeply dipping geology, and the water pressures imposed by the steep terrain. The main groundwater system within the Project area is the limestone ore body targeted for mining. The steeply dipping limestone unit means the rock mass is more permeable in the vertical direction than the horizontal direction along bedding planes and joints. Fracturing within the limestone also appears to facilitate the vertical drainage of groundwater (refer to Section 5.2, Section 7.4 and Appendix E). Fracture networks convey water vertically and appear to connect with karst seepage zones that form springs surfacing within the gorge (e.g. on the gorge slopes). Less permeable rock units ‘sandwich’ the limestone and retard lateral groundwater flow with fine-grained siltstones and sandstones present to the east towards the gorge, and a sequence of volcanic units to the west.

The limestone and overlying volcanics were deposited on the already deformed rocks of the Adaminaby and Bendoc Groups. These units were subsequently deformed and are currently dipping with variable degree of steepness toward the west. As discussed, this deformation process created a predominantly north-south jointing/fracture pattern in the limestone which is the main flow pathway within the limestone. This means that the original horizontal hydraulic conductivity creates anisotropy in an east-west direction.

Groundwater storage and flow within the limestone body is dominated by fractures, jointing and solution-enhanced fissures. This tends to promote rapid flow through fissures and solution cavities, while the limestone matrix itself is relatively impermeable. This conceptualization is supported by data collected from the mine pits as discussed in Section 7.4 and Appendix E. Monitoring bores installed within the pit floor did not respond to the accumulation of water above the pit floor, despite water readily draining from the pit indicating the secondary porosity fracture network conveys the water while the primary porosity of the limestone matrix is very tight.

The limestone is intruded with a number of dykes, both parallel and perpendicular to the strike of the limestone body. Based on site observation data, the dykes oriented perpendicular to the strike of the limestone appear to act as hydraulic barriers, as evidenced by groundwater levels varying considerably on either side of the dykes (GeoRes, 2018).

These low permeability dykes appear to convey groundwater to the surface as observed through the presence of a groundwater spring in a dolerite dyke in the North Pit (refer to Figure 7-13). The springs and pools also occur where the steep topography along the incised drainage lines cuts below the level of the water table promoting drainage of groundwater. Spring fauna of high ecological value was identified within pools along the drainage lines that discharge into Bungonia Gorge.

Regionally, groundwater level measurements indicate flow is generally toward the east-south-east towards the deeply incised gullies of Bungonia and Barber’s Creeks. Locally around the mine the anisotropy conveys groundwater preferentially though the limestone fracture network parallel to the strike towards the south-west, but some flow towards the south-east is also expected based on local properties of the rock units. The groundwater table shape and gradient across the Project Area is influenced by changes in geology, which often mark changes in hydraulic properties both on a local and regional scale. An example of this feature can be observed where the geological boundary between Kerillon Tuff Member (volcanic tuffs) and Devils Pulpit Member (volcanic breccias) delineates a border between harder, possibly less weathered bedrock westward of the geological boundary and softer, deeply weathered and more eroded bedrock east of the geological boundary (Figure 7-12).

Up gradient of the mine, the water table elevation is generally between 550 m AHD and 600 m AHD with a relatively low gradient. Adjacent the mine the elevation of Bungonia Creek is in the order of 120 m AHD. The hydraulic gradient of the water table steepens considerably closer to the escarpment in proximity to Bungonia and Barber’s Creeks with groundwater discharging into the gorge and also “daylighting” at springs on the northern face of the gorge.

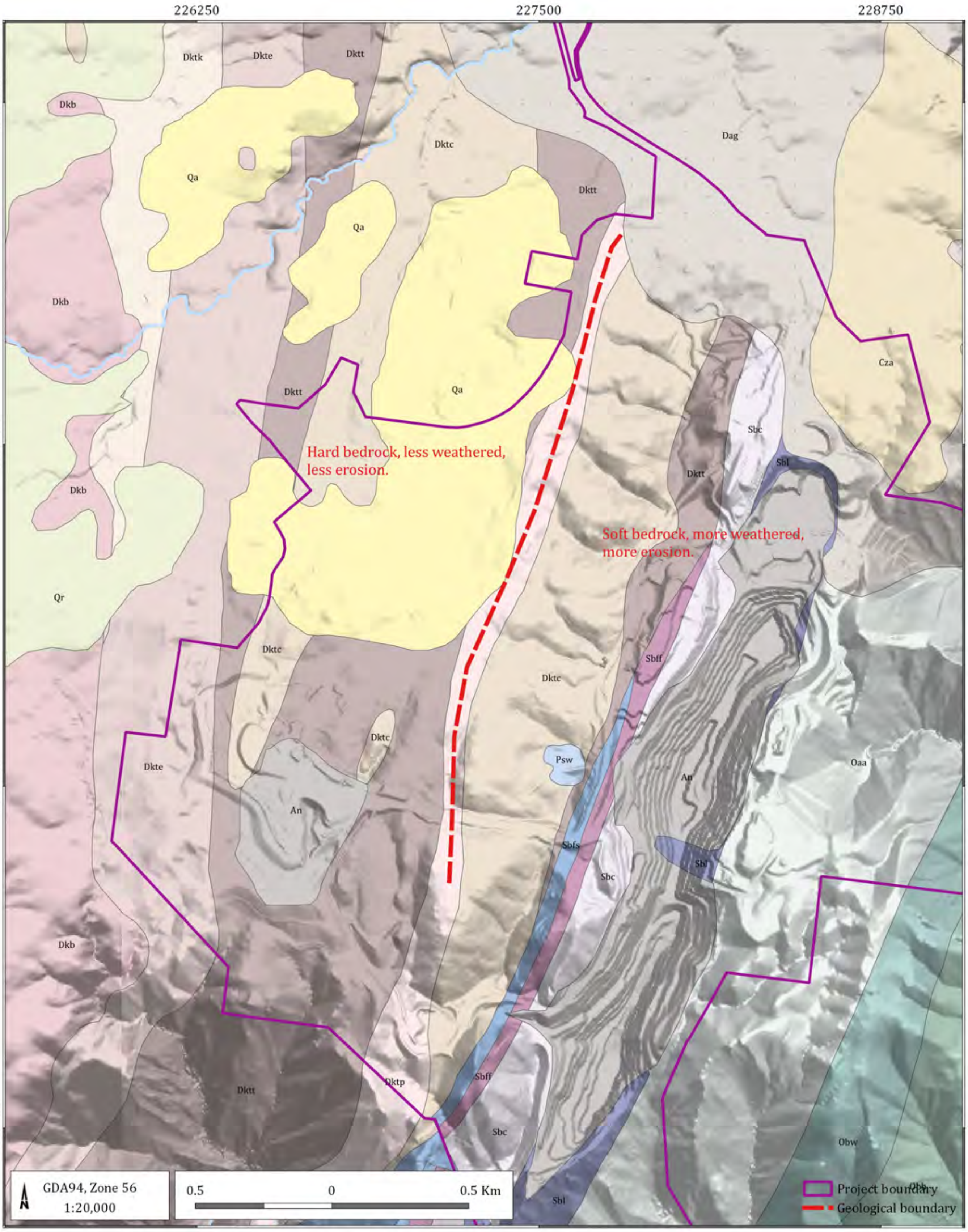
The chemistry of spring water closely matches groundwater from the in-pit monitoring bores. This indicates springs present on and at the base of the limestone outcrop in Bungonia Gorge, south of the mine are likely to be the main discharge points for the limestone aquifer. Deuterium and Oxygen-18 isotope analysis identifies the aquifer feeding the spring sampled is recharged relatively quickly. This would indicate that the recharge is likely to be the exposed limestone within the mine and outcrop, where higher permeability and exposure allows direct rainfall recharge.

Tritium dating of the groundwater indicates that the groundwater is “modern” and that the groundwater residence time is in the order of 20 years.

A second source of recharge to the limestone aquifer is the Glenrock Granodiorite intrusion north of the limestone body. As the hydraulic connection of the limestone with the Adaminaby Group and the Tangerang Formation is minimal, a result of the anisotropy in the permeability between and within the units, the predominant recharge source from outside of the limestone is possibly the granodiorite intrusion to the north (Figure 7-13). Groundwater from the limestone and overlying Tangerang Volcanics is low in salinity and close to neutral pH. These aquifers provide some base-flow to Bungonia Creek which has a similar water quality signature to the limestone aquifer. A general view of Bungonia Creek approximately 50 m upstream from the confluence with Main Gully stream is shown in Figure 7-14.

A weathering profile is present west of the pit where the topography flattens, which could potentially contain an elevated water table that has the capacity to be a moderately permeable water bearing unit. During the lifetime of the mine, gullies immediately west of the south pit were in-filled with overburden. Some of the overburden rock material was also dumped southwards towards Bungonia Creek and eastwards towards Barbers Creek, forming coarse slope colluvium/screen. These areas could become a source of runoff seepage in response to having an enhanced rainfall recharge potential as a result of the loose nature of the unconsolidated overburden rock materials.

Figure 7-15 presents a simplified cross-section of the conceptual model showing stratigraphy and groundwater regime including groundwater flow, recharge and discharge zones.



LEGEND

Surface geology

- An - Anthropogenic deposits
- Qa - Anthropogenic deposits
- Qr - Cenozoic pisolithic iron laterite
- Cza - Cenozoic alluvial and colluvial deposits of gravels;sands and clays
- Psw - Wandrawandian Formation
- Dag - Glenrock Granodiorite
- Dkb - Barrallier Ignimbrite
- Dktc - Carne Dacite Member
- Dkte - Kerillon Tuff Member
- Dktk - Kerrawarra Dacite Membe
- Dktp - Devils Pulpit Member
- Dktt - Tangerang Formation - unnamed tuffaceous member
- Sbc - Cardinal View Formation
- Sbfe - Efflux Siltstone Member
- Sbff - Folly Point Limestone Member
- Sbfs - Sawtooth Ridge Limestone Member
- Sbl - Lookdown Limestone
- Obw - Warbisco Shale
- Obb - Bumballa Formation
- Oaa - Adaminaby Group

Marulan South COP (G1714C)

Change of bedrock properties

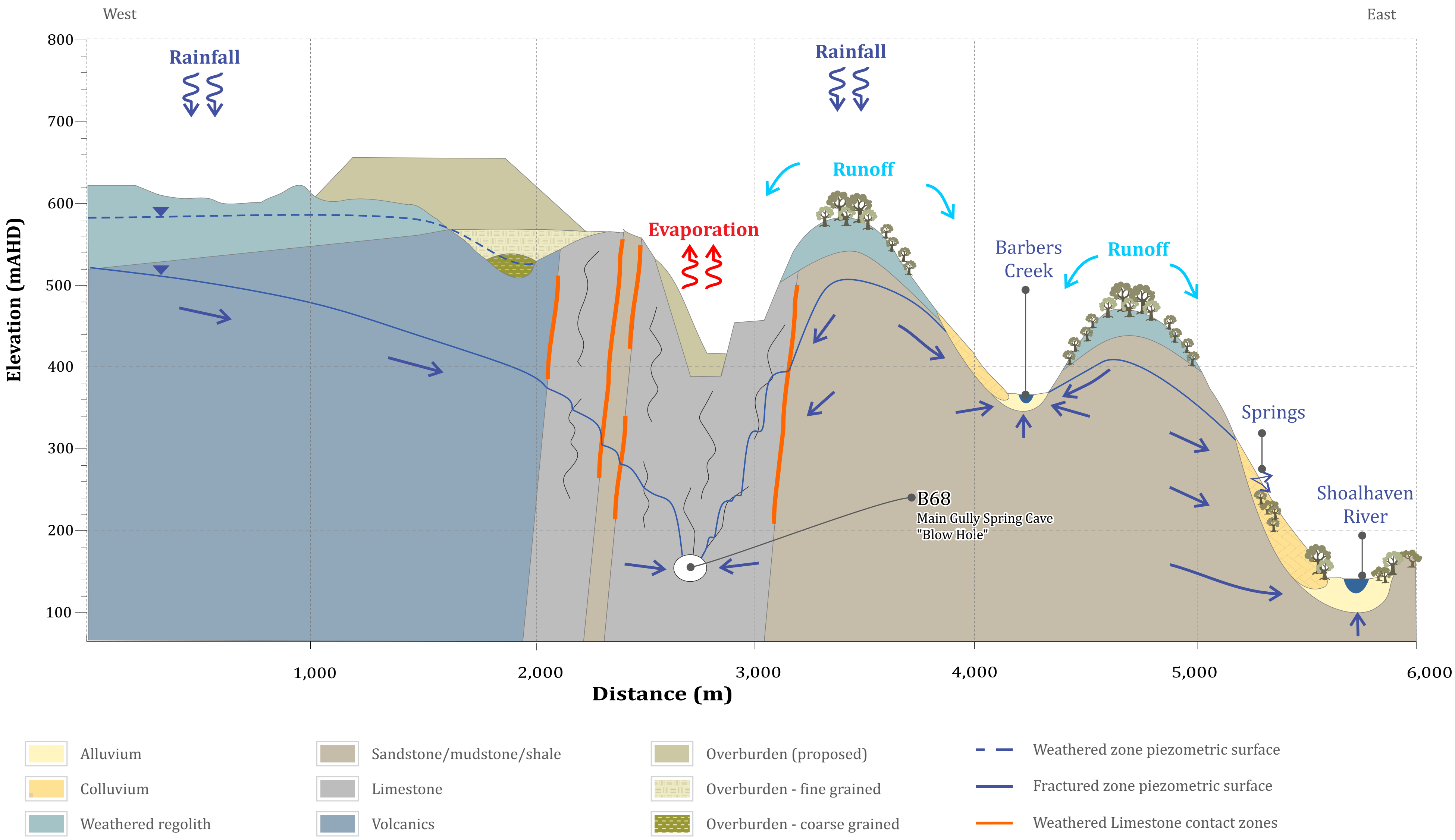
DATE 28/08/2018

FIGURE No: **7-12**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006;
G:/Projects/G1714C.Marulan South COP/3_GIS/Workspaces/001_Deliverable1/07.12_G1714C change of bedrock properties.qgs

Figure 7-13 North pit dolerite dyke and groundwater spring

Figure 7-14 Bungonia Creek – approximately 50m upstream from the confluence with Main Gully stream.



Simplified W-E cross-section through the model domain (conceptual)

Figure 7-15

Marulan South COP (G17

8 Impact assessment

8.1 Impact predictions methodology

The impact of the future mining activities was assessed using a numerical groundwater flow model as required under the Aquifer Interference Policy. The modelling objectives, process and results are presented in the following sections. Appendix D and Appendix E provide technical details on the model construction, calibration and associated investigations.

8.2 Summary of sensitive groundwater resources

In summary the sensitive aspects of the groundwater regime are:

- the volume and quality of groundwater flowing to the creeks and springs that occur between the mining area in the west and the Bungonia gorge system in the east; and
- the water level at private water bores in the plateau to the west of the mine.

8.3 Impact assessment criteria

The impact assessment criteria was the ‘minimal impact considerations’ outlined within the Aquifer Interference Policy (pg 15, Table 1, section ‘Less Productive Groundwater Source’). All the criteria are listed and addressed in Appendix A.

8.4 Model objectives

The numerical model was developed to assess the impacts of the Project on the surrounding groundwater environment including the:

- groundwater take from the alluvial and fractured/sedimentary rock water sources;
- baseflow reduction;
- influence on GDEs; and
- water licensing requirements (groundwater only).

While the numerical model does not simulate changes in groundwater quality, it was used as a tool to qualitatively assess the potential for significant changes in groundwater quality to occur.

8.5 Model construction and development

8.5.1 Classification of the model – confidence level

Barnett et al (2012) developed a system to classify the confidence-level for groundwater models. Models are classified as either Class 1, Class 2 or Class 3 in order of increasing confidence (i.e. Class 3 has the highest level of confidence). The system considers data, calibration quality, system stresses and the consistency between calibration and prediction periods when determining the model confidence level. Although the model occasionally meets Class 3 indicators, it is considered a Class 2 model. Whilst it is acknowledged modelling potentially fracture controlled systems with the effective porous media approach is challenging the model generally satisfies Class 2 which is recommended for assessing impacts of major projects. The classification of the model is discussed in greater detail in Appendix D, Section 5.

8.5.2 Modelling code selection

MODFLOW-USG (Panday et.al, 2013) was determined to be the most suitable modelling code to meet the model objectives. The distinct advantage MODFLOW-USG has over its predecessors is the ability to discretise the model using an unstructured mesh, meaning that the cells in the model are not restricted to rectangular shapes. Small cells can be used in the area of interest to represent geological or mining features, with larger cells outside these areas where refinement is not required. This produces an optimal model grid, aiding numerical stability and limiting the number of cells. In addition, model layering does not need to be continuous over the model area, and layers can pinch out where geological units are not present. MODFLOW-USG also simulates unsaturated conditions and has robust numerical solution schemes to handle the more complex numerical problem resulting from the unsaturated flow formulation.

8.5.3 Limitations

As discussed in earlier sections, the conceptual groundwater regime in the Project Area is relatively unique due to the steeply dipping limestone units and topography. The fractured nature of the limestone along with the karst properties means the chosen numerical groundwater flow model is not capable of representing the small scale geological detail that occurs within the limestone body at the site, however it is adequate to assess the impacts of the Mine on the adjacent groundwater systems, groundwater users and groundwater dependent ecosystems.

Use of the MODFLOW-USG model assumes the fractured rock system can be represented by the numerical model as an 'equivalent porous medium'. Additionally, to the comprising porous matrix, the model uses interconnected high conductivity cells to represent contact zone discontinuities as well as fracture system draining the limestone body towards the Bungonia Gorge. While the contact zones conduits (refer to Appendix D, Figure D6) are based on geological mapping, the existence of the karst conduit system (refer to Appendix D, Figure D5) is based on the existence of discharge points (springs) in the Bungonia Gorge. Although not precisely defined in terms of spatial extent and interconnectedness, its function as drainage is understood enough to be modelled with sufficient level of precision, especially where the dewatering impacts on groundwater levels surrounding the Mine are concerned. Modelling of the water table within the limestone body needs to be interpreted with caution.

Towards the west of the mine in the plateau area where the topography is more gentle and a weathered rock aquifer system occurs, the model use of the 'equivalent porous medium' approach is considered valid.

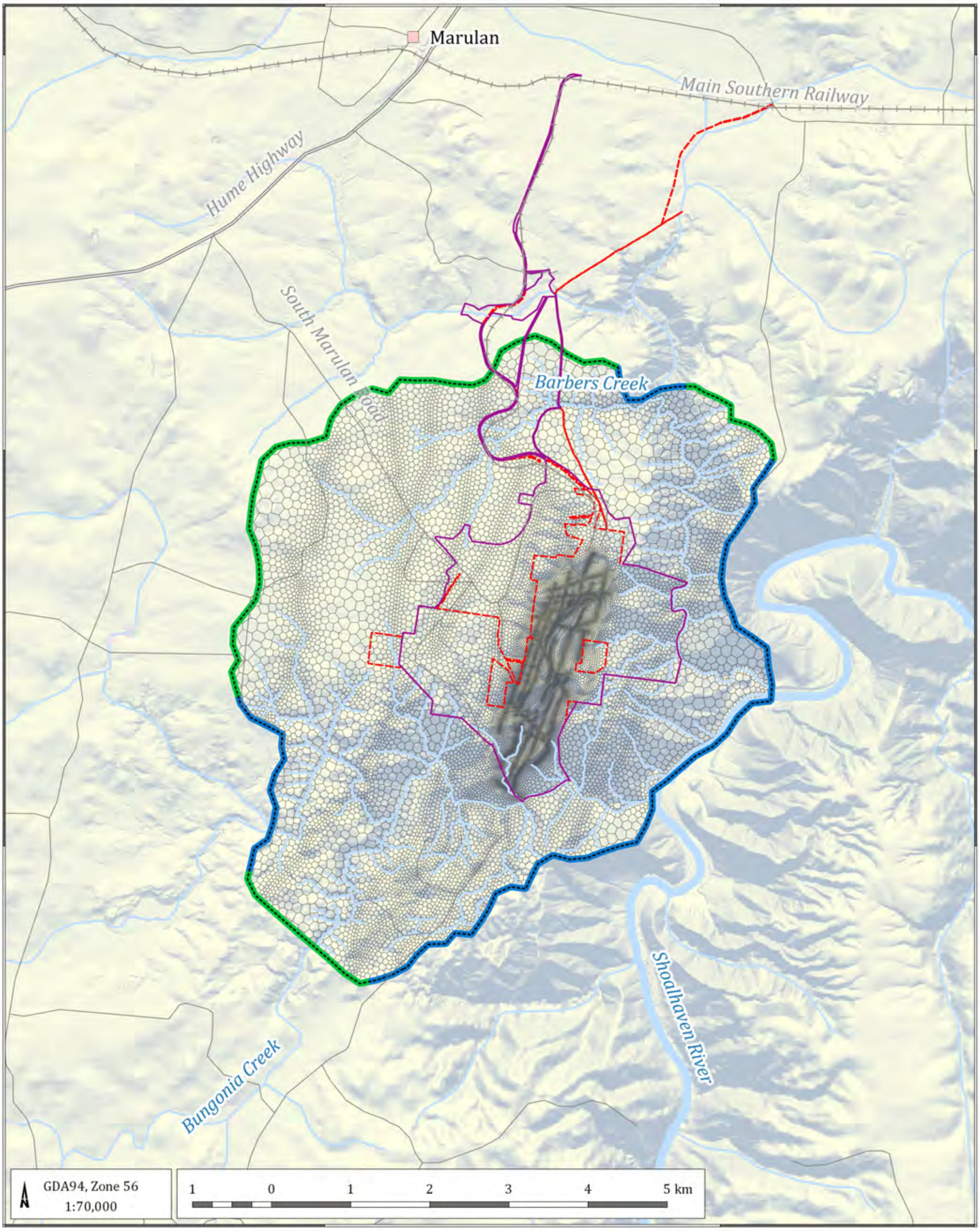
Despite these limitations, as long as they are considered, the model is a valuable tool to assist in assessing the potential impacts of the Project on the groundwater regime.

8.5.4 Model design, domain and boundary conditions

The model extended approximately 6.8 km from east to west, and 8.5 km from north to south, covering a total area of 38.7 km^2. The model mesh consists of 184,592 active nodes. The model domain was discretised using mostly hexagonal Voronoi polygons (Figure 8-1). There were 25,164 nodes defined across the model domain with the dimensions of the cells varying from approximately 10 m by 10 m within the Project area (to represent structural features) to approximately 200 m by 200 m outside of the Project area. The cells sizes were refined to add detail and better represent small geological structures such as faults, fracture systems or geological boundaries and locations of groundwater monitoring bores.

The horizontal extent of the numerical model was selected to be sufficiently distant from the area of the proposed mining to limit its influence on the predicted water levels and flows. Most of the model boundaries were located along watershed lines, assuming that the water table is a subdued reflection of the surface topography with topographical highs that translate into groundwater divides. Where groundwater divides were not thought to exist, a general head boundary condition was implemented along the edge of the model to allow for the model domain to interact with outside influences such as aquifer systems continuing beyond the boundary.

The model consists of ten layers. The uppermost layer represents unconsolidated sediments and regolith as well as areas of alluvium adjacent to the significant streams within the model domain. Layer 2 to Layer 10 represent the bedrock, including structural (linear) features such as faults, weathering contact zones and volcanic intrusions - (i.e. dykes). The bedrock was divided into layers with the intent to capture the major elevations of the pit floor during proposed mining expansion as well as other structural features such as the karst system behind the Main Gully Spring Cave (B68 – 'Blowhole').



LEGEND

- Populated place
- Project boundary
- CML16
- Model boundary
- Model mesh
- Road
- Rail
- Watercourse, drainage
- GHB - general head boundary condition
- NF - no-flow boundary condition

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Model mesh and conceptual boundaries of the model domain

AGE

DATE 23/03/2018

FIGURE No: **8-1**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:/Projects/G1714C.Marulan South COP/3_GIS/Workspaces/001_Deliverable1/08.01_G1714C_Model mesh and conceptual boundaries of the model domain.qgs

8.5.5 Timing of the groundwater flow model

Timing of the numerical model run is defined around the existence and frequency of observation data for the calibration period and coarseness of stresses (specifically mining progression) for the prediction period. The model uses an adaptive timestepping approach where it can change (decrease or increase) the timestep length depending on ease of the numerical convergence. The time units used in the model are days. Given these initial limitations, the numerical model runs using time intervals as defined in Table 8-1 below.

Table 8-1 Timing of the numerical model run

SP	# of SP	SP length	date from	date to	comment
Calibration (transient) – 61 stress periods					
01 - 10	10	365.25	1/01/2003	31/12/2012	Lead-in period
11 - 12	2	182.625	1/01/2013	31/12/2013	Lead-in period
13 - 61	49	30.4375	1/01/2014	31/01/2018	Model calibration
Prediction – mining (transient) – 32 stress periods					
01	1	150	1/02/2018	30/06/2018	Pre-SSD
02	1	365	1/07/2018	30/06/2019	Pre-SSD
03 - 07	5	365-366	1/07/2019	30/06/2024	Stage 1 development
08 - 15	8	365-366	1/07/2024	30/06/2032	Stage 2 development
16 - 21	6	365-366	1/07/2032	30/06/2038	Stage 3 development
22 - 32	11	365-366	1/07/2038	30/06/2049	Stage 4 development
Prediction – recovery (transient) – 14 stress periods					
01 - 03	3	30-31	1/07/2049	30/09/2049	-
04	1	92	1/10/2049	31/12/2049	-
05	1	365	1/01/2050	31/12/2050	-
06 - 10	5	3652-3653	1/01/2051	31/12/2100	-
11 - 14	4	18262	1/01/2101	21/12/2300	-

8.5.6 Model calibration

Calibration of a groundwater flow model is the process that demonstrates the model's capability for replicating observed field data. Calibration is accomplished by finding a set of parameters, boundary conditions and stresses that produce simulated heads and fluxes that match field measured values within an acceptable range of error. The model calibration method was primarily driven by adjusting selected parameters (hydraulic conductivities) within realistic ranges to match historic regional and local groundwater levels.

Calibration was undertaken in two steps: (1) steady state calibration – to approximate the hydraulic properties and generate starting heads for (2) the transient calibration run, during which the hydraulic properties were fine-tuned and recharge factors were calibrated.

Groundwater level information used for the steady state calibration was collated from multiple sources, mainly, publicly available records (NSW Office of Water – Pinneena database), records provided by Boral (groundwater data from site), as well as information collected during a bore census. Measurements from 16 bores were used to compile the calibration dataset.

All observation locations were used for both steady state calibration and transient calibration, except for MW7, which was dry during the monitoring period and omitted from the calibration dataset. In order to improve the performance of the calibration run, the pressure transducer data (bores MW1-MW6) were resampled from 3 measurements per day to a single (average) observation per week. This frequency was deemed sufficient with respect to the calibration stress period length (1 month).

The model was calibrated and verified to existing groundwater levels, using reliable measurements from representative bores within the model domain. A detailed description of the calibration method is provided in Appendix D. The objective of the calibration was to replicate the observed groundwater levels in accordance with the modelling guidelines developed by Barnett *et al.,* (2012). The steady state calibration achieved a 2.5% scaled root mean square (SRMS) error and the transient calibration achieved a 3.0% SRMS error.

Although not specifically quantified in modelling guidelines (Barnett *et al.*, 2012), it is generally recommended that the value of scaled RMS (SRMS) is below 10%. This criterion was satisfied for both steady state and transient calibration runs. Comparison of the predicted and observed hydrographs show acceptable qualitative match in groundwater level trends, indicating the adopted parameter set is considered to produce a representative groundwater table and flow predictions on a regional scale.

8.6 Modelled mining stresses

Boral proposes to continue mining the current pits (Eastern Limestone) as well as expand to the adjacent units (Mt. Frome Limestone) until end of June 2049. The groundwater model stress periods reflect the mining which will be conducted in five stages as shown in Table 8-2. The spatial extent of mining activities for individual stages of the Project is presented in Figure 8-2.

Table 8-2 Modelled mining schedule – stages, years

Stage of mining	Stress period	Mining years	Calendar years
Pre-SSD	1-2	-2 - 0	2018 – 2019
1	3-7	1 - 5	2019 - 2024
2	8-15	6 - 13	2024 - 2032
3	16-21	14 - 19	2032 - 2038
4	22-32	20 - 30	2038 - 2049

8.7 Groundwater modelling results

The results of the groundwater flow model comprises two main dataset outputs. These are the predicted groundwater levels (heads) during the model run and the predicted groundwater budgets that are further used to estimate flows into the mine pits or other areas of interest. Comparison of model runs with and without mining allows to establish and quantify the influence of mining activities on the groundwater system.

8.7.1 Predicted groundwater levels

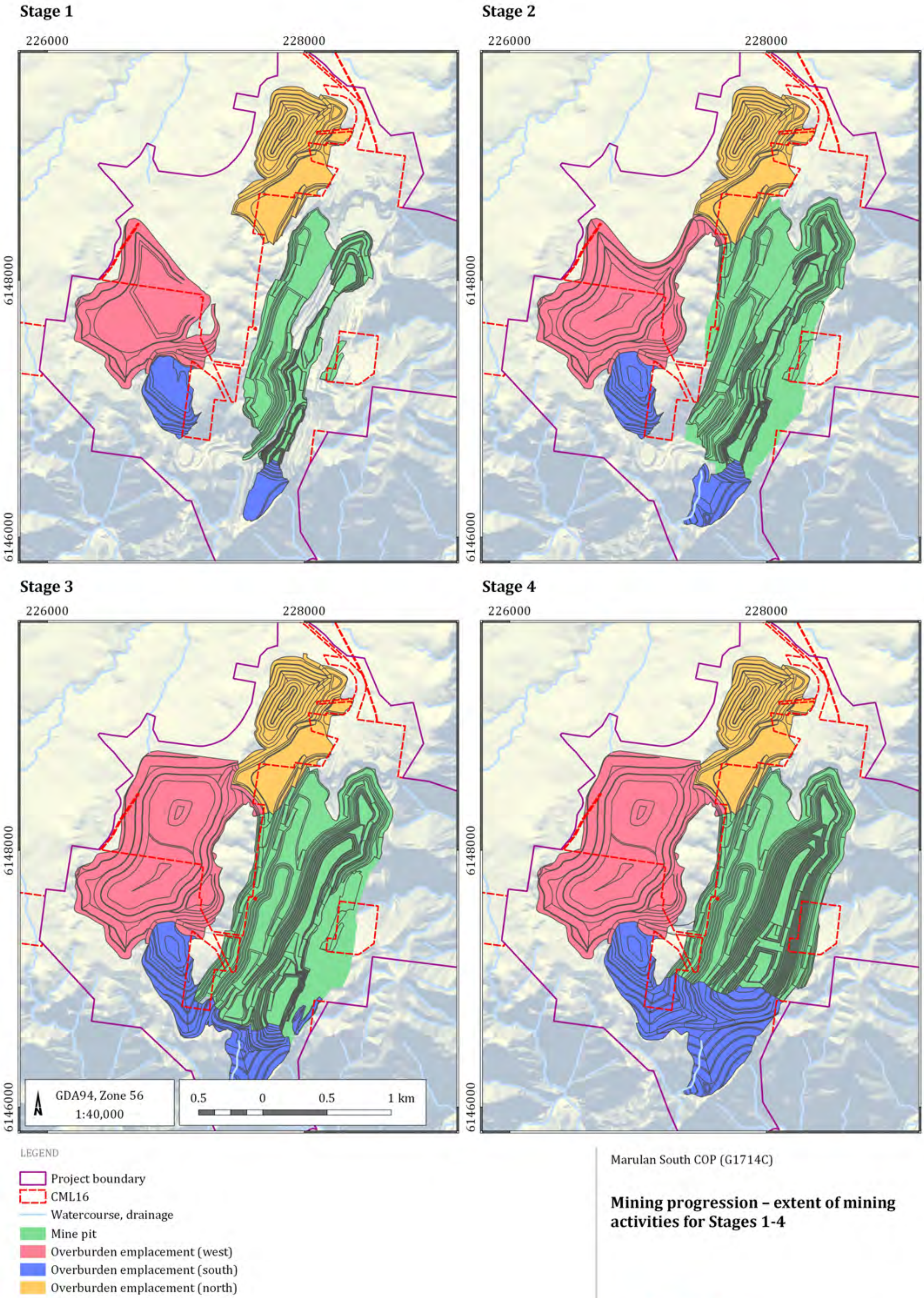
Figure 8-3 shows predicted groundwater levels at the end of the proposed mining (mid 2049, mining year 30) in the bedrock. The groundwater potentiometric surface shows the same general trend observed at the start of the mining process, which is consistent with the conceptual model (refer to Section 7.10). Groundwater generally moves from topographically higher terrain in the north-west and west to topographically lower areas in the east and south-east. The deeply incised valleys and gorges of Bungonia and Barbers Creeks remain the main drainage features for the groundwater system as mining progresses. Figure 8-3 shows steep hydraulic gradients remain around the pit at the end of mining.

The water level contours for model layer 8 also highlight the role played by the fault fractures, weathered zones at the edge of limestone bodies, pit floor fractures and volcanic intrusions. The numerical model behaves in accordance with conceptualization of the groundwater system (refer to Section 7.10) and drainage of the bedrock blocks intersected by fractures can be observed. The only major barrier preventing the drainage of the granodiorite north of the pit is the dolerite dyke, running across the northern part of the current North Pit (refer to Section 7.10).

As the active fractures connect the bedrock with the Bungonia Creek alluvium, the groundwater elevation below the active mining area appears to stabilize between RL 210 mAHD and RL 250 mAHD. This suggests that the volume of groundwater contained within the limestone can be expected to actively discharge into the Bungonia Creek alluvium and ultimately contribute the flow of Bungonia Creek.

Comparison of groundwater levels at the beginning and at the end of mining shows minimal change outside the limestone bodies. This observation confirms the concept of a combined porous and fractured aquifer system, in which the interconnected fractures have effectively pre-drained the limestone and the mining activity removes only 'residual' water from the in-situ porous space of the rock.

Assuming there are no changes to the nature and extent of fractures within the base of the pit, extending the model run for a further 250 years post-mining shows continued drainage from the limestone units (see Figure 8-4). The only change to the overall water balance will be a slight increase in recharge into the limestone due to a larger overall area of the mine pit. The net response to this will be an associated increase in baseflow to Bungonia Creek.



Marulan South COP (G1714C)

Mining progression – extent of mining activities for Stages 1-4

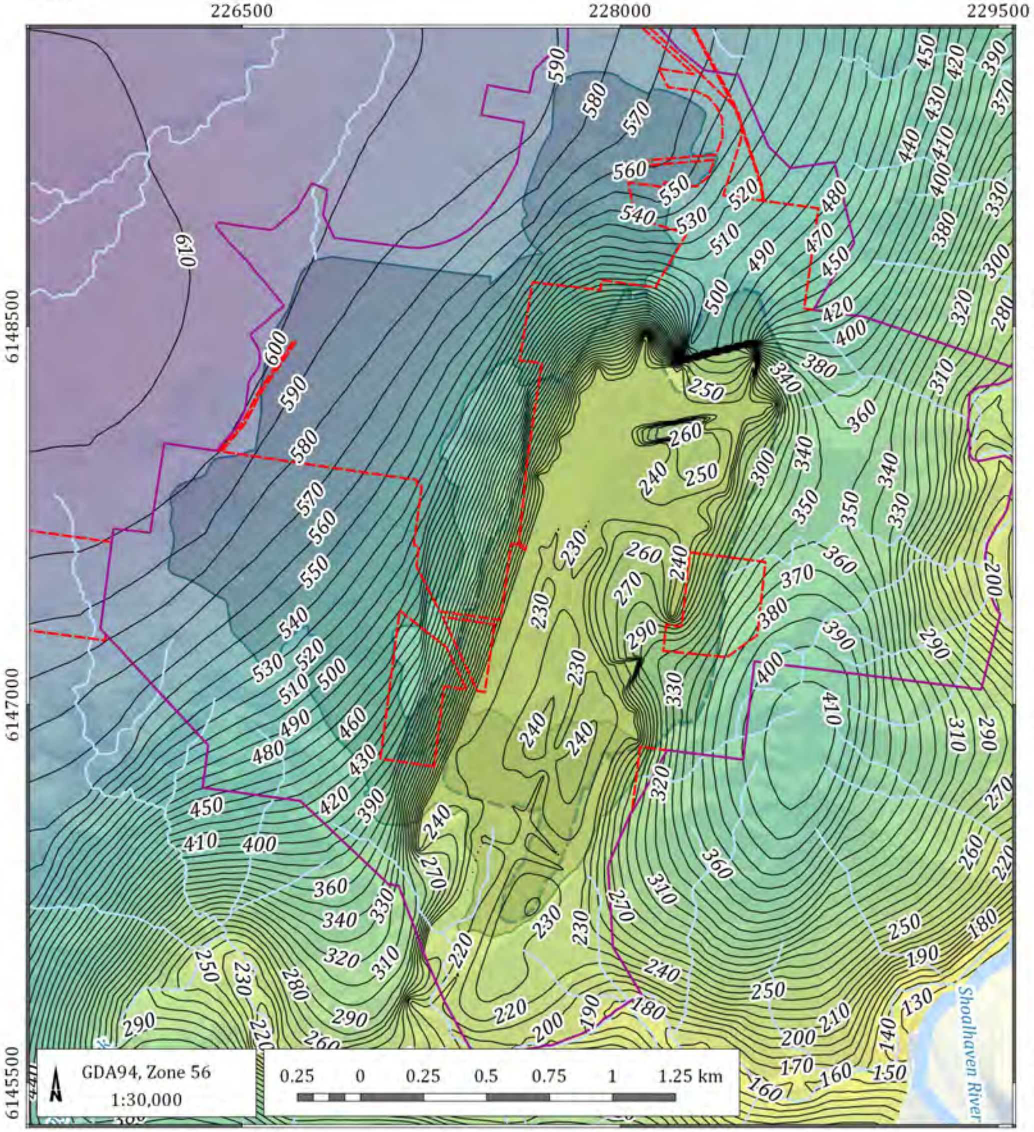
AGE

DATE 23/03/2018

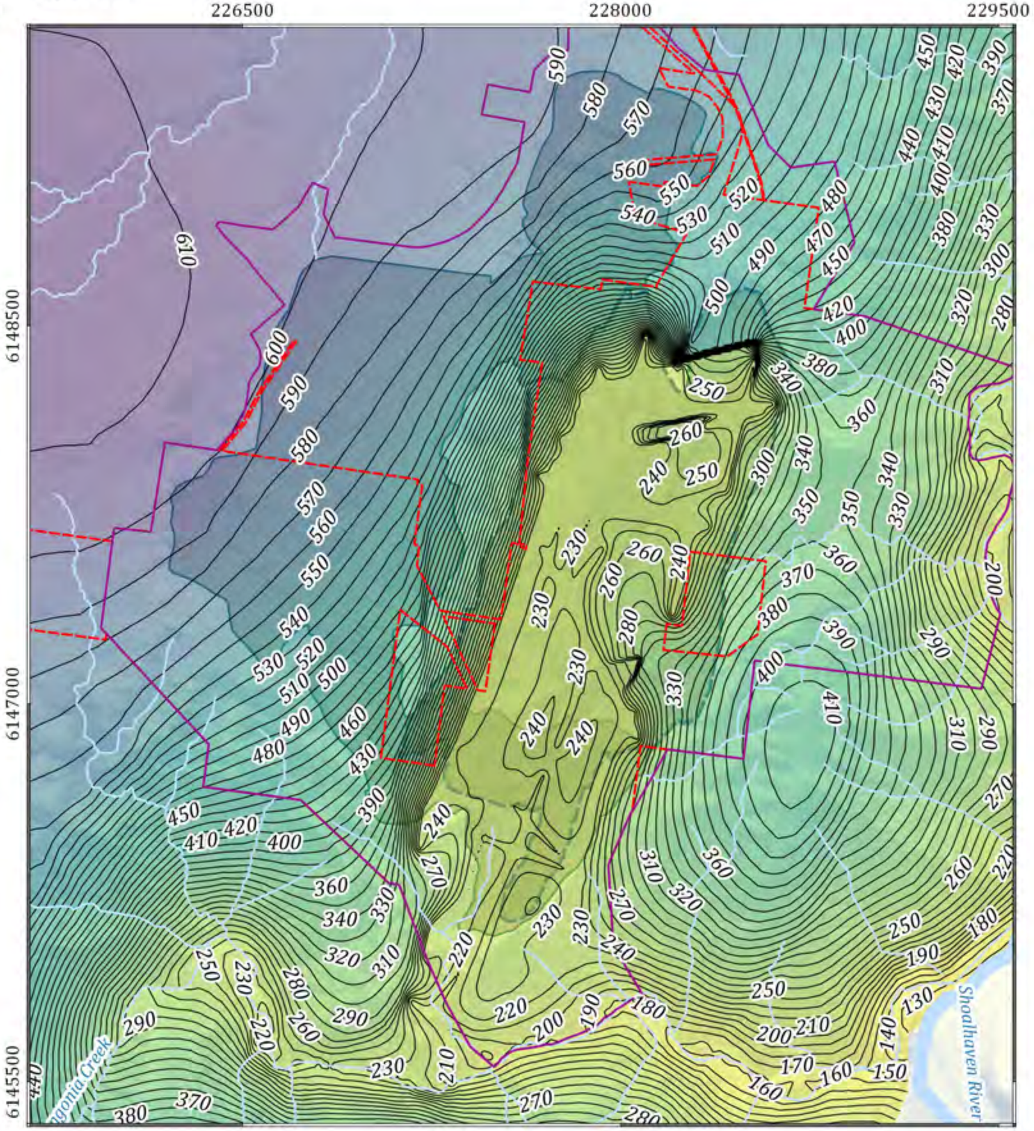
FIGURE No: **8-2**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:/Projects/G1714C.Marulan South COP/3_GIS/Workspaces/001_Deliverable1/08.02_G1714C_Mining progression – extent of mining activities for Stages 1-4.qgs

Layer 8



Layer 10



LEGEND

- Project boundary
- CML16
- Pit extent
- Spoil extent
- Watercourse, drainage

Head (mAHD)

- 100
- 250
- 350
- 450
- 550
- 650

— Head contour (mAHD)

Marulan South COP (G1714C)

AGE

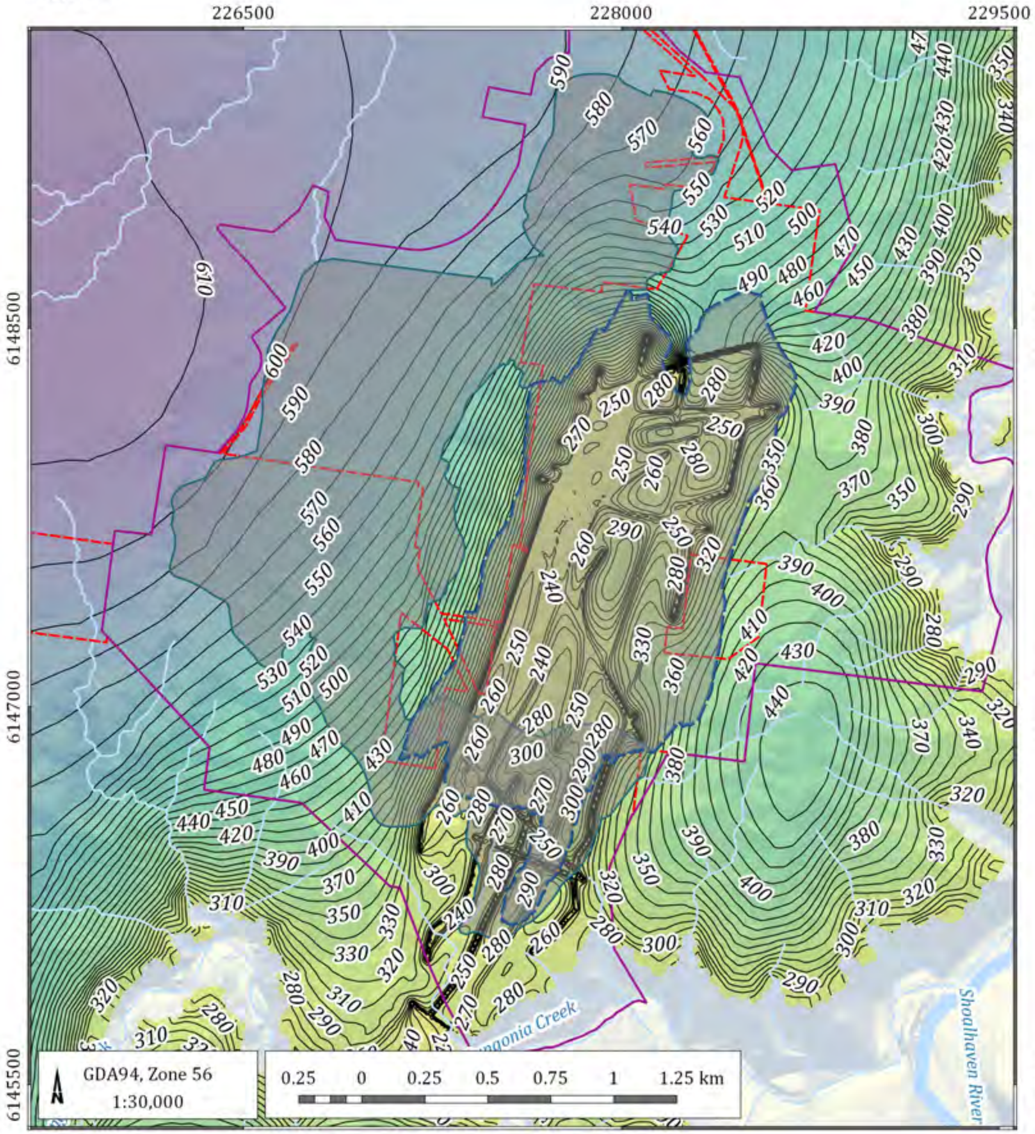
Predicted groundwater heads – end of mining - stage 4, year 30, FY2049

DATE
23/03/2018

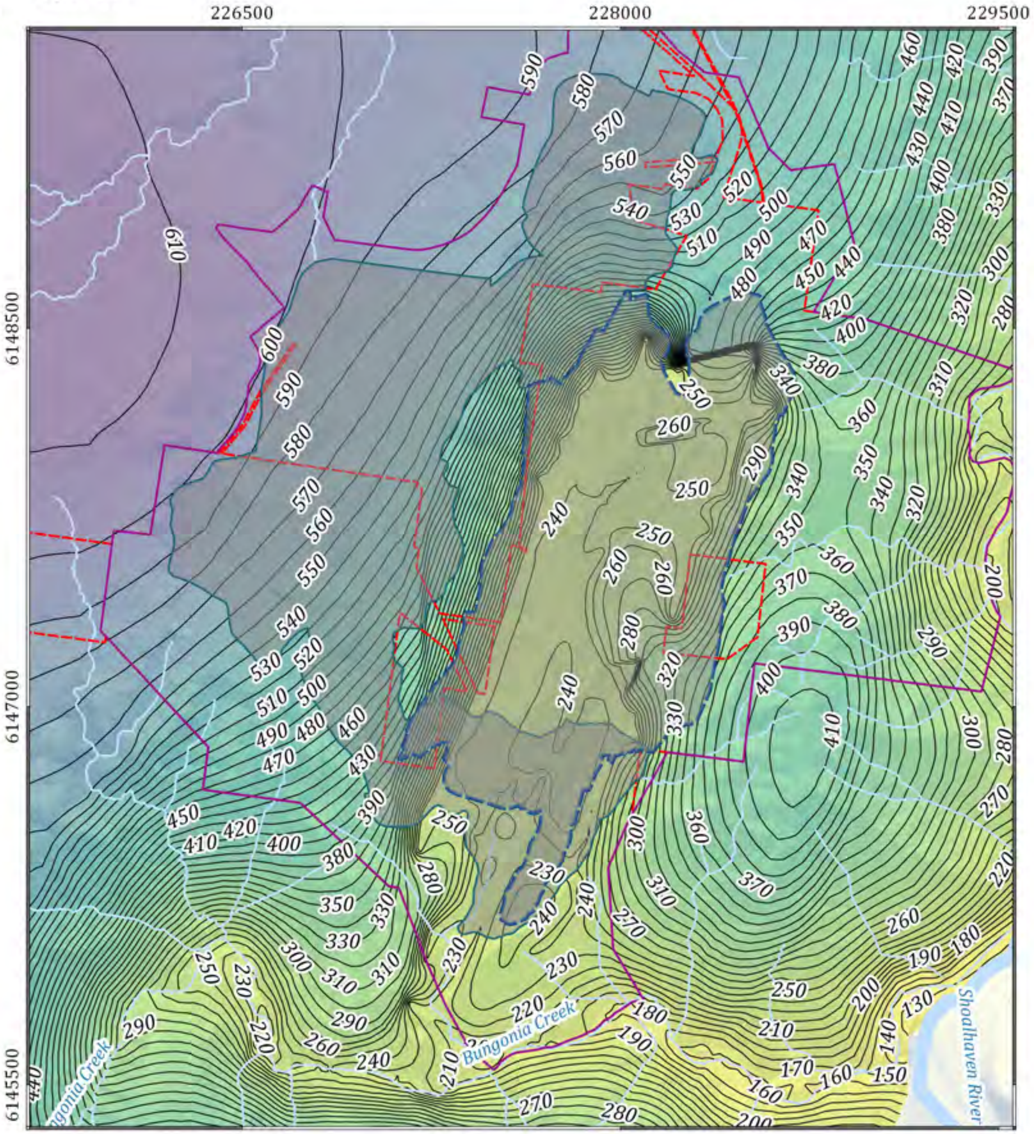
FIGURE No:
8-3

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:/Projects/G1714C.Marulan South COP/3_GIS/Workspaces/001_Deliverable1/08.03_G1714C_Predicted groundwater heads – end of mining - stage 4, year 30, FY2049.qgs

Layer 8



Layer 10



LEGEND

- Project boundary
- CML16
- Pit extent
- Spoil extent
- Watercourse, drainage

Head (mAHD)

- 100
- 250
- 350
- 450
- 550
- 650

— Head contour (mAHD)

Marulan South COP (G1714C)

Predicted groundwater heads – post-mining equilibrium – year 2300

DATE
23/03/2018

FIGURE No:
8-4

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:/Projects/G1714C.Marulan South COP/3_GIS/Workspaces/001_Deliverable1/08.04_G1714C_Predicted groundwater heads – post-mining equilibrium – year 2300.qgs

8.7.2 Water take from fractured bedrock aquifers

The flow from the fractured rock aquifer into the mine pit is determined using the cell-by-cell budget which groups individual model cells into relevant zones from which groundwater flows can be summarised. This approach quantifies flows from the fractured aquifer into the pit as well as flows to and from the recharge (RCH), evaporation (EVT) and drains (DRN) boundaries within the numerical model.

The water budget for the mine pit zone is summarised in Table 8-3, which shows inflows into the pit from the surrounding bedrock are small (9.1 m^3/day on average), compared to the main source of recharge, which is rainfall (142.4 m^3/day on average). In terms of outflows, most of the water disappears through bedrock seepage via fractures that connect the mine pit to the underlying limestone karst system (approximately 111 m^3/day). Significantly lesser amounts of available excess water is removed by evaporation (1.7 m^3/day).

Table 8-3 Predictive run – average zone budgets – fractured bedrock aquifer

Mine Pit Zone		Flow rate (m3/day)	Flow rate (ML/year)
From (inflow to zone)	Geo environment (GEO)	9.14	3.3
	Recharge (RCH)	142.43	52.0
To (outflow from zone)	Geo environment (GEO)	111.06	40.6
	Evapotranspiration (EVT)	1.69	0.6
	Mining (DRN)	38.82	14.2

8.7.3 Pit inflows

Pit inflows are represented in the numerical model by the drain (DRN) package. The drain elevations are set to the pit floor and are progressively lowered or expanded as the mining progresses downwards and sideways. The annual pit shells were calculated by linear interpolation of depth between available pit shells for the end of mining years 5 (Stage 1), 13 (Stage 2), 19 (Stage 3) and 30 (Stage 4). The predicted take of groundwater (as inflow into the pit) from the proposed mining was estimated from the water budget for the drain (DRN) boundary condition.

As the limestone is mostly pre-drained from the various interconnected fracture systems, the associated groundwater table is below the pit floor during mining operations and the only water removed during the mining is groundwater in storage in the rock itself. The estimated take from the consolidated limestone ('ore body'), sandstone and shale (overburden) aquifers, varies from 19 m^3/day to 63 m^3/day (7 ML/year to 22 ML/year) with average take of 39 m^3/day (14.2 ML/year). The DRN flow rates are presented in Figure 8-5 and Table 8-4.

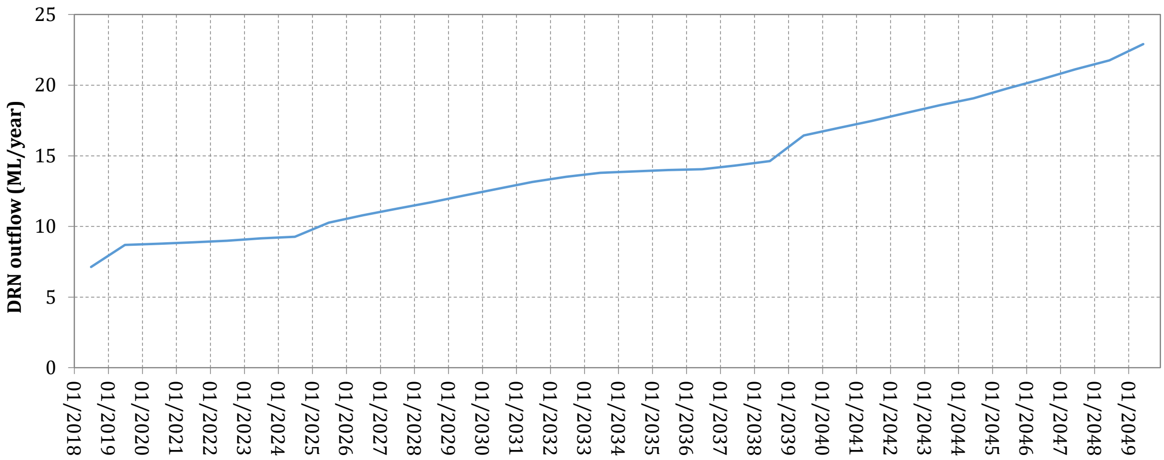


Figure 8-5 Water removed from the pit as a result of mining

Table 8-4 Predictive run – zone budget – water removed from the pit as a result of mining

Stress period	Date at end of stress period	Predicted drain (DRN) inflow (ML/year)
1	30/06/2018	7.13
2	30/06/2019	8.69
3	30/06/2020	8.78
4	30/06/2021	8.87
5	30/06/2022	8.99
6	30/06/2023	9.16
7	30/06/2024	9.27
8	30/06/2025	10.27
9	30/06/2026	10.78
10	30/06/2027	11.26
11	30/06/2028	11.70
12	30/06/2029	12.20
13	30/06/2030	12.68
14	30/06/2031	13.15
15	30/06/2032	13.52
16	30/06/2033	13.80
17	30/06/2034	13.89
18	30/06/2035	14.00
19	30/06/2036	14.06
20	30/06/2037	14.31

Stress period	Date at end of stress period	Predicted drain (DRN) inflow (ML/year)
21	30/06/2038	14.62
22	30/06/2039	16.44
23	30/06/2040	16.96
24	30/06/2041	17.47
25	30/06/2042	18.02
26	30/06/2043	18.58
27	30/06/2044	19.07
28	30/06/2045	19.78
29	30/06/2046	20.42
30	30/06/2047	21.13
31	30/06/2048	21.76
32	30/06/2049	22.91

8.7.4 Water take from alluvial aquifers

There are three alluvial zones represented in the model. These are: alluvium associated with Shoalhaven River (zone 02), alluvium along Bungonia Creek (zone 03) and alluvium along Barbers Creek (zone 04 - refer to Appendix D, Section D2.3, Figure D3). Although the alluvial zones are not particularly extensive, they play a key role as groundwater sinks, removing groundwater from the system (using a river [RIV] boundary condition). This setup is forced by the topography of the modelled area, as the alluvium is mostly located in the lower lying parts of the model domain.

All alluvial zones represented in the model receive water from three sources. One of the sources is the surface water stream (river or creek) itself, which is in the form of the recharge from the river, through the stream bed, to the alluvial sediments. The second source is groundwater seeping upwards or sideways from underlying bedrock or flowing from the upstream section of the alluvium. The third source is rainfall related recharge, which depends on the area of the alluvium and compared to the previous two sources is quite small.

In terms of outflow, the alluvium loses water to the rivers or creeks in the form of baseflow. Groundwater losses also occur as seepage either into the underlying bedrock or as flow within the alluvial sediments to a downstream section of the same alluvium. Lastly, there is groundwater loss in the form of evapotranspiration, which is the least significant mechanism for water loss from the alluvium.

Shoalhaven River alluvial zone receives the majority of water flow from Shoalhaven River with contribution from Bungonia Creek alluvium, Barbers Creek alluvium, underlying bedrock and weathered regolith. The total inflows from the contributing geological environments are as much as 151 m^3/day. Diffuse rainfall recharge constitutes only a minor portion (6 m^3/day) of this total inflow.

Because both Bungonia and Barbers Creeks are modelled as having intermittent flow, the head in the creek was defined roughly equivalent to the creek bed resulting in a reduced recharge potential from the creek. This is reflected by the model water budget, where the creek alluvial zones receive on average 17 m^3/day (Bungonia Creek alluvium) and 23 m^3/day (Barbers Creek alluvium) from their respective surface water streams. Bungonia Creek alluvium also shows elevated inflow from underlying bedrock (601 m^3/day) which is driven by a system of fractures within the limestone, underlying the alluvium.

The river boundary condition provides a groundwater sink as it enables groundwater to drain from the alluvium, that means the alluvial aquifers recharge the creeks in the form of baseflow. This volume of water represents the majority of the outflow portion of the numerical model water budget for both the Shoalhaven River alluvium (391 m^3/day) and the Bungonia Creek alluvium (454 m^3/day). The Barbers Creek alluvial zone shows no baseflow from the alluvium to the creek, as it only loses groundwater via down-valley flow (~81 m^3/day into Shoalhaven River alluvium) and seepage to bedrock (~ 6 m^3/day). The budgets for individual zones are summarized in Table 8-5 and presented in full in Appendix D, Table D17.

Table 8-5 Predictive run – average zone budgets – alluvium

Boundary Condition		Shoalhaven River (m^3/day)	Bungonia Creek (m^3/day)	Barbers Creek (m^3/day)
From (inflow to zone)	River (RIV)	242.8	17.5	23.4
	Recharge (RCH)	5.6	8.0	2.2
	GEO	150.8	601.4	46.0
	Total inflow	399.2	626.9	71.6
To (outflow from zone)	River (RIV)	390.7	454.4	0
	Evapotranspiration (EVT)	1.3	5.1	0
	GEO	0.0	167.5	87.3
	Total outflow	392.1	627.0	87.3

Notes: *Input/output boundary conditions:*
RIV – river;
RCH – recharge;
ET – evapotranspiration:
GEO – represents flows from and to geological environment bedrock and/or adjacent alluvial zone.

8.7.5 Groundwater extraction for water supply

Introduction

As the water balance for the proposed 30 years of continued mining (Advisian, 2018) identified a water deficit (if the proposed Marulan Creek dam was not built), an option for obtaining a groundwater supply from the area between the mine and Peppertree Quarry was explored using pumping wells. Six hypothetical extraction wells were incorporated into the numerical model, spaced approximately equidistantly along the northern edge of mine. The proposed locations were selected to cover the largest possible volume of the granodiorite aquifer, and optimize the distance between the wells to minimise the inclusion of potentially unnecessary pumping infrastructure. The well locations were adjusted to avoid areas occupied by existing or proposed infrastructure (roads, rail, supporting mine machinery, and proposed overburden emplacement areas). The exact locations of the proposed pumping wells are presented in Table 8-6.

Table 8-6 Location of pumping wells

Well ID	Easting (GDA94, z56)	Northing (GDA94, z56)
w01	228675	6148595
w02	228635	6148863
w03	228594	6149157
w04	228458	6149349
w05	227914	6149554
w06	228173	6149528

Additional modelling inputs

As a part of the production well network assessment, AGE was provided with the two following datasets:

- one evaluating decline and/or increase in groundwater heads around Peppertree Quarry between March 2016 to October 2017 (RPS 2017a), updated with measurements to January 2018; and
- the other being undated simplified drill logs for eleven exploration holes south east from Peppertree quarry.

Based on this data, the groundwater levels around the Peppertree quarry appear to be relatively stable, approximately 23 m below ground surface (ranging from 11.7 m to 42.5 m, based on 62 water level observations in 11 bores). The simplified drill logs indicate the thickness of the weathered regolith to generally be around 9 m (ranging from 2 m to 17 m). This data suggests the weathered regolith is mostly dry, with groundwater most likely available within the deeper, inferred fractured aquifer. Although basic data on aquifer hydraulic parameters exist (RPS, 2015), the information was not available at the time of the water supply analysis. RPS (2015) estimated that the 'low' horizontal hydraulic conductivity of the fractured granodiorite aquifer was between 0.03-0.10 m/day, based on 11 in-situ permeability (slug) tests. This information is consistent with the observed mining impacts on groundwater levels around the Peppertree Quarry, which are only minimally impacted from quarrying in the granodiorite.

Model verification

The model predictions for the behaviour of the groundwater system surrounding Peppertree Quarry were verified by comparing the groundwater level observations in the Peppertree monitoring bores to the modelled groundwater levels. Although the fit was not ideal, and the model is generally underpredicting for certain observation and overpredicting for others, the trend of the model prediction follows the trend of the observations. Based on the updated calibration statistics (RMS = 8.07, SRMS = 2.94%), the overall fit of the observed and modelled data (with the Peppertree observation data included) is acceptable.

Model predictions

The numerical model predicts the available pumping rate will vary from approximately 80 ML/year at the start of groundwater abstraction, to 15 ML/year towards the end of mining activities (refer to Figure 8-6 and Table 8-7). The net decline in the overall rate of groundwater abstraction confirms that given the low hydraulic conductivity of the fractured granodiorite aquifer, the amount of groundwater available to be pumped from the aquifer is limited, suggesting the tested volume of 300 ML/year is unlikely to be available to be accessed from proposed well network. Predicted groundwater heads for layers 3 and 10 in year 30 (FY2049) are shown in Figure 8-7.

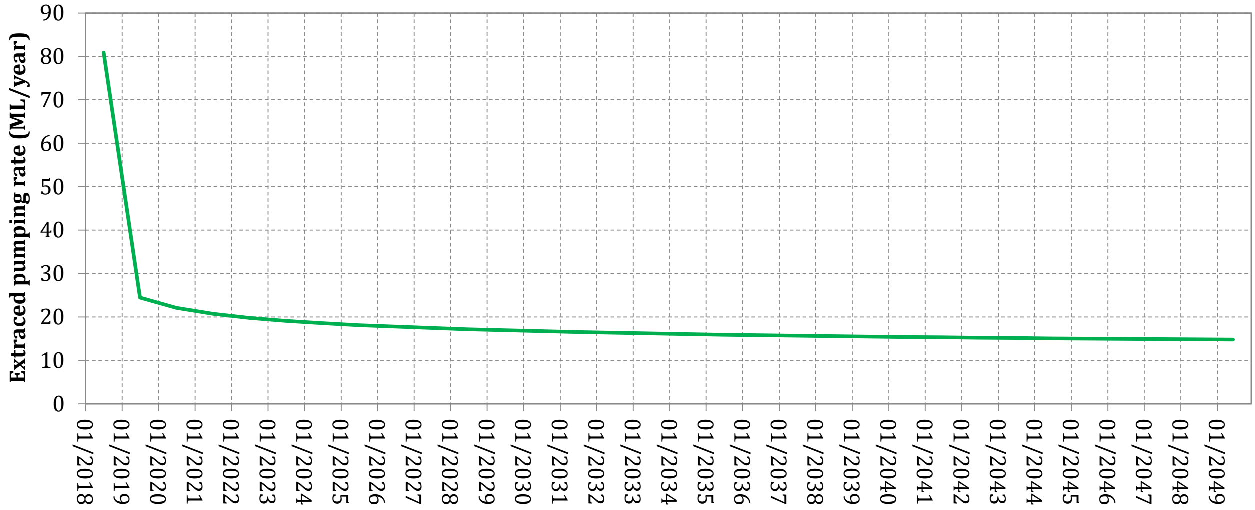


Figure 8-6 Predicted extraction from proposed well field

Model limitations

There are a number of factors influencing the potential for a groundwater supply option from the fractured granodiorite aquifer. Similar to the limestone, the groundwater storage capability of the granodiorite will be limited to the shallower weathered regolith zone and the deeper fractured zone. Recharge to groundwater hosted in this type of aquifer will be a function of downward seepage into weathered regolith, which in turn recharges the deeper fractured granodiorite. The volume of groundwater that is 'available' for abstraction (pumping) will depend on depth of the bore into both the weathered regolith and fractured bedrock. The potential for aquifer storage will therefore be a function of the extent of fractures intersected by the borehole and interconnected across this fractured bedrock aquifer.

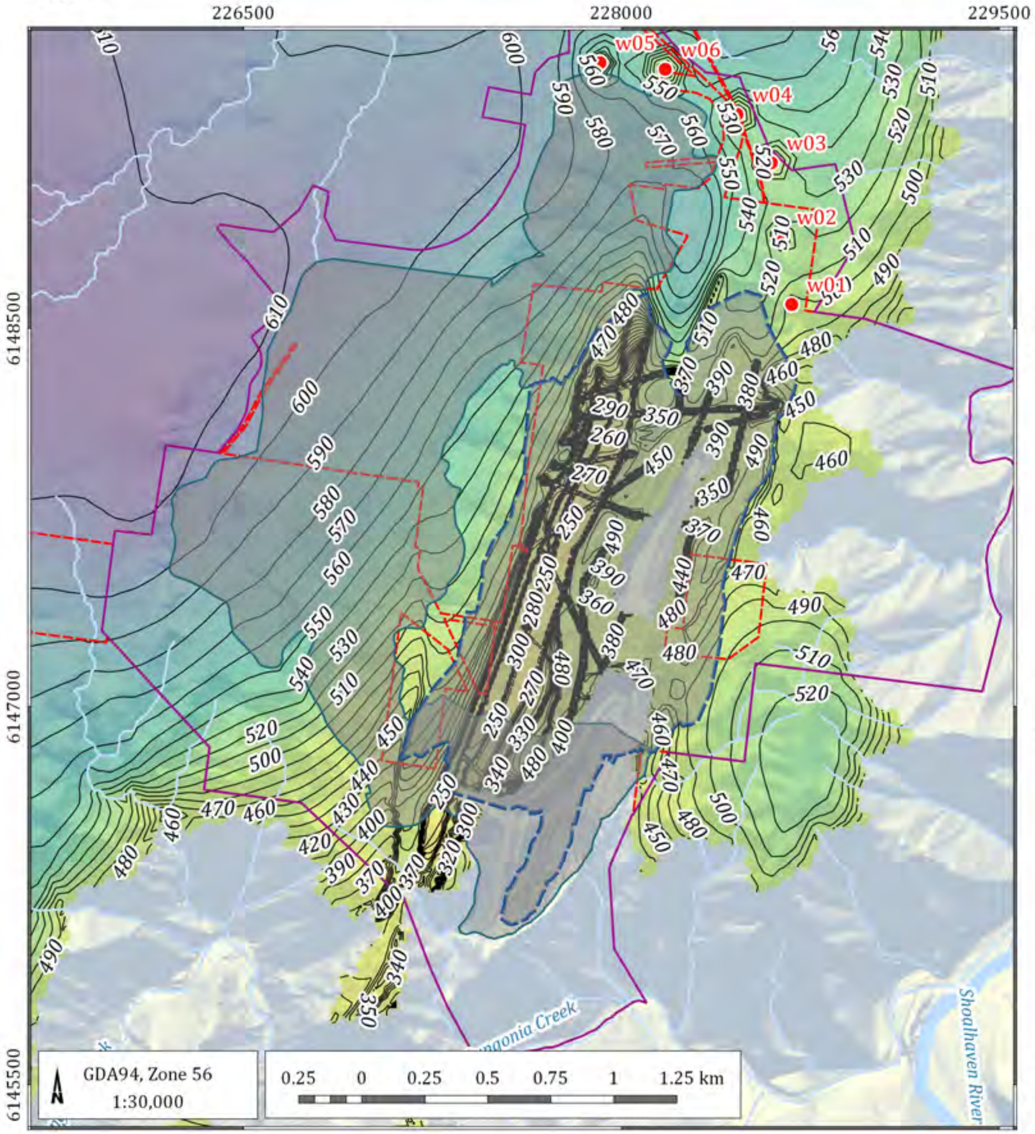
Further limitations constraining the numerical model and increasing its uncertainty (with respect to the granodiorite pumping scenario) are:

- The numerical model was not calibrated with Peppertree data, as the data was not available during the model calibration.
- The thickness of the weathered zone surrounding the Peppertree quarry is based on the data provided, which does not fully quantify the thickness of regolith across the entire granodiorite zone.
- The transition zone between the weathered granodiorite and fractured bedrock is not well understood.
- The granodiorite aquifer hydraulic property appears to be a function of secondary (fracture) porosity. An understanding of how this fracture system behaves under the stress from long term pumping would assist with the current numerical model setup and decrease the uncertainty of the prediction.

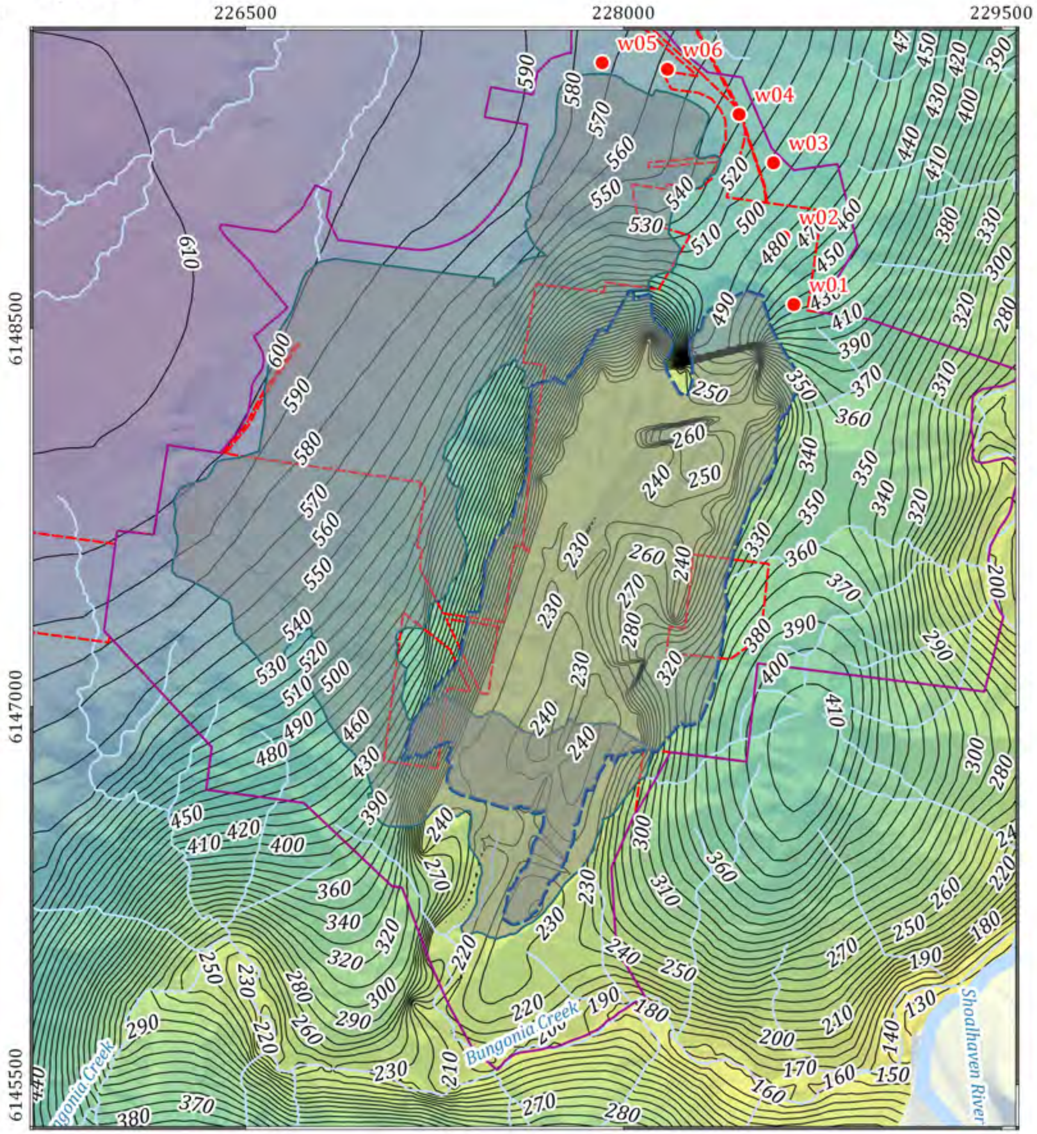
Conclusion and recommendations

Although the model can be made more precise by implementing hydraulic properties from Peppertree observation network into the model (as well as information regarding structural features and depth of weathered regolith), this increased precision will not necessarily change the modelling outcome given the overall low hydraulic conductivity for the granodiorite, and there simply being insufficient groundwater available in storage for abstraction. Given the acceptable level of calibration (as determined from the calibration statistics including the Peppertree groundwater level observation data), the model predictions are considered valid, even if not calibrated with focus on the Peppertree area.

Layer 3



Layer 10



LEGEND

- Project boundary
- CML16
- Pit extent
- Spoil extent
- Watercourse, drainage
- Pumping wells

Head (mAHD)

- 100
- 250
- 350
- 450
- 550
- 650

— Head contour (mAHD)

Marulan South COP (G1714C)

AGE

Predicted groundwater heads – water supply wells – stage 4, year 30, FY2049

DATE
23/03/2018

FIGURE No:
8-7

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:/Projects/G1714C.Marulan South COP/3_GIS/Workspaces/001_Deliverable1/08.06_G1714C_Predicted groundwater heads – water supply wells – stage 4, year 30, FY2049.qgs

Table 8-7 Predicted water extraction from pumping wells

SP	SP length (days)	Extracted volume (m^3/SP length)	extracted rate (m^3/day)	extracted rate (ML/year)
1	150	33216.9	221.4	80.9
2	365	24447.0	67.0	24.5
3	366	22137.7	60.5	22.1
4	365	20723.9	56.8	20.7
5	365	19793.1	54.2	19.8
6	365	19100.5	52.3	19.1
7	366	18602.6	50.8	18.6
8	365	18112.3	49.6	18.1
9	365	17753.2	48.6	17.8
10	365	17443.4	47.8	17.5
11	366	17217.0	47.0	17.2
12	365	16931.9	46.4	16.9
13	365	16718.7	45.8	16.7
14	365	16527.2	45.3	16.5
15	366	16395.1	44.8	16.4
16	365	16189.8	44.4	16.2
17	365	16044.3	44.0	16.1
18	365	15912.7	43.6	15.9
19	366	15831.1	43.3	15.8
20	365	15674.9	42.9	15.7
21	365	15570.2	42.7	15.6
22	365	15472.9	42.4	15.5
23	366	15421.8	42.1	15.4
24	365	15295.1	41.9	15.3
25	365	15215.0	41.7	15.2
26	365	15139.8	41.5	15.2
27	366	15107.9	41.3	15.1
28	365	15000.9	41.1	15.0
29	365	14937.9	40.9	14.9
30	365	14878.8	40.8	14.9
31	366	14861.1	40.6	14.8
32	365	14768.2	40.5	14.8
		Min:	40.5	14.8
		Avg:	51.7	18.9
		Max:	221.4	80.9

9 Summary of mining impacts

The mining impacts are modelled as a difference between 'no-mining' and 'mining' predictive scenarios. Impacts are then expressed as the difference in heads (as drawdown) and in flows (impact on bedrock aquifers, alluvial aquifers) between these two scenarios. If drawdown is positive, it represents a decrease in groundwater levels; if it is negative, it represents increase in groundwater levels or mounding.

For this Project, the 'no-mining' scenario is defined as the current state of mine operations to represent the groundwater system if it were only subjected to natural stresses which are rainfall recharge and evapotranspiration. The 'mining' scenario is defined as the change in landform resulting from the proposed mine plan using the drain (DRN) boundary condition to simulate removal of groundwater through mining activities, as well as the natural stresses represented by rainfall recharge and evapotranspiration.

9.1 Impact on fractured rock aquifers surrounding the Mine

Conceptually, the limestone-sedimentary-metamorphic blocks targeted by the westward expansion of the Project is assessed to have already been 'drained' via naturally interconnected structural features intersecting the bedrock. This therefore assumes the impact of the mining from the Project would only minimally impact the groundwater system, on the basis the mining occurs in essentially 'dry' limestone from which the only groundwater removed would be from groundwater storage within the limestone (i.e. groundwater contained in the porous spaces of the limestone).

The 'mining' scenario predicts slightly increased groundwater inflows to the pits, which are a function of an increased groundwater gradient towards the pits. The inflows into the pits from the surrounding geological environments will increase on average by 1 m^3/day over the 30 years of mining activity. As the water intercepted by model drains ceases to be available to discharge back to the fractured geological environment, the outflows will decrease by ~24 m^3/day (8.8 ML/year).

9.2 Impact on groundwater users

The predicted groundwater drawdown extents at the end of mining are presented in Figure 9-2. This shows groundwater drawdown is more extensive within the upper North Pit area and along the eastern edge of the pit, in the area between the current North and South pits. The 1 m drawdown contour extends approximately 620 m to the northeast from the northern edge of the pit and approximately 290 m from the eastern edge of the current mine pit.

None of the currently identified groundwater users (refer to Table 7-1) are predicted to be impacted by the Project. Within the Project site, bores WP16, WP17 and monitoring in-pit bores MW1 and MW2 will be consumed and removed as a result of mining activities.

The post mining equilibrium drawdown predicts the drawdown impact will continue to expand away from the void into the granodiorite to the north and into the sediments and metamorphics that bound the limestone from east and west (refer to Figure 9-3). The 1 m drawdown contour is predicted to extend approximately 1.2 km to the northeast from the edge of the void and approximately 600 m to the west and east of the pit edge.

9.3 Impacts on groundwater dependent ecosystems (GDEs)

A Groundwater Dependent Ecosystem (GDE) is one in which the plant and animal community is dependent on the availability of groundwater to maintain its structure and function. The Bureau of Meteorology (BoM, 2017) GDE Atlas shows ecosystems including springs, wetlands, rivers, and vegetation that interact with the subsurface presence of groundwater, or the surface expression of groundwater. The Atlas categorises groundwater dependent ecosystems into two classes in New South Wales. These are ecosystems that potentially rely on the:

- surface expression of groundwater - this includes all the surface water ecosystems which may have a groundwater component, such as rivers, wetlands, and springs; and
- subsurface presence of groundwater - this includes all vegetation ecosystems.

The eastern slopes towards Barbers Creek as well as southern slopes towards Bungonia Gorge are classified as having high potential for groundwater interactions (relying on subsurface presence of groundwater) while the zone immediately west of existing pit is classified as having moderate to low potential for interaction with groundwater. The area of Bungonia Gorge (along Bungonia Creek) and Barbers Creek are again classified as having high potential for groundwater interaction (relying on surface expression of groundwater) while the Main Gully drainage line is classified as having a moderate potential for groundwater interaction.

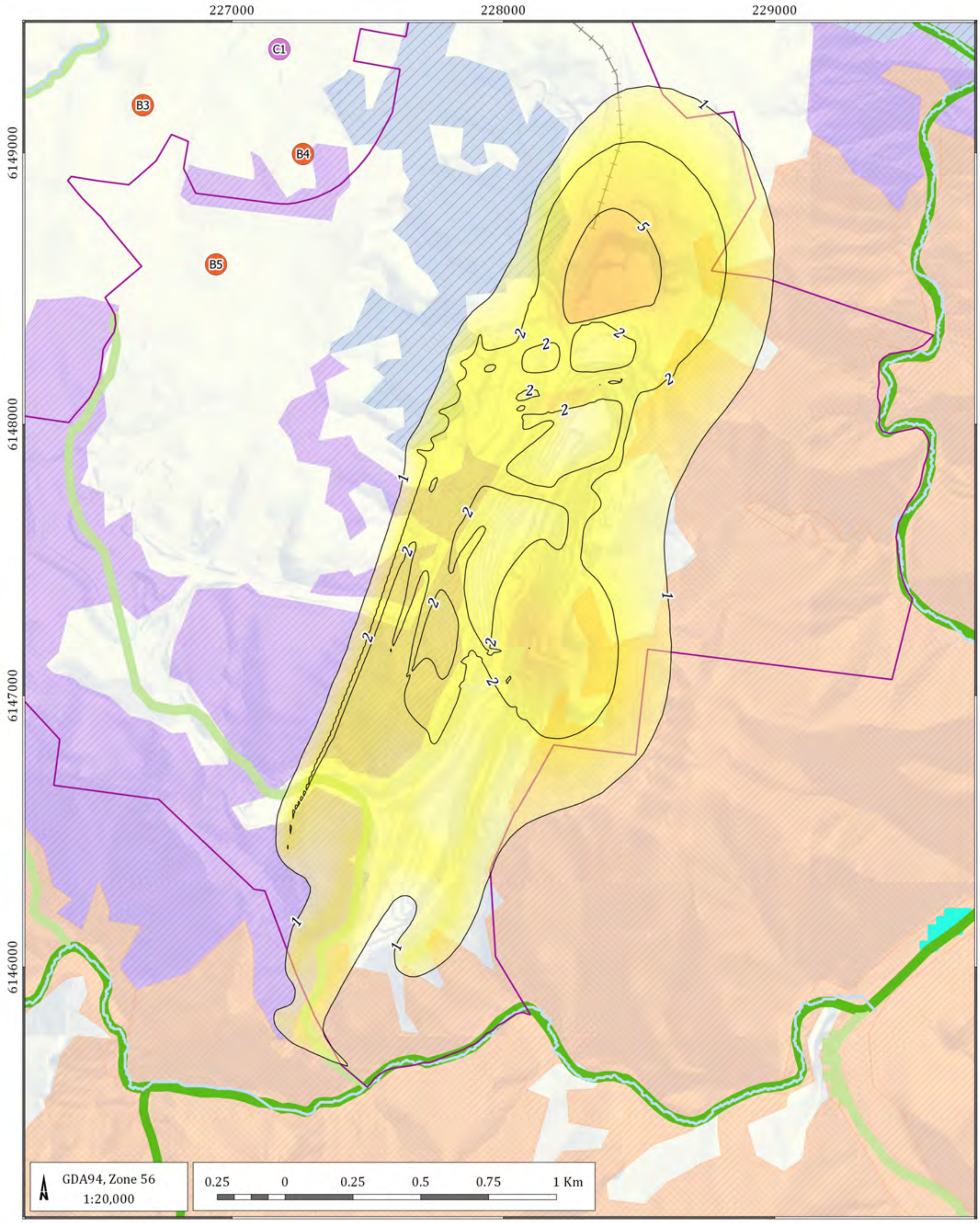
The predicted drawdown at the end of mining (Figure 9-1) extends eastwards into the eastern slopes towards Barbers Creek. The topography of this area is highly variable with prominent ridges and gullies and although the predicted groundwater table roughly follows the topography, it will typically be deeper under the ridges and shallower within the gullies.

Based on the field survey undertaken by Niche (2018), aquatic fauna as well as spring dependent flora of high ecological value was found along the drainage lines, mainly along Barbers Creek and in Bungonia Gorge. Niche (2018) advises that there are currently no apparent adverse effects on the aquatic groundwater faunas in any of the receiving streams as a result of mining operations at the Marulan South Limestone Mine. Predicted drawdown of the Project is therefore unlikely to impact on mapped GDEs along Bungonia Creek and Barbers Creek. This conclusion is also supported by the results of the groundwater model where the modelled drawdown at the end of mining (Figure 9-1) does only marginally overlay the zones with high potential for groundwater interaction towards Barbers Creek and Bungonia Gorge.

9.4 Impact on springs

Springs and groundwater seeps have been observed features at the base of the steep slopes of Bungonia Gorge. It is assumed that similar features are also present on the face of the gorge slopes elsewhere. The springs can either occur at the intersection of the groundwater table with the steep slopes of Bungonia gorge, or be fed by fracturing in limestone and karst features or sandstone bedrock aquifers.

The springs were not modelled directly except for the karst conduit behind the Main Gully Spring Cave B68 and Main Gully Spring Too B128, mostly because the exact location of minor springs is unknown Despite this it is considered unlikely that springs will be impacted as the seepage through the pit floor will continue to recharge the limestone and the springs. As presented in Section 8.7.2 (Table 8-3) outflow from the Marulan pit to geological environment will continue at a rate of 111 m^3/day (an decrease of 24 m^3/day compared to baseline conditions).



LEGEND

Project boundary

Watercourse, drainage

GDE reliant on surface expression of groundwater

High potential for GW interaction

Moderate potential for GW interaction

Low potential for GW interaction

GDE reliant on subsurface expression of groundwater

High potential for GW interaction

Moderate potential for GW interaction

Low potential for GW interaction

Drawdown (m)

0

1

2

5

Drawdown contour (m)

Receivers

Commercial receiver

Residential receiver (Boral owned)

Marulan South COP (G1714C)

Impact of mining on groundwater dependant ecosystems; Drawdown at the end of mining

AGE

DATE 04/10/2018

FIGURE No: **9-1**

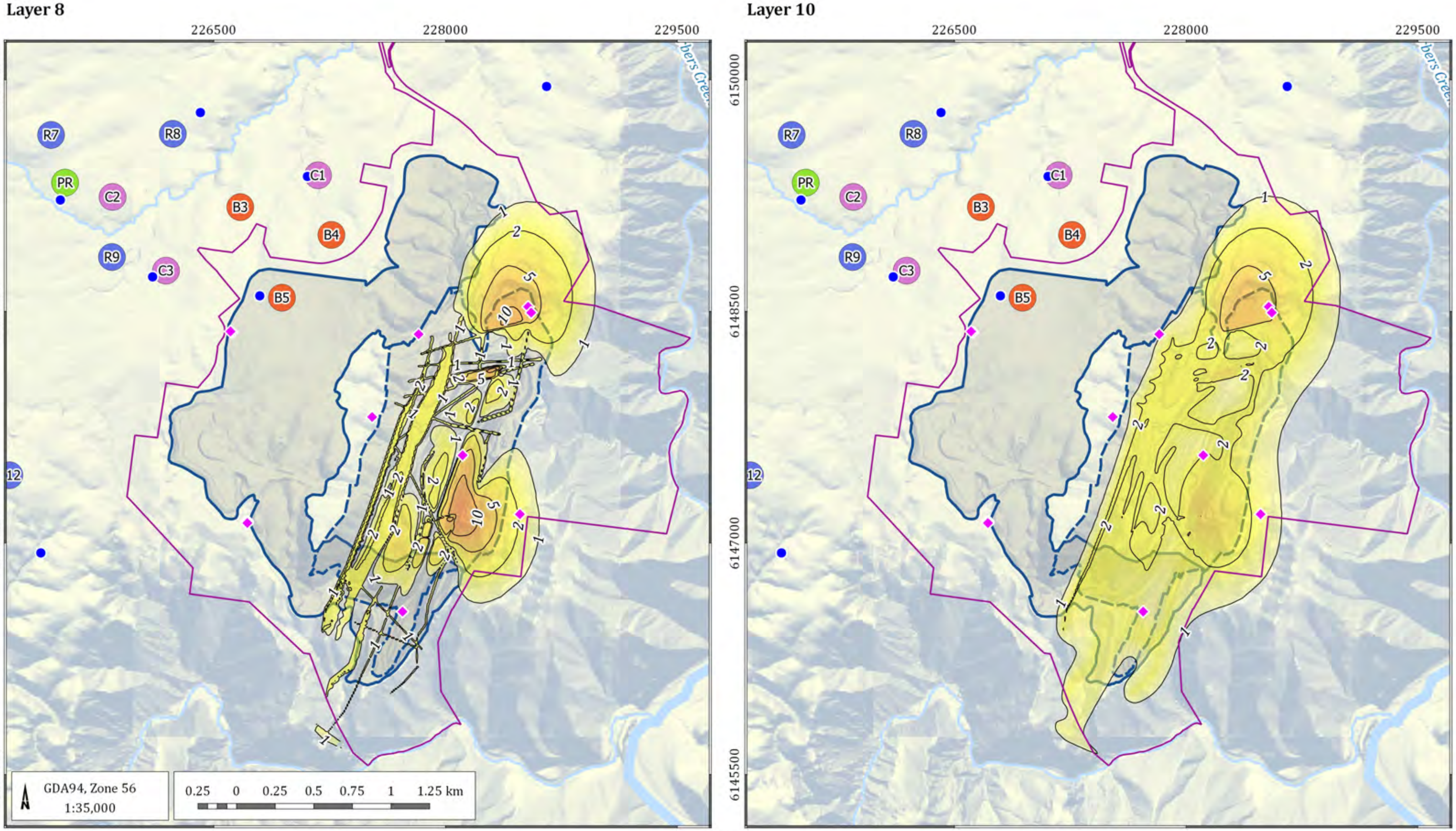
Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:/Projects/G1714C.Marulan South COP/3_GIS/Workspaces/001_Deliverable1/09.01_G1714C_Impact of mining on groundwater dependant ecosystems; drawdown at the end of mining.qgs

9.5 Impacts on groundwater quality

Significant impacts to groundwater quality are not anticipated. Currently, the limestone aquifer is recharged directly by rainfall, surface runoff and groundwater flow from adjacent geological units. On the condition that this recharge mechanism remains unchanged, and with surface runoff management in place (Advisian, 2018) then the groundwater quality of the limestone will not be altered significantly.

The potential groundwater impacts of mined overburden and limestone ore were the subject of a geochemical investigation (refer to Appendix C). The outcome of this investigation indicated that the overburden material and limestone mined at the site will have a minimal, if not negligible, impact on the downstream groundwater quality.

The baseflow supporting the flow of Bungonia and Barber's Creeks receives a proportion of its recharge from the underlying bedrock. The bedrock recharge rate into Bungonia Creek alluvium is predicted to decrease by 1% on average, the recharge from bedrock into Barbers Creek alluvium will not be decreased at all. Given the modelled changes in recharge rates from the bedrock, the potential impact of this volume change on the baseflow water quality of Bungonia and Barber's Creeks is considered to be negligible.



LEGEND

- Project boundary
- Pit extent
- Active mine footprint at the end of mining
- Watercourse, drainage
- Monitoring bores Marulan
- Water users

Receivers

- Commercial receiver
- Proposed residential dwelling (private)
- Residential receiver (Boral owned)
- Residential receiver (private)

Drawdown (m)

- 0
- 1
- 2
- 5
- 10
- Drawdown contours (m)

Marulan South COP (G1714C)

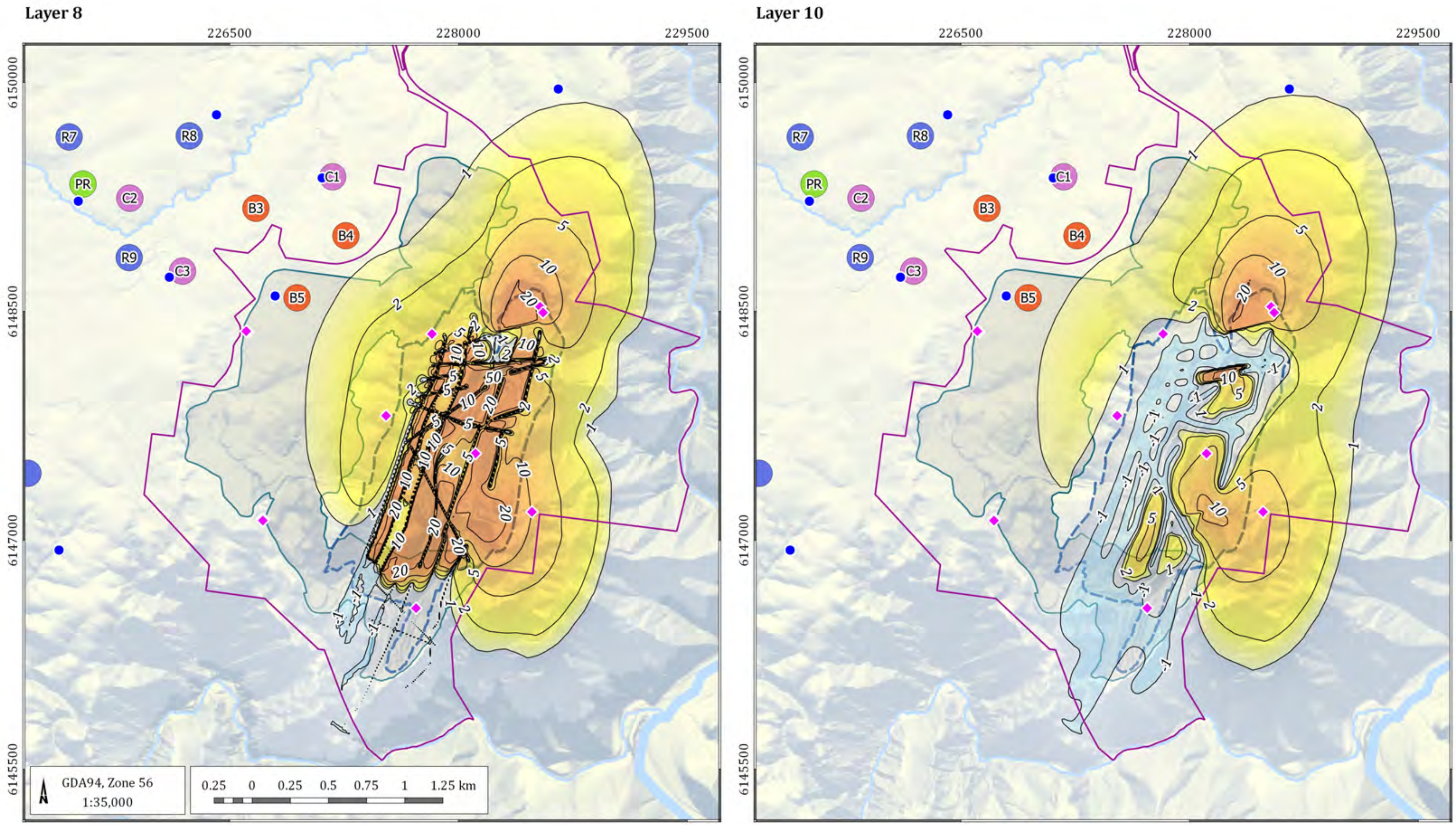
AGE

Predicted drawdown – end of mining - stage 4, year 30, FY2049

DATE
07/02/2019

FIGURE No:
9-2

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:\Projects\G1714C.Marulan South COP\3_GIS\Workspaces\001_Deliverable1\09.02_G1714C_Predicted drawdown - end of mining - stage 4, year 30, FY2049.qgs



LEGEND

- Project boundary
- Pit extent
- Active mine footprint at the end of mining
- Watercourse, drainage
- Monitoring bores Marulan
- Water users

Receivers

- Commercial receiver
- Proposed residential dwelling (private)
- Residential receiver (Boral owned)
- Residential receiver (private)

Drawdown (m)

0, 1, 2, 5, 10, 20, 50, 100, 200, 500, -500, -200, -100, -50, -20, -10, -5, -2, -1, 0

Drawdown contours (m)

Marulan South COP (G1714C)

AGE

Predicted drawdown – post mining equilibrium – year 2300

DATE
27/09/2018

FIGURE No:
9-3

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:/Projects/G1714C.Marulan South COP/3_GIS/Workspaces/001_Deliverable1/09.03_G1714C_Predicted drawdown – post mining equilibrium – year 2300.qgs

9.6 Cumulative impacts

Peppertree Quarry, located immediately to the north of the mine, is also owned by Boral. The current Peppertree Quarry is relatively shallow and any impact to groundwater from this quarry operation (with respect to the impact caused by Marulan Mine) is considered to be negligible and as such was not included in the groundwater model.

The groundwater model predicts the impact from mining will be spatially constrained to the mined limestone body and the adjoining geological units that immediately surround the mine. The geological constraints described in Section 7.10 (such as heterogeneity in hydraulic properties limiting flow in west-east direction) are predicted to nullify impacts on surrounding groundwater users.

10 Impact of Marulan Creek Dam

An additional dam is required to ensure sufficient water supply for the Project. Boral propose construction of a new in-stream water supply dam on Marulan Creek with storage capacity of 118 ML (full storage level at 597 m AHD). The dam is planned to be located on the edge of the plateau on Marulan Creek approximately 1 km upstream of its confluence with Barbers Creek. A preliminary survey and conceptual design of the proposed dam site was undertaken by PSM in 2016.

The site of the proposed dam is within the mapped area of Marulan granodiorite. Based on data obtained from the closest water supply bores (refer to Table 10-1), the granodiorite weathering depths is ~10 to ~20 m below ground surface. The regional groundwater table occurs below the weathered zone, within the upper sections of the slightly weathered to fresh, fractured granodiorite.

Table 10-1 Registered groundwater bores in Marulan granodiorite closest to the proposed Marulan Creek dam

Bore ID	Easting (GDA94, z56)	Northing (GDA94, z56)	Drilled depth (m)	Standing water level (mbs)	Thickness of weathered zone (m)
GW109179	226776	6153375	54	22	16
GW111815	226511	6150861	24	12	< 18
GW072404	223642	6151752	35	9	13.7

Geology details for bore GW109179 identify the weathered zone comprising clay, which is a typical product of granodiorite weathering. This clayey weathered granodiorite profile will have the potential to provide a hydraulic barrier between the proposed Marulan Creek Dam body of water and the underlying groundwater system. On this basis, leakage of surface water from the dam into the groundwater is considered to be limited. Based on this conceptualisation, development of the Marulan Creek dam is considered to have minimal impact on the groundwater regimes of the Peppertree Quarry and Marulan Mine.

11 Management and mitigation measures

Boral has an established groundwater (refer to Section 7.4) and surface water monitoring network (refer to Section 7.5). This includes monitoring water emanating from a drainage line immediately below two groundwater springs located within Bungonia Gorge, to the south of the South Pit.

During the life of the mine, Boral will continue to monitor the existing groundwater monitoring wells at quarterly intervals (or as otherwise may be deemed necessary in the future) in order to measure the potential extent and rate of depressurisation against model predictions. Similarly, the recommendation to monitor seepage from the overburden storage areas (refer Appendix C) will be accommodated using the existing groundwater and surface water monitoring network. Ongoing surface water monitoring recommendations are included in the Surface Water Assessment Report (Advisian, 2018).

Any groundwater monitoring bores consumed and removed as a result of the continued operation of the mine, will be progressively replaced over the life of the Project, where considered necessary in consultation with a suitably qualified groundwater specialist.

11.1 Water level monitoring

Boral has monitored groundwater levels manually on a routine basis in the groundwater monitoring well network mentioned above. All of the monitoring wells are equipped with pressure transducers to electronically record water levels. This electronic monitoring of groundwater levels and the regular downloading of data from the pressure transduces will continue for the life of the Project.

Yearly reporting of the water level results from the groundwater monitoring network would be included in the *Annual Environmental Management Report* (AEMR). The AEMR would consider if any additional groundwater monitoring wells are required, or if the number of groundwater monitoring wells could be reduced.

11.2 Water quality monitoring

Boral currently collects groundwater samples from the groundwater monitoring well network on a quarterly basis (as of September 2017) for laboratory analysis. Groundwater samples are tested for:

- pH and EC;
- major cations - calcium, magnesium, sodium and potassium;
- major anions - chloride, sulphate, carbonate/bicarbonate, hydroxide, total alkalinity and total hardness;
- dissolved and total metals (Al, As, Be, Ba, Cd, Cr, Co, Cu, Pb, Mn, Mo, Ni, Se, Sr, Va, Zn, B, Fe, and Si) and dissolved and total recoverable mercury;
- fluoride; and
- sodium adsorption ratio (SAR).

Boral would continue to take water quality samples from the groundwater well network when undertaking quarterly monitoring.

Similar to the water level monitoring, yearly reporting of the water quality results from the groundwater monitoring well network would be included in the AEMR. The AEMR would consider if any additional groundwater quality monitoring sites are required, or if the number of groundwater monitoring sites, frequency of sampling and analytical suite could be reduced.

11.3 Overburden and interburden material

The geochemical assessment indicated most overburden and interburden material is geochemically stable, and no special management measures were recommended for the handling or storage of the majority of these materials. It was recommended that the small amount of contact material between limestone and shale and any shale/mudstone materials encountered during mining be preferentially placed within the core of the overburden emplacements away for the final rehabilitated surfaces.

Surface water runoff and seepage from overburden emplacements will automatically report to sediment basins around the site and will be monitored in accordance with existing surface water monitoring procedures in accordance with AEMR.

11.4 Data management and reporting

It is recommended the data management and reporting include:

- annual assessment of departures from identified monitoring data trends and comparison against historical levels;
- formal review of potential impact to aquifers which should be undertaken annually by a suitably qualified hydrogeologist;
- annual reporting (including all water level, water quality and seepage data); and
- storage and management of all groundwater data in a database customised for the Project and with suitable quality assurance/quality control (QA/QC).

11.5 Management and mitigation strategies

Management of groundwater beneath and adjacent to the Project did involve the establishment of a robust groundwater level and quality monitoring program, for all groundwater and surface water sources. Operational reporting will occur at frequencies suited to the mine development and be part of the basis of annual reporting (AEMR) to key stakeholders. Should monitoring indicate that changes in groundwater levels and quality deviate significantly from established baseline as given by historical monitoring results, an investigation will be undertaken to establish the cause of the changes.

Similar for surface water, mitigation of potential groundwater impacts would be addressed primarily through the design and operation of the water management system for the Project. The key objective would be to minimise discharge into 'sensitive' environments. Resultant depressurisation of groundwater surrounding the mine pits results in groundwater gradients being directed towards the mine pit(s). Any seepage water reporting to the pit would be managed in accordance with the Surface Water Assessment (Advisian, 2018) which requires 'dirty' water to be *"directed to a series of sediment dams … to comply with the requirements for capture of fine and dispersive sediments"* for reuse in either limestone processing or dust suppression.

This groundwater impact assessment predicts no private groundwater bores will be impacted by drawdown greater than 1 m during the lifetime of the mine. On this basis, 'make good' arrangement with surrounding landholders is not considered necessary. Review of observed versus predicted aquifer drawdown responses using the groundwater monitoring program will ensure no land owner bores are impacted during the lifetime of the mine.

The implementation of the above mitigation strategies for the Project is expected to minimise the potential for groundwater impacts resulting from the Project.

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Appendix A SEAR Comments and references

Appendix A-1 – SEAR Comments and references

Table A-1 below summarises the groundwater SEAR comments and report reference sections.

Table A-1 SEAR requirements and references to document sections

Stakeholder and Contact Details	Comments	Response / EIS Section Reference
NSW Department of Primary Industries (DPI) NSW Office of Water David Zerafa, Senior Water Regulation Officer (02) 4428 9142.	Groundwater contamination as a result of mining operations and its impact on poultry farm operations	Section 9.5 Section 9.6 Appendix C
	Details of water proposed to be taken (including through inflow and seepage) from each surface and groundwater source as defined by the relevant water sharing plan.	Section 8.7.3 Section 8.7.4 Appendix D
	Assessment of any volumetric water licensing requirements (including those for ongoing water take following completion of the project).	Section 8.7 Appendix E
	A detailed assessment against the NSW Aquifer Interference Policy (2012) using the NSW Office of Water's assessment framework.	Appendix A includes an AIP requirements checklist with comments
	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.	Section 9.5 Section 9.6 Appendix D
	Full technical details and data of groundwater modelling, and an independent peer review.	Section 8 Appendix D
	Proposed groundwater monitoring activities and methodologies.	Section 10
	Assessment of any potential cumulative impacts on water resources, and any proposed options to manage the cumulative impacts.	Section 9.5 Section 9.6 Appendix D Section 10
	Consideration of relevant policies and guidelines.	Section 4

Stakeholder and Contact Details	Comments	Response / EIS Section Reference
	A statement of where each element of the SEARs is addressed in the EIS (i.e. in the form of a table).	Section 2 Appendix A
	DESCRIPTION OF EXISTING ENVIRONMENT, IDENTIFICATION OF IMPACTS AND CONSTRAINTS	
	Groundwater usage and management;	Section 4.2.2 and 7
	Impacts associated with the operational and post closure stages of the project must also be identified in detail and control management strategies outlined.	Section 9 Section 10
	The identification and description of impacts must draw out those aspects of the site that may present barriers or limitations to effective rehabilitation and which may limit the mine closure potential of the land. The following are the key issues to be addressed in the EIS that are likely to have a bearing on rehabilitation and mine closure: • an assessment and life of mine management strategy of the potential for geochemical constraints to rehabilitation (e.g. acid rock drainage, spontaneous combustion etc.), particularly associated with the management of overburden/interburden and reject material. Based on this assessment, the EIS is to document the processes that will be implemented throughout the mine life to identify and appropriately manage geochemical risks that may affect the ability to achieve sustainable rehabilitation outcomes; • where a void is proposed to remain as part of the final landform, the assessment is to provide details in regards to the following: 3. Outcomes of the groundwater assessments in relation to the likely final water level in the void. This should include an assessment of the potential for fill and spill along with measures required be implemented to minimise associated impacts to the environment and downstream water users.	Section 10, Appendix C Section 8.7
	OPEN CUT MINING The EIS must assess surface water flow and flooding regimes and how these will be impacted and mitigated by the project both during and after mining has ceased. This is to include an evaluation of potential impacts from the final void on both surface and groundwater quality and flow regimes. To carry out the assessment of the impact of mining the proponent must: • conduct a groundwater assessment to determine the likelihood and associated impacts of groundwater accumulating and subsequently discharging (e.g. acid or neutral mine drainage) from the workings post cessation of mining. • include a consideration of the likely controls required to either prevent or mitigate against these risks as part of the closure plan for the site.	Section 7.6, Section 10.3, and Appendix C

Stakeholder and Contact Details	Comments	Response / EIS Section Reference
	E-4. WATER Describe baseline conditions: Describe existing surface and groundwater quality - an assessment needs to be undertaken for any water resource likely to be affected by the proposal and for all conditions (e.g. a wet weather sampling program is needed if runoff events may cause impacts).	Sections 7.6 and 7.7
	Methods of sampling and analysis need to conform with an accepted standard (e.g. Approved Methods for the Sampling and Analysis of Water Pollutants in NSW (DEC 2004) or be approved and analyses undertaken by accredited laboratories).	Appendix B
	Describe baseline conditions - an outline of baseline groundwater information, including, but not restricted to: - depth to water table, flow direction and gradient - groundwater quality - reliance on groundwater by surrounding users and by the environment	Sections 7.4, 7.6, 7.7, 7.9 and 7.10
	Assess impacts: - Identify any potential impacts on quality or quantity of groundwater describing their source.	Section 8.7 and Section 9.6
	- Describe the effects and significance of any pollutant loads on the receiving environment. This should include impacts of residual discharges through modelling, monitoring or both, depending on the scale of the proposal. Determine changes to hydrology (including drainage patterns, surface runoff yield, flow regimes, wetland hydrologic regimes and groundwater).	Section 9
	Describe management and mitigation measures: - Describe hydrological impact mitigation measures including: d) avoiding modifications to groundwater	Section 10
	- Describe groundwater impact mitigation measures including: a) site selection b) retention of native vegetation and revegetation c) artificial recharge d) providing surface storages with impervious linings e) monitoring program Any proposed monitoring should be undertaken in accordance with the Approved Methods for the Sampling and Analysis of Water Pollutants in NSW (DEC 2004).	Section 10

Stakeholder and Contact Details	Comments	Response / EIS Section Reference
	E-7. Cumulative Impacts Identify the extent that the receiving environment is already stressed by existing development and background levels of emissions to which this proposal will contribute.	Section 8.7 Section 9.6
	Assess the impact of the proposal against the long term water quality objectives for the area or region.	Section 8.7 Section 9.6
	Assess likely impacts from such additional infrastructure and measures reasonably available to the proponent to contain such requirements or mitigate their impacts (e.g. travel demand management strategies).	Section 8.7 Section 9.6
	F. LIST OF APPROVALS AND LICENCES Identify all approvals and licences required under environment protection legislation including details of all scheduled activities, types of ancillary activities and types of discharges (to air, land, water).	Section 4
	G. COMPILATION OF MITIGATION MEASURES: - Outline how the proposal and its environmental protection measures would be implemented and managed in an integrated manner so as to demonstrate that the proposal is capable of complying with statutory obligations under EPA licences or approvals (e.g outline of an environmental management plan). - The mitigation strategy should include the environmental management and cleaner production principles which would be followed when planning, designing, establishing and operating the proposal. It should include two sections, one setting out the program for managing the proposal and the other outlining the monitoring program with a feedback loop to the management program.	Section 10 Section 10
Office of Environment and Heritage (OEH) Miles Boak 02 6229 7905 Miles.Boak@enviornment.nsw.gov.au	The EIS must map the following features relevant to water and soils including: - Groundwater - Groundwater dependent ecosystems. - Proposed intake and discharge locations	Section 7 Section 7.3 Sections 7.9 and 7.10, Appendix D
	The EIS must describe background conditions for any water resource likely to be affected by the project including: - Existing surface and groundwater - Water Quality Objectives (as endorsed by the NSW Government http://www.environment.nsw.gov.au/ieo/index.htm) including groundwater as appropriate that represent the community's uses and values for the receiving waters - Indicators and trigger values/criteria for the environmental values identified at (c) in accordance with the ANZECC (2000) Guidelines for Fresh and Marine Water Quality and/or local objectives, criteria or targets endorsed by the NSW Government.	Section 5 and Section 7

Stakeholder and Contact Details	Comments	Response / EIS Section Reference
	The EIS must assess the impact of the proposed project on hydrology, including: - Effects to downstream water-dependent fauna and flora including groundwater dependent ecosystems and stygofauna - Changes to environmental water availability, both regulated/licensed and unregulated/rules-based sources of such water.	Section 8.7 and Section 9.6 Section 4.2
	The EIS must assess the impacts of the project on water quality, including: - The nature and degree of impact on receiving waters for both surface and groundwater, demonstrating how Water Quality Objectives are currently being achieved, and contributes towards achievement of the Water Quality Objectives over time where they are currently not being achieved. This should include an assessment of the mitigating effects of proposed stormwater and wastewater management during and after construction. - Identification of proposed monitoring of water quality	Section 7.6 Section 10.2
Water NSW Jim Caddey 02 4824 3401	The proximity of the site to Bungonia Creek and Shoalhaven River and any impacts on water quality and quantity from the proposed project are of concern to Water NSW. The EIS will need to demonstrate that the proposed measures to capture and treat water impacted by the proposal will have no impact on water quality within the Shoalhaven River. To address the above issues Water NSW recommends:	
	- The EIS must assess potential risks to surface and groundwater quality during construction and operation, demonstrating clear consideration of the principle of achieving a neutral or beneficial effect on water quality in the drinking water catchment, consistent with the State Environmental Planning Policy (Sydney Drinking Water Catchment) 2011. - The EIS must include a framework for the avoidance, mitigation, management and monitoring of water quality impacts during construction and operation"	Section 8.7 Section 9.6 Section 10
	- A detailed description of those aspects of the project which have the potential to impact on the quality and quantity of surface and ground waters at and adjacent to the project. This should include: d) location of and description of all water monitoring points (surface and ground waters)	Section 7.4
	The surface water and groundwater assessment should also address the following matters: b) details of the measures to manage wastewaters associated with processing quarry materials, general stormwater runoff and any human activities likely to affect water quality at the site, and how neutral or beneficial effect on water quality (NorBE) principles will be assessed and applied d) details of how potential connections between waters within the quarry area will be separated from groundwater and external surface water e) assessment of the impacts of the development on receiving water quality and volume, both surface and groundwater including implications from keeping the quarry void	Section 5 and Appendix E Section 5 and Appendix E Section 8.7 Section 9.6

Stakeholder and Contact Details	Comments	Response / EIS Section Reference
	h) details of proposed monitoring of groundwater levels, surface water flows, groundwater and surface water quality, along with information as to how the proposed monitoring will be used to monitor and, if necessary, mitigate impacts on surface water and groundwater resources	Section 10
	Provide details of measured and predicted quarry performance with respect to water quality management since its commencement including details of any incidents.	Section 7.6.3
	CUMULATIVE IMPACTS Water NSW notes that there are a number of large quarries operating in the Marulan area. These quarries have the potential to have a cumulative impact. Water NSW recommends the Secretary's requirements specifically address cumulative impacts with respect to water quality and water quantity.	Section 9.6

Appendix A-2 – AIP requirements checklist

Table A-2 to Table A-4 below compare the groundwater impact predictions for the Project against the requirements under the NSW AIP (NOW, 2012).

There are two levels of minimal impact considerations specified in the AIP. If the predicted impacts are less than the Level 1 minimal impact considerations, then these impacts will be considered as acceptable. Where the predicted impacts are greater than the Level 1 minimal impact considerations then the AIP requires additional studies to fully assess these predicted impacts. If this assessment shows that the predicted impacts do not prevent the long-term viability of the relevant water-dependent asset, then the impacts will be considered to be acceptable.

The modelling indicates no potential for drawdown in private bores to exceed the Level 1 minimal impact considerations.

Table A-2 Accounting for or preventing the take of water

AIP requirement		Response
1	Described the water source (s) the activity will take water from?	Based on the AIP, the groundwater system impacted by the Project is the Goulburn Fractured Rock Groundwater Source which includes two groundwater systems, as follows: • porous and / or fractured consolidated sedimentary rock primarily of the Lookdown Limestone Formation (Bungonia Group) and underlying units of the Adaminaby Group and the overlying units of the Bindook Group; • groundwater within alluvium associated with the Bungonia and Barber's Creek alluvium Water yields for the fractured rock aquifers and alluvium aquifers is considered a less productive aquifer according to the AIP because yields >5L/sec are considered unlikely; albeit, the water quality within the project area is generally less than 1,500 mg/L.
2	Predicted the total amount of water that will be taken from each connected groundwater or surface water source on an annual basis as a result of the activity?	Predicted take based on this modelling for the Project include: • The estimated take from the consolidated limestone (ore body), sandstone and shale (overburden) aquifers varies from 7 ML/year at the beginning of mining up to 23 ML/year with average value of 14.2 ML/year; • Flow of groundwater from bedrock to Bungonia and Barber's Creek alluvium is predicted by the model to decrease on average by 1.8 ML/year, peaking at the end of mining period at 4.2 ML/year. • Flow of groundwater from bedrock to Shoalhaven River alluvium is predicted by the model to decrease on average by 0.003 ML/year, peaking at the end of mining period at 0.03 ML/year.
3	Predicted the total amount of water that will be taken from each connected groundwater or surface water source after the closure of the activity?	After the cessation of mining activities, the final void remains dry. The estimated average flow rate from bedrock will be equivalent to the predicted take from the bedrock to the open pit at the end of mining, i.e. 23 ML/year (refer Section 8.7.3). This is considered an upper bound volume of water (combined with surface runoff) which will either seep through the pit floor and recharge the bedrock limestone or evaporate from the pit floor (see Section 8.7.2.)
4	Made these predictions in accordance with Section 4.2.3 of the AIP? (page 22)	Based on 3D numerical modelling.

AIP requirement		Response
5	Described how and in what proportions this take will be assigned to the affected aquifers and connected surface water sources?	The modelling predicts that the water take will come predominantly from the fractured rock aquifer; less than 1 % will be in the form of loss of recharge to alluvium from the bedrock.
6	Described how any licence exemptions might apply?	NIL
7	Described the characteristics of the water requirements?	Figure 8-5 shows the predicted take of groundwater through the mine life, with the annual take varying from 7 ML/year at the start of mining and continually increasing to 23 ML/year at the end of mining.
8	Determined if there are sufficient water entitlements and water allocations that are able to be obtained for the activity?	Groundwater at the site is managed under the water sharing plan of the Goulburn fractured rock groundwater source. The Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources 2011, authorises groundwater extraction requires under a water access licence. Boral currently holds a groundwater allocation of 838 ML granted on 27 September 2017 under licence ROI17-1-061.
9	Considered the rules of the relevant water sharing plan and if it can meet these rules?	Water Access Licenses held for the alluvium within the Goulburn fractured rock groundwater source allow take from the fracture rock aquifer. Other than not exceeding the licensed volumes there are no restrictions placed on licenses within the Greater Metropolitan Region Groundwater Sources 2011 WSP in relation to the Project. The Project is therefore adequately licensed for take from the WSP during the life of the Project.
10	Determined how it will obtain the required water?	• Water will be obtained via seepage to the mine face – a portion will likely evaporate or be removed as moisture in in limestone ore and will not enter the site water circuit. • Water will also be extracted through existing production water supply bores (WP16 and WP17).
11	Considered the effect that activation of existing entitlement may have on future available water determinations?	According to the Goulburn fractured rock groundwater sources, 53,074 ML/year is the long-term average annual extraction limit. The status and usage of existing entitlements is not available within the public domain. However the Project is predicted to take up to 23 ML/year, which accounts for less than 0.04% of annual entitlements.
12	Considered actions required both during and post-closure to minimise the risk of inflows to a mine void as a result of flooding?	The mine is not located within any known flood prone areas. Surface water modelling and management studies have been undertaken as part of this EIS. The final void is not expected to receive water from outside of the pit post closure.
13	Developed a strategy to account for any water taken beyond the life of the operation of the Project?	Allocate existing and future water entitlements to the Project's water take to license take of water as necessary.

AIP requirement		Response
14-16	Will uncertainty in the predicted inflows have a significant impact on the environment or other authorised water users? Items 14-16 must be addressed, if so.	The inflows are closely correlated to specific yield, storage and the secondary porosity (fracturing) of the limestone. Changes within these hydraulic properties in the limestone will not have a significant impact on water flows from surrounding geological units. The very low predicted inflows indicate there will not be a significant impact on other authorised water users or the environment – Refer to Sections 9.2.
14	Considered any potential for causing or enhancing hydraulic connections, and quantified the risk?	Not applicable
15	Quantified any other uncertainties in the groundwater or surface water impact modelling conducted for the activity?	Not applicable
16	Considered strategies for monitoring actual and reassessing any predicted take of water throughout the life of the Project, and how these requirements will be accounted for?	Not applicable

Table A-3 Determining water predictions

AIP requirement		Proponent response
1	Addressed the minimum requirements found on page 27 of the AIP for the estimation of water quantities both during and following cessation of the proposed activity?	Predictions are based on modelling made to address the requirements of page 27 of the AIP.

Table A-4 Other requirements

AIP requirement		Proponent response
1	Establishment of baseline groundwater conditions?	The Project's monitoring has been undertaken over a period of three and a half years and includes groundwater levels and quality monitoring (refer Section 7.6). Numerous individual regional and on-site monitoring data points are available that extend back to 1983 for the key groundwater units and tested for a selection of analytes.
2	A strategy for complying with any water access rules?	The Mine currently has adequate water licences to comply with the requirements of the Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources 2011 (refer Section 4.2.1). Boral will ensure the mine maintains sufficient water access licences at appropriate stages during the 30 year continuation of mining operations.
3	Potential water level, quality or pressure drawdown impacts on nearby basic landholder rights water users?	None of the currently identified groundwater users are predicted to be impacted by the Project (refer Section 9.2). Predicted drawdown at each identified groundwater user is less than 1 m. See Appendix D, Section D4.4.2
4	Potential water level, quality or pressure drawdown impacts on nearby licensed water users in connected groundwater and surface water sources?	Drawdown of up to 1m at the end of mining is predicted to extend approximately 620 m to the northeast from the northern edge of the pit and approximately 290 m from the eastern edge of the current mine pit. Post mining equilibrium drawdown predicts the drawdown impact will extend approximately 1.2 km to the northeast from the edge of the void and approximately 600 m to the west and east of the pit edge (refer Section 9.2). The predicted impact of change on the baseflow water quality of Bungonia and Barber's Creeks is considered to be negligible and significant impact to groundwater quality is not anticipated (refer Section 9.5).
5	Potential water level, quality or pressure drawdown impacts on groundwater dependent ecosystems?	Modelled drawdown at the end of mining extends eastwards into the eastern slopes towards Barbers Creek. Field survey has identified aquatic fauna and spring dependant flora of high ecological value along the drainage lines that include Barbers Creek and Bungonia Gorge. No apparent adverse effects resulting from mining operations at the Marulan South Limestone Mine have been identified on these aquatic groundwater faunas. Predicted drawdown of the Project is therefore unlikely to impact on mapped GDEs along Bungonia Creek and Barbers Creek (refer Section 9.3). Similarly, groundwater springs observed at the base of the steep slopes of Bungonia Gorge are not considered to be impacted by this drawdown, as the seepage through the pit floor will continue to recharge the limestone and the springs (refer Section 9.4).
6	Potential for increased saline or contaminated water inflows to aquifers and highly connected river systems?	Significant impacts to groundwater quality are not expected. Currently, the limestone aquifer is recharged directly by rainfall and groundwater flow from adjacent geological units. On the condition that this recharge mechanism remains unchanged, then the groundwater quality of the limestone will not be altered significantly (refer Section 9.5). The potential groundwater impacts of mined overburden rock and limestone ore were the subject of a geochemical investigation (refer Section 4.1.3 and Appendix C). The outcome of this investigation indicated that the overburden rock and limestone mined at the site will have a minimal, if not negligible, impact on the groundwater quality. The baseflow supporting the flow of Bungonia and Barber's Creeks receives a small proportion of its recharge from the underlying bedrock. This recharge is estimated to decrease by 1% (on average) of the Bungonia Creek, and nil into Barber's Creeks baseflow. The potential impact of this volume on the baseflow water quality of Bungonia and Barber's Creeks is assessed to be negligible.

AIP requirement		Proponent response
7	Potential to cause or enhance hydraulic connection between aquifers?	The mine will not fracture nor deform during mining or post-closure. Enhanced hydraulic connection is not expected.
8	Potential for river bank instability, or high wall instability or failure to occur?	A geotechnical assessment of the mine pit design, including high walls, has been undertaken as part of the EIS.
9	Details of the method for disposing of extracted activities (for CSG activities)?	Not applicable

Appendix B Summary of 2015 AGE supplementary groundwater sampling, analysis results and certificates of analysis

B1 Introduction

Between 10/2/2015 and 12/2/2015, AGE undertook a complementary groundwater/surface water sampling round of seven locations (refer to Table B 1 and Figures 7-4 and 7-5 of the main report). The main goal of the sampling collection round was to provide evidence of the age and recharge source of the groundwater and increase our understanding concerning the groundwater-surface water interaction. The data also added to the groundwater and surface water quality dataset maintained by Boral.

B2 Methodology

Monitoring bores were purged of greater than three bores volumes of water with a 12V Monsoon pump. When field parameters (pH, EC and temperature) had stabilised, the sample was collected from the pump at a reduced flow rate. Surface water samples were collected by submerging the sampling container into water or by having the water flow/drip into the container. Sample containers were plastic and glass bottles provided by Australian Laboratory Services Pty Ltd (ALS) and GNS Science (GNS). Sample bottles were stored and shipped in chilled cooler boxes. Samples not shipped on the day of sampling were stored temporarily in a refrigerator.

Table B 1 AGE Groundwater Sample Locations (2015)

Sample ID	Easting	Northing	Geology	Date collected	Date analysed
MW01	228111	6147568	limestone	12/02/2015	17/2/2015
MW02	227722	6146555	limestone	11/02/2015	17/2/2015
MW05	227826	6148352	regolith, volcanics	11/02/2015	17/2/2015
Seep Blowhole	227432	6145835	limestone	10/02/2015	17/2/2015
Spring	228411	6148404	volcanics - basalt dyke	11/02/2015	18/2/2015
WP16	228535	6148530	limestone	11/02/2015	17/2/2015
Main Gully Sampling Point	227578	6145625	limestone	10/02/2015	25/05/2015

Four groundwater samples (MW01, MW02, Seep Blowhole and Main Gully sampling point) were sent to GNS Science laboratories in New Zealand for isotope analysis. These samples were analysed for the following parameters:

- deuterium versus Oxygen-18 ratio;
- radiocarbon dating through Carbon-14 isotope analysis; and
- tritium count dating.

The rest of the analyses was undertaken at ALS in Brisbane. ALS samples were analysed for the following parameters:

- pH and EC;
- dissolved and total metals (Al, As, Be, Ba, Cd, C, Co, Cu, Pb, Mn, Mo, Ni, Se, Sr, Va, Zn, B, Fe, and Si), dissolved and total recoverable mercury, and fluoride;
- Hydroxide, carbonate, bicarbonate, total alkalinity and total hardness; and
- sulphate, chloride, sodium, calcium, magnesium and potassium and sodium adsorption ratio (SAR).

B3 Isotope analysis

B3.1 Deuterium and Oxygen-18

Natural variation of the oxygen (O) isotopic composition of water, when combined with hydrogen (H) isotopes, can be used for determining recharge sources as well as evaporation effects. As a result of evaporative fractionation, waters develop unique isotopic compositions that can be indicative of their source or the processes that formed them. Samples were analysed for stable isotope Oxygen-18 (δ18O) and the stable isotope Deuterium (δ2H). The results are summarised in Table B 2 and the certificates of analysis are attached at the end of this report. The objective of the isotopic assessment was to identify if any isotopic trends were available to assist defining the potential for connection between groundwater and surface water. Figure B 1 plots measured $\delta^{18}O$ versus $\delta^{2}H$.

Table B 2 Summary of stable isotopes results

Sample ID	Delta ^{2}H [‰]	Delta ^{18}O [‰]
MW01	-35.9	-6.30
MW02	-43.4	-7.17
Seep Blowhole	-36.6	-6.28
Main Gully Sampling Point (MGSP)	-34.8	-6.10

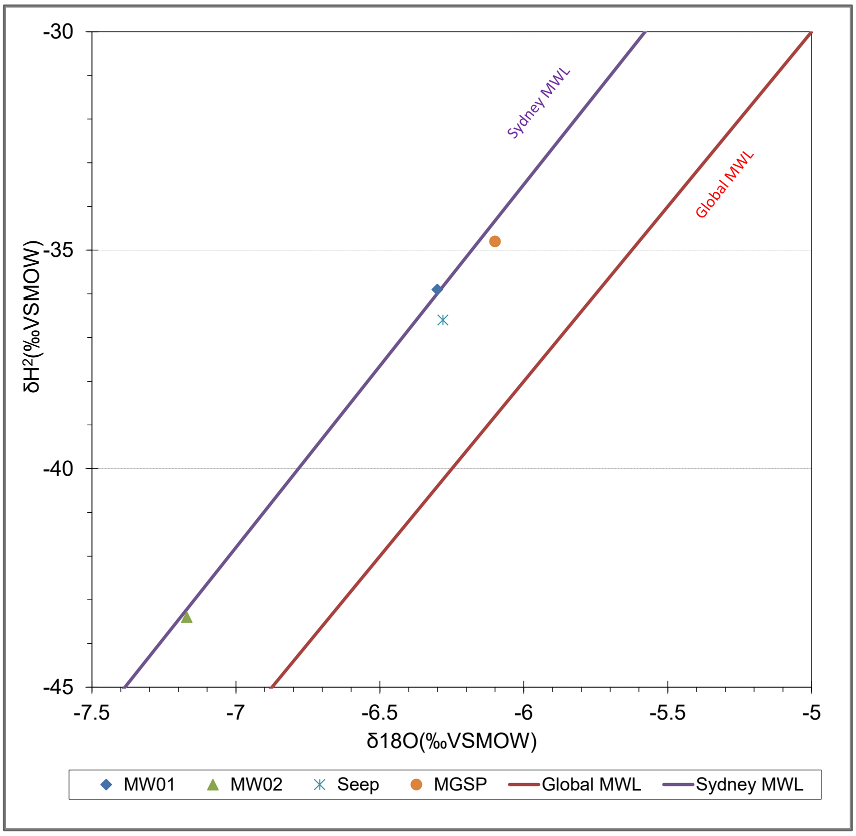

Figure B 1 Plot of δ18O versus δ2H and relationship to Meteoric Water Lines

The Global Meteoric Water Line (MWL) is calculated by assessment of the average relationship between hydrogen and oxygen isotope ratios in natural terrestrial water, expressed as a worldwide average. A MWL can be calculated for a given area, provided a sufficient amount of data is available. The closest pre-defined meteoric water line to the Marulan area is the Sydney MWL (Crosbie et al. 2013). All samples fall on or below the Sydney MWL indicating that the Sydney MWL is a good representation of the local meteoric water line.

Evaporation occurs when water molecules move (escape) from the water phase into the vapour phase. Isotopically light water molecules evaporate more efficiently than the heavy molecules (Gat, 1981). As a result, an isotopic fractionation occurs resulting in:

- water vapour being enriched in light molecules, reflected in negative values of $\delta^{18}O$ and $\delta^{2}H$. In these cases, the terms depleted or light water are commonly applied; and
- residual water being enriched in heavy molecules, reflected in positive values of $\delta^{18}O$ and $\delta^{2}H$. In these cases, the terms enriched or heavy water are commonly applied.

The results of the stable isotope analyses show one primary water grouping where evaporative processes have been minimal and so the water can be considered "depleted".

Water samples – MW01 and MW02 – plot on the Sydney MWL indicating they are likely sourced predominately from rainfall which has undergone minimal evaporative loss. These monitoring bores are located within the current pit where rainfall rapidly recharges the underlying limestone.

The sample collected at the seepage point adjacent the "Blowhole" plots close to but below the Sydney MWL. The water collected at this point is considered to be groundwater and on the basis of the $\delta^{18}O$ and $\delta^{2}H$ ratio is predominantly sourced from rainfall; however, it is likely that the water contains a portion of surface infiltration that has been subjected to evaporation.

Similarly, the result of the water sample collected at the Main Gully Sampling Point within Bungonia Gorge plots close to but below the Sydney MWL. This indicates that the water sampled is predominantly sourced from rainfall and has been subjected to some amount of evaporation; however, as the sample was collected from the creek at the end of summer it is likely that the sample is representative of creek baseflow sourced mainly from groundwater seepage.

B3.2 Tritium

Tritium is the heavy isotope of hydrogen and the atoms are unstable and disintegrate radioactively. The rate of radioactive decay is measurable and this rate can be used as a semi-quantitative guide for age dating recent waters. Tritium within water samples can be derived from two sources:

- natural tritium production in the atmosphere; and
- man-made tritium production resulting from atomic / nuclear testing undertaken in the 1950s and 1960s.

The natural production of tritium in the Australian atmosphere introduces between one and three tritium units (TU) to precipitation and surface water. Nuclear testing during the 1950s and 1960s added large amounts of tritium into the atmosphere which peaked in 1963. Man-made tritium values in Australia reached about 100 TU in precipitation during 1963, completely masking the natural tritium production. However, since 1963 the amount of tritium in the atmosphere has steadily declined to levels that have now stabilised slightly below the natural tritium level (Trados et al., 2004).

Cartwright and Morgenstern (2015) state that the TU value of precipitation in south eastern Australia is between 1 and 3 TU. Cartwright and Morgenstern (2015) present tritium analysis results from precipitation at Mt Buffalo in Victoria that range between 2.7 and 2.9 (for the period between December 2013 and September 2014). McLean et al. (2013) present tritium concentrations in the Nepean River near Sydney NSW of 1.5 which is likely to be predominantly rainfall sourced and has already undergone some degradation. On this basis, it can be assumed that rainfall at the Mine is likely to have a tritium content of between 1.5 and 3 TU. On the assumption that site rainfall were to have a TU concentration of 2.8 (as per Cartwright and Morgenstern) and based on tritium half-life of 12.3 years, it can be assumed that water of 12.3 years would have a TU concentration in the order of 1.4 TU.

This simple calculation assumes that no mixing between older water and younger water has occurred. Notwithstanding the limitation of this approach, this method is able to provide a relative level of context regarding the ages of the waters. The results of tritium analysis of groundwater samples are summarised in Table B 3.

Table B 3 Tritium analysis results

Sample ID	Tritium concentration (TU)	Error (+/-)
MW1	2.511	0.051
MW2	1.765	0.040
Seep / Blowhole	1.870	0.041
Main Gully Sampling Point (MGSP)	1.931	0.043

Using the simplified approach described above and the summarised tritium concentrations, the approximate ages of the water samples range from 16 to 22 years. The order of magnitude of these values being "in the order of 20 years" was confirmed by GNS Laboratories – New Zealand (pers. comm. Rob van der Raaij, 2015).

The results of the tritium analyses provides further evidence that groundwater from the limestone at the Mine is "modern water" and the dominant recharge source is from direct rainfall and overland flow from up-gradient catchments.

B3.3 Carbon-14

Radiocarbon (carbon-14) is produced by the reaction of cosmic radiation secondary neutrons with nitrogen in our air. Surface water and rainfall infiltrating into the ground contain small amounts of carbon dioxide extracted from the air and will have the same radiocarbon content as the earth's atmosphere. Once underground the contribution of atmospheric carbon-14 is minimal and the concentration begins to decrease exponentially in a predictable relationship with time. The half-life of radiocarbon is approximately 5568 years, a number used by all radiocarbon dating laboratories by international convention.

Radiocarbon dating of groundwater can give indications as to when the water was taken out of contact with the atmosphere; however, there are uncertainties present in calculating the percentage of carbonate species that originated from organic material, such as living plants in the aquifer outcrop and the atmosphere, as opposed to that added by ancient carbonaceous / carbonate deposits in the aquifer matrix.

Absolute ages with their attendant uncertainties are not the primary numbers used in site interpretations. The uncorrected apparent ages can be interpreted as maximum ages, i.e. the real age of the groundwater is equal to or less than the apparent age. Aquifers containing fossil carbon, such as limestone aquifers carbon-14 apparent ages, require a correction to give a "best estimate" age; however, carbon-14 dating loses resolution under a "few hundred" years and is generally coupled with tritium dating to establish an age (pers. comm. Rob van der Raaij – GNS laboratories NZ, 2015).

Table B 4 summarises the results of carbon-14 dating of the samples collected at site. The raw and unprocessed date estimates are impacted by the marine carbonate matrix of the limestone aquifer. A δ13C value of 10 or less is generally an indication of the degree of fossil carbon impact on the results. In this case the data in Table B 4 are clearly impacted and hence the estimated dates are an overestimate. GNS NZ has confirmed the results are skewed by the presence of fossil carbon and that the results indicate an age of significantly less than 100 years (pers. comm. Rob van der Raaij – GNS laboratories NZ, 2015).

This estimate, coupled with the tritium based age estimate, indicate the samples are all of a similar and modern age and are relatively close to the aquifer recharge zone.

Table B 4 Summary of carbon-14 dating results

Sample ID	Date analysed	Source	$\delta\ ^{13}C$ [‰]	$\Delta^{14}C$ [‰]	Radiocarbon age [yBP]	Radiocarbon age Error (+/-)
MW01	08/05/2015	IRMS	-6.84	-778.43	12,042	52
MW02	08/05/2015	IRMS	-5.96	-689.1	9,321	40
Seep / Blowhole	08/05/2015	IRMS	-10.13	-401.37	4,059	28
Main Gully Sampling Point	08/05/2015	IRMS	-7.97	-357.72	3,493	27

B4 References

Cartwright, I. and Morgenstern, U. (2015), *"Transit times from rainfall to baseflow in headwater catchments estimated using tritium: the Ovens River, Australia"*, Hydrol. Earth Syst. Sci., 19, 3771-3785, https://doi.org/10.5194/hess-19-3771-2015.

Crosbie R.S., Pickett T., Mpelasoka F.S., Hodgson G., Charles S.P., Barron O.V. (2013), *"An assessment of the climate change impacts on groundwater recharge across Australia using a probabilistic approach with an ensemble of GCMs"*. Climatic Change, 2013; 117(1):41-53. https://doi.org/10.1007/s10584-012-0558-6

Gat, J. R., (1981), Isotope Fractionation, in J. R. Gat and Gonfiantini (eds), "*Stable Isotope Hydrology Deuterium and Oxygen-18 in the Water Cycle*". IAEA Technical Report Series No. 210, International Atomic Energy Agency, Vienna

McLean, W., Brown, S. & Duggleby, J. (2013), "*Water Quality Investigation Camden Gas Project"*. Parsons Brinkerhoff Report - 2114759C PT_7196 dated 02 July 2013.

Trados C.V., Henderson-Sellers A., Hill D.M., Twining J.R., and Stone D.J. (2004), "*Tritium in Australian Precipitation: A 40 year Record",* American Geophysical Union, Fall Meeting 2004, abstract #C51B-1033.

CHAIN OF CUSTODY

ALS

ALS Laboratory: please tick →

☐ADELAIDE 21 Burma Road Pooraka SA 5095 Ph: 08 8359 0890 E: adelaide@alsglobal.com
☐BRISBANE 2 Byth Street Stafford QLD 4053 Ph: 07 3243 7222 E: samples.brisbane@alsglobal.com
☐GLADSTONE 46 Callemondah Drive Clinton QLD 4680 Ph: 07 7471 5600 E: gladstone@alsglobal.com
☐MACKAY 78 Harbour Road Mackay QLD 4740 Ph: 07 4944 0177 E: mackay@alsglobal.com
☐MELBOURNE 2-4 Westall Road Springvale VIC 3171 Ph: 03 8549 9600 E: samples.melbourne@alsglobal.com
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☐TOWNSVILLE 14-15 Desma Court Bohle QLD 4818 Ph: 07 4796 0600 E: townsville.environmental@alsglobal.com
☐WOLLONGONG 99 Kenny Street Wollongong NSW 2500 Ph: 02 4225 3125 E: wollongong@alsglobal.com

CLIENT: *AGE Consultants*
OFFICE: *Newcastle*
PROJECT: *Marulan Limestone* **PROJECT NO** *G1714*
ORDER NUMBER: **PURCHASE ORDER NO.:**
PROJECT MANAGER: *Costante Conte* **CONTACT PH:** *02 4962 2091*

TURNAROUND REQUIREMENTS : (Standard TAT may be longer for some tests e.g., Ultra Trace Organics)
☐ Standard TAT (**List due date**):
☐ Non Standard or urgent TAT (**List due date**):

ALS QUOTE NO.: BNBQ/011/14
COUNTRY OF ORIGIN:

COC SEQUENCE NUMBER (Circle)
COC: 8 2 3 4 5 6 7
OF: 8 2 3 4 5 6 7

FOR LABORATORY USE ONLY (Circle)
Custody Seal Intact? Yes No N/A
Free ice / frozen ice bricks present upon receipt? (Yes) No N/A
Random Sample Temperature on Receipt: 6.2 °C
Other comment: chest drop off

SAMPLER: *Pavel Dvoracek* **SAMPLER MOBILE:** *0414 324 504*
COC Emailed to ALS? (YES / NO) **EDD FORMAT (or default):**
Email Reports to (will default to PM if no other addresses are listed): pavel@ageconsultants.com.au
Email Invoice to (will default to PM if no other addresses are listed): [redacted]@ageconsultants.com.au

RELINQUISHED BY:	RECEIVED BY:	RELINQUISHED BY:	RECEIVED BY:
Thomas Walters	KB		Kam
DATE/TIME:	DATE/TIME: 16/2/15 13.25	DATE/TIME:	DATE/TIME: 16/2/15 19:10

COMMENTS/SPECIAL HANDLING/STORAGE OR DISPOSAL: BRISBANE @

ALS USE ONLY	SAMPLE DETAILS MATRIX: Solid(S) Water(W)			CONTAINER INFORMATION		ANALYSIS REQUIRED including SUITES (NB. Suite Codes must be listed to attract suite price) Where Metals are required, specify Total (unfiltered bottle required) or Dissolved (field filtered bottle required).								Additional Information
LAB ID	SAMPLE ID	DATE / TIME	MATRIX	TYPE & PRESERVATIVE *(refer to codes below)*	TOTAL BOTTLES	CSG-2	WS-24							Comments on likely contaminant levels, dilutions, or samples requiring specific QC analysis etc.
1	seep ✓	10/02/2015 12:00	w		5	x								not field filtered
2	Main Gully SP (MGSP) ✓	10/02/2015 12:30	w		5	x								
3	WP16 ✓	11/02/2015 12:10	w		10	x	x							
4	spring ✓	11/02/2015 13:08	w		5	x								
5	MW2 ✓	11/02/2015 16:20	w		5	x								
6	MW1 ✓	12/02/2015 13:10	w		5	x								
7	MW5 ✓	11/02/2015 15:00	w		10	x	x							
				TOTAL	45									

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Environmental Division
Sydney
Work Order
ES1503501
Telephone : +61-2-8784 8555

Water Container Codes: P = Unpreserved Plastic; N = Nitric Preserved Plastic; ORC = Nitric Preserved ORC; SH = Sodium Hydroxide/Cd Preserved; S = Sodium Hydroxide Preserved Plastic; AG = Amber Glass Unpreserved; AP - Airfreight Unpreserved Plastic
V = VOA Vial HCl Preserved; VB = VOA Vial Sodium Bisulphate Preserved; VS = VOA Vial Sulfuric Preserved; AV = Airfreight Unpreserved Vial SG = Sulfuric Preserved Amber Glass; H = HCl preserved Plastic; HS = HCl preserved Speciation bottle; SP = Sulfuric Preserved Plastic; F = Formaldehyde Preserved Glass;
Z = Zinc Acetate Preserved Bottle; E = EDTA Preserved Bottles; ST = Sterile Bottle; ASS = Plastic Bag for Acid Sulphate Soils; B = Unpreserved Bag; LI = Lugols Iodine Preserved Bottles; STT = Sterile Sodium Thiosulfate Preserved Bottles.

2.5. ALS GENERAL INORGANICS & NUTRIENTS WATER TESTING SUITES

TEST PARAMETERS	ALS SUITE CODE	PRICE/ SAMPLE ($)
Cations: Major (Ca, Mg, Na, K)	NT-1	12.00
Cations(Ca, Mg, Na, K) + **SAR:**	NT-1B	14.00
Cations (Ca + Mg) + Hardness	NT-1C	12.00
Cations: Major (Ca, Mg, Na, K) + **Hardness**	NT-1D	14.00
Anions: Minor (Cl, SO_4, Alkalinity)	NT-2	20.00
Anions: Major (Cl, SO_4 F, Alkalinity)	NT-2A	28.00
Anions: Nitrite, Nitrate as N, Fluoride, Reactive Phos'	NT-3	35.00
Nitrite as N and Nitrate as N	NT-4	18.00
Total Nitrogen (including TKN + NOx)	NT-5	32.00
Total Nitrogen, TKN, NOx, NO_2 NO_3	NT-6	42.00
Total Nitrogen, TKN, NOx, NO_2 NO_3, NH_3	NT-7	54.00
Total Nitrogen, TKN, NOx, NO_2, NO_3, NH_3, Total Phosphorus	NT-8	57.00
Total Nitrogen, TKN, NOx, NO_2, NO_3, NH_3, Total Phosphorus, Reactive Phosphorous	NT-8A	62.00
TKN, Total Phosphorus	NT-9	29.00
Total Nitrogen, TKN, NOx, Total Phosphorus	NT-11	41.00
General Water Suite: Ca, Mg, Na, K, pH, EC, Cl, SO_4, Alkalinity, Fluoride, Hardness & TDS (Calc')	NT-12	46.00
Extended Water Suite A: Ca, Mg, Na, K, pH, EC, Cl, F, SO_4, Alkalinity, Hardness & TDS (Calc'), Nitrate, Nitrite, Ammonia, Reactive Phosphorus	NT-13	75.00
Extended Water Suite B: Ca, Mg, Na, K, pH, EC, Cl, F, SO_4, Alkalinity, Hardness & TDS (Calc'), Nitrate, Nitrite, Ammonia, Reactive Phosphorus, Total P&N, TKN	NT-14	98.00
Conductivity (EC) plus TDS Calculated	IN-1	10.00
Sulfite/Thiosulfate	IN-2	32.00
TOC, TIC and TC Combined Suite	IN-3	45.00
Trace Chlorite, Chlorate, Bromate, Bromide [E]	OX-01	180.00
TN, TP – Ultra trace	UTN-01	37.00
Nitrite, Nitrate, Ammonia, Reactive P – UT	UTN-03	55.00
Nitrite, Nitrate, Ammonia, Reactive P – UT TN, TKN, TP [E]	UTN-04	80.00
Basic CSG Suite: Ca, Mg, Na, K, (SAR, TDS and Hardness by calc') pH, EC, Alkalinity, F, Cl, SO4, Dissolved Silica plus an Ion Balance;	CSG-1	84.00
Extended CSG Suite: CSG-1 analytes plus: 19 Total & 19 Dissolved metals: Al, As, B, Ba, Be, Cd, Co, Cr, Cu, Fe, Hg, Mo, Mn, Ni, Pb, Se, Sr, V, Zn + Bromide	CSG-2	210.00

ALS Suite prices only apply when the suite codes is recorded on the COC.

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2. WATER

2.4. ALS MAJOR WATER TESTING SUITES

TEST PARAMETER	ALS SUITE CODES	METHOD REFERENCE	LOR (mg/L unless noted)	PRICE/ SAMPLE ($)
7 Metals: As, Cd, Cr, Cu, Ni, Pb, Zn*	**W-1**	ICP/MS	Cd / Hg (0.0001), Zn(0.005), Al(0.01), Fe & B(0.05), Others 0.001	21.00
8 Metals: As, Cd, Cr, Cu, Ni, Pb, Zn, Hg*	**W-2**	ICP/MS/CV/FIMS		26.00
11 Metals: As, Cd, Cr, Cu, Pb, Ni, Zn, Al, Fe, Se, Hg*	**W-30**			31.00
15 Metals(NEPM Suite) (As, B, Ba, Be, Cd, Cr, Co, Cu, Mn, Ni, Pb, Se, V, Zn, Hg)*	**W-3**		See W1 & W2 V (0.01)	35.00
TPH (C6-C9), TRH(C6-C10)/BTEXN plus F1 & F2	**W-18**	P&T/HS-GC/MS	20 / 1-5 µg/L	24.00
TPH/TRH (C6-C36 or 40)/BTEXN plus F1 & F2	**W-4**	GC/FID, P&T/HS/MS	20-100 / 1-5 µg/L	42.00
TPH/TRH (C6-C36 or 40)/BTEXN, F1 & F2 (Silica Gel)	**W-4 SG**		20-100 / 1-5 µg/L	54.00
TPH/TRH(C6-C36 or 40)/BTEX plus VOC	**W-9**	See W-4	VOC (1-50 µg/L)	95.00
PAH/Phenols (16 PAHs & 12 Phenols)	**W-14A**	GC/MS - SIM	0.5-2 µg/L	70.00
TRH(C6-C40)/BTEXN/Pb	**W-6**	See W-4 & W-1		48.00
TRH(C6-C40)/BTEXN/Pb (Silica Gel)	**W-6 SG**	See W-4 & W-1		60.00
TRH(C6-C40)/BTEXN/8 Metals*	**W-5**	See W-4 & W-2		70.00
TRH(C6-C40)/BTEXN/8 Metals* (Silica Gel)	**W-5 SG**	See W-4 & W-2		82.00
TRH(C6-C40)/BTEXN/PAH	**W-7**	See W-4 & W14A		75.00
TRH(C6-C40)/BTEXN/PAH (Silica Gel)	**W-7 SG**	See W-4 & W14A		87.00
TRH(C6-C40)/BTEXN/PAH,Pb*	**W-21**	See W-7 & W-1		82.00
TRH(C6-C40)/BTEXN/PAH plus 8 metals*	**W-26**	See W-7 & W-2		98.00
TRH(C6-C40)/BTEXN/PAH plus 8 metals*(Silica Gel)	**W-26 SG**	See W-7 & W-2		110.00
TRH(C6-C40)/BTEXN/PAH/Phenols	**W-24**	See W-4 & W14A		100.00
TRH(C6-C40)/BTEXN/PAH/Phenols & Pb*	**W-25**	See W-4, W14A & W1		107.00
TRH(C6-C40)/BTEXN/PAH/Phenols,8 metals*	**W-27**	See W-4, W14A & W2		125.00
TRH(C6-C40)/BTEXN/PAH/Phenols/OC/OP/PCB/8 Metals*	**W-19**	See W-4, W-14, W-13 & W-2		195.00
TRH(C6-C40)/BTEXN/PAH plus VOC	**W-10**	See W7	See W4, W9	125.00
VOC/SVOC	**W-23**	P&T-GC/MS, GC/MS	2-50 µg/L	195.00
OC/PCB	**W-11**	GC/ECD/ECD-MS	0.5-2 µg/L	55.00
OC/OP Pesticides	**W-12**	GC/ECD/FPD-MS	0.5-2 µg/L	58.00
OC/OP/PCB	**W-13**	GC/ECD/FPD-MS	See W-11, W-12	70.00
Natural attenuation Indicators (nitrate, Sulfate, Ferrous Iron, Methane)	**W-28**	Various	Inorganics 0.01-1, Methane 10µg/L	100.00

ALS Suite prices only apply when the suite codes is recorded on the COC.

* Please note: All suites listed above are for dissolved metals. Where total metals are required the suite name will have a suffix 'T' (e.g. W-2T for 8 total metals). Additional charges of $5.00 apply. In the absence of advice dissolved metals will be the default.

E-MAILED

ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order	: **ES1503501**	Page	: 1 of 13
Client	: **AUST GROUNDWATER & ENVIRO CONSULTANTS**	Laboratory	: Environmental Division Sydney
Contact	: MR PAVEL DVORACEK	Contact	: Client Services
Address	: Harbour Pier, Shop 8, 21 Merewether Street, NEWCASTLE NSW 2300	Address	: 277-289 Woodpark Road Smithfield NSW Australia 2164
E-mail	: pavel.dvoracek@ageconsultants.com.au	E-mail	: sydney@alsglobal.com
Telephone	: +61 02 4926 2811	Telephone	: +61-2-8784 8555
Facsimile	: +61 02 4926 2611	Facsimile	: +61-2-8784 8500
Project	: G1714 MARULAN LIMESTONE	QC Level	: NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Order number	: ----		
C-O-C number	: ----	Date Samples Received	: 16-FEB-2015
Sampler	: PD	Issue Date	: 24-FEB-2015
Site	: ----		
		No. of samples received	: 7
Quote number	: BNBQ/011/14	No. of samples analysed	: 7

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. All pages of this report have been checked and approved for release.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results
- Surrogate Control Limits

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting

- **Benzo(a)pyrene Toxicity Equivalent Quotient (TEQ) is the sum total of the concentration of the eight carcinogenic PAHs multiplied by their Toxicity Equivalence Factor (TEF) relative to Benzo(a)pyrene. TEF values are provided in brackets as follows: Benz(a)anthracene (0.1), Chrysene (0.01), Benzo(b+j) & Benzo(k)fluoranthene (0.1), Benzo(a)pyrene (1.0), Indeno(1.2.3.cd)pyrene (0.1), Dibenz(a.h)anthracene (1.0), Benzo(g.h.i)perylene (0.01). Less than LOR results for 'TEQ Zero' are treated as zero.**
- **EA016: Calculated TDS is determined from Electrical conductivity using a conversion factor of 0.65.**
- **EG020: It has been confirmed by re-digestion and re-analysis that total Aluminium concentrations is less than dissolved for sample ES1503501 #007. For all other samples and analytes where dissolved is greater than total, the difference is within experimental variation of the methods.**
- **EG035: Positive Mercury results have been confirmed by re-digestion and re-analysis.**

NATA Accredited Laboratory 825

Accredited for compliance with ISO/IEC 17025.

WORLD RECOGNISED ACCREDITATION

Signatories

This document has been electronically signed by the authorized signatories indicated below. Electronic signing has been carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Ankit Joshi	Inorganic Chemist	Sydney Inorganics
Ashesh Patel	Inorganic Chemist	Sydney Inorganics
Pabi Subba	Senior Organic Chemist	Sydney Organics
Shobhna Chandra	Metals Coordinator	Sydney Inorganics
Wisam Marassa	Inorganics Coordinator	Sydney Inorganics

Analytical Results

Sub-Matrix: **WATER** (Matrix: **WATER**)

Compound	CAS Number	LOR	Unit	SEEP	MAIN GULLY SP(MGSP)	WP16	SPRING	MW2
Client sampling date / time				10-FEB-2015 12:00	10-FEB-2015 12:30	11-FEB-2015 12:10	11-FEB-2015 13:08	11-FEB-2015 16:20
				ES1503501-001	**ES1503501-002**	**ES1503501-003**	**ES1503501-004**	**ES1503501-005**
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	**7.80**	**7.89**	**7.58**	**7.70**	**7.64**
EA006: Sodium Adsorption Ratio (SAR)								
Sodium Adsorption Ratio	----	0.01	-	**0.55**	**0.62**	**0.65**	**0.61**	**0.09**
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	**665**	**610**	**1010**	**896**	**704**
EA016: Non Marine - Estimated TDS Salinity								
Total Dissolved Solids (Calc.)	----	1	mg/L	**432**	**396**	**656**	**582**	**458**
EA065: Total Hardness as CaCO3								
Total Hardness as CaCO3	----	1	mg/L	**280**	**237**	**402**	**402**	**366**
ED009: Anions								
Bromide	24959-67-9	0.010	mg/L	**0.131**	**0.129**	**0.502**	**0.294**	**0.029**
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	**199**	**160**	**324**	**314**	**188**
Total Alkalinity as CaCO3	----	1	mg/L	**199**	**160**	**324**	**314**	**188**
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA								
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	**62**	**63**	**30**	**26**	**161**
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	1	mg/L	**36**	**37**	**77**	**81**	**5**
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	**89**	**72**	**118**	**128**	**112**
Magnesium	7439-95-4	1	mg/L	**14**	**14**	**26**	**20**	**21**
Sodium	7440-23-5	1	mg/L	**21**	**22**	**30**	**28**	**4**
Potassium	7440-09-7	1	mg/L	**2**	**2**	**2**	**2**	<1
EG020F: Dissolved Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Arsenic	7440-38-2	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Beryllium	7440-41-7	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Barium	7440-39-3	0.001	mg/L	**0.028**	**0.028**	**0.067**	**0.054**	**0.016**
Cadmium	7440-43-9	0.0001	mg/L	<0.0001	<0.0001	**0.0002**	<0.0001	<0.0001
Chromium	7440-47-3	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Cobalt	7440-48-4	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)

Compound	CAS Number	LOR	Unit	SEEP	MAIN GULLY SP(MGSP)	WP16	SPRING	MW2
Client sampling date / time				10-FEB-2015 12:00	10-FEB-2015 12:30	11-FEB-2015 12:10	11-FEB-2015 13:08	11-FEB-2015 16:20
				ES1503501-001	ES1503501-002	ES1503501-003	ES1503501-004	ES1503501-005
EG020F: Dissolved Metals by ICP-MS - Continued								
Copper	7440-50-8	0.001	mg/L	<0.001	<0.001	**0.009**	<0.001	<0.001
Lead	7439-92-1	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Manganese	7439-96-5	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	**0.025**
Molybdenum	7439-98-7	0.001	mg/L	**0.004**	**0.001**	<0.001	<0.001	<0.001
Nickel	7440-02-0	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	**0.015**
Selenium	7782-49-2	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Strontium	7440-24-6	0.001	mg/L	**0.192**	**0.190**	**0.237**	**0.164**	**0.151**
Vanadium	7440-62-2	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc	7440-66-6	0.005	mg/L	<0.005	<0.005	**0.017**	<0.005	<0.005
Boron	7440-42-8	0.05	mg/L	<0.05	<0.05	<0.05	<0.05	<0.05
Iron	7439-89-6	0.05	mg/L	<0.05	<0.05	<0.05	<0.05	<0.05
EG020T: Total Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	**0.45**	**0.13**	**0.08**	**0.01**	**37.3**
Arsenic	7440-38-2	0.001	mg/L	**0.002**	<0.001	<0.001	<0.001	**0.056**
Beryllium	7440-41-7	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	**0.007**
Barium	7440-39-3	0.001	mg/L	**0.037**	**0.035**	**0.062**	**0.048**	**0.390**
Cadmium	7440-43-9	0.0001	mg/L	<0.0001	<0.0001	**0.0002**	<0.0001	**0.0014**
Chromium	7440-47-3	0.001	mg/L	**0.002**	<0.001	<0.001	<0.001	**0.300**
Cobalt	7440-48-4	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	**0.118**
Copper	7440-50-8	0.001	mg/L	**0.003**	<0.001	**0.232**	**0.005**	**0.154**
Lead	7439-92-1	0.001	mg/L	<0.001	<0.001	**0.019**	<0.001	**0.106**
Manganese	7439-96-5	0.001	mg/L	**0.016**	**0.002**	**0.001**	<0.001	**3.73**
Molybdenum	7439-98-7	0.001	mg/L	**0.001**	<0.001	<0.001	<0.001	**0.002**
Nickel	7440-02-0	0.001	mg/L	**0.001**	<0.001	**0.001**	<0.001	**0.311**
Selenium	7782-49-2	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	**0.01**
Strontium	7440-24-6	0.001	mg/L	**0.181**	**0.169**	**0.210**	**0.183**	**0.539**
Vanadium	7440-62-2	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	**0.10**
Zinc	7440-66-6	0.005	mg/L	**0.049**	<0.005	**0.060**	<0.005	**0.349**
Boron	7440-42-8	0.05	mg/L	<0.05	<0.05	<0.05	<0.05	<0.05
Iron	7439-89-6	0.05	mg/L	**0.55**	**0.10**	**0.05**	<0.05	**67.3**
EG035F: Dissolved Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	**0.0005**	**0.0003**	<0.0001
EG035T: Total Recoverable Mercury by FIMS								

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Client sample ID	SEEP	MAIN GULLY SP(MGSP)	WP16	SPRING	MW2
			Client sampling date / time	10-FEB-2015 12:00	10-FEB-2015 12:30	11-FEB-2015 12:10	11-FEB-2015 13:08	11-FEB-2015 16:20
Compound	CAS Number	LOR	Unit	ES1503501-001	ES1503501-002	ES1503501-003	ES1503501-004	ES1503501-005
EG035T: Total Recoverable Mercury by FIMS - Continued								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	**0.0002**
EG052F: Dissolved Silica by ICPAES								
Silicon as SiO2	14464-46-1	0.1	mg/L	**10.4**	**10.6**	**18.4**	**18.4**	**6.6**
EK040P: Fluoride by PC Titrator								
Fluoride	16984-48-8	0.1	mg/L	**0.2**	**0.2**	**0.2**	**0.2**	<0.1
EN055: Ionic Balance								
Total Anions	----	0.01	meq/L	**6.28**	**5.55**	**9.27**	**9.10**	**7.25**
Total Cations	----	0.01	meq/L	**6.56**	**5.75**	**9.38**	**9.30**	**7.49**
Ionic Balance	----	0.01	%	**2.17**	**1.80**	**0.63**	**1.13**	**1.67**
EP075(SIM)A: Phenolic Compounds								
Phenol	108-95-2	1.0	µg/L	----	----	<1.0	----	----
2-Chlorophenol	95-57-8	1.0	µg/L	----	----	<1.0	----	----
2-Methylphenol	95-48-7	1.0	µg/L	----	----	<1.0	----	----
3- & 4-Methylphenol	1319-77-3	2.0	µg/L	----	----	<2.0	----	----
2-Nitrophenol	88-75-5	1.0	µg/L	----	----	<1.0	----	----
2.4-Dimethylphenol	105-67-9	1.0	µg/L	----	----	<1.0	----	----
2.4-Dichlorophenol	120-83-2	1.0	µg/L	----	----	<1.0	----	----
2.6-Dichlorophenol	87-65-0	1.0	µg/L	----	----	<1.0	----	----
4-Chloro-3-methylphenol	59-50-7	1.0	µg/L	----	----	<1.0	----	----
2.4.6-Trichlorophenol	88-06-2	1.0	µg/L	----	----	<1.0	----	----
2.4.5-Trichlorophenol	95-95-4	1.0	µg/L	----	----	<1.0	----	----
Pentachlorophenol	87-86-5	2.0	µg/L	----	----	<2.0	----	----
EP075(SIM)B: Polynuclear Aromatic Hydrocarbons								
Naphthalene	91-20-3	1.0	µg/L	----	----	<1.0	----	----
Acenaphthylene	208-96-8	1.0	µg/L	----	----	<1.0	----	----
Acenaphthene	83-32-9	1.0	µg/L	----	----	<1.0	----	----
Fluorene	86-73-7	1.0	µg/L	----	----	<1.0	----	----
Phenanthrene	85-01-8	1.0	µg/L	----	----	<1.0	----	----
Anthracene	120-12-7	1.0	µg/L	----	----	<1.0	----	----
Fluoranthene	206-44-0	1.0	µg/L	----	----	<1.0	----	----
Pyrene	129-00-0	1.0	µg/L	----	----	<1.0	----	----
Benz(a)anthracene	56-55-3	1.0	µg/L	----	----	<1.0	----	----
Chrysene	218-01-9	1.0	µg/L	----	----	<1.0	----	----

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)

Compound	CAS Number	LOR	Unit	SEEP	MAIN GULLY SP(MGSP)	WP16	SPRING	MW2
Client sampling date / time				10-FEB-2015 12:00	10-FEB-2015 12:30	11-FEB-2015 12:10	11-FEB-2015 13:08	11-FEB-2015 16:20
				ES1503501-001	ES1503501-002	ES1503501-003	ES1503501-004	ES1503501-005
EP075(SIM)B: Polynuclear Aromatic Hydrocarbons - Continued								
Benzo(b+j)fluoranthene	205-99-2 205-82-3	1.0	µg/L	----	----	<1.0	----	----
Benzo(k)fluoranthene	207-08-9	1.0	µg/L	----	----	<1.0	----	----
Benzo(a)pyrene	50-32-8	0.5	µg/L	----	----	<0.5	----	----
Indeno(1.2.3.cd)pyrene	193-39-5	1.0	µg/L	----	----	<1.0	----	----
Dibenz(a.h)anthracene	53-70-3	1.0	µg/L	----	----	<1.0	----	----
Benzo(g.h.i)perylene	191-24-2	1.0	µg/L	----	----	<1.0	----	----
^ Sum of polycyclic aromatic hydrocarbons	----	0.5	µg/L	----	----	<0.5	----	----
^ Benzo(a)pyrene TEQ (zero)	----	0.5	µg/L	----	----	<0.5	----	----
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	20	µg/L	----	----	<20	----	----
C10 - C14 Fraction	----	50	µg/L	----	----	<50	----	----
C15 - C28 Fraction	----	100	µg/L	----	----	<100	----	----
C29 - C36 Fraction	----	50	µg/L	----	----	<50	----	----
^ C10 - C36 Fraction (sum)	----	50	µg/L	----	----	<50	----	----
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
C6 - C10 Fraction	C6_C10	20	µg/L	----	----	<20	----	----
^ C6 - C10 Fraction minus BTEX (F1)	C6_C10-BTEX	20	µg/L	----	----	<20	----	----
>C10 - C16 Fraction	>C10_C16	100	µg/L	----	----	<100	----	----
>C16 - C34 Fraction	----	100	µg/L	----	----	<100	----	----
>C34 - C40 Fraction	----	100	µg/L	----	----	<100	----	----
^ >C10 - C40 Fraction (sum)	----	100	µg/L	----	----	<100	----	----
^ >C10 - C16 Fraction minus Naphthalene (F2)	----	100	µg/L	----	----	<100	----	----
EP080: BTEXN								
Benzene	71-43-2	1	µg/L	----	----	<1	----	----
Toluene	108-88-3	2	µg/L	----	----	<2	----	----
Ethylbenzene	100-41-4	2	µg/L	----	----	<2	----	----
meta- & para-Xylene	108-38-3 106-42-3	2	µg/L	----	----	<2	----	----
ortho-Xylene	95-47-6	2	µg/L	----	----	<2	----	----
^ Total Xylenes	1330-20-7	2	µg/L	----	----	<2	----	----
^ Sum of BTEX	----	1	µg/L	----	----	<1	----	----
Naphthalene	91-20-3	5	µg/L	----	----	<5	----	----

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Client sample ID	SEEP	MAIN GULLY SP(MGSP)	WP16	SPRING	MW2
			Client sampling date / time	10-FEB-2015 12:00	10-FEB-2015 12:30	11-FEB-2015 12:10	11-FEB-2015 13:08	11-FEB-2015 16:20
Compound	*CAS Number*	*LOR*	*Unit*	**ES1503501-001**	**ES1503501-002**	**ES1503501-003**	**ES1503501-004**	**ES1503501-005**
EP075(SIM)S: Phenolic Compound Surrogates								
Phenol-d6	13127-88-3	0.1	%	----	----	**33.2**	----	----
2-Chlorophenol-D4	93951-73-6	0.1	%	----	----	**56.3**	----	----
2.4.6-Tribromophenol	118-79-6	0.1	%	----	----	**49.3**	----	----
EP075(SIM)T: PAH Surrogates								
2-Fluorobiphenyl	321-60-8	0.1	%	----	----	**54.6**	----	----
Anthracene-d10	1719-06-8	0.1	%	----	----	**70.0**	----	----
4-Terphenyl-d14	1718-51-0	0.1	%	----	----	**70.1**	----	----
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.1	%	----	----	**104**	----	----
Toluene-D8	2037-26-5	0.1	%	----	----	**103**	----	----
4-Bromofluorobenzene	460-00-4	0.1	%	----	----	**91.1**	----	----

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)

Compound	CAS Number	LOR	Unit	MW1	MW5	----	----	----
			Client sampling date / time	12-FEB-2015 13:10	11-FEB-2015 15:00	----	----	----
				ES1503501-006	ES1503501-007	----	----	----
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	7.42	10.7	----	----	----
EA006: Sodium Adsorption Ratio (SAR)								
Sodium Adsorption Ratio	----	0.01	-	0.55	2.58	----	----	----
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	964	1140	----	----	----
EA016: Non Marine - Estimated TDS Salinity								
Total Dissolved Solids (Calc.)	----	1	mg/L	627	741	----	----	----
EA065: Total Hardness as CaCO3								
Total Hardness as CaCO3	----	1	mg/L	448	267	----	----	----
ED009: Anions								
Bromide	24959-67-9	0.010	mg/L	0.066	0.415	----	----	----
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	36	----	----	----
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	33	----	----	----
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	351	<1	----	----	----
Total Alkalinity as CaCO3	----	1	mg/L	351	69	----	----	----
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA								
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	93	144	----	----	----
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	1	mg/L	28	179	----	----	----
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	112	102	----	----	----
Magnesium	7439-95-4	1	mg/L	41	3	----	----	----
Sodium	7440-23-5	1	mg/L	27	97	----	----	----
Potassium	7440-09-7	1	mg/L	10	10	----	----	----
EG020F: Dissolved Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	<0.01	0.18	----	----	----
Arsenic	7440-38-2	0.001	mg/L	<0.001	0.006	----	----	----
Beryllium	7440-41-7	0.001	mg/L	<0.001	<0.001	----	----	----
Barium	7440-39-3	0.001	mg/L	0.059	0.044	----	----	----
Cadmium	7440-43-9	0.0001	mg/L	0.0002	<0.0001	----	----	----
Chromium	7440-47-3	0.001	mg/L	<0.001	0.003	----	----	----
Cobalt	7440-48-4	0.001	mg/L	<0.001	<0.001	----	----	----

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Client sample ID	MW1	MW5	----	----	----
			Client sampling date / time	12-FEB-2015 13:10	11-FEB-2015 15:00	----	----	----
Compound	CAS Number	LOR	Unit	ES1503501-006	ES1503501-007	----	----	----
EG020F: Dissolved Metals by ICP-MS - Continued								
Copper	7440-50-8	0.001	mg/L	**0.003**	<0.001	----	----	----
Lead	7439-92-1	0.001	mg/L	<0.001	<0.001	----	----	----
Manganese	7439-96-5	0.001	mg/L	**0.037**	<0.001	----	----	----
Molybdenum	7439-98-7	0.001	mg/L	**0.002**	**0.002**	----	----	----
Nickel	7440-02-0	0.001	mg/L	**0.010**	<0.001	----	----	----
Selenium	7782-49-2	0.01	mg/L	<0.01	<0.01	----	----	----
Strontium	7440-24-6	0.001	mg/L	**0.262**	**0.274**	----	----	----
Vanadium	7440-62-2	0.01	mg/L	<0.01	<0.01	----	----	----
Zinc	7440-66-6	0.005	mg/L	**0.018**	**0.023**	----	----	----
Boron	7440-42-8	0.05	mg/L	<0.05	<0.05	----	----	----
Iron	7439-89-6	0.05	mg/L	<0.05	<0.05	----	----	----
EG020T: Total Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	**0.52**	**0.10**	----	----	----
Arsenic	7440-38-2	0.001	mg/L	**0.002**	**0.006**	----	----	----
Beryllium	7440-41-7	0.001	mg/L	<0.001	<0.001	----	----	----
Barium	7440-39-3	0.001	mg/L	**0.067**	**0.041**	----	----	----
Cadmium	7440-43-9	0.0001	mg/L	**0.0002**	<0.0001	----	----	----
Chromium	7440-47-3	0.001	mg/L	**0.015**	**0.003**	----	----	----
Cobalt	7440-48-4	0.001	mg/L	**0.004**	<0.001	----	----	----
Copper	7440-50-8	0.001	mg/L	**0.015**	<0.001	----	----	----
Lead	7439-92-1	0.001	mg/L	**0.003**	<0.001	----	----	----
Manganese	7439-96-5	0.001	mg/L	**0.106**	<0.001	----	----	----
Molybdenum	7439-98-7	0.001	mg/L	**0.002**	**0.002**	----	----	----
Nickel	7440-02-0	0.001	mg/L	**0.019**	<0.001	----	----	----
Selenium	7782-49-2	0.01	mg/L	<0.01	<0.01	----	----	----
Strontium	7440-24-6	0.001	mg/L	**0.246**	**0.309**	----	----	----
Vanadium	7440-62-2	0.01	mg/L	<0.01	<0.01	----	----	----
Zinc	7440-66-6	0.005	mg/L	**0.046**	<0.005	----	----	----
Boron	7440-42-8	0.05	mg/L	<0.05	<0.05	----	----	----
Iron	7439-89-6	0.05	mg/L	**5.16**	<0.05	----	----	----
EG035F: Dissolved Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	----	----	----
EG035T: Total Recoverable Mercury by FIMS								

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Client sample ID	MW1	MW5	----	----	----
			Client sampling date / time	12-FEB-2015 13:10	11-FEB-2015 15:00	----	----	----
Compound	CAS Number	LOR	Unit	ES1503501-006	ES1503501-007	----	----	----
EG035T: Total Recoverable Mercury by FIMS - Continued								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	----	----	----
EG052F: Dissolved Silica by ICPAES								
Silicon as SiO2	14464-46-1	0.1	mg/L	**8.1**	**13.5**	----	----	----
EK040P: Fluoride by PC Titrator								
Fluoride	16984-48-8	0.1	mg/L	**0.2**	**0.2**	----	----	----
EN055: Ionic Balance								
Total Anions	----	0.01	meq/L	**9.74**	**9.43**	----	----	----
Total Cations	----	0.01	meq/L	**10.4**	**9.81**	----	----	----
Ionic Balance	----	0.01	%	**3.26**	**2.03**	----	----	----
EP075(SIM)A: Phenolic Compounds								
Phenol	108-95-2	1.0	µg/L	----	**5.0**	----	----	----
2-Chlorophenol	95-57-8	1.0	µg/L	----	<1.0	----	----	----
2-Methylphenol	95-48-7	1.0	µg/L	----	<1.0	----	----	----
3- & 4-Methylphenol	1319-77-3	2.0	µg/L	----	<2.0	----	----	----
2-Nitrophenol	88-75-5	1.0	µg/L	----	<1.0	----	----	----
2.4-Dimethylphenol	105-67-9	1.0	µg/L	----	<1.0	----	----	----
2.4-Dichlorophenol	120-83-2	1.0	µg/L	----	<1.0	----	----	----
2.6-Dichlorophenol	87-65-0	1.0	µg/L	----	<1.0	----	----	----
4-Chloro-3-methylphenol	59-50-7	1.0	µg/L	----	<1.0	----	----	----
2.4.6-Trichlorophenol	88-06-2	1.0	µg/L	----	<1.0	----	----	----
2.4.5-Trichlorophenol	95-95-4	1.0	µg/L	----	<1.0	----	----	----
Pentachlorophenol	87-86-5	2.0	µg/L	----	<2.0	----	----	----
EP075(SIM)B: Polynuclear Aromatic Hydrocarbons								
Naphthalene	91-20-3	1.0	µg/L	----	<1.0	----	----	----
Acenaphthylene	208-96-8	1.0	µg/L	----	<1.0	----	----	----
Acenaphthene	83-32-9	1.0	µg/L	----	<1.0	----	----	----
Fluorene	86-73-7	1.0	µg/L	----	<1.0	----	----	----
Phenanthrene	85-01-8	1.0	µg/L	----	<1.0	----	----	----
Anthracene	120-12-7	1.0	µg/L	----	<1.0	----	----	----
Fluoranthene	206-44-0	1.0	µg/L	----	<1.0	----	----	----
Pyrene	129-00-0	1.0	µg/L	----	<1.0	----	----	----
Benz(a)anthracene	56-55-3	1.0	µg/L	----	<1.0	----	----	----
Chrysene	218-01-9	1.0	µg/L	----	<1.0	----	----	----

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Client sample ID	MW1	MW5	----	----	----
			Client sampling date / time	12-FEB-2015 13:10	11-FEB-2015 15:00	----	----	----
Compound	CAS Number	LOR	Unit	ES1503501-006	ES1503501-007	----	----	----
EP075(SIM)B: Polynuclear Aromatic Hydrocarbons - Continued								
Benzo(b+j)fluoranthene	205-99-2 205-82-3	1.0	µg/L	----	<1.0	----	----	----
Benzo(k)fluoranthene	207-08-9	1.0	µg/L	----	<1.0	----	----	----
Benzo(a)pyrene	50-32-8	0.5	µg/L	----	<0.5	----	----	----
Indeno(1.2.3.cd)pyrene	193-39-5	1.0	µg/L	----	<1.0	----	----	----
Dibenz(a.h)anthracene	53-70-3	1.0	µg/L	----	<1.0	----	----	----
Benzo(g.h.i)perylene	191-24-2	1.0	µg/L	----	<1.0	----	----	----
^ Sum of polycyclic aromatic hydrocarbons	----	0.5	µg/L	----	<0.5	----	----	----
^ Benzo(a)pyrene TEQ (zero)	----	0.5	µg/L	----	<0.5	----	----	----
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	20	µg/L	----	<20	----	----	----
C10 - C14 Fraction	----	50	µg/L	----	<50	----	----	----
C15 - C28 Fraction	----	100	µg/L	----	<100	----	----	----
C29 - C36 Fraction	----	50	µg/L	----	<50	----	----	----
^ C10 - C36 Fraction (sum)	----	50	µg/L	----	<50	----	----	----
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
C6 - C10 Fraction	C6_C10	20	µg/L	----	<20	----	----	----
^ C6 - C10 Fraction minus BTEX (F1)	C6_C10-BTEX	20	µg/L	----	<20	----	----	----
>C10 - C16 Fraction	>C10_C16	100	µg/L	----	<100	----	----	----
>C16 - C34 Fraction	----	100	µg/L	----	<100	----	----	----
>C34 - C40 Fraction	----	100	µg/L	----	<100	----	----	----
^ >C10 - C40 Fraction (sum)	----	100	µg/L	----	<100	----	----	----
^ >C10 - C16 Fraction minus Naphthalene (F2)	----	100	µg/L	----	<100	----	----	----
EP080: BTEXN								
Benzene	71-43-2	1	µg/L	----	<1	----	----	----
Toluene	108-88-3	2	µg/L	----	<2	----	----	----
Ethylbenzene	100-41-4	2	µg/L	----	<2	----	----	----
meta- & para-Xylene	108-38-3 106-42-3	2	µg/L	----	<2	----	----	----
ortho-Xylene	95-47-6	2	µg/L	----	<2	----	----	----
^ Total Xylenes	1330-20-7	2	µg/L	----	<2	----	----	----
^ Sum of BTEX	----	1	µg/L	----	<1	----	----	----
Naphthalene	91-20-3	5	µg/L	----	<5	----	----	----
EP075(SIM)S: Phenolic Compound Surrogates								

Analytical Results

Sub-Matrix: **WATER** (Matrix: **WATER**)			*Client sample ID*	**MW1**	**MW5**	----	----	----
			Client sampling date / time	12-FEB-2015 13:10	11-FEB-2015 15:00	----	----	----
Compound	*CAS Number*	*LOR*	*Unit*	**ES1503501-006**	**ES1503501-007**	----	----	----
EP075(SIM)S: Phenolic Compound Surrogates - Continued								
Phenol-d6	13127-88-3	0.1	%	----	**37.6**	----	----	----
2-Chlorophenol-D4	93951-73-6	0.1	%	----	**67.6**	----	----	----
2.4.6-Tribromophenol	118-79-6	0.1	%	----	**64.5**	----	----	----
EP075(SIM)T: PAH Surrogates								
2-Fluorobiphenyl	321-60-8	0.1	%	----	**78.4**	----	----	----
Anthracene-d10	1719-06-8	0.1	%	----	**78.2**	----	----	----
4-Terphenyl-d14	1718-51-0	0.1	%	----	**77.2**	----	----	----
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.1	%	----	**94.5**	----	----	----
Toluene-D8	2037-26-5	0.1	%	----	**98.1**	----	----	----
4-Bromofluorobenzene	460-00-4	0.1	%	----	**89.2**	----	----	----

Surrogate Control Limits

Sub-Matrix: **WATER**

Compound	*CAS Number*	*Recovery Limits (%)* Low	High
EP075(SIM)S: Phenolic Compound Surrogates			
Phenol-d6	13127-88-3	10.0	44
2-Chlorophenol-D4	93951-73-6	14	94
2.4.6-Tribromophenol	118-79-6	17	125
EP075(SIM)T: PAH Surrogates			
2-Fluorobiphenyl	321-60-8	20	104
Anthracene-d10	1719-06-8	27.4	113
4-Terphenyl-d14	1718-51-0	32	112
EP080S: TPH(V)/BTEX Surrogates			
1.2-Dichloroethane-D4	17060-07-0	71	137
Toluene-D8	2037-26-5	79	131
4-Bromofluorobenzene	460-00-4	70	128

ALS Environmental

QUALITY CONTROL REPORT

Work Order	: **ES1503501**	Page	: 1 of 13
Client	: **AUST GROUNDWATER & ENVIRO CONSULTANTS**	Laboratory	: Environmental Division Sydney
Contact	: MR PAVEL DVORACEK	Contact	: Client Services
Address	: Harbour Pier, Shop 8, 21 Merewether Street, NEWCASTLE NSW 2300	Address	: 277-289 Woodpark Road Smithfield NSW Australia 2164
E-mail	: pavel.dvoracek@ageconsultants.com.au	E-mail	: sydney@alsglobal.com
Telephone	: +61 02 4926 2811	Telephone	: +61-2-8784 8555
Facsimile	: +61 02 4926 2611	Facsimile	: +61-2-8784 8500
Project	: G1714 MARULAN LIMESTONE	QC Level	: NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Site	: ----		
C-O-C number	: ----	Date Samples Received	: 16-FEB-2015
Sampler	: PD	Issue Date	: 24-FEB-2015
Order number	: ----		
		No. of samples received	: 7
Quote number	: BNBQ/011/14	No. of samples analysed	: 7

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. All pages of this report have been checked and approved for release.

This Quality Control Report contains the following information:

- Laboratory Duplicate (DUP) Report; Relative Percentage Difference (RPD) and Acceptance Limits
- Method Blank (MB) and Laboratory Control Spike (LCS) Report; Recovery and Acceptance Limits
- Matrix Spike (MS) Report; Recovery and Acceptance Limits

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

Key :
Anonymous = Refers to samples which are not specifically part of this work order but formed part of the QC process lot
CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
RPD = Relative Percentage Difference
# = Indicates failed QC

NATA Accredited Laboratory 825

Accredited for compliance with ISO/IEC 17025.

WORLD RECOGNISED ACCREDITATION

Signatories

This document has been electronically signed by the authorized signatories indicated below. Electronic signing has been carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Ankit Joshi	Inorganic Chemist	Sydney Inorganics
Ashesh Patel	Inorganic Chemist	Sydney Inorganics
Pabi Subba	Senior Organic Chemist	Sydney Organics
Shobhna Chandra	Metals Coordinator	Sydney Inorganics
Wisam Marassa	Inorganics Coordinator	Sydney Inorganics

Laboratory Duplicate (DUP) Report

The quality control term Laboratory Duplicate refers to a randomly selected intralaboratory split. Laboratory duplicates provide information regarding method precision and sample heterogeneity. The permitted ranges for the Relative Percent Deviation (RPD) of Laboratory Duplicates are specified in ALS Method QWI-EN/38 and are dependent on the magnitude of results in comparison to the level of reporting: Result < 10 times LOR: No Limit; Result between 10 and 20 times LOR: 0% - 50%; Result > 20 times LOR: 0% - 20%.

Sub-Matrix: **WATER**

				Laboratory Duplicate (DUP) Report					
Laboratory sample ID	Client sample ID	Method: Compound	CAS Number	LOR	Unit	Original Result	Duplicate Result	RPD (%)	Recovery Limits (%)
EA005P: pH by PC Titrator (QC Lot: 3827219)									
ES1503501-001	SEEP	EA005-P: pH Value	----	0.01	pH Unit	7.80	7.81	0.1	0% - 20%
ES1503501-003	WP16	EA005-P: pH Value	----	0.01	pH Unit	7.58	7.59	0.1	0% - 20%
EA010P: Conductivity by PC Titrator (QC Lot: 3827220)									
ES1503501-001	SEEP	EA010-P: Electrical Conductivity @ 25°C	----	1	µS/cm	665	666	0.2	0% - 20%
ES1503501-003	WP16	EA010-P: Electrical Conductivity @ 25°C	----	1	µS/cm	1010	890	12.4	0% - 20%
ED009: Anions (QC Lot: 3828250)									
ES1503501-001	SEEP	ED009-X: Bromide	24959-67-9	0.010	mg/L	0.131	0.119	9.6	0% - 50%
ES1503770-003	Anonymous	ED009-X: Bromide	24959-67-9	0.010	mg/L	0.427	0.412	3.6	0% - 20%
ED037P: Alkalinity by PC Titrator (QC Lot: 3827218)									
ES1503501-001	SEEP	ED037-P: Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	0.0	No Limit
		ED037-P: Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	0.0	No Limit
		ED037-P: Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	199	200	0.6	0% - 20%
		ED037-P: Total Alkalinity as CaCO3	----	1	mg/L	199	200	0.6	0% - 20%
ES1503501-003	WP16	ED037-P: Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	0.0	No Limit
		ED037-P: Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	0.0	No Limit
		ED037-P: Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	324	326	0.7	0% - 20%
		ED037-P: Total Alkalinity as CaCO3	----	1	mg/L	324	326	0.7	0% - 20%
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA (QC Lot: 3826443)									
ES1503340-001	Anonymous	ED041G: Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	14	14	0.0	0% - 50%
ES1503501-004	SPRING	ED041G: Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	26	26	0.0	0% - 20%
ED045G: Chloride Discrete analyser (QC Lot: 3826442)									
ES1503340-001	Anonymous	ED045G: Chloride	16887-00-6	1	mg/L	126	123	2.9	0% - 20%
ES1503501-004	SPRING	ED045G: Chloride	16887-00-6	1	mg/L	81	80	0.0	0% - 20%
ED093F: Dissolved Major Cations (QC Lot: 3827901)									
ES1503501-006	MW1	ED093F: Calcium	7440-70-2	1	mg/L	112	116	3.3	0% - 20%
		ED093F: Magnesium	7439-95-4	1	mg/L	41	41	0.0	0% - 20%
		ED093F: Sodium	7440-23-5	1	mg/L	27	26	4.2	0% - 20%
		ED093F: Potassium	7440-09-7	1	mg/L	10	11	9.6	0% - 50%
EG020F: Dissolved Metals by ICP-MS (QC Lot: 3827899)									
ES1503480-001	Anonymous	EG020A-F: Cadmium	7440-43-9	0.0001	mg/L	0.0008	0.0008	0.0	No Limit
		EG020A-F: Arsenic	7440-38-2	0.001	mg/L	0.007	0.010	24.5	No Limit
		EG020A-F: Beryllium	7440-41-7	0.001	mg/L	<0.001	<0.001	0.0	No Limit
		EG020A-F: Barium	7440-39-3	0.001	mg/L	<0.001	<0.001	0.0	No Limit
		EG020A-F: Chromium	7440-47-3	0.001	mg/L	<0.001	<0.001	0.0	No Limit
		EG020A-F: Cobalt	7440-48-4	0.001	mg/L	<0.001	<0.001	0.0	No Limit

Sub-Matrix: **WATER**

Laboratory sample ID	Client sample ID	Method: Compound	CAS Number	LOR	Unit	Original Result	Duplicate Result	RPD (%)	Recovery Limits (%)
				Laboratory Duplicate (DUP) Report					
EG020F: Dissolved Metals by ICP-MS (QC Lot: 3827899) - continued									
ES1503480-001	Anonymous	EG020A-F: Copper	7440-50-8	0.001	mg/L	0.008	0.009	0.0	No Limit
		EG020A-F: Lead	7439-92-1	0.001	mg/L	<0.001	<0.001	0.0	No Limit
		EG020A-F: Manganese	7439-96-5	0.001	mg/L	0.179	0.174	2.6	0% - 20%
		EG020A-F: Molybdenum	7439-98-7	0.001	mg/L	0.041	0.042	0.0	0% - 20%
		EG020A-F: Nickel	7440-02-0	0.001	mg/L	0.016	0.018	16.2	0% - 50%
		EG020A-F: Zinc	7440-66-6	0.005	mg/L	0.102	0.115	11.6	0% - 20%
		EG020A-F: Aluminium	7429-90-5	0.01	mg/L	<0.01	<0.01	0.0	No Limit
		EG020A-F: Selenium	7782-49-2	0.01	mg/L	<0.01	<0.01	0.0	No Limit
		EG020A-F: Vanadium	7440-62-2	0.01	mg/L	<0.01	<0.01	0.0	No Limit
		EG020A-F: Boron	7440-42-8	0.05	mg/L	<0.05	<0.05	0.0	No Limit
		EG020A-F: Iron	7439-89-6	0.05	mg/L	<0.05	<0.05	0.0	No Limit
ES1503501-006	MW1	EG020A-F: Cadmium	7440-43-9	0.0001	mg/L	0.0002	0.0002	0.0	No Limit
		EG020A-F: Arsenic	7440-38-2	0.001	mg/L	<0.001	<0.001	0.0	No Limit
		EG020A-F: Beryllium	7440-41-7	0.001	mg/L	<0.001	<0.001	0.0	No Limit
		EG020A-F: Barium	7440-39-3	0.001	mg/L	0.059	0.058	0.0	0% - 20%
		EG020A-F: Chromium	7440-47-3	0.001	mg/L	<0.001	<0.001	0.0	No Limit
		EG020A-F: Cobalt	7440-48-4	0.001	mg/L	<0.001	<0.001	0.0	No Limit
		EG020A-F: Copper	7440-50-8	0.001	mg/L	0.003	0.004	0.0	No Limit
		EG020A-F: Lead	7439-92-1	0.001	mg/L	<0.001	<0.001	0.0	No Limit
		EG020A-F: Manganese	7439-96-5	0.001	mg/L	0.037	0.036	0.0	0% - 20%
		EG020A-F: Molybdenum	7439-98-7	0.001	mg/L	0.002	0.001	0.0	No Limit
		EG020A-F: Nickel	7440-02-0	0.001	mg/L	0.010	0.011	0.0	0% - 50%
		EG020A-F: Zinc	7440-66-6	0.005	mg/L	0.018	0.024	28.0	No Limit
		EG020A-F: Aluminium	7429-90-5	0.01	mg/L	<0.01	<0.01	0.0	No Limit
		EG020A-F: Selenium	7782-49-2	0.01	mg/L	<0.01	<0.01	0.0	No Limit
		EG020A-F: Vanadium	7440-62-2	0.01	mg/L	<0.01	<0.01	0.0	No Limit
		EG020A-F: Boron	7440-42-8	0.05	mg/L	<0.05	<0.05	0.0	No Limit
		EG020A-F: Iron	7439-89-6	0.05	mg/L	<0.05	<0.05	0.0	No Limit
EG020F: Dissolved Metals by ICP-MS (QC Lot: 3827902)									
ES1503501-006	MW1	EG020B-F: Strontium	7440-24-6	0.001	mg/L	0.262	0.261	0.0	0% - 20%
EG020T: Total Metals by ICP-MS (QC Lot: 3827906)									
ES1503480-001	Anonymous	EG020A-T: Cadmium	7440-43-9	0.0001	mg/L	0.0009	0.0009	0.0	No Limit
		EG020A-T: Arsenic	7440-38-2	0.001	mg/L	0.009	0.009	0.0	No Limit
		EG020A-T: Beryllium	7440-41-7	0.001	mg/L	<0.001	<0.001	0.0	No Limit
		EG020A-T: Barium	7440-39-3	0.001	mg/L	0.006	0.005	0.0	No Limit
		EG020A-T: Chromium	7440-47-3	0.001	mg/L	0.003	0.003	0.0	No Limit
		EG020A-T: Cobalt	7440-48-4	0.001	mg/L	0.001	0.002	0.0	No Limit
		EG020A-T: Copper	7440-50-8	0.001	mg/L	0.014	0.015	0.0	0% - 50%
		EG020A-T: Lead	7439-92-1	0.001	mg/L	0.002	0.002	0.0	No Limit
		EG020A-T: Manganese	7439-96-5	0.001	mg/L	0.204	0.209	2.3	0% - 20%

Sub-Matrix: **WATER**

Laboratory sample ID	Client sample ID	Method: Compound	CAS Number	LOR	Unit	Original Result	Duplicate Result	RPD (%)	Recovery Limits (%)
				Laboratory Duplicate (DUP) Report					
EG020T: Total Metals by ICP-MS (QC Lot: 3827906) - continued									
ES1503480-001	Anonymous	EG020A-T: Molybdenum	7439-98-7	0.001	mg/L	0.041	0.042	4.4	0% - 20%
		EG020A-T: Nickel	7440-02-0	0.001	mg/L	0.014	0.014	0.0	0% - 50%
		EG020A-T: Zinc	7440-66-6	0.005	mg/L	0.214	0.223	4.3	0% - 20%
		EG020A-T: Aluminium	7429-90-5	0.01	mg/L	0.36	0.36	0.0	0% - 20%
		EG020A-T: Selenium	7782-49-2	0.01	mg/L	<0.01	<0.01	0.0	No Limit
		EG020A-T: Vanadium	7440-62-2	0.01	mg/L	<0.01	<0.01	0.0	No Limit
		EG020A-T: Boron	7440-42-8	0.05	mg/L	<0.05	<0.05	0.0	No Limit
		EG020A-T: Iron	7439-89-6	0.05	mg/L	0.57	0.48	15.9	0% - 50%
ES1503501-006	MW1	EG020A-T: Cadmium	7440-43-9	0.0001	mg/L	0.0002	0.0003	47.1	No Limit
		EG020A-T: Arsenic	7440-38-2	0.001	mg/L	0.002	0.002	0.0	No Limit
		EG020A-T: Beryllium	7440-41-7	0.001	mg/L	<0.001	<0.001	0.0	No Limit
		EG020A-T: Barium	7440-39-3	0.001	mg/L	0.067	0.079	16.5	0% - 20%
		EG020A-T: Chromium	7440-47-3	0.001	mg/L	0.015	0.016	8.2	0% - 50%
		EG020A-T: Cobalt	7440-48-4	0.001	mg/L	0.004	0.002	63.9	No Limit
		EG020A-T: Copper	7440-50-8	0.001	mg/L	0.015	0.010	41.3	0% - 50%
		EG020A-T: Lead	7439-92-1	0.001	mg/L	0.003	0.005	48.5	No Limit
		EG020A-T: Manganese	7439-96-5	0.001	mg/L	0.106	0.122	14.2	0% - 20%
		EG020A-T: Molybdenum	7439-98-7	0.001	mg/L	0.002	0.003	0.0	No Limit
		EG020A-T: Nickel	7440-02-0	0.001	mg/L	0.019	0.017	11.8	0% - 50%
		EG020A-T: Zinc	7440-66-6	0.005	mg/L	0.046	0.054	14.1	0% - 50%
		EG020A-T: Aluminium	7429-90-5	0.01	mg/L	0.52	0.52	0.0	0% - 20%
		EG020A-T: Selenium	7782-49-2	0.01	mg/L	<0.01	<0.01	0.0	No Limit
		EG020A-T: Vanadium	7440-62-2	0.01	mg/L	<0.01	<0.01	0.0	No Limit
		EG020A-T: Boron	7440-42-8	0.05	mg/L	<0.05	<0.05	0.0	No Limit
		EG020A-T: Iron	7439-89-6	0.05	mg/L	5.16	4.82	6.9	0% - 20%
EG020T: Total Metals by ICP-MS (QC Lot: 3827907)									
ES1503501-006	MW1	EG020B-T: Strontium	7440-24-6	0.001	mg/L	0.246	0.253	2.9	0% - 20%
EG035F: Dissolved Mercury by FIMS (QC Lot: 3827900)									
ES1503501-002	MAIN GULLY SP(MGSP)	EG035F: Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	0.0	No Limit
ES1503636-001	Anonymous	EG035F: Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	0.0	No Limit
EG035T: Total Recoverable Mercury by FIMS (QC Lot: 3831394)									
ES1503240-020	Anonymous	EG035T: Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	0.0	No Limit
ES1503646-001	Anonymous	EG035T: Mercury	7439-97-6	0.0001	mg/L	<0.0001	0.0001	0.0	No Limit
EK040P: Fluoride by PC Titrator (QC Lot: 3827221)									
ES1503501-001	SEEP	EK040P: Fluoride	16984-48-8	0.1	mg/L	0.2	0.2	0.0	No Limit
ES1503501-003	WP16	EK040P: Fluoride	16984-48-8	0.1	mg/L	0.2	0.2	0.0	No Limit
EP080/071: Total Petroleum Hydrocarbons (QC Lot: 3829767)									
ES1503618-003	Anonymous	EP080: C6 - C9 Fraction	----	20	µg/L	100	<20	132	No Limit
ES1503628-005	Anonymous	EP080: C6 - C9 Fraction	----	20	µg/L	110	110	0.0	No Limit

Sub-Matrix: **WATER**

Laboratory sample ID	Client sample ID	Method: Compound	CAS Number	Laboratory Duplicate (DUP) Report LOR	Unit	Original Result	Duplicate Result	RPD (%)	Recovery Limits (%)
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions (QC Lot: 3829767)									
ES1503618-003	Anonymous	EP080: C6 - C10 Fraction	C6_C10	20	µg/L	110	<20	137	No Limit
ES1503628-005	Anonymous	EP080: C6 - C10 Fraction	C6_C10	20	µg/L	130	130	0.0	No Limit
EP080: BTEXN (QC Lot: 3829767)									
ES1503618-003	Anonymous	EP080: Benzene	71-43-2	1	µg/L	<1	<1	0.0	No Limit
		EP080: Toluene	108-88-3	2	µg/L	<2	<2	0.0	No Limit
		EP080: Ethylbenzene	100-41-4	2	µg/L	<2	<2	0.0	No Limit
		EP080: meta- & para-Xylene	108-38-3 106-42-3	2	µg/L	<2	<2	0.0	No Limit
		EP080: ortho-Xylene	95-47-6	2	µg/L	<2	<2	0.0	No Limit
		EP080: Naphthalene	91-20-3	5	µg/L	<5	<5	0.0	No Limit
ES1503628-005	Anonymous	EP080: Benzene	71-43-2	1	µg/L	2	2	0.0	No Limit
		EP080: Toluene	108-88-3	2	µg/L	<2	<2	0.0	No Limit
		EP080: Ethylbenzene	100-41-4	2	µg/L	<2	<2	0.0	No Limit
		EP080: meta- & para-Xylene	108-38-3 106-42-3	2	µg/L	8	8	0.0	No Limit
		EP080: ortho-Xylene	95-47-6	2	µg/L	44	43	3.3	0% - 20%
		EP080: Naphthalene	91-20-3	5	µg/L	<5	<5	0.0	No Limit

Method Blank (MB) and Laboratory Control Spike (LCS) Report

The quality control term Method / Laboratory Blank refers to an analyte free matrix to which all reagents are added in the same volumes or proportions as used in standard sample preparation. The purpose of this QC parameter is to monitor potential laboratory contamination. The quality control term Laboratory Control Spike (LCS) refers to a certified reference material, or a known interference free matrix spiked with target analytes. The purpose of this QC parameter is to monitor method precision and accuracy independent of sample matrix. Dynamic Recovery Limits are based on statistical evaluation of processed LCS.

Sub-Matrix: **WATER**

				Method Blank (MB) Report	Laboratory Control Spike (LCS) Report			
					Spike	Spike Recovery (%)	Recovery Limits (%)	
Method: Compound	CAS Number	LOR	Unit	Result	Concentration	LCS	Low	High
EA010P: Conductivity by PC Titrator (QCLot: 3827220)								
EA010-P: Electrical Conductivity @ 25°C	----	1	µS/cm	<1	2000 µS/cm	105	95	113
ED009: Anions (QCLot: 3828250)								
ED009-X: Bromide	24959-67-9	0.01	mg/L	<0.010	2 mg/L	106	93	109
ED037P: Alkalinity by PC Titrator (QCLot: 3827218)								
ED037-P: Total Alkalinity as CaCO3	----	1	mg/L	----	200 mg/L	95.6	81	111
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA (QCLot: 3826443)								
ED041G: Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	<1	25 mg/L	98.1	86	122
ED045G: Chloride Discrete analyser (QCLot: 3826442)								
ED045G: Chloride	16887-00-6	1	mg/L	<1	10 mg/L	107	75	123
				----	1000 mg/L	105	77	119
ED093F: Dissolved Major Cations (QCLot: 3827901)								
ED093F: Calcium	7440-70-2	1	mg/L	<1	50 mg/L	99.2	90	114
ED093F: Magnesium	7439-95-4	1	mg/L	<1	50 mg/L	94.4	90	110
ED093F: Sodium	7440-23-5	1	mg/L	<1	50 mg/L	87.2	82	118
ED093F: Potassium	7440-09-7	1	mg/L	<1	50 mg/L	95.5	87	117
EG020F: Dissolved Metals by ICP-MS (QCLot: 3827899)								
EG020A-F: Aluminium	7429-90-5	0.01	mg/L	<0.01	0.5 mg/L	94.2	85	115
EG020A-F: Arsenic	7440-38-2	0.001	mg/L	<0.001	0.1 mg/L	90.7	85	115
EG020A-F: Beryllium	7440-41-7	0.001	mg/L	<0.001	0.1 mg/L	95.4	85	115
EG020A-F: Barium	7440-39-3	0.001	mg/L	<0.001	0.1 mg/L	103	85	115
EG020A-F: Cadmium	7440-43-9	0.0001	mg/L	<0.0001	0.1 mg/L	102	85	115
EG020A-F: Chromium	7440-47-3	0.001	mg/L	<0.001	0.1 mg/L	100	85	115
EG020A-F: Cobalt	7440-48-4	0.001	mg/L	<0.001	0.1 mg/L	101	85	115
EG020A-F: Copper	7440-50-8	0.001	mg/L	<0.001	0.1 mg/L	94.8	85	115
EG020A-F: Lead	7439-92-1	0.001	mg/L	<0.001	0.1 mg/L	94.8	85	115
EG020A-F: Manganese	7439-96-5	0.001	mg/L	<0.001	0.1 mg/L	86.0	85	115
EG020A-F: Molybdenum	7439-98-7	0.001	mg/L	<0.001	0.1 mg/L	102	85	115
EG020A-F: Nickel	7440-02-0	0.001	mg/L	<0.001	0.1 mg/L	101	85	115
EG020A-F: Selenium	7782-49-2	0.01	mg/L	<0.01	0.1 mg/L	91.9	85	115
EG020A-F: Vanadium	7440-62-2	0.01	mg/L	<0.01	0.1 mg/L	97.3	85	115
EG020A-F: Zinc	7440-66-6	0.005	mg/L	<0.005	0.1 mg/L	95.9	85	115
EG020A-F: Boron	7440-42-8	0.05	mg/L	<0.05	0.1 mg/L	100	85	115

Sub-Matrix: **WATER**

				Method Blank (MB) Report	Laboratory Control Spike (LCS) Report			
					Spike	Spike Recovery (%)	Recovery Limits (%)	
Method: Compound	CAS Number	LOR	Unit	Result	Concentration	LCS	Low	High
EG020F: Dissolved Metals by ICP-MS (QCLot: 3827899) - continued								
EG020A-F: Iron	7439-89-6	0.05	mg/L	<0.05	0.5 mg/L	96.7	85	115
EG020F: Dissolved Metals by ICP-MS (QCLot: 3827902)								
EG020B-F: Strontium	7440-24-6	0.001	mg/L	<0.001	0.1 mg/L	107	80	112
EG020T: Total Metals by ICP-MS (QCLot: 3827906)								
EG020A-T: Aluminium	7429-90-5	0.01	mg/L	<0.01	0.5 mg/L	98.9	81	121
EG020A-T: Arsenic	7440-38-2	0.001	mg/L	<0.001	0.1 mg/L	89.6	79	121
EG020A-T: Beryllium	7440-41-7	0.001	mg/L	<0.001	0.1 mg/L	93.9	79	119
EG020A-T: Barium	7440-39-3	0.001	mg/L	<0.001	0.1 mg/L	94.8	84	116
EG020A-T: Cadmium	7440-43-9	0.0001	mg/L	<0.0001	0.1 mg/L	100	83	113
EG020A-T: Chromium	7440-47-3	0.001	mg/L	<0.001	0.1 mg/L	90.9	84	116
EG020A-T: Cobalt	7440-48-4	0.001	mg/L	<0.001	0.1 mg/L	94.6	84	116
EG020A-T: Copper	7440-50-8	0.001	mg/L	<0.001	0.1 mg/L	91.9	83	117
EG020A-T: Lead	7439-92-1	0.001	mg/L	<0.001	0.1 mg/L	97.9	84	116
EG020A-T: Manganese	7439-96-5	0.001	mg/L	<0.001	0.1 mg/L	95.6	85	115
EG020A-T: Molybdenum	7439-98-7	0.001	mg/L	<0.001	0.1 mg/L	104	84	124
EG020A-T: Nickel	7440-02-0	0.001	mg/L	<0.001	0.1 mg/L	92.1	84	116
EG020A-T: Selenium	7782-49-2	0.01	mg/L	<0.01	0.1 mg/L	110	68	128
EG020A-T: Vanadium	7440-62-2	0.01	mg/L	<0.01	0.1 mg/L	90.0	84	114
EG020A-T: Zinc	7440-66-6	0.005	mg/L	<0.005	0.1 mg/L	90.0	77	117
EG020A-T: Boron	7440-42-8	0.05	mg/L	<0.05	0.1 mg/L	106	75	129
EG020A-T: Iron	7439-89-6	0.05	mg/L	<0.05	0.5 mg/L	92.8	82	120
EG020T: Total Metals by ICP-MS (QCLot: 3827907)								
EG020B-T: Strontium	7440-24-6	0.001	mg/L	<0.001	0.1 mg/L	90.2	83	117
EG035F: Dissolved Mercury by FIMS (QCLot: 3827900)								
EG035F: Mercury	7439-97-6	0.0001	mg/L	<0.0001	0.010 mg/L	95.3	78	114
EG035T: Total Recoverable Mercury by FIMS (QCLot: 3831394)								
EG035T: Mercury	7439-97-6	0.0001	mg/L	<0.0001	0.010 mg/L	94.7	77	115
EK040P: Fluoride by PC Titrator (QCLot: 3827221)								
EK040P: Fluoride	16984-48-8	0.1	mg/L	<0.1	5.0 mg/L	104	75	119
EP075(SIM)A: Phenolic Compounds (QCLot: 3826347)								
EP075(SIM): Phenol	108-95-2	0.2	µg/L	<1.0	5 µg/L	48.1	24.5	61.9
EP075(SIM): 2-Chlorophenol	95-57-8	0.2	µg/L	<1.0	5 µg/L	72.4	63.8	110
EP075(SIM): 2-Methylphenol	95-48-7	0.2	µg/L	<1.0	5 µg/L	71.2	55.9	112
EP075(SIM): 3- & 4-Methylphenol	1319-77-3	0.4	µg/L	<2.0	10 µg/L	70.2	42.5	114
EP075(SIM): 2-Nitrophenol	88-75-5	0.2	µg/L	<1.0	5 µg/L	78.4	62.7	117
EP075(SIM): 2.4-Dimethylphenol	105-67-9	0.2	µg/L	<1.0	5 µg/L	68.8	59.9	112

Sub-Matrix: **WATER**

Method: Compound	CAS Number	LOR	Unit	Method Blank (MB) Report	Laboratory Control Spike (LCS) Report			
					Spike	Spike Recovery (%)	Recovery Limits (%)	
				Result	Concentration	LCS	Low	High
EP075(SIM)A: Phenolic Compounds (QCLot: 3826347) - continued								
EP075(SIM): 2.4-Dichlorophenol	120-83-2	0.2	µg/L	<1.0	5 µg/L	88.8	59.3	122
EP075(SIM): 2.6-Dichlorophenol	87-65-0	0.2	µg/L	<1.0	5 µg/L	86.0	64.3	118
EP075(SIM): 4-Chloro-3-Methylphenol	59-50-7	0.2	µg/L	<1.0	5 µg/L	86.1	63	119
EP075(SIM): 2.4.6-Trichlorophenol	88-06-2	0.2	µg/L	<1.0	5 µg/L	87.6	58.7	118
EP075(SIM): 2.4.5-Trichlorophenol	95-95-4	0.2	µg/L	<1.0	5 µg/L	81.8	50	108
EP075(SIM): Pentachlorophenol	87-86-5	0.4	µg/L	<2.0	10 µg/L	77.2	10	95
EP075(SIM)B: Polynuclear Aromatic Hydrocarbons (QCLot: 3826347)								
EP075(SIM): Naphthalene	91-20-3	0.2	µg/L	<1.0	5 µg/L	79.1	58.6	119
EP075(SIM): Acenaphthylene	208-96-8	0.2	µg/L	<1.0	5 µg/L	86.6	63.6	114
EP075(SIM): Acenaphthene	83-32-9	0.2	µg/L	<1.0	5 µg/L	78.6	62.2	113
EP075(SIM): Fluorene	86-73-7	0.2	µg/L	<1.0	5 µg/L	86.2	63.9	115
EP075(SIM): Phenanthrene	85-01-8	0.2	µg/L	<1.0	5 µg/L	94.1	62.6	116
EP075(SIM): Anthracene	120-12-7	0.2	µg/L	<1.0	5 µg/L	95.7	64.3	116
EP075(SIM): Fluoranthene	206-44-0	0.2	µg/L	<1.0	5 µg/L	98.8	63.6	118
EP075(SIM): Pyrene	129-00-0	0.2	µg/L	<1.0	5 µg/L	100	63.1	118
EP075(SIM): Benz(a)anthracene	56-55-3	0.2	µg/L	<1.0	5 µg/L	96.9	64.1	117
EP075(SIM): Chrysene	218-01-9	0.2	µg/L	<1.0	5 µg/L	106	62.5	116
EP075(SIM): Benzo(b+j)fluoranthene	205-99-2 205-82-3	0.2	µg/L	<1.0	5 µg/L	101	61.7	119
EP075(SIM): Benzo(k)fluoranthene	207-08-9	0.2	µg/L	<1.0	5 µg/L	93.1	61.7	117
EP075(SIM): Benzo(a)pyrene	50-32-8	0.2	µg/L	<0.5	5 µg/L	87.5	63.3	117
EP075(SIM): Indeno(1.2.3.cd)pyrene	193-39-5	0.2	µg/L	<1.0	5 µg/L	81.6	59.9	118
EP075(SIM): Dibenz(a.h)anthracene	53-70-3	0.2	µg/L	<1.0	5 µg/L	81.8	61.2	117
EP075(SIM): Benzo(g.h.i)perylene	191-24-2	0.2	µg/L	<1.0	5 µg/L	83.1	59.1	118
EP080/071: Total Petroleum Hydrocarbons (QCLot: 3826346)								
EP071: C10 - C14 Fraction	----	50	µg/L	<50	2000 µg/L	96.6	59	129
EP071: C15 - C28 Fraction	----	100	µg/L	<100	3000 µg/L	92.6	71	131
EP071: C29 - C36 Fraction	----	50	µg/L	<50	2000 µg/L	93.3	62	120
EP080/071: Total Petroleum Hydrocarbons (QCLot: 3829767)								
EP080: C6 - C9 Fraction	----	20	µg/L	<20	260 µg/L	87.7	75	127
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions (QCLot: 3826346)								
EP071: >C10 - C16 Fraction	>C10_C16	100	µg/L	<100	2500 µg/L	95.2	58.9	131
EP071: >C16 - C34 Fraction	----	100	µg/L	<100	3500 µg/L	94.1	73.9	138
EP071: >C34 - C40 Fraction	----	50	µg/L	<100	1500 µg/L	104	67	127
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions (QCLot: 3829767)								
EP080: C6 - C10 Fraction	C6_C10	20	µg/L	<20	310 µg/L	91.0	75	127

Sub-Matrix: **WATER**

Method: Compound	CAS Number	LOR	Unit	Method Blank (MB) Report Result	Laboratory Control Spike (LCS) Report Spike Concentration	Spike Recovery (%) LCS	Recovery Limits (%) Low	Recovery Limits (%) High
EP080: BTEXN (QCLot: 3829767)								
EP080: Benzene	71-43-2	1	µg/L	<1	10 µg/L	84.4	70	124
EP080: Toluene	108-88-3	2	µg/L	<2	10 µg/L	86.1	65	129
EP080: Ethylbenzene	100-41-4	2	µg/L	<2	10 µg/L	86.7	70	120
EP080: meta- & para-Xylene	108-38-3 106-42-3	2	µg/L	<2	10 µg/L	85.8	69	121
EP080: ortho-Xylene	95-47-6	2	µg/L	<2	10 µg/L	89.4	72	122
EP080: Naphthalene	91-20-3	5	µg/L	<5	10 µg/L	93.0	70	124

Matrix Spike (MS) Report

The quality control term Matrix Spike (MS) refers to an intralaboratory split sample spiked with a representative set of target analytes. The purpose of this QC parameter is to monitor potential matrix effects on analyte recoveries. Static Recovery Limits as per laboratory Data Quality Objectives (DQOs). Ideal recovery ranges stated may be waived in the event of sample matrix interference.

Sub-Matrix: **WATER**

Laboratory sample ID	Client sample ID	Method: Compound	CAS Number	Matrix Spike (MS) Report Spike Concentration	SpikeRecovery(%) MS	Recovery Limits (%) Low	Recovery Limits (%) High
ED009: Anions (QCLot: 3828250)							
ES1503501-001	SEEP	ED009-X: Bromide	24959-67-9	0.2 mg/L	93.0	70	130
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA (QCLot: 3826443)							
ES1503340-001	Anonymous	ED041G: Sulfate as SO4 - Turbidimetric	14808-79-8	10 mg/L	95.5	70	130
ED045G: Chloride Discrete analyser (QCLot: 3826442)							
ES1503340-001	Anonymous	ED045G: Chloride	16887-00-6	250 mg/L	102	70	130
EG020F: Dissolved Metals by ICP-MS (QCLot: 3827899)							
ES1503480-002	Anonymous	EG020A-F: Arsenic	7440-38-2	0.2 mg/L	99.4	70	130
		EG020A-F: Beryllium	7440-41-7	0.2 mg/L	106	70	130
		EG020A-F: Barium	7440-39-3	0.2 mg/L	126	70	130
		EG020A-F: Cadmium	7440-43-9	0.05 mg/L	113	70	130
		EG020A-F: Chromium	7440-47-3	0.2 mg/L	103	70	130
		EG020A-F: Cobalt	7440-48-4	0.2 mg/L	110	70	130
		EG020A-F: Copper	7440-50-8	0.2 mg/L	99.7	70	130
		EG020A-F: Lead	7439-92-1	0.2 mg/L	100	70	130
		EG020A-F: Manganese	7439-96-5	0.2 mg/L	114	70	130
		EG020A-F: Nickel	7440-02-0	0.2 mg/L	107	70	130
		EG020A-F: Vanadium	7440-62-2	0.2 mg/L	104	70	130
		EG020A-F: Zinc	7440-66-6	0.2 mg/L	106	70	130
EG020T: Total Metals by ICP-MS (QCLot: 3827906)							
ES1503480-002	Anonymous	EG020A-T: Arsenic	7440-38-2	1 mg/L	106	70	130

Sub-Matrix: **WATER**

Laboratory sample ID	Client sample ID	Method: Compound	CAS Number	Matrix Spike (MS) Report Spike Concentration	SpikeRecovery(%) MS	Recovery Limits (%) Low	Recovery Limits (%) High
EG020T: Total Metals by ICP-MS (QCLot: 3827906) - continued							
ES1503480-002	Anonymous	EG020A-T: Beryllium	7440-41-7	1 mg/L	104	70	130
		EG020A-T: Barium	7440-39-3	1 mg/L	103	70	130
		EG020A-T: Cadmium	7440-43-9	0.250 mg/L	95.8	70	130
		EG020A-T: Chromium	7440-47-3	1 mg/L	96.3	70	130
		EG020A-T: Cobalt	7440-48-4	1 mg/L	93.2	70	130
		EG020A-T: Copper	7440-50-8	1 mg/L	101	70	130
		EG020A-T: Lead	7439-92-1	1 mg/L	109	70	130
		EG020A-T: Manganese	7439-96-5	1 mg/L	123	70	130
		EG020A-T: Nickel	7440-02-0	1 mg/L	91.7	70	130
		EG020A-T: Vanadium	7440-62-2	1 mg/L	97.1	70	130
		EG020A-T: Zinc	7440-66-6	1 mg/L	102	70	130
EG035F: Dissolved Mercury by FIMS (QCLot: 3827900)							
ES1503501-001	SEEP	EG035F: Mercury	7439-97-6	0.0100 mg/L	85.5	70	130
EG035T: Total Recoverable Mercury by FIMS (QCLot: 3831394)							
ES1503408-001	Anonymous	EG035T: Mercury	7439-97-6	0.010 mg/L	86.7	70	130
EK040P: Fluoride by PC Titrator (QCLot: 3827221)							
ES1503501-001	SEEP	EK040P: Fluoride	16984-48-8	5.0 mg/L	106	70	130
EP080/071: Total Petroleum Hydrocarbons (QCLot: 3829767)							
ES1503618-003	Anonymous	EP080: C6 - C9 Fraction	----	325 µg/L	83.5	70	130
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions (QCLot: 3829767)							
ES1503618-003	Anonymous	EP080: C6 - C10 Fraction	C6_C10	375 µg/L	84.9	70	130
EP080: BTEXN (QCLot: 3829767)							
ES1503618-003	Anonymous	EP080: Benzene	71-43-2	25 µg/L	83.5	70	130
		EP080: Toluene	108-88-3	25 µg/L	86.7	70	130
		EP080: Ethylbenzene	100-41-4	25 µg/L	89.9	70	130
		EP080: meta- & para-Xylene	108-38-3 106-42-3	25 µg/L	87.8	70	130
		EP080: ortho-Xylene	95-47-6	25 µg/L	92.4	70	130
		EP080: Naphthalene	91-20-3	25 µg/L	101	70	130

Matrix Spike (MS) and Matrix Spike Duplicate (MSD) Report

The quality control term Matrix Spike (MS) and Matrix Spike Duplicate (MSD) refers to intralaboratory split samples spiked with a representative set of target analytes. The purpose of these QC parameters are to monitor potential matrix effects on analyte recoveries. Static Recovery Limits as per laboratory Data Quality Objectives (DQOs). Ideal recovery ranges stated may be waived in the event of sample matrix interference.

Sub-Matrix: **WATER**

Matrix Spike (MS) and Matrix Spike Duplicate (MSD) Report			
Spike	Spike Recovery (%)	Recovery Limits (%)	RPDs (%)

Sub-Matrix: **WATER**

				Matrix Spike (MS) and Matrix Spike Duplicate (MSD) Report						
				Spike	Spike Recovery (%)		Recovery Limits (%)		RPDs (%)	
Laboratory sample ID	Client sample ID	Method: Compound	CAS Number	Concentration	MS	MSD	Low	High	Value	Control Limit
ED045G: Chloride Discrete analyser (QCLot: 3826442)										
ES1503340-001	Anonymous	ED045G: Chloride	16887-00-6	250 mg/L	102	----	70	130	----	----
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA (QCLot: 3826443)										
ES1503340-001	Anonymous	ED041G: Sulfate as SO4 - Turbidimetric	14808-79-8	10 mg/L	95.5	----	70	130	----	----
EK040P: Fluoride by PC Titrator (QCLot: 3827221)										
ES1503501-001	SEEP	EK040P: Fluoride	16984-48-8	5.0 mg/L	106	----	70	130	----	----
EG020F: Dissolved Metals by ICP-MS (QCLot: 3827899)										
ES1503480-002	Anonymous	EG020A-F: Arsenic	7440-38-2	0.2 mg/L	99.4	----	70	130	----	----
		EG020A-F: Beryllium	7440-41-7	0.2 mg/L	106	----	70	130	----	----
		EG020A-F: Barium	7440-39-3	0.2 mg/L	126	----	70	130	----	----
		EG020A-F: Cadmium	7440-43-9	0.05 mg/L	113	----	70	130	----	----
		EG020A-F: Chromium	7440-47-3	0.2 mg/L	103	----	70	130	----	----
		EG020A-F: Cobalt	7440-48-4	0.2 mg/L	110	----	70	130	----	----
		EG020A-F: Copper	7440-50-8	0.2 mg/L	99.7	----	70	130	----	----
		EG020A-F: Lead	7439-92-1	0.2 mg/L	100	----	70	130	----	----
		EG020A-F: Manganese	7439-96-5	0.2 mg/L	114	----	70	130	----	----
		EG020A-F: Nickel	7440-02-0	0.2 mg/L	107	----	70	130	----	----
		EG020A-F: Vanadium	7440-62-2	0.2 mg/L	104	----	70	130	----	----
		EG020A-F: Zinc	7440-66-6	0.2 mg/L	106	----	70	130	----	----
EG035F: Dissolved Mercury by FIMS (QCLot: 3827900)										
ES1503501-001	SEEP	EG035F: Mercury	7439-97-6	0.0100 mg/L	85.5	----	70	130	----	----
EG020T: Total Metals by ICP-MS (QCLot: 3827906)										
ES1503480-002	Anonymous	EG020A-T: Arsenic	7440-38-2	1 mg/L	106	----	70	130	----	----
		EG020A-T: Beryllium	7440-41-7	1 mg/L	104	----	70	130	----	----
		EG020A-T: Barium	7440-39-3	1 mg/L	103	----	70	130	----	----
		EG020A-T: Cadmium	7440-43-9	0.250 mg/L	95.8	----	70	130	----	----
		EG020A-T: Chromium	7440-47-3	1 mg/L	96.3	----	70	130	----	----
		EG020A-T: Cobalt	7440-48-4	1 mg/L	93.2	----	70	130	----	----
		EG020A-T: Copper	7440-50-8	1 mg/L	101	----	70	130	----	----
		EG020A-T: Lead	7439-92-1	1 mg/L	109	----	70	130	----	----
		EG020A-T: Manganese	7439-96-5	1 mg/L	123	----	70	130	----	----
		EG020A-T: Nickel	7440-02-0	1 mg/L	91.7	----	70	130	----	----
		EG020A-T: Vanadium	7440-62-2	1 mg/L	97.1	----	70	130	----	----
		EG020A-T: Zinc	7440-66-6	1 mg/L	102	----	70	130	----	----
ED009: Anions (QCLot: 3828250)										

Sub-Matrix: **WATER**

Laboratory sample ID	Client sample ID	Method: Compound	CAS Number	Spike Concentration	Spike Recovery (%) MS	Spike Recovery (%) MSD	Recovery Limits (%) Low	Recovery Limits (%) High	RPDs (%) Value	RPDs (%) Control Limit
ED009: Anions (QCLot: 3828250) - continued										
ES1503501-001	SEEP	ED009-X: Bromide	24959-67-9	0.2 mg/L	93.0	----	70	130	----	----
EP080/071: Total Petroleum Hydrocarbons (QCLot: 3829767)										
ES1503618-003	Anonymous	EP080: C6 - C9 Fraction	----	325 µg/L	83.5	----	70	130	----	----
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions (QCLot: 3829767)										
ES1503618-003	Anonymous	EP080: C6 - C10 Fraction	C6_C10	375 µg/L	84.9	----	70	130	----	----
EP080: BTEXN (QCLot: 3829767)										
ES1503618-003	Anonymous	EP080: Benzene	71-43-2	25 µg/L	83.5	----	70	130	----	----
		EP080: Toluene	108-88-3	25 µg/L	86.7	----	70	130	----	----
		EP080: Ethylbenzene	100-41-4	25 µg/L	89.9	----	70	130	----	----
		EP080: meta- & para-Xylene	108-38-3 106-42-3	25 µg/L	87.8	----	70	130	----	----
		EP080: ortho-Xylene	95-47-6	25 µg/L	92.4	----	70	130	----	----
		EP080: Naphthalene	91-20-3	25 µg/L	101	----	70	130	----	----
EG035T: Total Recoverable Mercury by FIMS (QCLot: 3831394)										
ES1503408-001	Anonymous	EG035T: Mercury	7439-97-6	0.010 mg/L	86.7	----	70	130	----	----

ALS Environmental

INTERPRETIVE QUALITY CONTROL REPORT

Work Order	: **ES1503501**	Page	: 1 of 12
Client	: AUST GROUNDWATER & ENVIRO CONSULTANTS	Laboratory	: Environmental Division Sydney
Contact	: MR PAVEL DVORACEK	Contact	: Client Services
Address	: Harbour Pier, Shop 8, 21 Merewether Street, NEWCASTLE NSW 2300	Address	: 277-289 Woodpark Road Smithfield NSW Australia 2164
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Facsimile	: +61 02 4926 2611	Facsimile	: +61-2-8784 8500
Project	: G1714 MARULAN LIMESTONE	QC Level	: NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Site	: ----		
C-O-C number	: ----	Date Samples Received	: 16-FEB-2015
Sampler	: PD	Issue Date	: 24-FEB-2015
Order number	: ----		
		No. of samples received	: 7
Quote number	: BNBQ/011/14	No. of samples analysed	: 7

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. All pages of this report have been checked and approved for release.

This Interpretive Quality Control Report contains the following information:

- Analysis Holding Time Compliance
- Quality Control Parameter Frequency Compliance
- Brief Method Summaries
- Summary of Outliers

Analysis Holding Time Compliance

This report summarizes extraction / preparation and analysis times and compares each with recommended holding times (USEPA SW 846, APHA, AS and NEPM) based on the sample container provided. Dates reported represent first date of extraction or analysis and preclude subsequent dilutions and reruns. A listing of breaches (if any) is provided herein.

Holding time for leachate methods (e.g. TCLP) vary according to the analytes reported. Assessment compares the leach date with the shortest analyte holding time for the equivalent soil method. These are: organics 14 days, mercury 28 days & other metals 180 days. A recorded breach does not guarantee a breach for all non-volatile parameters.

Holding times for ***VOC in soils*** vary according to analytes of interest. Vinyl Chloride and Styrene holding time is 7 days; others 14 days. A recorded breach does not guarantee a breach for all VOC analytes and should be verified in case the reported breach is a false positive or Vinyl Chloride and Styrene are not key analytes of interest/concern.

Matrix: **WATER** Evaluation: ✘ = Holding time breach ; ✓ = Within holding time.

Method *Container / Client Sample ID(s)*		*Sample Date*	*Extraction / Preparation*			*Analysis*		
			Date extracted	*Due for extraction*	*Evaluation*	*Date analysed*	*Due for analysis*	*Evaluation*
EA005P: pH by PC Titrator								
Clear Plastic Bottle - Natural (EA005-P) SEEP,	MAIN GULLY SP(MGSP)	**10-FEB-2015**	---	10-FEB-2015	----	**17-FEB-2015**	10-FEB-2015	✘
Clear Plastic Bottle - Natural (EA005-P) WP16, MW2,	SPRING, MW5	**11-FEB-2015**	---	11-FEB-2015	----	**17-FEB-2015**	11-FEB-2015	✘
Clear Plastic Bottle - Natural (EA005-P) MW1		**12-FEB-2015**	---	12-FEB-2015	----	**17-FEB-2015**	12-FEB-2015	✘
EA010P: Conductivity by PC Titrator								
Clear Plastic Bottle - Natural (EA010-P) SEEP,	MAIN GULLY SP(MGSP)	**10-FEB-2015**	---	10-MAR-2015	----	**17-FEB-2015**	10-MAR-2015	✓
Clear Plastic Bottle - Natural (EA010-P) WP16, MW2,	SPRING, MW5	**11-FEB-2015**	---	11-MAR-2015	----	**17-FEB-2015**	11-MAR-2015	✓
Clear Plastic Bottle - Natural (EA010-P) MW1		**12-FEB-2015**	---	12-MAR-2015	----	**17-FEB-2015**	12-MAR-2015	✓
ED009: Anions								
Clear Plastic Bottle - Natural (ED009-X) SEEP,	MAIN GULLY SP(MGSP)	**10-FEB-2015**	----	----	----	**18-FEB-2015**	10-MAR-2015	✓
Clear Plastic Bottle - Natural (ED009-X) WP16, MW2,	SPRING, MW5	**11-FEB-2015**	----	----	----	**18-FEB-2015**	11-MAR-2015	✓
Clear Plastic Bottle - Natural (ED009-X) MW1		**12-FEB-2015**	----	----	----	**18-FEB-2015**	12-MAR-2015	✓
ED037P: Alkalinity by PC Titrator								
Clear Plastic Bottle - Natural (ED037-P) SEEP,	MAIN GULLY SP(MGSP)	**10-FEB-2015**	---	24-FEB-2015	----	**17-FEB-2015**	24-FEB-2015	✓
Clear Plastic Bottle - Natural (ED037-P) WP16, MW2,	SPRING, MW5	**11-FEB-2015**	---	25-FEB-2015	----	**17-FEB-2015**	25-FEB-2015	✓
Clear Plastic Bottle - Natural (ED037-P) MW1		**12-FEB-2015**	---	26-FEB-2015	----	**17-FEB-2015**	26-FEB-2015	✓

Matrix: **WATER**

Evaluation: ✗ = Holding time breach ; ✓ = Within holding time.

Method / *Container / Client Sample ID(s)*		*Sample Date*	*Extraction / Preparation*			*Analysis*		
			Date extracted	*Due for extraction*	*Evaluation*	***Date analysed***	*Due for analysis*	*Evaluation*
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA								
Clear Plastic Bottle - Natural (ED041G) SEEP,	MAIN GULLY SP(MGSP)	**10-FEB-2015**	---	10-MAR-2015	----	**17-FEB-2015**	10-MAR-2015	✓
Clear Plastic Bottle - Natural (ED041G) WP16, MW2,	SPRING, MW5	**11-FEB-2015**	---	11-MAR-2015	----	**17-FEB-2015**	11-MAR-2015	✓
Clear Plastic Bottle - Natural (ED041G) MW1		**12-FEB-2015**	---	12-MAR-2015	----	**17-FEB-2015**	12-MAR-2015	✓
ED045G: Chloride Discrete analyser								
Clear Plastic Bottle - Natural (ED045G) SEEP,	MAIN GULLY SP(MGSP)	**10-FEB-2015**	---	10-MAR-2015	----	**17-FEB-2015**	10-MAR-2015	✓
Clear Plastic Bottle - Natural (ED045G) WP16, MW2,	SPRING, MW5	**11-FEB-2015**	---	11-MAR-2015	----	**17-FEB-2015**	11-MAR-2015	✓
Clear Plastic Bottle - Natural (ED045G) MW1		**12-FEB-2015**	---	12-MAR-2015	----	**17-FEB-2015**	12-MAR-2015	✓
ED093F: Dissolved Major Cations								
Clear Plastic Bottle - Natural (ED093F) SEEP,	MAIN GULLY SP(MGSP)	**10-FEB-2015**	---	17-FEB-2015	----	**18-FEB-2015**	17-FEB-2015	✗
Clear Plastic Bottle - Nitric Acid; Filtered (ED093F) WP16, MW2,	SPRING, MW5	**11-FEB-2015**	---	11-MAR-2015	----	**18-FEB-2015**	11-MAR-2015	✓
Clear Plastic Bottle - Nitric Acid; Filtered (ED093F) MW1		**12-FEB-2015**	---	12-MAR-2015	----	**18-FEB-2015**	12-MAR-2015	✓
EA006: Sodium Adsorption Ratio (SAR)								
Clear Plastic Bottle - Natural (ED093F) SEEP,	MAIN GULLY SP(MGSP)	**10-FEB-2015**	---	17-FEB-2015	----	**18-FEB-2015**	17-FEB-2015	✗
Clear Plastic Bottle - Nitric Acid; Filtered (ED093F) WP16, MW2,	SPRING, MW5	**11-FEB-2015**	---	11-MAR-2015	----	**18-FEB-2015**	11-MAR-2015	✓
Clear Plastic Bottle - Nitric Acid; Filtered (ED093F) MW1		**12-FEB-2015**	---	12-MAR-2015	----	**18-FEB-2015**	12-MAR-2015	✓
EA065: Total Hardness as CaCO3								
Clear Plastic Bottle - Natural (ED093F) SEEP,	MAIN GULLY SP(MGSP)	**10-FEB-2015**	---	17-FEB-2015	----	**18-FEB-2015**	17-FEB-2015	✗
Clear Plastic Bottle - Nitric Acid; Filtered (ED093F) WP16, MW2,	SPRING, MW5	**11-FEB-2015**	---	11-MAR-2015	----	**18-FEB-2015**	11-MAR-2015	✓
Clear Plastic Bottle - Nitric Acid; Filtered (ED093F) MW1		**12-FEB-2015**	---	12-MAR-2015	----	**18-FEB-2015**	12-MAR-2015	✓

Matrix: **WATER**

Evaluation: × = Holding time breach ; ✓ = Within holding time.

Method	*Sample Date*	*Extraction / Preparation*			*Analysis*		
Container / Client Sample ID(s)		*Date extracted*	*Due for extraction*	*Evaluation*	*Date analysed*	*Due for analysis*	*Evaluation*
EG020F: Dissolved Metals by ICP-MS							
Clear Plastic Bottle - Natural (EG020A-F) SEEP	**10-FEB-2015**	---	09-AUG-2015	----	**18-FEB-2015**	09-AUG-2015	✓
Clear Plastic Bottle - Nitric Acid; Filtered (EG020A-F) WP16, SPRING, MW2, MW5	**11-FEB-2015**	---	10-AUG-2015	----	**18-FEB-2015**	10-AUG-2015	✓
Clear Plastic Bottle - Nitric Acid; Filtered (EG020A-F) MW1	**12-FEB-2015**	---	11-AUG-2015	----	**18-FEB-2015**	11-AUG-2015	✓
Clear Plastic Bottle - Nitric Acid; Unspecified (EG020A-F) MAIN GULLY SP(MGSP)	**10-FEB-2015**	---	09-AUG-2015	----	**18-FEB-2015**	09-AUG-2015	✓
EG020T: Total Metals by ICP-MS							
Clear Plastic Bottle - Natural (EG020A-T) WP16, SPRING, MW2, MW5	**11-FEB-2015**	**18-FEB-2015**	10-AUG-2015	✓	**18-FEB-2015**	10-AUG-2015	✓
Clear Plastic Bottle - Natural (EG020A-T) MW1	**12-FEB-2015**	**18-FEB-2015**	11-AUG-2015	✓	**18-FEB-2015**	11-AUG-2015	✓
Clear Plastic Bottle - Nitric Acid; Unfiltered (EG020A-T) SEEP	**10-FEB-2015**	**18-FEB-2015**	09-AUG-2015	✓	**18-FEB-2015**	09-AUG-2015	✓
Clear Plastic Bottle - Nitric Acid; Unspecified (EG020A-T) MAIN GULLY SP(MGSP)	**10-FEB-2015**	**18-FEB-2015**	09-AUG-2015	✓	**18-FEB-2015**	09-AUG-2015	✓
EG020F: Dissolved Metals by ICP-MS							
Clear Plastic Bottle - Natural (EG020B-F) SEEP, MAIN GULLY SP(MGSP)	**10-FEB-2015**	---	09-AUG-2015	----	**18-FEB-2015**	09-AUG-2015	✓
Clear Plastic Bottle - Nitric Acid; Filtered (EG020B-F) WP16, SPRING, MW2, MW5	**11-FEB-2015**	---	10-AUG-2015	----	**18-FEB-2015**	10-AUG-2015	✓
Clear Plastic Bottle - Nitric Acid; Filtered (EG020B-F) MW1	**12-FEB-2015**	---	11-AUG-2015	----	**18-FEB-2015**	11-AUG-2015	✓
EG020T: Total Metals by ICP-MS							
Clear Plastic Bottle - Natural (EG020B-T) WP16, SPRING, MW2, MW5	**11-FEB-2015**	**18-FEB-2015**	10-AUG-2015	✓	**18-FEB-2015**	10-AUG-2015	✓
Clear Plastic Bottle - Natural (EG020B-T) MW1	**12-FEB-2015**	**18-FEB-2015**	11-AUG-2015	✓	**18-FEB-2015**	11-AUG-2015	✓
Clear Plastic Bottle - Nitric Acid; Unfiltered (EG020B-T) SEEP	**10-FEB-2015**	**18-FEB-2015**	09-AUG-2015	✓	**18-FEB-2015**	09-AUG-2015	✓
Clear Plastic Bottle - Nitric Acid; Unspecified (EG020B-T) MAIN GULLY SP(MGSP)	**10-FEB-2015**	**18-FEB-2015**	09-AUG-2015	✓	**18-FEB-2015**	09-AUG-2015	✓

Matrix: **WATER**

Evaluation: × = Holding time breach ; ✓ = Within holding time.

Method / Container / Client Sample ID(s)		Sample Date	Extraction / Preparation			Analysis		
			Date extracted	Due for extraction	Evaluation	Date analysed	Due for analysis	Evaluation
EG035F: Dissolved Mercury by FIMS								
Clear Plastic Bottle - Natural (EG035F)								
SEEP,	MAIN GULLY SP(MGSP)	**10-FEB-2015**	---	10-MAR-2015	----	**20-FEB-2015**	10-MAR-2015	✓
Clear Plastic Bottle - Nitric Acid; Filtered (EG035F)								
WP16, MW2,	SPRING, MW5	**11-FEB-2015**	---	11-MAR-2015	----	**20-FEB-2015**	11-MAR-2015	✓
Clear Plastic Bottle - Nitric Acid; Filtered (EG035F)								
MW1		**12-FEB-2015**	---	12-MAR-2015	----	**20-FEB-2015**	12-MAR-2015	✓
EG035T: Total Recoverable Mercury by FIMS								
Clear Plastic Bottle - Natural (EG035T)								
WP16, MW2,	SPRING, MW5	**11-FEB-2015**	----	----	----	**23-FEB-2015**	11-MAR-2015	✓
Clear Plastic Bottle - Natural (EG035T)								
MW1		**12-FEB-2015**	----	----	----	**23-FEB-2015**	12-MAR-2015	✓
Clear Plastic Bottle - Nitric Acid; Unfiltered (EG035T)								
SEEP		**10-FEB-2015**	----	----	----	**23-FEB-2015**	10-MAR-2015	✓
Clear Plastic Bottle - Nitric Acid; Unspecified (EG035T)								
MAIN GULLY SP(MGSP)		**10-FEB-2015**	----	----	----	**23-FEB-2015**	10-MAR-2015	✓
EK040P: Fluoride by PC Titrator								
Clear Plastic Bottle - Natural (EK040P)								
SEEP,	MAIN GULLY SP(MGSP)	**10-FEB-2015**	---	10-MAR-2015	----	**17-FEB-2015**	10-MAR-2015	✓
Clear Plastic Bottle - Natural (EK040P)								
WP16, MW2,	SPRING, MW5	**11-FEB-2015**	---	11-MAR-2015	----	**17-FEB-2015**	11-MAR-2015	✓
Clear Plastic Bottle - Natural (EK040P)								
MW1		**12-FEB-2015**	---	12-MAR-2015	----	**17-FEB-2015**	12-MAR-2015	✓
EP080/071: Total Petroleum Hydrocarbons								
Amber Glass Bottle - Unpreserved (EP071)								
WP16,	MW5	**11-FEB-2015**	**18-FEB-2015**	18-FEB-2015	✓	**19-FEB-2015**	30-MAR-2015	✓
EP075(SIM)A: Phenolic Compounds								
Amber Glass Bottle - Unpreserved (EP075(SIM))								
WP16,	MW5	**11-FEB-2015**	**18-FEB-2015**	18-FEB-2015	✓	**19-FEB-2015**	30-MAR-2015	✓
EP075(SIM)B: Polynuclear Aromatic Hydrocarbons								
Amber Glass Bottle - Unpreserved (EP075(SIM))								
WP16,	MW5	**11-FEB-2015**	**18-FEB-2015**	18-FEB-2015	✓	**19-FEB-2015**	30-MAR-2015	✓
EP080: BTEXN								
Amber VOC Vial - Sulfuric Acid (EP080)								
WP16,	MW5	**11-FEB-2015**	**20-FEB-2015**	25-FEB-2015	✓	**20-FEB-2015**	25-FEB-2015	✓
EP080/071: Total Petroleum Hydrocarbons								
Amber VOC Vial - Sulfuric Acid (EP080)								
WP16,	MW5	**11-FEB-2015**	**20-FEB-2015**	25-FEB-2015	✓	**20-FEB-2015**	25-FEB-2015	✓

Quality Control Parameter Frequency Compliance

The following report summarises the frequency of laboratory QC samples analysed within the analytical lot(s) in which the submitted sample(s) was(were) processed. Actual rate should be greater than or equal to the expected rate. A listing of breaches is provided in the Summary of Outliers.

Matrix: **WATER**

Evaluation: ✗ = Quality Control frequency not within specification ; ✓ = Quality Control frequency within specification.

Quality Control Sample Type		Count		Rate (%)			Quality Control Specification
Analytical Methods	*Method*	*QC*	*Regular*	***Actual***	***Expected***	*Evaluation*	
Laboratory Duplicates (DUP)							
Alkalinity by PC Titrator	ED037-P	2	20	**10.0**	**10.0**	✓	NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Chloride by Discrete Analyser	ED045G	2	20	**10.0**	**10.0**	✓	NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Conductivity by PC Titrator	EA010-P	2	18	**11.1**	**10.0**	✓	NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Dissolved Mercury by FIMS	EG035F	2	13	**15.4**	**10.0**	✓	NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Dissolved Metals by ICP-MS - Suite A	EG020A-F	2	20	**10.0**	**10.0**	✓	NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Dissolved Metals by ICP-MS - Suite B	EG020B-F	1	13	**7.7**	**10.0**	✗	NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Fluoride by PC Titrator	EK040P	2	17	**11.8**	**10.0**	✓	NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Major Cations - Dissolved	ED093F	1	15	**6.7**	**10.0**	✗	NEPM 2013 Schedule B(3) and ALS QCS3 requirement
pH by PC Titrator	EA005-P	2	20	**10.0**	**10.0**	✓	NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Standard Anions -by IC (Extended Method)	ED009-X	2	12	**16.7**	**10.0**	✓	NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Sulfate (Turbidimetric) as SO4 2- by Discrete Analyser	ED041G	2	20	**10.0**	**10.0**	✓	NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Total Mercury by FIMS	EG035T	2	12	**16.7**	**10.0**	✓	NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Total Metals by ICP-MS - Suite A	EG020A-T	2	19	**10.5**	**10.0**	✓	NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Total Metals by ICP-MS - Suite B	EG020B-T	1	11	**9.1**	**10.0**	✗	NEPM 2013 Schedule B(3) and ALS QCS3 requirement
TRH Volatiles/BTEX	EP080	2	20	**10.0**	**10.0**	✓	NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Laboratory Control Samples (LCS)							
Alkalinity by PC Titrator	ED037-P	1	20	**5.0**	**5.0**	✓	NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Chloride by Discrete Analyser	ED045G	2	20	**10.0**	**10.0**	✓	NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Conductivity by PC Titrator	EA010-P	1	18	**5.6**	**5.0**	✓	NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Dissolved Mercury by FIMS	EG035F	1	13	**7.7**	**5.0**	✓	NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Dissolved Metals by ICP-MS - Suite A	EG020A-F	1	20	**5.0**	**5.0**	✓	NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Dissolved Metals by ICP-MS - Suite B	EG020B-F	1	13	**7.7**	**5.0**	✓	NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Fluoride by PC Titrator	EK040P	1	17	**5.9**	**5.0**	✓	NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Major Cations - Dissolved	ED093F	1	15	**6.7**	**5.0**	✓	NEPM 2013 Schedule B(3) and ALS QCS3 requirement
PAH/Phenols (GC/MS - SIM)	EP075(SIM)	1	4	**25.0**	**5.0**	✓	NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Standard Anions -by IC (Extended Method)	ED009-X	1	12	**8.3**	**5.0**	✓	NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Sulfate (Turbidimetric) as SO4 2- by Discrete Analyser	ED041G	1	20	**5.0**	**5.0**	✓	NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Total Mercury by FIMS	EG035T	1	12	**8.3**	**5.0**	✓	NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Total Metals by ICP-MS - Suite A	EG020A-T	1	19	**5.3**	**5.0**	✓	NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Total Metals by ICP-MS - Suite B	EG020B-T	1	11	**9.1**	**5.0**	✓	NEPM 2013 Schedule B(3) and ALS QCS3 requirement
TRH - Semivolatile Fraction	EP071	1	8	**12.5**	**5.0**	✓	NEPM 2013 Schedule B(3) and ALS QCS3 requirement
TRH Volatiles/BTEX	EP080	1	20	**5.0**	**5.0**	✓	NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Method Blanks (MB)							
Chloride by Discrete Analyser	ED045G	1	20	**5.0**	**5.0**	✓	NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Conductivity by PC Titrator	EA010-P	1	18	**5.6**	**5.0**	✓	NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Dissolved Mercury by FIMS	EG035F	1	13	**7.7**	**5.0**	✓	NEPM 2013 Schedule B(3) and ALS QCS3 requirement

Matrix: **WATER**

Evaluation: × = Quality Control frequency not within specification ; ✓ = Quality Control frequency within specification.

Quality Control Sample Type		Count		Rate (%)			Quality Control Specification
Analytical Methods	*Method*	*QC*	*Regular*	***Actual***	***Expected***	*Evaluation*	
Method Blanks (MB) - Continued							
Dissolved Metals by ICP-MS - Suite A	EG020A-F	1	20	**5.0**	**5.0**	✓	NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Dissolved Metals by ICP-MS - Suite B	EG020B-F	1	13	**7.7**	**5.0**	✓	NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Fluoride by PC Titrator	EK040P	1	17	**5.9**	**5.0**	✓	NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Major Cations - Dissolved	ED093F	1	15	**6.7**	**5.0**	✓	NEPM 2013 Schedule B(3) and ALS QCS3 requirement
PAH/Phenols (GC/MS - SIM)	EP075(SIM)	1	4	**25.0**	**5.0**	✓	NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Standard Anions -by IC (Extended Method)	ED009-X	1	12	**8.3**	**5.0**	✓	NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Sulfate (Turbidimetric) as SO4 2- by Discrete Analyser	ED041G	1	20	**5.0**	**5.0**	✓	NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Total Mercury by FIMS	EG035T	1	12	**8.3**	**5.0**	✓	NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Total Metals by ICP-MS - Suite A	EG020A-T	1	19	**5.3**	**5.0**	✓	NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Total Metals by ICP-MS - Suite B	EG020B-T	1	11	**9.1**	**5.0**	✓	NEPM 2013 Schedule B(3) and ALS QCS3 requirement
TRH - Semivolatile Fraction	EP071	1	8	**12.5**	**5.0**	✓	NEPM 2013 Schedule B(3) and ALS QCS3 requirement
TRH Volatiles/BTEX	EP080	1	20	**5.0**	**5.0**	✓	NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Matrix Spikes (MS)							
Chloride by Discrete Analyser	ED045G	1	20	**5.0**	**5.0**	✓	NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Dissolved Mercury by FIMS	EG035F	1	13	**7.7**	**5.0**	✓	NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Dissolved Metals by ICP-MS - Suite A	EG020A-F	1	20	**5.0**	**5.0**	✓	NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Fluoride by PC Titrator	EK040P	1	17	**5.9**	**5.0**	✓	NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Standard Anions -by IC (Extended Method)	ED009-X	1	12	**8.3**	**5.0**	✓	NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Sulfate (Turbidimetric) as SO4 2- by Discrete Analyser	ED041G	1	20	**5.0**	**5.0**	✓	NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Total Mercury by FIMS	EG035T	1	12	**8.3**	**5.0**	✓	NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Total Metals by ICP-MS - Suite A	EG020A-T	1	19	**5.3**	**5.0**	✓	NEPM 2013 Schedule B(3) and ALS QCS3 requirement
TRH Volatiles/BTEX	EP080	1	20	**5.0**	**5.0**	✓	NEPM 2013 Schedule B(3) and ALS QCS3 requirement

Brief Method Summaries

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the US EPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request. The following report provides brief descriptions of the analytical procedures employed for results reported in the Certificate of Analysis. Sources from which ALS methods have been developed are provided within the Method Descriptions.

Analytical Methods	*Method*	*Matrix*	*Method Descriptions*
pH by PC Titrator	EA005-P	WATER	In house: Referenced to APHA 21st ed. 4500 H+ B. This procedure determines pH of water samples by automated ISE. This method is compliant with NEPM (2013) Schedule B(3)
Conductivity by PC Titrator	EA010-P	WATER	In house: Referenced to APHA 21st ed., 2510 B. This procedure determines conductivity by automated ISE. This method is compliant with NEPM (2013) Schedule B(3)
Calculated TDS (from Electrical Conductivity)	EA016	WATER	In house. Calculation from Electrical Conductivity (APHA 21st ed., 2510 B) using a conversion factor specified in the analytical report. This method is compliant with NEPM (2013) Schedule B(3)
Standard Anions -by IC (Extended Method)	ED009-X	WATER	In house: Referenced to APHA 21st ed., 4110. This method is compliant with NEPM (2013) Schedule B(3)
Alkalinity by PC Titrator	ED037-P	WATER	In house: Referenced to APHA 21st ed., 2320 B This procedure determines alkalinity by automated measurement (e.g. PC Titrate) using pH 4.5 for indicating the total alkalinity end-point. This method is compliant with NEPM (2013) Schedule B(3)
Sulfate (Turbidimetric) as SO4 2- by Discrete Analyser	ED041G	WATER	In house: Referenced to APHA 21st ed., 4500-SO4. Dissolved sulfate is determined in a 0.45um filtered sample. Sulfate ions are converted to a barium sulfate suspension in an acetic acid medium with barium chloride. Light absorbance of the BaSO4 suspension is measured by a photometer and the SO4-2 concentration is determined by comparison of the reading with a standard curve. This method is compliant with NEPM (2013) Schedule B(3)
Chloride by Discrete Analyser	ED045G	WATER	In house: Referenced to APHA 21st ed., 4500 Cl - G.The thiocyanate ion is liberated from mercuric thiocyanate through sequestration of mercury by the chloride ion to form non-ionised mercuric chloride.in the presence of ferric ions the librated thiocynate forms highly-coloured ferric thiocynate which is measured at 480 nm APHA 21st edition seal method 2 017-1-L april 2003
Major Cations - Dissolved	ED093F	WATER	In house: Referenced to APHA 3120 and 3125; USEPA SW 846 - 6010 and 6020; Cations are determined by either ICP-AES or ICP-MS techniques. This method is compliant with NEPM (2013) Schedule B(3) Sodium Adsorption Ratio is calculated from Ca, Mg and Na which determined by ALS in house method QWI-EN/ED093F. This method is compliant with NEPM (2013) Schedule B(3) Hardness parameters are calculated based on APHA 21st ed., 2340 B. This method is compliant with NEPM (2013) Schedule B(3)
Dissolved Metals by ICP-MS - Suite A	EG020A-F	WATER	In house: Referenced to APHA 21st ed., 3125; USEPA SW846 - 6020, ALS QWI-EN/EG020. Samples are 0.45 um filtered prior to analysis. The ICPMS technique utilizes a highly efficient argon plasma to ionize selected elements. Ions are then passed into a high vacuum mass spectrometer, which separates the analytes based on their distinct mass to charge ratios prior to their measurement by a discrete dynode ion detector.
Total Metals by ICP-MS - Suite A	EG020A-T	WATER	In house: Referenced to APHA 21st ed., 3125; USEPA SW846 - 6020, ALS QWI-EN/EG020. The ICPMS technique utilizes a highly efficient argon plasma to ionize selected elements. Ions are then passed into a high vacuum mass spectrometer, which separates the analytes based on their distinct mass to charge ratios prior to their measurement by a discrete dynode ion detector.

Analytical Methods	Method	Matrix	Method Descriptions
Dissolved Metals by ICP-MS - Suite B	EG020B-F	WATER	In house: Referenced to APHA 21st ed., 3125; USEPA SW846 - 6020, ALS QWI-EN/EG020. Samples are 0.45 um filtered prior to analysis. The ICPMS technique utilizes a highly efficient argon plasma to ionize selected elements. Ions are then passed into a high vacuum mass spectrometer, which separates the analytes based on their distinct mass to charge ratios prior to their measurement by a discrete dynode ion detector.
Total Metals by ICP-MS - Suite B	EG020B-T	WATER	In house: Referenced to APHA 21st ed., 3125; USEPA SW846 - 6020, ALS QWI-EN/EG020. The ICPMS technique utilizes a highly efficient argon plasma to ionize selected elements. Ions are then passed into a high vacuum mass spectrometer, which separates the analytes based on their distinct mass to charge ratios prior to their measurement by a discrete dynode ion detector.
Dissolved Mercury by FIMS	EG035F	WATER	In house: Referenced to AS 3550, APHA 21st ed. 3112 Hg - B (Flow-injection (SnCl2)(Cold Vapour generation) AAS) Samples are 0.45 um filtered prior to analysis. FIM-AAS is an automated flameless atomic absorption technique. A bromate/bromide reagent is used to oxidise any organic mercury compounds in the filtered sample. The ionic mercury is reduced online to atomic mercury vapour by SnCl2 which is then purged into a heated quartz cell. Quantification is by comparing absorbance against a calibration curve. This method is compliant with NEPM (2013) Schedule B(3)
Total Mercury by FIMS	EG035T	WATER	In house: Referenced to AS 3550, APHA 21st ed. 3112 Hg - B (Flow-injection (SnCl2)(Cold Vapour generation) AAS) FIM-AAS is an automated flameless atomic absorption technique. A bromate/bromide reagent is used to oxidise any organic mercury compounds in the unfiltered sample. The ionic mercury is reduced online to atomic mercury vapour by SnCl2 which is then purged into a heated quartz cell. Quantification is by comparing absorbance against a calibration curve. This method is compliant with NEPM (2013) Schedule B(3)
Silica (Total Dissolved) by ICPAES	EG052F	WATER	In house: Referenced to APHA 21st ed., 4500-SiO2. Silica (Total) determined by calculation from Silicon by ICPAES.
Fluoride by PC Titrator	EK040P	WATER	In house: Referenced to APHA 21st ed., 4500 F--C CDTA is added to the sample to provide a uniform ionic strength background, adjust pH, and break up complexes. Fluoride concentration is determined by either manual or automatic ISE measurement. This method is compliant with NEPM (2013) Schedule B(3)
Ionic Balance by PCT DA and Turbi SO4 DA	EN055 - PG	WATER	In house: Referenced to APHA 21st Ed. 1030F. This method is compliant with NEPM (2013) Schedule B(3)
TRH - Semivolatile Fraction	EP071	WATER	USEPA SW 846 - 8015A The sample extract is analysed by Capillary GC/FID and quantification is by comparison against an established 5 point calibration curve of n-Alkane standards. This method is compliant with the QC requirements of NEPM (2013) Schedule B(3)
PAH/Phenols (GC/MS - SIM)	EP075(SIM)	WATER	USEPA SW 846 - 8270D Sample extracts are analysed by Capillary GC/MS in SIM Mode and quantification is by comparison against an established 5 point calibration curve. This method is compliant with NEPM (2013) Schedule B(3)
TRH Volatiles/BTEX	EP080	WATER	USEPA SW 846 - 8260B Water samples are directly purged prior to analysis by Capillary GC/MS and quantification is by comparison against an established 5 point calibration curve. Alternatively, a sample is equilibrated in a headspace vial and a portion of the headspace determined by GCMS analysis. This method is compliant with the QC requirements of NEPM (2013) Schedule B(3)

Preparation Methods	Method	Matrix	Method Descriptions
Digestion for Total Recoverable Metals	EN25	WATER	USEPA SW846-3005 Method 3005 is a Nitric/Hydrochloric acid digestion procedure used to prepare surface and ground water samples for analysis by ICPAES or ICPMS. This method is compliant with NEPM (2013) Schedule B(3)

Preparation Methods	Method	Matrix	Method Descriptions
Separatory Funnel Extraction of Liquids	ORG14	WATER	USEPA SW 846 - 3510B 100 mL to 1L of sample is transferred to a separatory funnel and serially extracted three times using 60mL DCM for each extract. The resultant extracts are combined, dehydrated and concentrated for analysis. This method is compliant with NEPM (2013) Schedule B(3) . ALS default excludes sediment which may be resident in the container.

Summary of Outliers

Outliers : Quality Control Samples

The following report highlights outliers flagged in the Quality Control (QC) Report. Surrogate recovery limits are static and based on USEPA SW846 or ALS-QWI/EN/38 (in the absence of specific USEPA limits). This report displays QC Outliers (breaches) only.

Duplicates, Method Blanks, Laboratory Control Samples and Matrix Spikes

- **For all matrices, no Method Blank value outliers occur.**
- **For all matrices, no Duplicate outliers occur.**
- **For all matrices, no Laboratory Control outliers occur.**
- **For all matrices, no Matrix Spike outliers occur.**

Regular Sample Surrogates

- **For all regular sample matrices, no surrogate recovery outliers occur.**

Outliers : Analysis Holding Time Compliance

This report displays Holding Time breaches only. Only the respective Extraction / Preparation and/or Analysis component is/are displayed.

Matrix: **WATER**

Method		Extraction / Preparation			Analysis		
Container / Client Sample ID(s)		Date extracted	Due for extraction	Days overdue	Date analysed	Due for analysis	Days overdue
EA005P: pH by PC Titrator							
Clear Plastic Bottle - Natural							
SEEP,	MAIN GULLY SP(MGSP)	----	----	----	17-FEB-2015	10-FEB-2015	**7**
Clear Plastic Bottle - Natural							
WP16, MW2,	SPRING, MW5	----	----	----	17-FEB-2015	11-FEB-2015	**6**
Clear Plastic Bottle - Natural							
MW1		----	----	----	17-FEB-2015	12-FEB-2015	**5**
EA006: Sodium Adsorption Ratio (SAR)							
Clear Plastic Bottle - Natural							
SEEP,	MAIN GULLY SP(MGSP)	----	----	----	18-FEB-2015	17-FEB-2015	**1**
EA065: Total Hardness as CaCO3							
Clear Plastic Bottle - Natural							
SEEP,	MAIN GULLY SP(MGSP)	----	----	----	18-FEB-2015	17-FEB-2015	**1**
ED093F: Dissolved Major Cations							
Clear Plastic Bottle - Natural							
SEEP,	MAIN GULLY SP(MGSP)	----	----	----	18-FEB-2015	17-FEB-2015	**1**

Outliers : Frequency of Quality Control Samples

The following report highlights breaches in the Frequency of Quality Control Samples.

Matrix: **WATER**

Matrix: **WATER**

Quality Control Sample Type	Count		Rate (%)		Quality Control Specification
Method	QC	Regular	Actual	Expected	
Laboratory Duplicates (DUP)					
Dissolved Metals by ICP-MS - Suite B	1	13	7.7	10.0	NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Major Cations - Dissolved	1	15	6.7	10.0	NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Total Metals by ICP-MS - Suite B	1	11	9.1	10.0	NEPM 2013 Schedule B(3) and ALS QCS3 requirement

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GST Registration Number 59-583-921

Age Consultants
Attention: Anna Eskola
Level 2 15 Mallon Street
Bowen Hills
Queensland QLD 4006
Australia

TAX INVOICE

Date:	*16/06/2015*
Due Date:	*20/07/2015*
Invoice Number:	*PSINV219182*
Customer Number:	*602364*
Customer Reference:	
GNS contact:	*Uwe Morgenstern*
Project Number:	*633W2233*
Page	*1*

Description	**Quantity**	**Rate**		**Amount**
Batch 164 Tritium Analyses TAUS925-928	4	690.00	NZD	2,760.00
C14 Analyses CAUS25-28	4	850.00	NZD	3,400.00
Stable isotopes IC205-205	4	120.00	NZD	480.00
MPI inspection fee	1	22.22	NZD	22.22

Payment can be made by direct credit, quoting our invoice number, to:
ANZ Bank NZ Ltd, 1 Victoria St, Wellington 6011,NZ
Account No: 06-0545-0205241-00
Swift Code: ANZBNZ22
or by cheque payable to GNS Science

Subtotal	NZD	*6,662.22*
GST	NZD	*0.00*
Amount Due	NZD	***6,662.22***

Please detach and forward with your payment to:
GNS Science

PO Box 30 368
LOWER HUTT 5040
New Zealand

REMITTANCE ADVICE

Invoice Number:	*PSINV219182*
Customer Number:	*602364*
Project Number:	*633W2233*
Amount Due NZD:	*6,662.22*

Card number [ ] [ ] [ ] [ ] Security Code MASTERCARD VISA

Cardholder's name Card expiry date Cardholder's signature

WATER DATING LABORATORY ANALYTICAL RESULTS

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www.gns.cri.nz

16th June 2015

AGE Consultants

FAO: Pavel Dvoracek

Results of Tritium Analyses

Lab ID Batch 164	Collection Date	Sample ID	Tritium conc. TR	± TR
TAUS925	10/02/2015	Seep	1.870	0.041
TAUS926	10/02/2015	Main Gully	1.931	0.043
TAUS927	11/02/2015	MW1	2.511	0.051
TAUS928	11/02/2015	MW2	1.765	0.040

Tritium is measured by electrolytic enrichment and liquid scintillation counting using Quantulus low-level counters (Morgenstern & Taylor, 2009).. 1 TR is a $^{3}H/^{1}H$ ratio of 1×10^{-18}. ±TR = one sigma standard measurement error. The detection limit is approximately 0.025 TR.

Regards,

Vanessa TrompetterGNS Science Water Dating Laboratory
1 Fairway Drive,Avalon,Lower Hutt

Reviewed by:
Rob van der Raaij

Morgenstern, U. Taylor, C.B. 2009 Ultra low-level tritium measurement using electrolytic enrichment and LSC. Isotopes in Environmental and Health Studies. 45(2), 96-117

Rafter Radiocarbon

Accelerator Mass Spectrometry Result

This result for the sample submitted is for the exclusive use of the submitter. All liability whatsoever to any third party is excluded.

NZA 58977

R 40718/1

Job No: 201798

Report issued: 13 May 2015

Sample ID	CAUS25-SEEP
Description	
Fraction dated	Water
Submitter	Vanessa Trompetter NIC Water Dating Lab, GNS

Conventional Radiocarbon Age (years BP)	**4059**	±	**28**	
$\delta^{13}C$ and Source of measurement	-10.1	±	0.2	IRMS
Fraction modern	0.6034	±	0.0021	
$\Delta^{14}C$ (‰) and collection date	-401.4	±	2.1	10 Feb 2015

Measurement Comment:

Sample Treatment Details

Sample was submitted as a clear, colourless, and odourless water with no precipitate or sediment and no head space. CO_2 was generated by phosphoric acid evolution, and carbonate content was 44.9mgC/kgH_2O, total dissolved inorganic carbon (TDIC) 3.7mmol/kgH_2O. Sample carbon dioxide was converted to graphite by reduction with hydrogen over iron catalyst.

Conventional Radiocarbon Age and $\Delta^{14}C$ are reported as defined by Stuiver and Polach (*Radiocarbon 19*:355-363, 1977). $\Delta^{14}C$ is reported only if collection date was supplied and is decay corrected to that date. Fraction modern (F) is the blank corrected fraction modern normalized to $\delta^{13}C$ of -25‰, defined by Donahue et al. (*Radiocarbon*, *32*(2):135-142, 1990). $\delta^{13}C$ normalization is always performed using $\delta^{13}C$ measured by AMS, thus accounting for AMS fractionation. Although not used in the ^{14}C age calculations, the environmental $\delta^{13}C$ measured offline by IRMS is reported if sufficient sample material was available. The reported errors comprise statistical errors in sample and standard determinations, combined in quadrature with a system error based on the analysis of an ongoing series of measurements on an oxalic acid standard. Further details of pretreatment and analysis are available on request.

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Rafter Radiocarbon

NZA 58978
R 40718/2
Job No: 201799
Report issued: 13 May 2015

Accelerator Mass Spectrometry Result

This result for the sample submitted is for the exclusive use of the submitter. All liability whatsoever to any third party is excluded.

Sample ID CAUS26-M6SP

Description

Fraction dated Water

Submitter Vanessa Trompetter
NIC Water Dating Lab, GNS

Conventional Radiocarbon Age (years BP)	**3493**	±	**27**	
$\delta^{13}C$ and Source of measurement	-8.0	±	0.2	IRMS
Fraction modern	0.6474	±	0.0022	
$\Delta^{14}C$ (‰) and collection date	-357.7	±	2.2	10 Feb 2015

Measurement Comment:

Sample Treatment Details

Sample was submitted as a clear, colourless, and odourless water with a very small amount of reddish brown coloured sediment on the bottom of bottle and some head space. CO2 was generated by phosphoric acid evolution, and carbonate content was 35.2mgC/kgH2O, total dissolved inorganic carbon (TDIC) 2.9mmol/kgH2O. Sample carbon dioxide was converted to graphite by reduction with hydrogen over iron catalyst.

Conventional Radiocarbon Age and $\Delta^{14}C$ are reported as defined by Stuiver and Polach (*Radiocarbon 19*:355-363, 1977). $\Delta^{14}C$ is reported only if collection date was supplied and is decay corrected to that date. Fraction modern (F) is the blank corrected fraction modern normalized to $\delta^{13}C$ of -25‰, defined by Donahue et al. (*Radiocarbon*, *32*(2):135-142, 1990). $\delta^{13}C$ normalization is always performed using $\delta^{13}C$ measured by AMS, thus accounting for AMS fractionation. Although not used in the ^{14}C age calculations, the environmental $\delta^{13}C$ measured offline by IRMS is reported if sufficient sample material was available. The reported errors comprise statistical errors in sample and standard determinations, combined in quadrature with a system error based on the analysis of an ongoing series of measurements on an oxalic acid standard. Further details of pretreatment and analysis are available on request.

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Rafter Radiocarbon

NZA 58979

R 40718/3

Job No: 201800

Report issued: 13 May 2015

Accelerator Mass Spectrometry Result

Sample ID	CAUS27-MW2
Description	
Fraction dated	Water
Submitter	Vanessa Trompetter NIC Water Dating Lab, GNS

Conventional Radiocarbon Age (years BP)	**9321**	±	**40**	
$\delta^{13}C$ and Source of measurement	-6.0	±	0.2	IRMS
Fraction modern	0.3134	±	0.0016	
$\Delta^{14}C$ (‰) and collection date	-689.1	±	1.6	11 Feb 2015

Measurement Comment:

Sample Treatment Details

Sample was submitted as a clear, colourless, and odourless water with a thick layer of reddish brown coloured sediment on the bottom of the bottle and no head space. CO2 was generated by phosphoric acid evolution, and carbonate content was 42.2mgC/kgH2O, total dissolved inorganic carbon (TDIC) 3.5mmol/kgH2O. Sample carbon dioxide was converted to graphite by reduction with hydrogen over iron catalyst.

Conventional Radiocarbon Age and $\Delta^{14}C$ are reported as defined by Stuiver and Polach (*Radiocarbon 19*:355-363, 1977). $\Delta^{14}C$ is reported only if collection date was supplied and is decay corrected to that date. Fraction modern (F) is the blank corrected fraction modern normalized to $\delta^{13}C$ of -25‰, defined by Donahue et al. (*Radiocarbon*, *32*(2):135-142, 1990). $\delta^{13}C$ normalization is always performed using $\delta^{13}C$ measured by AMS, thus accounting for AMS fractionation. Although not used in the ^{14}C age calculations, the environmental $\delta^{13}C$ measured offline by IRMS is reported if sufficient sample material was available. The reported errors comprise statistical errors in sample and standard determinations, combined in quadrature with a system error based on the analysis of an ongoing series of measurements on an oxalic acid standard. Further details of pretreatment and analysis are available on request.

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Rafter Radiocarbon

Accelerator Mass Spectrometry Result

This result for the sample submitted is for the exclusive use of the submitter. All liability whatsoever to any third party is excluded.

NZA 58980

R 40718/4

Job No: 201801

Report issued: 13 May 2015

Sample ID	CAUS28-MW-1
Description	
Fraction dated	Water
Submitter	Vanessa Trompetter NIC Water Dating Lab, GNS

Conventional Radiocarbon Age (years BP)	**12042**	±	**52**	
$\delta^{13}C$ and Source of measurement	-6.8	±	0.2	IRMS
Fraction modern	0.2233	±	0.0015	
$\Delta^{14}C$ (‰) and collection date	-778.4	±	1.4	12 Feb 2015

Measurement Comment:

Sample Treatment Details

Sample was submitted as a clear, colourless, and odourless water with brown coloured sediment on the bottom of the bottle and some head space. CO2 was generated by phosphoric acid evolution, and carbonate content was 846.4mgC/kgH2O, total dissolved inorganic carbon (TDIC) 70.5mmol/kgH2O. Sample carbon dioxide was converted to graphite by reduction with hydrogen over iron catalyst.

Conventional Radiocarbon Age and $\Delta^{14}C$ are reported as defined by Stuiver and Polach (*Radiocarbon 19*:355-363, 1977). $\Delta^{14}C$ is reported only if collection date was supplied and is decay corrected to that date. Fraction modern (F) is the blank corrected fraction modern normalized to $\delta^{13}C$ of -25‰, defined by Donahue et al. (*Radiocarbon*, *32*(2):135-142, 1990). $\delta^{13}C$ normalization is always performed using $\delta^{13}C$ measured by AMS, thus accounting for AMS fractionation. Although not used in the ^{14}C age calculations, the environmental $\delta^{13}C$ measured offline by IRMS is reported if sufficient sample material was available. The reported errors comprise statistical errors in sample and standard determinations, combined in quadrature with a system error based on the analysis of an ongoing series of measurements on an oxalic acid standard. Further details of pretreatment and analysis are available on request.

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Appendix C RGS – Geochemical assessment of overburden rock materials from the Marulan limestone quarry

23 March 2015
Project Number 201427

AGE Consultants Pty Ltd
4 Hudson Street
Hamilton Newcastle NSW 2303

Attention: Pavel Dvoracek

Subject: Letter Report: Geochemical Assessment of Waste Rock Materials from the Marulan Limestone Quarry

1.0 INTRODUCTION

RGS Environmental Pty Ltd (RGS) was commissioned by AGE Consultants Pty Ltd (AGE) to complete a geochemical assessment of representative samples of waste rock materials from Marulan Quarry owned by Boral Resources (NSW) Pty Ltd (Boral). The existing quarry is located 10 km south-east of Marulan, 31 km east of Goulburn and 175 km south-west of Sydney in the Goulburn Mulwaree local government area of NSW (**Figure 1**).

The quarry extracts a granodiorite resource and produces up to 3.5 million tonnes of quarry products (hard rock, aggregate and manufactured sand) a year. The quarry products are transported by rail to the Sydney construction materials market (NSW Department of Planning, 2007).

Waste rock materials generated at the quarry is stored at a waste rock storage facility adjacent to the open pit area.

2.0 SCOPE OF WORK

The RGS scope of work was to complete a geochemical assessment program on waste rock materials from Marulan Quarry. A batch of 25 representative samples of waste rock material were received by RGS and subjected to a series of static geochemical tests to determine the potential for this material to generate acidity, salts and soluble metals/metalloids.

This letter report presents the results of the geochemical assessment of the waste rock materials and provides a discussion of the main findings. It is understood that the geochemical tests results presented in this letter report will be used by AGE/Boral as part of the environmental management of waste rock materials at the quarry.

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Webpage: http://www.rgsenv.com

Figure 1: Location of Marulan Quarry (Source: NSW Department of Planning, 2007)

3.0 METHODOLOGY

3.1 Sampling Program

In February 2015, RGS received 20 representative samples of waste rock materials from Marulan Quarry. The samples were taken by AGE personnel under instruction form RGS personnel. The samples were taken to represent the various rock types occurring at the quarry and likely to report to the waste rock storage facility. The waste rock samples were subjected to a series of static geochemical tests as described in **Section 3.2**.

The geochemical assessment work on waste rock was completed in accordance with existing technical guidelines for the geochemical assessment of mine waste in Australia (DITR, 2007, AMIRA, 2002) and worldwide (INAP, 2009). These guidelines were used to ensure that the sampling (and testing) program used at the Project was appropriately risk-based and focused on obtaining and testing a representative sample of the waste rock materials likely to be produced from excavating quarry material from the open pit.

3.2 Geochemical Test Program

A summarised overview of a typical static geochemical assessment program for mine waste materials is provided in **Attachment A.**

The 20 waste rock samples were sent to ALS Environmental laboratory in Brisbane (ALS Brisbane). The samples were crushed to pass 10mm and then sub-samples pulverised in preparation for static geochemical testing. Each sample was tested for:

- pH and Electrical conductivity (EC);
- Total sulfur [Leco Method]; and
- Acid neutralising capacity (ANC) [AMIRA, 2002].

The results of these tests were used to calculate the Net Acid Producing Potential (NAPP).

One of the waste rock samples was also subjected to further testing to determine the sulfide sulfur content of the sample using:

- Chromium Reducible Sulfur [AS 4969.7-2008]

A total of 12 of the original 20 waste rock samples received by RGS were used to generate six composite samples of waste rock materials on the basis on lithology. The six composite samples were tested for:

- Total cations [HCl and HNO_3 acid digest followed by ICP-AES/MS];
- Total metals/metalloids [HCl and HNO_3 acid digest followed by FIMS and/or ICP-AES/MS];
- Soluble metals/metalloids [ICP-AES/MS and FIMS (1:5 w:v water extracts)]; and
- Major cations and anions [ICP-AES/MS and PC Titrator (1:5 w:v water extracts)].

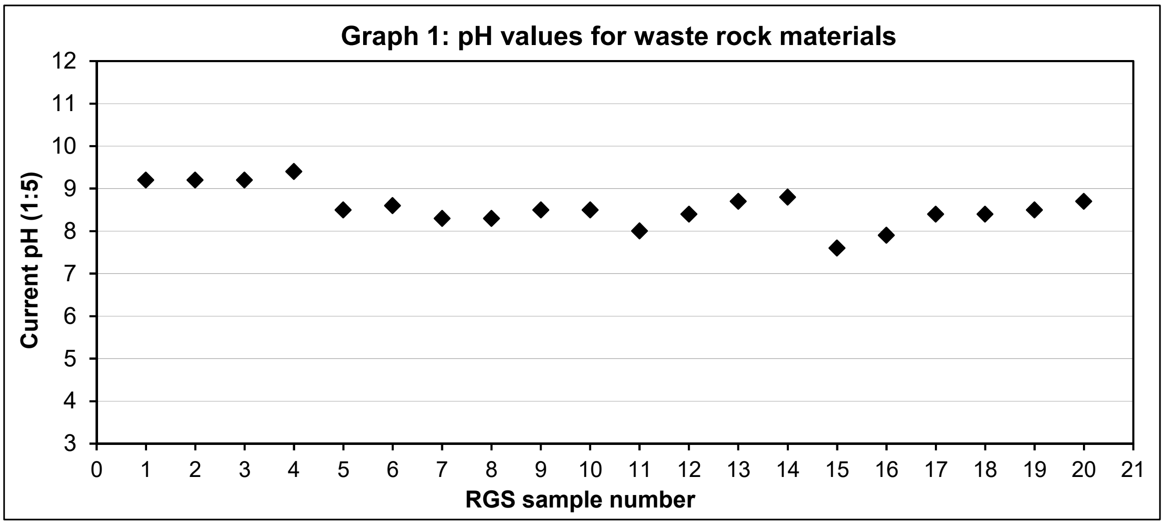
Summary tables of results for the static geochemical test program are provided in **Attachment B** and a copy of all the raw geochemical results received from ALS Brisbane for the static tests is provided in **Attachment C.**

4.0 RESULTS

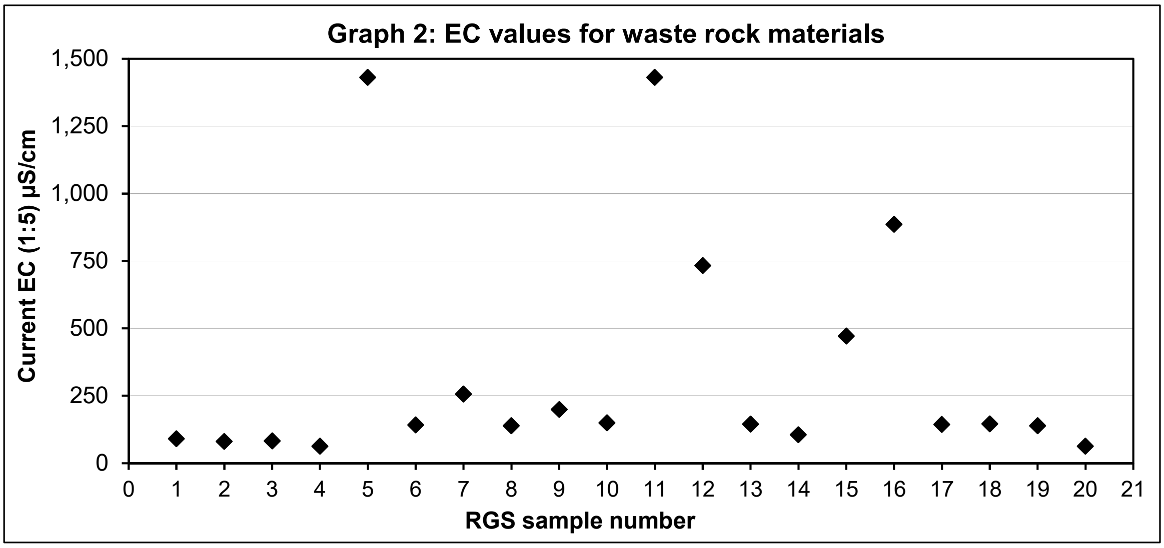
4.1 Acid Base Account Results

Acid-Base Account (ABA) test results for the waste rock samples are summarised below and also presented in **Table B1 (Attachment B)**. An explanation of the methodology used in this section, including a description of the ABA test method, is provided at **Section 3.2**. The ABA data trends are presented in **Graphs 1** to **6**.

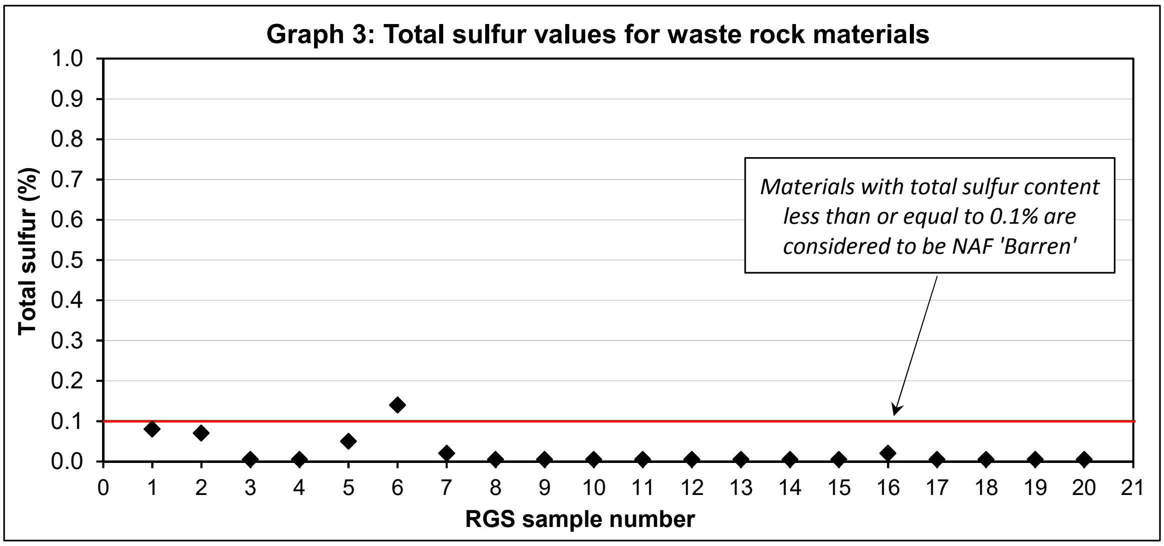
- **pH**: The natural pH of the deionised water used in the pH tests is typically in the pH range 5.5 to 6.5. The $pH_{(1:5)}$ of the 20 waste rock samples ranges from pH 7.6 to 9.4 and has a slightly alkaline median pH value of 8.5 (**Graph 1**). The majority of the samples (80 %) have pH values within the range pH 7.0 to 9.0. Four waste rock samples described as "Limestone" have a pH value greater than pH 9.0 indicating the presence of excess alkalinity. There is no other correlation between sample pH and sample location, type or lithology.



- **Electrical Conductivity (EC)**: The current $EC_{(1:5)}$ of the 20 waste rock samples ranges from 62 to 1,430 µS/cm and is typically low, (median 144 µS/cm). Two waste rock samples have an EC value greater than 1,000 µS/cm (**Graph 2,** overleaf) and represent extremely weathered dyke material and shale mudstone material, which make up a relatively small component of total waste rock materials. There is no other correlation between sample EC and sample location, type or lithology.

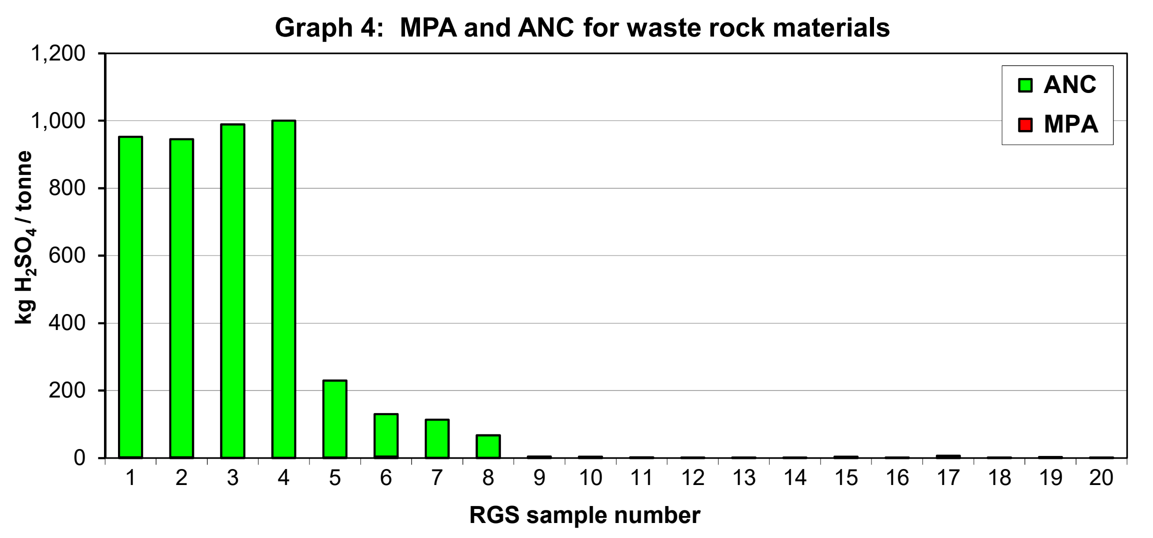


- **Total Sulfur:** The total sulfur content of the 20 waste rock samples ranges from 0.005 percent sulfur (%S) to 0.14 %S and is typically very low (median 0.005 %S) compared to average crustal abundance (0.1 %) for this element (INAP, 2009). Materials with a total sulfur content less than or equal to 0.1 %S are essentially barren of sulfur, generally represent background concentrations, and have negligible capacity to generate acidity[1]. One of the waste rock samples tested (described as mafic dyke) has a total sulfur value slightly greater than 0.1 %S and the Chromium Reducible Sulfur (Scr) test result in **Table B1** (**Attachment B**) suggests that the the sulfur in this sample is mainly present as sulfide sulfur.



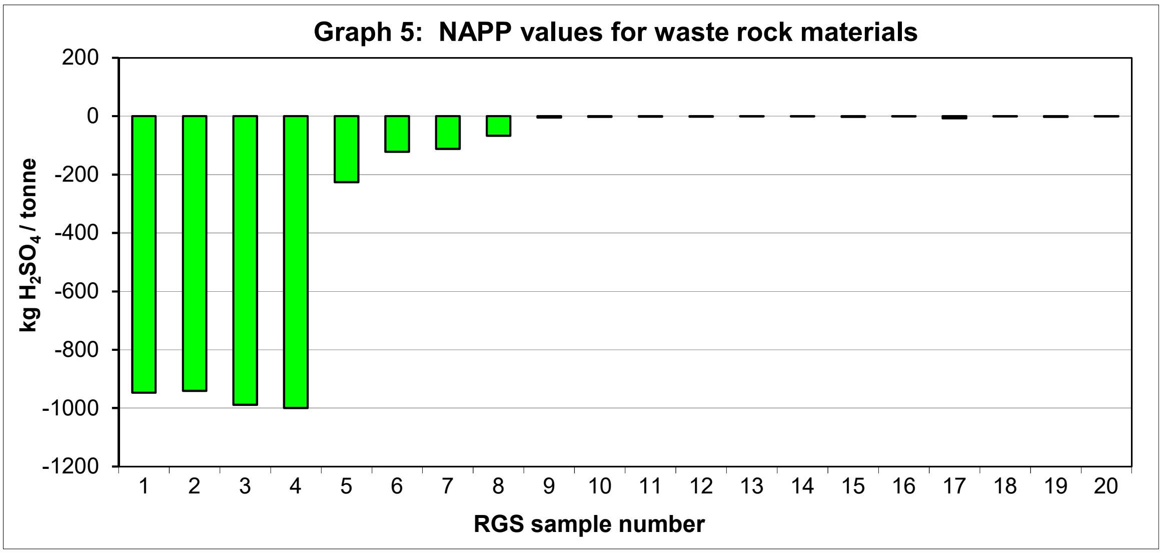
[1] The average crustal abundance of sulfur is approximately 0.1 % (INAP, 2009).

- **Maximum Potential Acidity (MPA)**: The MPA for the waste rock samples ranges from 0.15 to 4.3 kg H_2SO_4/t, and is typically very low with a median value of 0.15 kg H_2SO_4/t (**Graph 4**).
- **Acid Neutralising Capacity (ANC)**: The ANC value for the waste rock samples ranges from 0.3 to 1,000 kg H_2SO_4/t and has a median value of 3.9 kg H_2SO_4/t (more than an order of magnitude greater the median MPA)(**Graph 4**). The highest ANC values are associated with the four limestone samples.



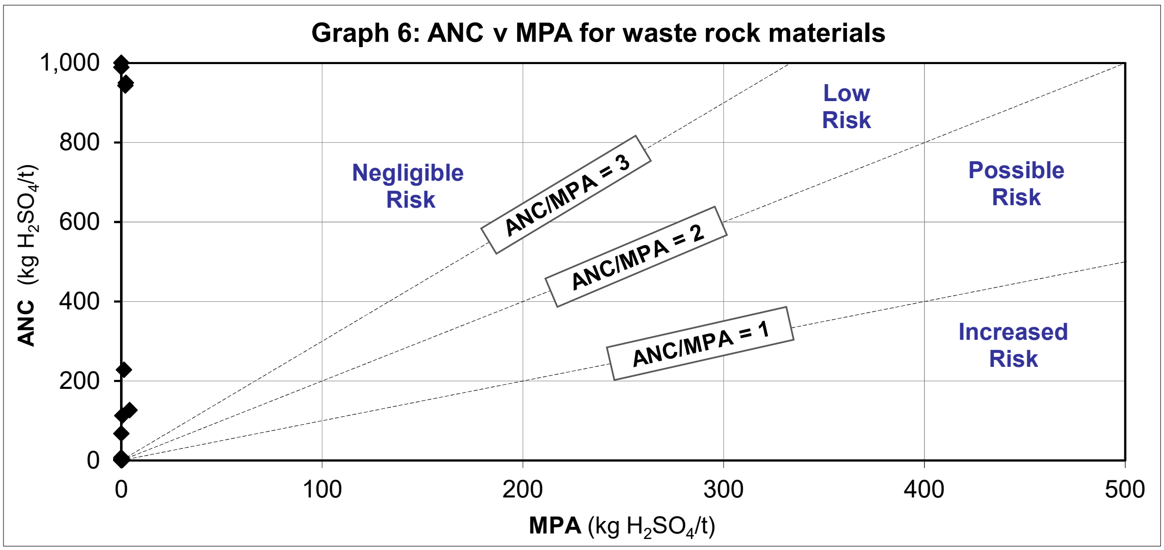
- **Net Acid Producing Potential (NAPP)**: The NAPP is the balance between the capacity of a sample to generate acidity (MPA) minus its capacity to neutralise acidity (ANC). The calculated NAPP value for the samples ranges from -999.8 to -0.1 kg H_2SO_4/t and has a negative median value of -3.7 kg H_2SO_4/t. The NAPP data for the samples are presented in **Graph 5** and illustrate that the waste rock materials have NAPP values that are either negative or close to zero.

  Given the very low sulfur content of these waste rock materials, the risk of generating any significant acidity and/or neutral mine drainage (NMD) from bulk waste rock materials is negligible.



- **ANC:MPA ratio**: The ANC:MPA ratio of the waste rock samples ranges from 1.3 to 6,531 and is typically elevated (median 25.1). In simplistic terms, this means that the ANC is many times greater than the small amount of MPA that could theoretically be generated from the waste rock samples.

Graph 6 shows a plot of ANC versus MPA for the waste rock samples. ANC:MPA ratio lines have been plotted on the graph to illustrate the factor of safety associated with the samples, in terms of potential for generation of AMD. Generally those samples with an ANC:MPA ratio of greater than 2 and a sulfide sulfur content of <0.1% are considered to represent material with a low to negligible risk of acid generation and a high factor of safety in terms of potential for AMD (DITR, 2007; INAP, 2009). The majority of the samples fall within the negligible risk domain in the graph and therefore have a high factor of safety and very low risk of acid generation.



The ABA test data presented in **Table B1 (Attachment B)** and discussed in this section has been used to classify the acid forming nature of the waste rock materials. These classification criteria generally reflect Australian (DITR, 2007) and international (INAP, 2009) guideline criteria for classification of mine waste materials.

Table 1 provides a summary of the criteria used by RGS to classify the acid forming nature of the samples and a breakdown of the number of samples in each classification category by material type. The data presented in **Table 1** show that 19 of the 20 samples are classified as Non-Acid Forming (Barren) and one sample is classified as NAF.

Table 1: Geochemical classification criteria for waste rock

Geochemical Classification	Total Sulfur[1] (%)	NAPP (kg H_2SO_4/t)	ANC:MPA Ratio	Waste Rock (n = 20)
Non-Acid Forming (Barren)[2]	≤ 0.1	-	-	19
Non-Acid Forming	> 0.1	< -5	-	1
Uncertain[3]	> 0.1	< 5	< 2	0
Potentially Acid Forming (PAF)	> 0.1	> 5	< 2	0

Notes:
1. If total sulfur is less than or equal to 0.1 %, the NAPP and ANC:MPA ratio are not required for material classification as the sample is essentially barren of oxidisable sulfur.
2. A sample classified as NAF can be further described as 'barren' if the total sulfur content is less than or equal to 0.1 per cent, as the sample essentially has negligible acid generating capacity.
3. Samples that fall outside the stated NAF/PAF classification categories based on the criteria provided are classified as Uncertain.

4.2 Multi-Element Concentration

Multi-element tests were completed on the six selected composite waste rock samples (**Table B2**, **Attachment B**) to identify any elements (particularly metals/metalloids) present in this material at concentrations that may be of environmental concern with respect to revegetation. The results were compared to potentially relevant guideline criteria to determine any potential concerns related to mine operation and final rehabilitation. For total metal/metalloid concentrations in mine waste materials in NSW, there are no specific guidelines and/or regulatory criteria. In the absence of these and to provide relevant context, RGS has compared the total metal concentration in the waste rock samples with health-based investigation levels (HIL(C)) that apply to public open spaces (NEPC, 2013). The applicability of this guideline stems from the potential final land use of the mine following closure (*e.g.* low intensity grazing and ecological values).

The results of the multi-element test work on the waste rock samples are presented in **Table B3 (Attachment B)**. The results show that the concentration of metals/ metalloids in the samples is low and below the applied NEPC (2013) health-based investigation guideline levels (HIL'C') for recreational public open spaces. The results indicate that the bulk waste rock material contains relatively low concentrations of metals/metalloids.

4.3 Geochemical Abundance Index

An alternative approach to determining if a mine waste material is enriched with metals/metalloids is to compare the multi-element concentration results with the median crustal abundance for unmineralised soils (INAP, 2009; and Bowen, 1979). The extent of enrichment is reported as the Geochemical Abundance Index (GAI), which relates the actual concentration with a median (or average) abundance on a $\log_{10}$ scale.

The GAI is expressed in integer increments from 0 to 6, where a GAI value of 0 indicates that the element is present at a concentration less than, or similar to, the median crustal abundance; and a GAI value of 6 indicates an approximate 100-fold enrichment above median crustal abundance **(Table 2)**.

Table 2: Geochemical Abundance Index (GAI) values and Enrichment Factor

GAI	Enrichment factor	GAI	Enrichment factor
-	Less than 3-fold enrichment	4	24 – 48 fold enrichment
1	3 – 6 fold enrichment	5	48 – 96 fold enrichment
2	6 – 12 fold enrichment	6	Greater than 96 fold enrichment
3	12 – 24 fold enrichment		

As a general rule, a GAI of 3 or greater signifies enrichment that may warrant further examination. This is particularly the case with some environmentally important 'trace' elements, such as As, Cr, Cd, Cu, Pb, Se and Zn, more so than with major rock-forming elements, such as Al, Ca, Fe, Mg and Na.

Elements identified as enriched may not necessarily be a concern for revegetation, water quality or public health, but their significance should still be evaluated. Similarly, because an element is not enriched does not mean it will never be a concern, because under some conditions (eg. low pH) the solubility of common environmentally important elements such as Al, Cu, Cd, Fe and Zn increases significantly.

The results from multi-element testing (total metals/metalloids) of the six composite waste rock samples are presented in **Table B3 (Attachment B)**. The relative enrichment of metals/metalloids in the sample compared to average crustal abundance is presented in **Table B4 (Attachment B)**.

The results indicate that the metals/metalloids tested in the most waste rock samples are not enriched compared to average crustal abundance. Minor exceptions include calcium in limestone and arsenic, cobalt and manganese in the relatively small amount of contact material between the limestone and shales.

The potential solubility of metals/metalloids in the waste rock materials is investigated further using water extracts in **Section 4.4** of this report.

4.4 Water Quality

RGS has compared the multi-element results in water extracts from the six composite waste rock samples described in **Sections 4.2** and **4.3** with ANZECC & ARCANZ (2000) guideline values. These guidelines are provided for context only and are not intended to be interpreted as "maximum permissible levels" for site water storage or discharge.

It should also be recognised that direct comparison of geochemical data with guideline values can be misleading. For the purpose of this study, guideline values are only provided for broad context and should not be interpreted as arbitrary 'maximum' values or 'trigger' values. Using sample pulps (ground to passing 75 µm) provides a very high surface area to solution ratio, which encourages mineral reaction and dissolution of the solid phase. As such, the results of screening tests on water extract solutions are assumed to represent an assumed 'worst case' scenario for initial surface runoff and seepage from waste rock materials.

The results from multi-element testing of water extracts (1:5 solid:water) from the six composite waste rock samples are presented in **Table B5 (Attachment B)**.

The pH of the water extracts ranges from pH 8.3 to 9.5 and is typically slightly alkaline. This indicates that these materials are likely to contribute alkalinity to initial surface runoff and seepage. This is further supported by the very low acidity values of the water extracts, which ranges from <0.2 to 2 mg/L. The alkalinity of the water extracts ranges from 23 to 1,426 mg/L (median 50 mg/L), and is typically well in excess of the measured acidity leading to positive net alkalinity values.

The EC in the water extracts ranges from 79 to 983 µS/cm and is typically low (median 125 µS/cm). The highest EC value was obtained for the shale/mudstone sample. This confirms that most materials exhibit low salinity and low concentrations of dissolved solids when in contact with water. The concentrations of the major cations and anions in the water extracts are typically very low for all but the shale/mudstone sample.

The concentration of all trace metals/metalloids tested in the water extracts is below the laboratory LoR in most samples. Minor exceptions include aluminium and chromium which have concentrations slightly above trigger values for aquatic ecosystems (95% species protection level). However, the concentrations of these and other metals/metalloids are at least an order of magnitude below the applied livestock drinking water guideline values (ANZECC & ARCANZ, 2000).

The results indicate that dissolved metal/metalloid concentrations in initial surface runoff and seepage from most waste rock materials at the waste rock storage facility are unlikely to impact upon the quality of surface and groundwater resources at the site.

5.0 CONCLUSIONS

The results of the geochemical assessment program on the tailing material from the Project indicate that:

- Waste rock materials are classified as NAF and are essentially barren of sulfur. The waste rock materials therefore have a high factor of safety with respect to potential acid generation.
- Surface runoff and seepage from waste rock materials is likely to be slightly alkaline and contain low concentrations of dissolved salts.
- The waste rock materials contain relatively low concentration of metals/metalloids in solids. Whilst the concentration of arsenic, cobalt and manganese may be elevated compared to average crustal abundance in some of the contact material between limestone and shales, these elements are sparingly soluble in contact water.
- Most trace metal/metalloids in waste rock are sparingly soluble in slightly alkaline contact water and are unlikely to impact upon the quality of surface and groundwater resources at the site.

6.0 MANAGEMENT MEASURES

Most waste rock materials are geochemically stable, with no special management measures required for the handling or storage of the majority of these materials.

However, it is recommended that the small amount of contact material between limestone and shale and any shale/mudstone materials encountered during mining be preferentially placed within the core of the waste rock storage facility away for the final rehabilitated surfaces.

Surface water and seepage from waste rock storage facility should be monitored to ensure that key water quality parameters remain within appropriate criteria. It is therefore recommended that Boral:

- Monitors surface run-off and seepage from the waste rock storage facility for pH, EC, total suspended solids (TSS) and the range of dissolved trace metals/metalloids and major ions described in **Table B5** (**Attachment B**) on a quarterly basis.

7.0 LIST OF REFERENCES

AMIRA (2002). *ARD Test Handbook*: Project 387A Prediction and Kinetic Control of Acid Mine Drainage. Australian Minerals Industry Research Association, Ian Wark Research Institute and Environmental Geochemistry International Pty Ltd, May 2002.

ANZECC & ARCANZ (2000). *Australian and New Zealand Guidelines for Fresh and Marine Water Quality: Livestock Drinking Water*. Australian and New Zealand Environment Conservation Council (ANZECC) and Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ). Canberra, ACT.

AS 4969.7-2008. *Analysis of acid sulfate soil – Dried samples – Methods of test. Method 7: Determination of chromium reducible sulfur (Scr)*. Standards Australia, June 2008.

Bowen, H.J.M. (1979). *Environmental Chemistry of the Elements*. Academic Press, New York, USA.

DITR (2007). Department of Industry, Tourism and Resources. *Leading Practice Sustainable Development Program for the Mining Industry. Managing Acid and Metalliferous Drainage*. February 2007, Canberra ACT.

NSW Department of Planning (2006). *Major Project Assessment: Marulan South Quarry Project*. Director General's Environmental Assessment Report, February 2007.

INAP (2009). *Global Acid Rock Drainage Guide (GARD Guide).* Document prepared by Golder Associates on behalf of the International Network on Acid Prevention (INAP). June 2009 (http://www.inap.com.au/).

NEPC (2013). *National Environmental Protection Council (NEPC). National Environmental Protection (Assessment of Site Contamination) Measure (NEPM). Guideline on investigation levels for soil and groundwater*. HIL(C) levels for recreational open spaces.

8.0 SIGNOFF

RGS trusts that this letter report meets your current requirements. Please contact Dr. Alan Robertson on 07 3344 1222 or 0431 620 623 if you have any queries.

Yours sincerely,
RGS ENVIRONMENTAL PTY LTD

Dr. Alan Robertson
Principal Geochemist

Attachment A
Geochemical Assessment of Mine Waste Materials

ATTACHMENT A

GEOCHEMICAL ASSESSMENT OF MINE WASTE MATERIALS

A1. ACID GENERATION AND PREDICTION

Acid generation is caused by the exposure of sulfide minerals, most commonly pyrite (FeS_2), to atmospheric oxygen and water. Sulfur assay results are used to calculate the maximum acid that could be generated by the sample by either directly determining the pyritic S content or assuming that all sulfur not present as sulfate occurs as pyrite. Pyrite reacts under oxidising conditions to generate acid according to the overall reaction:

$$\mathbf{FeS_2 + 15/4\ O_2 + 7/2\ H_2O \longrightarrow Fe(OH)_3 + 2\ H_2SO_4}$$

According to this reaction, the maximum potential acidity (MPA) of a sample containing 1%S as pyrite would be 30.6 kg H_2SO_4/t. The chemical components of the acid generation process consist of the above sulfide oxidation reaction and acid neutralization, which is mainly provided by inherent carbonates and to a lesser extent silicate materials. The amount and rate of acid generation is determined by the interaction and overall balance of the acid generation and neutralisation components.

Net Acid Producing Potential

The net acid producing potential (NAPP) is used as an indicator of materials that may be of concern with respect to acid generation. The NAPP calculation represents the balance between the maximum potential acidity (MPA) of a sample, which is derived from the sulfide sulfur content, and the acid neutralising capacity (ANC) of the material, which is determined experimentally. By convention, the NAPP result is expressed in units of kg H_2SO_4/t sample. If the capacity of the solids to neutralise acid (ANC) exceeds their capacity to generate acid (MPA), then the NAPP of the material is negative. Conversely, if the MPA exceeds the ANC, the NAPP of the material is positive. A NAPP assessment involves a series of analytical tests that include:

Determination of pH and EC

pH and EC measured on 1:5 w/w water extract. This gives an indication of the inherent acidity and salinity of the waste material when initially exposed in a waste emplacement area.

Total sulfur content, sulfate sulfur content, and Maximum Potential Acidity (MPA)

Total sulfur content is determined by the Leco high temperature combustion method. The total sulfur content is then used (in conjunction with the sulfate sulfur content) to calculate the MPA, which is based on the assumption that the entire sulfur content, minus the non-reactive sulfate sulfur content, is present as reactive pyrite. Direct determination of the pyritic sulfur content can provide a more accurate estimate of the MPA.

Acid neutralising capacity (ANC)

By addition of acid to a known weight of sample, then titration with NaOH to determine the amount of residual acid. The ANC measures the capacity of a sample to react with and neutralise acid. The ANC can be further evaluated by slow acid titration to a set end-point in the Acid Buffering Characteristic Curve (ABCC) test through calculation of the amount of acid consumed and evaluation of the resultant titration curve.

Net acid producing potential (NAPP)

Calculated from the MPA and ANC results. The NAPP represents the balance between a samples' inherent capacities to generate and neutralise acid. If the MPA is greater than the ANC then the NAPP is positive. If the MPA is less than the ANC then the sample then the NAPP is negative.

A2. ASSESSMENT OF ELEMENT ENRICHMENT AND SOLUBILITY

In mineralised areas it is common to find a suite of enriched elements that have resulted from natural geological processes. Multi-element scans are carried out to identify any elements that are present in a material (or readily leachable from a material) at concentrations that may be of environmental concern with respect to surface water quality, revegetation and public health. The samples are generally analysed for the following elements:

Major elements Al, Ca, Fe, K, Mg, Na and S.

Minor elements As, Cd, Co, Cr, Cu, F, Mn, Mo, Ni, Pb, Sb, Se and Zn.

The concentration of these elements in samples can be directly compared with relevant state or national environmental and health based concentration guideline criteria to determine the level of significance. Water extracts are used to determine the immediate element solubilities under the existing sample pH conditions of the sample. The following tests are normally carried out:

Multi-element composition of solids. Multi-element composition of solid samples determined using a combination of ICP-mass spectroscopy (ICP-MS), ICP-optical emission spectroscopy (OES), and atomic absorption spectrometry (AAS).

Multi-element composition of water extracts (1:5 sample:deionised water). Multi-element composition of water extracts from solid samples determined using a combination of ICP-mass spectroscopy (ICP-MS), ICP-optical emission spectroscopy (OES), and atomic absorption spectrometry (AAS).

Attachment B
Static Geochemical Test Results

Table B1: Acid-Base Account (ABA) Test Results for Waste Rock Samples

RGS Sample No.	ALS Laboratory ID	Client Sample ID	Northing	Easting	Elevation (m)	Lithological Description	Moisture Content (%)	pH[1]	EC[1] µS/cm	Total S (%)	Scr[2] (%)	MPA[2] kg H_2SO_4/t	ANC[2] kg H_2SO_4/t	NAPP[2] kg H_2SO_4/t	ANC: MPA Ratio	Sample Classification[3]
1	EB1513149001	RS01-1	227712	6146575	390.0	W - limestone = Mg rich	<1.0	9.2	90	0.080	-	2.45	950	-948	388	NAF (Barren)
2	EB1513149002	RS01-2	227712	6146575	390.0	W - limestone = Mg rich	<1.0	9.2	80	0.070	-	2.14	943	-941	440	NAF (Barren)
3	EB1513149003	RS02-1	228113	6147570	450.6	E - limestone	<1.0	9.2	82	0.005	-	0.15	989	-989	6459	NAF (Barren)
4	EB1513149004	RS02-2	228113	6147570	450.6	E - limestone	<1.0	9.4	62	0.005	-	0.15	1000	-1000	6531	NAF (Barren)
5	EB1513149005	RS03a	228099	6147230	624.1	E - extremely weathered dyke, material peeling by hand	3.5	8.5	1,430	0.050	-	1.53	228	-226	149	NAF (Barren)
6	EB1513149006	RS03b	228129	6147192	536.0	E - mafic dyke	2.2	8.6	141	0.140	0.114	4.29	126	-122	29	NAF
7	EB1513149007	RS04-1	228124	6147169	538.0	E - contact between limestone and shales - ferrugized material	1.6	8.3	256	0.020	-	0.61	113	-112	184	NAF (Barren)
8	EB1513149008	RS04-2	228124	6147169	538.0	E - contact between limestone and shales - ferrugized material	2.0	8.3	138	0.005	-	0.15	67	-67	440	NAF (Barren)
9	EB1513149009	RS05-1	228132	6147157	539.6	E - transitional zone - insitu weathered material - clays	2.0	8.5	199	0.005	-	0.15	4.6	-4.4	30	NAF (Barren)
10	EB1513149010	RS05-2	228132	6147157	539.6	E - transitional zone - insitu weathered material - clays	<1.0	8.5	149	0.005	-	0.15	3.2	-3.0	21	NAF (Barren)
11	EB1513149011	RS06-1	228161	6147145	540.9	E - shale, mudstone	1.3	8.0	1,430	0.005	-	0.15	2.0	-1.8	13	NAF (Barren)
12	EB1513149012	RS06-2	228161	6147145	540.9	E - shale, mudstone	1.4	8.4	733	0.005	-	0.15	1.5	-1.3	10	NAF (Barren)
13	EB1513149013	RS07-1	227768	6147266	566.2	W - white sandstone(?), brittle, feldspar, silica-rich (?)	<1.0	8.7	144	0.005	-	0.15	0.3	-0.1	2.0	NAF (Barren)
14	EB1513149014	RS07-2	227768	6147266	566.2	W - white sandstone(?), brittle, feldspar, silica-rich (?)	<1.0	8.8	105	0.005	-	0.15	0.3	-0.1	2.0	NAF (Barren)
15	EB1513149015	RS08-1	227785	6147392	572.5	W - red soil/clay, decomposed sandstone with ferritic bands, nodules	1.1	7.6	471	0.005	-	0.15	3.2	-3.0	21	NAF (Barren)
16	EB1513149016	RS08-2	227785	6147392	572.5	W - red soil/clay, decomposed sandstone with ferritic bands, nodules	1.9	7.9	886	0.020	-	0.61	0.8	-0.2	1.3	NAF (Barren)
17	EB1513149017	RS09-1	227860	6147638	557.1	W - brown sandstone, claystone, blocky, hard	<1.0	8.4	143	0.005	-	0.15	7.0	-6.8	46	NAF (Barren)
18	EB1513149018	RS09-2	227860	6147638	557.1	W - brown sandstone, claystone, blocky, hard	<1.0	8.4	145	0.005	-	0.15	0.9	-0.7	5.9	NAF (Barren)
19	EB1513149019	RS10-1	228279	6147381	568.9	E - unweathered shale	<1.0	8.5	138	0.005	-	0.15	2.4	-2.2	16	NAF (Barren)
20	EB1513149020	RS10-2	228279	6147381	568.9	E - unweathered shale	<1.0	8.7	62	0.005	-	0.15	0.8	-0.6	5.2	NAF (Barren)

Notes:

1. Current pH, EC, Alkalinity and Acidity provided for 1:5 sample:water extracts
2. Scr = Chromium Reducible Sulfur; MPA = Maximum Potential Acidity; ANC = Acid Neutralising Capacity; and NAPP = Net Acid Producing Potential.
3. Sample classification detail provided in report text.

Table B2: Waste Rock Samples Selected for Additional Static Geochemical Tests

RGS Sample No.	RGS Comp. Sample No.	ALS Laboratory ID	Client Sample ID	Northing	Easting	Elevation (m)	Lithological Description	pH[1]	EC[1] µS/cm	Total S (%)	Scr[2] (%)	MPA[2] kg H_2SO_4/t	ANC[2] kg H_2SO_4/t	NAPP[2] kg H_2SO_4/t	ANC:MPA Ratio	Sample Classification[3]
1	1	EB1513149001	RS01-1	227712	6146575	390.0	W - limestone = Mg rich	9.2	90	0.080	-	2.45	950	-948	388	NAF (Barren)
2		EB1513149002	RS01-2	227712	6146575	390.0	W - limestone = Mg rich	9.2	80	0.070	-	2.14	943	-941	440	NAF (Barren)
5	2	EB1513149005	RS03a	228099	6147230	624.1	E - extremely weathered dyke, material peeling by hand	8.5	1,430	0.050	-	1.53	228	-226	149	NAF (Barren)
6		EB1513149006	RS03b	228129	6147192	536.0	E - mafic dyke	8.6	141	0.140	0.114	4.29	126	-122	29	NAF
7	3	EB1513149007	RS04-1	228124	6147169	538.0	E - contact between limestone and shales - ferrugized material	8.3	256	0.020	-	0.61	113	-112	184	NAF (Barren)
8		EB1513149008	RS04-2	228124	6147169	538.0	E - contact between limestone and shales - ferrugized material	8.3	138	0.005	-	0.15	67	-67	440	NAF (Barren)
11	4	EB1513149011	RS06-1	228161	6147145	540.9	E - shale, mudstone	8.0	1,430	0.005	-	0.15	2.0	-1.8	13	NAF (Barren)
12		EB1513149012	RS06-2	228161	6147145	540.9	E - shale, mudstone	8.4	733	0.005	-	0.15	1.5	-1.3	10	NAF (Barren)
17	5	EB1513149017	RS09-1	227860	6147638	557.1	W - brown sandstone, claystone, blocky, hard	8.4	143	0.005	-	0.15	7.0	-6.8	46	NAF (Barren)
18		EB1513149018	RS09-2	227860	6147638	557.1	W - brown sandstone, claystone, blocky, hard	8.4	145	0.005	-	0.15	0.9	-0.7	5.9	NAF (Barren)
19	6	EB1513149019	RS10-1	228279	6147381	568.9	E - unweathered shale	8.5	138	0.005	-	0.15	2.4	-2.2	16	NAF (Barren)
20		EB1513149020	RS10-2	228279	6147381	568.9	E - unweathered shale	8.7	62	0.005	-	0.15	0.8	-0.6	5.2	NAF (Barren)

Notes:

1. Current pH, EC, Alkalinity and Acidity provided for 1:5 sample:water extracts
2. Scr = Chromium Reducible Sulfur; MPA = Maximum Potential Acidity; ANC = Acid Neutralising Capacity; and NAPP = Net Acid Producing Potential.
3. Sample classification detail provided in report text.

Table B3: Multi-Element Test Results for Composite Waste Rock Samples

		RGS Composite No. →	1	2	3	4	5	6
		ALS Laboratory ID →	EB1514367-013	EB1514367-014	EB1514367-015	EB1514367-016	EB1514367-017	EB1514367-018
		Sample Description →						
Parameters	Detection Limit	NEPC[1] Health-Based Investigation Level (HILs)-C	Limestone	Mafic Dyke	Contact Material Between Limestone and Shales	Shale/ Mudstone	Sandstone/ Claystone	Shale
Major Cations	All units in mg/kg							
Calcium (Ca)	50	-	396,000	55,200	30,400	1,260	2,050	600
Magnesium (Mg)	50	-	4,340	15,200	6,980	260	840	220
Potassium (K)	50	-	280	1,290	550	1,320	660	2,420
Sodium (Na)	50	-	<50	700	460	620	<50	70
Major, Minor and Trace Elements	All units in mg/kg							
Aluminium (Al)	50	-	410	19,500	7,340	5,010	4,170	5,730
Antimony (Sb)	5	-	<5	<5	<5	<5	<5	<5
Arsenic (As)	5	300	<5	<5	66	14	10	10
Barium (Ba)	10	-	<10	80	220	20	30	40
Beryllium (Be)	1	90	<1	1	3	1	<1	<1
Boron (B)	50	20,000	<50	<50	<50	<50	<50	<50
Cadmium (Cd)	1	90	<1	<1	2	<1	<1	<1
Chromium (Cr) - hexavalent	2	300 **	15	76	26	52	80	78
Cobalt (Co)	2	300	<2	30	561	6	12	3
Copper (Cu)	5	17,000	<5	40	43	28	19	22
Iron (Fe)	50	-	2,860	54,200	235,000	35,100	19,400	21,300
Lead (Pb)	5	600	<5	<5	9	24	12	17
Manganese (Mn)	5	19,000	291	923	18,300	81	118	20
Mercury (Hg)	0.1	80	<0.1	<0.1	0	<0.1	<0.1	<0.1
Molybdenum (Mo)	2	-	<2	<2	<2	<2	<2	<2
Nickel (Ni)	2	1,200	3	87	403	18	18	7
Selenium (Se)	5	700	<5	<5	<5	<5	<5	<5
Thorium (Th)	0.1	-	0.9	2	3	13	6	11
Uranium (U)	0.1	-	1.2	0	3	2	1	1
Vanadium (V)	5	-	<5	111	51	19	30	13
Zinc (Zn)	5	30,000	5	78	600	56	44	32

Notes: < indicates less than the laboratory limit of reporting. Shaded cells exceed applied guideline limit.
** Guideline level for Cr(VI) = 300 mg/kg. Guideline level for Cr(III) = 24% of total Cr.
1. NEPC (2013). National Environmental Protection Council (NEPC). *National Environmental Protection (Assessment of Site Contamination) Measure (NEPM)* , Amendment of Schedule B1-B7 of 1999 version. *Guideline on Investigation Levels for Soil and Groundwater. Health-Based Investigation Level - HIL(C); public open spaces - recreational use* .

Table B4: Geochemical Abundance Index (GAI) Results for Composite Waste Rock Samples

		RGS Composite No. →	1	2	3	4	5	6
		ALS Laboratory ID →	EB1514367-013	EB1514367-014	EB1514367-015	EB1514367-016	EB1514367-017	EB1514367-018
		Sample Description →						
Parameters	Detection Limit	Average Crustal Abundance[1]	Limestone	Mafic Dyke	Contact Material Between Limestone and Shales	Shale/ Mudstone	Sandstone/ Claystone	Shale
Major Elements	All units in mg/kg		GAI value					
Aluminium (Al)	50	71,000	0	0	0	0	0	0
Calcium (Ca)	50	15,000	4	1	0	0	0	0
Iron (Fe)	50	40,000	0	0	2	0	0	0
Magnesium (Mg)	50	5,000	0	1	0	0	0	0
Potassium (K)	50	14,000	0	0	0	0	0	0
Sodium (Na)	50	5,000	0	0	0	0	0	0
Minor Elements	All units in mg/kg		GAI value					
Antimony (Sb)	5	5	0	0	0	0	0	0
Arsenic (As)	5	6	0	0	3	1	0	0
Barium (Ba)	10	500	0	0	0	0	0	0
Beryllium (Be)	1	6	0	0	0	0	0	0
Boron (B)	50	100	0	0	0	0	0	0
Cadmium (Cd)	1	0.35	0	0	2	0	0	0
Chromium (Cr) - hexavalent	2	70	0	0	0	0	0	0
Cobalt (Co)	2	8	0	1	6	0	0	0
Copper (Cu)	5	30	0	0	0	0	0	0
Lead (Pb)	5	35	0	0	0	0	0	0
Manganese (Mn)	5	1,000	0	0	4	0	0	0
Mercury (Hg)	0.1	0.06	0	0	0	0	0	0
Molybdenum (Mo)	2	2	0	0	0	0	0	0
Nickel (Ni)	2	50	0	0	2	0	0	0
Selenium (Se)	5	0.4	0	0	0	0	0	0
Thorium (Th)	0.1	9	0	0	0	0	0	0
Uranium (U)	0.1	2	0	0	0	0	0	0
Vanadium (V)	5	90	0	0	0	0	0	0
Zinc (Zn)	5	90	0	0	2	0	0	0

Notes: GAI's greater than or equal to 3 are highlighted.

1. Average Crustal Abundance values sourced from the "GARD Guide", Chapter 5 (INAP, 2009).

1. When no GARD Guide value is available for particular element, then values are taken from Bowen H.J.M.(1979) Environmental Chemistry of the Elements, pages 42-43.

Table B5: Multi-Element Test Results for Water Extracts from Composite Waste Rock Samples

Parameters	Detection Limit	Aquatic Ecosystems (freshwater)[1]	Livestock Drinking Water[2]	1	2	3	4	5	6
			RGS Sample Number →	1	2	3	4	5	6
			ALS Laboratory ID →	EB1514367-013	EB1514367-014	EB1514367-015	EB1514367-016	EB1514367-017	EB1514367-018
			Sample Description →	Limestone	Mafic Dyke	Contact Material Between Limestone and Shales	Shale/ Mudstone	Sandstone/ Claystone	Shale
		Water Quality Guidelines:							
pH	0.01 pH unit	6 to 9	-	9.5	8.8	8.5	8.3	8.8	8.8
Electrical Conductivity	1 µS/cm	<1,000#	3,580^	79	126	177	983	123	94
Carbonate Alkalinity ($mgCaCO_3$/	0.2 mg/L	-	-	74	9	6	<0.2	7	3
Bicarbonate Alkalinity (mgCaCO	0.2 mg/L	-	-	1,352	54	52	23	35	41
Total Alkalinity ($mgCaCO_3$/L)	0.2 mg/L	-	-	1,426	63	57	23	42	44
Acidity ($mgCaCO_3$/L)	0.2 mg/L	-	-	<0.2	1	<0.2	2	<0.2	1
Net Alkalinity ($mgCaCO_3$/L)	0.2 mg/L	-	-	1,426	62	57	20	42	43
Major Ions	All units mg/L								
Calcium (Ca)	2	-	1,000	8	16	20	74	12	6
Magnesium (Mg)	2	-	-	<2	<2	<2	6	<2	<2
Potassium (K)	2	-	-	4	2	<2	20	6	16
Sodium (Na)	2	-	-	4	2	8	100	4	2
Chloride (Cl)	2	-	-	6	<2	18	336	10	4
Fluoride (F)	0.2	-	2	0.4	0.6	0.4	0.6	1.0	0.8
Phosphate (PO_4)	0.06	-	-	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06
Sulfate (SO_4)	2	-	1,000	4	10	6	<2	4	4
Trace Metals/Metalloids	All units mg/L								
Aluminium (Al)	0.02	0.055	5	0.30	<0.02	<0.02	<0.02	<0.02	0.12
Antimony (Sb)	0.002	-	-	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Arsenic (As) - pentavalent	0.002	0.013 **	0.5	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Barium (Ba)	0.002	-	-	<0.002	0.002	<0.002	0.008	0.00	<0.002
Beryllium (Be)	0.002	-	-	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Boron (B)	0.2	0.37	5	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Cadmium (Cd)	0.002	0.0002	0.01	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Chromium (Cr) - total	0.002	0.001 (hex)*	1 (total)	<0.002	<0.002	0.006	<0.002	0.002	<0.002
Cobalt (Co)	0.002	-	1	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Copper (Cu)	0.002	0.0014	1	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Iron (Fe)	0.2	-	-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Lead (Pb)	0.002	0.0034	0.1	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Manganese (Mn)	0.002	1.90	-	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Mercury (Hg)	0.0001	0.0006	0.002	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Molybdenum (Mo)	0.002	-	0.15	<0.002	0.002	<0.002	<0.002	<0.002	<0.002
Nickel (Ni)	0.002	0.011	1	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Selenium (Se)	0.02	0.011	0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Thorium (Th)	0.002	-	-	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Uranium (U)	0.002	-	0.2	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Vanadium (V)	0.02	-	-	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Zinc (Zn)	0.01	0.008	20	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

* Cr (VI) = hexavalent. ** 0.024 mg/Lfor trivalent Arsenic (III).
# for still water bodies only, moving rivers at low flow rates should not exceed 2,200µS/cı
^ calculated based on total dissolved solids (TDS) conversion rate of 0.67% of EC. TDS is an approximate measure of inorganic dissolved salts and should not exceed 2,400mg/L for livestock drinking water.

Notes: < indicates concentration less than the detection limit. Shaded cells exceed applied guideline values.
1. ANZECC & ARMCANZ (2000). Trigger values for aquatic ecosystems (95% species protection level)
2. ANZECC & ARMCANZ (2000). Recommended guideline limits for Livestock Drinking Water.
1 + 2. both taken from the "Australian and New Zealand Guidelines for Fresh and Marine Water Quality", National Water Quality Management Strategy, 2000, compilation by ANZECC and ARMCANZ.

Attachment C
ALS Laboratory Results

ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order	: **EB1513149**	Page	: 1 of 7
Client	: **RGS ENVIRONMENTAL PTY LTD**	Laboratory	: Environmental Division Brisbane
Contact	: MR ALAN ROBERTSON	Contact	: Customer Services EB
Address	: PO Box 3091 SUNNYBANK SOUTH QLD, AUSTRALIA 4109	Address	: 2 Byth Street Stafford QLD Australia 4053
E-mail	: alan@rgsenv.com	E-mail	: ALSEnviro.Brisbane@alsglobal.com
Telephone	: +61 07 3344 1222	Telephone	: +61-7-3243 7222
Facsimile	: +61 07 3344 1222	Facsimile	: +61-7-3243 7218
Project	: 201427-Marulan	QC Level	: NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Order number	: ----	Date Samples Received	: 19-Feb-2015 08:30
C-O-C number	: ----	Date Analysis Commenced	: 24-Feb-2015
Sampler	: ----	Issue Date	: 05-Mar-2015 14:32
Site	: ----		
		No. of samples received	: 21
Quote number	: ----	No. of samples analysed	: 21

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

NATA Accredited Laboratory 825

Accredited for compliance with ISO/IEC 17025.

Signatories

This document has been electronically signed by the authorized signatories indicated below. Electronic signing has been carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Kim McCabe	Senior Inorganic Chemist	Brisbane Inorganics
Satishkumar Trivedi	2 IC Acid Sulfate Soils Supervisor	Brisbane Acid Sulphate Soils

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting
ø = ALS is not NATA accredited for these tests.

- ASS: EA013 (ANC) Fizz Rating: 0- None; 1- Slight; 2- Moderate; 3- Strong; 4- Very Strong; 5- Lime.

Analytical Results

Sub-Matrix: DI WATER (Matrix: WATER)			Client sample ID	Di-Water used in 1:5 leach.	----	----	----	----
			Client sampling date / time	[19-Feb-2015]	----	----	----	----
Compound	CAS Number	LOR	Unit	EB1513149-021	--------	--------	--------	--------
				Result	Result	Result	Result	Result
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	**5.73**	----	----	----	----
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	**1**	----	----	----	----

Analytical Results

Sub-Matrix: ROCK (Matrix: SOIL)			Client sample ID	RS01-1	RS01-2	RS02-1	RS02-2	RS03a
			Client sampling date / time	[12-Feb-2015]	[12-Feb-2015]	[12-Feb-2015]	[12-Feb-2015]	[12-Feb-2015]
Compound	CAS Number	LOR	Unit	EB1513149-001	EB1513149-002	EB1513149-003	EB1513149-004	EB1513149-005
				Result	Result	Result	Result	Result
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	9.2	9.2	9.2	9.4	8.5
EA009: Nett Acid Production Potential								
^ Net Acid Production Potential	----	0.5	kg H2SO4/t	-948	-941	-989	-1000	-226
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	90	80	82	62	1430
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	950	943	989	1000	228
^ ANC as CaCO3	----	0.1	% CaCO3	97.0	96.2	101	102	23.3
Fizz Rating	----	0	Fizz Unit	5	5	5	5	3
EA055: Moisture Content								
^ Moisture Content (dried @ 103°C)	----	1	%	<1.0	<1.0	<1.0	<1.0	3.5
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.08	0.07	<0.01	<0.01	0.05

Analytical Results

Sub-Matrix: **ROCK** (Matrix: **SOIL**)			Client sample ID	RS03b	RS04-1	RS04-2	RS05-1	RS05-2
			Client sampling date / time	[12-Feb-2015]	[12-Feb-2015]	[12-Feb-2015]	[12-Feb-2015]	[12-Feb-2015]
Compound	CAS Number	LOR	Unit	EB1513149-006	EB1513149-007	EB1513149-008	EB1513149-009	EB1513149-010
				Result	Result	Result	Result	Result
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	**8.6**	**8.3**	**8.3**	**8.5**	**8.5**
EA009: Nett Acid Production Potential								
^ Net Acid Production Potential	----	0.5	kg H2SO4/t	**-122**	**-112**	**-67.4**	**-4.6**	**-3.2**
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	**141**	**256**	**138**	**199**	**149**
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	**126**	**113**	**67.4**	**4.6**	**3.2**
^ ANC as CaCO3	----	0.1	% CaCO3	**12.8**	**11.6**	**6.9**	**0.5**	**0.3**
Fizz Rating	----	0	Fizz Unit	**3**	**3**	**2**	**0**	**0**
EA055: Moisture Content								
^ Moisture Content (dried @ 103°C)	----	1	%	**2.2**	**1.6**	**2.0**	**2.0**	<1.0
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	**0.14**	**0.02**	<0.01	<0.01	<0.01

Analytical Results

Sub-Matrix: ROCK (Matrix: SOIL)			Client sample ID	RS06-1	RS06-2	RS07-1	RS07-2	RS08-1
			Client sampling date / time	[12-Feb-2015]	[12-Feb-2015]	[12-Feb-2015]	[12-Feb-2015]	[12-Feb-2015]
Compound	CAS Number	LOR	Unit	EB1513149-011	EB1513149-012	EB1513149-013	EB1513149-014	EB1513149-015
				Result	Result	Result	Result	Result
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	**8.0**	**8.4**	**8.7**	**8.8**	**7.6**
EA009: Nett Acid Production Potential								
^ Net Acid Production Potential	----	0.5	kg H2SO4/t	**-2.0**	**-1.5**	<0.5	<0.5	**-3.2**
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	**1430**	**733**	**144**	**105**	**471**
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	**2.0**	**1.5**	<0.5	<0.5	**3.2**
^ ANC as CaCO3	----	0.1	% CaCO3	**0.2**	**0.2**	<0.1	<0.1	**0.3**
Fizz Rating	----	0	Fizz Unit	**0**	**0**	**0**	**0**	**0**
EA055: Moisture Content								
^ Moisture Content (dried @ 103°C)	----	1	%	**1.3**	**1.4**	<1.0	<1.0	**1.1**
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	<0.01	<0.01	<0.01	<0.01	<0.01

Analytical Results

Sub-Matrix: ROCK (Matrix: SOIL)			Client sample ID	RS08-2	RS09-1	RS09-2	RS10-1	RS10-2
			Client sampling date / time	[12-Feb-2015]	[12-Feb-2015]	[12-Feb-2015]	[12-Feb-2015]	[12-Feb-2015]
Compound	CAS Number	LOR	Unit	EB1513149-016	EB1513149-017	EB1513149-018	EB1513149-019	EB1513149-020
				Result	Result	Result	Result	Result
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	7.9	8.4	8.4	8.5	8.7
EA009: Nett Acid Production Potential								
^ Net Acid Production Potential	----	0.5	kg H2SO4/t	0.00	-7.0	-0.9	-2.4	-0.8
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	886	143	145	138	62
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	0.8	7.0	0.9	2.4	0.8
^ ANC as CaCO3	----	0.1	% CaCO3	<0.1	0.7	<0.1	0.2	<0.1
Fizz Rating	----	0	Fizz Unit	0	0	0	0	0
EA055: Moisture Content								
^ Moisture Content (dried @ 103°C)	----	1	%	1.9	<1.0	<1.0	<1.0	<1.0
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	0.02	<0.01	<0.01	<0.01	<0.01

CERTIFICATE OF ANALYSIS

Work Order	: **EB1514367**	Page	: 1 of 8
Client	: **RGS ENVIRONMENTAL PTY LTD**	Laboratory	: Environmental Division Brisbane
Contact	: MR ALAN ROBERTSON	Contact	: Customer Services EB
Address	: PO Box 3091 SUNNYBANK SOUTH QLD, AUSTRALIA 4109	Address	: 2 Byth Street Stafford QLD Australia 4053
E-mail	: alan@rgsenv.com	E-mail	: ALSEnviro.Brisbane@alsglobal.com
Telephone	: +61 07 3344 1222	Telephone	: +61-7-3243 7222
Facsimile	: +61 07 3344 1222	Facsimile	: +61-7-3243 7218
Project	: 201427 - Marulan Limestone	QC Level	: NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Order number	: ----	Date Samples Received	: 09-Mar-2015 18:06
C-O-C number	: ----	Date Analysis Commenced	: 11-Mar-2015
Sampler	: ----	Issue Date	: 18-Mar-2015 16:56
Site	: ----		
		No. of samples received	: 18
Quote number	: ----	No. of samples analysed	: 7

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

NATA Accredited Laboratory 825

Accredited for compliance with ISO/IEC 17025.

Signatories

This document has been electronically signed by the authorized signatories indicated below. Electronic signing has been carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Andrew Epps	Senior Inorganic Chemist	Brisbane Inorganics
Kim McCabe	Senior Inorganic Chemist	Brisbane Inorganics
Satishkumar Trivedi	2 IC Acid Sulfate Soils Supervisor	Brisbane Acid Sulphate Soils

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting
ø = ALS is not NATA accredited for these tests.

Analytical Results

Sub-Matrix: PULP
(Matrix: SOIL)

Compound	CAS Number	LOR	Unit	RS03b EB1513149006	COMPOSITE 1 Composite of 1 & 2	COMPOSITE 2 Composite of 3 & 4	COMPOSITE 3 Composite of 5 & 6	COMPOSITE 4 Composite of 7 & 8
Client sampling date / time				[09-Mar-2015]	[09-Mar-2015]	[09-Mar-2015]	[09-Mar-2015]	[09-Mar-2015]
				EB1514367-004	EB1514367-013	EB1514367-014	EB1514367-015	EB1514367-016
				Result	Result	Result	Result	Result
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	----	9.5	8.8	8.5	8.3
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	----	79	126	177	983
EA026 : Chromium Reducible Sulfur								
Chromium Reducible Sulphur	----	0.005	%	0.114	----	----	----	----
ED037: Alkalinity								
Total Alkalinity as CaCO3	----	1	mg/kg	----	7130	317	286	113
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/kg	----	6760	272	258	113
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/kg	----	368	45	28	<5
ED038A: Acidity								
Acidity	----	1	mg/kg	----	<1	6	<1	11
ED040S : Soluble Sulfate by ICPAES								
Sulfate as SO4 2-	14808-79-8	10	mg/kg	----	20	50	30	<10
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	10	mg/kg	----	30	<10	90	1680
ED093S: Soluble Major Cations								
Calcium	7440-70-2	10	mg/kg	----	40	80	100	370
Magnesium	7439-95-4	10	mg/kg	----	<10	<10	<10	30
Sodium	7440-23-5	10	mg/kg	----	20	10	40	500
Potassium	7440-09-7	10	mg/kg	----	20	10	<10	100
ED093T: Total Major Cations								
Calcium	7440-70-2	50	mg/kg	----	396000	55200	30400	1260
Magnesium	7439-95-4	50	mg/kg	----	4340	15200	6980	260
Sodium	7440-23-5	50	mg/kg	----	<50	700	460	620
Potassium	7440-09-7	50	mg/kg	----	280	1290	550	1320
EG005S : Soluble Metals by ICPAES								
Boron	7440-42-8	1	mg/kg	----	<1	<1	<1	<1
Iron	7439-89-6	1	mg/kg	----	<1	<1	<1	<1
EG005T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	----	410	19500	7340	5010
Antimony	7440-36-0	5	mg/kg	----	<5	<5	<5	<5
Arsenic	7440-38-2	5	mg/kg	----	<5	<5	66	14
Barium	7440-39-3	10	mg/kg	----	<10	80	220	20
Beryllium	7440-41-7	1	mg/kg	----	<1	1	3	1

Analytical Results

Sub-Matrix: PULP (Matrix: SOIL)			Client sample ID	RS03b EB1513149006	COMPOSITE 1 Composite of 1 & 2	COMPOSITE 2 Composite of 3 & 4	COMPOSITE 3 Composite of 5 & 6	COMPOSITE 4 Composite of 7 & 8
			Client sampling date / time	[09-Mar-2015]	[09-Mar-2015]	[09-Mar-2015]	[09-Mar-2015]	[09-Mar-2015]
Compound	CAS Number	LOR	Unit	EB1514367-004	EB1514367-013	EB1514367-014	EB1514367-015	EB1514367-016
				Result	Result	Result	Result	Result
EG005T: Total Metals by ICP-AES - Continued								
Boron	7440-42-8	50	mg/kg	----	<50	<50	<50	<50
Cadmium	7440-43-9	1	mg/kg	----	<1	<1	**2**	<1
Chromium	7440-47-3	2	mg/kg	----	**15**	**76**	**26**	**52**
Cobalt	7440-48-4	2	mg/kg	----	<2	**30**	**561**	**6**
Copper	7440-50-8	5	mg/kg	----	<5	**40**	**43**	**28**
Iron	7439-89-6	50	mg/kg	----	**2860**	**54200**	**235000**	**35100**
Lead	7439-92-1	5	mg/kg	----	<5	<5	**9**	**24**
Manganese	7439-96-5	5	mg/kg	----	**291**	**923**	**18300**	**81**
Molybdenum	7439-98-7	2	mg/kg	----	<2	<2	<2	<2
Nickel	7440-02-0	2	mg/kg	----	**3**	**87**	**403**	**18**
Selenium	7782-49-2	5	mg/kg	----	<5	<5	<5	<5
Vanadium	7440-62-2	5	mg/kg	----	<5	**111**	**51**	**19**
Zinc	7440-66-6	5	mg/kg	----	**5**	**78**	**600**	**56**
EG020S: Soluble Metals by ICPMS								
Arsenic	7440-38-2	0.01	mg/kg	----	<0.01	<0.01	<0.01	<0.01
Selenium	7782-49-2	0.1	mg/kg	----	<0.1	<0.1	<0.1	<0.1
Barium	7440-39-3	0.01	mg/kg	----	<0.01	**0.01**	<0.01	**0.04**
Beryllium	7440-41-7	0.01	mg/kg	----	<0.01	<0.01	<0.01	<0.01
Cadmium	7440-43-9	0.01	mg/kg	----	<0.01	<0.01	<0.01	<0.01
Cobalt	7440-48-4	0.01	mg/kg	----	<0.01	<0.01	<0.01	<0.01
Chromium	7440-47-3	0.01	mg/kg	----	<0.01	<0.01	**0.03**	<0.01
Copper	7440-50-8	0.01	mg/kg	----	<0.01	<0.01	<0.01	<0.01
Manganese	7439-96-5	0.01	mg/kg	----	<0.01	<0.01	<0.01	<0.01
Molybdenum	7439-98-7	0.01	mg/kg	----	<0.01	**0.01**	<0.01	<0.01
Nickel	7440-02-0	0.01	mg/kg	----	<0.01	<0.01	<0.01	<0.01
Lead	7439-92-1	0.01	mg/kg	----	<0.01	<0.01	<0.01	<0.01
Antimony	7440-36-0	0.01	mg/kg	----	<0.01	<0.01	<0.01	<0.01
Uranium	7440-61-1	0.01	mg/kg	----	<0.01	<0.01	<0.01	<0.01
Zinc	7440-66-6	0.05	mg/kg	----	<0.05	<0.05	<0.05	<0.05
Vanadium	7440-62-2	0.1	mg/kg	----	<0.1	<0.1	<0.1	<0.1
Aluminium	7429-90-5	0.1	mg/kg	----	**1.5**	<0.1	<0.1	<0.1
Thorium	7440-29-1	0.01	mg/kg	----	<0.01	<0.01	<0.01	<0.01
EG020T: Total Metals by ICP-MS								
Thorium	7440-29-1	0.1	mg/kg	----	**0.9**	**1.9**	**2.7**	**12.8**
Uranium	7440-61-1	0.1	mg/kg	----	**1.2**	**0.4**	**2.8**	**2.1**

Analytical Results

Sub-Matrix: PULP (Matrix: SOIL)			Client sample ID	RS03b EB1513149006	COMPOSITE 1 Composite of 1 & 2	COMPOSITE 2 Composite of 3 & 4	COMPOSITE 3 Composite of 5 & 6	COMPOSITE 4 Composite of 7 & 8
			Client sampling date / time	[09-Mar-2015]	[09-Mar-2015]	[09-Mar-2015]	[09-Mar-2015]	[09-Mar-2015]
Compound	CAS Number	LOR	Unit	EB1514367-004	EB1514367-013	EB1514367-014	EB1514367-015	EB1514367-016
				Result	Result	Result	Result	Result
EG035S: Soluble Mercury by FIMS								
Mercury	7439-97-6	0.0005	mg/kg	----	<0.0005	<0.0005	<0.0005	<0.0005
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.1	mg/kg	----	<0.1	<0.1	**0.1**	<0.1
EK040S: Fluoride Soluble								
Fluoride	16984-48-8	1	mg/kg	----	**2**	**3**	**2**	**3**
EK071G: Reactive Phosphorus as P by discrete analyser								
Reactive Phosphorus as P	14265-44-2	0.1	mg/kg	----	<0.1	<0.1	<0.1	<0.1

Analytical Results

Sub-Matrix: PULP (Matrix: SOIL)			Client sample ID	COMPOSITE 5 Composite of 9 & 10	COMPOSITE 6 Composite of 11 & 12	----	----	----
			Client sampling date / time	[09-Mar-2015]	[09-Mar-2015]	----	----	----
Compound	CAS Number	LOR	Unit	EB1514367-017	EB1514367-018	--------	--------	--------
				Result	Result	Result	Result	Result
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	8.8	8.8	----	----	----
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	123	94	----	----	----
EA026 : Chromium Reducible Sulfur								
Chromium Reducible Sulphur	----	0.005	%	----	----	----	----	----
ED037: Alkalinity								
Total Alkalinity as CaCO3	----	1	mg/kg	211	221	----	----	----
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/kg	176	207	----	----	----
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/kg	35	14	----	----	----
ED038A: Acidity								
Acidity	----	1	mg/kg	<1	6	----	----	----
ED040S : Soluble Sulfate by ICPAES								
Sulfate as SO4 2-	14808-79-8	10	mg/kg	20	20	----	----	----
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	10	mg/kg	50	20	----	----	----
ED093S: Soluble Major Cations								
Calcium	7440-70-2	10	mg/kg	60	30	----	----	----
Magnesium	7439-95-4	10	mg/kg	<10	<10	----	----	----
Sodium	7440-23-5	10	mg/kg	20	10	----	----	----
Potassium	7440-09-7	10	mg/kg	30	80	----	----	----
ED093T: Total Major Cations								
Calcium	7440-70-2	50	mg/kg	2050	600	----	----	----
Magnesium	7439-95-4	50	mg/kg	840	220	----	----	----
Sodium	7440-23-5	50	mg/kg	<50	70	----	----	----
Potassium	7440-09-7	50	mg/kg	660	2420	----	----	----
EG005S : Soluble Metals by ICPAES								
Boron	7440-42-8	1	mg/kg	<1	<1	----	----	----
Iron	7439-89-6	1	mg/kg	<1	<1	----	----	----
EG005T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	4170	5730	----	----	----
Antimony	7440-36-0	5	mg/kg	<5	<5	----	----	----
Arsenic	7440-38-2	5	mg/kg	10	10	----	----	----
Barium	7440-39-3	10	mg/kg	30	40	----	----	----
Beryllium	7440-41-7	1	mg/kg	<1	<1	----	----	----

Analytical Results

Sub-Matrix: PULP (Matrix: SOIL)			Client sample ID	COMPOSITE 5 Composite of 9 & 10	COMPOSITE 6 Composite of 11 & 12	----	----	----
			Client sampling date / time	[09-Mar-2015]	[09-Mar-2015]	----	----	----
Compound	CAS Number	LOR	Unit	EB1514367-017	EB1514367-018	--------	--------	--------
				Result	Result	Result	Result	Result
EG005T: Total Metals by ICP-AES - Continued								
Boron	7440-42-8	50	mg/kg	<50	<50	----	----	----
Cadmium	7440-43-9	1	mg/kg	<1	<1	----	----	----
Chromium	7440-47-3	2	mg/kg	**80**	**78**	----	----	----
Cobalt	7440-48-4	2	mg/kg	**12**	**3**	----	----	----
Copper	7440-50-8	5	mg/kg	**19**	**22**	----	----	----
Iron	7439-89-6	50	mg/kg	**19400**	**21300**	----	----	----
Lead	7439-92-1	5	mg/kg	**12**	**17**	----	----	----
Manganese	7439-96-5	5	mg/kg	**118**	**20**	----	----	----
Molybdenum	7439-98-7	2	mg/kg	<2	<2	----	----	----
Nickel	7440-02-0	2	mg/kg	**18**	**7**	----	----	----
Selenium	7782-49-2	5	mg/kg	<5	<5	----	----	----
Vanadium	7440-62-2	5	mg/kg	**30**	**13**	----	----	----
Zinc	7440-66-6	5	mg/kg	**44**	**32**	----	----	----
EG020S: Soluble Metals by ICPMS								
Arsenic	7440-38-2	0.01	mg/kg	<0.01	<0.01	----	----	----
Selenium	7782-49-2	0.1	mg/kg	<0.1	<0.1	----	----	----
Barium	7440-39-3	0.01	mg/kg	**0.02**	<0.01	----	----	----
Beryllium	7440-41-7	0.01	mg/kg	<0.01	<0.01	----	----	----
Cadmium	7440-43-9	0.01	mg/kg	<0.01	<0.01	----	----	----
Cobalt	7440-48-4	0.01	mg/kg	<0.01	<0.01	----	----	----
Chromium	7440-47-3	0.01	mg/kg	**0.01**	<0.01	----	----	----
Copper	7440-50-8	0.01	mg/kg	<0.01	<0.01	----	----	----
Manganese	7439-96-5	0.01	mg/kg	<0.01	<0.01	----	----	----
Molybdenum	7439-98-7	0.01	mg/kg	<0.01	<0.01	----	----	----
Nickel	7440-02-0	0.01	mg/kg	<0.01	<0.01	----	----	----
Lead	7439-92-1	0.01	mg/kg	<0.01	<0.01	----	----	----
Antimony	7440-36-0	0.01	mg/kg	<0.01	<0.01	----	----	----
Uranium	7440-61-1	0.01	mg/kg	<0.01	<0.01	----	----	----
Zinc	7440-66-6	0.05	mg/kg	<0.05	<0.05	----	----	----
Vanadium	7440-62-2	0.1	mg/kg	<0.1	<0.1	----	----	----
Aluminium	7429-90-5	0.1	mg/kg	<0.1	**0.6**	----	----	----
Thorium	7440-29-1	0.01	mg/kg	<0.01	<0.01	----	----	----
EG020T: Total Metals by ICP-MS								
Thorium	7440-29-1	0.1	mg/kg	**6.3**	**11.2**	----	----	----
Uranium	7440-61-1	0.1	mg/kg	**0.6**	**0.9**	----	----	----

Analytical Results

Sub-Matrix: **PULP**
(Matrix: **SOIL**)

Compound	CAS Number	LOR	Unit	COMPOSITE 5 Composite of 9 & 10	COMPOSITE 6 Composite of 11 & 12	----	----	----
Client sampling date / time				[09-Mar-2015]	[09-Mar-2015]	----	----	----
				EB1514367-017	**EB1514367-018**	--------	--------	--------
				Result	Result	Result	Result	Result
EG035S: Soluble Mercury by FIMS								
Mercury	7439-97-6	0.0005	mg/kg	<0.0005	<0.0005	----	----	----
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.1	mg/kg	<0.1	<0.1	----	----	----
EK040S: Fluoride Soluble								
Fluoride	16984-48-8	1	mg/kg	**5**	**4**	----	----	----
EK071G: Reactive Phosphorus as P by discrete analyser								
Reactive Phosphorus as P	14265-44-2	0.1	mg/kg	<0.1	<0.1	----	----	----

RGS

LEADERS IN MINING GEOCHEMISTRY

Appendix D Technical report – Numerical model development

D1 Modelling objectives

The objective of the groundwater flow model is to assess impact of proposed mining (deepening of the North and South Pits and expansion to west) to surrounding areas - water users, surface water streams, groundwater dependant ecosystems etc. The impact is assessed as a change of groundwater table (drawdown) and change of inflow into various zones of interest (mining pit, alluvium of Shoalhaven River).

D2 Model design

The definition of the model domain (design of the numerical model) includes the definition of horizontal and vertical extent, discretization of the model domain (model grid / mesh), and model boundaries.

D2.1 Modelling code

MODFLOW-USG (Panday *et.al,* 2013) was determined to be the most suitable modelling code to meet the model objectives. Details of the modelling code selection can be found in Section 8.5.2 of the groundwater impacts assessment report.

D2.2 Model boundaries – horizontal extent

The horizontal extent of the numerical model was selected to be sufficiently distant from the area of the proposed mining to limit its influence on the predicted water levels and flows. Most the model boundaries were located along watershed lines, assuming that the water table is a reflection of the surface topography and topographical highs would translate into a groundwater divides. Where groundwater divides were not thought to exist, a general head boundary condition was implemented along the edge of the model to allow for the model domain to interact with outside influences such as where aquifers continue beyond the boundary. Please refer to Figure D 1 for the horizontal extent of the model domain as well as implemented types of boundary conditions.

D2.3 Model domain and grid geometry

The model extended approximately 6.8 km from east to west, and 8.5 km from north to south, covering a total area of 38.7 km^2. The model mesh consists of 184,592 active nodes.

The model domain was discretised using mostly hexagonal Voronoi polygons (Figure D 1). There were 25,164 nodes defined across the model domain with the dimensions of the cells varying from approximately 10 m by 10 m within the project area (structural features) to approximately 200 m by 200 m outside of the Project area. The cell sizes were refined to add detail and better represent small geological structures such as faults, fracture systems or geological boundaries and locations of groundwater monitoring bores.

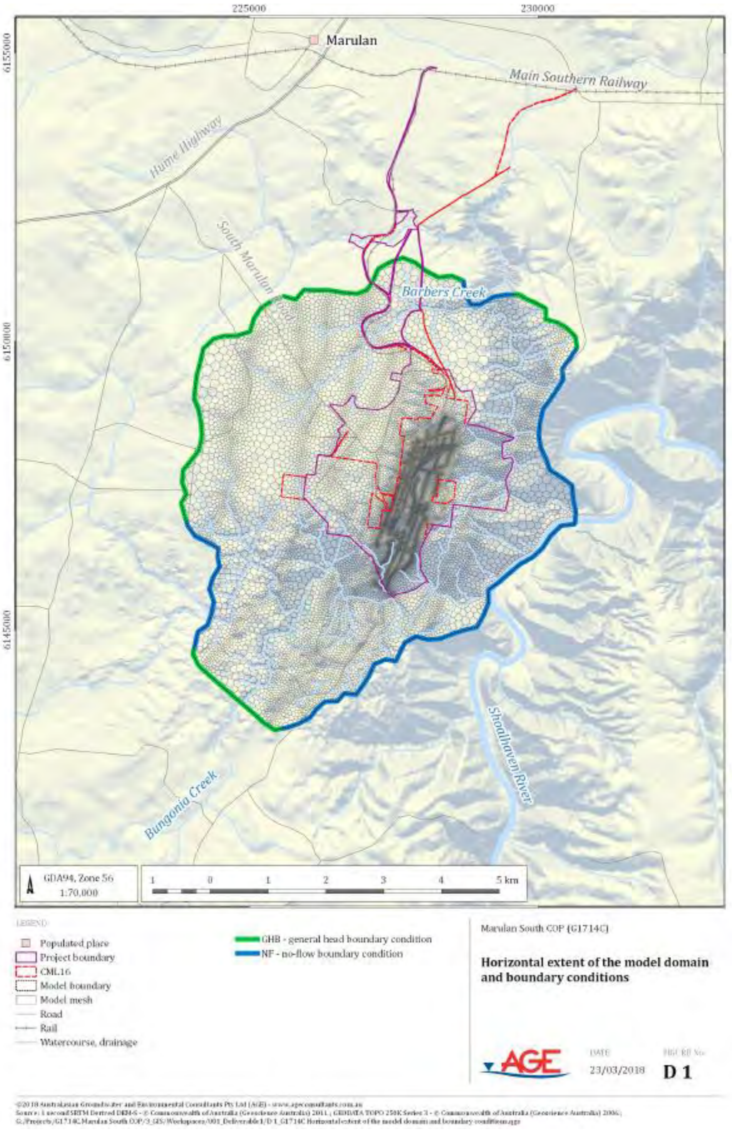


Figure D 1 Horizontal extent of the model domain and conceptual boundary conditions.

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D2.4 Model layers – vertical extent

The model consists of ten layers. The uppermost layer (layer 1) represents unconsolidated sediments and regolith as well as areas of alluvium adjacent to the significant streams within the model domain. Thickness of the first model layer was derived from the CSIRO Soil and Landscape Grid Data Extraction Tool, using the 'Depth of Regolith' dataset (Australian Government, CSIRO 2018). Layers 2 to 10 represent the bedrock, including structural (linear) features such as faults, weathering contact zones and volcanic intrusions (i.e. dykes). The numbers of active nodes in individual layers varies due to the lateral extent of the geology the layer represents and are summarised in Table D 1.

The bedrock layers were created with the intent to capture the major elevations of the pit floor during proposed mining expansion as well as other structural features such as the karst system behind the Main Gully Spring Cave (B68 – 'Blowhole'). The structural setup of the model is presented in a simplified W-E conceptual cross (Figure D 2) as well as in a series of four maps showing the extent and zonation of individual model layers (Figure D 3 to Figure D 6).

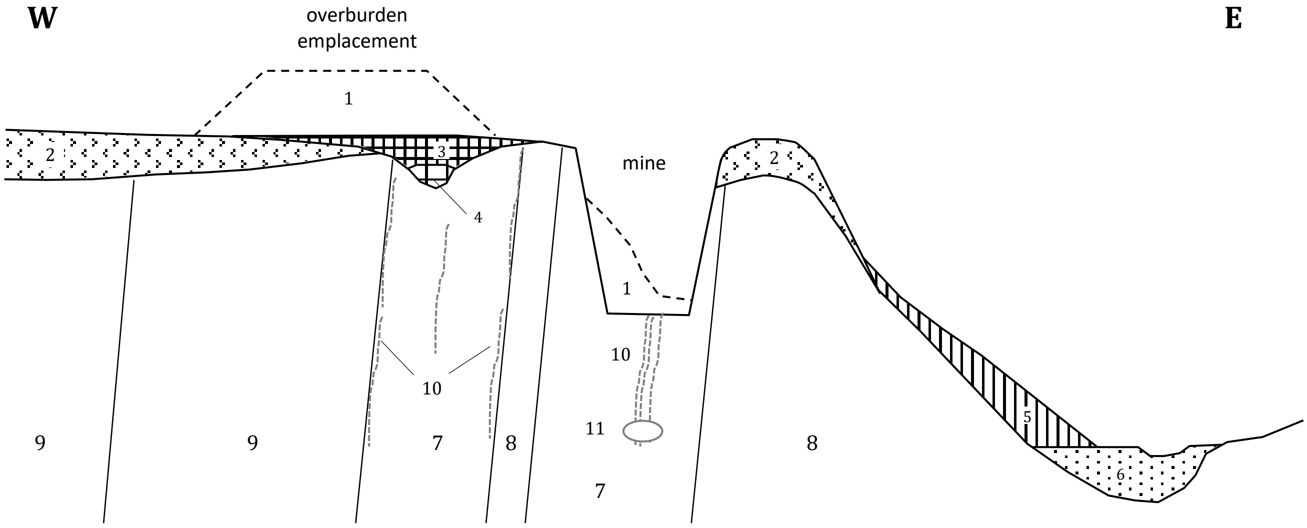
Table D 1 Summary of numbers of active nodes per model layer

Layer	Active nodes	Average layer floor elevation (m RL)	Average thickness (m)
Layer 1	15,243	variable	4.6
Layer 2	14,187	530	48.7
Layer 3	17,642	485	40.5
Layer 4	18,178	470	14.7
Layer 5	22,284	365	95.4
Layer 6	23,041	355	10.0
Layer 7	23,336	335	19.9
Layer 8	24,074	260	73.6
Layer 9	903	260	10.0
Layer 10	25,164	50	206.7

Model layers and zones were defined as follows:

- Layer 01 - (*Zones 01 - 04*) topsoil, regolith, alluvium, historical spoil (Figure D 3):
  - *Zone 01* - regolith/topsoil;
  - *Zone 02* - alluvium - Shoalhaven River;
  - *Zone 03* - alluvium - Bungonia Creek; and
  - *Zone 04* – alluvium – Barbers Creek.
- Layer 02 – Layer 10 - bedrock (Figure D 4):
  - *Zone 05* – granite – Marulan Granite;
  - *Zone 06* – ignimbrite – Barralier Ignimbrite, Bindook Group;
  - *Zone 07* - granodiorite – Glenrock Granodiorite;
  - *Zone 08* – tuffs – Kerillon Tuff Member, Tangerang Formation, Bindook Group;
  - *Zone 09* – limestone;

- *Zone 10* - conglomerate, volcanic breccia – Devils Pulpit Member, Tangerang Formation, Bindook Group;
- *Zone 11* - dacite – Carne Dacite, Tangerang Formation, Bindook Group;
- *Zone 12* - sandstone, undifferentiated – Adaminaby Group;
- *Zone 13* - sandstone, mudstone – Bumballa Formation, Bendock Group;
- *Zone 14* – limestone contact zones – weathered limestone, clastic material in clayey matrix, void space (washed out material);
- *Zone 15* – hypothesized pit floor fractures;
- *Zone 16* – fracture zones associated with faults intersecting the limestone bodies;
- *Zone 17* – basaltic dykes;
- *Zone 18* – karst fractures connected to Main Gully Spring Cave (B68 – 'Blowhole') – only Layer 09 (Figure D 5);
- *Zone 19* – limestone – North Pit – north;
- *Zone 20* – limestone – North Pit – central and southern parts;
- *Zone 21* – limestone – South Pit; and
- *Zone 22* – post-mining (recovery modelling only) – mining void.



Legend:

1 - future overburden emplacements (model layer 1), partial infill of South Pit;
2 - weathered regolith layer (model layer 1);
3, 4 - historical overburden emplacements - Western Emplacements - coarse and fine infill of gullies west of the South Pit - model layer 1;
5 - slope colluvium (model layer 1);
6 - alluvial sediments of surface water streams (model layer 1);
7 - limestone bodies;
8 - consolidated sediments - sandstone, mudstone, shale;
9 - volcanics - granodiorite, granite, tuff, dacite;
10 - limestone fracture systems (karst), weathered limestone contact zones (inferred);
11 - cave (inferred).

Figure D 2 Simplified W-E cross-section through the model domain

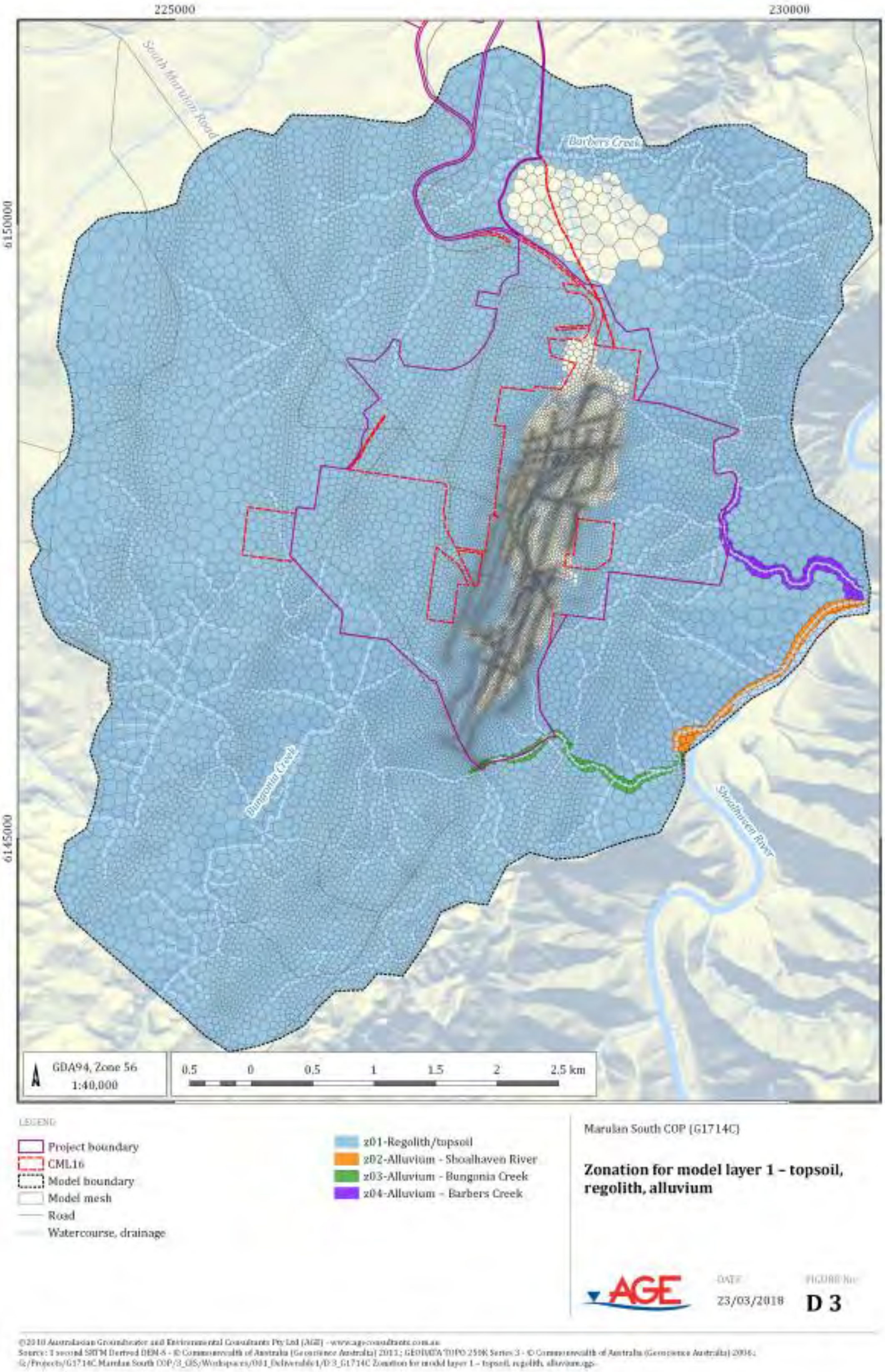


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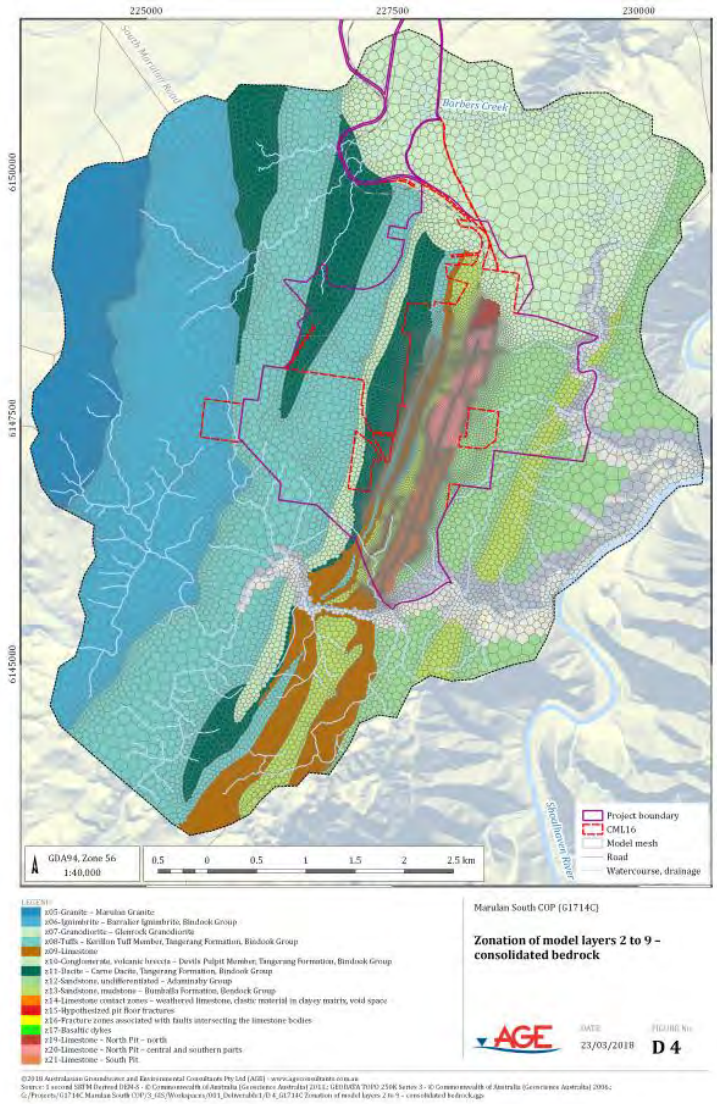
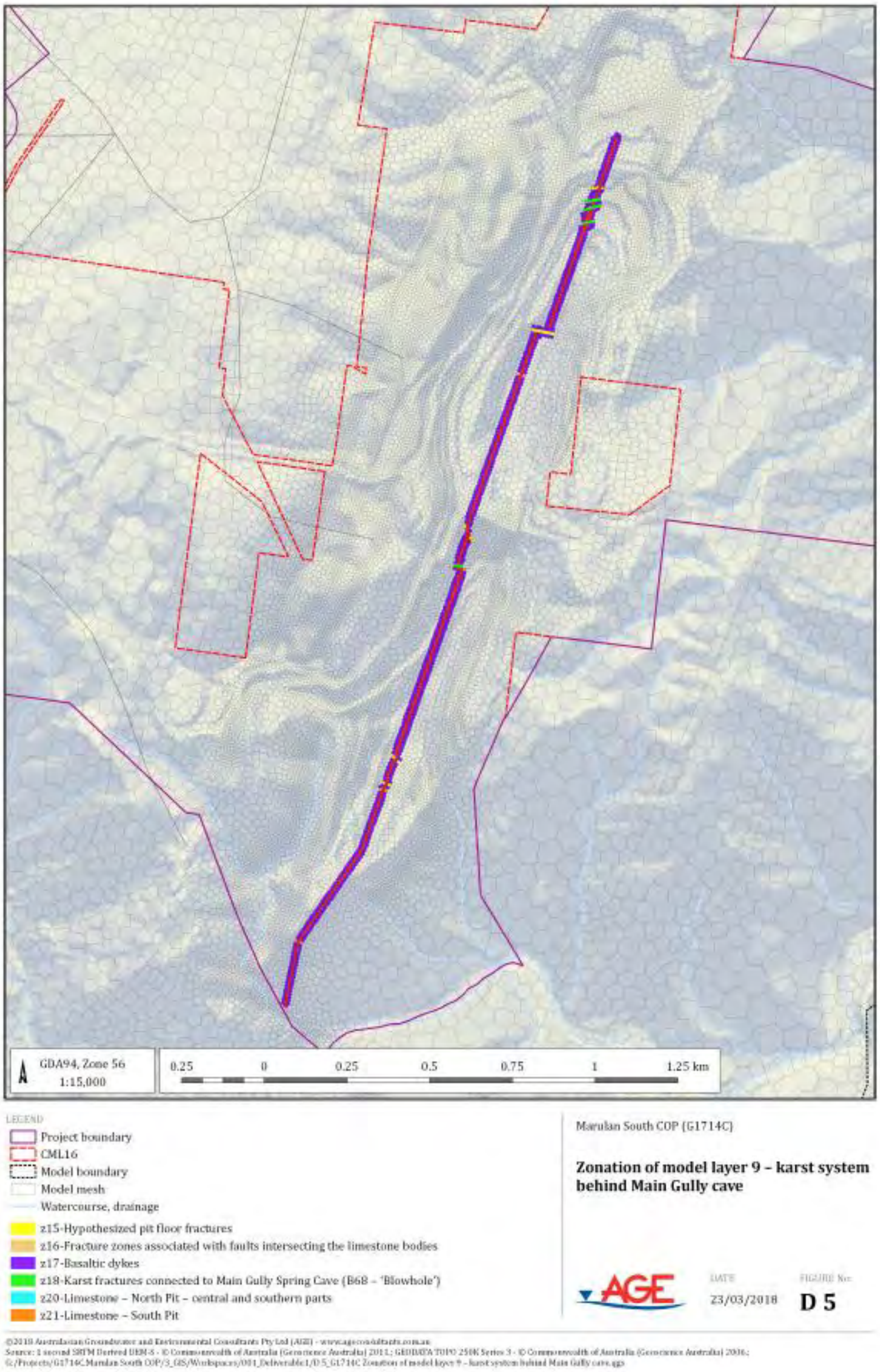
Figure D 3 Zonation of model layer 1 (L01) – topsoil, regolith, alluvium



"G:\Projects\G1714C.Marulan South COP\3_GIS\Workspaces\001_Deliverable1\PDFs\D 4_G1714C Zonation of layers 2 to 9 – consolidated bedrock.pdf"

Figure D 4 Zonation of layers 2 to 10 – consolidated bedrock



"G:\Projects\G1714C.Marulan South COP\3_GIS\Workspaces\001_Deliverable1\PDFs\D 5_G1714C Zonation of model layer 9 – karst system behind Main Gully cave.pdf"

Figure D 5 Zonation of model layer 9 – karst system behind Main Gully cave

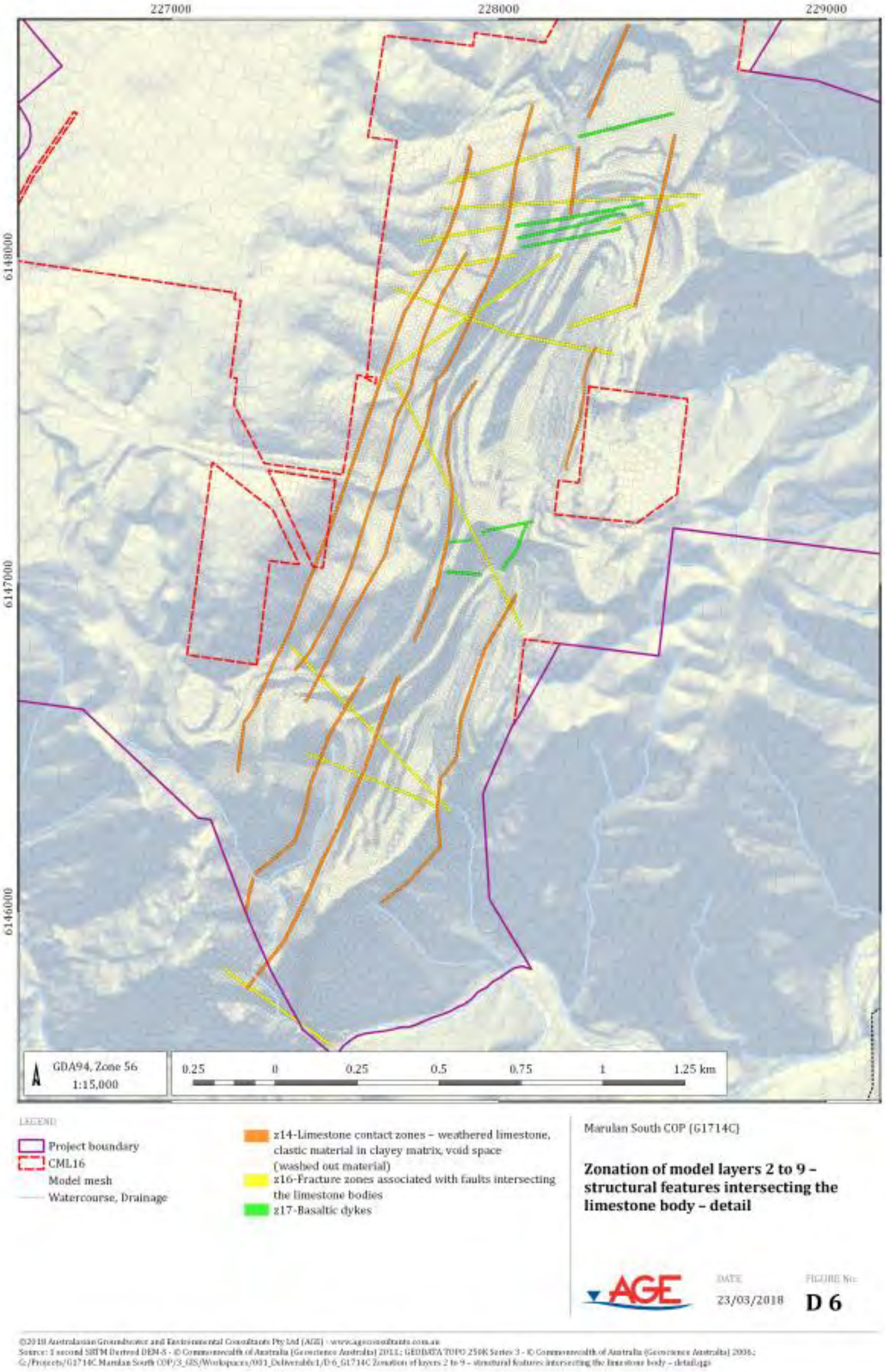


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Figure D 6 Zonation of layers 2 to 10 – structural features intersecting the limestone body - detail

D2.5 Topographic surface and drainage

The topographic surface, surface water catchments and drainage network datasets are presented in Figure D 7.

The publicly available, one-second, smoothed digital elevation model (DEM-S) with a 30 × 30 m grid spacing (Gallant *et al*., 2011) was used to represent the ground surface throughout the model domain. The DEM-S dataset was merged with two sets of detailed LIDAR derived DEM (provided by client), namely the 2008 LIDAR dataset and 2014 LIDAR dataset. The LIDAR datasets cover the entire project area and recent mine details were captured in the 2014 dataset.

Further analysis of the DEM-S was conducted (using QGIS) in order to extract the drainage network. Extracted drainage lines follow the line of lowest topographic surface and were used to define surface drainage (river boundary condition) for the model.

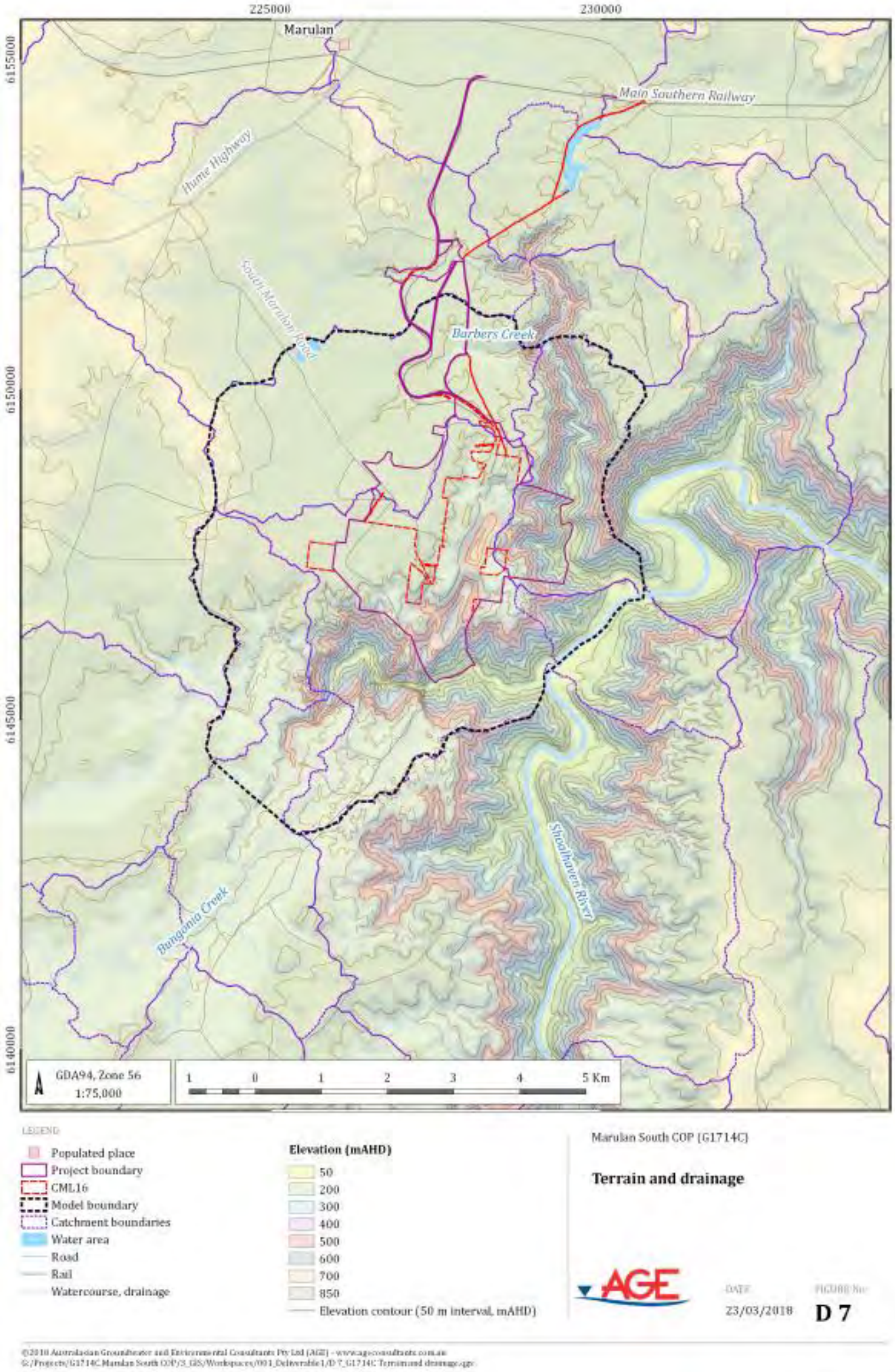

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Figure D 7 Topography and drainage

D2.6 Hydraulic properties and regional groundwater flow

The direction and capacity of groundwater flow depends on several factors, including hydraulic properties of the rock, heterogeneities stemming from the depositional process and regional / local structural heterogeneities (faults and fractures, linear intrusions such as dykes or plugs).

D2.6.1 Hydraulic properties (in-situ testing)

The hydraulic properties of the limestone and of the overburden geologic units were examined by RPS (2014) and AGE (2015). A discussion of the hydraulic properties is included in Section 7.8 of the main report.

D2.6.2 Depositional heterogeneities

Depositional heterogeneities are typical for sedimentary units, both unconsolidated and consolidated. The change of depositional conditions (change of sediment, change of depositional speed) is usually the cause of vertical heterogeneity in most sedimentary systems. While the ratio between horizontal hydraulic conductivities in X and Y directions (K_x and K_y) is close to unity, the ratio between K_x and K_z (vertical hydraulic conductivity) varies from 1:10 to up to 1:1000 (Anderson and Woessner, 1991; Freeze and Cherry, 1979).

Within the project area, the complex of consolidated sediments and volcanics has tilted and is dipping westwards under a very steep angle (Figure D 8). This means that the original depositional anisotropy has been modified as per Figure D 9, where the original vertical anisotropy has become an east-west horizontal anisotropy. Likewise, the secondary original horizontal anisotropy has become the vertical.

Figure D 8 Deformation/tilt of sedimentary layers – southern slope of Bungonia Creek gorge (February 2015)

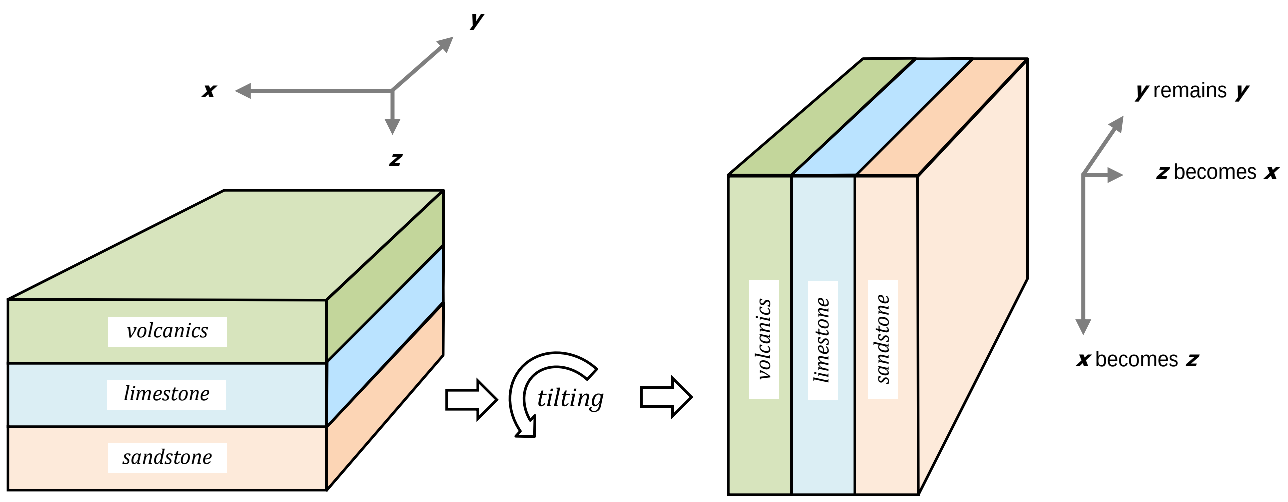

Figure D 9 Perceived change of heterogeneity directions (anisotropy) as a result of tilting of the stratigraphic units

As a result of the deformation, the horizontal plane is highly anisotropic and the movement of groundwater in the west to east direction, across the semi-vertical boundaries between different geologies is severely restricted. The horizontal anisotropy was applied to consolidated bedrock layers (layer 2 to layer 10).

D2.6.3 Structural heterogeneities

A discussion of the structural heterogeneities and their influence on the groundwater model is included in Section 5.2 of the main report.

D2.7 System stresses

D2.7.1 Timing

Timing of the numerical model run is defined around the existence and frequency of observation data for the calibration period and coarseness of stresses (specifically mining progression) for the prediction period. The model uses an adaptive timestepping approach where it can change (decrease or increase) the timestep length depending on ease of the numerical convergence. The time units used in the model are days.

Given these initial limitations (frequency of observation data, coarseness of mining related stresses), the numerical model runs using time intervals as defined in Table D 2 below.

Table D 2 Model run timing

Stress period	Stress period count	Stress period length (days)	Date from	Date to	Comment
Calibration (transient) – 61 stress periods					
01 - 10	10	365.25	1/01/2003	31/12/2012	lead-in
11 - 12	2	182.625	1/01/2013	31/12/2013	lead-in
13 - 61	49	30.4375	1/01/2014	31/01/2018	calibration
Prediction – mining (transient) – 32 stress periods					
01	1	150	1/02/2018	30/06/2018	pre-SSD
02	1	365	1/07/2018	30/06/2019	pre-SSD
03 - 07	5	365-366	1/07/2019	30/06/2024	stage 1
08 - 15	8	365-366	1/07/2024	30/06/2032	stage 2
16 - 21	6	365-366	1/07/2032	30/06/2038	stage 3
22 - 32	11	365-366	1/07/2038	30/06/2049	stage 4
Prediction – recovery (transient) – 14 stress periods					
01 - 03	3	30-31	1/07/2049	30/09/2049	-
04	1	92	1/10/2049	31/12/2049	-
05	1	365	1/01/2050	31/12/2050	-
06 - 10	5	3652-3653	1/01/2051	31/12/2100	-
11 - 14	4	18262	1/01/2101	21/12/2300	-

Note: *SSD – State Significant Development*

D2.7.2 Recharge

MODFLOW-USG simulates diffuse rainfall recharge using the recharge package (RCH). Five recharge zones were created in the model (see Table D 3).

Table D 3 Modelled recharge rates

Recharge zone	Diffuse recharge (% of rainfall)
Zone 01 - pits and voids – Marulan, Peppertree	11.41 %
Zone 02 - granodiorite	2.74 %
Zone 03 - limestone and interbedded metamorphics	5.07 %
Zone 04 - metamorphics (sedimentary – Adaminaby Group)	5.29 %
Zone 05 – metamorphics (volcanics – granite, tuffs, breccias)	1.57 %

To calculate a recharge rate for individual zones, a different factor is applied to the baseline transient rainfall. For the calibration period, two different rainfall timeseries were created – one for pits and voids (zone 01), the second one for the rest of the model domain. The reason for creating separate rainfall timeseries for the open pit zone was the distinctive recharge pattern displayed by the in-pit observation bores (MW1 and MW2), which were quite "peaky" as compared to the bores located outside of the pit (MW3 to MW6), which were muted in their recharge response. Both timeseries have the same amount of rainfall per year, however the timeseries for Zone 01 accentuates the extreme rainfall events.

The baseline calibration rainfall timeseries data is presented in Figure D 10 and Table D 4. The rainfall timeseries for both prediction (mining and recovery) runs are presented in Table D 5 and Table D 6.

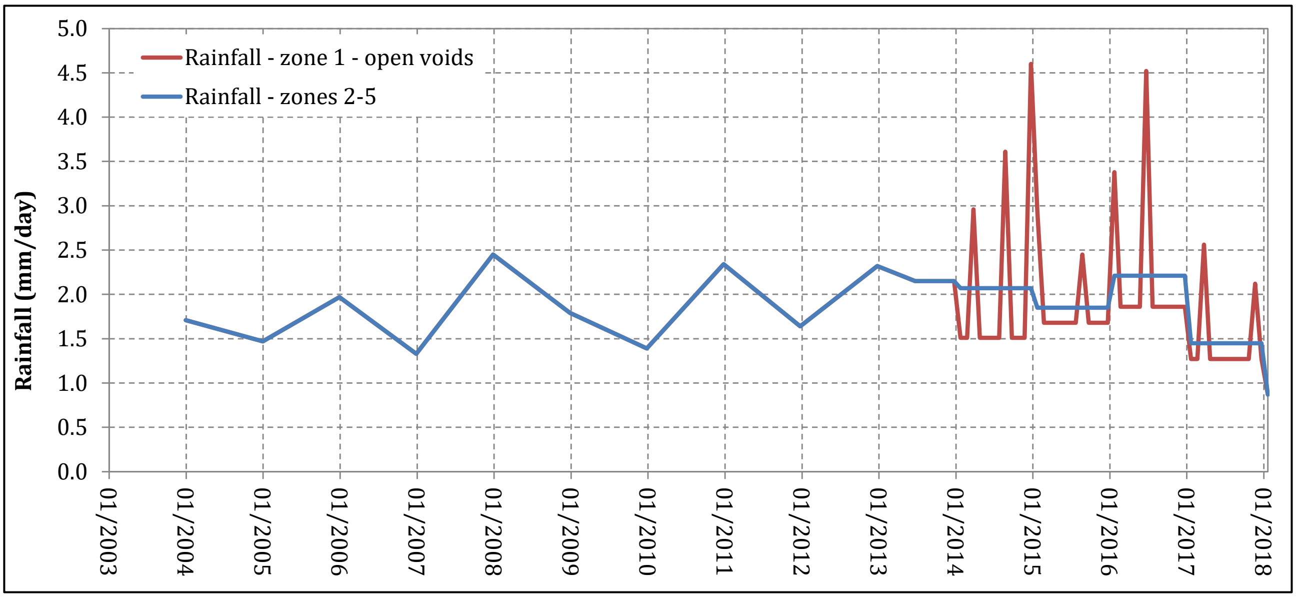

Figure D 10 Rainfall timeseries for RCH zones 01 and 02-05 - calibration

Map showing extent of individual recharge zones is presented in Figure D 11.

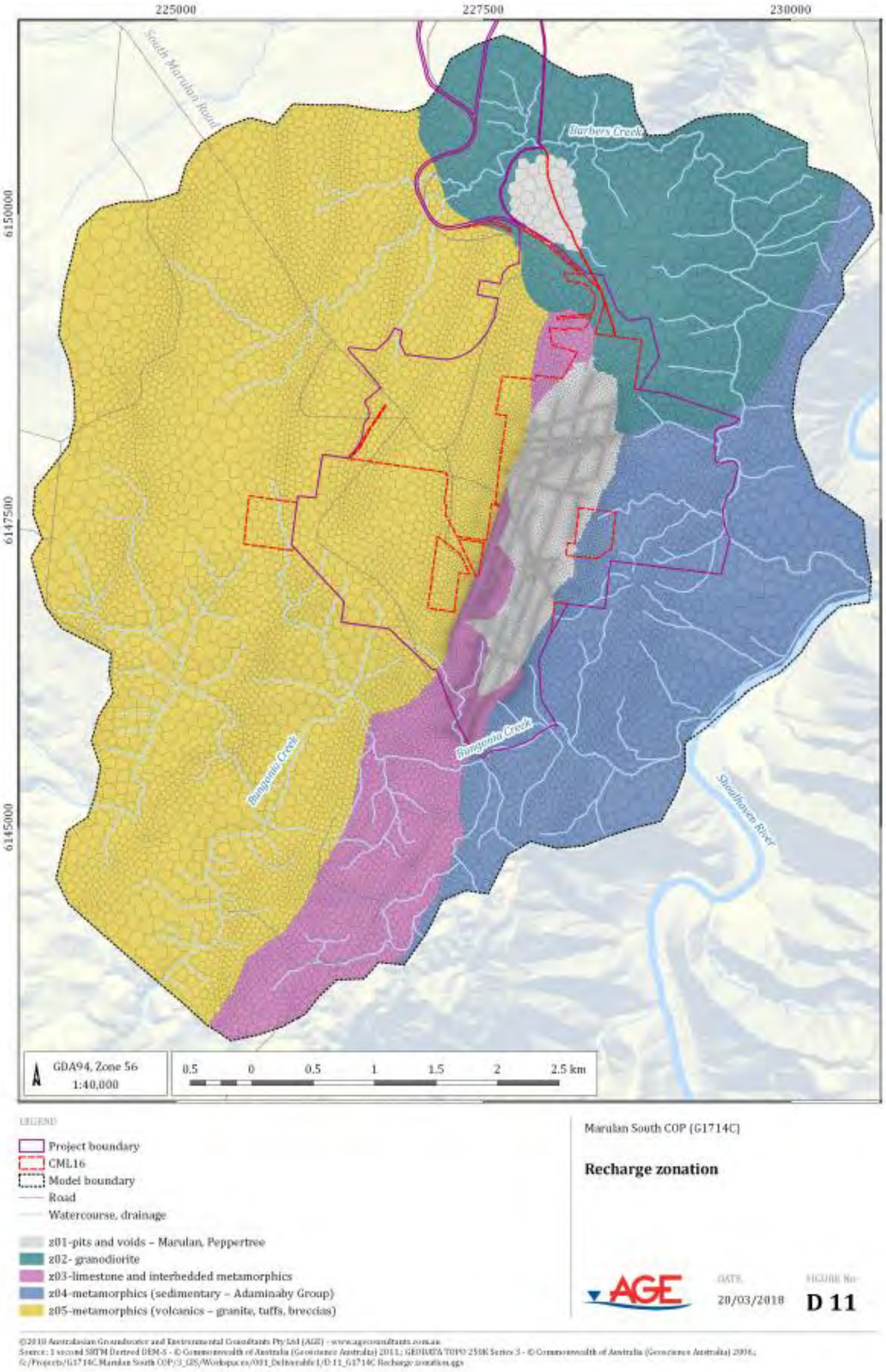

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Figure D 11 Recharge (RCH) zones

Table D 4 Rainfall – lead-in and calibration

Stress period	Interval	Indicative end date	Stress period length (days)	Rainfall (mm/SP length)		Rainfall (mm/day)	
				Zones 2-5	Zone 1	Zones 2-5	Zone 1
1	lead-in	31/12/2003	365.25	624.60	624.60	1.71	1.71
2	lead-in	31/12/2004	365.25	535.60	535.60	1.47	1.47
3	lead-in	31/12/2005	365.25	721.10	721.10	1.97	1.97
4	lead-in	31/12/2006	365.25	485.50	485.50	1.33	1.33
5	lead-in	31/12/2007	365.25	893.20	893.20	2.45	2.45
6	lead-in	31/12/2008	365.25	654.70	654.70	1.79	1.79
7	lead-in	31/12/2009	365.25	508.40	508.40	1.39	1.39
8	lead-in	31/12/2010	365.25	855.00	855.00	2.34	2.34
9	lead-in	31/12/2011	365.25	600.70	600.70	1.64	1.64
10	lead-in	31/12/2012	365.25	846.50	846.50	2.32	2.32
11	lead-in	30/06/2013	182.625	392.15	392.15	2.15	2.15
12	lead-in	31/12/2013	182.625	392.15	392.15	2.15	2.15
13	calibration	31/01/2014	30.4375	63.08	46.10	2.07	1.51
14	calibration	03/03/2014	30.4375	63.08	46.10	2.07	1.51
15	calibration	02/04/2014	30.4375	63.08	90.00	2.07	2.96
16	calibration	03/05/2014	30.4375	63.08	46.10	2.07	1.51
17	calibration	02/06/2014	30.4375	63.08	46.10	2.07	1.51
18	calibration	02/07/2014	30.4375	63.08	46.10	2.07	1.51
19	calibration	02/08/2014	30.4375	63.08	46.10	2.07	1.51
20	calibration	01/09/2014	30.4375	63.08	110.00	2.07	3.61
21	calibration	02/10/2014	30.4375	63.08	46.10	2.07	1.51
22	calibration	01/11/2014	30.4375	63.08	46.10	2.07	1.51
23	calibration	02/12/2014	30.4375	63.08	46.10	2.07	1.51
24	calibration	01/01/2015	30.4375	63.08	140.00	2.07	4.60
25	calibration	31/01/2015	30.4375	56.29	89.64	1.85	2.94
26	calibration	03/03/2015	30.4375	56.29	51.10	1.85	1.68
27	calibration	02/04/2015	30.4375	56.29	51.10	1.85	1.68
28	calibration	03/05/2015	30.4375	56.29	51.10	1.85	1.68
29	calibration	02/06/2015	30.4375	56.29	51.10	1.85	1.68
30	calibration	03/07/2015	30.4375	56.29	51.10	1.85	1.68
31	calibration	02/08/2015	30.4375	56.29	51.10	1.85	1.68
32	calibration	02/09/2015	30.4375	56.29	74.49	1.85	2.45
33	calibration	02/10/2015	30.4375	56.29	51.10	1.85	1.68
34	calibration	01/11/2015	30.4375	56.29	51.10	1.85	1.68

Stress period	Interval	Indicative end date	Stress period length (days)	Rainfall (mm/SP length)		Rainfall (mm/day)	
				Zones 2-5	Zone 1	Zones 2-5	Zone 1
35		02/12/2015	30.4375	56.29	51.10	1.85	1.68
36		01/01/2016	30.4375	56.29	51.10	1.85	1.68
37		01/02/2016	30.4375	67.33	103.03	2.21	3.38
38		02/03/2016	30.4375	67.33	56.74	2.21	1.86
39		02/04/2016	30.4375	67.33	56.74	2.21	1.86
40		02/05/2016	30.4375	67.33	56.74	2.21	1.86
41		01/06/2016	30.4375	67.33	56.74	2.21	1.86
42		02/07/2016	30.4375	67.33	137.48	2.21	4.52
43		01/08/2016	30.4375	67.33	56.74	2.21	1.86
44		01/09/2016	30.4375	67.33	56.74	2.21	1.86
45		01/10/2016	30.4375	67.33	56.74	2.21	1.86
46		01/11/2016	30.4375	67.33	56.74	2.21	1.86
47		01/12/2016	30.4375	67.33	56.74	2.21	1.86
48		01/01/2017	30.4375	67.33	56.74	2.21	1.86
49		31/01/2017	30.4375	44.02	38.60	1.45	1.27
50		02/03/2017	30.4375	44.02	38.60	1.45	1.27
51		02/04/2017	30.4375	44.02	77.81	1.45	2.56
52		02/05/2017	30.4375	44.02	38.60	1.45	1.27
53		02/06/2017	30.4375	44.02	38.60	1.45	1.27
54		02/07/2017	30.4375	44.02	38.60	1.45	1.27
55		02/08/2017	30.4375	44.02	38.60	1.45	1.27
56		01/09/2017	30.4375	44.02	38.60	1.45	1.27
57		01/10/2017	30.4375	44.02	38.60	1.45	1.27
58		01/11/2017	30.4375	44.02	38.60	1.45	1.27
59		01/12/2017	30.4375	44.02	64.42	1.45	2.12
60		01/01/2018	30.4375	44.02	38.60	1.45	1.27
61		31/01/2018	30.4375	26.60	26.60	0.87	0.87

Table D 5 Rainfall – model prediction - mining

Stress period	Stage	Indicative end date	Stress period length	Rainfall (mm/SP length)	Rainfall (mm/day)
1	pre-SSD	30/06/2018	150	285.62	1.904
2		30/06/2019	365	695.01	1.904
3	stage 1	30/06/2020	366	695.01	1.899
4		30/06/2021	365	695.01	1.904
5		30/06/2022	365	695.01	1.904
6		30/06/2023	365	695.01	1.904
7		30/06/2024	366	695.01	1.899
8	stage 2	30/06/2025	365	695.01	1.904
9		30/06/2026	365	695.01	1.904
10		30/06/2027	365	695.01	1.904
11		30/06/2028	366	695.01	1.899
12		30/06/2029	365	695.01	1.904
13		30/06/2030	365	695.01	1.904
14		30/06/2031	365	695.01	1.904
15		30/06/2032	366	695.01	1.899
16	stage 3	30/06/2033	365	695.01	1.904
17		30/06/2034	365	695.01	1.904
18		30/06/2035	365	695.01	1.904
19		30/06/2036	366	695.01	1.899
20		30/06/2037	365	695.01	1.904
21		30/06/2038	365	695.01	1.904
22	stage 4	30/06/2039	365	695.01	1.904
23		30/06/2040	366	695.01	1.899
24		30/06/2041	365	695.01	1.904
25		30/06/2042	365	695.01	1.904
26		30/06/2043	365	695.01	1.904
27		30/06/2044	366	695.01	1.899
28		30/06/2045	365	695.01	1.904
29		30/06/2046	365	695.01	1.904
30		30/06/2047	365	695.01	1.904
31		30/06/2048	366	695.01	1.899
32		30/06/2049	365	695.01	1.904

Table D 6 Rainfall – model prediction – post-mining (recovery)

Stress period	Indicative end date	Stress period length (days)	Rainfall (mm/SP length)	Rainfall (mm/day)
1	31/07/2049	31	58.99	1.903
2	31/08/2049	31	58.99	1.903
3	30/09/2049	30	57.09	1.903
4	31/12/2049	92	175.06	1.903
5	31/12/2050	365	694.53	1.903
6	31/12/2060	3653	6951.05	1.903
7	31/12/2070	3652	6949.15	1.903
8	31/12/2080	3653	6951.05	1.903
9	31/12/2090	3652	6949.15	1.903
10	31/12/2100	3652	6949.15	1.903
11	31/12/2150	18262	34749.55	1.903
12	31/12/2200	18262	34749.55	1.903
13	31/12/2250	18262	34749.55	1.903
14	31/12/2300	18262	34749.55	1.903

D2.7.3 Evapotranspiration

Evapotranspiration application is based on the zonation pattern presented in Table D 7. Compared to recharge however, the EVT value does not vary in time and it is based on the long term average evaporation value of 1095.0 mm/year. Different pan factors and extinction depths were applied to individual EVT zones and these are presented in Table D 7.

Table D 7 Modelled EVT rates and extinction depth

Evapotranspiration zone	Extinction depth (m)	EVT rate (% of pan EV)
Zone 01 – topsoil/regolith	3.00	10 %
Zone 02 – alluvium	1.50	15 %
Zone 03 – pits, voids	0.80	80 %

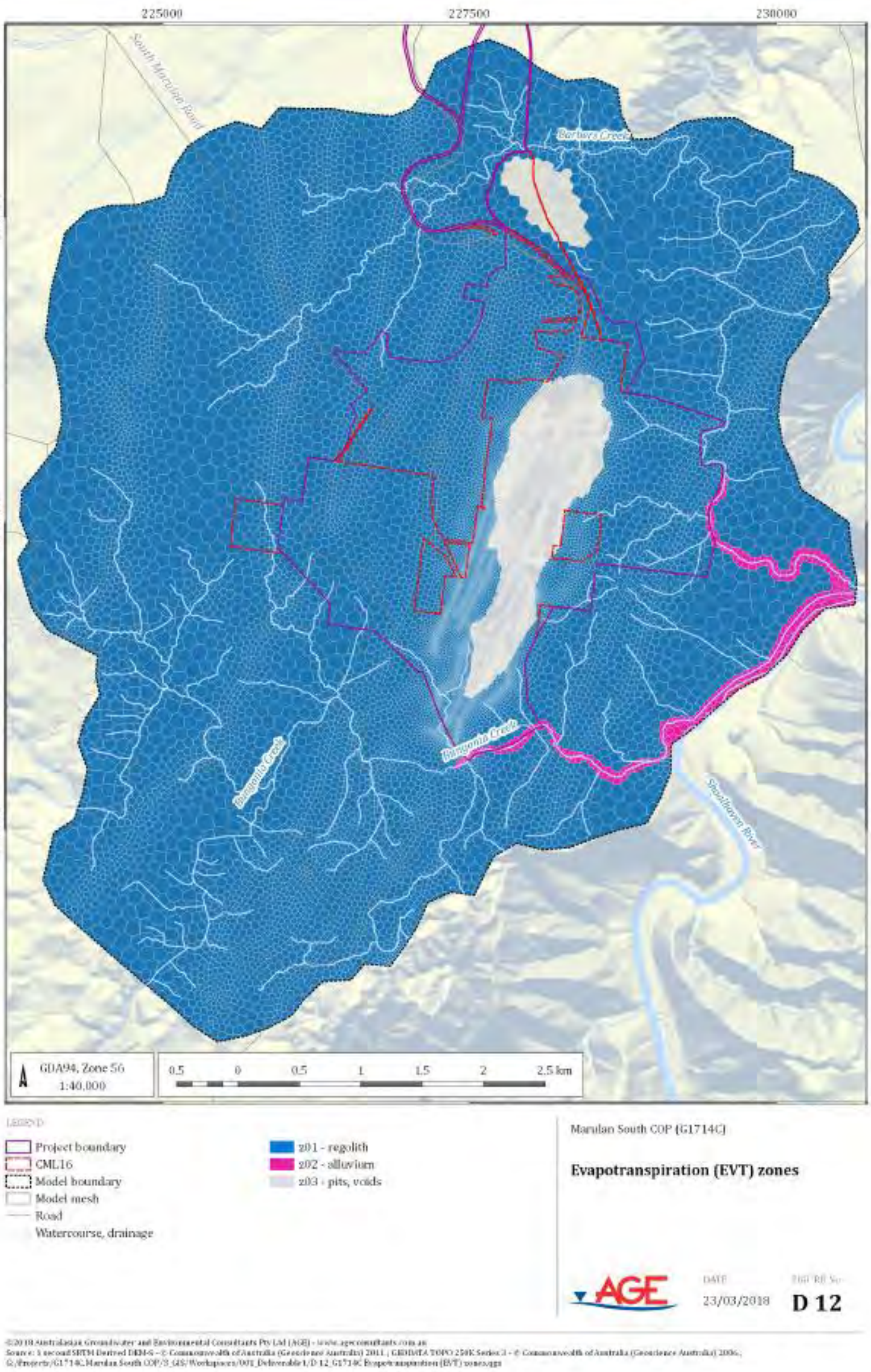

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Figure D 12 Evapotranspiration (EVT) zones

D2.7.4 Surface drainage

Groundwater interaction with surface drainage was modelled using the MODFLOW-USG river package (RIV). This package requires the level of the riverbed and the depth of water above this level. The riverbed elevation was calculated by extracting the minimum land elevation within each model cell from the LIDAR data along the drainage alignments and subtracting the depth to represent the creek bed elevation at each surface water feature. The river bed conductance was calculated from river width, river length, riverbed thickness, and the vertical hydraulic conductivity of the riverbed material. Surface drainage was assigned a nominally high vertical bed conductivity rate, to allow free drainage. Table D 8 summarises the parameters representing the drainage lines and creeks.

Table D 8 Modelled riverbed parameters

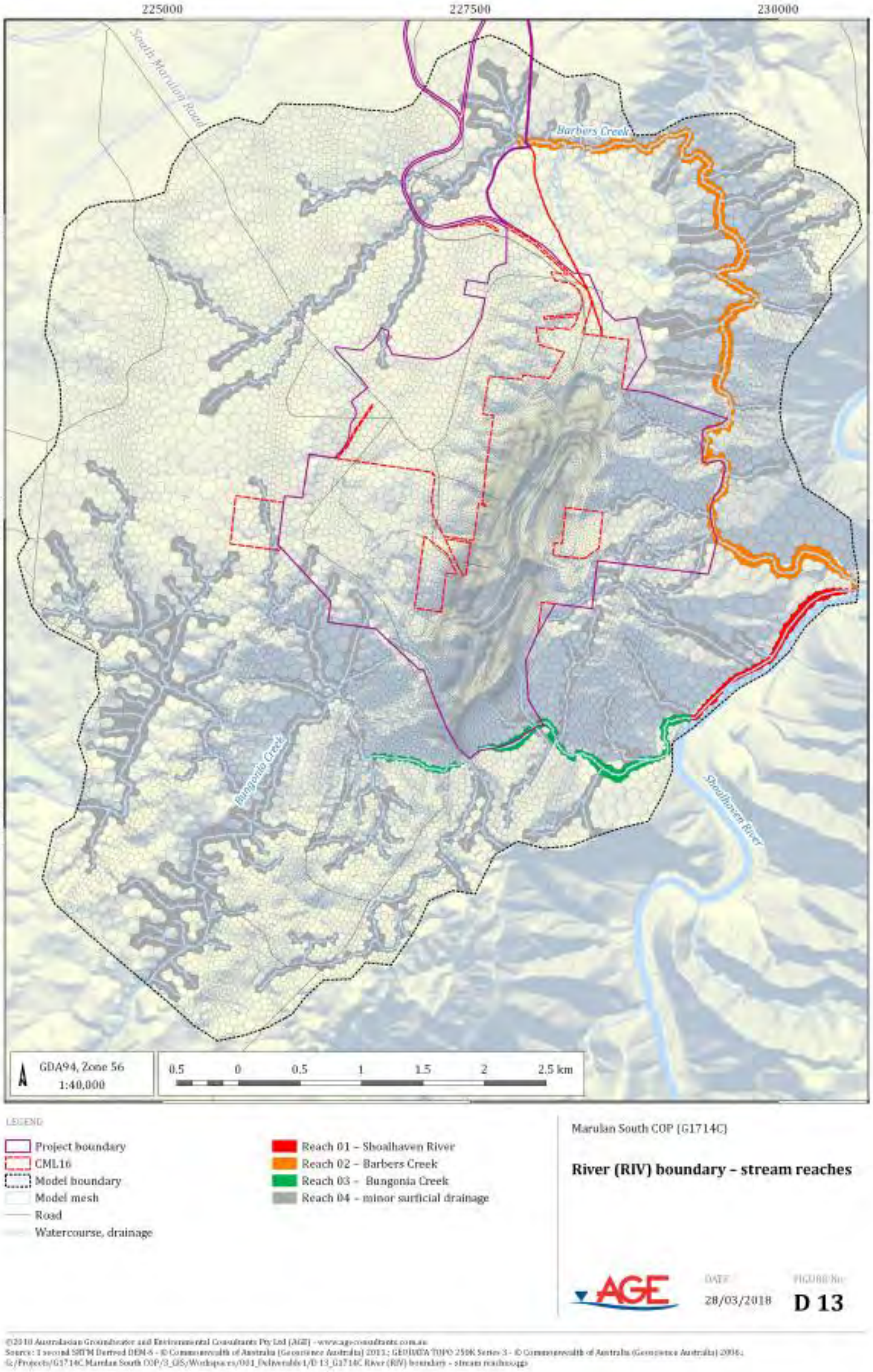
Zone	Vertical K (m/day)	Width (m)	River bed depth (m)	Stage height (m)	Bed thickness (m)
Reach 1 - Shoalhaven River	0.5	15	2.5	1.00	10.0
Reach 2 - Bungonia Creek	1.0	5.0	1.5	0.01	5.0
Reach 3 - Barbers Creek	1.0	5.0	1.0	0.01	5.0
Reach 4 - minor surface drainage	3.0	5.0	0.25	0.00	3.0

A river stage height of 1 m was applied to the major river reach of Shoalhaven River, stage of 0.01 m was applied to smaller streams such as Barbers, Bungonia, and no stage (0.0 m) was applied to minor surficial drainage channels. The spatial discretization of the river boundary condition is presented on Figure D 13.

D2.7.5 Mining progression

The dewatering of the pit as the mining progresses was simulated through applying the drain boundary condition to cells within the pit footprint. The drain elevations were derived from the known elevations of mining surfaces at the end of mining stages using the method of linear interpolation between individual surfaces. The drain boundary condition removes water from the model when the groundwater level is above its reference level, in this case the base of the pit.

The horizontal extents of the pit and overburden emplacements for mining stages 1-4 are presented in Figure D 14.



"G:\Projects\G1714C.Marulan South COP\3_GIS\Workspaces\001_Deliverable1\PDFs\D 13_G1714C River (RIV) boundary – stream reaches.pdf"

Figure D 13 River (RIV) boundary – stream reaches

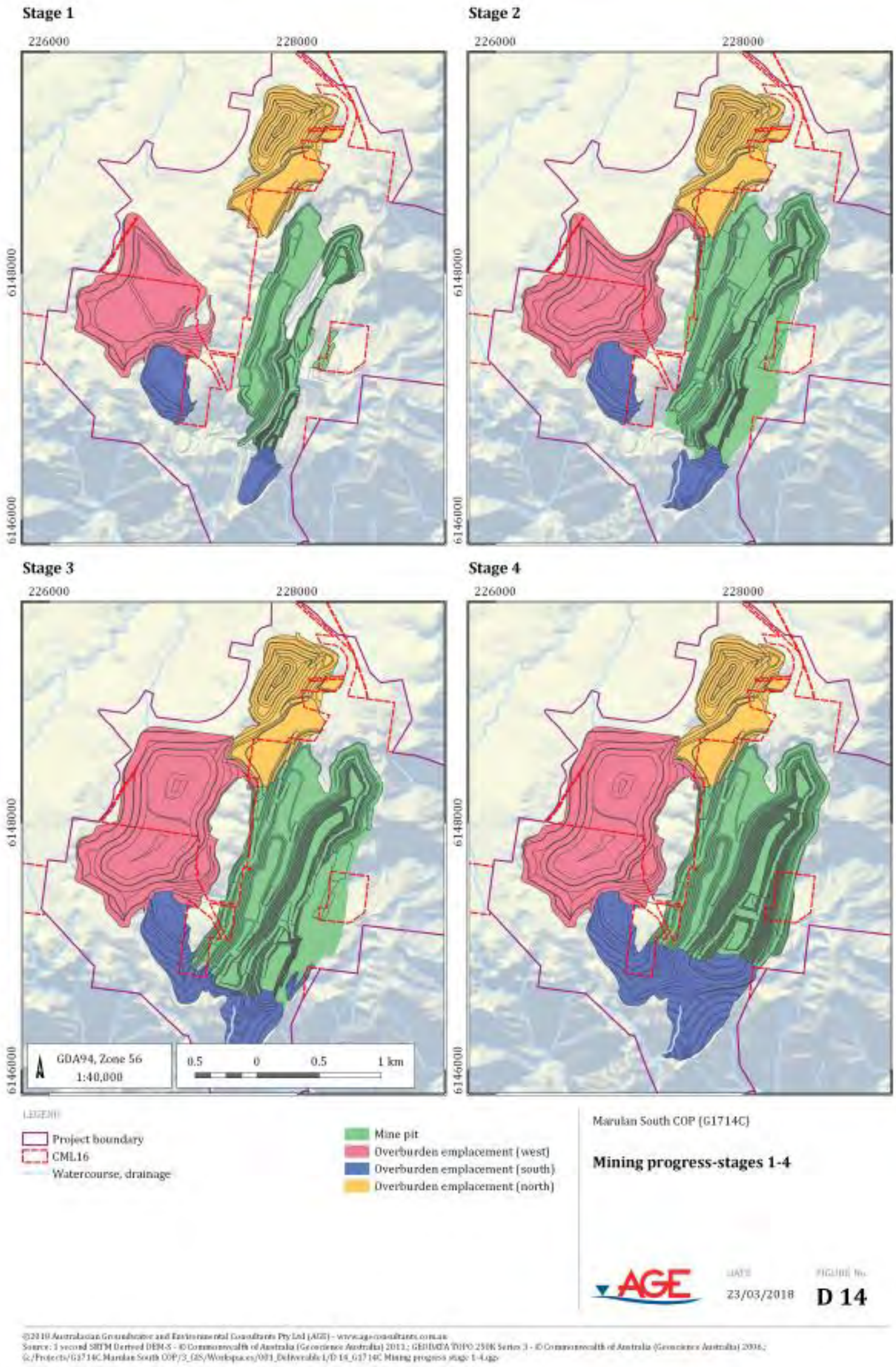


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Figure D 14 Mining progress – stages 1- 4

D3 Model calibration

Calibration of a groundwater flow model is a process that demonstrates that a model is capable of replicating observed field data. Calibration is accomplished by finding a set of parameters, boundary conditions and stresses that produce simulated heads and fluxes that match field measured values within an acceptable range of error and also conforms to the conceptual understanding of the system.

D3.1 Calibration method

The model calibration method was primarily driven by adjusting selected parameters (hydraulic conductivities, recharge rate, evapotranspiration rate, stream bed seepage, etc) within realistic ranges to match historic steady state regional and local groundwater levels. The calibration strategy involved both manual and automatic testing and adjusting of parameters to obtain an improved match to the observation data.

Calibration was undertaken in two steps: (1) steady state calibration – to approximate the hydraulic properties and generate starting heads for (2) a transient calibration run, during which the hydraulic properties were fine-tuned and recharge factors were calibrated. See Table D 2 above for timing of transient model calibration.

D3.2 Calibration targets

Groundwater level information for the calibration was collated from multiple sources, mainly, publicly available records (NSW Office of Water – Pinneena database), records provided by the client (groundwater data from site), as well as information collected during the bore census. Because the target aquifer information was limited, it was estimated based on additional background information such as bore construction, bore depth, and bore location.

Measurements from 16 bores were used to form the observation dataset. All observation locations were used for both steady state calibration and transient calibration, except for MW7, which was dry during the monitoring period and was omitted from the calibration dataset. In order to improve the performance of the calibration run, the pressure transducer data (bores MW1-MW6) were resampled from 3 measurements per day to single (average) observation per week. This frequency was deemed sufficient with respect to the calibration stress period length (1 month).

For the steady state calibration, the first measured head was used as a calibration target and the weights were set to 1. For transient calibration, the observation weights were adjusted so that the contribution of individual bores to the value of objective function is not skewed by number of individual observations. Each observation point weight was multiplied by $\frac{1}{\sqrt{n}}$, where n is a number of observations within the individual observation group.

All observation bores used during the calibration process are shown on the map (Figure D 15) as well as presented in Table D 9.

Table D 9 Observation dataset

Bore ID	Easting (GDA94, Z56)	Northing (GDA94, Z56)	Start date	End date	Number of observations	Weight
GW102505	224778.8	6147620.9	???		1	1.0000
GW105696	225506.3	6149221.6	04/12/2003		1	1.0000
GW107145	225101.4	6150126.4	30/05/2004		1	1.0000
GW108850	226103.6	6148723.7	13/02/2015		1	1.0000
GW110267 | WP16	228551.0	6148548.0	01/04/1983		1	1.0000
GW110268 | WP17	228529.7	6148447.9	01/04/1983		1	1.0000
LICH03	224649.5	6147080.1	13/02/2015		1	1.0000
LICH04	225379.8	6146935.3	13/02/2015		1	1.0000
MW1	228111.0	6147568.0	19/07/2014	17/12/2016	127	0.0887
MW2	227722.0	6146555.0	10/07/2014	19/10/2017	172	0.0762
MW3S	226618.0	6148365.0	15/07/2014	13/02/2018	188	0.0729
MW4D	226717.0	6147129.0	15/07/2014	13/02/2018	188	0.0729
MW4S	226718.0	6147140.0	15/07/2014	23/01/2018	185	0.0735
MW5	227826.0	6148352.0	15/07/2014	13/02/2018	188	0.0729
MW6	228482.0	6147186.0	15/07/2014	13/02/2018	188	0.0729
MW7	227525.0	6147816.0	11/04/2017	22/01/2018	5	n/a

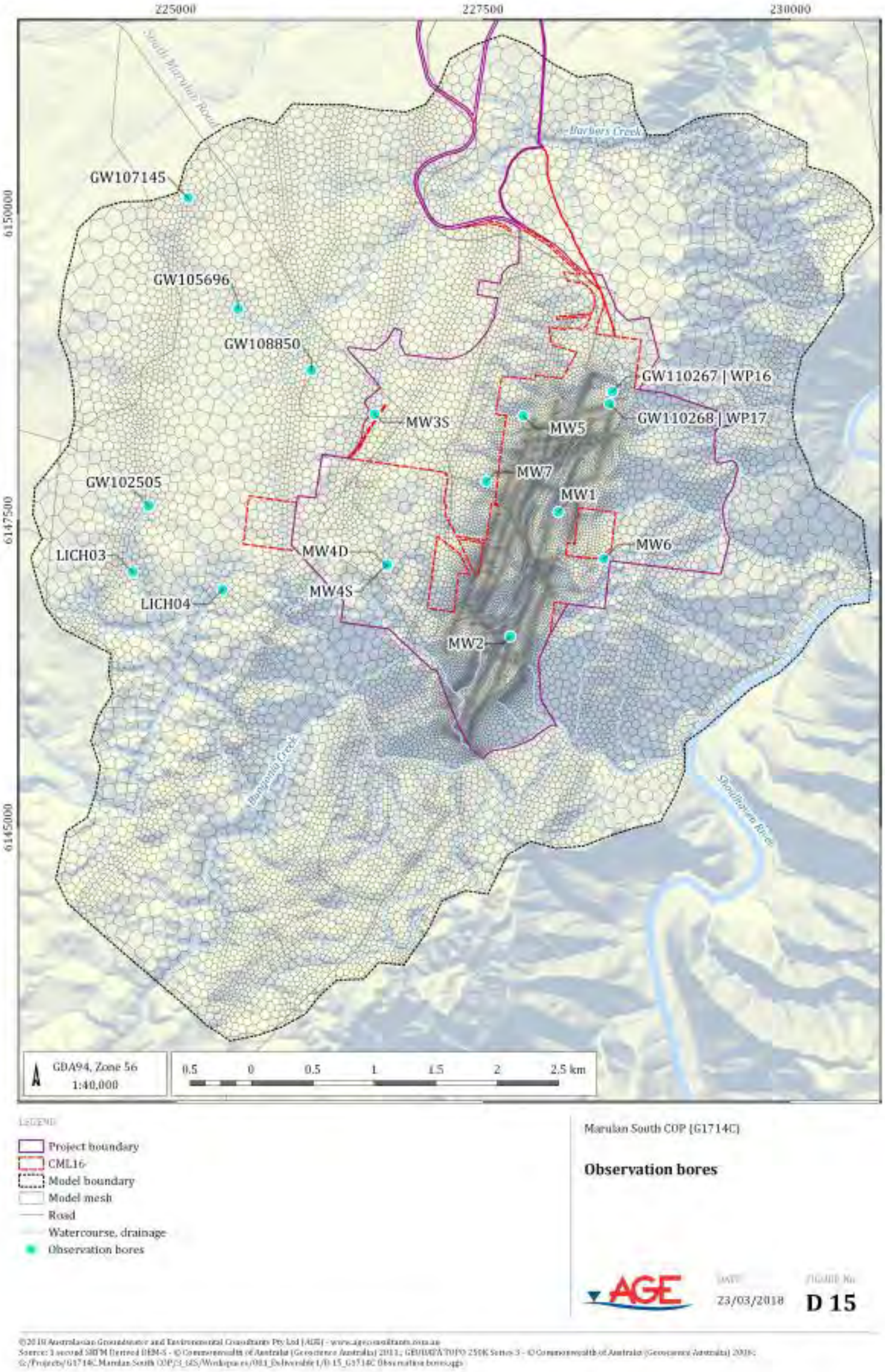

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Figure D 15 Observation bores

D3.3 Calibration parameter set

In total, 105 adjustable parameters were used to define hydraulic properties across the 21 geological zones (Kx, horizontal anisotropy - HANI, Kz, Sy, Ss), 5 adjustable parameters were used to define recharge rates to individual zones, 8 parameters were used to define vertical conductivity of creek bed and bed thickness for individual river reaches, 6 parameters were used to define evaporation rates and extinction depth. For the zonation of individual model layers, refer to Section D2.4.

D3.4 Calibration results

The quality of the calibration can be assessed by checking the model performance measures against the specific calibration criteria. The recommended performance measures (Hill and Tiedeman, 2007) include:

- Qualitative measures (representing goodness of fit between the predicted and measured groundwater heads). This assessment was undertaken by analysis of scatter diagrams comparing modelled and measured heads.
- Quantitative measures – assessment undertaken by calculating the calibration statistics.

The results of the model calibration are presented in the form of observation contribution to model error (Table D 10), calibration statistics (Table D 11), scatter diagram (Figure D 16) and a comparison between measured and modelled hydrographs (Figure D 17 to Figure D 21). Groundwater heads at the end of transient calibration are presented on Figure D 22.

In qualitative terms, the poorer correlation between measured and modelled hydrographs of in-pit bores reflects:

- the coarseness of the spatial distribution of hydraulic parameters within the mining pit;
- uncertainty in the hydraulic parameter values;
- uncertainty of the hydrogeologic function (and precise location) of the dykes;
- uncertainty of the spatial distribution of fractures governing the flow within pits, as well as
- uncertainty of the recharge and evaporation rates in / out of the pit.

Full set of calibrated hydraulic parameter values is presented in Table D 12.

Although not specifically quantified in modelling guidelines (Barnett *et al.*, 2012), it is generally recommended that the value of scaled RMS (SRMS) is below 10%. This criterion was satisfied for both steady state and transient calibration runs.

Given the compartmentalisation of the hydraulic system, the poorer correlation of observations within the limestone body will have very limited impact on the groundwater table outside of the mine (see the out-of-pit bore hydrographs) and the adopted parameter set is considered to produce a representative groundwater table / flow predictions on regional scale.

Table D 10 Contribution to calibration error – steady state and transient residuals

Bore ID	Residual (SS) (m)	Average residual (TR) (m)
gw102505	-6.58	-6.40
gw105696	-21.22	-20.77
gw107145	-0.96	-2.55
gw108850	2.32	2.50
gw110267	-0.06	-1.21
gw110268	0.06	0.56
lich03	5.91	6.83
lich04	2.35	2.62
mw1	0.00	0.37
mw2	3.42	0.32
mw3s	-16.49	-9.65
mw4d	-12.1	-0.37
mw4s	7.29	14.29
mw5	-0.25	-0.09
mw6	-0.01	0.05

Table D 11 Calibration statistics

	Steady state	Transient
# of observations (n)	15	1243
Sum of squared residuals – SSQ (m^2)	1023.42	58150.72
Root mean squared error – RMS (m)	8.26	6.84
Scaled root mean squared error – SRMS (%)	3.01	2.49

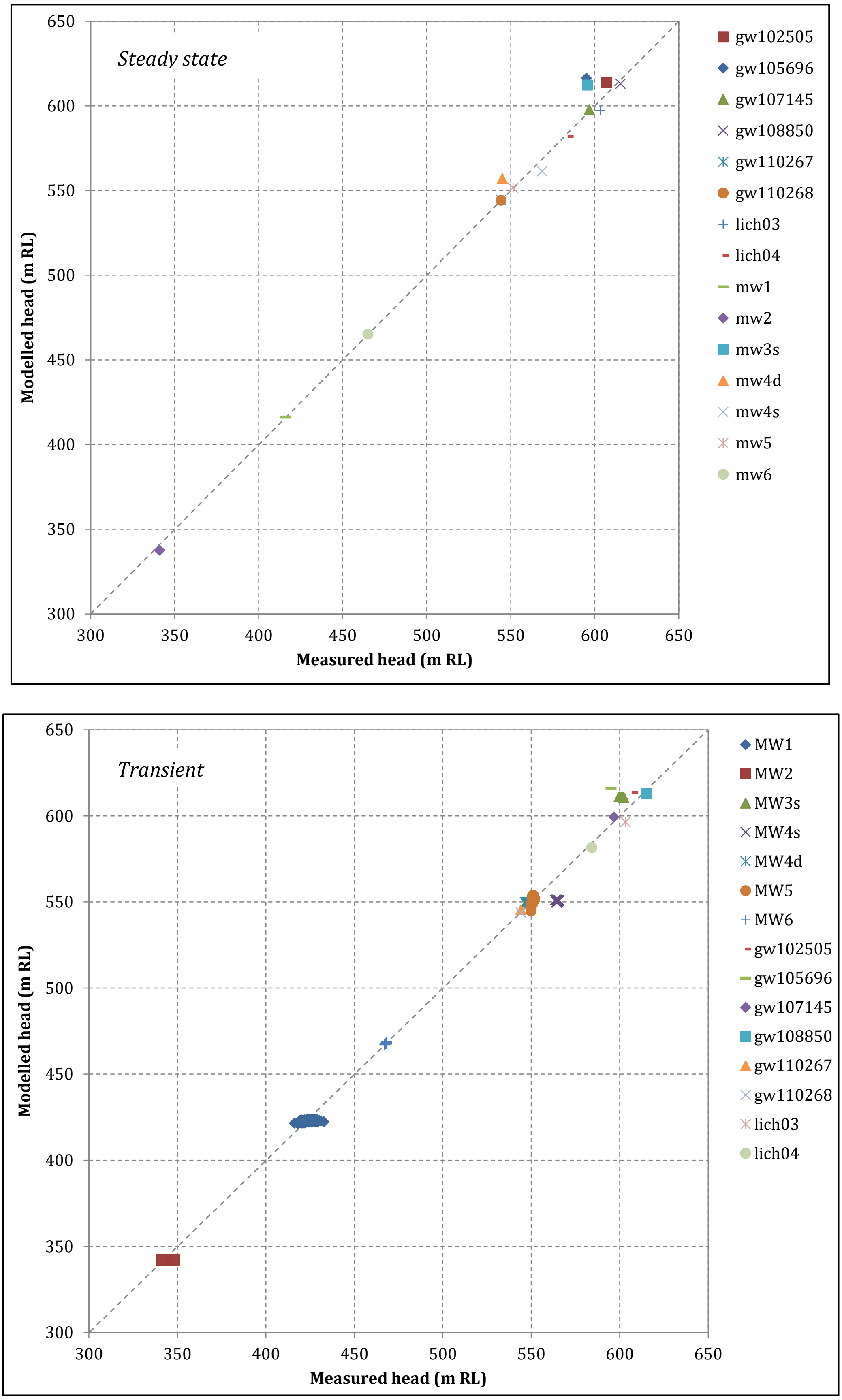

Figure D 16 Steady state and transient calibration – scatter diagrams

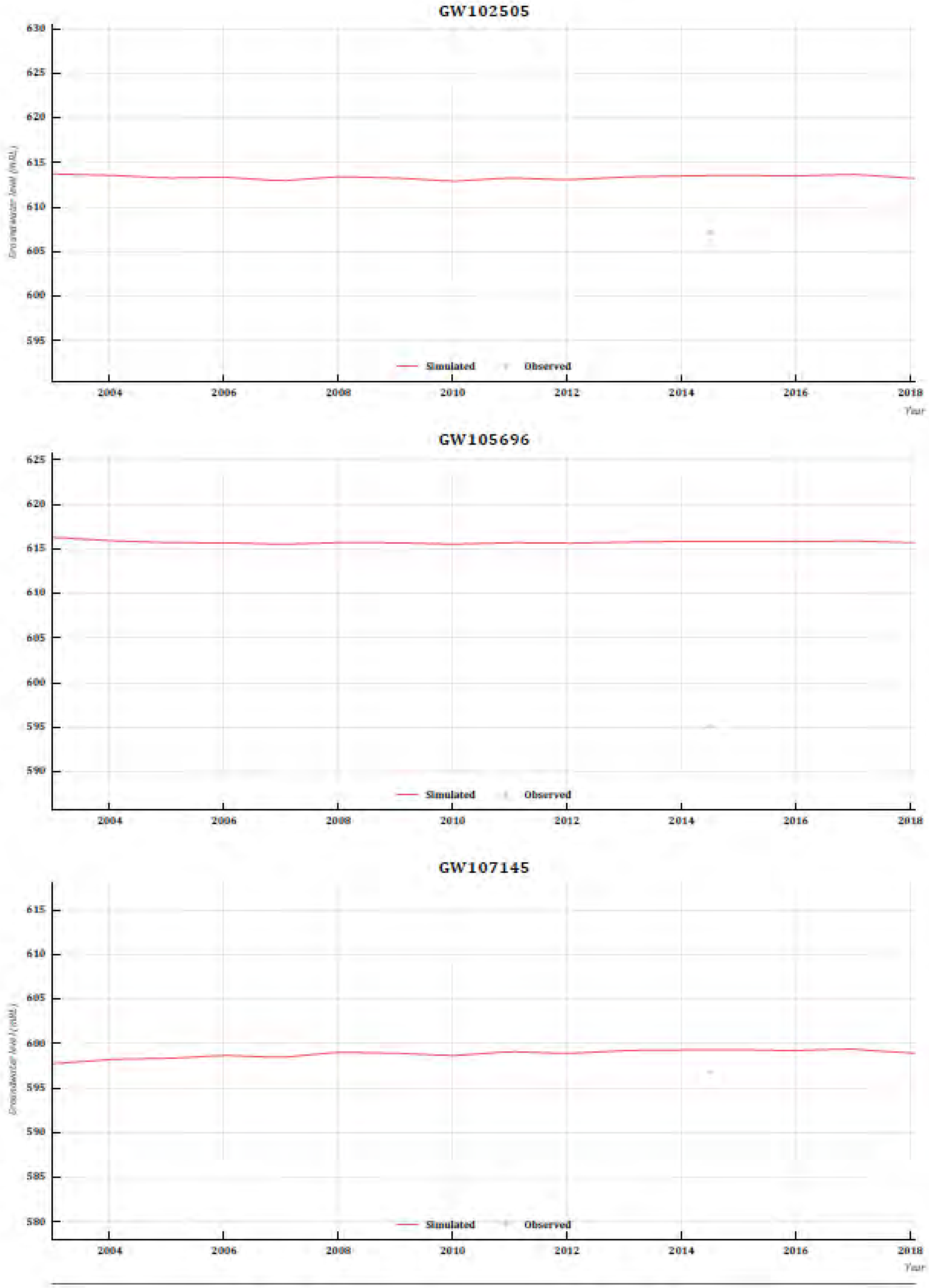

Figure D 17 Hydrographs – GW102505, GW105696, GW107145

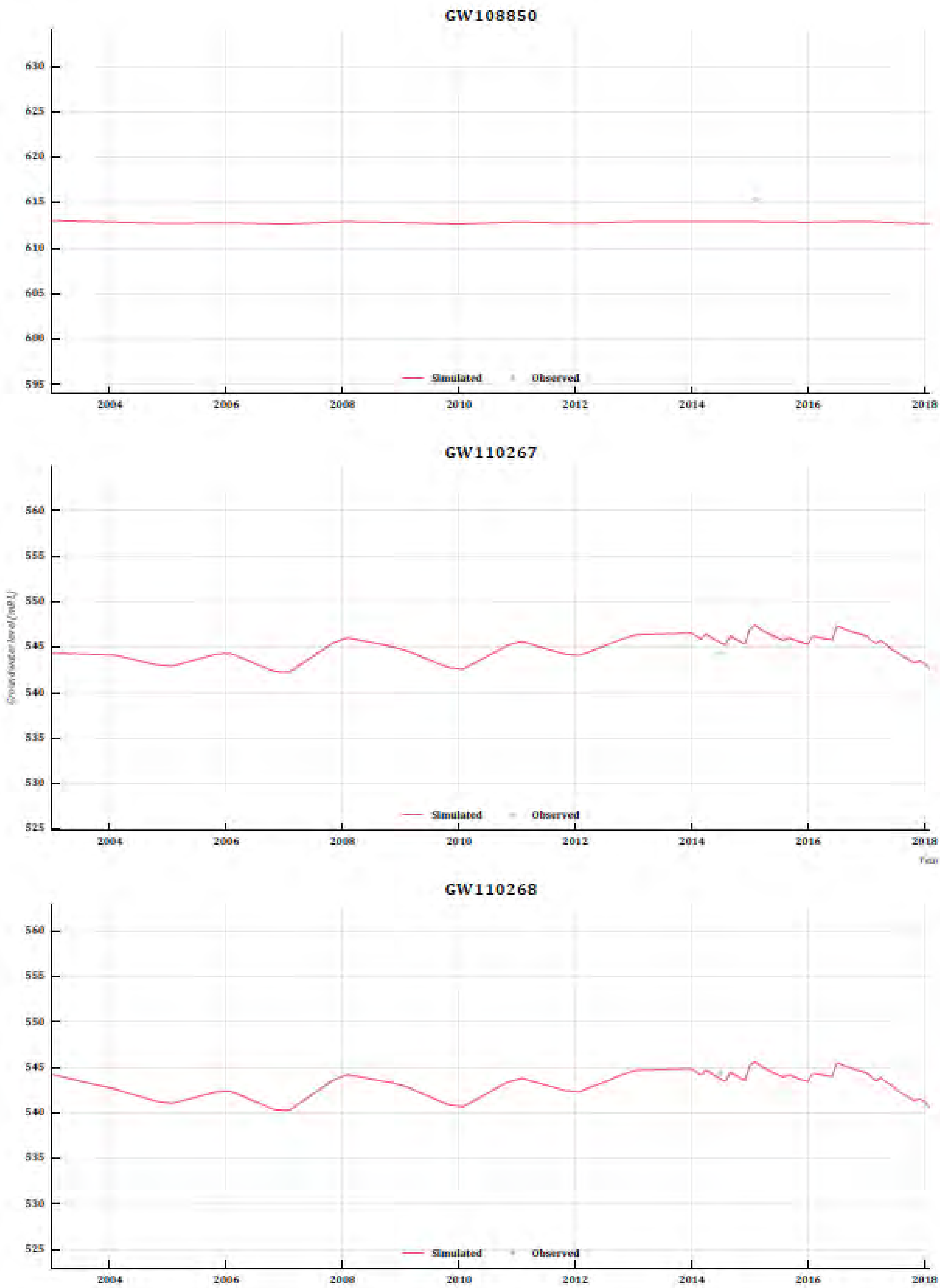

Figure D 18 Hydrographs – GW108850, GW110267, GW110268

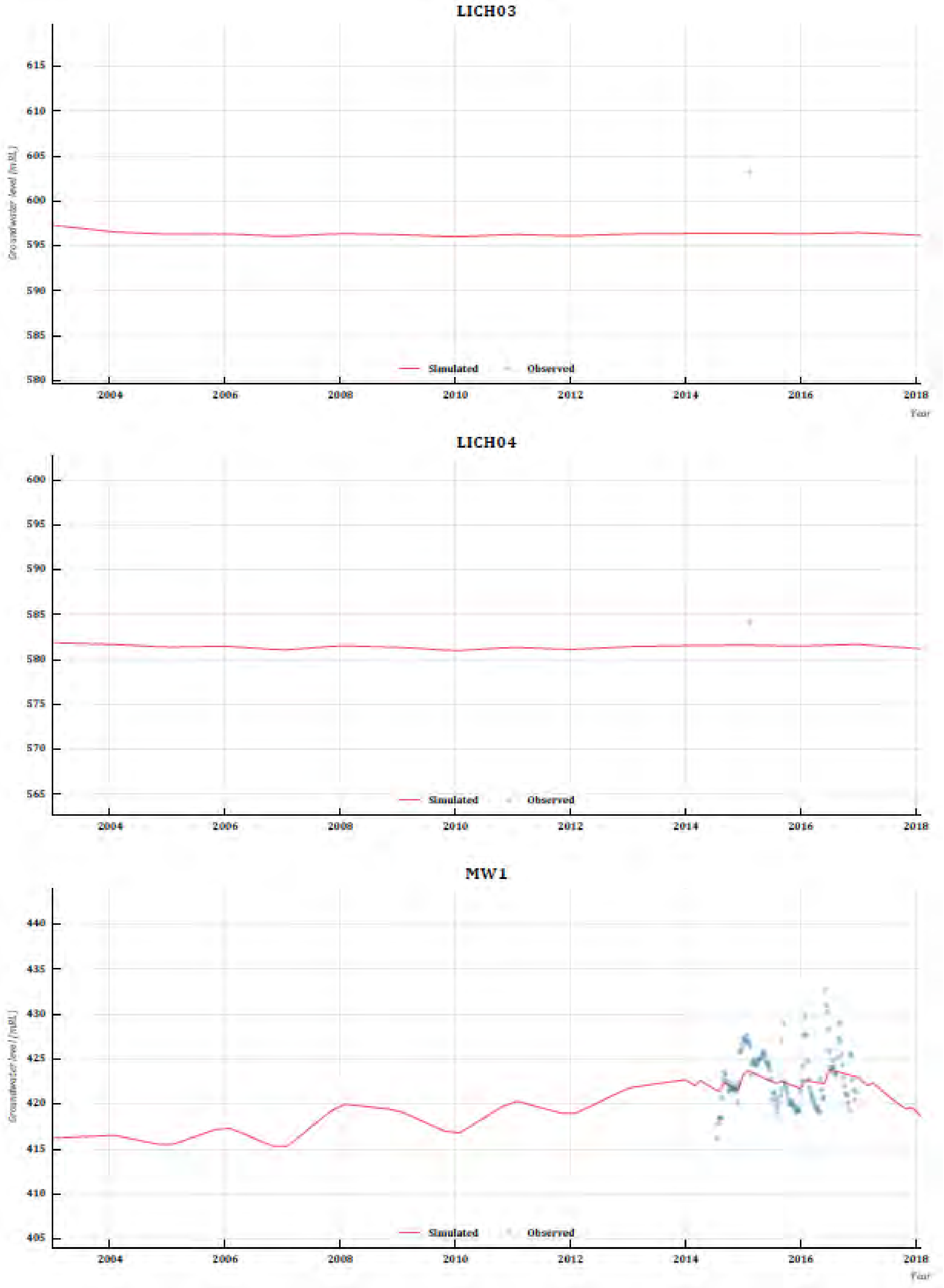

Figure D 19 Hydrographs – LICH03, LICH04, MW1

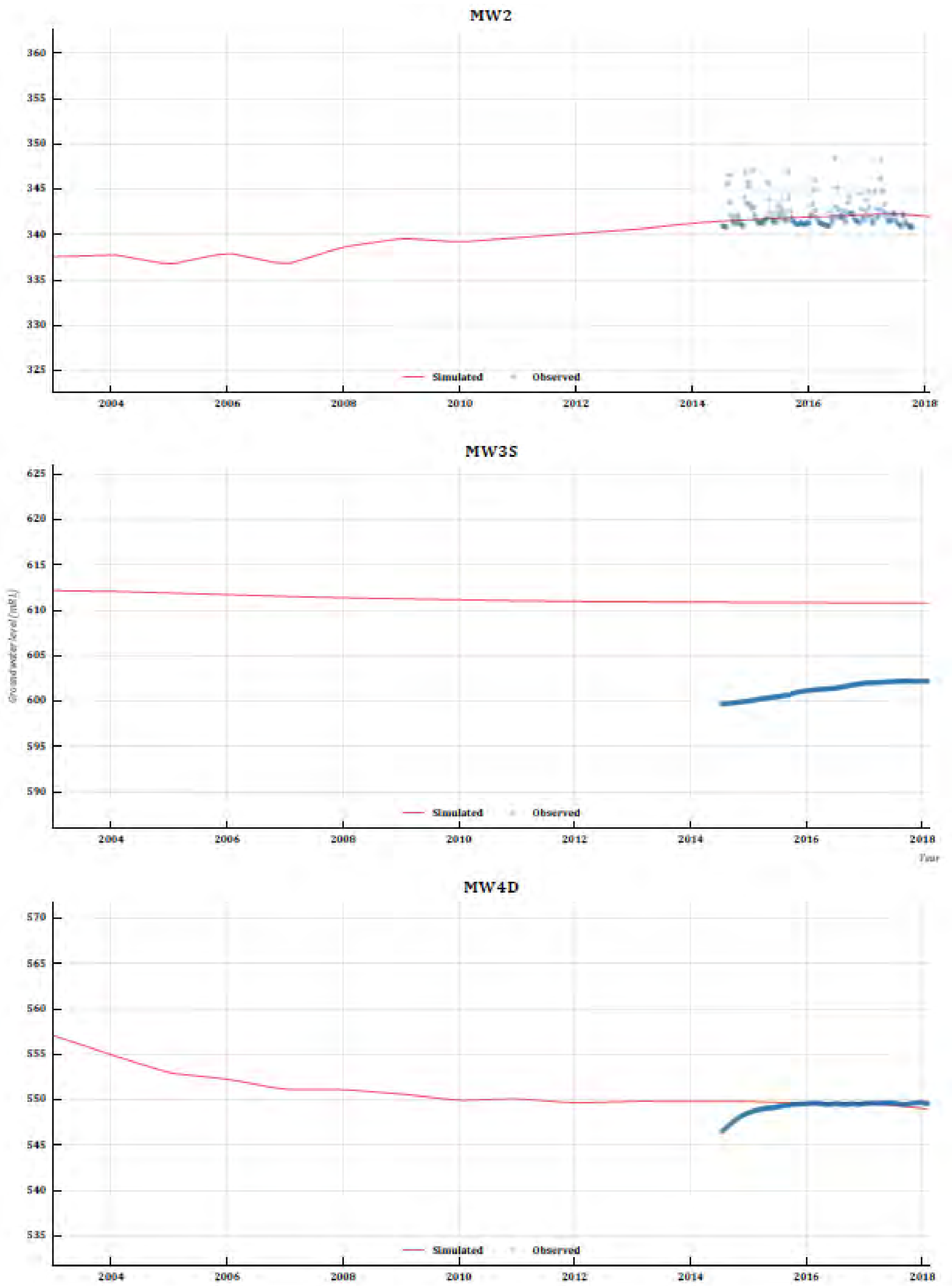

Figure D 20 Hydrographs – MW2, MW3S, MW4D

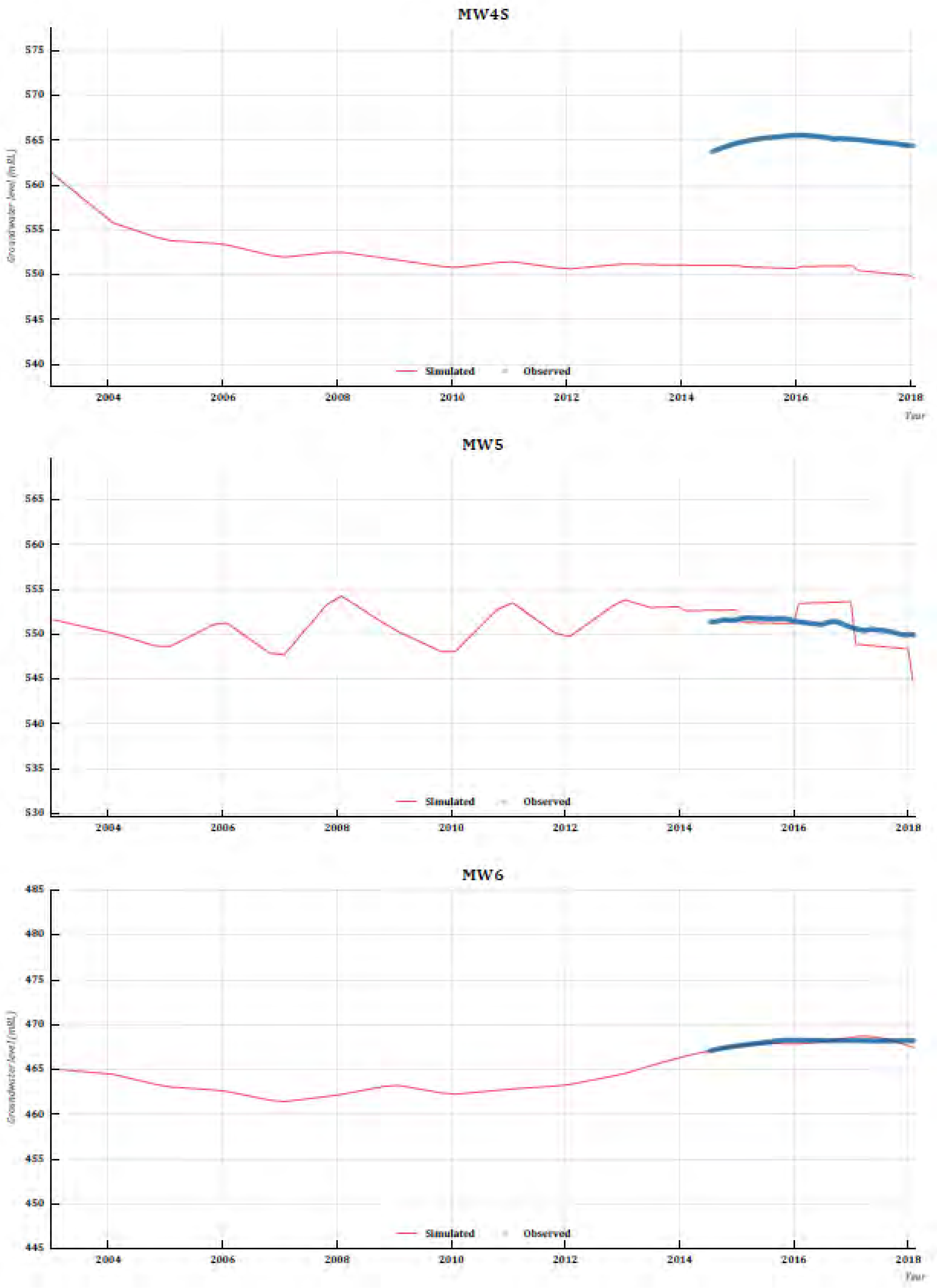

Figure D 21 Hydrographs – MW4S, MW5, MW6

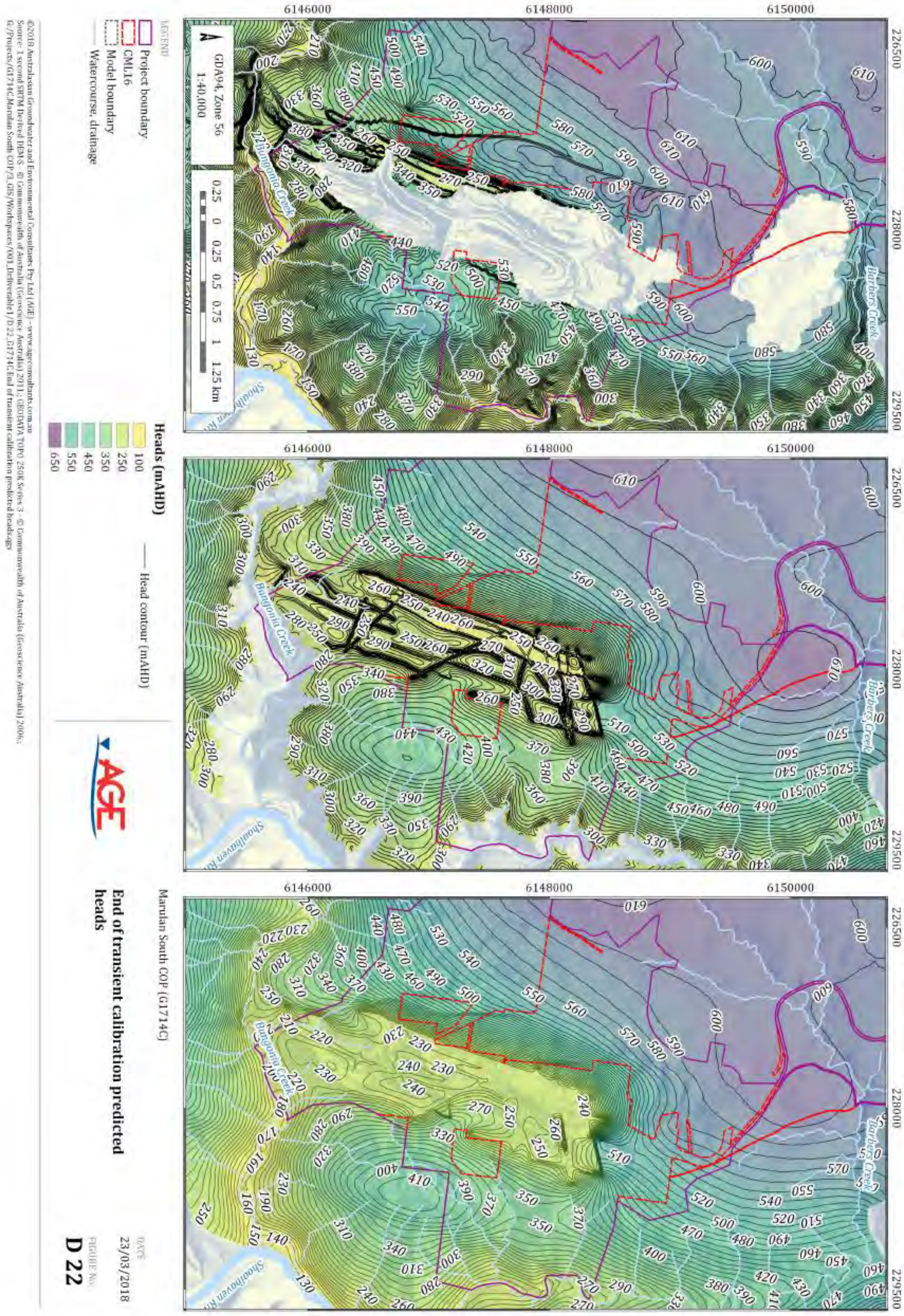

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Figure D 22 Groundwater heads – end of transient calibration

Table D 12 Calibrated hydraulic parameters

Layer	Zone	Comment	Kx (m/day)	HANI (-)	Ky (m/day)	Kz (m/day)	Sy (-)	Ss (m^{-1})
1	1	topsoil, regolith, alluvium, historical spoil	0.309519	1.00	0.30952	0.01548	0.01000	0.000100
1	2	alluvium - Shoalhaven River	5.000000	1.00	5.00000	1.25000	0.05000	0.000500
1	3	alluvium - Bungonia Creek	5.000000	1.00	5.00000	1.25000	0.05000	0.000500
1	4	alluvium – Barbers Creek	5.000000	1.00	5.00000	1.25000	0.05000	0.000500
2-10	5	granite – Marulan Granite	0.000339	2.00	0.00068	0.00169	0.00500	0.000010
2-10	6	ignimbrite – Barralier Ignimbrite, Bindook Group	0.000500	5.00	0.00250	0.00213	0.00500	0.000010
2-10	7	granodiorite – Glenrock Granodiorite	0.000108	5.00	0.00054	0.00020	0.00500	0.000010
2-10	8	tuffs – Kerillon Tuff Member, Tangerang Formation	0.000080	5.00	0.00040	0.00046	0.00500	0.000010
2-10	9	limestone	0.000101	5.00	0.00050	0.00202	0.00500	0.000010
2-10	10	conglomerate, volcanic breccia	0.000080	5.00	0.00040	0.00080	0.00500	0.000010
2-10	11	dacite – Carne Dacite, Tangerang Formation	0.000040	5.00	0.00020	0.00005	0.00500	0.000075
2-10	12	sandstone, undifferentiated – Adaminaby Group	0.000094	5.00	0.00047	0.00022	0.00100	0.000004
2-10	13	sandstone, mudstone – Bumballa Formation	0.000030	5.00	0.00015	0.00018	0.00100	0.000005
2-10	14	limestone contact zones – weathered limestone	10.00000	2.00	20.0000	8.54800	0.01000	0.000500
2-9	15	pit floor fractures	50.00000	1.00	50.0000	50.0000	0.01000	0.000500
2-10	16	fracture zones associated with faults	5.000000	1.00	5.00000	25.0000	0.01000	0.000500
2-10	17	basaltic dykes	0.000001	1.00	0.00000	0.00000	0.01000	0.000005
9	18	karst fractures connected to Main Gully Spring Cave	100.0000	1.00	100.000	100.000	1.00000	0.000005
2-10	19	limestone – North Pit – north	0.000120	5.00	0.00060	0.00076	0.00500	0.000018
2-10	20	limestone – North Pit – central and southern parts	0.000018	5.00	0.00009	0.00010	0.00500	0.000007
2-10	21	limestone – South Pit	0.000040	5.00	0.00020	0.00020	0.00500	0.000006

D4 Model predictions

D4.1 Predictive run – base case - volumetric budget

While the model is predicting changes to water levels, it is also predicting flow between model cells and flow to and from boundary conditions, and recording these flows in its output. This output can be processed and accumulated such that predicted flows for certain model components can be reported. In particular, predicted flows across model boundaries (general head boundary) and predicted flows caused by hydraulic stresses (rainfall recharge, stream bed recharge and discharge, evapotranspiration, mine dewatering) can be reported and presented.

The overall volumetric water balance is one of the measures of sufficient numerical convergence and hence correctness of the model predictions. It is generally recommended (Barnett *et al.*, 2012) that the cumulative water balance error (percent discrepancy) is below 1% for each timestep. The water balance error for the basecase predictive model run is below 0.01% for the entire model run.

The volumetric budget is summarized in Table D 13 and Figure D 23. The volumetric budget components are:

- Inflows: recharge (RCH), cross-boundary inflows (GHB) and seepage from flowing rivers and streams (RIV) – see Figure D 24; and
- Outflows: drains (DRN), evaporation/evapotranspiration (ET/EVT), cross-boundary outflow (GHB) and baseflows to streams (RIV) – see Figure D 25.

The model wide volumetric budget inputs are dominated by aerial rainfall related recharge (RCH) that contributes approximately 86% to the model inflows. The other component of budget input is recharge from the flowing rivers and streams (RIV) into the bedrock and alluvial aquifers, contributing approximately 11% of inflow. Inflows across the model boundary (GHB) into the model domain stand only for 3% of total inflows.

The outflows are dominated by stream baseflow (RIV boundary condition) that represents approximately 51% of outflow. This is followed by evapotranspiration, which removes approximately 43% of outflows from the system. Drains (DRN boundary condition representing mining of Marulan limestone) remove approximately 2% of outflow from the model domain and the cross-boundary outflows represent approximately 4% of the outflows.

Consistent with the conceptual model, the surface water streams act as major sinks for groundwater. The creeks and river are located in topographically “low” parts of the model and as the groundwater table is shaped significantly by topography, steep gradients towards the streams exist. The baseflow (recharge from the bedrock and underlying alluvium into streams) is estimated to be approximately 16422 ML over the life of the project (32 stress periods, 31.5 years) while the recharge of the alluvium from the streams is only 3375 ML. In terms of rainfall recharge, the modelled area receives 27298 ML. The losses from the groundwater system are on average 531 ML as a result of mining process and 13744 ML from evapotranspiration. The cross-boundary flows represent 984 ML inflows and 1420 ML outflows.

Table D 13   Predictive run – cumulative volumetric budget summary

Stress	Label	Volume (ML*)	Volume (% of total)	Volume (% of IN or OUT)
Rainfall recharge	rech_in	27298.4	42.8	86.2
River	riv_in	3375.2	5.3	10.7
General head boundary	head_in	983.9	1.5	3.1
Σ(in)		*31657.5*	*49.6*	*100.0*
Drains - mining	drn_out	531.4	0.8	1.7
Evapotranspiration	et_out	13744.0	21.6	42.8
River	riv_out	16422.7	25.8	51.1
General head boundary	head_out	1420.3	2.2	4.4
Σ(out)		*32118.5*	*50.4*	*100.0*
Δ (out-in)		461.0	0.7	n/a

Note: ** volumes in ML over the life of the project (32 stress periods, 31.5 years)*

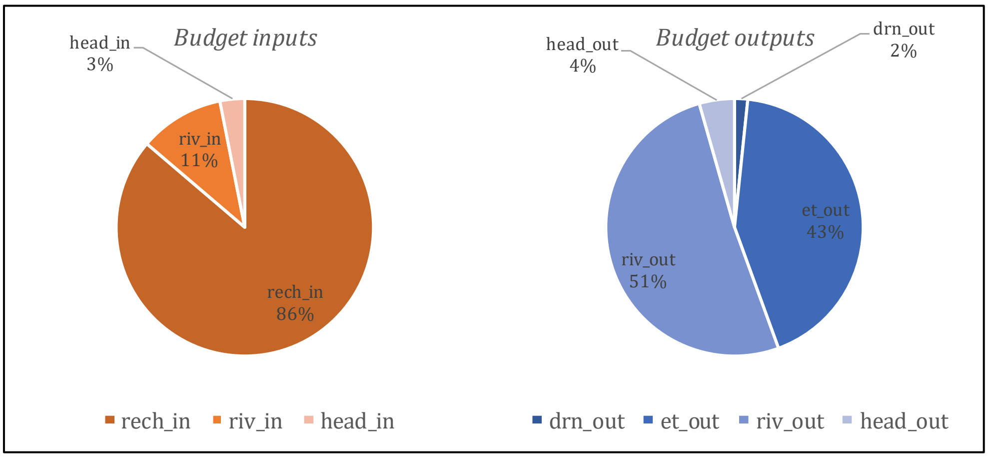

Figure D 23   Predictive run – volumetric budget summary

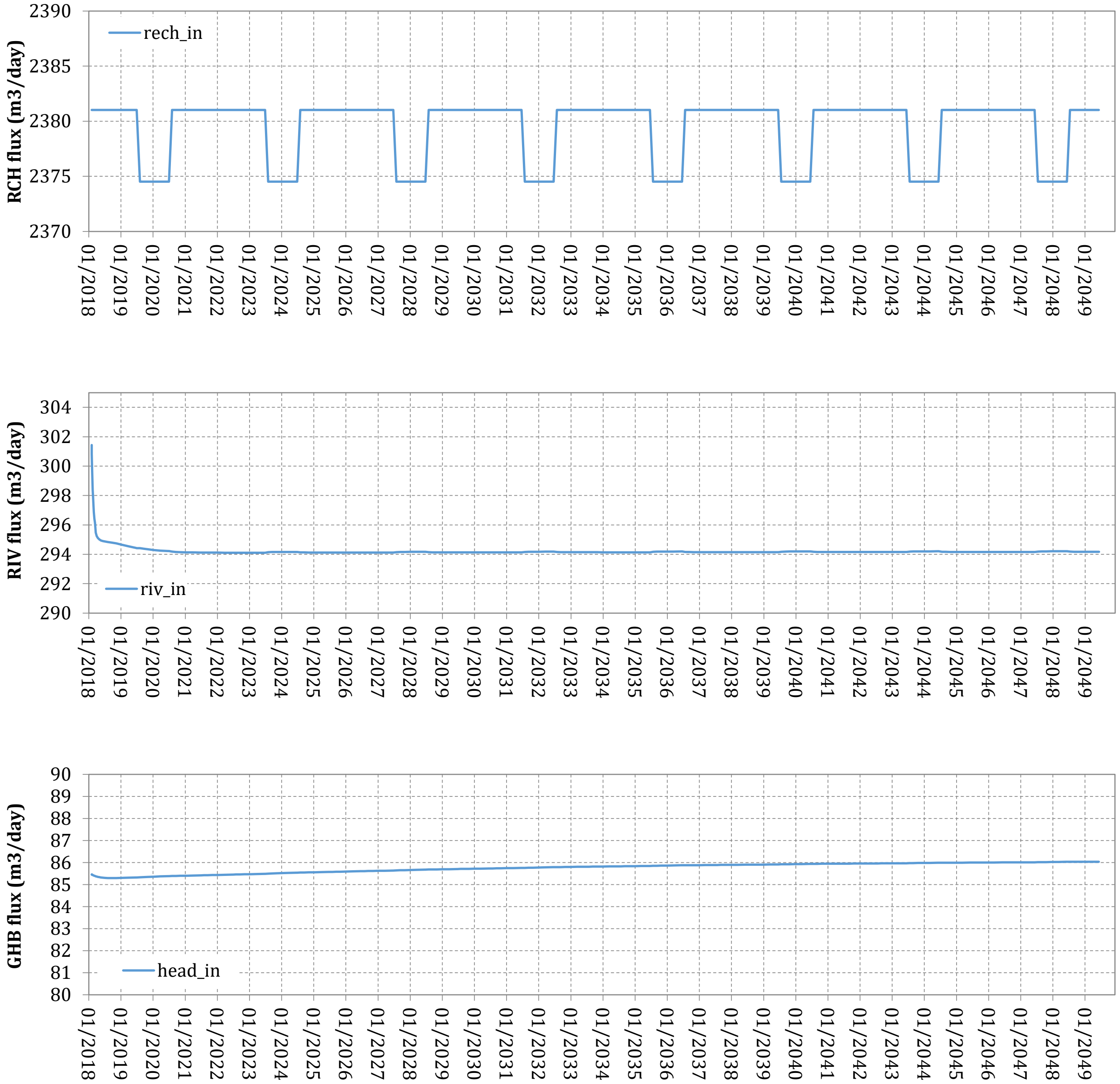

Figure D 24 Prediction run – global water budget – input components (RCH, RIV, GHB)

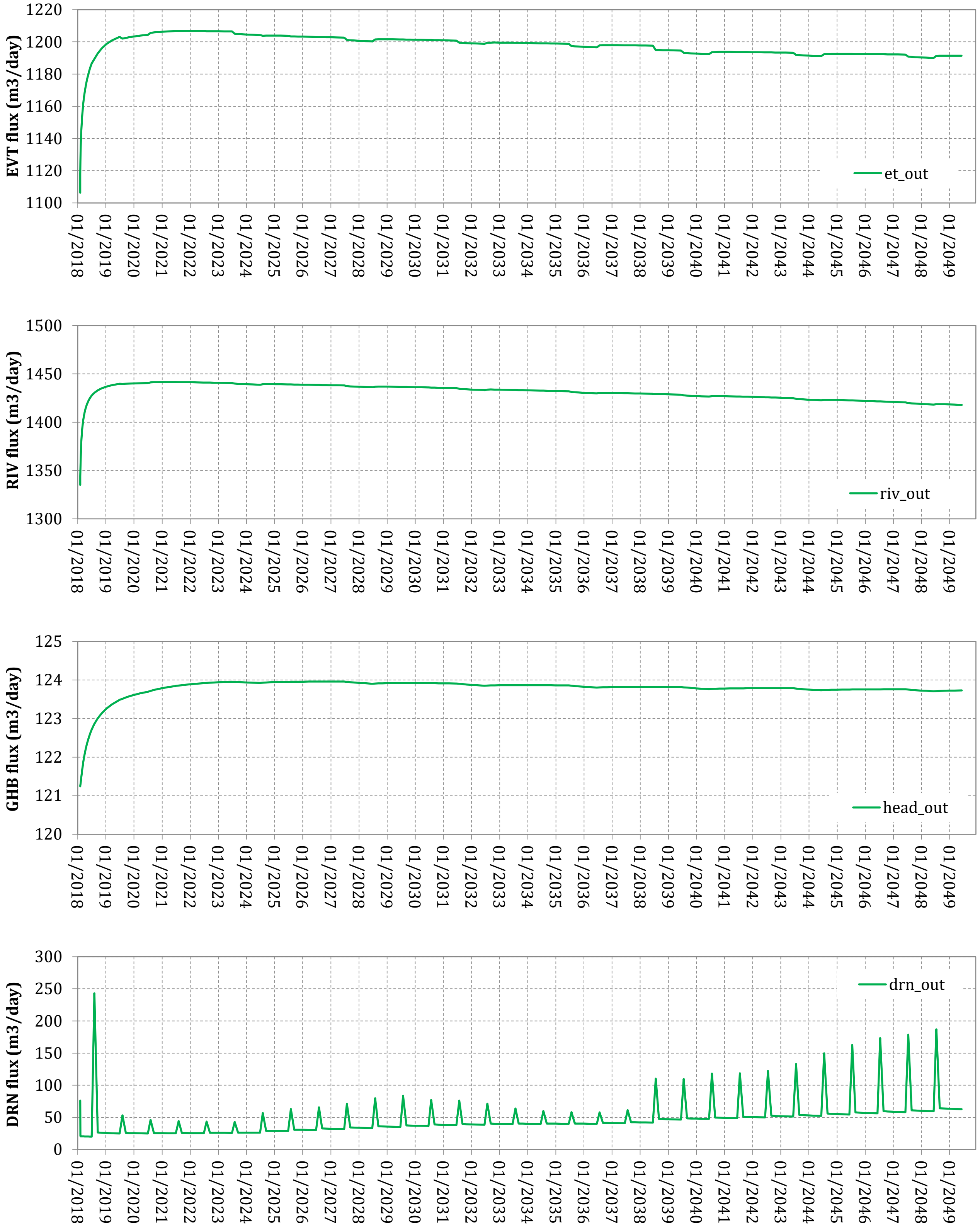

Figure D 25 Prediction run – global water budget – output components (EVT, RIV, GHB, DRN)

D4.2 Predictive run – base case - zone budgets

For the purpose of evaluating the impact of the Project on alluvial aquifers of Shoalhaven River, and Bungonia and Barbers Creeks and to satisfy AIP and SEARs requirements with respect to alluvial water sources, the predicted budgets for individual alluvial zones were extracted from the model output. Additionally, the zone of mining was defined by all cells within the final pit shell (i.e. at the end of Stage 4, mining year 30).

D4.2.1 Bedrock aquifers – mining

Dewatering of the pit is represented in the model by the drain package, with elevations of drains set to the pit floor and progressively lowered as the mining progresses. The annual pit shells were calculated by the linear interpolation of depth between available pit shells for end of mining years 5 (Stage 1), 13 (Stage 2), 19 (Stage 3) and 30 (Stage 4). Because of this interpolation process, the drain cells elevation are not considered absolutely precise for particular end of the stress period, however this imprecision does not have an impact on calculations of groundwater extraction from the bedrock aquifer. The predicted take from the groundwater regime (inflow to the pit) from the proposed mining can be then estimated by assessing the water budget on the drain boundary condition.

The zone budget calculation for the Marulan mine pit zone (Table D14) shows that inflows into the pit from the surrounding bedrock is relatively small (9.1 m^3/day on average) compared to main source of recharge – rainfall (142.4 m^3/day on average). In terms of outflows, most of the water disappears through the fractures and bedrock seepage into the karst connected to the mine pits (approximately 111 m^3/day) and available water excesses are removed by evaporation (1.7 m^3/day). As the limestone is mostly pre-drained due to various interconnected fracture systems, the water table will be below the pit floor during the mining operations and the only water removed during the mining is water in residual (not interconnected) storage in the rock itself. The predicted take from the consolidated limestone (ore body), sandstone and shale (overburden) aquifers varies from 19 m^3/day to 63 m^3/day (7 ML/year to 22 ML/year) with average take of 39 m^3/day (14.2 ML/year).

The full zone budget for the mine pits is presented in Table D 14, the drain take is summarized in Table D 15 and Figure D 26.

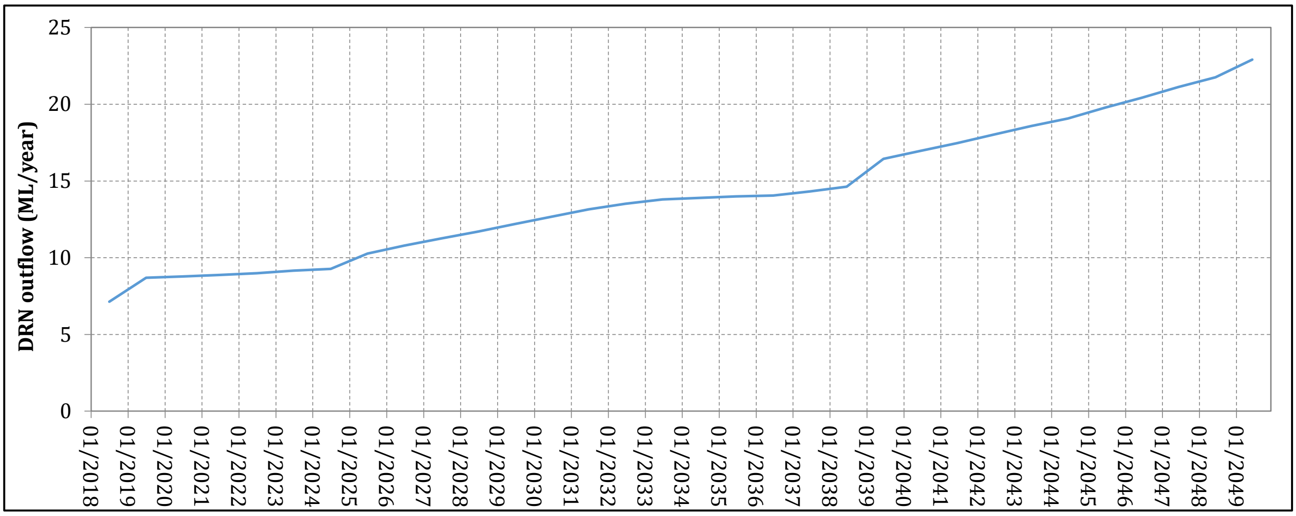

Figure D 26 Prediction run – zone budget – DRN outflow (mining)

Table D 14 Predictive run – zone budget – Marulan South Limestone Mine

Stress period	Inputs (m^3/day)		Outputs (m^3/day)			Total IN (m^3/day)	Total OUT (m^3/day)
	From geo environment	Rainfall recharge	To geo environment	Evapotranspi-ration	Mining		
1	7.57	142.53	127.10	3.46	19.54	150.10	150.10
2	7.87	142.53	123.54	3.04	23.81	150.40	150.39
3	7.97	142.14	123.19	2.94	23.98	150.11	150.11
4	8.04	142.53	123.30	2.96	24.31	150.57	150.57
5	8.07	142.53	123.01	2.95	24.64	150.60	150.60
6	8.09	142.53	122.60	2.94	25.09	150.62	150.63
7	8.08	142.14	121.93	2.94	25.34	150.22	150.21
8	8.19	142.53	120.10	2.47	28.15	150.72	150.72
9	8.33	142.53	118.95	2.37	29.54	150.86	150.86
10	8.49	142.53	117.85	2.33	30.84	151.02	151.02
11	8.63	142.14	116.49	2.31	31.97	150.77	150.77
12	8.86	142.53	115.65	2.32	33.42	151.39	151.39
13	9.20	142.53	114.67	2.33	34.73	151.73	151.73
14	9.82	142.53	113.96	2.35	36.04	152.35	152.35
15	10.30	142.14	113.09	2.42	36.94	152.44	152.45
16	10.00	142.53	112.55	2.18	37.81	152.53	152.54
17	9.94	142.53	112.23	2.16	38.07	152.47	152.46
18	9.88	142.53	111.89	2.16	38.35	152.41	152.40
19	9.81	142.14	111.39	2.14	38.41	151.95	151.94
20	9.75	142.53	110.90	2.17	39.21	152.28	152.28
21	9.71	142.53	109.99	2.19	40.06	152.24	152.24
22	9.66	142.53	106.94	0.21	45.04	152.19	152.19
23	9.63	142.14	105.32	0.11	46.35	151.77	151.78
24	9.62	142.53	104.18	0.11	47.87	152.15	152.16
25	9.61	142.53	102.66	0.10	49.38	152.14	152.14
26	9.62	142.53	101.15	0.09	50.91	152.15	152.15
27	9.62	142.14	99.57	0.08	52.11	151.76	151.76
28	9.64	142.53	97.90	0.08	54.19	152.17	152.17
29	9.64	142.53	96.15	0.08	55.94	152.17	152.17
30	9.62	142.53	94.20	0.08	57.88	152.15	152.16
31	9.60	142.14	92.21	0.08	59.45	151.74	151.74
32	9.74	142.53	89.42	0.08	62.78	152.27	152.28

Table D 15 Predictive run – zone budget – water removed through drains (DRN)

Stress period	Stress period duration (days)	Date at end of SP	DRN volume (m^3/SP)	DRN volume (ML/SP)	DRN volume (ML/year)
1	150	30/06/2018	2931.60	2.93	7.13
2	365	30/06/2019	8691.38	8.69	8.69
3	366	30/06/2020	8777.05	8.78	8.78
4	365	30/06/2021	8874.61	8.87	8.87
5	365	30/06/2022	8993.97	8.99	8.99
6	365	30/06/2023	9156.03	9.16	9.16
7	366	30/06/2024	9274.44	9.27	9.27
8	365	30/06/2025	10274.39	10.27	10.27
9	365	30/06/2026	10782.83	10.78	10.78
10	365	30/06/2027	11256.60	11.26	11.26
11	366	30/06/2028	11701.39	11.70	11.70
12	365	30/06/2029	12196.84	12.20	12.20
13	365	30/06/2030	12676.09	12.68	12.68
14	365	30/06/2031	13154.60	13.15	13.15
15	366	30/06/2032	13518.21	13.52	13.52
16	365	30/06/2033	13799.19	13.80	13.80
17	365	30/06/2034	13894.82	13.89	13.89
18	365	30/06/2035	13998.12	14.00	14.00
19	366	30/06/2036	14058.06	14.06	14.06
20	365	30/06/2037	14313.11	14.31	14.31
21	365	30/06/2038	14622.63	14.62	14.62
22	365	30/06/2039	16438.87	16.44	16.44
23	366	30/06/2040	16962.27	16.96	16.96
24	365	30/06/2041	17472.92	17.47	17.47
25	365	30/06/2042	18024.80	18.02	18.02
26	365	30/06/2043	18582.15	18.58	18.58
27	366	30/06/2044	19071.16	19.07	19.07
28	365	30/06/2045	19780.08	19.78	19.78
29	365	30/06/2046	20419.56	20.42	20.42
30	365	30/06/2047	21126.57	21.13	21.13
31	366	30/06/2048	21758.70	21.76	21.76
32	365	30/06/2049	22913.61	22.91	22.91

D4.2.2 Alluvial zones

There are three alluvial zones represented in the model. These are: alluvium of Shoalhaven River (zone 02), alluvium of Bungonia Creek (zone 03) and alluvium of Barbers Creek (zone 04 - refer to Section D2.4, Figure D 3). Although the alluvial zones are not particularly extensive, they play a key role as discharge areas, removing groundwater from the system (through a use of river boundary condition). This function is driven by topography of the modelled area, as the alluvium is mostly located in the lower lying parts of the model domain.

All alluvial zones represented in the model receive water from multiple sources. One of the sources is the surface water stream associated with the alluvium in the form of the leakage through the stream bed, to the alluvial sediments. The second major source is groundwater seeping upwards or sideways from underlying bedrock, or flowing from upstream section of alluvium. The last source is rainfall related recharge, which depends on the area of the alluvium and compared to the other two sources is quite small.

In terms of outflow, the alluvium loses water to the rivers or creeks in the form of baseflow. Second form of groundwater loss is either to the underlying bedrock or in the form of flow within the alluvial sediments to a downstream section of alluvium. Last, and in this case least significant, type of water loss is in the form of evapotranspiration.

Shoalhaven River alluvial zone receives the majority of its water (on average 243 m^3/day) from leakage from Shoalhaven River. Having both creek alluvial zones upstream, it also receives on average 25 m^3/day from alluvium of Bungonia Creek and 81 m^3/day from alluvium of Barbers Creek. The upwards recharge from bedrock constitutes on average 15 m^3/day and inflow from weathered regolith is approximately 27 m^3/day, bringing the inflows from the geological environment up to 151 m^3/day. The diffuse rainfall recharge constitutes of 6 m^3/day, averaged over a year.

Because both Bungonia and Barbers Creeks are modelled as having intermittent flow, the head in the creek was defined roughly equivalent to the creek bed resulting in a reduced recharge potential from the creek. This is reflected by the model water budget, where the creek alluvial zones receive on average 17 m^3/day (Bungonia Creek alluvium) and 23 m^3/day (Barbers Creek alluvium) from their respective surface water streams. Bungonia Creek alluvium also shows elevated inflow from underlying bedrock (601 m^3/day) which is driven by system of fractures within the limestone, underlying the alluvium.

The river boundary condition provides a groundwater sink as it enables groundwater to drain from the alluvium, that means the alluvial aquifers recharge the creeks in form of baseflow This volume of water represents the majority of the outflow portion of the numerical model water budget for both the Shoalhaven River alluvium (391 m^3/day) and the Bungonia Creek alluvium (454 m^3/day). The Barbers Creek alluvium zone shows no baseflow from the alluvium to the creek, as it only loses groundwater via down-valley flow (~81 m^3/day into Shoalhaven River alluvium) and seepage to bedrock (~ 6 m^3/day). The transient budgets for all alluvial zones are summarized in Table D 16.

Table D 16 Predictive run – average zone budgets – alluvium

Boundary Conditions		SHL (z02)	BUN (z03)	BAR (z04)
Input	RIV	242.8	17.5	23.4
	RCH	5.6	8.0	2.2
	GEO	150.8	601.4	46.0
	Σ	399.2	626.9	71.6
Output	RIV	390.7	454.4	0
	ET	1.3	5.1	0
	GEO	0.0	167.5	87.3
	Σ	392.1	627.0	87.3

***Note*:** *Input/output boundary conditions: RIV – river, RCH – recharge, ET – evapotranspiration, GEO – flows from and to geological environment (bedrock, adjacent alluvial zone);*

Budget zones: SHL – Shoalhaven River, BUN – Bungonia Creek, BAR – Barbers Creek.

D4.3 Predictive run – base case – groundwater levels

The predictive run provides output in the form of groundwater levels at all model cells and all layers. Three key model layers have been chosen as representative of the groundwater level behaviour:

- layer 1 – weathered regolith, representing water table in the unconsolidated and anthropogenic sediments;
- layer 8 – 'upper' consolidated bedrock aquifer; and
- layer 10 – 'lower' consolidated bedrock aquifer.

Contours of groundwater level are presented for the end of each mining stage (for model timing see Table D 2) – see Figure D 27 to Figure D 31 for model output times at the end of stress periods 2, 7, 15, 21 and 32.

Comparing groundwater table contours through time indicates how the mine expansion impacts on groundwater system. As the change is small, impact from mining expansion is expected to be small as well. Impact of the mining operations on the groundwater levels is discussed in Section D4.4 below.

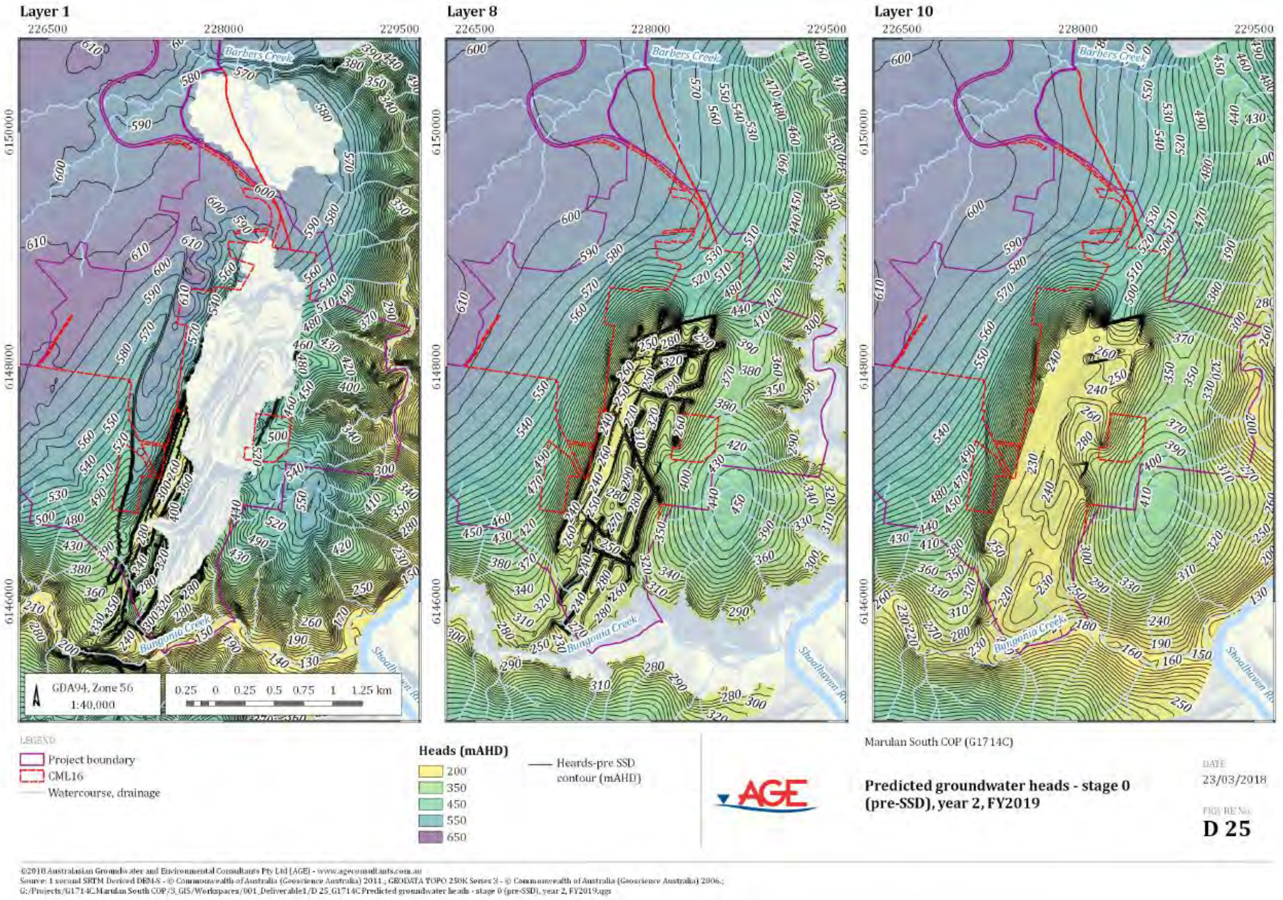

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Figure D 27 Predicted groundwater heads - stage 0 (pre-SSD), year 2, FY2019

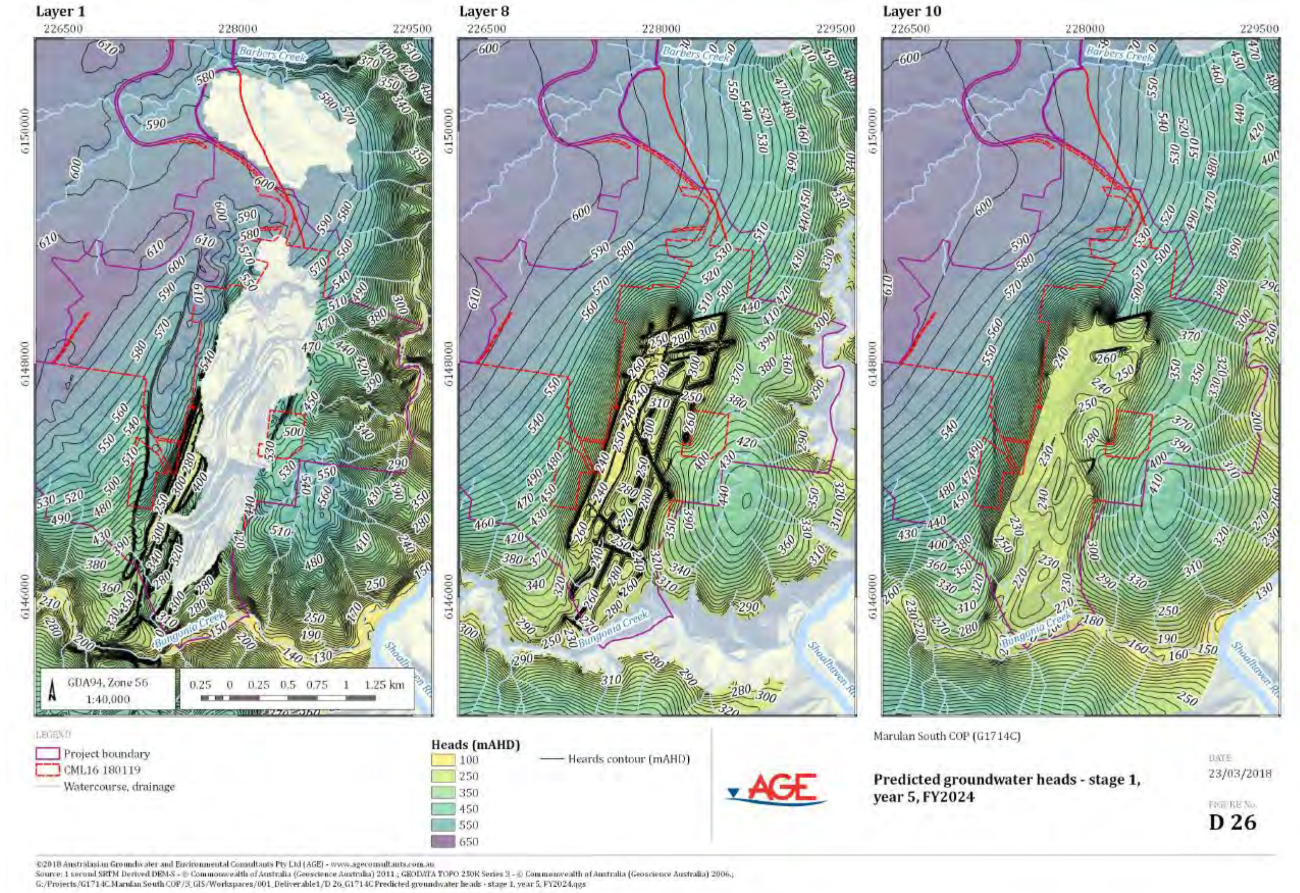

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Figure D 28 Predicted groundwater heads - stage 1, year 5, FY2024

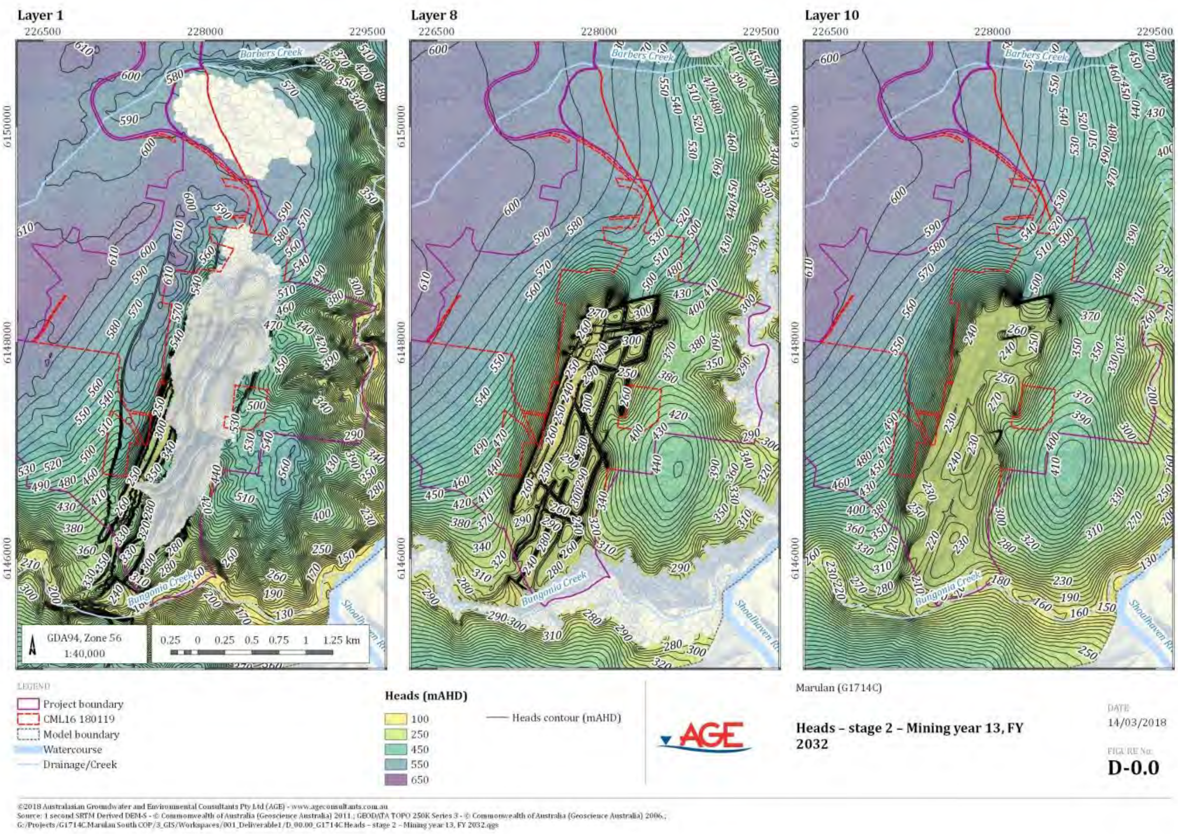

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Figure D 29 Predicted groundwater heads - stage 2, year 13, FY2032

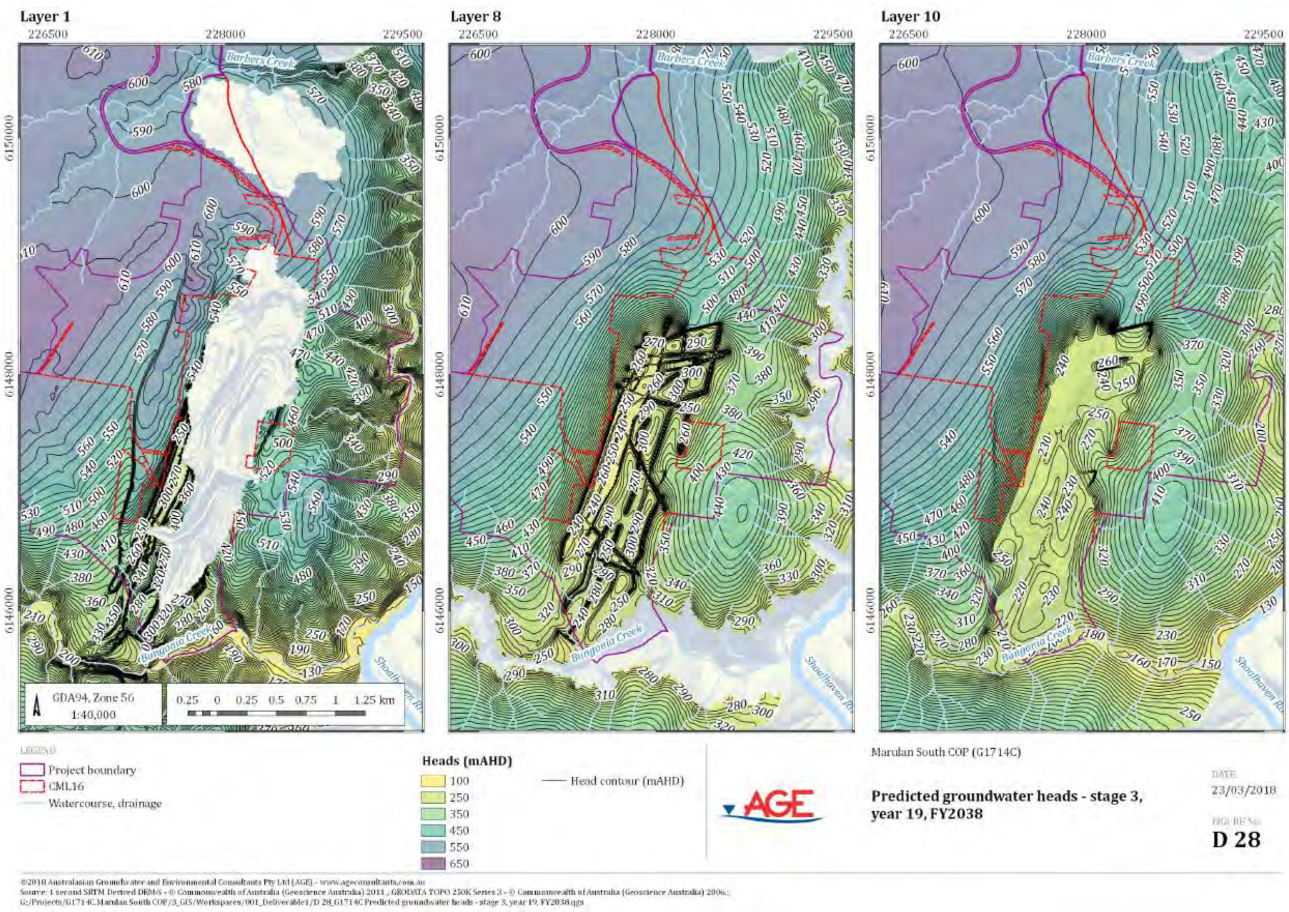

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Figure D 30 Predicted groundwater heads - stage 3, year 19, FY2038

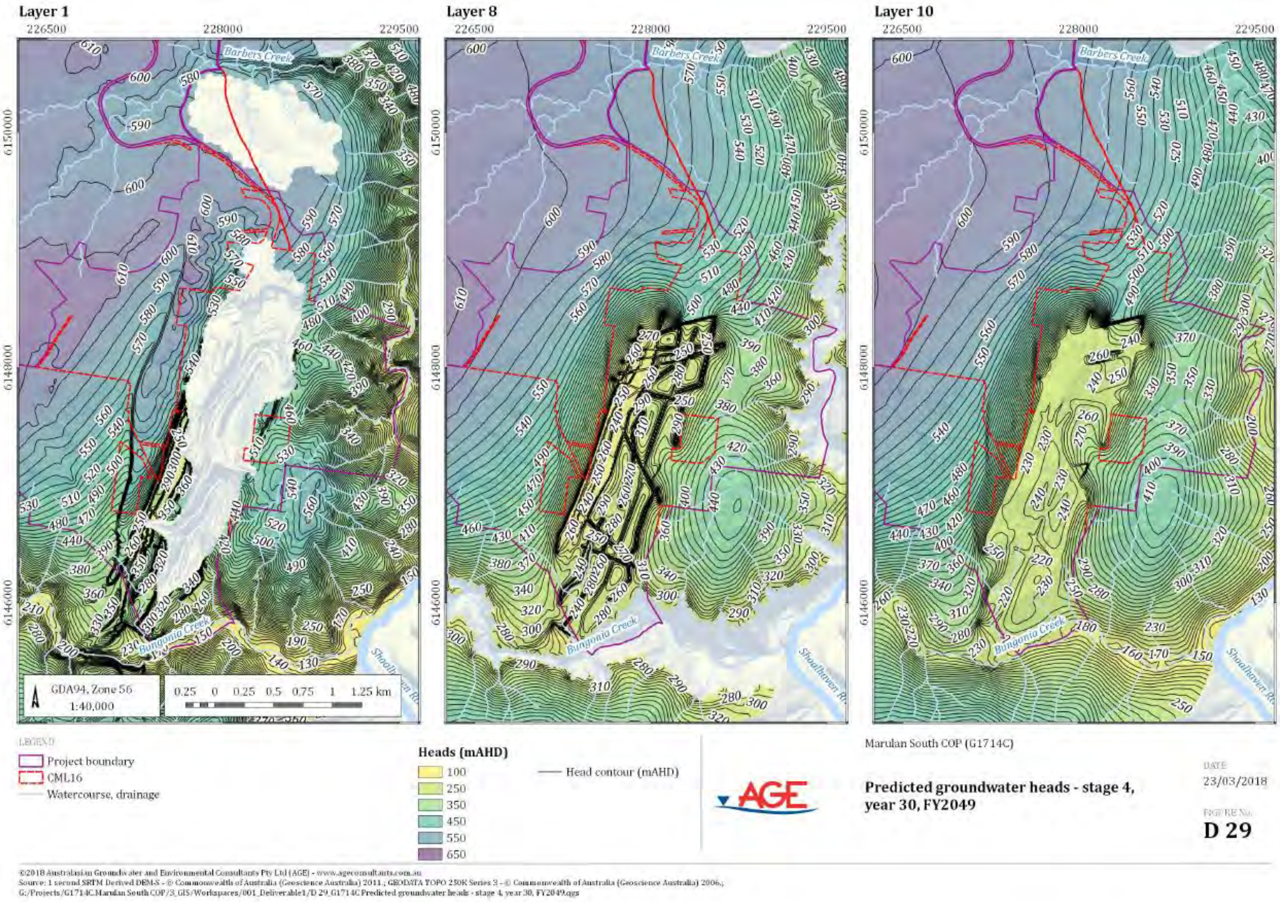

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Figure D 31 Predicted groundwater heads - stage 4, year 30, FY2049

D4.4 Predictive run – base case – mining impacts

To determine the groundwater level and groundwater flow changes attributable to the Project, two model simulations are required, one simulating the mining, and the other which does not – referred to as the 'no-mine' or 'null' run. Impacts are then expressed as the difference in heads (as drawdown) and in flows (impact on bedrock aquifers, alluvial aquifers) between these two scenarios.

In relation to this project, the 'no-mine' scenario was defined as current state of things that would eventuate if all mining operations stopped at the present development level (January 2018) and the groundwater system would have been subjected only to its natural stresses – rainfall recharge and evapotranspiration. The 'mining' scenario uses drain (DRN) boundary condition to simulate the removal of groundwater through mining activities.

D4.4.1 Impact on groundwater inflows to the existing mine area

The existence of structural discontinuities (fault fractures, weathered and partially washed out limestone contact zones, fractures in the pit floor), combined with groundwater levels observations west of current mining pits (MW7 and groundwater table observations made during the exploration drilling program), provides for a conceptual understanding for deep groundwater contained in the limestone-sedimentary-metamorphic blocks within the westwards expansion area. This groundwater system has already been 'drained' through naturally occurring, interconnected discontinuities intersecting the bedrock. These observations would lead to the conclusion that impact from mining during the expansion project would have only minimal impact on the groundwater system, as mining occurs in 'dry' limestone with water only removed through the mining is from the non-interconnected (porous space) storage within the limestone.

The 'mine' scenario presents us with slightly increased inflows from the geological environment (fractured bedrock aquifer) into the pits, which could be explained by increasing the groundwater gradient towards the pits. The inflows into the pits from the geological environment will increase on average by 1 m^3/day (Table D 17 and Figure D 32). As the water intercepted by model drains ceases to be available to discharge back to the fractured geological environment, the outflows will decrease by ~24 m^3/day (8.8 ML/year). The change of flows from and to fractured bedrock environment on annual basis is summarised in Table D 17 and Figure D 32.

Impact of the mining activities can be then quantified as the combination of water removed by mining itself (DRN boundary condition) with the reduction of water flow back into the surrounding bedrock aquifer. This predicts mining related groundwater inflow increasing from 28 m^3/day (10 ML/year) at the beginning of the Project to 108 m^3/day (40 ML/year) towards the end of the Project, with average groundwater inflow of 63 m^3/day (23 ML/year). The impacts of the Project are summarised in Table D 18 and presented graphically in Figure D 33.

Table D 17 Change of flows from and to geological environment

Stress period	Date - end of stress period	From geo environment (m³/day)			To geo environment (m³/day)		
		No-mine	Mine	Change in flow	No-mine	Mine	Change in flow
1	30/06/2018	7.58	7.57	0.01	135.47	127.10	8.37
2	30/06/2019	7.89	7.87	0.03	135.07	123.54	11.53
3	30/06/2020	8.01	7.97	0.04	134.73	123.19	11.55
4	30/06/2021	8.08	8.04	0.04	135.05	123.30	11.75
5	30/06/2022	8.11	8.07	0.04	135.05	123.01	12.05
6	30/06/2023	8.13	8.09	0.04	135.06	122.60	12.47
7	30/06/2024	8.13	8.08	0.05	134.76	121.93	12.83
8	30/06/2025	8.14	8.19	-0.05	135.07	120.10	14.97
9	30/06/2026	8.14	8.33	-0.19	135.07	118.95	16.12
10	30/06/2027	8.15	8.49	-0.34	135.07	117.85	17.22
11	30/06/2028	8.13	8.63	-0.49	134.77	116.49	18.28
12	30/06/2029	8.14	8.86	-0.73	135.07	115.65	19.42
13	30/06/2030	8.14	9.20	-1.06	135.07	114.67	20.41
14	30/06/2031	8.14	9.82	-1.68	135.07	113.96	21.11
15	30/06/2032	8.13	10.30	-2.17	134.77	113.09	21.68
16	30/06/2033	8.13	10.00	-1.87	135.07	112.55	22.52
17	30/06/2034	8.13	9.94	-1.81	135.07	112.23	22.84
18	30/06/2035	8.13	9.88	-1.75	135.07	111.89	23.18
19	30/06/2036	8.11	9.81	-1.70	134.76	111.39	23.37
20	30/06/2037	8.12	9.75	-1.63	135.06	110.90	24.17
21	30/06/2038	8.12	9.71	-1.59	135.06	109.99	25.08
22	30/06/2039	8.12	9.66	-1.55	135.06	106.94	28.12
23	30/06/2040	8.10	9.63	-1.53	134.76	105.32	29.44
24	30/06/2041	8.10	9.62	-1.52	135.06	104.18	30.88
25	30/06/2042	8.10	9.61	-1.51	135.06	102.66	32.40
26	30/06/2043	8.10	9.62	-1.52	135.05	101.15	33.91
27	30/06/2044	8.09	9.62	-1.53	134.75	99.57	35.17
28	30/06/2045	8.09	9.64	-1.55	135.05	97.90	37.15
29	30/06/2046	8.09	9.64	-1.55	135.05	96.15	38.90

Stress period	Date - end of stress period	From geo environment (m^3/day)			To geo environment (m^3/day)		
		No-mine	Mine	Change in flow	No-mine	Mine	Change in flow
30	30/06/2047	8.09	9.62	-1.53	135.05	94.20	40.85
31	30/06/2048	8.08	9.60	-1.52	134.74	92.21	42.53
32	30/06/2049	8.08	9.74	-1.66	135.04	89.42	45.62
	min:	7.58	7.57	-2.17	134.73	89.42	8.37
	average:	8.09	9.14	-1.06	135.00	111.06	23.93
	max:	8.15	10.30	0.05	135.47	127.10	45.62

Notes: *The change in flow is calculated as: 'no-mine' flow – 'mine' flow*
Positive (+) change in flow represents decrease of inflows or outflows due to mining activity ('mine' flow < 'no-mine' flow).
Negative (-) change in flow represents increase of inflows or outflows due to mining activity ('mine' flow > 'no-mine' flow)

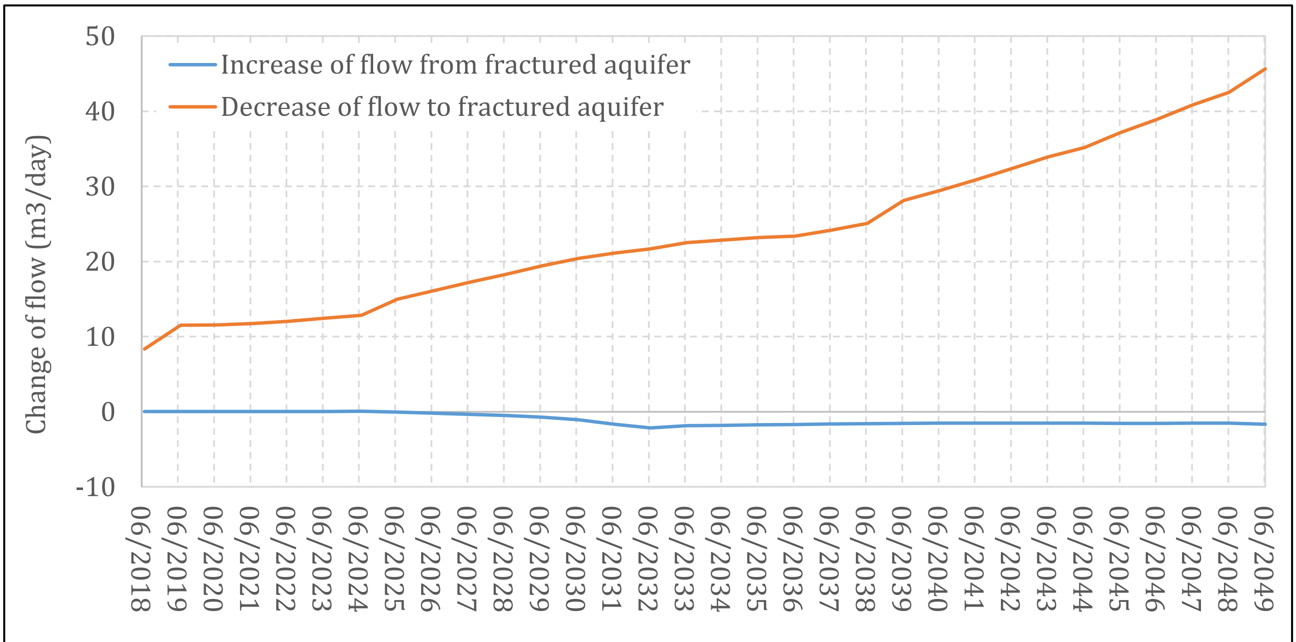

Figure D 32 Change of flows from and to fractured aquifer – mining pit

Table D 18 Total predicted impact on groundwater flows

Stress period	Date – end of stress period	Groundwater take (m^3/day)		
		Mining (flow to DRN)	Flow reduction to geo environment	Total take
1	30/06/2018	19.54	8.37	27.91
2	30/06/2019	23.81	11.53	35.34
3	30/06/2020	23.98	11.55	35.53
4	30/06/2021	24.31	11.75	36.06
5	30/06/2022	24.64	12.05	36.69
6	30/06/2023	25.09	12.47	37.56
7	30/06/2024	25.34	12.83	38.17
8	30/06/2025	28.15	14.97	43.12
9	30/06/2026	29.54	16.12	45.66
10	30/06/2027	30.84	17.22	48.06
11	30/06/2028	31.97	18.28	50.25
12	30/06/2029	33.42	19.42	52.84
13	30/06/2030	34.73	20.41	55.14
14	30/06/2031	36.04	21.11	57.15
15	30/06/2032	36.94	21.68	58.62
16	30/06/2033	37.81	22.52	60.33
17	30/06/2034	38.07	22.84	60.91
18	30/06/2035	38.35	23.18	61.53
19	30/06/2036	38.41	23.37	61.78
20	30/06/2037	39.21	24.17	63.38
21	30/06/2038	40.06	25.08	65.14
22	30/06/2039	45.04	28.12	73.16
23	30/06/2040	46.35	29.44	75.79
24	30/06/2041	47.87	30.88	78.75
25	30/06/2042	49.38	32.40	81.78
26	30/06/2043	50.91	33.91	84.82
27	30/06/2044	52.11	35.17	87.28
28	30/06/2045	54.19	37.15	91.34

Stress period	Date – end of stress period	Groundwater take (m³/day)		
		Mining (flow to DRN)	Flow reduction to geo environment	Total take
29	30/06/2046	55.94	38.90	94.84
30	30/06/2047	57.88	40.85	98.73
31	30/06/2048	59.45	42.53	101.98
32	30/06/2049	62.78	45.62	108.40
	min:	19.54	8.37	27.91
	average:	38.82	23.93	62.75
	max:	62.78	45.62	108.40

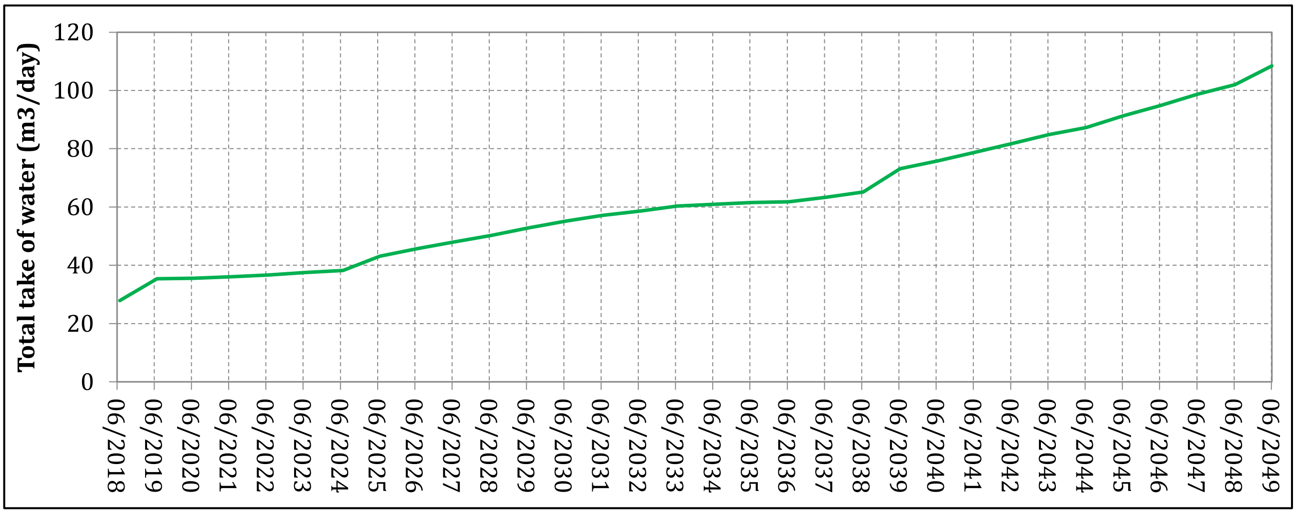

Figure D 33 Mining impact – total take of water from groundwater system

D4.4.2 Impacts on water users

As the minor changes in pit flows indicate, the change of groundwater levels due to mining (drawdown) is not expected to be extensive. Because drawdowns at the end of stages 1 and 2 were mostly less than 1 m, the drawdown maps are only provided for stages 3 (Figure D 34) and 4 (Figure D 35). The vertical drawdown extent is shown by yellow to dark orange hues, which show the change in groundwater level is generally greatest in the zones with most extensive elevation change of the pit floor. That is in the upper North Pit area and along the eastern edge of the pit, in the area between the current North and South pits. The 1 m drawdown contour extends approximately 620 m in the north easterly direction from the northern edge of the pit and approximately 290 m away from the eastern edge of the current mine.

None of the currently identified groundwater users (refer to Table D 19) are expected to be impacted by the mining activities. On the site, bores WP16, WP17 and in-pit monitoring bores MW1 and MW2 will be destroyed as a result of mining activities. Other on-site bores impacted by the drawdown are MW6 (~1.8m) and MW5 (<1m).

Table D 19 Potentially impacted groundwater users

Plan No.	Lot No.	Water user type	Bores	Drawdown (m)	Comment
DP867667	21/867667	Light industrial	GW106253	<1	Water only for office and domestic use
DP1190667	1/1190667	Poultry production	GW103697	<1	Poultry - turkeys
DP1013487 DP1061531	1/1013487 1/1061531	Poultry production	LICH01 GW102505 (LICH02) LICH03 LICH04	<1	Poultry - chicken
DP1056566	11/1056566	Light industrial	GW108850	<1	Water only for office and domestic use
DP830458	112/830458	Domestic	GW100656	<1	Garden, used rarely
DP1056566	9/1056566	Unknown/domestic	GW105696	<1	
DP106569	4/106569	Industrial	WP16 (GW110267)	Destroyed	Marulan mine – North Pit
DP106569	4/106569	Industrial	WP17 (GW110268)	Destroyed	Marulan mine – North Pit
DP557562	1/2032362	Industrial	GW102590	<1	Peppertree bore

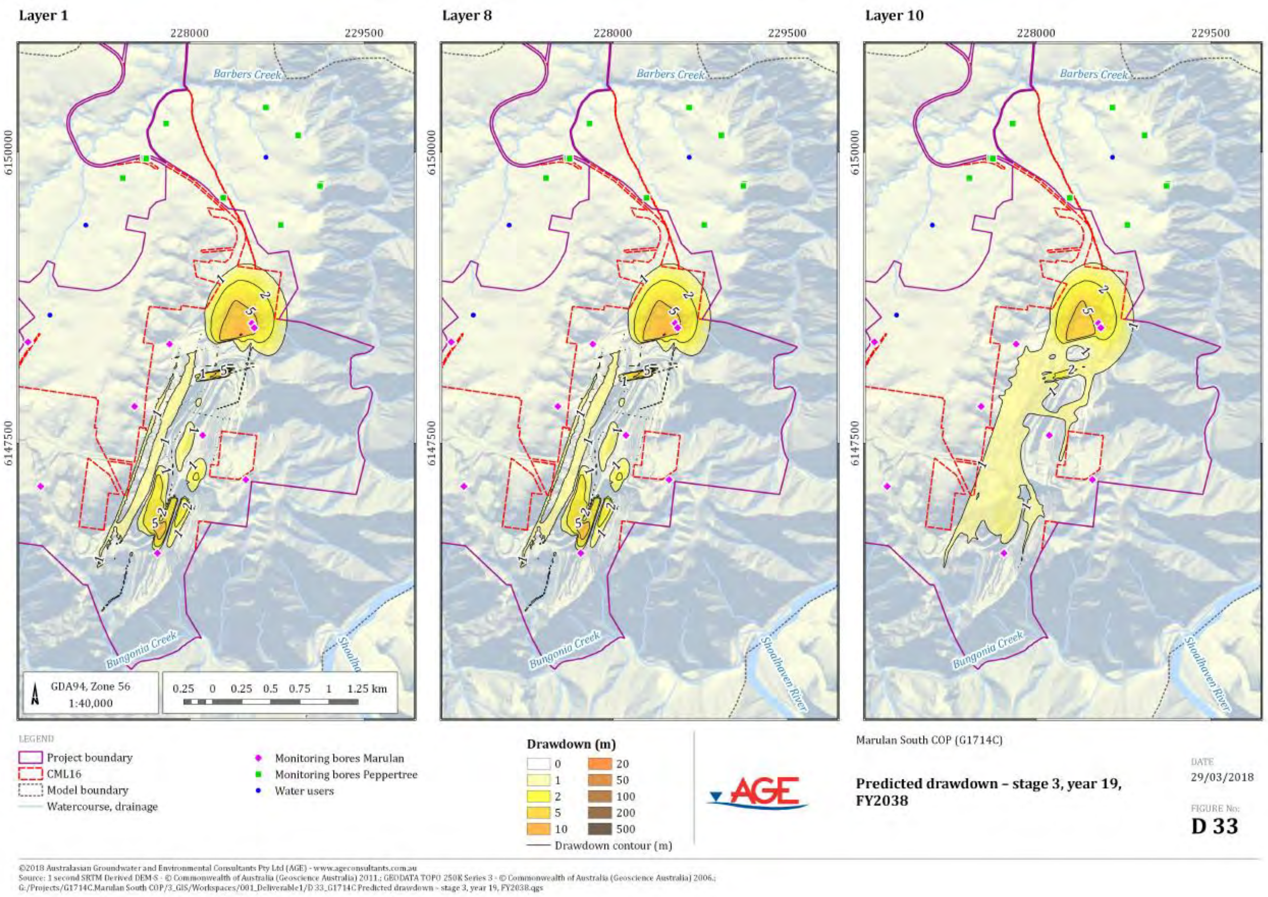

Figure D 34 Predicted drawdown – stage 3, year 19, FY2038

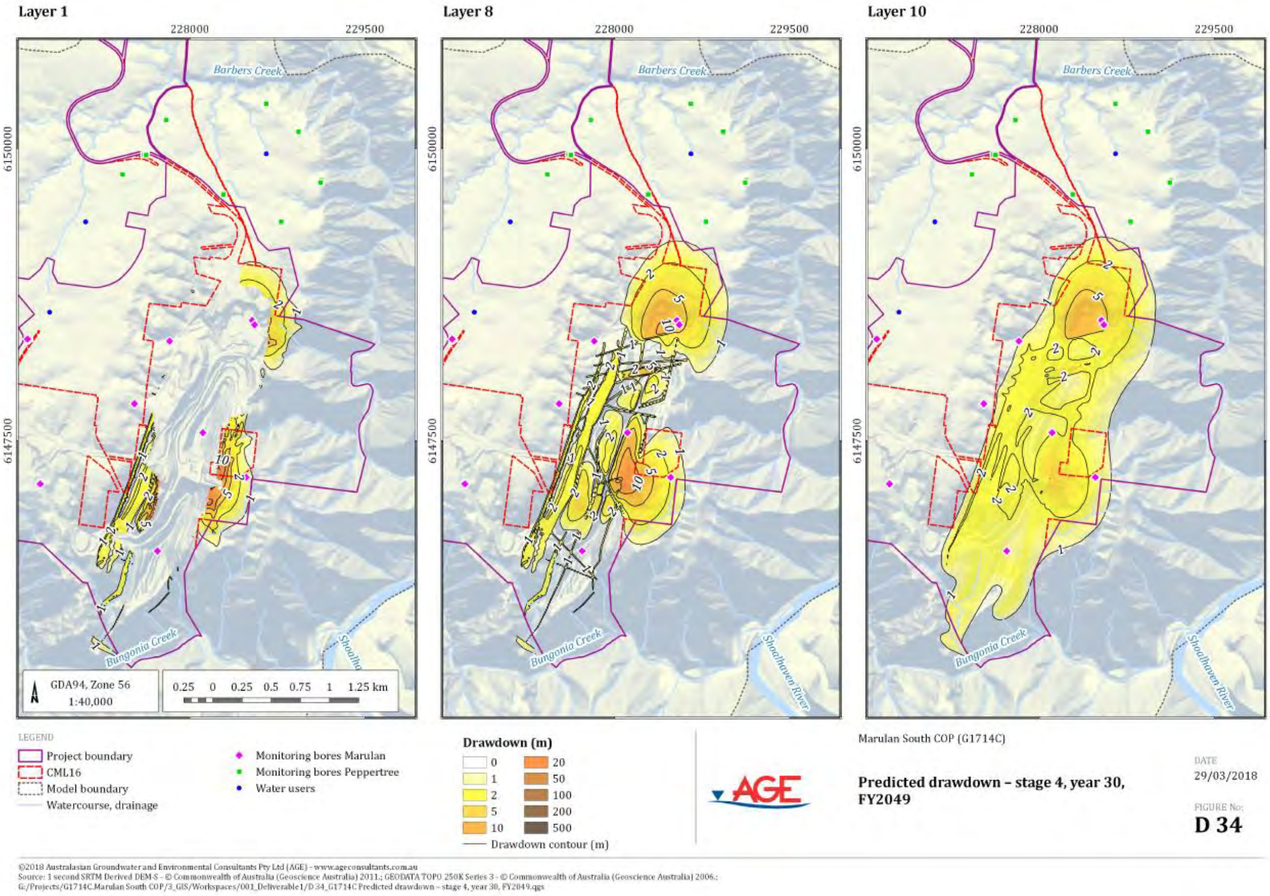

Figure D 35 Predicted drawdown – stage 4, year 30, FY2049

D4.4.3 Impacts on alluvial zones

The change of flows into and out of the alluvial zones are small. The impacted flows are those into and out of Bungonia Creek alluvium, where a slight decrease in drainage from the pits through the interconnected fracture system, translates into a decreased inflow into the alluvium from the underlying fractured bedrock. The inflow rate decreases by 6 m^3/day (on average) up to 14.5 m^3/day towards the end of the mining period.

As a result of there being less water available as inflow into the alluvium, the model predicts a decrease in baseflow from the alluvium to Bungonia Creek (on average ~4.8 m^3/day) and a decrease in recharge back to the bedrock aquifer (on average ~1.2 m^3/day) underlying the Bungonia alluvium. Impact on Shoalhaven River alluvium as well as Barbers Creek alluvium is predicted to be negligible. The summary of changes of inflows and outflows to and from all three alluvial zones is presented in Table D 20 and Table D 21.

Table D 20 Change in inflows – impact on alluvium zones

Range	From river (RIV) m^3/day			From recharge (RCH) m^3/day			From bedrock aquifer (GEO) m^3/day		
	SHL	BUN	BAR	SHL	BUN	BAR	SHL	BUN	BAR
Minimum	-0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
Average	0.00	0.00	0.00	0.00	0.00	0.00	0.01	6.05	0.00
Maximum	0.00	0.00	0.00	0.00	0.00	0.00	0.12	14.51	0.01

Table D 21 Change in outflows – impact on alluvium zones

Range	To river (RIV) m^3/day			To evapotranspiration (EVT) m^3/day			To bedrock aquifer (GEO) m^3/day		
	SHL	BUN	BAR	SHL	BUN	BAR	SHL	BUN	BAR
Minimum	0.00	0.02	0.00	0.01	0.03	0.00	0.00	0.01	0.00
Average	0.01	4.85	0.00	0.05	0.09	0.00	0.00	1.18	0.01
Maximum	0.09	11.64	0.00	0.10	0.13	0.00	0.00	2.83	0.12

Notes: *The change in flow is calculated as: 'no-mine' flow – 'mine' flow*

Positive (+) change in flow represents decrease of inflows or outflows due to mining activity ('mine' flow < 'no-mine' flow).
Negative (-) change in flow represents increase of inflows or outflows due to mining activity ('mine' flow > 'no-mine' flow)

Zones of alluvium:
SHL – Shoalhaven River alluvium
BUN – Bungonia Creek alluvium
BAR – Barbers Creek alluvium

D4.5 Predictive run – base case – post-mining period

After cessation of the proposed mining activities in the middle of year 2049, active dewatering ceases and groundwater levels begin to recover. The model was used to simulate this groundwater recovery for 250 years post mining (up to the end of the year 2300) to assess long term impacts. The recovery model set-up included implementing a pit void into the 'mine' model by changing the hydraulic conductivity of 'mined-out' cells to 500 m/day and specific yield of 100%.

The recovery model predicts post-mining equilibrium groundwater levels which are shown in Figure D 36. Using a corresponding extension of the 'no-mine' model, the long term post-mining drawdowns due to the Project are shown in Figure D 37. The drawdown is predicted to continue to expand away from the void in the directions along the limestone bodies and into the granodiorite, as well as into the sediments and metamorphics bounding the limestone from east and west. The 1 m drawdown contour will expand approximately 1.2 km from the edge of the void in the north-easterly direction and about 600 m from both the eastern and western mine pit extents. Due to the increased area of the void, a slightly higher recharge into the void is predicted. The increased recharge 'fills up' the fractures, resulting in a rising groundwater level in the lower bedrock layers within the pit footprint. This process is shown as water mounding (light to darker blue hues) in model layers 8 and 10.

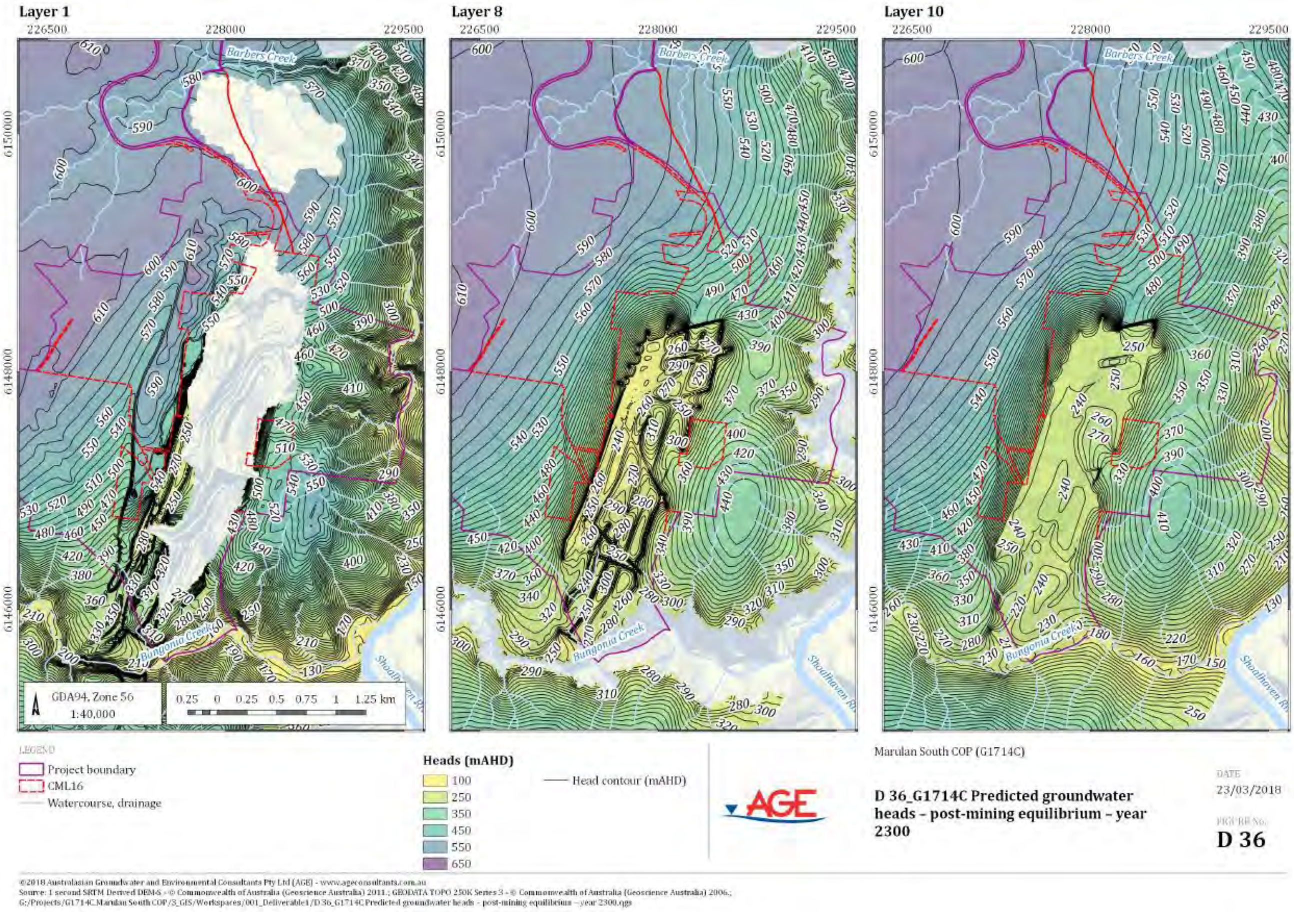

Figure D 36 Predicted groundwater heads – post-mining equilibrium – year 2300

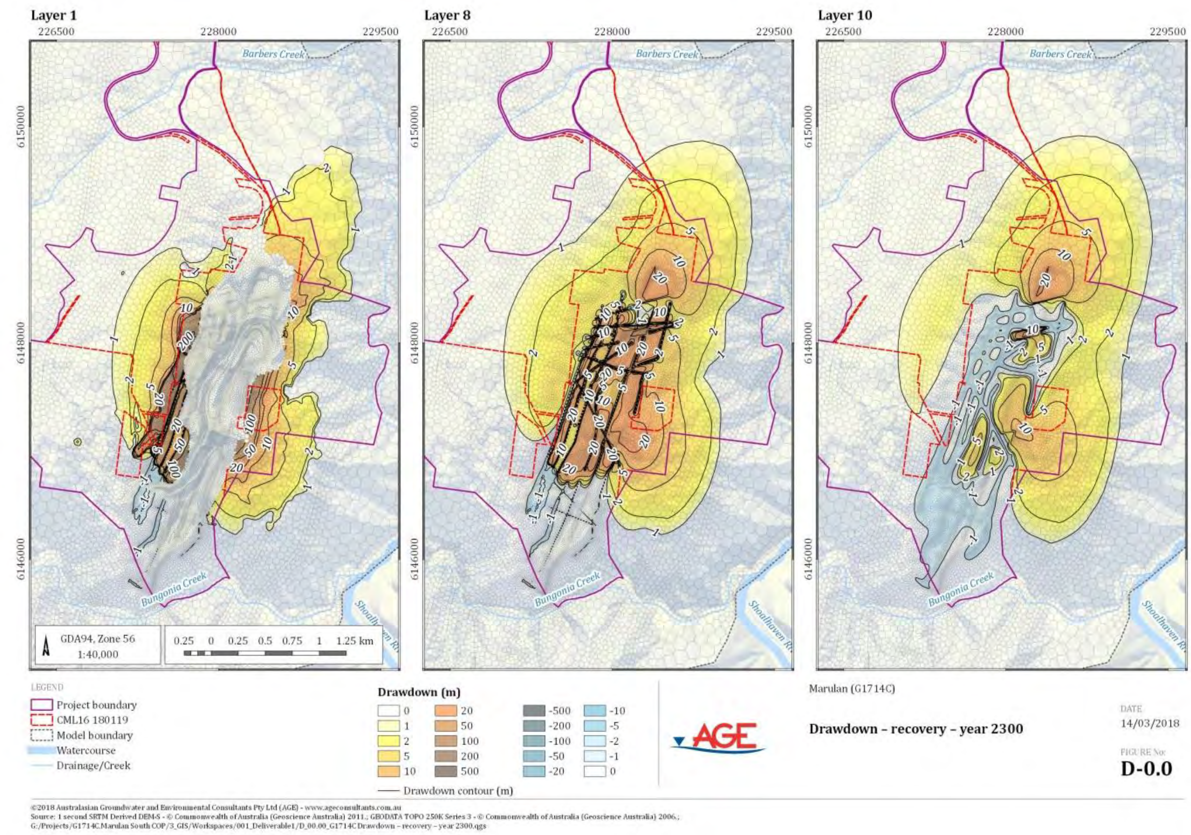

Figure D 37 Predicted drawdowns – post-mining equilibrium – year 2300

D4.6 Predictive run – groundwater extraction for water supply

As the water balance for the proposed 30 years of continued mining (Advisian, 2018) identified a water deficit (if the proposed Marulan Creek dam was not built), an option for obtaining a groundwater supply from the area between the mine and Peppertree Quarry was explored using pumping wells. Six hypothetical extraction wells were incorporated into the numerical model, spaced approximately equidistantly along the northern edge of mine. The proposed locations were selected to cover the largest possible volume of the granodiorite aquifer, and optimize the distance between the wells to minimise the inclusion of potentially unnecessary pumping infrastructure. The well locations were adjusted to avoid areas occupied by existing or proposed infrastructure (roads, rail, supporting mine machinery, and proposed overburden emplacement areas). The exact locations of the proposed pumping wells are presented in Table D 22.

Table D 22 Location of pumping wells

Well ID	Easting (GDA94, z56)	Northing (GDA94, z56)
w01	228675	6148595
w02	228635	6148863
w03	228594	6149157
w04	228458	6149349
w05	227914	6149554
w06	228173	6149528

D4.6.1 Additional modelling inputs

As a part of the production well network assessment, AGE was provided with the two following datasets:

- one evaluating decline and/or increase in groundwater heads around Peppertree Quarry between March 2016 to October 2017 (RPS 2017a), updated with measurements to January 2018; and
- the other being undated simplified drill logs for eleven exploration holes south east from Peppertree Quarry.

Based on this data, the groundwater levels around the Peppertree Quarry appear to be relatively stable, approximately 23 m below ground surface (ranging from 11.7 m to 42.5 m, based on 62 water level observations in 11 bores). The simplified drill logs indicate the thickness of the weathered regolith to generally be around 9 m (ranging from 2 m to 17 m). This data suggests the weathered regolith is mostly dry, with groundwater most likely available within the deeper, inferred fractured aquifer. Although basic data on aquifer hydraulic parameters exist (RPS, 2015), the information was not available at the time of the water supply analysis. RPS (2015) estimated that the 'low' horizontal hydraulic conductivity of the fractured granodiorite aquifer was between 0.03-0.10 m/day, based on 11 in-situ permeability (slug) tests. This information is consistent with the observed mining impacts on groundwater levels around the Peppertree Quarry, which are only minimally impacted from quarrying in the granodiorite.

D4.6.2 Model verification

The model predictions for the behaviour of the groundwater system surrounding Peppertree Quarry were verified by comparing the groundwater level observations in the Peppertree monitoring bores to the modelled groundwater levels. Although the fit was not ideal and the model is generally underpredicting for certain observation and overpredicting for others, the trend of the model prediction follows the trend of the observations. Based on the updated calibration statistics (RMS = 8.07, SRMS = 2.94%), the overall fit of the observed and modelled data (with the Peppertree observation data included) is acceptable.

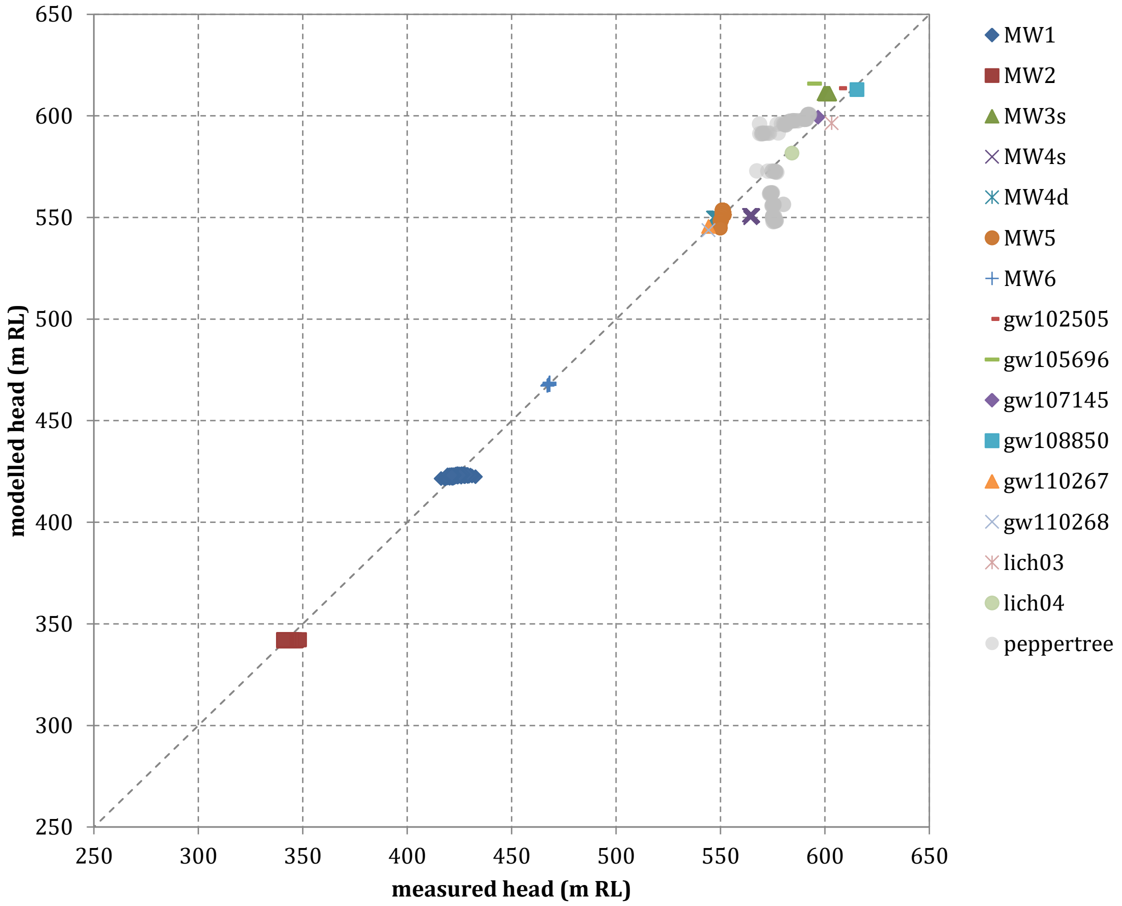

Figure D 38 Model verification – inclusion of Peppertree observation data – scatter diagram

D4.6.3 Model predictions

The numerical model predicts the available pumping rate will vary from approximately 80 ML/year at the start of groundwater abstraction, to 15 ML/year towards the end of mining activities (refer to Figure D 39 and Table D 23). The net decline in the overall rate of groundwater abstraction confirms that given the low hydraulic conductivity of the fractured granodiorite aquifer, the amount of groundwater available to be pumped from the aquifer is limited, suggesting the required volume of 300 ML/year is unlikely to be available to be accessed from proposed well network.

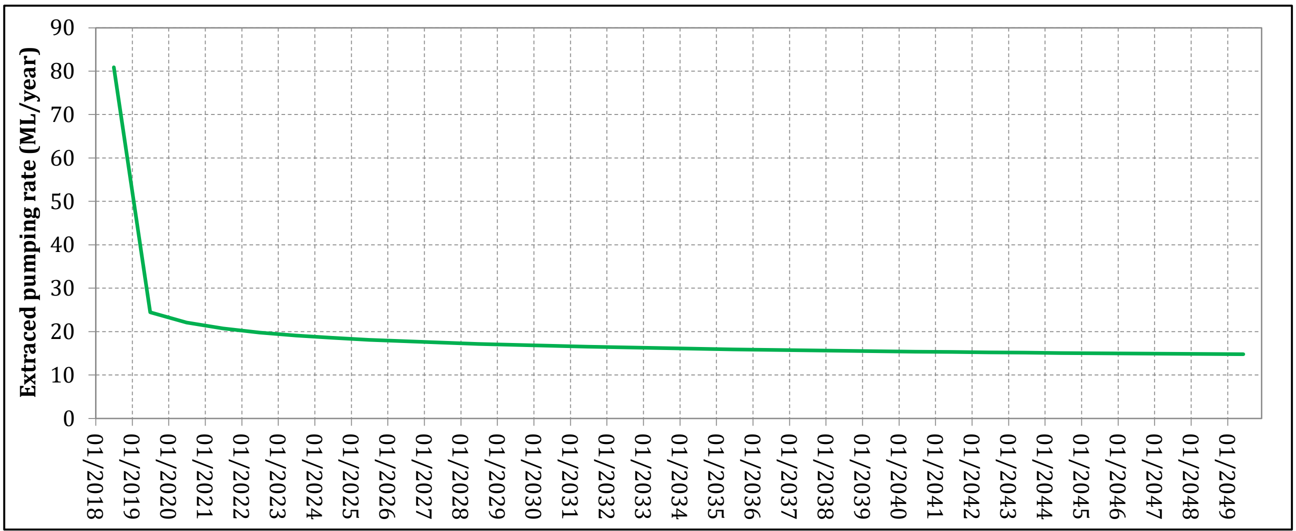

Figure D 39 Predicted extraction from the well field

Table D 23 Predicted water extraction from pumping wells

Stress period	Stress period length (days)	Extracted volume (m^3/SP length)	Extracted rate (m^3/day)	Extracted rate (ML/year)
1	150	33216.9	221.4	80.9
2	365	24447.0	67.0	24.5
3	366	22137.7	60.5	22.1
4	365	20723.9	56.8	20.7
5	365	19793.1	54.2	19.8
6	365	19100.5	52.3	19.1
7	366	18602.6	50.8	18.6
8	365	18112.3	49.6	18.1
9	365	17753.2	48.6	17.8
10	365	17443.4	47.8	17.5
11	366	17217.0	47.0	17.2
12	365	16931.9	46.4	16.9
13	365	16718.7	45.8	16.7
14	365	16527.2	45.3	16.5
15	366	16395.1	44.8	16.4
16	365	16189.8	44.4	16.2
17	365	16044.3	44.0	16.1
18	365	15912.7	43.6	15.9
19	366	15831.1	43.3	15.8
20	365	15674.9	42.9	15.7

Stress period	Stress period length (days)	Extracted volume (m^3/SP length)	Extracted rate (m^3/day)	Extracted rate (ML/year)
21	365	15570.2	42.7	15.6
22	365	15472.9	42.4	15.5
23	366	15421.8	42.1	15.4
24	365	15295.1	41.9	15.3
25	365	15215.0	41.7	15.2
26	365	15139.8	41.5	15.2
27	366	15107.9	41.3	15.1
28	365	15000.9	41.1	15.0
29	365	14937.9	40.9	14.9
30	365	14878.8	40.8	14.9
31	366	14861.1	40.6	14.8
32	365	14768.2	40.5	14.8
		Min:	40.5	14.8
		Avg:	51.7	18.9
		Max:	221.4	80.9

D4.6.4 Model limitations

There are a number of factors influencing the potential for a groundwater supply option from the fractured granodiorite aquifer. Similar to the limestone, the groundwater storage capability of the granodiorite will be limited to the shallower weathered regolith zone and the deeper fractured zone. Recharge to groundwater hosted in this type of aquifer will be a function of downward seepage into weathered regolith, which in turn recharges the deeper fractured granodiorite. The volume of groundwater that is 'available' for abstraction (pumping) will depend on depth of the bore into both the weathered regolith and fractured bedrock. The potential for aquifer storage will therefore be a function of the extent of fractures intersected by the borehole and interconnected across this fractured bedrock aquifer.

Further limitations constraining the numerical model and increasing its uncertainty (with respect to the granodiorite pumping scenario) are:

- The numerical model was not calibrated with Peppertree data, as the data was not available during the model calibration.
- The thickness of the weathered zone surrounding the Peppertree Quarry is based on the data provided, which does not fully quantify the thickness of regolith across the entire granodiorite zone.
- The transition zone between the weathered granodiorite and fractured bedrock is not well understood.
- The granodiorite aquifer hydraulic property appears to be a function of secondary (fracture) porosity. An understanding of how this fracture system behaves under the stress from long term pumping would assist with the current numerical model setup and decrease the uncertainty of the prediction.

D4.6.5 Conclusion and recommendations

Although the model can be made more precise by implementing hydraulic properties from Peppertree observation network into the model (as well as information regarding structural features and depth of weathered regolith), this increased precision will not necessarily change the modelling outcome given the overall low hydraulic conductivity for the granodiorite, and there simply being insufficient groundwater available in storage for abstraction. Given the acceptable level of calibration (as determined from the calibration statistics including the Peppertree groundwater level observation data), the model predictions are considered valid, even if not calibrated with focus on the Peppertree area.

The groundwater level (Figure D 40) and drawdown extents (Figure D41 and Figure D42) present the predicted potential impact of the groundwater extraction to the existing groundwater system. The drawdown maps represent cumulative drawdown of combined mining and pumping (Figure D 41) as well as drawdown of the pumping wells in isolation (Figure D 42).

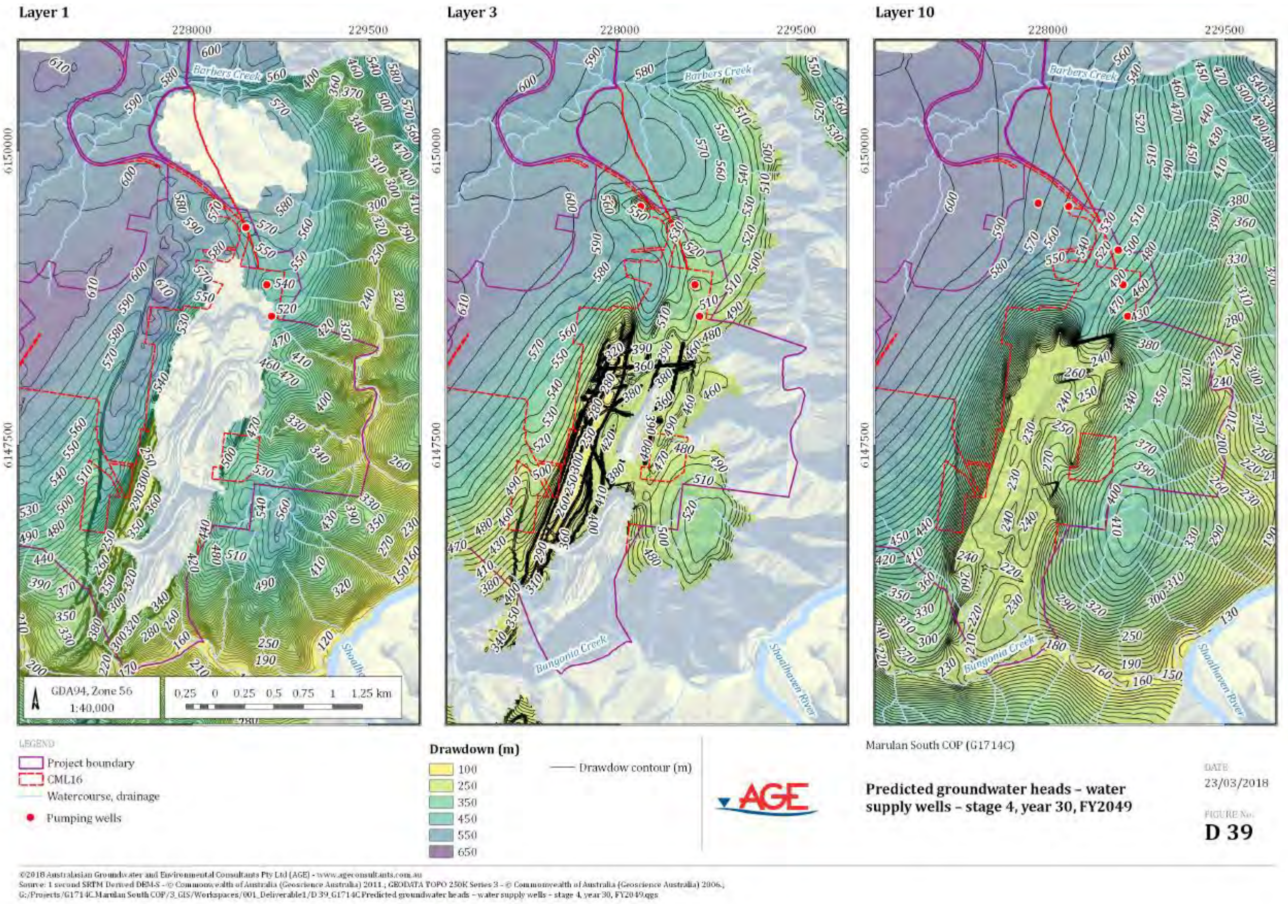

Figure D 40 Predicted groundwater heads – water supply wells – stage 4, year 30, FY2049

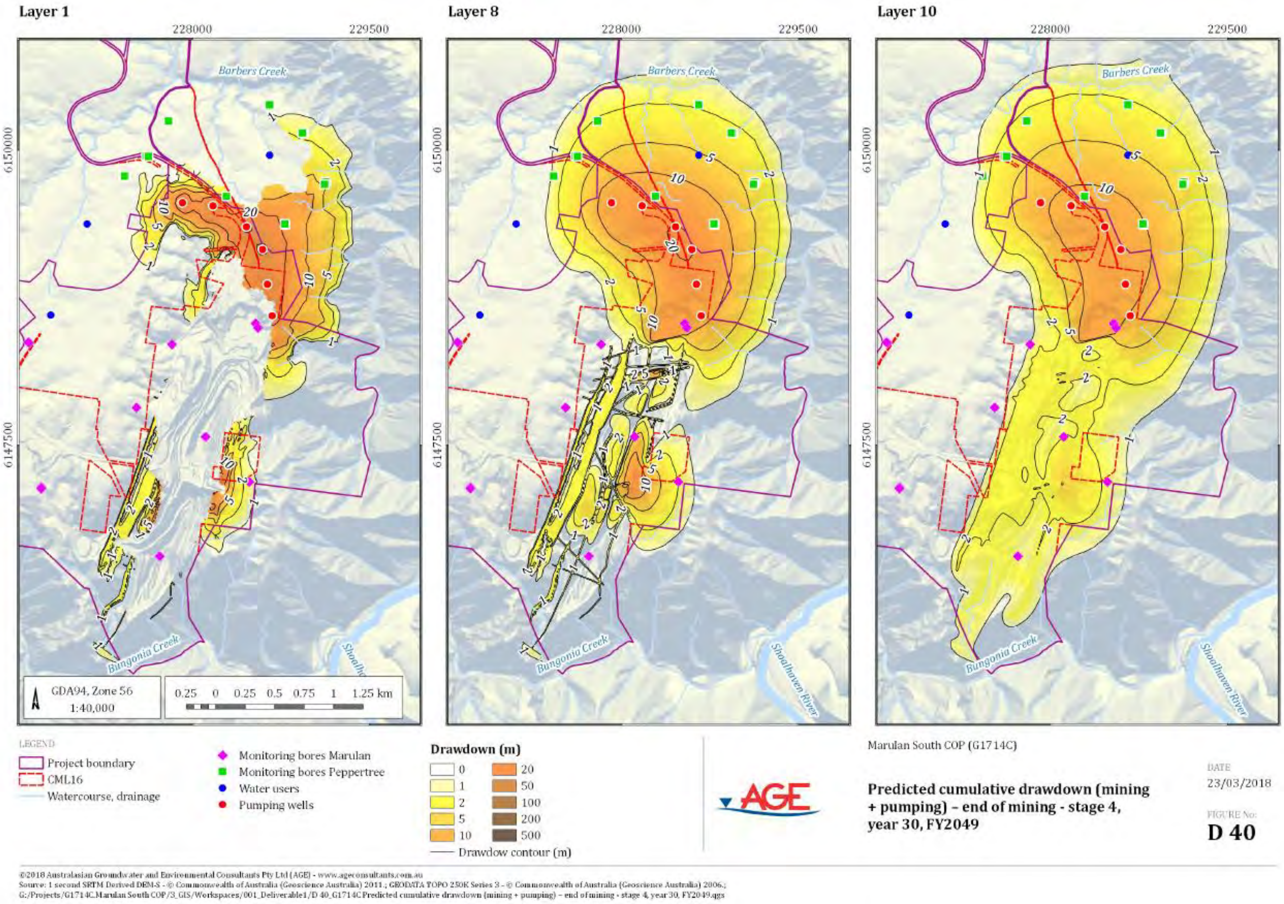

Figure D 41 Predicted cumulative drawdown (mining + pumping) – end of mining - stage 4, year 30, FY2049

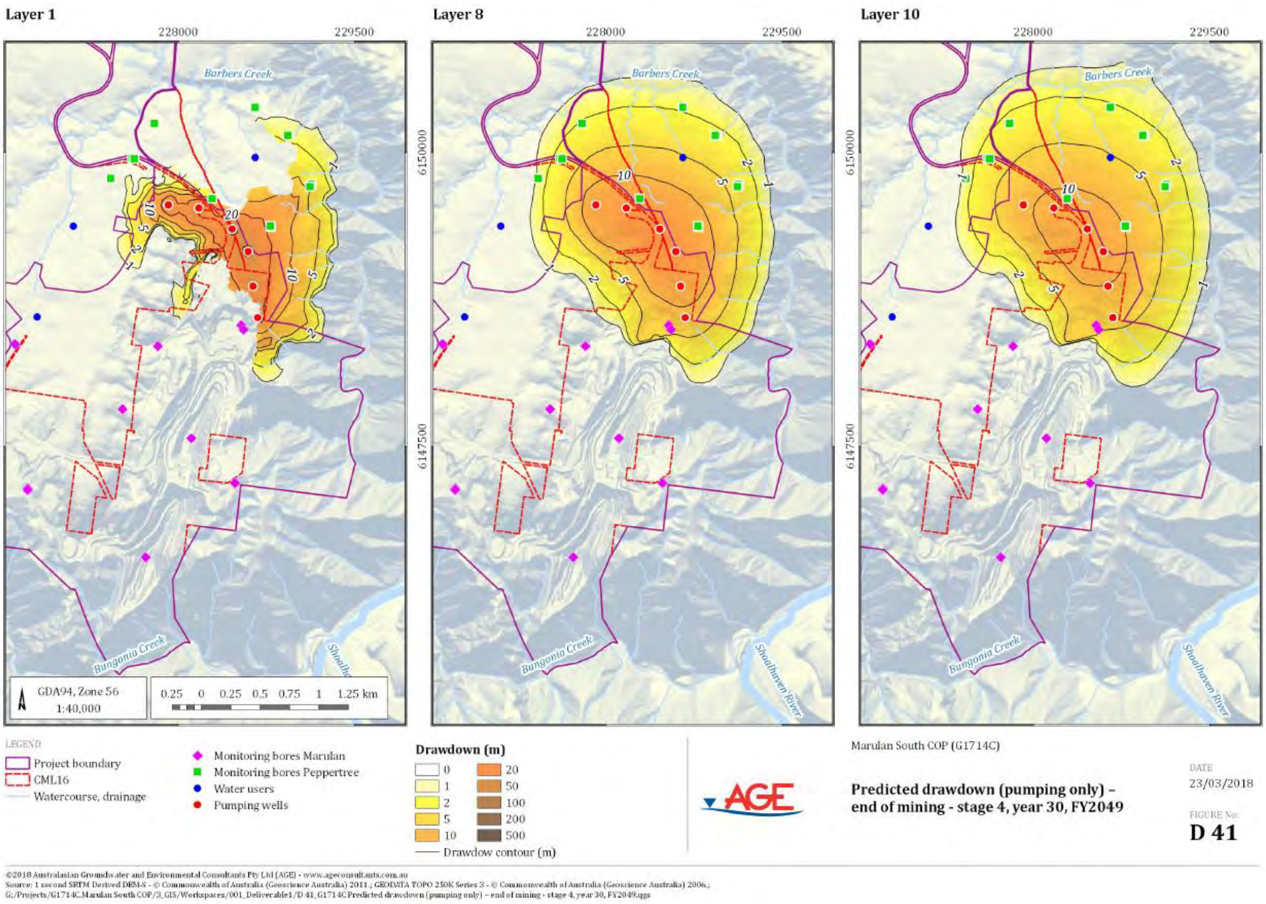

Figure D 42 Predicted drawdowns (pumping only) – end of mining – stage 4, year 30, FY2049

D5 Model classification

Based on the classification system developed by Barnett *et al* (2012), the model performance was evaluated based on:

- **available data**, their spatial distribution, and the length of transient time series (climatic data, groundwater elevation data);
- **quality of calibration** based on data suited to calibrate the model, comparison of calibration and prediction periods in terms of length and time-stepping setup, and demonstrated ability of the model to replicate / represent the state of the groundwater system induced by external stresses (recharge, pumping, mining related stresses); and
- **level of stresses** applied in the predictive part of the modelling process as compared to the stresses (or lack of) applied during the calibration period.

The performance indicators for individual model classes are presented in Table D 24 as well as discussed below.

D5.1 Data requirements

The topographic (LiDAR) and climatic (rainfall, ET) data were of high quality – up-to-date and collected on site (rainfall). Aquifer testing data were available only in very limited extent. The hydraulic testing on bores MW1 and MW2 shown not to be representative of the bulk hydraulic properties of the limestone because of the combination of porous and fractured systems within the limestone body.

In terms of spatial distribution, the groundwater levels were regularly collected on the mine site; the data further away from Marulan mine are sparse. In terms of temporal distribution, the transient data are available only from the mine site. No irrigation or pumping data were available (apart from anecdotal evidence collected during the bore census).

Based on the quality, spatial and temporal distribution of used data, the model falls between Class 2 and Class 3.

D5.2 Calibration

Due to the low number of calibration targets, all available data were used during the calibration process and it was not possible to validate the model on historical datasets. Calibration statistics are within the recommended range of acceptable values (SRMS less than 5%). Long term trends in groundwater table movement are replicated in most of the bores around the mine, however the lack of detailed understanding of the hydraulic properties within the mining pit (such as locations of fractures in the pit floor) prevented us from increasing the calibration level of the in-pit observation bores.

Based on the quality (length of time) of the calibration dataset and inability of the model to replicate behaviour of the groundwater system within the limestone ore body, the model can be described as Class 2 to Class 3.

D5.3 Prediction

Mining stresses applied to the predictive model were not included in the calibration modelling run. The time period used for calibration (49 months) is approximately 7x shorter than the prediction period (31.5 years) and due to the high level of detail of the transient observation data, time-stepping also varies between calibration and prediction models. Historical water extraction (on-site pumping) data was not available.

Based on the consistency (or lack of) between calibration and prediction runs, the model can be classified as Class 1 to Class 2.

D5.4 Key indicators

The calibration process and statistics suggest sufficient level of calibration in the area of the limestone ore body (in terms of groundwater level trend), however the extremes (hydrograph responses to rainfall events) were not replicated. Due to the mixed nature of the limestone aquifer (combination of fractured and porous media, fracture dominated flow), and uncertainty associated with the prevalence of the fracture driven flow, the model is not well suited to approximate flow within the limestone aquifer. The spatial discretization of the limestone ore body is too coarse, our current understanding of variability of hydraulic properties is insufficient, and the observation data related to the limestone is too short (temporally) and too sparse (spatially) to characterize the limestone aquifer in detail.

In spite of the limited capabilities of the predictive model to approximate localized groundwater system behaviour within the limestone ore body, the modelled impacts on the regional scale (potential impacts on water users and alluvial water sources) are consistent with the conceptual understanding of the groundwater system on a regional scale and are sufficiently precise to satisfy the goals of the study.

Based on the model performance indicators, it is not possible to simply classify the model as falling cleanly into one of three categories; the model performance can be however be assessed against its stated goals – to be used as an assessment tool to quantify possible impacts on regional groundwater system and its users. In this regard, model performance level is acceptable.

Table D 24 Model classification – model performance indicators

	Data requirements	*YES*	*SOME*	*NO*
Class 3	High density rainfall and evaporation data is available.	x		
	Aquifer-testing data to define key parameters.		x	
	Reliable land-use and soil-mapping data available.	x		
	Good quality and adequate spatial coverage of digital elevation model to define ground surface elevation.	x		
Class 2	Groundwater head observations and bore logs are available but may not provide adequate coverage throughout the model domain.	x		
	Metered groundwater-extraction data may be available but spatial and temporal coverage may not be extensive.			x
	Streamflow data and baseflow estimates available at a few points.			x
	Reliable irrigation-application data available in part of the area or for part of the model duration.		N/A	
Class 1	Few or poorly distributed existing wells from which to obtain reliable groundwater and geological information.	x		
	Observations and measurements unavailable or sparsely distributed in areas of greatest interest.	x		
	No available records of metered groundwater extraction or injection.			x
	Climate data only available from relatively remote locations.			x
	Little or no useful data on land-use, soils or river flows and stage elevations.			x
Calibration				
Class 3	Adequate validation is demonstrated.			x
	Scaled RMS error or other calibration statistics are acceptable.	x		
	Long-term trends are adequately replicated where these are important.	x		
	Seasonal fluctuations are adequately replicated where these are important.	x		
	Transient calibration is current, i.e. uses recent data.	x		
	Model is calibrated to heads and fluxes.			x
	Observations of the key modelling outcomes dataset is used in calibration.	x		
Class 2	Validation is either not undertaken or is not demonstrated for the full model domain.	x		
	Calibration statistics are generally reasonable but may suggest significant errors in parts of the model domain(s).	x		
	Long-term trends not replicated in all parts of the model domain.		x	
	Transient calibration to historic data but not extending to the present day.	x		
	Seasonal fluctuations not adequately replicated in all parts of the model domain.			x
	Observations of the key modelling outcome data set are not used in calibration.	x		
Class 1	No calibration is possible.			x
	Calibration illustrates unacceptable levels of error especially in key areas.			x
	Calibration is based on an inadequate distribution of data.			x
	Calibration only to datasets other than that required for prediction.			x
Prediction				
Class 3	Length of predictive model is not excessive compared to length of calibration period.			x
	Temporal discretisation used in the predictive model is consistent with the transient calibration.			x
	Level and type of stresses included in the predictive model are within the range of those used in the transient calibration.			x
	Model validation suggests calibration is appropriate for locations and/or times outside the calibration model.			x
	Steady-state predictions used when the model is calibrated in steady-state only.			x

Data requirements		YES	SOME	NO
Prediction (continued)				
Class 2	Groundwater head observations and bore logs are available but may not provide adequate coverage throughout the model domain.	x		
	Metered groundwater-extraction data may be available but spatial and temporal coverage may not be extensive.			x
	Streamflow data and baseflow estimates available at a few points.			x
	Reliable irrigation-application data available in part of the area or for part of the model duration.	N/A		
Class 1	Predictive model time frame far exceeds that of calibration.	x		
	Temporal discretisation is different to that of calibration.	x		
	Transient predictions are made when calibration is in steady state only.			x
	Model validation suggests unacceptable errors when calibration dataset is extended in time and/or space.			x

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Appendix E **Boral – Marulan South Limestone Mine**

Boral

Marulan South Limestone Mine

Flooding of Mine Pits: 2013 & 2015

September 2015

Prepared by:

Advisian
WorleyParsons Group

AGE

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1 Introduction

In July 2013 and August 2015 heavy rainfall led to runoff from the catchments that drain to the north and south mine pits at the South Marulan Limestone Mine.

Records of the rainfall resulting water level in each mine pit and the subsequent drainage of water provide valuable information for the assessment of runoff from the contributing catchments and the bulk permeability of the floor of each pit.

This report provides:

- Details of the rainfall that led to flooding in the pits;
- The geometry of the pits;
- The catchment areas draining to each pit;
- The recorded water levels and implied volume of water received and subsequently drained on each occasion;
- The implied drainage characteristics of each pit;
- The implied runoff characteristics of different parts of the landscape.

2 Rainfall

2.1 July 2013

Rainfall occurred between 23rd and 30th July 2013 with particularly heavy rainfall in the 24 hours to 9.00 am on 25th and 26th. This led to flooding in both the North Pit and South Pit. Table 1 summarises the rainfall for the 24 hours up to 9.00 am on the listed date, while Figure 1 shows the cumulative rainfall for the month.

Table 1: South Marulan Rainfall – June 2013

Date	Rainfall (mm) to 9.00 am
23/06/2013	1.5
24/06/2013	18.5
25/06/2013	113.0
26/06/2013	43.0
27/06/2013	4.0
28/06/2013	1.0
29/06/2013	3.5
30/06/2013	2.5

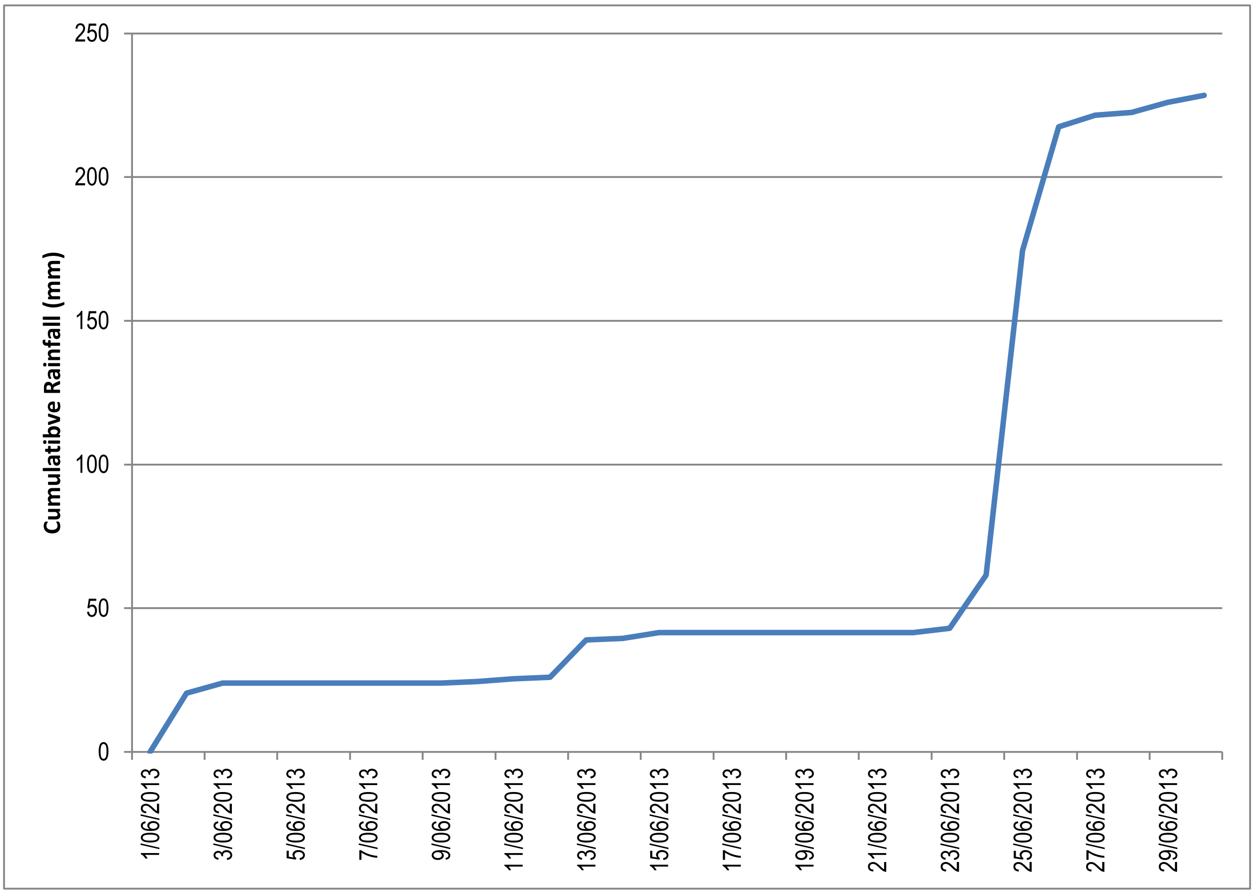


Figure 1: Cumulative Rainfall for South Marulan –June 2013
(Rainfall for 24 Hours up to 9.00 am)

2.2 August 2015

Heavy rainfall occurred on 25th and 26th August 2015 that led to flooding in both the North Pit and South Pit. Table 2 summarises the rainfall for the 24 hours up to 9.00 am on the listed date, while Figure 2 shows the cumulative rainfall for the month.

Table 2: South Marulan Rainfall – August 2015

Date	Rainfall (mm) to 9.00 am
20/08/15	0.0
21/08/15	0.0
22/08/15	0.0
23/08/15	0.0
24/08/15	7.5
25/08/15	47.0
26/08/15	84.0
27/08/15	2.0
28/08/15	0.0
29/08/15	0.0
30/08/15	0.0
31/08/15	0.0

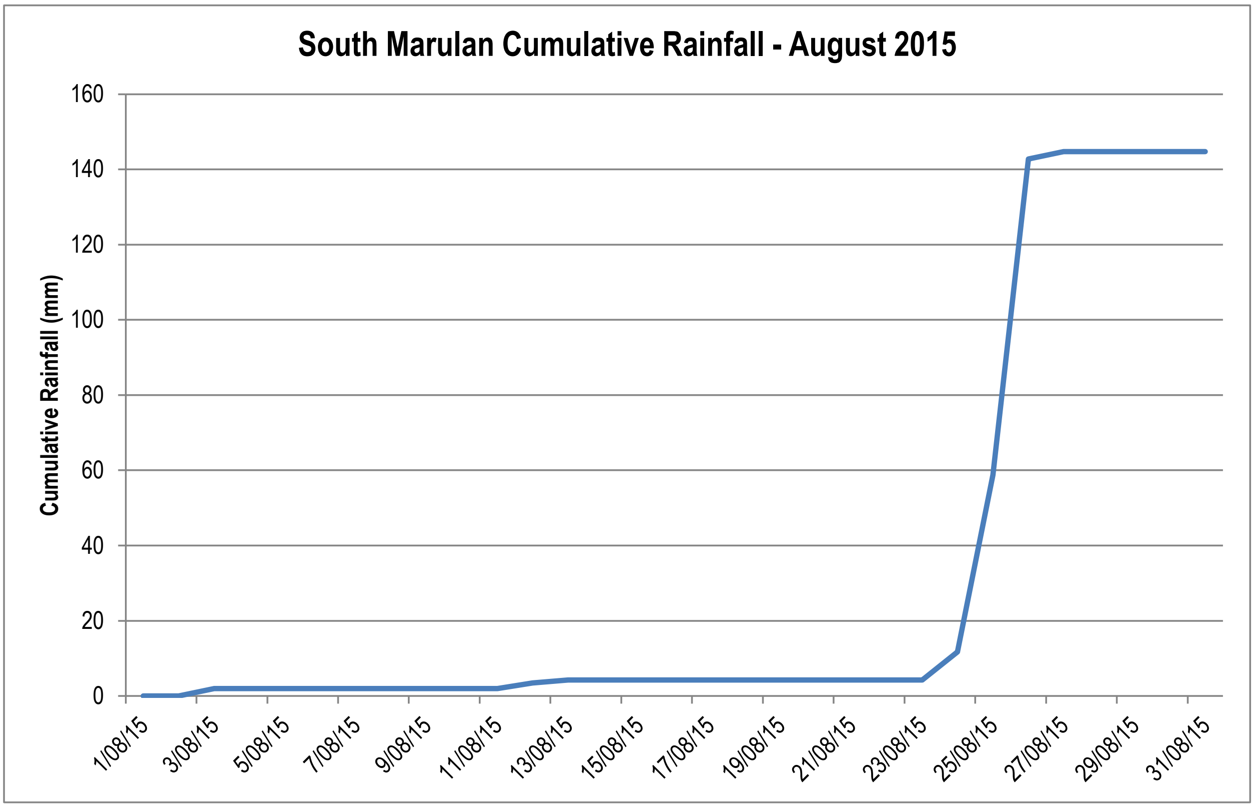


Figure 2: Cumulative Rainfall for South Marulan –August 2015
(Rainfall for 24 Hours up to 9.00 am)

3 Pit Geometry

The pit geometry is defined in terms of relationship between amount of water in the pit (head and volume) and area of the free water surface. The data describing pit geometry was provided by Boral (Gordon Atkinson). Data for North Pit varies for 2013 and 2015 flooding events as the geometry of the North Pit has changed due to mining, the geometry of the South Pit did not change between 2013 and 2015 events.

3.1 South Pit

South Pit has not been mined for a few years and the geometry of the pit remains the same for 2013 and 2015; and the elevation of the South Pit floor corresponds to the elevation of the final void at the cessation of mining. Table 3 and Figure 3 show the depth: area: volume relationship for the South Pit based on survey data provided by the mine.

Table 3: South Pit Geometry – 2013 and 2015

Water Surface Elevation (m AHD)	Head (m)	Cumulative Volume (m^3)	Area (m^2)
364.00	0.00	0	0
364.50	0.50	996	1,093
365.00	1.00	3,096	8,827
365.50	1.50	11,532	16,560
366.00	2.00	20,220	17,094
366.50	2.50	29,140	17,628
367.00	3.00	38,273	18,075
367.50	3.50	47,626	18,522
368.00	4.00	57,173	18,946
368.50	4.50	66,951	19,370
369.00	5.00	76,913	19,742
369.50	5.50	87,064	20,114
370.00	6.00	97,398	20,498
370.50	6.50	107,910	20,881
371.00	7.00	118,546	21,287
371.50	7.50	129,308	21,693
372.00	8.00	140,198	22,099
372.50	8.50	151,216	22,505
373.00	9.00	162,364	22,910

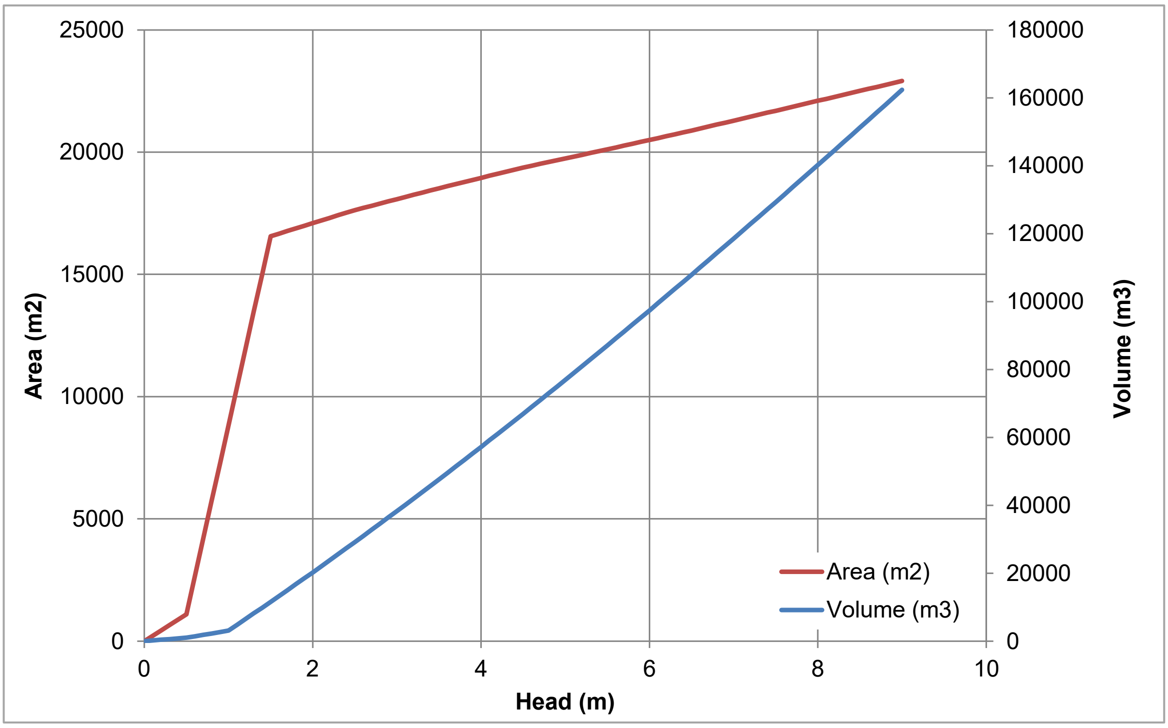


Figure 3: South Pit Geometry – 2013 and 2015

3.2 North Pit

Mining has continued in the North Pit since 2013. Table 4, Figure 4 and Figure 5 provide details of the geometry of the North Pit in 2013 and 2015 based on survey data provided by the mine.

Table 4: North Pit Geometry – 2013 and 2015

Head	2013			2015		
(m)	Water Surface Elevation (m AHD)	Volume (m^3)	Area (m^2)	Water Surface Elevation (m AHD)	Volume (m^3)	Area (m^2)
0.5	435.5	266	461	433.5	0	
1.0	436.0	604	762	434.0	0	2,172
1.5	436.5	1,015		434.5	1,138	
2.0	437.0	1,487	1,028	435.0	2,395	2,732
2.5	437.5	2,039		435.5	3,840	
3.0	438.0	2,669	1,357	436.0	5,445	3,385
3.5	438.5	3,392		436.5	7,215	
4.0	439.0	4,209	1,748	437.0	9,151	4,059
4.5	439.5	5,280		437.5	11,256	
5.0	440.0	6,830	9,253	438.0	13,515	4,731
5.5	440.5	12,360		438.5	15,958	

6.0	441.0	19,161	19,477	439.0	18,566	5,430
6.5	441.5	29,053		439.5	21,402	
7.0	442.0	39,294	23,000	440.0	24,479	9,943
7.5	442.5	50,911		440.5	29,946	
8.0	443.0	62,782	27,092	441.0	36,294	16,884
8.5	443.5	76,440		441.5	44,867	
9.0	444.0	90,315		442.0	53,768	20,225
9.5	444.5	104,415		442.5	63,975	
10.0	445.0	118,747	28,918	443.0	74,374	22,113
10.5	445.5	133,384		443.5	90,315	
11.0	446.0	148,211		444.0	104,415	
11.5	446.5	163,226		444.5	118,747	
12.0	447.0	178,427		445.0	133,384	
12.5	447.5	193,812		445.5	148,211	
13.0	448.0	209,378		446.0	163,226	
13.5	448.5	225,124		446.5	178,427	
14.0	449.0	241,047		447.0	193,812	
14.5	449.5	257,146		447.5	209,378	
15.0	450.0	273,418	33,431	448.0	225,124	
15.5	450.5	290,277		448.5	241,047	
16.0	451.0	307,328		449.0	257,146	
16.5	451.5	324,575		449.5	273,418	
17.0	452.0	342,019		450.0	290,277	
17.5	452.5	359,664		450.5	307,328	
18.0	453.0	377,512	36,186	451.0	324,575	

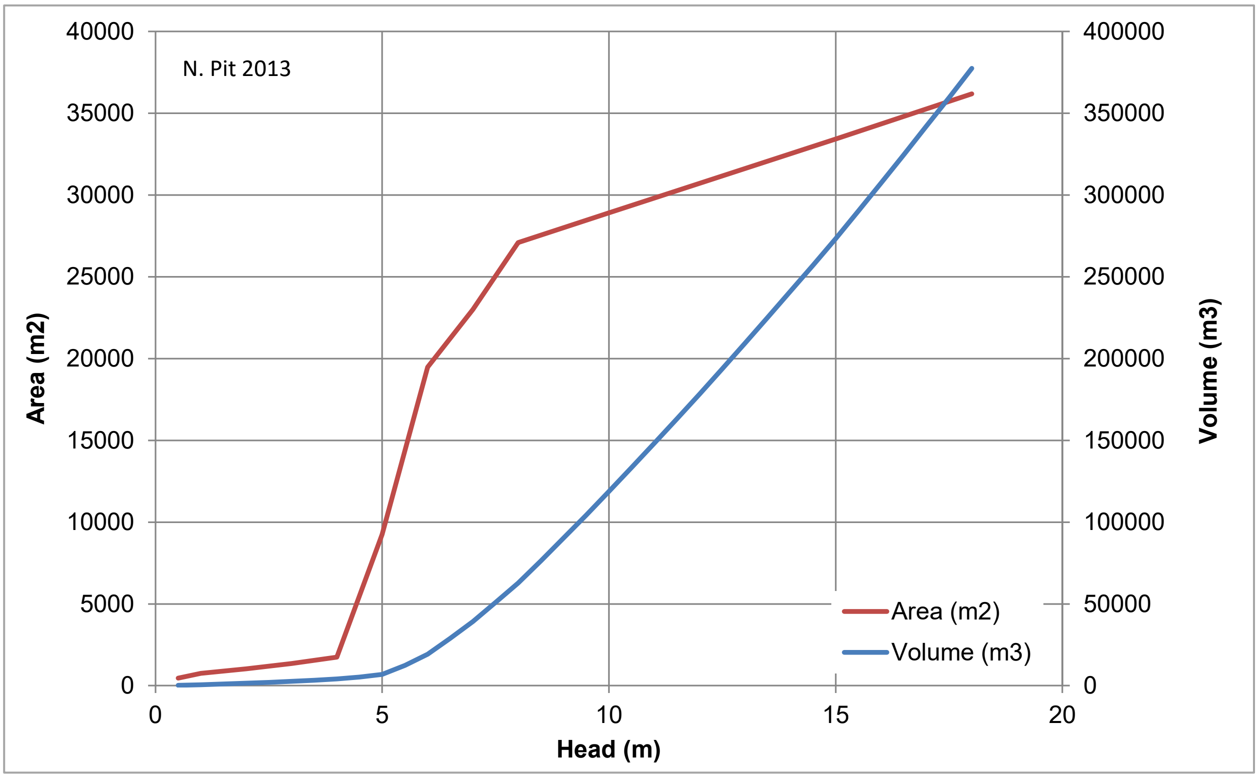


Figure 4: North Pit Geometry – 2013

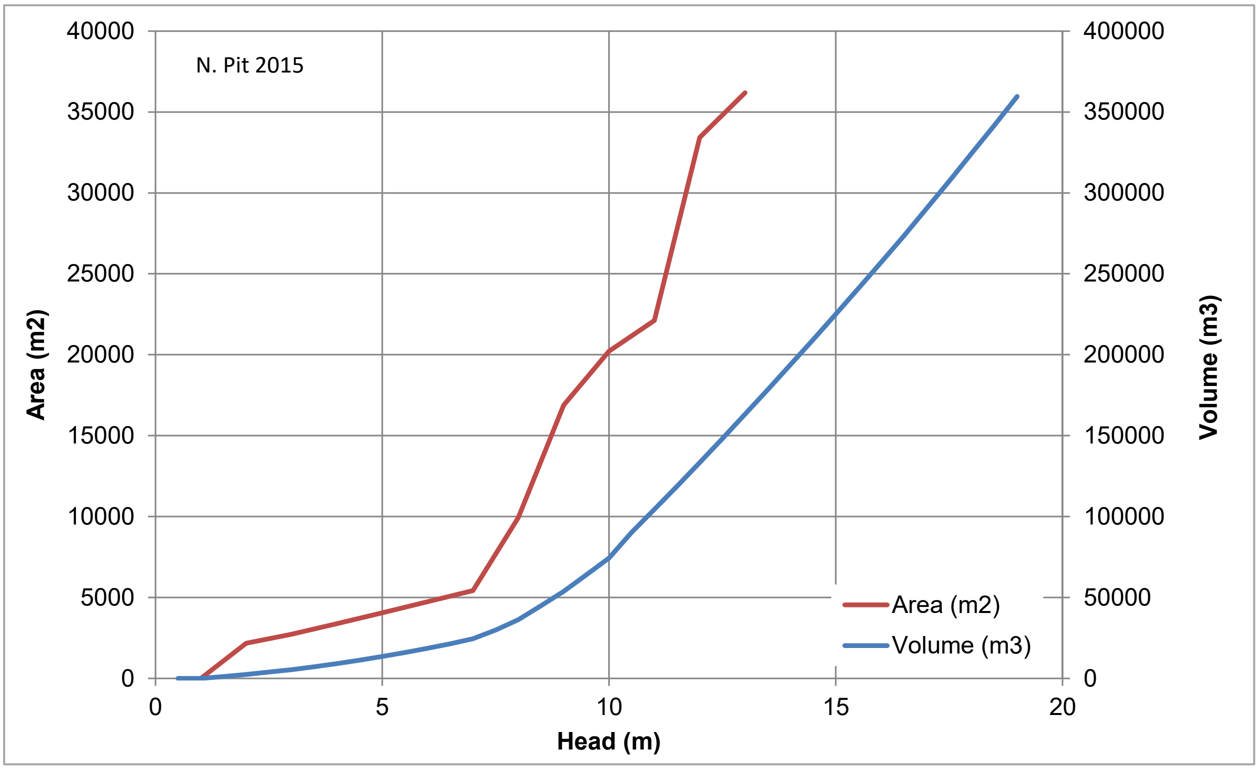


Figure 5: North Pit Geometry – 2015

4 Catchment Areas and Land Surfaces

4.1 Land Surfaces

The catchments draining to the mine pits contain a variety of land surfaces, each of which can be expected to have different responses to rainfall. The surface and runoff characteristics of the different surfaces within the catchments draining to the mine pits are outlined below, together with an initial estimate of the long term runoff as a percentage of rainfall. Section 6 describes the process adopted for revising these initial estimates of runoff characteristics in order to be consistent with the volumes of water captured in the mine pits in July 2013 and August 2015.

Natural Vegetation

For purposes of assessing runoff characteristics, 'natural' vegetation is taken to include both forested areas and cleared land used for grazing.

Analysis of the relationship between rainfall and runoff for gauged catchments in the Southern Highlands (described in the Annexure D to the *Surface Water Assessment*) indicates that the long term average runoff in the vicinity of South Marulan can be expected to be about 7.7% of rainfall. However, for individual rainfall events, the runoff can be very different from this, depending on the preceding rainfall.

Overburden emplacement

Overburden emplacements are subject to progressive development that may be characterised as series of stages:

- Bare overburden which has a high degree of porosity, but may exhibit high runoff characteristics due to slaking of the surface soil and the relatively steep slope.
- Shaped overburden that has been re-worked into a landform suitable for establishment of vegetation. In this state, the surface may be cultivated to provide a medium for vegetation establishment. The absence of vegetation means that evaporation only occurs from near the surface and elevated moisture content can be expected beneath a surface crust. In this state the surface will continue to exhibit high runoff characteristics.
- Rehabilitated overburden that has established vegetation. The presence of vegetation means that moisture is taken up by the root system and the soil is more able to absorb rainfall that when the surface is bare. However, because of the relatively shallow depth of 'soil' and the steep slopes, a rehabilitated overburden emplacement can be expected to produce more runoff that the undisturbed natural landscape.

The technical literature is relatively sparse in relation to the runoff characteristics of overburden emplacements. The most comprehensive study (ACARP, 2001) relates to overburden on coal mines. The application of the range of runoff characteristics documented in that publication to the full historic climate record (July 1887 – June 2015) at South Marulan gives the runoff (as a percentage of rainfall) set out in Table 5.

Table 5: Runoff Characteristics of Overburden Emplacements

Surface Condition	Runoff as Percentage of Rainfall		
	Minimum	Average	Maximum
Bare Overburden	18%	22%	29%
Shaped Overburden	12%	15%	21%
Rehabilitated Overburden	7%	13%	16%

Haul Roads, Hardstand and Mine Infrastructure Areas

Haul roads and hardstand areas have compacted surfaces which tend to have low infiltration rates, and have limited water holding capacity in the surface layer and minor depressions. The Mine Infrastructure Area can be expected to have some sealed areas (roofs and roads), however, for runoff modelling purposes the Mine Infrastructure Area is lumped with haul roads and hardstand areas.

Parameters representing the soil moisture storage and runoff characteristics hardstand areas derived from (ACARP, 2001) and benchmarked against the runoff characteristics for hardstand areas in MUSIC (V5, eWater, 2012). Data from these sources, combined with rainfall from the full historic climate record (July 1887 – June 2015) give an average runoff of 63%.

Mine Pits

A typical mine pit is characterised by bare rock surfaces with some loose material in the base of the pit. Parameters representing the range of runoff characteristics hardstand areas derived from (ACARP, 2001) combined with rainfall from the full historic climate record (July 1887 – June 2015) give an average runoff of 49% with a range from 39% to 56%.

4.2 Catchment Areas

Boral advises that the catchment areas draining to the mine pits have remained relatively constant over the period 2013 to 2015. Figure 6 shows the main catchment areas in the vicinity if the mine pits. In consultation with site staff, the following drainage arrangements have been adopted:

- Catchment A drains to Barbers Creek via the eastern side of the North Pit;
- Catchment B drains to the North Pit;
- Catchment C drains towards the South Pit, but site staff consider that runoff from some of this area may bypass the pit as seepage through previous overburden emplacement or redirection by the haul road;
- Catchment D drains to a large existing sediment dam;
- Catchment E drains to Main Mine Dam 1;
- Catchment F drains to a water storage formed upstream of the Western Overburden Emplacement.

For purposes of assessing the runoff reporting direct to the mine pits, only catchments B and C have been considered.

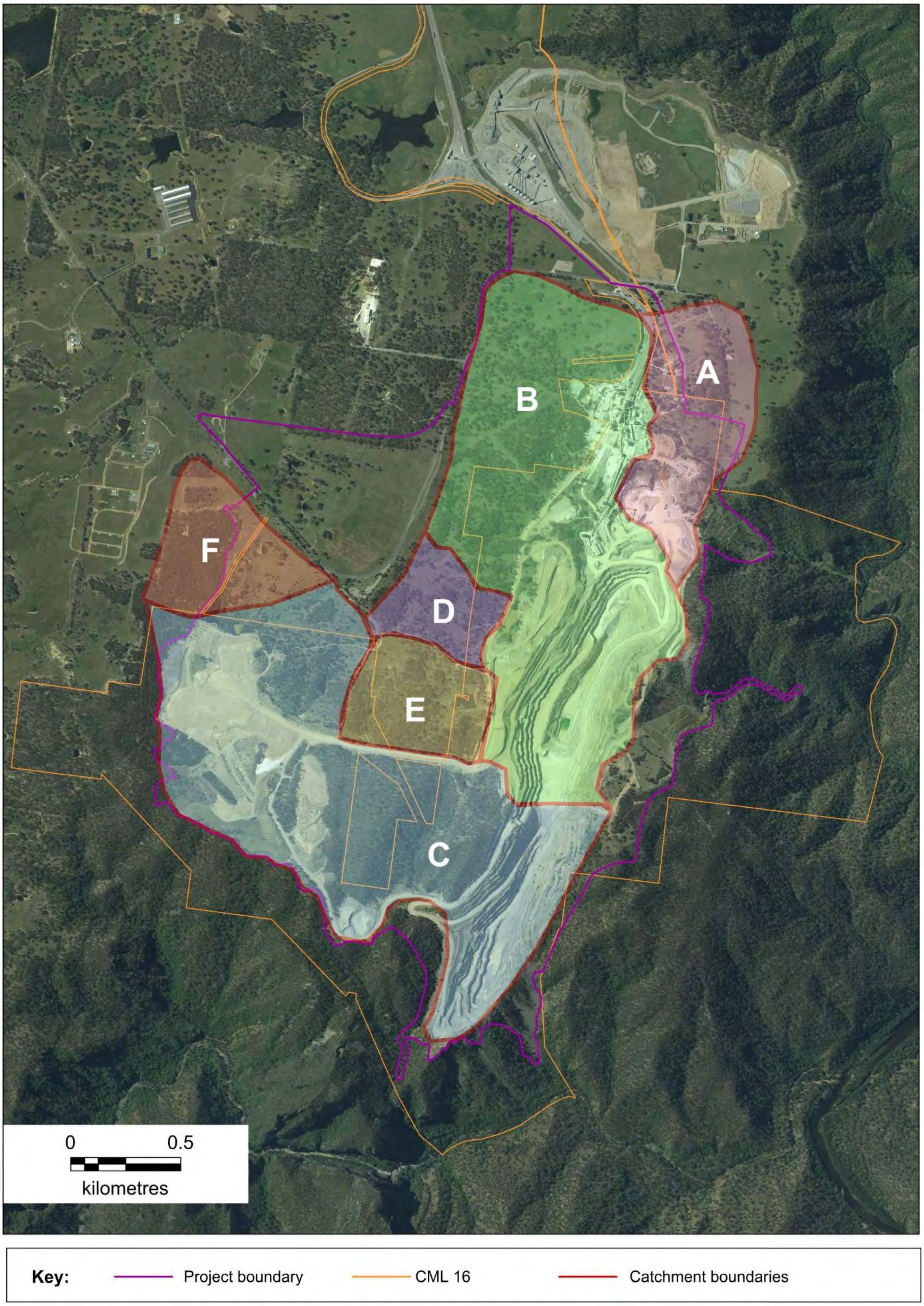


Figure 6: Catchments in the Vicinity of the South Marulan Mine Pits

The area of each land surface type draining to each pit are summarised in Table 6 below.

Table 6: Contributing Catchment Areas

Land Type	Area Draining to Pits (ha)	
	North Pit (B)	South Pit (C)
Natural Vegetation	85	115
Overburden Emplacement/Bare	25	33
Haul Roads and Hardstand Areas	0	2.5
Hard Stand and Mine Infrastructure Area	18	0.0
Mine Pit	55	40

5 Water Levels and Volumes

Increased water levels in both North and South Pits were observed during two separate rainfall events: 24 to 26 June 2013 and 24 to 26 August 2015. For the 2013 flooding event, only anecdotal information is available - estimated maximum water table elevation in the North Pit. During the 2015 flooding event regular photographs were taken and a pressure transducer was located in South Pit until 3/9/2015 and then moved to North Pit (until 11/9/2015). The pressure transducer data combined with visual observation and photographic records of water levels in both pits provides valuable information suitable for estimation of:

- Runoff characteristics of the contributing catchments;
- Seepage rates in the floor of the North Pit and South Pit.

5.1 July 2013 – North Pit

The available records of the flood water level in the North Pit following heavy rainfall in late June 2013, comprise photographs such as that in Figure 7 from which the water level has been estimated. It is not clear from the mine records whether Figure 7 represents the maximum water lever, or was taken after the level had receded. Figure 8 is a contour plot of the geometry of the North Pit in 2013, with the inferred/observed water level (443 m AHD) marked in white.

Figure 7: North Pit - View to "Centre Ridge", Water Level at ~443 m AHD (25/6/2013, 4.00 pm)

Based on the photograph of the July 2013 event (Figure 7), the water in the North Pit reached an elevation of approximately 443 m AHD (Figure 8) with a level of 8 m above pit floor and an estimated volume of 63 ML.

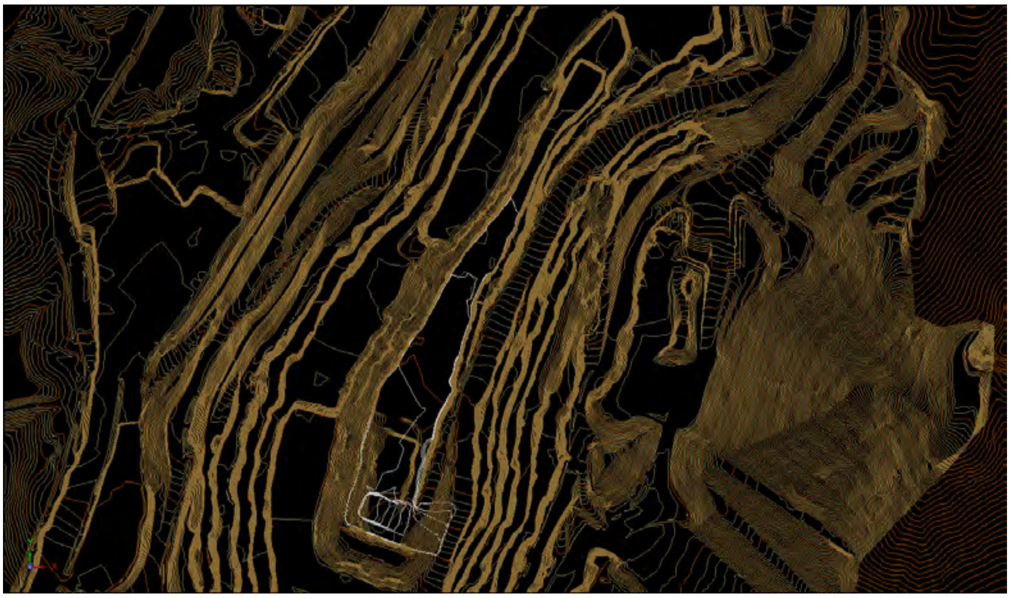


Figure 8: Observed Water Level in North Pit (July 2013).
Source: 2013-14 AEMR (Boral, 2014)

5.2 July 2013 – South Pit

No photographs of the peak water elevation of the South Pit are available. The information provided by the Marulan Mine staff indicates that the water which accumulated in the South Pit disappeared in a 'couple of days' or 'in less than one week's time'.

5.3 August 2015 – North Pit

During the 2015 flooding event, the water elevation in the North Pit peaked following maximum rainfall on 26/8/2015. The maximum elevation of accumulated runoff water is estimated to be between 444 and 444.5 m AHD.

The first actual observation of the water level in North Pit was made approximately one day later, on 27/8/2015 at 8.42 am (see Figure 9 and Table 7). This observation was used to estimate the water level (Figure 10) and accumulated volume of runoff water at that time. In total, the water in the North Pit was photographed four times between 27/8 and 7/9/2015. Each of the observations was used to estimate water level in the pit (Table 7).

From 3/9/2015, the drop of the water level in the North Pit was further documented using the pressure transducer located on the pit floor (Table 8). The maximum accumulated volume of water during the event was 104.4 ML (water elevation of 444.5 m AHD), estimated volume of water on 10/9/2015 was 11.3 ML (water elevation of 437.5 m AHD). The water elevation in the North Pit dropped by 7 m in 15 days and the North Pit lost about 93 ML of water.

Table 7: Estimated Water Level Elevation from Photographs – North Pit, August 2015

Date, time	Head Above Pit Floor (m)	Water Surface Elevation (m AHD)
27/08/2015 8:42	10.0	443.0
2/09/2015 13:17	7.4	440.4
3/09/2015 11:53	6.6	439.6
7/09/2015 9:45	5.5	438.5

Table 8: Measured Water Level Elevation from Transducer Records – North Pit, August 2015

Date, time	Head Above Pit Floor (m)	Water Surface Elevation (m AHD)
4/09/2015 0:00	10.4	439.4
5/09/2015 0:00	9.9	438.9
6/09/2015 0:00	9.4	438.4
7/09/2015 0:00	8.9	437.9
8/09/2015 0:00	8.7	437.7
9/09/2015 0:00	8.5	437.5
10/09/2015 0:00	8.4	437.4

Figure 9: North Pit – View Due North from "Centre Ridge" (27/8/2015, 8.42 am)

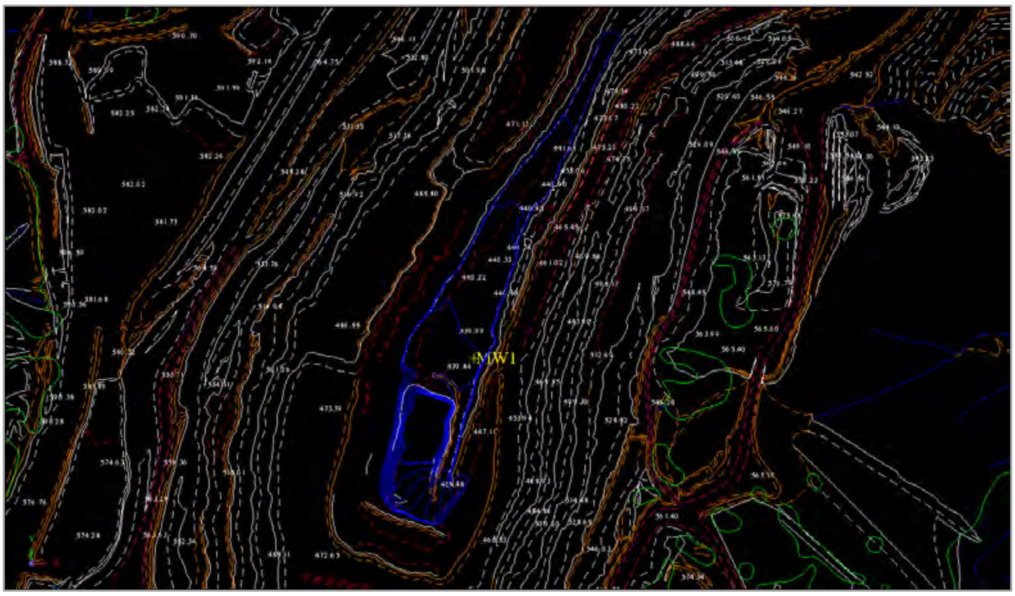


Figure 10: Estimated Maximum Elevation of Water in North Pit (August 2015) – Contours

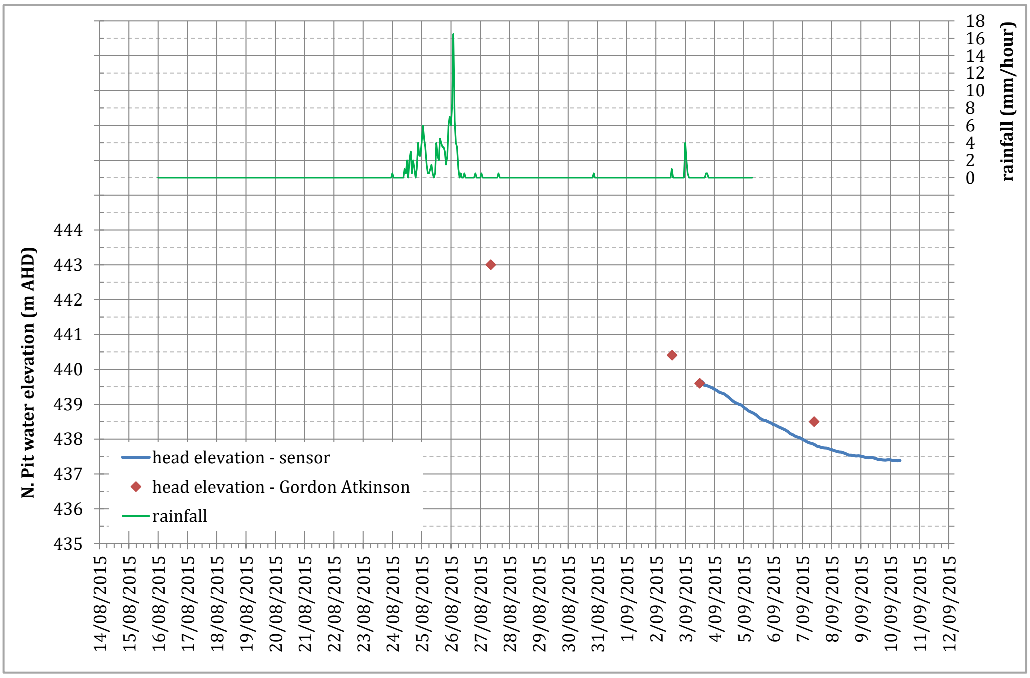


Figure 11: Rainfall and Water Level in the North Pit (August 2015)

5.4 August 2015 – South Pit

The elevation of the accumulated runoff in the South Pit was documented visually (see Figure 12) as well as using the pressure transducer located in the deepest part of the South Pit. The elevation data recorded by the pressure transducer (Table 9, Figure 13) indicate that the water in the South Pit did not accumulate as much as in the North Pit. Because of faster discharge through the pit floor, the water reached only 0.5 m above the baseline level and returned to the pre-flooding conditions in about 3 days.

Figure 12: South Pit – 26/8/2015 – view from the eastern ramp

Table 9: Measured Water Level (Pressure Transducer) – South Pit, August 2015

Date, time	Head above pit floor (m)	Water table elevation (m AHD)
25/08/2015 0:00	0.85	364.85
25/08/2015 12:00	0.91	364.91
26/08/2015 0:00	1.07	365.07
26/08/2015 12:00	1.03	365.03
27/08/2015 0:00	1.00	365.00
27/08/2015 12:00	0.89	364.89
28/08/2015 0:00	0.84	364.84
28/08/2015 12:00	0.83	364.83
29/08/2015 0:00	0.80	364.80
29/08/2015 12:00	0.81	364.81
30/08/2015 0:00	0.78	364.78
30/08/2015 12:00	0.81	364.81
31/08/2015 0:00	0.80	364.80
31/08/2015 12:00	0.80	364.80

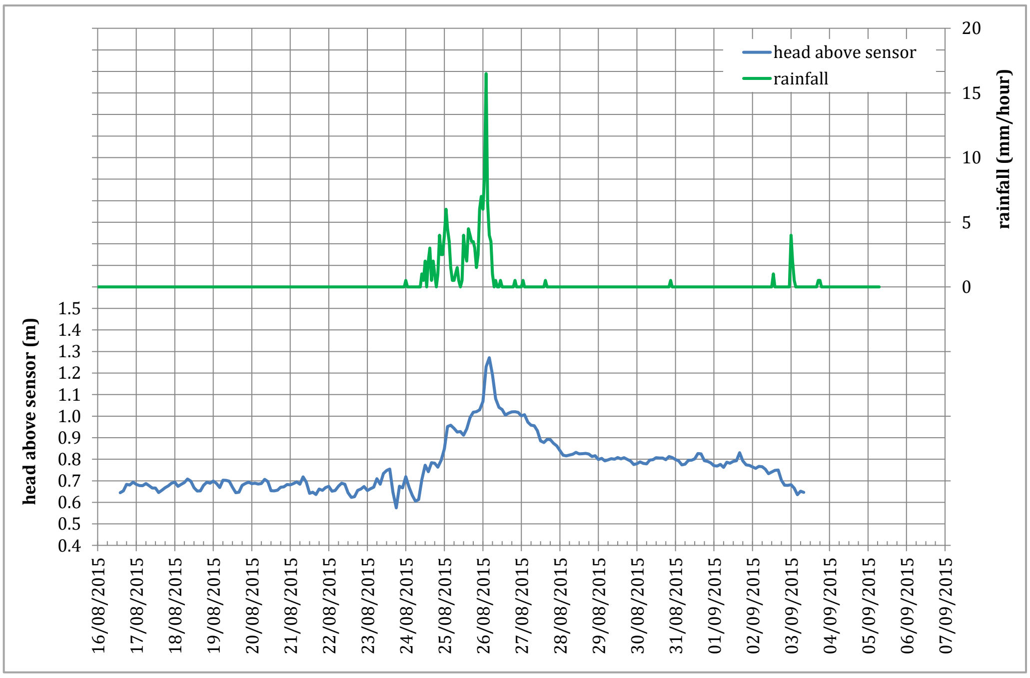


Figure 13: Rainfall and Water Level in the South Pit (August 2015)

6 Runoff Characteristics

The date and time that photograph in Figure 7 was taken are not known and are note useful for purposes of validating the modelled runoff. The most reliable data is the water level estimates based on the series of photographs taken in the North Pit following the heavy rainfall between 9.00 am on 24 August and 9.00 am on 26 August 2015, which form the basis for Figure 11. The first photograph was taken at 8.45 am on 27 August, some 24 hours after rainfall had ceased.

As shown by the relationship between rainfall and water levels in Figure 13, peak water level in the South Pit occurred at about 4.00 am on 26 August, about 2 hours after the heaviest rainfall at 2.00 am. Assuming similar time of concentration for the both catchments (similar total area and slopes), it is likely that the peak water level in the North Pit occurred before 9.00 am on 26 August. From Figure 11, the inferred peak water level would have been in the range of 443.5 m AHD to 444.0 m AHD corresponding to water volume in the pit in the range of 90 ML to 104 ML (from Table 4).

The rainfall: runoff model (AWBM) was run for the range of parameters that give rise to the various runoff characteristics described in Section 4.1. In order to account for antecedent rainfall before the storms of interest and eliminate any model 'warm-up' effects, the model was run using the daily rainfall from November 2009 to August 2015 (which includes both periods when there was recorded flooding). By adopting the model parameters that gave the minimum volume of runoff reaching the North Pit (Section 4.1), the estimated volume in the pit was 102 ML, which is within the range of the estimated maximum volume immediately following the storm after accounting for some drainage through the base of the pit during the storm.

Based on these model parameters, the estimated volume of runoff reporting to the North Pit and South Pit for the storms of June 2013 and August 2015 are set out in Table 10 and Table 11. These estimates should be interpreted with caution, particularly for the South Pit. While the base of the South Pit is recognised as being more permeable than the North Pit (see Section 5.2), the inferred total runoff into the south pit following the August 2015 storm (74 ML) is not consistent with the maximum recorded increase in water level of 0.6 m (Figure 13). Even if only the runoff from the pit itself was considered (about 46 ML or 63% of the total), the discrepancy remains.

Table 10: Estimated Runoff Volume up to 9.00 am on the Listed Date (2013)

Date	North Pit (ML)	South Pit (ML)
24/06/2013	10	6
25/06/2013	102	75
26/06/2013	48	42

Table 11: Estimated Runoff Volume up to 9.00 am on the Listed Date (2015)

Date	North Pit (ML)	South Pit (ML)
25/08/2015	22	16
26/08/2015	80	58

7 Drainage Characteristics of Mine Pits

A simple spreadsheet model was used to estimate the bulk conductivity of the North and South Pit floors. The flood events of July 2013 and August 2015 were used as 'calibration' events for the spreadsheet model.

Given our understanding of runoff volumes to both pits, time it took for the water to seep through the pit floor and dimensions of the pits, discharge rates and volumes can be calculated for both pits. The model parameters can be then adjusted, so that the calculated discharge curves match the actual, observed discharge curves (Figure 11 and Figure 13).

The conceptual setup and spreadsheet model parameters are presented in Figure 14:

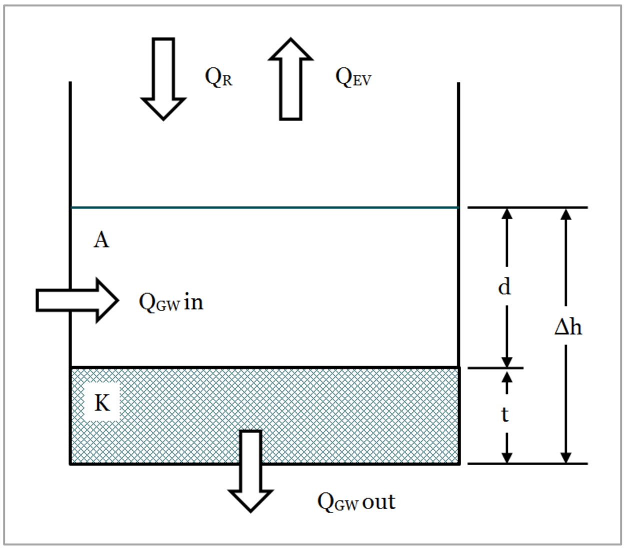


Figure 14: Conceptualization of the Pit Floor Seepage Calculations

Where:

Q_R	– inflow – rainfall and runoff
Q_{EV}	– loss – evaporation
Q_{GW} in	– inflow – groundwater
Q_{GW} out	– loss – groundwater
K	– bulk vertical hydraulic conductivity of pit floor
A	– area of the lake/flooded pit floor
d	– depth of water
t	– saturated thickness of the South Pit floor
Δh	– head gradient

The saturated thickness of the pit floor was defined arbitrarily as 50 m, however the sensitivity of this parameter is quite low. Outflow from the pit can be then calculated as:

$$Q_{GW} out = K \times A \times \frac{\Delta h}{t}$$

7.1 South Pit

The observed discharge through the South Pit floor was very fast – based on the data obtained from the pressure transducer placed in the South Pit, the runoff water disappeared in less than 3 days (the volume and head peaked in the early hours of 26/8/2015 and by the end of 29/8/2015 the accumulated runoff was gone.

Because of the coarseness of the spreadsheet model (heads and volumes were calculated on daily basis) the model over predicts the calculated head. In order to use the model as an estimation tool for the bulk vertical conductivity of the South Pit floor, the calibration concentrated on replicating the ***time*** necessary to discharge the accumulated water and replication of the discharge trend (see Figure 15), rather than attempting to match the head.

The calculated seepage loss through the South Pit floor for the August 2015 flooding event is presented in Table 12.

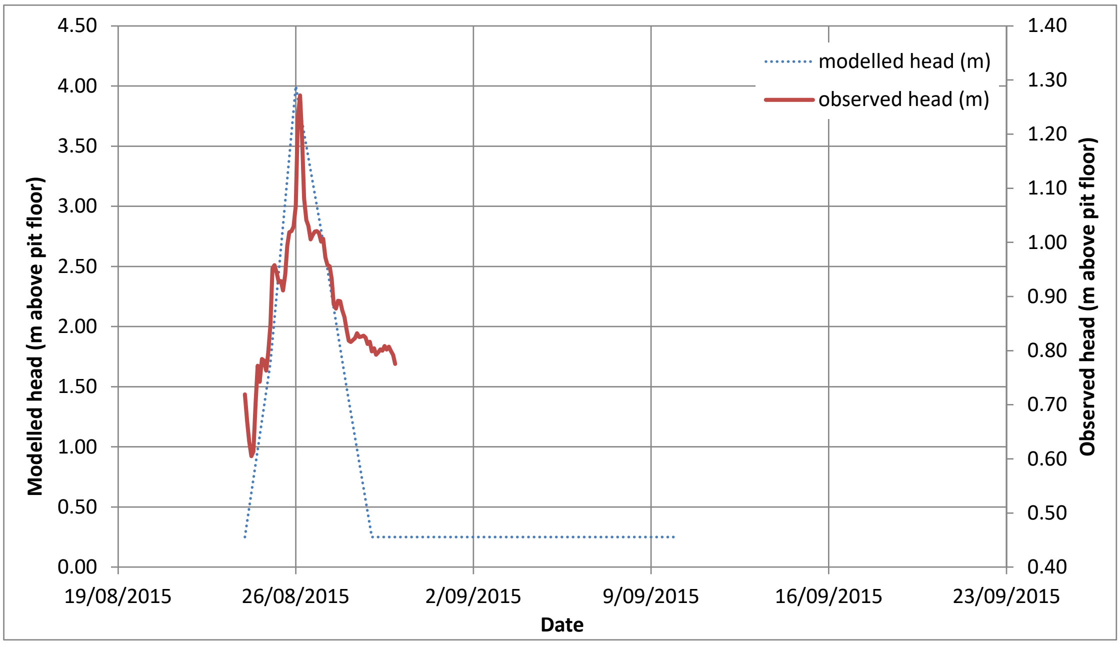


Figure 15: Measured and Modelled Head in the South Pit (August 2015)

Table 12: Calculated Seepage Loss through the South Pit Floor (August 2015)

Date	Runoff Inflow (m^3)	Rainfall (mm)	Pan EV (mm)	Head (m)	Area (m^2)	Seepage Loss (m^3)
24/08/2015	0	7.5	3.4	0.10	219	274
25/08/2015	16,000	47.0	3.4	1.70	16,774	1,6297
26/08/2015	58,000	84.0	3.4	4.00	18,946	25,036
27/08/2015	0	2.0	3.4	2.70	17,807	23,117
28/08/2015	0	0.0	3.4	1.40	15,013	10,659
29/08/2015	0	0.0	3.4	0.10	219	274
30/08/2015	0	0.0	3.4	0.10	219	274
31/08/2015	0	0.0	3.4	0.10	219	274
1/09/2015	0	0.0	3.4	0.10	219	274
2/09/2015	0	0.0	3.4	0.20	219	274
3/09/2015	0	0.0	3.4	0.10	219	274
4/09/2015	0	0.0	3.4	0.10	219	274
5/09/2015	0	0.0	3.4	0.10	219	274
6/09/2015	0	0.0	3.4	0.10	219	274
7/09/2015	0	0.0	3.4	0.20	219	274
8/09/2015	0	0.0	3.4	0.10	219	274
9/09/2015	0	0.0	3.4	0.10	219	274
10/09/2015	0	0.0	3.4	0.10	219	274

Parameters calibrating the model for in terms of the speed of discharge were:

Q_{GW} in = 300 m^3/day;

K = 1.25 m/day (value lies between 1.0 and 1.5 m/day).

7.2 North Pit

Because of the accumulated volume and discharge speed in the North Pit, the spreadsheet model was better suited for the conditions of the North Pit than the South Pit. The model parameters (namely K and Q_{GW}in) were calibrated against the water elevation data obtained by direct and indirect measurement (see Section 5.3). The modelled decrease of water table in the North Pit during the August 2015 flooding event is presented in Figure 16.

Parameters 'calibrating' the model are:

Q_{GW} in = 1,200 m^3/day;

K = 0.5 m/day.

All other parameters were obtained from the field measurements (head above the pit floor, rainfall, pan EV) or calculated from the field data (runoff volume, intermittent volume of water in the pit, area of the flooded pit). The calculated seepage rates during the flooding event are presented in Table 13.

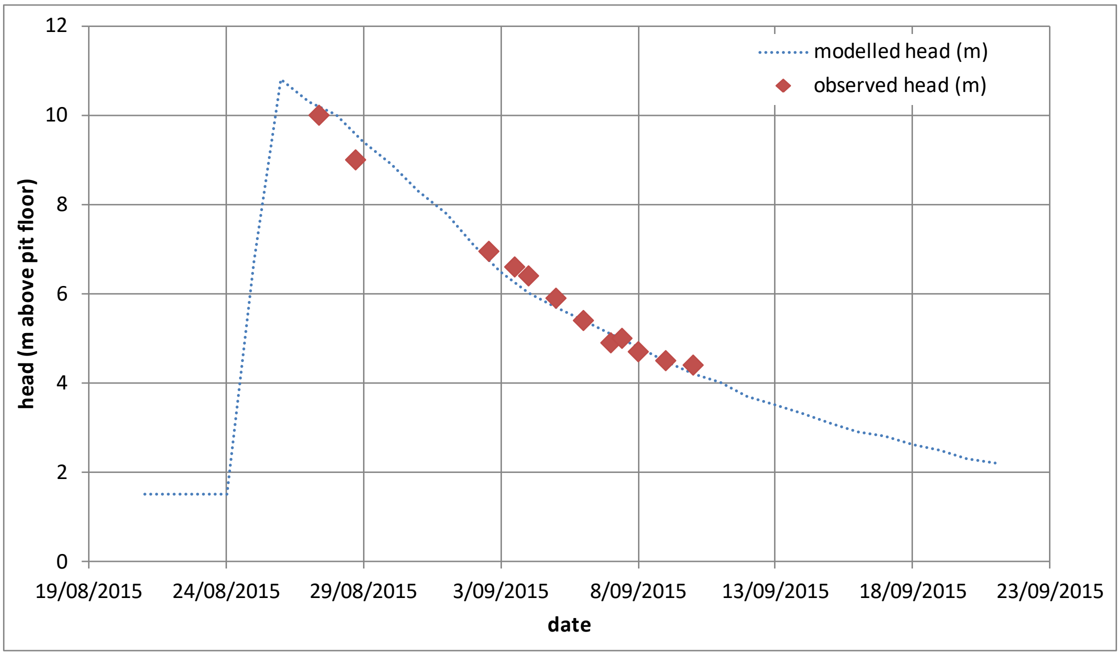


Figure 16: Measured and Modelled Head in the North Pit (August 2015)

The rates of the groundwater inflow (Q_{GW} in) are consistent with the results obtained by the regional numerical model; however the bulk hydraulic conductivity of the limestone pit floor is higher than previously suggested by the pumping tests on bores MW1 and MW2.

Table 13: Calculated Seepage Loss through the North Pit Floor (August 2015)

Date	Runoff Inflow (m^3)	Rainfall (mm)	Pan EV (mm)	Head (m)	Area (m^2)	Seepage Loss (m^3)
24/08/2015	0	7.5	3.4	1.5	2,452	1,196
25/08/2015	22,000	47	3.4	6.7	8,589	4,706
26/08/2015	80,000	84	3.4	10.8	23,924	13,808
27/08/2015	0	2	3.4	10.3	22,792	13,073
28/08/2015	0	0	3.4	10	22,113	12,636
29/08/2015	0	0	3.4	9.4	20,980	11,899
30/08/2015	0	0	3.4	8.9	19,891	11,210
31/08/2015	0	0	3.4	8.3	17,886	10,004
1/09/2015	0	0	3.4	7.8	15,496	8,611
2/09/2015	0	0	3.4	7.1	10,637	5,858
3/09/2015	0	0	3.4	6.5	7,687	4,200
4/09/2015	0	0	3.4	6	5,430	2,948
5/09/2015	0	0	3.4	5.7	5,220	2,823
6/09/2015	0	0	3.4	5.4	5,011	2,699
7/09/2015	0	0	3.4	5.1	4,801	2,575
8/09/2015	0	0	3.4	4.8	4,597	2,456
9/09/2015	0	0	3.4	4.5	4,395	2,339
10/09/2015	0	0	3.4	4.2	4,193	2,223
11/09/2015	0	0	3.4	4	4,059	2,145
12/09/2015	0	0	3.4	3.7	3,857	2,030
13/09/2015	0	0	3.4	3.5	3,722	1,954
14/09/2015	0	0	3.4	3.3	3,587	1,878
15/09/2015	0	0	3.4	3.1	3,452	1,803
16/09/2015	0	0	3.4	2.9	3,320	1,729
17/09/2015	0	0	3.4	2.8	3,254	1,692
18/09/2015	0	0	3.4	2.6	3,124	1,620
19/09/2015	0	0	3.4	2.5	3,059	1,584
20/09/2015	0	0	3.4	2.3	2,928	1,512

7.3 Final Void

Final Void will be created by mining in the North Pit to the elevation of the current South Pit floor and extending the pit into the eastern and western sides. Part of the South Pit floor will be covered by spoil. The shape of the final void was provided by Boral and the pit geometry is presented in Table 14 below.

Table 14: Final Void Geometry – Post Closure

Water Surface Elevation (m AHD)	Head (m)	Cumulative volume (m^3)	Area (m^2)
366	1	191,643	191,520
367	2	393,202	201,560
368	3	596,568	203,366
369	4	801,765	205,196
370	5	1,008,925	207,161
371	6	1,218,053	209,127
372	7	1,428,979	210,926
373	8	1,641,634	212,655
374	9	1,856,105	214,471
375	10	2,072,581	216,476
380	15	3,206,150	248,606
385	20	4,503,975	263,711
390	25	5,852,958	273,823
395	30	7,275,186	306,271
400	35	8,900,745	329,756
410	45	12,343,524	374,185
420	55	16,246,611	400,273
430	65	20,529,529	450,379
440	75	25,198,953	507,471
450	85	30,461,601	537,662
460	95	36,155,692	597,082
470	105	42,284,504	635,033
480	115	49,151,429	699,192
490	125	56,551,342	777,965

As the Final Void is going to be effectively created by joining the North and South Pits, the hydraulic properties of the Final Void are to be 'inherited' from the existing properties of the North and South Pits. The seepage from the Final Void can be calculated as sum of seepages from the zones formerly representing the North and South Pits, keeping their distinct hydraulic properties. The conceptualization of this case is presented in Figure 17.

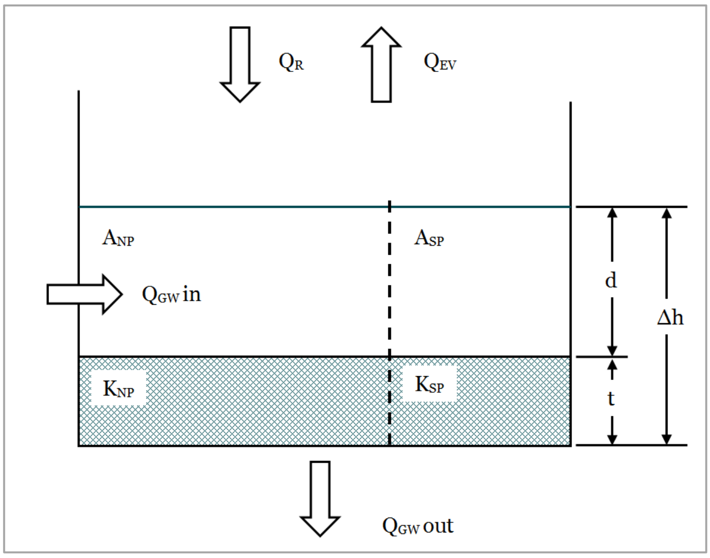


Figure 17: Conceptualization of the Pit Floor Seepage Calculations – Final Void

Where:

Q_R	– inflow – rainfall and runoff
Q_{EV}	– loss – evaporation
Q_{GW} in	– inflow – groundwater
Q_{GW} out	– loss – groundwater
K_{NP}	– bulk vertical hydraulic conductivity of North Pit floor
K_{SP}	– bulk vertical hydraulic conductivity of South Pit floor
A_{NP}	– area of the lake/flooded pit floor representing former North Pit
A_{SP}	– area of the lake/flooded pit floor representing former South Pit
d	– depth of water
t	– saturated thickness of the Final Void floor
Δh	– head gradient

Outflow from the Final Void can be then calculated as:

$$Q_{GW} out = [(K_{NP} \times A_{NP}) + (K_{SP} \times A_{SP})] \times \frac{\Delta h}{t}$$

The overall volume of outflow depends on areas and vertical K of individual pits. The ratio between the North and South Pit floor area within the Final Void was estimated to be between 70% (NP): 30% (SP) and 95% (NP): 5% (SP). The sensitivity of the seepage calculations with respect to the change in the ratio between North and South Pits conditions is explored in Figure 18.

With the incresing area representing North Pit, the overall seepage rate decreases. The 'worst case scenario' is that the whole Final Void inherits North Pit parameters. The difference of seepage rate between the 30% of South Pit and 0% of South Pit is approximately 30% decrease in seepage from the Final Void.

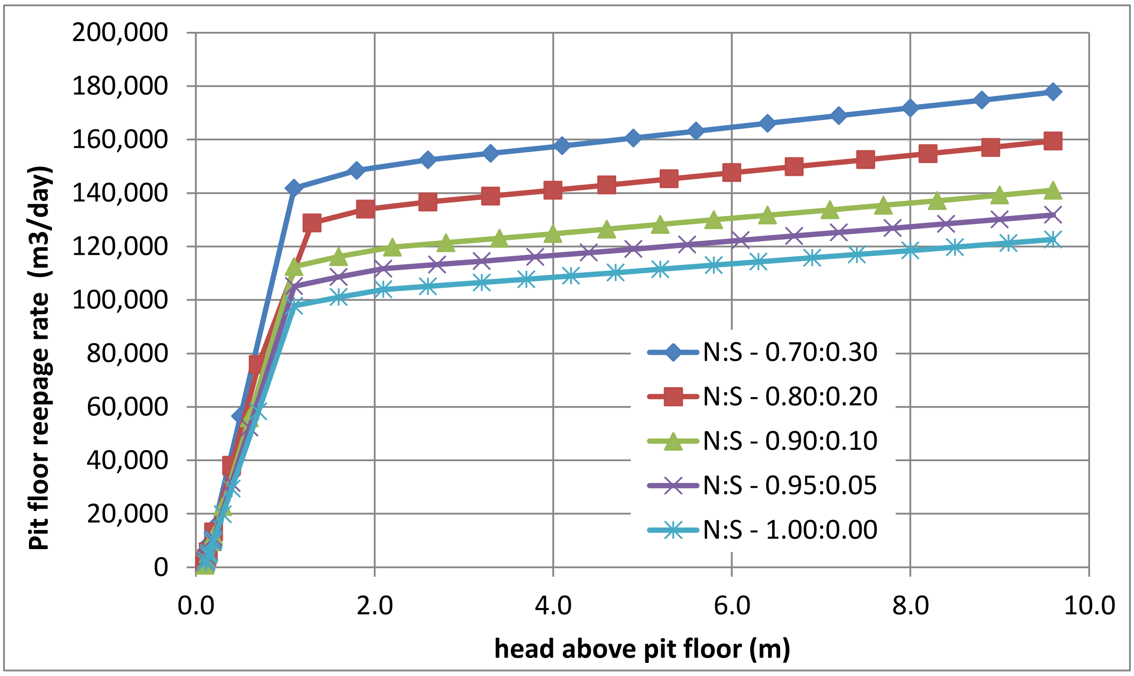


Figure 18: Final Void Head to Seepage Volume Ratio.

8 References

Boral Cement Limited (2014). *Annual Environmental Management Report 2013/2014: Marulan South Limestone Mine*

Boughton, W. (2010). *Rainfall-Runoff Modelling with the AWBM*. Engineers Media, Crows Nest.

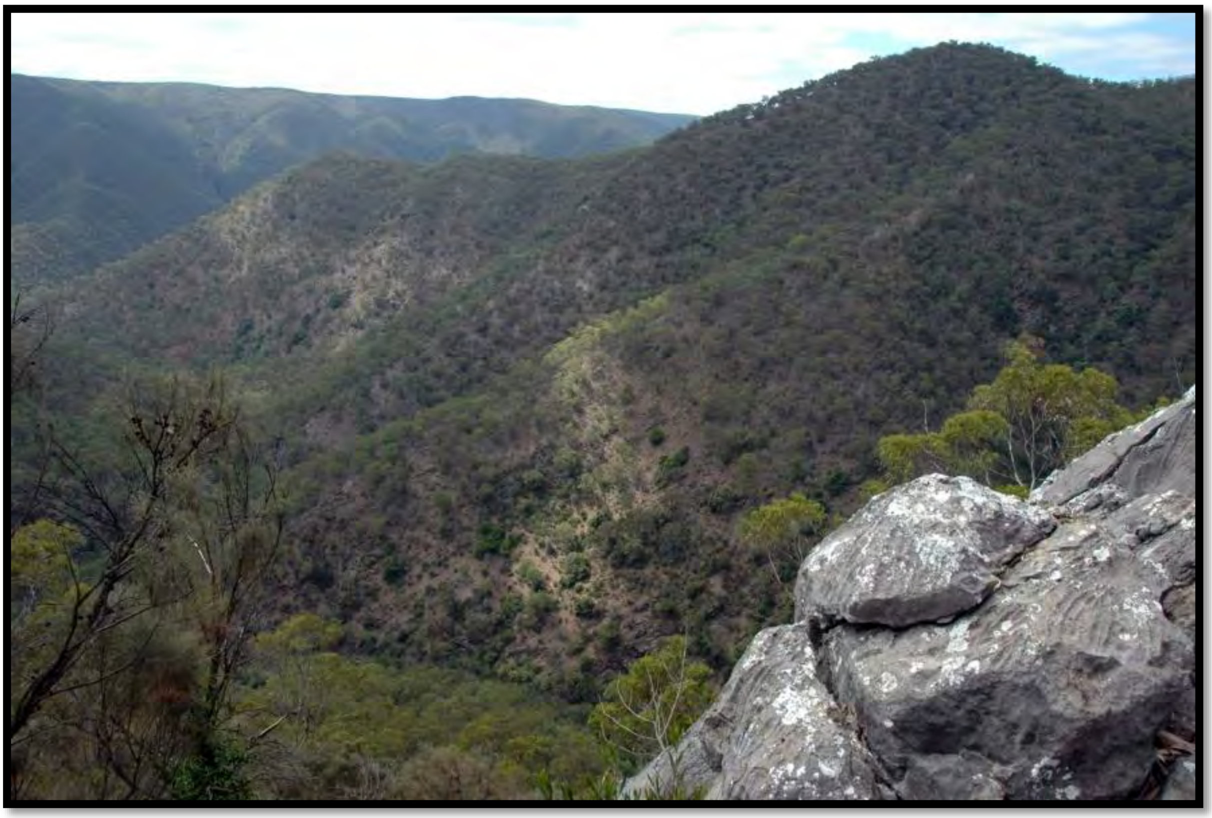
ACARP (2001), *Water Quality and Discharge Predictions for Final Void and Spoil Catchments*, Report prepared by PPK for Australian Coal Association Research Program

Appendix I

Soil, land resources and rehabilitation assessment

VOLUME 3

MARULAN SOUTH LIMESTONE MINE CONTINUED OPERATIONS PROJECT

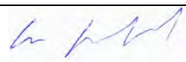


SOIL, LAND RESOURCES AND REHABILITATION ASSESSMENT

LAMAC Management, September 2018

Document Control

Title	Marulan South Limestone Mine Continued Operations Project – Soil, Land Resources and Rehabilitation Assessment
General Description	Assessment of existing soils, land and rehabilitation resources at Marulan South Limestone Mine, and proposed methodology for future mined land rehabilitation.

					Approved	
Rev No	**Date**	**Description**	**By**	**Checked**	**Name**	**Signed**
0	11/9/2015	First Draft	L.Crawford	C.Bagnall		
1	10/5/2016	V2 Final Draft	L.Crawford	Client		
2	19/6/2018	V3 Draft	L.Crawford	Client		
3	29/8/2018	V4 Draft	L.Crawford	Client		
4	19/9/2018	V5 Final Draft	L.Crawford	Client	L.Crawford	

Executive Summary

Boral Cement Limited (Boral) owns and operates the Marulan South Limestone Mine (the mine). It is a long standing, open cut mine that has extracted up to 3.38 million tonnes of limestone per year and produces limestone and lime based products for the cement, steel, agricultural, construction and commercial markets.

The mine operates under Consolidated Mining Lease No. 16 (CML 16), Mining Lease No. 1716, Environment Protection Licence (EPL) 944 and a combination of development consents issued by Goulburn Mulwaree Council and continuing use rights.

Due to changes between the Mining Act 1992 and the Environmental Planning & Assessment Act 1979 (EP&A Act), when mining moves beyond the area covered by the current Mining Operations Plan, a development consent under the EP&A Act will need to be in place.

An Environmental Impact Statement (EIS) has been prepared by Element Environment, on behalf of Boral for submission to the Department of Planning and Environment (DP&E) to satisfy the provisions of Part 4 of the EP&A Act. Boral is seeking approval for continued operations at the site through a development application for a State Significant Development including a 30 year mine plan, associated overburden emplacement areas and a mine water supply dam (hereafter referred to as ‘the Project’).

A specialist soils and rehabilitation team was engaged by Boral to undertake a soils, land resources and rehabilitation assessment (SLRRA) of the Project site, as part of the Project EIS investigation team. The initial SLRRA was undertaken between November 2014 and July 2015.

Following further geological exploration and resource definition, a revised mining plan (Mine Plan 2) was finalised by Boral in late 2017. This SLRRA was subsequently revised in February 2018 to reflect proposed modifications to mining related disturbance and rehabilitation included in Mine Plan 2.

The SLRRA consisted of a soils and land capability assessment of the existing Project site, and an assessment of existing and proposed rehabilitation. An assessment of the Project site against Biophysical Strategic Agricultural Land (BSAL) verification criteria was also completed as part of the Site Verification Certificate (SVC) application process.

Soils

The SLRRA identifies no hostile soils, subsoils or overburden material in areas of proposed disturbance within the 30 year mine plan footprint that would require special management. Six soil landscape units identified and mapped within the Project site, consist of:

- 143.5 ha Sodosols (Red / Brown);
- 11.5 ha Kurosols, Brown;
- 119.9 ha Tenosols (Bleached-Orthic / Brown-Orthic);
- 229 ha Tenosols / Rudosols (Steep Slopes);
- 2.5 ha Rudosols (Alluvial); and
- 340 ha Disturbed / Anthroposols.

These soil landscape units are shown in **Figure 5**.

Based on the attributes of the mapped soil landscape units, the following topsoil stripping depths are recommended.

- 10cm - Sodosol and Tenosol soil landscape unit within the southern section of the assessment area;
- 15cm - Sodosol soil landscape unit within the northern section of the assessment area; and
- 15cm – Kurosols soil landscape unit within the southern section of the assessment area.

Recommended topsoil stripping depth units are shown in **Figure 6**.

An estimated 215,510 m^3 of good quality topsoil is identified as available for stripping within the Project site. Potential alternate top-dressing materials are also identified to address the forecast deficit in good quality topsoil material.

Land

No Biophysical Strategic Agricultural Land (BSAL) was identified within the Project site (which was certified by DP&E in consultation with OEH, by issuing a Site Verification Certificate dated 17 November 2015), and impact on existing agricultural resources is expected to be minor. Land Capability Classes within the Project site are detailed in Table 12 and summarised below as:

- 155 ha Class V: Moderate to low capability land;
- 120 ha Class VII: Very low capability land;
- 231 ha Class VIII: Extremely low capability land; and
- 340 ha Not Assessed: Mining disturbed land.

Land capability mapping units are shown in **Figure 7**.

Rehabilitation

Section 4 of this SLRRA outlines the conceptual Project rehabilitation and mine closure strategy, post-mining land use, conceptual final landform design and strategic rehabilitation considerations.

The rehabilitation and mine closure strategy anticipates that operations could continue beyond the initial 30-year Project period with a further 110 million tonnes of limestone available for mining. As continuation of mining following the 30-year Project life is a likely option, post mining land is currently considered in conceptual terms, particularly in regard the mine void. Further development of final land use over the Project life will be guided by regulatory approvals and consultation with local interested parties.

The 30-year mine development considers both “above ground” and “in-pit” options for overburden emplacement to achieve a balance between resource utilisation and long term environmental considerations - especially visual impacts of the rehabilitated landform. At Project end, reshaped emplacements will be the likely final landforms, even if mining should continue past the current 30-year Project life.

The post mining land use goal for the overburden emplacements is the re-establishment and development of native woodland vegetation communities that reflect the existing ecological communities identified in the Project biodiversity assessment (Niche, 2018).

If mining were to cease towards the end of the proposed 30-year Project life, potential post-mining use options for the final 156 ha mine void include:

(a) temporary water storage;

(b) landfill / backfill capacity, including additional overburden emplacement or metropolitan infrastructure projects; or

(c) potential recreation area consistent with adjacent State administered conservation and recreation areas.

A conceptual final landform design has been developed as detailed in Section 4.1.2 to guide the post mining land use planning process and assist in the development of rehabilitation objectives.

An assessment of historic rehabilitation at the site also identified several key constraints to establishing rehabilitation within the Project site, including:

- *Soil pH conditions*: The overall limited availability of topsoil material suitable for use in rehabilitation is exacerbated by elevated pH levels exhibited in the overburden materials used as growth medium layers to date. This has impeded the successful development of a growth medium layer that can support rehabilitation.
- *Steep slopes*: Although overburden emplacements have been designed to mimic adjacent natural steep slopes, landform steepness has contributed to rehabilitation establishment issues in some emplacements, leading to potential derivative impacts of erosion and downstream water quality impacts.
- *Climate*: Highly variable and irregular climatic conditions hinder rehabilitation development. Such conditions include hot summers, cold winters and periodic droughts. It is important to plan towards rehabilitation in the traditional windows of Spring and Autumn, but allow flexibility in long term rehabilitation planning to allow for drought periods.
- *Water supply*: Rehabilitation success has been impacted upon by water shortages following good initial germination. Irrigation trials have been set up previously, with mixed success.
- *Environment*: Local environmental factors resulting from mine location have impeded rehabilitation establishment. Such factors include browsing by herbivorous pests such as goats and rabbits, native macropod species, as well as weed competition.

For planning purposes, proposed rehabilitation areas within the Project site are grouped into primary and secondary rehabilitation domains, consisting of:

Primary Domains (operational land management units)

1. Infrastructure Area;
2. Waste Lime Storage / Emplacement Area;
3. Water Management Areas;
4. Overburden Emplacement Areas;
5. Stockpiled Material Area;
6. Open cut Mine void; and
7. Rehabilitation Areas.

Secondary Domains (rehabilitation management land units)

A – Native Woodland Areas
B – Trees over Grass – landform stability
C – Final Mine Void
D – Visual Screening
E – Water Management

F – Infrastructure

Rehabilitation objectives for each rehabilitation domain are outlined in **Table 15**, for each of the following rehabilitation phases:

1. Decommissioning;
2. Landform Establishment;
3. Growth Medium Development;
4. Ecosystem and Land Use Establishment
5. Ecosystem and Land Use Sustainability; and
6. Relinquishment.

Provisional completion criteria (developed from the 2018-2023 MOP) is also presented in **Table 16**.

Rehabilitation methodology was recommended for each of these rehabilitation domains, with native woodland being recommended as the predominant final vegetation cover, with 327 ha being rehabilitated to this community. Vegetation will also be established around the perimeter, and on the upper benches, of the final void primarily for visual screening purposes. The proposed SOBE was identified as potentially the highest erosion risk rehabilitation domain, due to the moderately steep slopes and proximity to sensitive receptors such as Bungonia Creek and adjacent publicly administered conservation areas.

The following rehabilitation objectives were recommended as applicable to all rehabilitation domains.

- Rehabilitated land will be geotechnically stable and will not present a greater safety hazard than surrounding land to land-users, public, livestock and native fauna accessing or transiting the post-mining area.
- Land capability will, at a minimum, be returned to a class similar to that existing prior to Project commencement (Class V, VII or VIII).
- Except for mine void, mined land will be visually compatible with the surrounding natural landscape.
- Rehabilitated landforms will be designed to shed water without causing excessive erosion or increasing downstream pollution.
- Rehabilitated landforms will not negatively impact visual amenity for nearby residents and users of conservation reserves.

These general objectives were supplemented by objectives specific to each rehabilitation domain, which will be used to derive detailed specific rehabilitation progress indicators and completion criteria, for inclusion in subsequent site Mining Operations Plans (MOP) / Rehabilitation Management Plans (RMP).

Subject to local constraints, topsoil resources identified in the soil assessment should be stripped and handled with care to minimise the expected deficit in topsoil material. Any alternative top-dressing material sourced to address this topsoil deficit should be characterised through geochemical assessment before being used in rehabilitation.

The proposed Southern Overburden Emplacement (SOBE) should be the priority for rehabilitation planning and resource allocation, including topsoil placement. Given the access and slope constraints, specialised techniques have been recommended to rehabilitate this emplacement.

A geotechnical investigation of the Eastern Batters identified that, while mass movement failure was not likely, management works will be required to manage the existing erosion gullies on these emplacements. A remedial management strategy for the existing Eastern Batters is subject to continuing discussions with state regulatory authorities.

With careful management, adequate land resources should be recoverable from within the proposed area of Project disturbance to successfully rehabilitate the final landform, meet the rehabilitation objectives and achieve the proposed final land use.

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1. Introduction

Boral Cement Limited (Boral) owns and operates the Marulan South Limestone Mine (the mine). It is a long standing, open cut mine that has extracted up to 3.38 million tonnes of limestone per year and produces limestone and lime based products for the cement, steel, agricultural, construction and commercial markets.

The mine is a strategically important asset for Boral, as it supplies the main ingredient for the manufacture of cement at Boral's Berrima Cement Works. This is also a strategically important operation for Sydney based consumers of these products as this represents around 60% of the cement sold in NSW and feeds into more than 30% of concrete sold in Sydney.

The mine operates under Consolidated Mining Lease No. 16 (CML 16), Mining Lease No. 1716, Environment Protection Licence (EPL) 944 and a combination of development consents issued by Goulburn Mulwaree Council and continuing use rights.

Due to changes between the Mining Act 1992 and the Environmental Planning & Assessment Act 1979 (EP&A Act), when mining moves beyond the area covered by the current Mining Operations Plan, a development consent under the EP&A Act will need to be in place.

An Environmental Impact Statement has been prepared by Element Environment Pty Ltd on behalf of Boral for submission to the Department of Planning and Environment to satisfy the provisions of Part 4 of the EP&A Act. Boral is seeking approval for continued operations at the site through a development application for a State Significant Development including a 30 year mine plan, associated overburden emplacement areas and a mine water supply dam (hereafter referred to as 'the Project').

A specialist soils and rehabilitation team was engaged by Boral to undertake a soils, land resources and rehabilitation assessment (SLRRA) of the Project site, as part of the Project EIS investigation team. The initial SLRRA was undertaken between November 2014 and July 2015.

Following further geological exploration and resource definition, a revised mining plan (Mine Plan 2) was finalised by Boral in late 2017. This SLRRA was subsequently revised in February 2018 to reflect proposed modifications to mining related disturbance and rehabilitation included in Mine Plan 2. The methods and findings of the revised SLRRA are presented in this report.

1.1. Objectives

The objectives of the SLRRA were to:

1. Investigate the quality of soils and land resources within the Project site, to allow further assessment of potential agricultural impact from Project related disturbance;
2. Identify topsoil, subsoil and other strata of potential value for use as vegetation growth media in the rehabilitation of mined land within the Project site; and
3. Identify suitable rehabilitation methodology for future operations at the mine, based on a consideration of;
    - existing rehabilitation planning documentation,
    - potential impacts related to Project disturbance,
    - available soil and land resources,
    - performance of previous rehabilitation trials and treatments,
    - regulatory requirements (as discussed in Section 1.2.3), and
    - operational considerations.

1.2. Assessment Scope and Relevant Guidelines

1.2.1. Project site

The mine is in Marulan South, 10 km southeast of Marulan village and 35 km east of Goulburn, within the Goulburn Mulwaree Local Government Area in the Southern Tablelands of NSW (**Figure 1**). Access is via Marulan South Road, which connects the mine and Boral's Peppertree Hard Rock Quarry (Peppertree Quarry) with the Hume Highway approximately 9 km to the northwest (**Figure 1**). Boral's private rail line connects the mine and Peppertree Quarry with the Main Southern Railway approximately 6 km to the north (**Figure 2**).

The assessment area covers an area of approximately 846.4 ha and consists of two main sections. The northern section of the assessment includes a proposed water supply dam for the Project on Marulan Creek, approximately 3km north of the existing mine. The Marulan Creek Dam disturbance footprint was determined by the likely maximum inundation level, and proposed surface disturbance area resulting from the construction of the dam, including the dam wall, spillway and construction access roads. Existing railway and pipeline corridors connect this northern section of the assessment area to the southern section. The southern section of the assessment includes the section of the Project site required for the open cut pit expansion, out of pit overburden emplacements, and construction or realignment of associated infrastructure.

1.2.2. Assessment Content

The SLRRA investigated existing soil and land resources within the Project site, and assessed significant ground disturbance and rehabilitation issues likely to result from proposed Project activities. Issue significance was determined through a risk assessment completed as part of the Project definition process, and as identified in the Secretary's Environmental Assessment Requirements (SEARs).

A *project definition and constraints analysis* process was completed during the planning stages of the EIS investigation to ensure the early identification, and adequate investigation, of potential Project risks and impacts. The SLRRA was designed to ensure the four key issues relating to soil, land and rehabilitation identified during this process, were adequately assessed. These issues included:

- Management of the outer slopes of the existing eastern batters including the Bryces and Barbers Creek overburden emplacements and the outer eastern slopes of the South Pit;
- Construction and rehabilitation of the proposed Southern Overburden Emplacement area;
- Identification of BSAL and obtaining a SVC; and
- A potential deficit of suitable topsoil material for proposed rehabilitation requirements.

The assessment of Project rehabilitation within the SLRRA considered the existing status of the mine. As a well-established operation with an approved Rehabilitation Strategy (GSSE, 2010), the mine has documented rehabilitation planning processes in place. The Rehabilitation Strategy outlines the:

- commitment to progressive rehabilitation;
- rehabilitation objectives, success criteria and monitoring methodology;
- proposed rehabilitation schedule and methodology;
- management strategies for overburden emplacements and the final void; and
- final mine closure strategy.

This SLRRA discusses these existing planning processes in the context of the Project's proposed rehabilitation activities as described in Section 4.

1.2.3. Secretary's Environmental Assessment Requirements

The SLRRA was also structured to ensure the requirements relating to Soils, Land and Rehabilitation in the SEARs were assessed. These requirements are presented in Table 1.

Table 1: EIS and stakeholder submission requirements relevant to the SLRRA.

Stakeholder	Environmental Requirement	Relevant SLRRA Report Section
Department of Planning and Environment (SEARs 7009, June 2015)	In addition, the EIS must include: • A full description of the development, including: g) a rehabilitation strategy, having regard to DRE's requirements;	1.5 4.1
	• A list of any approvals that must be obtained before the development may commence;	1.2.4
	• An assessment of the likely impacts of the development on the environment, focussing on the specific issues identified below, including: a) a description of the existing environment likely to be affected by the development, using sufficient baseline data;	2.2.2 2.1.1 – 2.1.5
	b) an assessment of the potential impacts of all stages of the development, including any cumulative impacts, taking into consideration relevant laws, environmental planning instruments, guidelines, policies, plans and industry codes of practice;	1.2.4 2.2.2 Appendix 3
	c) a description of the measures that would be implemented to mitigate and/or offset the potential impacts of the development, and an assessment of:	4.1 4.5 Appendix 5
	– whether these measures are consistent with industry best practice, and represent the full range of reasonable and feasible mitigation measures that could be implemented;	4.5
	– the likely effectiveness of these measures; and	4.5 5
	– whether contingency plans would be necessary to manage any residual risks;	4.4.1.1
	d) a description of the measures that would be implemented to monitor and report on the environmental performance of the development if it is approved;	4.4.1.2
	• An assessment of the likely impacts of the development on the soils, land capability, and landforms (topography) of the site;	2.2.2 3.2.1- 3.2.5
	• An assessment of the likely agricultural impacts of the development; and	3.2.6
	• An assessment of the compatibility of the development with other land uses in the vicinity of the development in accordance with the requirements in Clause 12 of State Environmental Planning Policy (Mining, Petroleum Production and Extractive Industries) 2007.	2.2.1 3.2.6 4.1.1 Appendix 2
NSW Department of Primary Industries (DPI) - Comment by Agriculture, NSW	The guideline *"Agriculture Issues for Extractive Industry Development"* provides further information on the issues and information to be included in an EIS for extractive industries	
	Rehabilitation of the site must be to a standard that minimises any long-term impacts on surrounding land uses and optimises sustainable future land use. Check that the proposal adequately:	Proposed post-mining land use is biodiversity, not agricultural.
	Describes (and justifies) the proposed final land form for the site and compatibility of the final site with surrounding land uses.	3.2.6 4.1.1 Appendix 2

Stakeholder	Environmental Requirement	Relevant SLRRA Report Section
	Demonstrates the proponent's capacity to rehabilitate disturbed lands and protect natural resources. Progressive rehabilitation is encouraged.	4.1 4.5
	Commits to preparing a rehabilitation plan that documents; • Design criteria, future landform and timelines for the rehabilitation program.	4.1 4.2 Appendix 3
	• The relative post operational area and location of pasture and/or biodiversity conservation areas (preferably including diagrams or maps).	4.2.1.1 Figure 8 Figure 12 Figure 13
	• Any final voids, water storages and unrehabilitated areas	4.2.1.1 Figure 8 Figure 12 Figure 13
	• Opportunities to encourage sustainable agricultural production on land under the control of the extractive company during and post extraction.	4.5.1.5
	• The standard of exclusion fencing, how long it will be required, maintenance schedules and proposals to remove when the site is stabilised.	N/A: biodiversity land use. Fencing not required.
	• Measures to maintain the viability of topsoil over time and to re-use this resource for site rehabilitation.	4.5.1.3 Appendix 5
	• Appropriate and enduring erosion control structures and practices.	Discussed in Project Surface Water Assessment (Advisian, 2018)
	• Proposed pasture types to be re-established (predominant species) and sowing methods.	Generally woodland revegetation, but seeding discussed in 4.5.1.4 and pasture seed mix presented in Appendix 6.
	• Weed management proposals in accordance with existing State, regional or local weed management plans or strategies.	Weed control requirements discussed 4.5.1.3, 4.5.1.4 & Appendix 5
	• Specific monitoring proposals and timeframes, and what actions will be taken to ensure that any necessary remedial actions identified by monitoring are completed in a timely and effective manner.	4.4.1.1 4.4.1.2
	• Who will be responsible for undertaking any further remediation after operations cease or the operations go into care and maintenance mode, and for further consultation with adjoining landowners.	4.1.1 4.5.1.5
NSW Department of Primary Industries (DPI)- Comment by NSW Office of Water	• Details surrounding the final landform of the site, including final void management (where relevant) and rehabilitation measures.	4.1.2
NSW Department of Primary Industries (DPI)- Comment by Crown Lands	Generally, NSW Trade & Investment Crown Lands would like reiterate the importance of the long term maintenance of the natural resources (water, soil, flora, fauna and scenic quality) of the Crown land adjoining the proposed boundary of disturbance identified in the PEA. Further, it is also considered paramount that the disturbed areas of Crown land, namely the Reserves	Section 4

Stakeholder	Environmental Requirement	Relevant SLRRA Report Section
	listed above are progressively rehabilitated using leading practise mine reclamation techniques throughout the life of the mine that results in a stable post-mining landscape.	
Department of Resources and Energy (DRE)	Impacts associated with the operational and post closure stages of the project must also be identified in detail and control management strategies outlined. The identification and description of impacts must draw out those aspects of the site that may present barriers or limitations to effective rehabilitation and which may limit the mine closure potential of the land. The following are the key issues to be addressed in the EIS that are likely to have a bearing on rehabilitation and mine closure: • An evaluation of current rehabilitation techniques and performance against existing rehabilitation objectives and completion criteria;	2.2.2 4.1.3.3 Appendix 4
	• An assessment and life of mine management strategy of the potential for geochemical constraints to rehabilitation (e.g. acid rock drainage, spontaneous combustion etc.), particularly associated with the management of overburden/interburden and reject material. Based on this assessment, the EIS is to document the processes that will be implemented throughout the mine life to identify and appropriately manage geochemical risks that may affect the ability to achieve sustainable rehabilitation outcomes;	2.1.3 3.2.4.2 4.5.1.2 (final void) 4.5.1.3
	• A life of mine tailings management strategy, which details measures to be implemented to avoid the exposure of tailings material that may cause environmental risk, as well as promote geotechnical stability of the rehabilitated landform;	N/A (no tailings generated in Project)
	• Existing and surrounding landforms (showing contours and slopes) and how similar characteristics can be incorporated into the post-mining final landform design. This should include an evaluation of how the key geomorphological characteristics evident in stable landforms within the natural landscape can be adapted to the materials and other constraints associated with the site;	2.1.4 4.1.2 4.5.1.2
	• Where a void is proposed to remain as part of the final landform, the assessment is to provide details in regards to the following: 1. a constraints and opportunities analysis of final void options, including backfilling, to justify that the proposed design is the most feasible and environmentally sustainable option to minimise the sterilisation of land post mining;	4.1.2 4.5.1.2
	To carry out the assessment of the impact of mining the proponent must: • Assess the biological resources associated with the proposed disturbance area and how they can be practically salvaged for utilisation in rehabilitation (i.e. topsoil, seed banks, tree hollows and logs, native seed etc.). This should include an evaluation of how topsoil/subsoil of suitable quality can be direct-returned for use in rehabilitation	3.2.4 4.5.1.4 Appendix 5
	• Carry out an evaluation of current land capability class and associated condition	3.1.4 3.2.5
	• Characterise soils across the proposed area of surface disturbance and assess their value and identify opportunities and constraints for use in rehabilitation	3.2.3
	Where an ecological land use is proposed, the EIS should demonstrate that the revegetation strategy (e.g. seed mix, habitat features, corridor width etc.) has been developed in consideration of the target vegetation community(s).	4.1.1 4.5.1.4 4.5.1.5 Appendix 6

Stakeholder	Environmental Requirement	Relevant SLRRA Report Section
	The EIS is to include a detailed description of the scope of decommissioning and rehabilitation activities required to meet the nominated closure objectives and completion criteria for each domain. The scope of these activities must be developed in consideration of the existing environment, identification of impacts and constraints as listed above.	4.1 4.5.1.1
	Each of the following aspects of rehabilitation planning should be addressed in the strategy: **Post Mining Land Use** The proponent must identify and assess post mining land use options and provide a statement of the preferred post mining land use outcome in the EIS. This should include a discussion of how the final land use(s) are aligned with relevant local and regional strategic land use objectives. In addition, the benefits of the post mining land to the surrounding environment, a subsequent landowner, the local community and the state of NSW.	4.1.1
	In addition, the proponent must identify how the rehabilitation of the project will integrate with the rehabilitation strategies of neighbouring mines within the region. On a local scale this should include the project and adjacent mines, with a particular emphasis on the coordination of rehabilitation activities along common boundary areas.	4.1.1
	Rehabilitation Objectives and Domains A set of project rehabilitation objectives and completion criteria must be included that clearly define the environmental outcomes required to achieve the final land use for each domain. The completion criteria must be specific, measurable, achievable, realistic and time-bound. If necessary, objective criteria may be presented as ranges rather than finite indicator levels. Subjective criteria may also apply where a gap in technical knowledge is experienced. Further refinement of these criteria will be undertaken and included in the Rehabilitation Management Plan (RMP).	4.2.1 Tables 13 - 16 Figure 8 Figure 9
	Rehabilitation Methodology Provide details regarding the rehabilitation methods for disturbed areas and expected time frames for each stage of the rehabilitation process. Provide details on proposed rehabilitation monitoring and an outline of proposed rehabilitation research programs and trials.	4.1 4.1.3.3 4.5.1.1 – 4.5.1.5 4.4.1.1 4.4.1.2 Appendix 4
	Conceptual Final Landform Design A drawing at an appropriate scale with final landform contours should be provided. This drawing should identify the following attributes of the final landform: vegetation types; habitat features; contaminated areas; final voids; drainage infrastructure; access and internal roads; fencing design; and other remaining infrastructure such as sheds, dams, bores and pipelines.	4.1.2 Figure 12 Figure 13
	Monitoring and Research Outline the proposed monitoring programs that will be implemented to assess how rehabilitation is trending towards the nominated land use objectives and completion criteria. This should include details of the process for triggering intervention and adaptive management measures to address potential adverse results as well as continuously improve rehabilitation practices.	4.4.1.1 4.4.1.2

Stakeholder	Environmental Requirement	Relevant SLRRA Report Section
	In addition, an outline of proposed rehabilitation research programs and trials, including objectives, are to be included in the EIS. This should include details of how the outcomes of research are considered as part of the ongoing review and improvement of rehabilitation practices.	4.1.3.3
	Post-closure maintenance Describe how post-rehabilitation areas will be actively managed and maintained in accordance with the intended land use(s) in order to demonstrate progress towards meeting the closure objectives and completion criteria in a timely manner.	4.4.1.1 4.5.1.5
	Justification must be supported by the information provided by the proponent, including, but not limited to: • Description of the proposed mining operation (e.g. mining methods, layout and sequences);	1.5 Appendix 3
	• General and relevant site conditions including depths of cover, geological, hydrogeological, hydrological, geotechnical, topographic and climatic conditions; and	2.1.1 – 2.1.5
	• Identification and general characteristics of any previously excavated or abandoned workings that may interact with the proposed or existing mine workings.	1.4.1
Environment Protection Authority (EPA)	• Outline considerations of site maintenance, and proposed plans for the final condition of the site (ensuring its suitability for future uses).	4.1.1 4.1.2 4.5.1.1 – 4.5.1.5
	• Provide an overview of the affected environment to place the proposal in its local and regional environmental context including: e) Soil types and properties (including erodibility; engineering and structural properties; dispersibility; permeability; presence of acid sulfate soils and potential acid sulfate soils);	2.1.1– 2.1.5 3.2
	Describe management and mitigation measures • Describe and assess the effectiveness or adequacy of any soil management and mitigation measures during construction and operation of the proposal including: a) erosion and sediment control measures	4.5.1.3 Appendix 5 Detailed erosion and sediment control measures presented in Project Surface Water Assessment (Advisian, 2018)
Water NSW	Provide concept plans / protocols / procedures for the following: • Post-quarrying rehabilitation Plan.	Section 4

1.2.4. Relevant Guidelines

Amendments to the 2013 Mining State Environmental Planning Policy (SEPP) in 2013 introduced a *Gateway process* for new mining and petroleum project development applications, to protect high value agricultural land. Under this process, state significant mining developments that require a new mining lease are required to assess the soils and landform within the Project site to determine the presence of BSAL. As the Project will require a mine lease application, a BSAL assessment was completed in accordance with the requirements of the *Interim Protocol for Site Verification and Mapping of Biophysical Strategic Agricultural Land* (NSW Government, April 2013) (Interim Protocol).

The SLRRA has assessed land capability for the Project site in accordance with the classification guidelines presented in *The Land and Soil Capability Assessment Scheme: Second approximation. A general rural land evaluation system for New South Wales* (OEH, October 2012). Agricultural suitability class was not determined for the Project site as part of the SLRRA as minimal areas of the proposed Project disturbance area is currently being used for agricultural production and the proposed post-mining land use for the Project disturbance footprint is native woodland vegetation.

Guidelines used to complete soil classification and mapping, and topsoil identification, are identified in Section 3.1 *Assessment Methodology*. Rehabilitation planning is discussed in Section 4.1 with reference to *ESG3: Mining Operations Plan (MOP) Guidelines* (NSW Trade and Investment, September 2013) (ESG3). The mine currently operates under a MOP, which describes proposed operational disturbance and rehabilitation measures. Following approval of this development application, a new MOP (consistent with the Project EIS) will need to be approved.

1.3. Assessment Team

The specialist investigation team assembled to complete the SLRRA and their particular areas of input consisted of:

- *Erosion and soils* – Assoc. Professor Greg Hancock, Associate Professor of Earth Sciences, The University of Newcastle;
- *Rehabilitation* - Dr Mark Burns, Director, Global Soil Systems Pty Ltd;
- *BSAL Assessment* - Dr David McKenzie, Certified Practicing Soil Scientist, SoilMgt Pty Ltd;
- *Rehabilitation /soils fieldwork* - Lachlan Crawford, Director, LAMAC Management Pty Ltd; and
- *Project Management* – Craig Bagnall, Snr Environmental Engineer, Niche Environment and Heritage.

1.4. Project Background

1.4.1. Operational History

Limestone mining within the vicinity of the Project site commenced in 1869, with major expansion in the 1920s supplying limestone to regional cement manufacturing and steel making industries. By 1953, two main limestone mines were established on the current mine site, and by the early 1970s limestone was being extracted and processed for cement, steel making, agriculture, glass making, lime manufacturing, quicklime and hydrated lime.

In 1974, the parent companies of the two established limestone mines, *Blue Circle* and *BHP,* agreed to merge their operations to form Blue Circle Southern Cement (BCSC). In 1987, Boral Ltd purchased BCSC and continues to retain ownership of the company as a wholly owned subsidiary. As at 1st August 2010, BCSC changed the company name to Boral Cement Limited.

1.4.2. Existing Operations

The mine is sited on a high grade limestone resource. Subject to market demand the mine has typically produced 3 to 3.38 million tonnes of limestone and 120,000 to 200,000 tonnes of shale per annum.

The mine currently produces a range of limestone products for internal and external customers in the Southern Highlands / Tablelands, the Illawarra and Metropolitan Sydney markets for use primarily in cement and lime manufacture, steel making, agriculture and other commercial uses. Products produced at the mine are despatched by road and rail, with the majority despatched by rail.

Historically limestone mining was focused on the approximately 200-300 m wide Eastern Limestone and was split between a North Pit and a South Pit. A limestone wall (referred to by the mine as the 'centre ridge') rising almost to the original land surface, divided the two pits. The North and South Pits were recently joined in 2016 / 2017 by mining the centre ridge to form a single contiguous pit, approximately 2 km in length. However, the North Pit / South Pit nomenclature remains important as current mining operation locations continue to be reported with respect to one or other of the old pits.

Limestone and shale are extracted using open-cut hard rock drill and blast techniques. Material is loaded using front end loaders and hauled either to stockpiles or the processing plant using haul trucks. Oversized material is stockpiled and reduced in size using a hydraulic hammer attached to an excavator.

Limestone processing facilities including primary and secondary crushing, screening, conveying and stockpiling plant and equipment are in the northern end of the North Pit. Kiln stone grade limestone is also processed on site through the existing lime plant comprising kiln stone stockpiles, rotary lime kiln, hydration plant and associated auxiliary conveying, processing, storage, despatch plant and equipment. Overburden from stripping operations is emplaced in the Western Overburden Emplacement, west of the open cut pits.

The current operations are 24 hour, 7 days per week with personnel employed on a series of 8, 10 and 12 hour shifts to cover the different operational aspects of the mine. Blasting is restricted to daylight hours and on weekdays, excluding public holidays.

1.5. Proposed Project

1.5.1. Mining Operations

Boral proposes to continue mining limestone from the mine at a rate of up to 4 million tonnes per annum (mtpa) for a period of up to 30 years. This represents an increase in extraction rate from historic levels (peak of 3.38 mtpa) due to forecast increased demand from the construction industry. Shale will continue to be extracted at a rate of up to 200,000 tonnes per annum (tpa).

The proposed 30 year mine plan accesses approximately 120 million tonnes of limestone down to a depth of 335 m AHD. The mine footprint focuses on an expansion of the North Pit westwards to mine the Middle Limestone and to mine deeper into the Eastern Limestone. As the Middle Limestone lies approximately 70 m to 150 m west of the Eastern Limestone, the 30 year mine plan avoids mining where practical the interburden between these two limestone units thereby creating a smaller second, north-south oriented West Pit with a ridge remaining between. The North Pit will also be expanded southwards, encompassing part of the South Pit, leaving the remainder of the South Pit for overburden emplacement and a visual barrier (**Figure 3**).

In addition to mining approximately 5 million tonnes of shale, the extraction of the limestone requires the removal of approximately 108 million tonnes of overburden over the 30 year period. This material will be emplaced within existing and proposed overburden emplacement areas (**Figure 3**).

Limestone will continue to be mined using drilling and blasting methods. Shale will continue to be mined by excavator / front end loader. Limestone, shale and overburden will be transported to the primary crusher, stockpile areas and overburden emplacements respectively, using the load and haul fleet of trucks.

Products produced at the mine will continue to be despatched by road and rail, with the majority despatched by rail.

The limestone sand plant, produces a crushed and air classified limestone sand for use in concrete. The mine currently produces 500,000 tpa for Peppertree Quarry and propose to increase production of manufactured sand to approximately 1 million tpa.

Boral's adjoining Peppertree Quarry currently has approval to emplace some of its overburden in the South Pit mine void. As the South Pit is required for the emplacement of over 30 million tonnes of overburden from the mine after the removal of accessible limestone, Boral proposes to emplace up to 15 million tonnes of overburden from Peppertree Quarry within the Northern Overburden Emplacement (**Figure 3**).

1.5.2. Associated Infrastructure

1.5.2.1. Processing

The existing facilities for processing limestone will continue to be utilised to produce a series of graded and blended limestone products that are despatched from site for use primarily in cement manufacture, steel making, commercial and agricultural applications.

Limestone processing facilities (**Figure 3**) include primary and secondary crushing, screening, conveying and stockpiling plant and equipment located north-west of the North Pit and extending to the tertiary crushing, screening, bin storage and despatch (rail and road) systems that form part of the main processing facilities.

Kiln stone grade limestone will also continue to be processed on site through the existing lime plant comprising kiln stone stockpiles, rotary lime kiln, hydration plant and associated auxiliary conveying, processing, storage, despatch plant and equipment.

Processing infrastructure and the reclaim and stockpile area at the northern end of the North Pit will be relocated during the life of the 30 year pit to enable full development of the mine plan. The timing and location of this is presented in the EIS.

Shale and white clay will not be processed and will be stockpiled directly from the pit, ready for dispatch by road to the Berrima and Maldon cement operations.

1.5.2.2. Water Supply

Water supply for the Project, including dust suppression, processing activities and some non-potable amenities will be from existing and new on-site dams and a proposed new water supply dam on Marulan Creek (**Figures 2** and **4**). This dam would be located on Boral owned land north of Peppertree Quarry and utilises Boral's adjoining Tallong water pipeline to transfer water to the mine. This dam would require the purchase of water entitlements.

Mine water demand will also be supplemented by Tallong Weir via the Tallong water pipeline.

1.5.2.3. Rail

No changes are proposed to the existing rail infrastructure. A 1.2 km long passing line was constructed at Medway Junction during construction of the Peppertree Quarry, which will also be used by the mine to enhance access to the Main Southern Railway.

1.5.2.4. Road

Road access from the mine to the Hume Highway is via Marulan South Road. The proposed Western Overburden Emplacement (WOBE) extends northwards over Marulan South Road. Boral propose to realign a section of Marulan South Road, to accommodate the northern portion of the proposed WOBE (**Figure 3**).

All public roads within the former village of Marulan South as well as the section of Marulan South Road between Boral's operations and the entrance to the agricultural lime manufacturing facility will be de-proclaimed.

1.5.2.5. Power

Power supply to the mine is via a high voltage power line that commences at a sub-station on the southern side of Marulan South Road, immediately west of the Project boundary. A section of this power line will be relocated to accommodate the proposed Northern Overburden Emplacement (NOBE) (**Figure 3**).

1.5.3. Transport

The majority of limestone products will continue to be transported to customers by rail for cement, steel, commercial and agricultural uses. Boral seeks no limitation on the volume of products transported by rail.

Manufactured sand will continue to be transported by truck along a dedicated internal road, across Marulan South Road and into Peppertree Quarry for blending and dispatch by rail.

Agricultural lime, quick lime and fine limestone products will continue to be transported by powder tanker, bulk bags on trucks or open tipper trucks along Marulan South Road.

Shale, limestone aggregates, sand and tertiary crushed products will be transported by predominantly truck and dog along Marulan South Road.

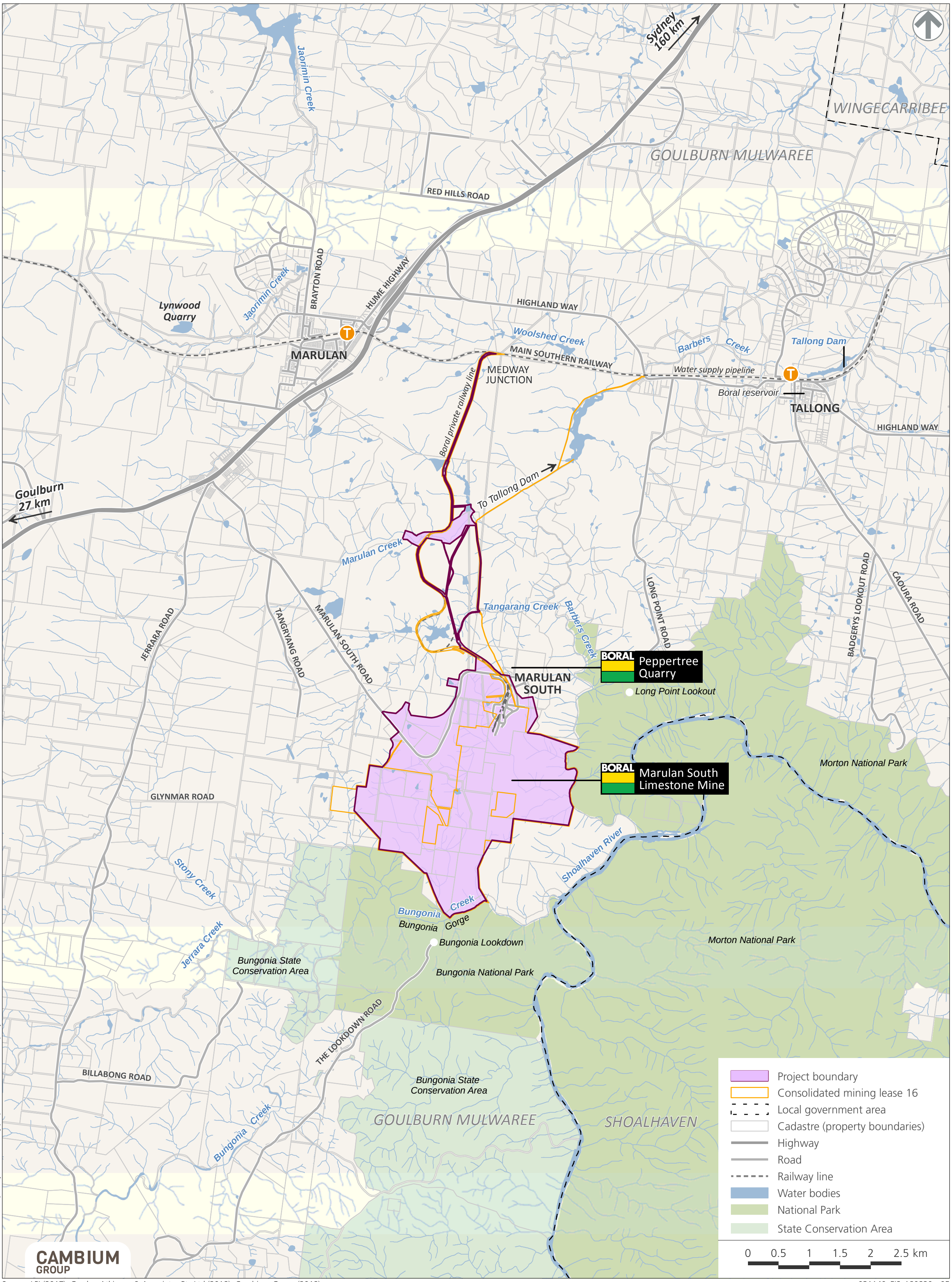
The adjoining Peppertree Quarry is currently approved to transport all products by rail. Boral will seek to transport approximately 150,000 tpa of Peppertree Quarry's products from the mine to customers via Marulan South Road. This could be achieved by back loading to a new shared road sales product stockpile area by the trucks carrying the limestone sand to Peppertree Quarry. A new shared road sales product stockpile area is proposed on the northern side of Marulan South Road, immediately west of the mine and Peppertree Quarry entrances (**Figure 3**). This shared finished product stockpile area, includes a weighbridge and wheel wash and will service both the mine and Peppertree Quarry.

In total, Boral is seeking to transport up to 600,000 tpa of limestone and hard rock products along Marulan South Road to the Hume Highway, as well as 120,000 tpa of limestone products to the agricultural lime manufacturing facility.

Figure 1

Regional context

MARULAN SOUTH LIMESTONE MINE CONTINUED OPERATIONS - SSD APPLICATION
ENVIRONMENTAL IMPACT STATEMENT



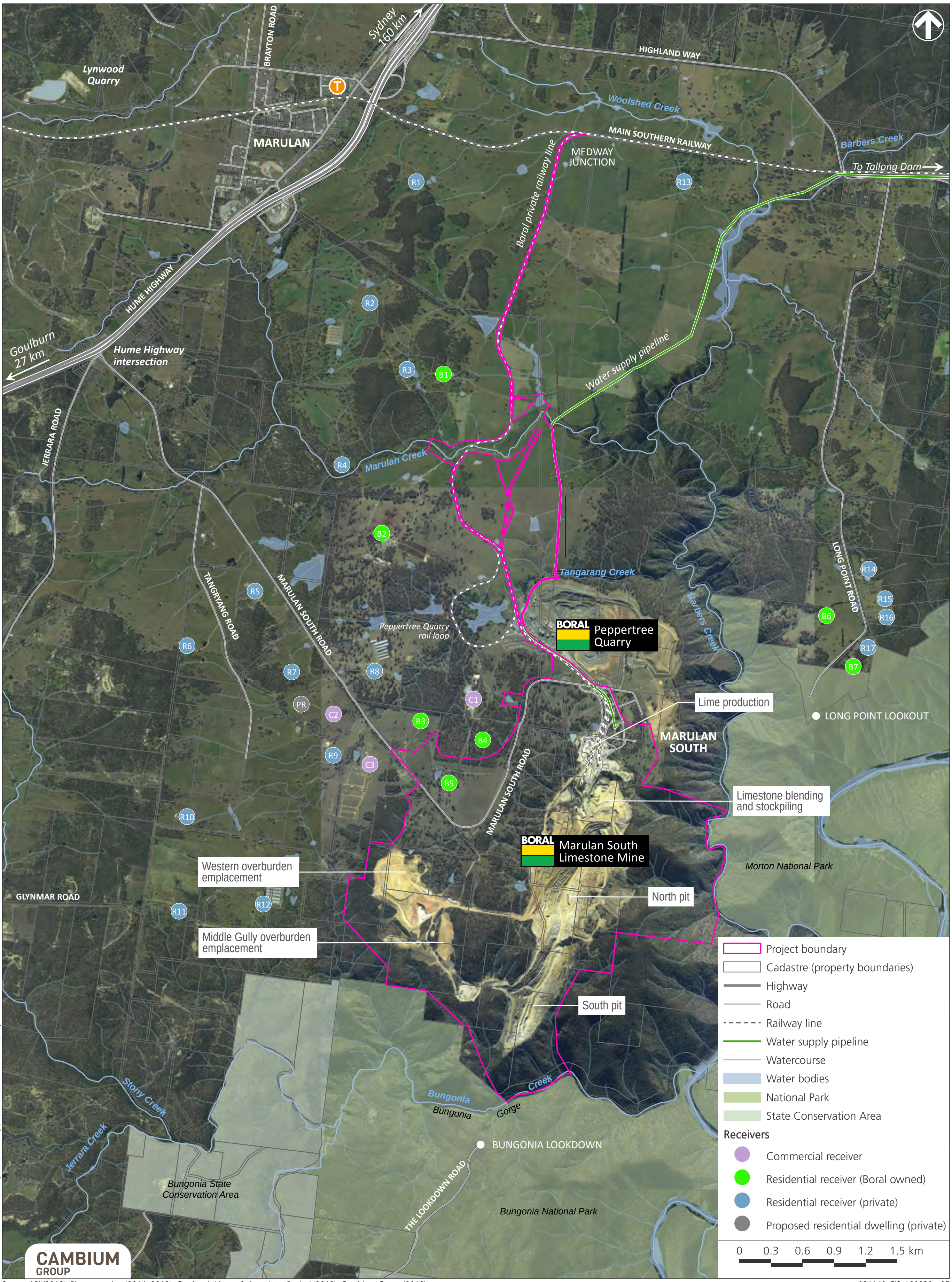
Source: LPI (2017), Gordon Atkinson & Associates Pty Ltd (2018), Cambium Group (2018).

031140_EIS_180820_v05

Figure 2

Local context

MARULAN SOUTH LIMESTONE MINE CONTINUED OPERATIONS - SSD APPLICATION
ENVIRONMENTAL IMPACT STATEMENT



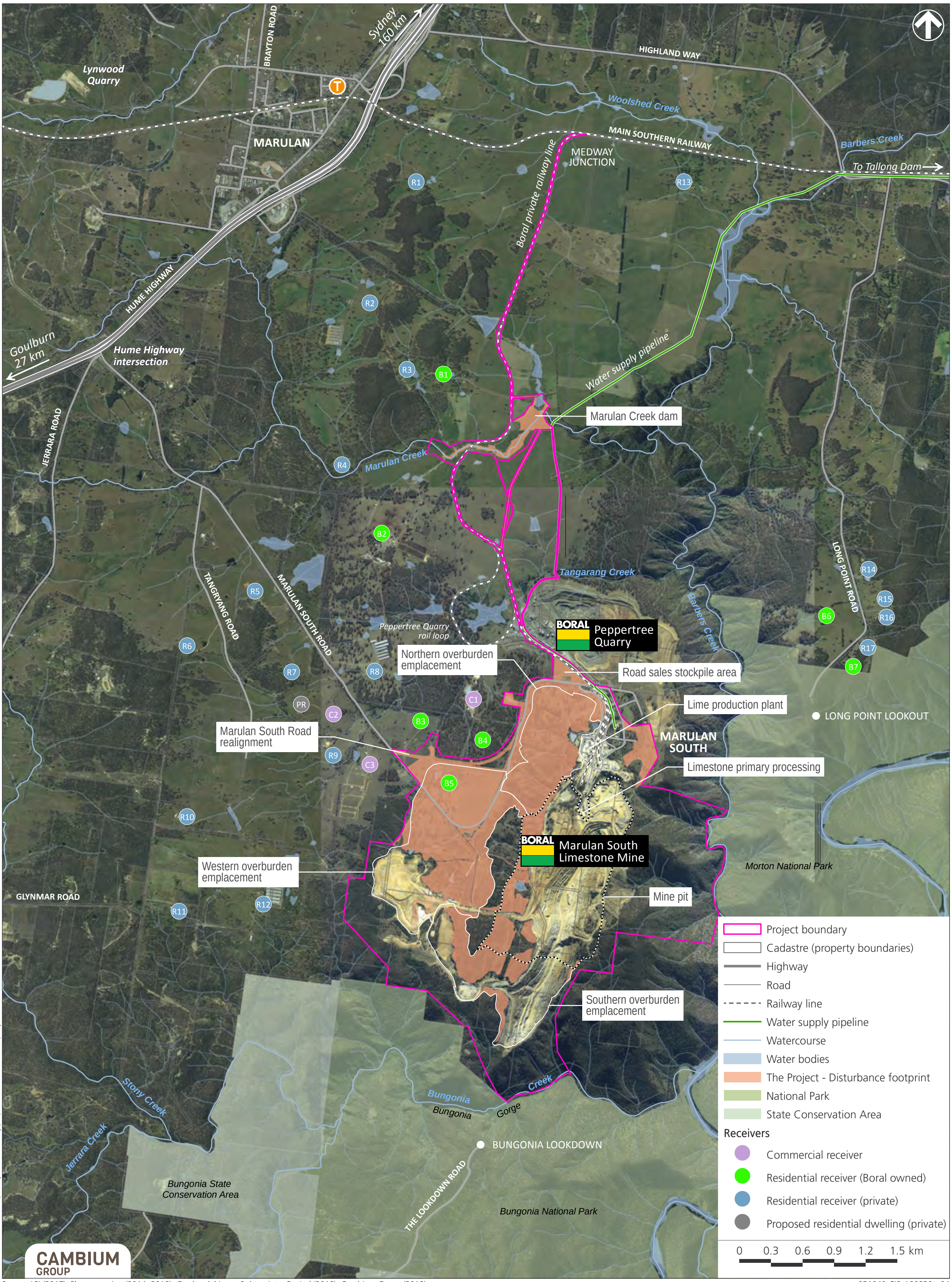
Source: LPI (2018), Photomapping (2014, 2018), Gordon Atkinson & Associates Pty Ltd (2018), Cambium Group (2018).

031140_EIS_180830_v05

Figure 3

The Project - Disturbance footprint

MARULAN SOUTH LIMESTONE MINE CONTINUED OPERATIONS - SSD APPLICATION
ENVIRONMENTAL IMPACT STATEMENT



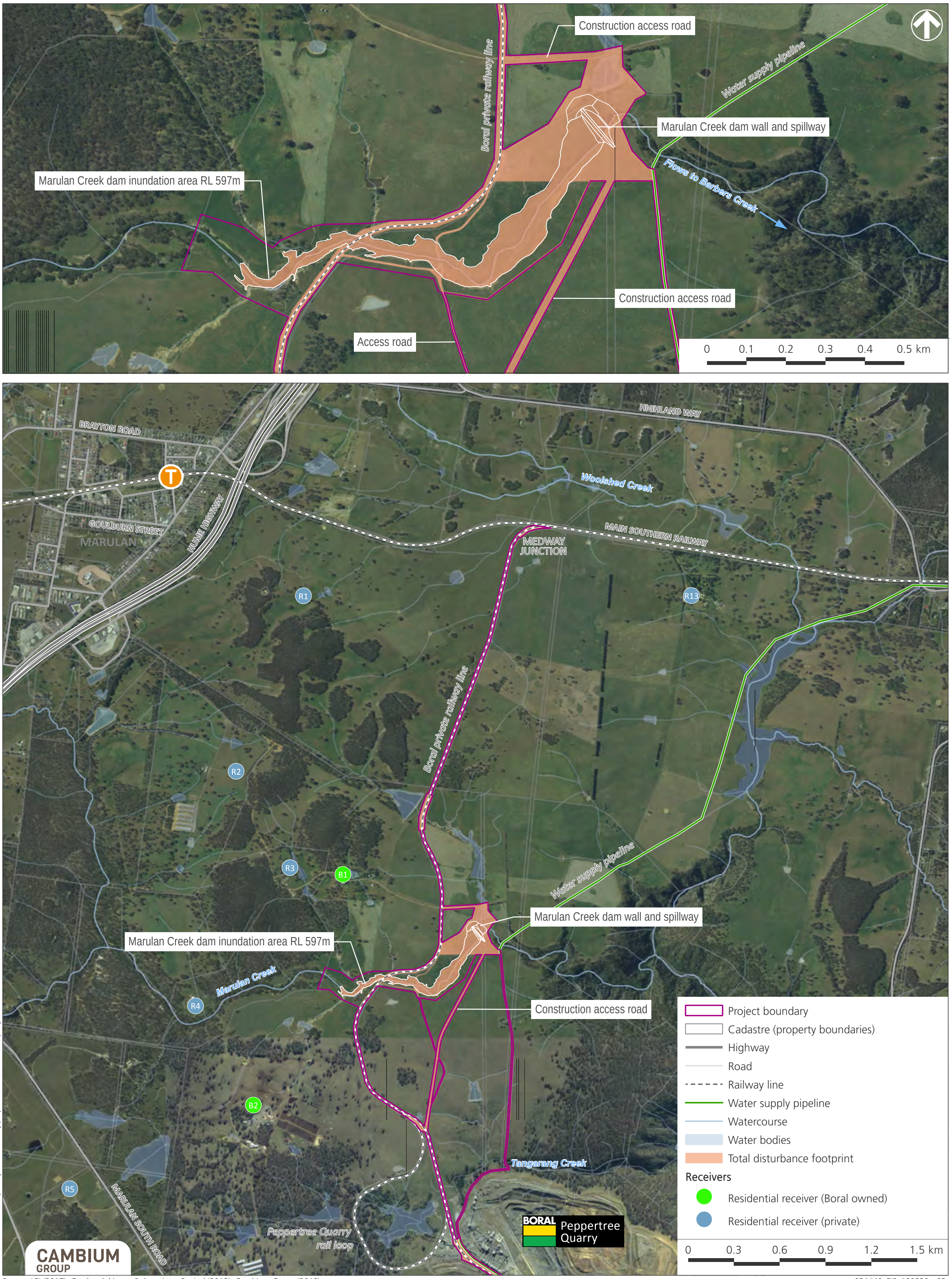
Source: LPI (2017), Photomapping (2014, 2018), Gordon Atkinson & Associates Pty Ltd (2018), Cambium Group (2018).

031040_EIS_180830_v04

Figure 4

Marulan Creek Dam - Disturbance footprint

MARULAN SOUTH LIMESTONE MINE CONTINUED OPERATIONS - SSD APPLICATION
ENVIRONMENTAL IMPACT STATEMENT



Source: LPI (2017), Gordon Atkinson & Associates Pty Ltd (2018), Cambium Group (2018).

031140_EIS_180830_v03

2. Existing Environment

2.1.1. Climate

The mine is in Australia's cool temperate climatic region, which is characterised by mild to warm summers and cold winters, with common frost and occasional snow fall.

Long term climatic data was obtained from the Bureau of Meteorology (BoM) automatic weather station at Goulburn Airport, approximately 25 km west-southwest of the mine.

The BoM weather station shows that January is the hottest month with a mean maximum temperature of 27.9 degrees Celsius (ºC) and July is the coldest month with a mean minimum temperature of 0.3ºC.

Average annual rainfall is 551.9 mm. Rainfall peaks during the summer and the month of June. June is the wettest month with an average rainfall of 60.9 mm over 7.0 days and April is the driest month with an average rainfall of 25.6 mm over 4.0 days.

Relative humidity levels exhibit variability and seasonal flux across the year. Mean 9am relative humidity levels range from 65% in October and December to 88% in June. Mean 3pm relative humidity levels vary from 39% in December to 63% in June. Wind direction is predominantly from the west in winter and from the east in summer.

Wind speeds have a generally similar spread between the 9am and 3pm conditions. The mean 9am wind speeds range from 12.2 km/h in March to 19.8km/h in September. The mean 3pm wind speeds vary from 19.8km/h in April to 26.5km/h in August.

2.1.2. Geology

The Marulan South limestone deposit lies within the Lachlan Geosynclinal Province. During the Palaeozoic Era (500 to 300 million years ago) thick sedimentary formations were laid down in the region. The formations included sediments, volcanic lavas and ash, and limestone reefs.

A reef complex formed the Bungonia Limestone Group, which was later folded and faulted by crustal collisions and then subsequently levelled by substantial erosion. About 65 million years ago the area was again uplifted giving way to a rejuvenated river system leading to the landscape of today.

The Bungonia Limestone formations at Marulan South consist of a number of generally parallel and north-south striking beds dipping to the west. The Bungonia Limestone includes:

- Eastern Limestone, which is the oldest, easternmost and thickest unit; and
- Mt. Frome Limestone, which is the younger unit that lies to the west of the Eastern Limestone and is made up of three sub-parallel sub-units including the Upper Limestone (furthest west), Middle Limestone and Lower Limestone (furthest east).

Separating the limestone units are fine grained sediments including shales, mudstones, siltstones and minor fine sandstones.

The total horizontal width of the Bungonia Limestone is approximately 670m east-west. The true depth of the Bungonia Limestone is not known as the termination of the limestone is not visible either in the mine or at the bottom of the Bungonia gorge to the south. To date even the deepest drill holes (approximately 300 m) in the mine have ended in limestone.

The Eastern Limestone has the highest grade and was therefore selected for the commencement of mining. The Eastern Limestone is still the focus of current mining operations, however mining of Mt. Frome Middle Limestone commenced in approximately 2016.

The Bungonia Limestone Group is bound to the east by the older Tallong shale beds and in the west by the Tangarang Volcanics (younger shales, volcanic and associated sedimentary rocks). A north-south and various east-west dolerite dykes penetrate the limestone from beneath and the limestone bed is cut off in the north by the Glenrock Granodiorite intrusion, which is extracted by Peppertree Quarry.

2.1.3. Geochemistry

A geochemical assessment of the open cut geological strata likely to be mined (limestone) or emplaced as overburden was undertaken (RGS, 2015). This assessment indicated that both limestone and these potential overburden materials are essentially barren of sulphur, have a high factor of safety with respect to potential acid generation, and can be classified as non-acid forming (NAF).

Potential overburden strata contained relatively low concentration of metals / metalloids in solids. While arsenic, cobalt and manganese concentrations were elevated (compared to average crustal abundance) in some of the contact material between limestone and shales, these elements are sparingly soluble in contact water, and are unlikely to impact upon surface and groundwater quality.

The geochemical assessment concluded that surface runoff and seepage from emplaced overburden materials is also likely to be slightly alkaline and contain low concentrations of dissolved salts.

Erosion potential of likely overburden material was also assessed as part of the SLRRA, with laboratory testing being undertaken for four composite weathered geological samples. Laboratory tests included calculation of K-factor, Emerson Aggregate Test (EAT), and dispersion percentage (D%). Erosion potential was assessed as being low to moderate, with one sample (Sample Point 5) collected from transitional weathered clay material in the east of the pit, indicating high erosion potential. Laboratory results for erosion potential testing of geological strata are included in **Appendix 1**.

2.1.4. Topography and Hydrology

The Southern Highlands, similar to the Blue Mountains to the north-west, are predominantly comprised of a level plateau with the occasional high intrusive volcanic remnant mountains, such as Mount Jellore, Mount Gibraltar and Mount Gingenbullen. On the seaward side they decline into a steep escarpment that is heavily divided by the headwaters of the Shoalhaven River.

The Project site and surrounds is characterised by the rolling hills of pasture and grazing lands interspersed with woodland to the west, contrasting with the heavily wooded, deep gorges that begin abruptly to the east of the mine, forming part of the Great Escarpment and catchment of the Shoalhaven River. As such, local relief of Marulan South ranges from around 130 m Australian Height Datum (AHD) to over 630 m AHD.

The Project site is drained by a number of minor ephemeral drainage lines into Barbers Creek to the east and Bungonia Creek to the south. These creeks are tributaries of the Shoalhaven River, which is 1.5 km from the mine (at its closest point) and flows eastwards into Lake Yarrunga, approximately 20 km downstream and enters the Pacific Ocean approximately 15 km east of Nowra (approximately 100 km downstream).

2.1.5. Vegetation

A biodiversity assessment conducted as part of the Project EIS studies identified the following vegetation communities within the study area (Niche, 2018):

- Blakely's Red Gum - Yellow Box - Grassy open woodland (SR670);
  - condition a – woodland
  - condition b – occasional eucalypts with moderate to low diversity
  - condition c – generally lack of eucalypts with low diversity
- Coast Grey Box - stringybark dry woodland (SR534);
- Silvertop Ash - Blue-leaved Stringybark shrubby open forest on ridges (SR624); and
- Exotic pasture.

The key vegetation communities relevant to rehabilitation planning are the *Blakely's Red Gum – Yellow – Box Grassy open woodland* variants and the *Stringybark - Blakely's Red Gum shrubby open forest*. These two communities will be used as indicative reference communities for revegetation of the level to moderately sloping rehabilitation areas and steeply sloping rehabilitation areas, respectively.

2.2. Land Use

2.2.1. Existing Land Use and Ownership

CML 16 (which encompasses ML 1716) covers an area of 616.5 hectares (ha), which includes land owned by Boral (approximately 475 ha), Crown Land (adjoining to the south and east) and five privately owned titles (**Figure 2**). There is also Boral owned land surrounding the mine that does not fall within CML 16.

Land use surrounding the mine is a mixture of extractive industry, grazing, rural residential, commercial / industrial and conservation.

The mine is separated from the Bungonia State Conservation Area to the south by Bungonia Creek and is separated from the Shoalhaven River and Morton National Park to the east by Barbers Creek.

Peppertree Quarry, owned by Boral Resources (NSW) Pty Limited, borders the mine to the north. The site of the former village of Marulan South is between the mine and Peppertree Quarry on land owned by Boral. The village was established principally to service the mine but has been uninhabited since the late 1990's. The majority of the village's infrastructure has been removed and only a village hall and former bowling club remains. The bowling club has been converted into administration offices for the mine and the hall is used by the mine services team.

A small number of rural landholdings surround the Boral properties to the north and west, including an agricultural lime manufacturing facility, fireworks storage facility, turkey farm and rural residential (a number of these properties are actively grazed). The main access for these properties is via Marulan South Road. Rural residential properties are also located to the northeast of the mine along Long Point Road. These properties are separated from the mine by the deep Barbers Creek gorge. Sensitive receivers are shown in **Figure 2**.

2.2.2. Proposed Disturbance

Within the northern section of the Project assessment area, 18.4 ha is already disturbed, with a further 13.3 ha predicted to be impacted by Project development. Proposed disturbance includes area of inundation (at maximum dam capacity as defined by the RL597m contour), retained infrastructure (water pipeline, dam wall, spillway, and access road) and temporary disturbance related to dam construction.

Within the southern section of the Project assessment area, approximately 323.1 ha is already disturbed (53.5 ha of which has been revegetated) and an additional 243.3 ha is predicted to be significantly impacted by Project development. The remaining 248.4 ha of land within the assessment area not proposed for disturbance will continue to be used as conservation / buffer land during Project development.

3. Soil and Land Resources Identification and Mapping

Soil and land resources within the Project site were assessed as part of the SLRRA, to determine existing agricultural value, and to identify resources suitable for recovery and re-use in post-mining rehabilitation.

3.1. Assessment Methodology

The soil and land resources assessment was completed for all land within the Project site boundary. The assessment followed the methodology presented in Part 5 of *Guidelines for Surveying Soil and Land Resources* (McKenzie *et al*. 2008) and, for the BSAL assessment area, was completed in accordance with the requirements of the Interim Protocol.

Soil and landscape attributes were characterised using the terminology described in the *Australian Soil and Land Survey Field Handbook* (National Committee on Soil and Terrain 2009) (field handbook), and soil profiles were classified according to the *Australian Soil Classification* (Isbell 2002) (ASC).

Soil resources across the Project site were identified, assessed and mapped as part of the SLRRA. Soils were mapped as soil landscape units, which group related soils types in association with particular landscape features.

The assessment consisted of two main components; the preliminary assessment, and the field assessment.

3.1.1. Preliminary Assessment

Before commencing the field assessment, a preliminary assessment was undertaken to produce a preliminary soil and landscape map. This assessment referenced the following sources of information.

- Surface Geology Mapping (online Atlas of NSW, NSW Land & Property Information);
- Regional BSAL mapping (NSW Government 2014);
- Land and Soil Capability mapping (Office of Environment and Heritage 2013);
- Soils and landscape information contained in Boral documents;
- Aerial photography and LiDAR imagery provided by Boral; and
- Soil profile and landscape information contained in the Soil and Land Information System (SALIS), accessed via eSPADE spatial viewer.

No detailed soil mapping covers the assessment area; however, *Soil Landscapes of the Goulburn 1:250 000 sheet* (Hird, 1991) maps soil landscape units to within 900 m of the Southern assessment area western boundary, and was referenced for background information.

Soil investigation site locations were provisionally selected during the preliminary assessment, based on the information discussed above.

3.1.2. Field Assessment

3.1.2.1. Reconnaissance Inspection

An inspection of the Project site was undertaken on the 7 April 2015 to ground-truth the preliminary soil and landscape map and make initial observations of landscape attributes such as existing disturbance, steep slopes, rock outcropping and surface soil exposures such as creek and road cuttings. Soil investigation site locations were also finalised and marked for archaeological cultural heritage clearance prior to test pit excavation.

3.1.2.2. Test Pits

In late June / early July 2015, thirteen test pits (Sites 1 to 14, excluding Site 10) were excavated to 1.4m, or until refusal on weathered bedrock, to facilitate detailed soil profile description. Test pit locations were selected to provide even and representative coverage of the Project site, with emphasis on the areas of proposed significant disturbance discussed in Section 2.2.2.

As test pits were excavated with backhoe, sites within the Southern assessment area were generally restricted to the north and northwest areas, where lower gradient land allowed for safe access and excavation. These were supplemented by surface observations throughout the steeper sloping areas. The proposed Site 10 was not investigated, due to physical accessibility constraints.

Test pit and surrounding landscape features were each photographed and described for each location including:

- Site identification and location;
- Excavation method and depth;
- Land-use and vegetation cover;
- Slope gradient;
- Microrelief; and
- Rock outcropping.

Soil profiles were photographed and sampled, with soil profiles being described as per the methods presented in the field handbook. The following soil profile attributes were recorded for each location.

- Horizon identification and lower boundary depth;
- Horizon boundary distinctiveness;
- Horizon colour and mottling;
- Field texture;
- Soil structure / pedality;
- Field pH (using Raupach test kit);
- Soil moisture and drainage conditions;
- Coarse fragments and segregations;
- Root presence;
- Dispersion and slaking in deionised water; and
- Lower horizon carbonate presence (effervescence with 1M HCL).

Several test pits had been hand-excavated to the upper boundary of the B horizon as part of an archaeological assessment being undertaken across the assessment area. Several of these pits were inspected during the field assessment and, along with other surface observations (such as road, creek and erosion cuttings), were used to assist with delineation of soil unit boundaries and topsoil stripping depths. These test pits are shown as “ATP” sites on **Figure 5**.

3.1.2.3. Laboratory Analysis

Sixty-three soil samples were collected from test pit horizons and sent for analysis to the NATA (National Association of Testing Authorities) registered NSW Soil Conservation Service Laboratory, Scone NSW.

Samples were typically collected from depth intervals 0-5cm; 5-15cm; 15-30cm; 30-60cm; and, 60-100cm. However, minor variation in sampling interval depths did occur to ensure samples did not cross horizon boundaries.

Samples were analysed for:

- Soil pH (1:5 soil:water or 1:5 soil:$CaCl_2$);
- Electrical conductivity (EC 1:5, and calculation of ECe 1:5);
- Cation Exchange Capacity (CEC); and
- Exchangeable cations for calculation of exchangeable sodium percentage (ESP) and Ca:Mg ratio.

Seven samples that indicated moderate to high dispersion in field testing were also tested for EAT including:

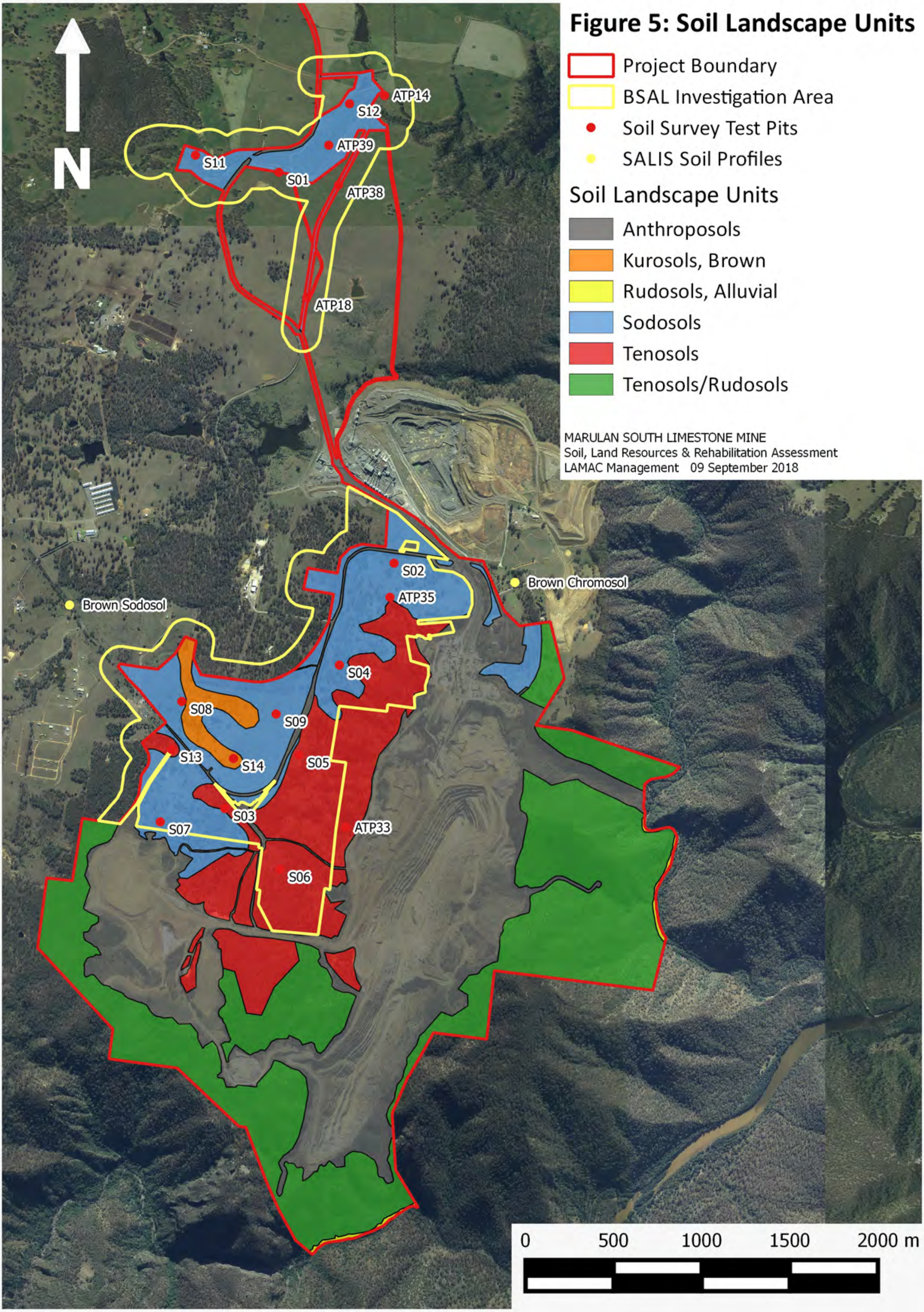
- Site S01: 30-60 cm;
- Site S04: 30-48 cm;
- Site S06: 9-15 cm;
- Site S07: 32-60 cm;
- Site S08: 8-15 cm;
- Site S08: 15-30 cm; and
- Site 14: 15-30 cm.

3.1.2.4. Soil Landscape Unit Mapping

Soil landscape association units were mapped, based on the preliminary soil and landscape map, with soil landscape unit boundaries refined according to observations and findings from the field assessment, including:

- Soil profile descriptions;
- Analytical results;
- Surface observations and archaeological test pits; and
- Topography and drainage patterns.

Figure 5: Soil Landscape Units



3.1.3. Identification of Topsoil Resources

One of the primary objectives of the SLRRA was to identify topsoil with properties suitable for re-use as a post-mining vegetation growth medium. Secondary objectives, related to topsoil characterisation, were the identification of materials which:

- following ameliorative treatment, could also be used as a surface medium if topsoil resources were to prove deficient; or
- exhibit hostile properties (highly saline, sodic, alkaline or acidic) requiring selective management to avoid compromising rehabilitation establishment.

Assessment of suitable topsoil material within the Project site followed the following steps:

1. Identify the proposed ground disturbance boundary, from which topsoil material may be recovered for re-use in post-mining rehabilitation, and delineate areas precluded from topsoil stripping due to:
    a. Existing infrastructure and man-made disturbance such as buildings, roads, drains, dams, mining areas or areas previously stripped of topsoil;
    b. Rocky outcrops, or skeletal stony soils (surface rock content >30%), usually associated with hill crests or upper slopes;
    c. Areas of dense (or deeply incised) gullying, scalds, bare patches, saline surface expressions, or areas where the A horizon has clearly been lost through sheet erosion; and
    d. Boggy or perennially inundated land.
2. Assess soil resources over the remaining area for suitability as topsoil material, following the procedure described by Elliot and Reynolds (2007), which is derived from the topsoil identification criteria originally devised by Elliot and Veness (1981). This procedure determines soil suitability based on soil profile attributes such as structure, coherence (force to disrupt peds), texture, pH and salinity, mottling, root presence and sand / gravel content.
3. Map topsoil resources, considering local topographical and drainage variations, and ensuring suitable topsoil depths, no-stripping areas and hostile material are identified.
4. Estimate volumes of suitable topsoil available for use in rehabilitation, based on soil unit areas and recommended stripping depths, identified in Step 3.

3.1.4. Land Capability Classification and Mapping

Land within the Project site was assessed and mapped for land and soil capability according to *The Land and Soil Capability Assessment Scheme: Second approximation. A general rural land evaluation system for New South Wales* (OEH, October 2012). This scheme uses the biophysical features of the land and soil including landform position, slope gradient, drainage, climate, soil type and soil characteristics to class rural land into one of eight classes (Class I to Class VIII). Land capability class indicates the level of land management required to sustain a potential land use, without causing degradation to the land and soil. General definition of the eight Land Capability Classes are presented in **Table 2**.

Table 2: General definitions of land and soil capability classes.

Class	General definition
Land capable of a wide variety of land uses (cropping, grazing, horticulture, forestry, nature conservation)	
I	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.
II	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.
III	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)	
IV	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.
V	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)	
VI	Low capability land: Land has very high limitations for high-impact land uses. Land use restricted to low-impact land uses such as grazing, forestry and nature conservation. Careful management of limitations is required to prevent severe land and environmental degradation.
Land generally incapable of agricultural land use (selective forestry and nature conservation)	
VII	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.
VIII	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.

3.1.5. BSAL and Agricultural Impact

That part of the Project site not already covered by CML 16, ML 1716 or existing surface disturbance, was subject to a BSAL verification survey completed in accordance with the Interim Protocol). The BSAL assessment area is shown in **Figure 5**, and a copy of the BSAL assessment report is included as **Appendix 2**.

3.2. Results and Impact Assessment

3.2.1. Preliminary Investigation

Other than areas of mining disturbance, and associated *Anthroposols* (soils of human origin), a preliminary review of background soils information indicates the presence of two major soil landscape associations within the Project site, comprising: *texture contrast* (or duplex) soils, and *shallow* soils.

Texture Contrast Soils

An assessment of topsoil suitability for use in post-mine rehabilitation, conducted by GSS Environmental (2010), identified the dominant soil types in the Southern assessment area as Yellow Duplex and Red Duplex soils, both of which are texture contrast soils.

Regional soil mapping (accessed via eSPADE) also identified the following texture contrast soil landscape associations across the majority of the Northern assessment area and over the lower gradient landforms of the Southern assessment area:

- Kurosols – low hills in far west of Northern assessment area;
- Kurosols, natric – lower slopes, flats and drainage depressions across both areas; and
- Sodosols – mid-slopes, upper-slopes and crests of undulating low rises across both areas.

The SALIS database (accessed via eSPADE) identified two recorded soil profiles in the vicinity of the Southern assessment area. Both eSPADE soil profiles included detailed descriptions of texture contrast soil types. Summary information on these two profiles are included in **Table 3**.

Table 3: Summary of SALIS soil profile descriptions in vicinity of Project site.

Profile	***ASC Classification***	***Location***
Sydney Catchment Authority reconnaissance soil survey - Moss Vale Survey (1004229), Profile 117	Brown Chromosol, *?**, Haplic, thin, slightly gravelly, loamy, clayey, deep	100m east of northeast boundary of Southern assessment area
Sydney Catchment Authority reconnaissance soil survey - Moss Vale Survey (1004229), Profile 118	Brown Sodosol, *?**, *?**, thin, non-gravelly, loamy, clayey, deep	300m northwest of western boundary of Southern assessment area

**the inclusion of a question mark ("?") denotes an incomplete soil profile description as recorded on eSPADE*

Shallow Soils

Regional soil mapping (accessed via eSPADE) identified Tenosols / Rudosols in association with the steep slopes and ridges in eastern and southern parts of the Southern assessment area, and far eastern extremity of the Northern assessment area. Narrow strips of Alluvial Rudosols were also identified in association with the Barbers Creek and Bungonia Creek corridors, along the eastern and southern Project site boundaries.

The 2014 BSAL mapping of NSW indicates that the nearest mapped BSAL is approximately 7.5 km to the northeast of the assessment area. The nearest mapped BSAL land is shown in the BSAL Assessment report, attached as **Appendix 2**.

3.2.2. Field Assessment

Thirteen detailed soil profiles descriptions were recorded during the field assessment, mainly in the Northern assessment area, and north western section of the Southern assessment area. Numerous surface soil exposures and archaeological test pits were also observed to assist with delineation of soil unit boundaries. **Table 4** presents summary information on the 13 test pits and six main archaeological test pits observed during the field assessment. Soil profile descriptions (and photographs) for the 13 test pits are contained in the BSAL Assessment Report, included as **Appendix 2**.

Laboratory analysis results for samples collected from the 13 test pits are also included in **Appendix 2**.

Table 4: Summary of soil field assessment sites.

Site No.	Location (GDA 94 Zone 56)		Assessment Area	Soil Type (ASC Order)	Soil Chemistry							
					Topsoil (A1 horizon)				Subsoil (B horizons)			
	Easting	Northing			pH (water)	EC (dS/m)	CEC	ESP	pH	EC (dS/m)	CEC	ESP
S01	227308	6151706	Northern	Sodosol, Red	6.5-6.7	0.03-0.06	13.2-14.3	1.39-2.27	7-7.8	0.174	26.2-29.6	4.39-6.87
S02	227962	6149485	Southern	Sodosol, Brown	6.9-7.2	0.03-0.05	12.1-14.9	2.68-3.3	6.9-7	0.13-0.27	30.9-33.5	7.44-10.74
S03	227000	6148093	Southern	Tenosol, Bleached-Orthic	6.6-6.8	0.02-0.04	9.3-12.2	2.15-4.92	5.5	0.01	4.2	4.76
S04	227652	6148906	Southern	Sodosol, Brown	8-8.1	0.05-0.06	11.8-13.2	1.51-1.69	5.9	0.08	19.9	7.54
S05	227422	6148396	Southern	Tenosol, Brown-Orthic	7.4-7.5	0.06-0.08	15.1-18.3	0.5-0.66	5.6	0.02	8	1.25
S06	227316	6147747	Southern	Tenosol, Bleached-Orthic	7.5	0.04	16.2	0.61	8	0.05-0.06	19.2-22.5	2.22-3.12
S07	226634	6148017	Southern	Sodosol, Red	6.1	0.02-0.04	10.3-12.3	1.62-1.94	5.8	0.04	20.8	6.25
S08	226757	6148701	Southern	Sodosol, Brown	6.8	0.03	8	3.75	6.3	0.75-0.9	22-24.3	9.46-11.81
S09	227292	6148630	Southern	Chromosol, Brown	7.1-7.3	0.03	6.8-8.1	3.7-4.41	5.2-5.7	0.01	9.8-10.6	4.72-5.1
S11	226834	6151803	Northern	Sodosol, Brown	6.2-6.5	0.03-0.07	15.8-19.7	8.6	6.1-6.5	0.02-0.03	22.6-26.8	4.42-4.85
S12	227709	6152096	Northern	Sodosol, Brown	5.9-6.2	0.04	5.2-5.9	7.69-8.47	6.8-7.7	0.08-0.11	20.3-23.6	8.05-8.37
S13	226699	6148428	Southern	Tenosol, Brown-Orthic	6.2-6.6	0.04	22.4-22.5	76.5-8.6	5.9	0.04-0.05	36.1-37.9	4.48-6.09
S14	227050	6148377	Southern	Kurosol, Brown	6.9-7.2	0.01-0.02	6.8-8.3	4.82-5.88	5.2-5.4	0.01	10.5-14.4	4.86-6.66
ATP 14	227908	6152143	Northern	*Sodosol, Brown								
ATP 18	227467	6150995	Northern	*Sodosol, Red								
ATP 33	227689	6147985	Southern	*Tenosol, Brown-Orthic								
ATP 35	227939	6149291	Northern	*Sodosol, Red								
ATP 38	227647	6151634	Northern	*Sodosol, Brown								
ATP 39	227591	6151860	Northern	*Sodosol, Brown								

*Estimate only, based on landscape and adjacent profile descriptions, as no B horizon soil chemistry data collected

3.2.3. Soil Unit Classification and Mapping

Following completion of the field assessment, soil types at each of the 13 test pit sites were classified according to the ASC. Surface observations and archaeological test pits were also used to delineate soil type distribution. Soil landscape units were then determined and mapped. Six soil landscape units were identified within the Project site, consisting of:

- Sodosols, Red / Brown;
- Kurosols, Brown;
- Tenosols, Brown-Orthic / Bleached-Orthic;
- Tenosols / Rudosols (Steep slopes);
- Rudosols (Alluvial); and
- Disturbed land and Anthroposols.

Descriptions of these six landscape units are presented in **Tables 5** to **10**. The soil landscape units map is presented as **Figure 5**.

Table 5: Description of Sodosol Landscape Unit

Soil Landscape Unit (ASC Order): Sodosol, Red / Brown		
Area within Assessment Area	143.5 ha	
Location within Assessment Area	Northern: Majority Southern: Northwest	
Landscape Association:	Mid to upper slopes of gently undulating slopes and low rises	
Typical Soil Profile	A1: 0-11 – Very dark grey loam, very weak angular-blocky, rough-faced, peds 30-40mm, moist, nil gravel	
	A2: 11-21 – Yellowish brown, sandy loam, weak polyhedral, sandy to rough faced peds, 20-40mm, moist, nil gravel	
	B2: 21-95 – Light olive brown heavy clay, apedal massive, moist, increasing weathered bedrock fragments	Soil Profile Site: S02 (Brown Sodosol)
Representative Sites:	S01 & S07 (Red Sodosol); S02, S04, S08 & S12 (Brown Sodosol); S09 & S11(Brown Chromosol); ATP14, ATP18, ATP35, ATP38 & ATP39	
Typical topsoil (A1 horizon) depth	Northern assessment area: 15cm Southern assessment area: 10cm	
Landuse	Low density sheep grazing	
Fertility:	Sodosols - Moderately Low Chromosols – Moderately High	Landscape Site: S01

Table 6: Description of Kurosol Landscape Unit

Soil Landscape Unit (ASC Order): Kurosol, Brown		
Area within Assessment Area	11.5 ha	
Location within Assessment Area	Northern: Nil Southern: Northwest	
Landscape Association:	Flats and drainage depressions	
Typical Soil Profile	A1: 0-12 – Dark greyish brown sandy loam, weak polyhedral, rough-faced, peds 10-20mm, moist, nil gravel	
	A2: 12-44 – Light yellowish brown, sandy clay loam, weak polyhedral / lenticular, rough faced peds, 20-30mm, moist, 20% ironstone nodules	
	B2: 44-65 – Yellowish brown medium clay, weak polyhedral to platy peds, 5-10mm, moist, 5% weathered bedrock fragments	
	B/C: 65- >110 – weathered bedrock	Soil Profile Site: S14
Representative Sites:	S14	
Typical topsoil (A1 horizon) depth	Northern assessment area: N/A Southern assessment area: 15cm	
Landuse	Low density sheep grazing	
Fertility:	Moderately Low	
		Landscape Site: S14

Table 7: Description of Tenosol Landscape Unit

Soil Landscape Unit (ASC Order): Tenosol, Bleached-Orthic / Brown-Orthic		
Area within Assessment Area	119.9 ha	 
Location within Assessment Area	Northern: Nil Southern: Central	
Landscape Association:	Ridge crests, upper slopes and steep slopes	
Typical Soil Profile	A1: 0-11 – Dark brown sandy loam, weak angular-blocky, rough-faced, peds 10-30mm, moist, 0-10% gravel	
	B2: 11-60 – Yellowish brown heavy clay, apedal massive	
	B/C: 60 - >95 – weathered bedrock	
		Soil Profile Sites: S06 & S13
Representative Sites:	S03, S05, S06 & S13 ATP 33	
Typical topsoil (A1 horizon) depth	Northern assessment area: N/A Southern assessment area: 10cm	
Landuse	Mine buffer land; historic sheep grazing	
Fertility:	Moderately Low	
		Landscape Site: S05

Table 8: Description of Tenosol / Rudosol Landscape Unit

Soil Landscape Unit (ASC Order): Tenosol / Rudosol (Steep Slopes)		
Area within Assessment Area	229 ha	
Location within Assessment Area	Northern: Nil Southern: Southwest, south and east	
Landscape Association:	Steep to precipitous slopes and ridgelines	
Typical Soil Profile (based on surface observations and description of *Lickinghole* Soil Landscape in Hird, (1991).	Shallow, stony, fine sandy to loamy Rudosols on crests, grading to shallow Red and Yellow Tenosols on sideslopes. Significant outcropping and cliffs.	Landscape: Shallow ridgeline soils
Representative Sites:	N/A (surface observations only)	
Typical topsoil (A1 horizon) depth	Northern assessment area: N/A Southern assessment area: 0cm (not to be stripped)	
Land use	Native forest	
Fertility:	Low	Landscape: Shallow stony sideslope soils

Table 9: Description of Rudosol (Alluvial) Landscape Unit

Soil Landscape Unit (ASC Order): Rudosol (Alluvial)		
Area within Assessment Area	2.5 ha	
Location within Assessment Area	Northern: Nil Southern: Eastern and Southern boundaries	
Landscape Association:	Stream channels, and adjacent terraces, on valley floor.	
Typical Soil Profile (based on surface observations)	Shallow, loose alluvial sands and gravels, grading to colluvial stones and boulders. Significant outcropping.	Landscape: Barbers Creek
Representative Sites:	N/A (surface observations only)	
Typical topsoil (A1 horizon) depth	Northern assessment area: N/A Southern assessment area: N/A (not proposed for disturbance)	
Land use	Native forest / conservation area	
Fertility:	Low	Landscape: Bungonia Creek

Table 10: Description of disturbed / Anthroposol Landscape Unit

Soil Landscape Unit (ASC Order): Disturbed / Anthroposol (Mined land)		
Area within Assessment Area	340 ha	
Location within Assessment Area	Northern: Nil Southern: Central and Southwest	
Landscape Association:		
Typical Soil Profile (based on surface observations)	Disturbed land: Open cut pit and infrastructure Anthroposols: Overburden emplacements	Disturbed areas:
Representative Sites:	N/A (surface observations only)	
Typical topsoil (A1 horizon) depth	Northern assessment area: N/A Southern assessment area: 0cm (already stripped)	
Land use	Mining	
Fertility:	Low	Anthroposols: Rehabilitated overburden emplacement

3.2.4. Topsoil Resource Identification

3.2.4.1. Topsoil Stripping

Topsoil recovery from texture contrast soils that dominate much of the proposed disturbance footprint is restricted to the A1 horizon. Below the A1 horizon, soils are limited by soil chemical and physical properties, such as:

- Increased sodicity in the A2 horizon (Sites S02, S08, S09 and S14);
- Moderate to strongly acidic B horizon (Sites S04, S07, S09 and S14); and
- Heavy clay B horizon (Sites S01, S02, S04, S11 and S12).

The Tenosol soil landscape unit is similarly limited to the A1 horizon (10cm) due to a moderately acidic B horizon and the presence of a heavy clay B horizon and / or shallow weathered bedrock.

Topsoil stripping is not recommended in the Tenosol / Rudosol (steep slopes) soil landscape unit due to shallow, poor quality soils. Areas of heavy outcropping, erosion, stony soils or very steep slopes should also be excluded from topsoil stripping. Such outcropping areas include the far east of the northern section of the assessment area, and the far southern section of the Tenosol soil landscape unit.

Maximum topsoil stripping depths, and estimated stripping volumes, are presented in **Table 11**. A plan of the proposed Project disturbance footprint, and associated topsoil stripping areas, is presented as **Figure 6**.

Stripping depths presented in **Table 11** and **Figure 6** are based on observed soil conditions, topography and surface conditions. Actual stripped areas or depths may vary with local topography, specific conditions or constraints encountered during stripping. Generally, topsoil will be deeper in depressions and lower slopes, and shallower on upper slopes and crests. However, the transition from topsoil to subsoil is quite distinct in most soils within the proposed disturbance footprint. Field conditions which may prevent full topsoil recovery include:

- severe weed infestation;
- steep or broken terrain;
- outcropping or increased rock content;
- existing scalding or erosion;
- waterlogging;
- soil contamination; or
- infrastructure (such as drains, dam and trails).

Recommended topsoil stripping and handling techniques to minimise the potential for erosion and resource loss are presented in **Appendix 4**.

Table 11: Topsoil Stripping Summary Information

Assessment Area Section	Soil Landscape Unit	Stripping Depth (cm)	Proposed Disturbance Area (m^2)	Volume (m^3)
Northern	Sodosol (creek and dam)	15	48,317	7,248
	Sodosol (access road)	10	23,480	2,348
Southern	Sodosol	10	1,018,764	101,876
	Kurosol, Brown	15	104,069	15,610
	Tenosol	10	884,281	88,428
Total				***215,510***

3.2.4.2. Other Materials

Other than the heavy clay and moderately to strongly acidic B horizons, no particularly hostile soils were identified as requiring specific management.

Alternate materials have been trialled as surface growth media in previous onsite rehabilitation. These materials include decomposed granite (from the adjacent Peppertree Quarry) and a weathered shale material from the open cut mine. Both materials have demonstrated measured success, and the potential use of these materials is discussed further in Section 4.

Geochemical and erosion potential testing of geological strata from the open cut mine did identify transitional weathered material of high erosion potential. It is recommended that characterisation testing is undertaken before any material from the open cut is used as a growth medium in rehabilitation.

Where alternative materials are used as a growth medium, the supplementary use of composted organic material may ameliorate deficiencies in those materials and enhance vegetation establishment. The potential use of composted organic material is discussed further in Section 4.

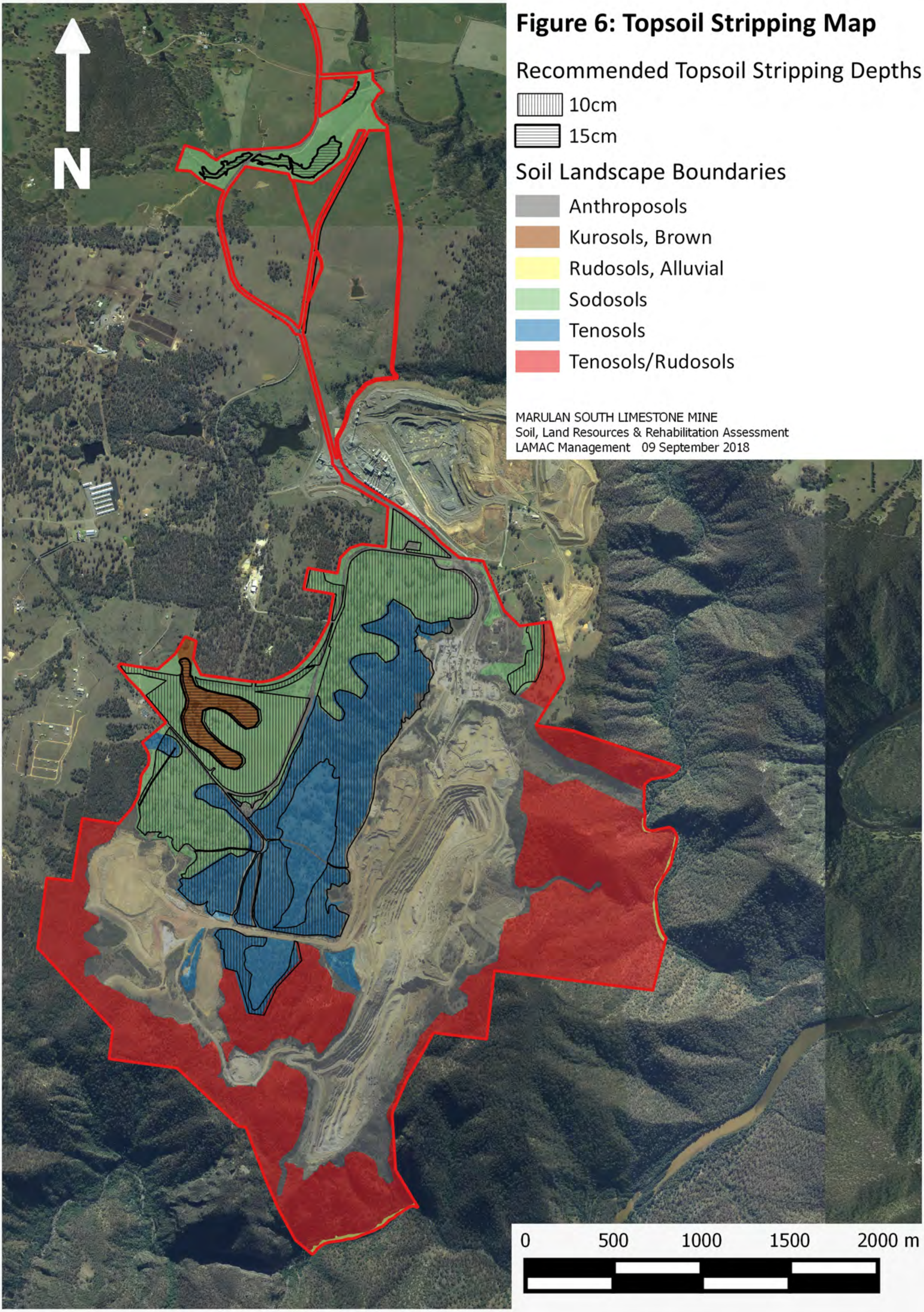


Figure 6: Topsoil Stripping Map

3.2.5. Land Capability

Broadscale regional Land and Soil Capability mapping identified the flat to undulating land that comprises the majority of the northern section of the assessment area, and the north western part of the southern section, as *Class V: Severe Limitations - land not capable of sustaining high impact land uses without special management*. During the field assessment, the land mapped as *Class V* was generally identified in association with the texture contrast soil units (Sodosols and Kurosols) in the assessment area, with limiting factors being shallow soil depth, waterlogging potential, and acidic or sodic subsoils.

The moderate to steep slopes in the central southern part of the assessment area, which divide the flat undulating land from the operational open cut mine, are regionally mapped as *Class VII: Extremely severe limitations – land incapable of sustaining most land uses.* This area was identified in association with the Tenosol (Bleached-Orthic / Brown-Orthic) soil landscape unit delineated during the field assessment. Limiting factors for this particular soil landscape unit include shallow soil depth, acidic subsoils, slope gradient and localised outcropping.

The area of very steep to precipitous slopes that make up the southern and eastern sections of the assessment area, and the far eastern corner of the northern section of the assessment area, is mapped as *Class VIII: Extreme limitations – land incapable of sustaining any land uses*. This regionally mapped area was identified in association with the Tenosol / Rudosol (steep slopes) soil landscape unit. Limiting factors for this land include steep slope gradients, shallow soils, soil rockiness and extensive rock outcropping.

The areas of mining related disturbance were not assessed for land capability class.

Given the low pre-disturbance land capability classes (V, VII and VIII) of the land proposed for disturbance, the Project will have minimal negative impact on the overall land capability. A summary of land capability classes within the Project site is included in **Table 12**, and a map of land capability class distribution across the Project site is presented as **Figure 7**.

Table 12: Land Capability Class Summary for Project site.

Land Capability Class	Assessment Area Section		Total (ha)
	Northern	Southern	
Class V: Moderate to low capability land	27.5	127.2	155
Class VII: Very low capability land	-	119.8	119.8
Class VIII: Extremely low capability land	0.2	230.4	230.6
Not Assessed: Mining disturbed land	-	340.6	340.6
Total			***846***

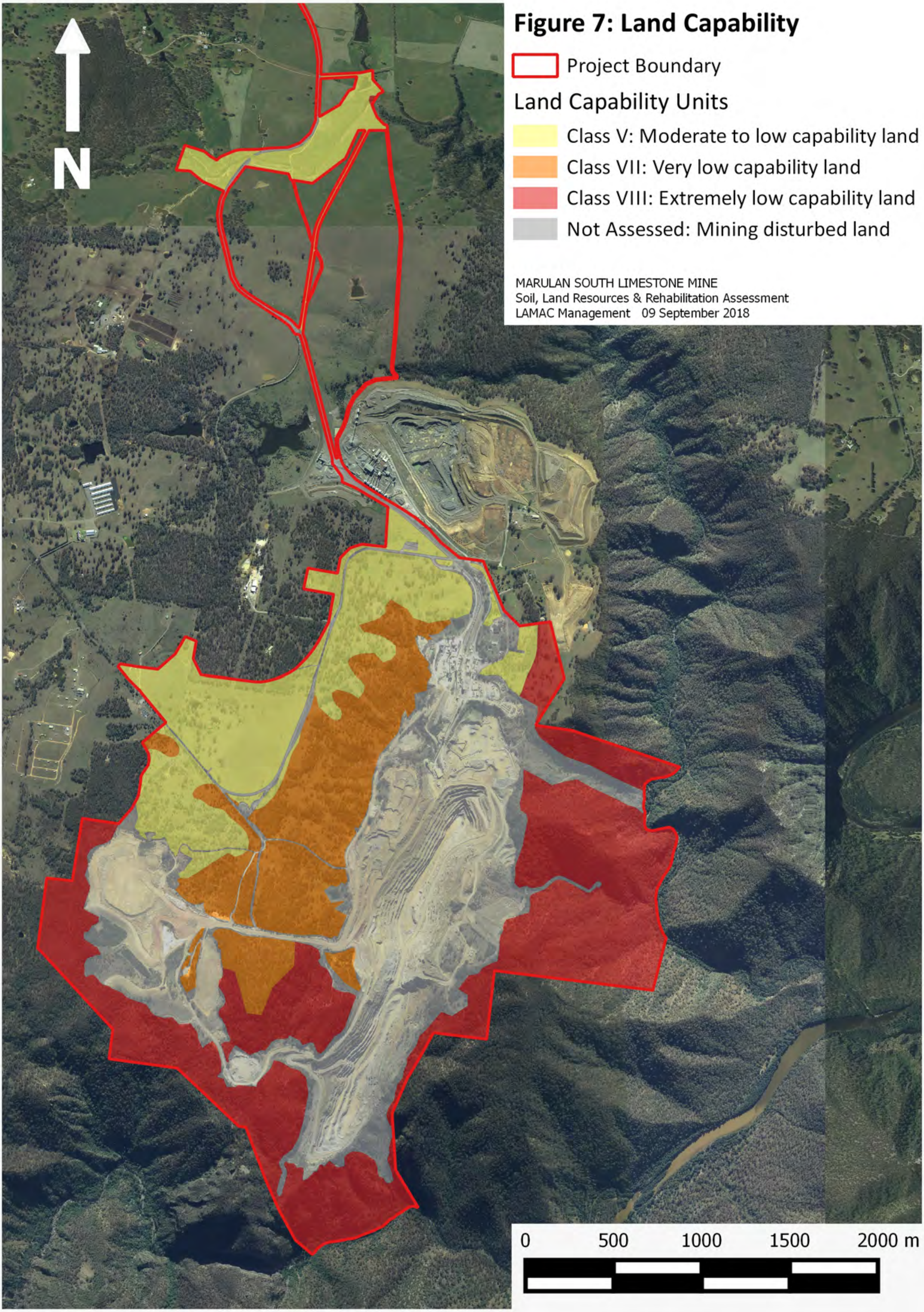


Figure 7: Land Capability

3.2.6. BSAL and Agricultural Impact

A soils and landscape assessment against the BSAL verification criteria presented in the Interim Protocol was completed for that section of the Project site not covered by CML 16 or ML 1716, and not already disturbed by historic mining activities. This BSAL assessment area is shown on **Figure 5**. The BSAL assessment determined that the nearest regionally mapped BSAL land is approximately 7.5 km to the north east of the Project site, and that the land and soils within that assessment area were not BSAL. A BSAL Site Verification Report was submitted to OEH in October 2015 for assessment. OEH assessed that no BSAL was located within the Project BSAL assessment area, and a Site Verification Certificate (SVC) was issued by DPE on 17 November 2015.

A risk assessment of potential impact from Project activities on agricultural resources within the BSAL assessment area was completed as part of the BSAL assessment. The risk assessment followed the methodology presented in the *Strategic Regional Land Use Policy, Guideline for Agricultural Impact Statements at the Exploration Stage* (Department of Trade and Investment Regional Infrastructure and Services, 2012). Based on likelihood and consequence (permanence) of disturbance, the assessment identified a moderate to high risk of impact on agricultural resources within the BSAL assessment area. However, given the relatively small area of proposed disturbance (256.5 ha), and low land capability within the assessment area, the overall risk of impact on agricultural resources is considered to be minimal.

Negligible impact on agricultural land outside the BSAL assessment area is proposed as part of the Project, with the majority of the remaining Project site being existing mining-disturbed land, or land capability Class VIII steep slopes and ridges. The BSAL assessment, therefore, captures the potential agricultural impact associated with the overall project.

Copies of the BSAL assessment report and SVC are included as **Appendix 2**.

4. Rehabilitation

The rehabilitation of land disturbed by mining activities is a standard requirement of mining project approvals and mining leases issued by the NSW government. There is also a community expectation that once mining has finished, a safe, useful and non-polluting landscape will be left behind. Given the location of the Project site – with agricultural properties to the west and conservation land to the south and east – it is important that effective rehabilitation processes are integrated into mine operational planning.

This section outlines Boral's conceptual rehabilitation and mine closure strategy for the orderly transition from a mining land use to an agreed stable and beneficial post mining use. The overall Project rehabilitation and mine closure strategy, along with strategic considerations, are outlined. Proposed rehabilitation methodology for the proposed Project disturbance footprint, and planning considerations, are also detailed. Project disturbance and rehabilitation are discussed in terms of management units referred to as *rehabilitation domains*, which are discussed in Section 4.2.1. Primary domains (start of Project disturbance management land units) are presented in **Figure 8** and secondary domains (post-mining rehabilitation management land units) are presented in **Figure 9**.

Information presented in this section is based on observations and findings of the SLRRA, which included the following activities.

- Review of relevant background information, including the;
    - Description of mining activities proposed as part of the Project,
    - Marulan South Limestone Mine Mining Operations Plan 2009 – 2015 (and accompanying Review of Environmental Factors),
    - Marulan South Limestone Mine Mining Operations Plan 2018 – 2023,
    - Marulan South Limestone Mine Rehabilitation Strategy (GSSE, July 2010),
    - Marulan South Limestone Mine Rehabilitation / Revegetation Planning Requirements (Global Soil Systems, 2012),
    - Marulan South Limestone Mine – Progressive Rehabilitation Strategy (Global Soil Systems, 2012),
    - Establishment Report - Rehabilitation of Marulan South Limestone Mine (Global Soil Systems, 2014),
    - Marulan South Limestone Mine – Revegetation Strategy (Global Soil Systems, 2017),
    - Letter Report entitled Status of Eastern Batters – Marulan South Limestone Mine (PSM, August 2015), and
    - Soils and landscape information on the proposed disturbance area, as outlined in Section 3;
- Three inspections of existing rehabilitation at the mine, including the steep eastern emplacement slopes and western emplacement rehabilitation; and
- Conversations with:
    - Mr Grant Thompson (Boral Environmental Officer) regarding rehabilitation design and methodology previously used onsite,
    - Mr Gordon Atkinson (mine planning consultant), regarding proposed disturbance, overburden emplacement staging and design, and the overall rehabilitation and mine closure strategy,
    - Dr Mark Burns, Assoc. Prof. Greg Hancock and Mr Craig Bagnall as part of the soil and rehabilitation investigation team.

4.1. Rehabilitation and Mine Closure Strategy

The proposed 30-year mine development for the Project is based on mining approximately 120 million tonnes of limestone at 4 million tonnes per annum. This mine development includes emplacement of approximately 113 million tonnes of overburden of which an estimated 30 million tonnes will be emplaced within the southern overburden emplacement (SOBE) at the southern end of the mine void. Backfilling the southern section of the void is a significant component of the Project rehabilitation and mine closure strategy, which aims to balance resource utilisation with environmental considerations.

The 120 million tonnes of limestone to be mined during this Project is only part of a much larger deposit identified and estimated by GeoRes (2018) to be 640 million tonnes. Complete extraction of this larger deposit is unlikely, given the associated potential for environmental impacts. However, it is anticipated that operations could continue beyond the initial 30-year Project period with a further 110 million tonnes of limestone available for mining by extending the mine north, north-westwards and down to RL 300m. This post Project development would require the relocation of infrastructure and the removal of an additional 141 million tonnes of overburden. It is estimated that 60 million tonnes of this overburden could be emplaced in the mine void by extending the existing SOBE northwards without constraining potential post Project development.

4.1.1. Post Mining Land Use

As continuation of mining following the 30-year Project life is a likely option, post mining land is currently considered in conceptual terms, particularly in regard the mine void. Further development of final land use over the Project life will be guided by regulatory approvals and commitments, and will be undertaken in consultation with local interested parties, such as neighbouring landowners / managers, regulators and community groups.

The 30-year mine development considers both “above ground” and “in-pit” options for overburden emplacement to achieve a balance between resource utilisation and long term environmental considerations - especially visual impacts of the rehabilitated landform. Overburden emplacements developed or expanded during Project operations, including the WOBE, NOBE, western and southern sections of the SOBE, and existing Eastern Batter slopes will occupy approximately 242 ha of the total 598 ha disturbance footprint at the end of the 30-year Project life. The end of Project reshaped emplacements, as shown on **Figure 9** and **Figure 12**, will be the likely final landforms, even if mining should continue past the current 30-year Project life.

The post mining land use goal for the overburden emplacements is the re-establishment and development of native woodland vegetation communities that reflect the existing ecological communities identified in the Project biodiversity assessment (Niche, 2018) and outlined in Section 2.1.5. Specifically, overburden emplacement rehabilitation will incorporate the:

- Re-establishment of native woodland communities that reflect the structure and composition of the federally listed Critical Endangered Ecological Community (CEEC), *Blakely's Red Gum - Yellow Box - Grassy open woodland* particularly in NOBE and WOBE, by incorporating key tree species of this community into the proposed seed mix for emplacement rehabilitation;
- Establishment of woodland communities in the vicinity of the WOBE that will also improve movement corridors for native fauna species, including Koalas and Yellow-bellied Gliders; and
- Selection of species from the *Coast Grey Box – stringybark dry woodland* community, (commonly found on the upper slopes of adjacent steep gorges) for the rehabilitation of steep slopes of the SOBE.

In addition, the re-establishment of native woodland communities within the nominated overburden emplacement domains is compatible with the proposed rehabilitation objectives of the adjacent Peppertree Quarry, which are to rehabilitate disturbed areas to *Blakely's Red Gum - Yellow Box - Grassy open woodland*, increase native wildlife habitat and re-establish movement corridors across the site.

If mining were to cease towards the end of the proposed 30-year Project life, potential post-mining use options for the final 156 ha mine void include:

(a) temporary water storage;

(b) landfill / backfill capacity, including additional overburden emplacement or metropolitan infrastructure projects; or

(c) potential recreation area consistent with adjacent State administered conservation and recreation areas.

A conceptual final landform design has been developed as detailed in Section 4.1.2 to guide the post mining land use planning process and assist in the development of rehabilitation objectives.

4.1.2. Conceptual Final Landform Design

If operations were to cease at the end of the proposed 30-year Project period, detailed closure planning would commence at approximately the midway point of Stage 4 (five to six years prior to closure). This would allow sufficient time to complete limestone mining, including the removal and emplacement of overburden in accordance with final land use and closure planning commitments. Until confirmation of closure timing triggers the requirement for detailed closure planning, the proposed 30-year mine development and overburden emplacement schedule allows for some final land use flexibility, while maintaining public safety, providing guidance for rehabilitation design and minimising potential environmental impacts.

Figure 9 provides a “snap shot” of a conceptual final landform design, including rehabilitated areas and retained infrastructure, approximately five years after the proposed 30-year mine Project period. This conceptual final landform design is also presented as 3D visualisations in **Figures 10** and **11**. Features of the conceptual final landform design, based on the 30-year mine development and progressive rehabilitation schedule, are outlined below.

Safety
Development of a nominally 30m wide haul road access around the mine void at an elevation of between 560m and 590m (western side) and 545m (eastern side), permitting the installation of security fencing (typically 2.1m in height) and earth / rock safety berms to physically restrict access to the mine void. The location of proposed and existing security fences is indicated by the black dashed line on **Figure 9.**

Approximately 10 to 13m of the former haul road can be planted / seeded with trees, forming a visual barrier whilst still providing safe road / track access around the approximate 7.1 km perimeter of the final mine void.

Visual
To improve visual amenity, additional tree planting / seeding may be established on the 9m wide berms of the upper 15m bench and 50-degree face slope, down to the approximately 500m elevation. Possible bench planting locations (4m to 5m wide) are shown on **Figure 9** as darker green shaded areas

from 600m down to 530m elevations on the western rim, and from 560m to 500m around the eastern perimeter.

Wider areas, from 60m to 140m wide, are available for planting at the 530m and 545m elevations (western side), with safe road / track access being maintained for revegetation monitoring and maintenance.

The upper in-pit slopes of the SOBE would, where practical, be battered to achieve 1:2 to 1:3 slope gradients down to 485m, and revegetated to improve visual amenity from the south. If the lower in-pit slopes, concealed from view by the southern rim of the SOBE, were not battered to approximately 1:3 in the final closure planning period then plantings along the three, 9m wide berms (at approximately 455m, 440m and 395m elevations) could be undertaken to assist with slope stabilisation, as indicated in **Figure 9**.

In total, approximately 30ha of additional "Visual Screening" Rehabilitation has been identified within the mine void as shown on **Figure 9**, assuming no further mining was to be undertaken. This rehabilitation comprises 24 ha of planting / seeding over the remaining 9m wide mine benches, and 6 ha of the SOBE in-pit slopes and berms.

If final mine closure did occur at the end of the 30-Year Project period, the majority of the infrastructure area would also be subject to final rehabilitation. An estimated 70 ha of the infrastructure area (comprising existing processing plant, shared product stockpile and the relocated mine stockpile / reclaim facility) would be decommissioned and rehabilitated. Retained infrastructure areas would include road access, services and infrastructure used in support of future land uses.

The existing Eastern Batter rehabilitated areas (east of the mine void) would also be well advanced towards the post mining land use objective of a stable landform with established native woodland vegetation, following a further 30-years of progressive rehabilitation, monitoring and maintenance.

Water Management
Sediment and water retention dams proposed as part of the Project development, together with water supply pipelines and multiple water tank storages, are likely to be retained for continued sediment and erosion control, and to facilitate water supply in support of the post-mining land use.

Services and Infrastructure
Subject to landholder agreement (BCL being the landholder for the majority of land titles), and in accordance with development approval, services including rail and road access, and electricity supply would be retained to service post-mining land uses. Maintaining partial road and rail access to, and around, the Project site is considered necessary for ongoing land access and management, including bush fire prevention.

As with services, various buildings (e.g. workshops, stores, production and administration offices) may be retained, where agreed, to support post-mining land uses. Processing plant and equipment is likely to be decommissioned, removed from site and the remaining area rehabilitated in accordance with final land use requirements. Proposed infrastructure to remain at end of Project is shown in **Figure 12**.

4.1.3. Strategic Considerations

As well as the biodiversity enhancement opportunities discussed in Section 4.1.1, the following aspects of rehabilitation planning were considered in the development of the conceptual final landform, rehabilitation and mine closure strategy.

4.1.3.1. Surface Water Quality

Surface water runoff from the SOBE and the southern sections of the WOBE will drain to the mine void via sediment dams. Once mining is complete and the emplacements are sufficiently rehabilitated, surface drainage will flow via Main Gully to Bungonia Creek. The northern sections of the Northern and Western Overburden Emplacements will report to Tangarang Creek during and after emplacement operations. The southern section of the NOBE, and adjacent areas will drain to the North Pit during and after mining operations. Bryces and Barbers Overburden Emplacements will continue to report to Barbers Creek.

These creeks flow to the Shoalhaven River, which discharges into Lake Yarrunga, which is a water supply dam for the Sydney Catchment Authority. Bungonia National Park, State Conservation Area and Morton National Park, all heavily used recreationally by the public, are also located immediately to the south and east of the Project site. Increased erosion resulting from unsuccessful rehabilitation within the Project site could potentially impact on these receptors. To reduce potential erosion impacts, graded banks, drop structures and sediment detention structures have been incorporated into the final landform design, as outlined in Section 4.5.1. The location of final water management infrastructure is shown in **Figure 9**, **Figure 12** and **Figure 13**.

4.1.3.2. Visual Amenity

From most public vantage points and private residences to the north and west, development within the Project site is screened by existing topography, remnant native trees and woodlands. The WOBE is marginally visible from a short section along Marulan South Rd. Bungonia Lookdown, located in Bungonia National Park across the gorge from the Project site, is a popular local tourist attraction. The SOBE and WOBE, and the open cut pit, are highly visible from the scenic lookout.

The open woodland vegetation communities proposed for the SOBE and WOBE, and remedial planting on the existing Eastern Batters rehabilitation, will reduce the visual impact of the Project by partially screening these emplacements. The proposed establishment of tree screens on the perimeter of the mine void and, where possible, on in-pit benches, will also reduce the visual impact of the void. A visual assessment of the Project, which presents greater detail on potential visual impacts and recommended mitigation measures, has been undertaken by Richard Lamb and Associates as part of EIS investigations.

Potential impacts on local and district agricultural production from Project development are discussed in Section 3.2.6.

4.1.3.3. Existing Rehabilitation and Trials

Historic rehabilitation performance within the Project site has been mixed. Successful woodland rehabilitation has been established in the WOBE. However, sections of rehabilitation on the Eastern Batters require further attention. The performance of previous rehabilitation programs and trials within the Project site indicate several key challenges. This section outlines the key challenges that need to be addressed to successfully achieve the proposed final rehabilitated landform. A summary of previous rehabilitation and rehabilitation trials within the Project area is presented in **Appendix 4**.

- *Soil pH conditions*: The overall limited availability of topsoil material suitable for use in rehabilitation is exacerbated by elevated pH levels exhibited in the overburden materials used as growth medium layers to date. This has impeded the successful development of a growth medium layer that can support rehabilitation.
- *Steep slopes*: Although overburden emplacements have been designed to mimic adjacent natural steep slopes, landform steepness has contributed to rehabilitation establishment issues in some emplacements, leading to potential derivative impacts of erosion and downstream water quality impacts.
- *Climate*: Highly variable and irregular climatic conditions hinder rehabilitation development. Such conditions include hot summers, cold winters and periodic droughts. It is important to plan towards rehabilitation in the traditional windows of Spring and Autumn, but allow flexibility in long term rehabilitation planning to allow for drought periods.
- *Water supply*: Rehabilitation success has been impacted upon by water shortages following good initial germination. Irrigation trials have been set up previously, with mixed success.
- *Environment*: Local environmental factors resulting from mine location have impeded rehabilitation establishment. Such factors include browsing by herbivorous pests such as goats and rabbits, native macropod species, as well as weed competition.

Opportunities for future research programs and field trials have also been identified, including:

- Development of rehabilitation methods that incorporate tolerance / resilience to climatic fluctuations;
- Modelling of erosion on steep overburden emplacement slopes;
- Suitability and availability of alternate growth medium materials;
- Reducing herbivore browsing impacts on revegetation; and
- Further investigation of suitable post-mining land uses.

The potential feasibility of such research options will be further evaluated, with selected programs being detailed in subsequent MOP / RMP.

4.2. Rehabilitation Planning

To assist with rehabilitation planning and assessment, ESG3 requires mine rehabilitation programs to be broken down (a) spatially, into *Domains* of similar mining or rehabilitation function, and (b) temporally, into *Rehabilitation phases*. The following sections discusses these rehabilitation planning concepts, with regards to the proposed Project development.

4.2.1. Rehabilitation Domains

Domains are defined in ESG3 as land management units (or areas), usually with unique operational and functional purpose and, therefore, similar geophysical characteristics. Domains can be operationally based “primary” domains, or “secondary” domains characterised by a similar post mining land use objective. For example, overburden emplacements are considered a single primary domain for rehabilitation planning purposes, while areas of the site rehabilitated to native woodland may be considered a single secondary domain.

4.2.1.1. Domains Proposed for Project

The extended Project disturbance footprint totals 598 ha is located within the Project application area, and has been divided into the proposed Project primary domains, as shown on **Figure 8.** The Project application area includes the majority of CML 16 together with additional areas for overburden emplacements and a new mine water supply dam located on Marulan Creek. These primary domains may be subject to further revision and refinement resulting from new mining authority application or preparations of future MOP / RMP. **Figure 8** also shows existing site disturbance of about 341.5 ha within the Project application boundary, indicating proposed Project disturbance to be 256.5 ha.

Proposed secondary domains for the post mining rehabilitated Project site, as described in the conceptual final landform design (Section 4.1.2) are shown in **Figure 9** and summarised in **Table 14**.

Table 13: Primary rehabilitation domains at start of Project.

	Rehabilitation Domain	Description	Area (ha)
1	Infrastructure Area	Mining related infrastructure situated on lower gradient land in the central northern section of the Project site, including processing facilities, workshops, administrative buildings, roads, rail facilities, dams, pipelines, and hard stands. . Some additional disturbance associated with site haul and access roads together with existing access tracks of about 1ha. Infrastructure within the domain will generally remain operational (and unrehabilitated) until end of Project life. Infrastructure not required post mining will be decommissioned and demolished. It is expected that the Marulan Creek Dam (and vehicle access road) will remain operational post-mining, and will be in parts rehabilitated at the end of the mine life.	106.2
2	Waste Lime Storage / Emplacement Area	Discrete area within Western Overburden Emplacement designated for placement and capping of waste lime materials.	2.0
3	Water Management Areas	Sediment control and water supply dams across the mine site including Marulan Creek Dam infrastructure.	30.0
4	Overburden Emplacement Areas	Existing overburden emplacement to the west and south of the open cut pit.	246.3
5	Stockpiled Material Area	Designated areas within infrastructure and mine void areas for management of raw, processed and product materials. This area has been incorporated into domain 1 (infrastructure).	0
6	Open Cut Mine Void	Open cut mine void. Will expand towards the west as the pit develops.	155.5
7	Rehabilitation Areas	Rehabilitated overburden emplacement areas, currently consisting of rehabilitation areas of Western Overburden Emplacement; Bryces Gully Emplacement; Barbers Emplacement and Eastern Batters (South).	58
		Total Area	598

Table 14: Secondary domains at Project end

	Rehabilitation Domain	Description	Area (ha)
A	Native woodland areas	Former overburden emplacements and infrastructure areas rehabilitated to native woodland communities.	326.8
B	Trees over Grass – landform stability	Mix of tree, shrub and groundcover vegetation established on the Eastern batters to promote long term erosion control and landform stability.	37.1
C	Final mine void	Post mining, the residual void will be approximately 240-270 m deep, up to 900m wide (east to west) and 2000m long (north to south) with steeply sloping “benched” walls and generally level floor. This domain also includes approximately 8.9 ha of the SOBE.	106.3

D	Visual Screening	Tree and shrub vegetation established around void perimeter and upper slopes / benches to promote visual screening visual screening and landform stability.	29.7
E	Water management	Drainage control and water supply structures	23.4
F	Infrastructure	Individual infrastructure items (mainly roads) incorporated into other domains to support post mining land use.	74.6
		Total Area	598

4.3. Rehabilitation Phases

The broad rehabilitation strategy for disturbed land within the Project site includes the reshaping and stabilisation of post-mining landforms, topdressing of reshaped landforms, and the establishment and development of native woodland vegetation communities. In accordance with ESG3, this overall rehabilitation process has been divided into rehabilitation phases to assist with detailed rehabilitation planning. These phases include:

1. Decommissioning;
2. Landform Establishment;
3. Growth Medium Development;
4. Ecosystem and Land Use Establishment
5. Ecosystem and Land Use Sustainability; and
6. Relinquishment.

4.4. Rehabilitation Objectives

To facilitate effective long term rehabilitation planning, objectives have been selected for each rehabilitation domain. The selected objectives reflect the selected final land use for each secondary domain, and will be used to guide rehabilitation planning and assess rehabilitation performance. The objectives discussed are conceptual and may be further defined in future MOP / RMP.

These general objectives should apply across all rehabilitation domains within the Project site.

- Rehabilitated land will be geotechnically stable and will not present a greater safety hazard than surrounding land to land-users, public, livestock and native fauna accessing or transiting the post-mining area.
- Land capability will, at a minimum, be returned to a class similar to that existing prior to Project commencement (Class V, VII or VIII).
- Except for mine void, mined land will be visually compatible with the surrounding natural landscape.
- Rehabilitated landforms will be designed to shed water without causing excessive erosion or increasing downstream pollution.
- Rehabilitated landforms will not negatively impact visual amenity for nearby residents and users of conservation reserves.

4.4.1. Rehabilitation Domain Specific Objectives

Proposed final land use objectives are presented by relevant rehabilitation domain and phase in **Table 15**.

4.4.1.1. Completion Criteria and Rehabilitation Monitoring

Rehabilitation development should be periodically measured and assessed to determine whether rehabilitated communities are progressing towards the objectives. Specific and measurable progress indicators that reflect rehabilitation objectives should be selected to assist with progress assessment.

Completion criteria, also to be derived from rehabilitation objectives, consist of agreed values or standards that indicate if rehabilitated land is resilient and sustainable, and considered suitable for relinquishment. At a minimum, completion criteria should address landscape parameters such as stability, soils, vegetation establishment, and potential for off-site impacts and suitability for the agreed post-mining land-use.

A set of preliminary rehabilitation success criteria are detailed in the 2018-2023 MOP, and have been referenced in developing the provisional completion criteria presented in **Table 16**. Domain-specific rehabilitation progress indicators for each rehabilitation phase, and overall success criteria, will also be developed from the domain objectives presented in **Table 15.** These criteria will continue to be reviewed and refined throughout the Project life to reflect rehabilitation methodology, monitoring results, rehabilitation trials and research, stakeholder feedback, and further delineation of selected post-mining land uses. Revised completion criteria will be included in subsequent MOP / RMP.

Boral have currently adopted the Ecosystem Function Analysis (EFA) monitoring methodology to assess rehabilitation progress. EFA is a transect-based monitoring method that measures for:

- Landscape Function Analysis;
- Vegetation Dynamics;
- Habitat Complexity; and
- Disturbance.

EFA involves the periodic measurement of landscape and vegetation parameters along transects established in rehabilitated areas. The data collected is converted into indices for comparison against measurements made at nearby analogue (or reference) sites established in undisturbed target communities. Repeated EFA measurements should demonstrate development of rehabilitation towards completion criteria over time.

The use of EFA as a stand-alone monitoring methodology may be reviewed as the Project develops and post-mining land uses are further defined. While EFA is a relatively sound rehabilitation monitoring methodology, regulatory approvals may require statistical assessment of vegetation community structure and composition. Several floristic monitoring options are available with selection of appropriate method largely determined by the target biodiversity conditions included in the project approval. Given the steepness of the final SOBE landform, and sensitivity of downstream receivers, consideration should be given to incorporation of erosion assessment methodology into monitoring program methodology.

4.4.1.2. Rehabilitation Threats and Contingencies

A monitoring program has been implemented to assess rehabilitation progress towards post-mining land use and identify potential threats that may impede development. Timely identification of these threats will allow for an early introduction of effective management actions. Such actions may include the implementation of remedial works strategies or the modification of existing management practices to prevent impacts worsening.

A Trigger Action Response Plan (TARP) has been included in the 2017 MOP. This TARP will be further developed following approval of the Project and included subsequent MOP / RMP to provide guidance on appropriate and timely response. The TARP identifies potential trigger events or indicators, and the appropriate response strategies to be implemented should those triggers be realised. Likely threats to be addressed in revised TARP may include:

Soils, Geology & Erosion

- Poor quality / insufficient topsoil due to natural deficiency or poor management preventing establishment of desired vegetation communities;
- Erosion leading to degradation of growth medium and rehabilitation;
- Major geotechnical failure of overburden emplacements and void walls, such as slumping or subsidence;
- Failure of water management structures (or natural drainage lines), leading to erosion, unstable landform and potential pollution;
- Targeted land capability class not met by rehabilitated landform and soils;

Biological and Environmental factors

- Insufficient, poor quality or incorrect species seed / seedlings leading to poor vegetation establishment;
- Inadequate weed control, leading to extreme weed competition preventing establishment of desired species;
- Vertebrate predation of juvenile vegetation and / or insect attack, disease infestation causing premature vegetation die-back;
- Poor vegetation development leading to simplified, non-stratified community structure of poor habitat value;
- Severe and / or prolonged drought leading to widespread failure of revegetation;
- Uncontrolled bush fire events leading to widespread failure of revegetation areas;
- Major Storm event resulting in flooding, geotechnical instability, major erosion and / or widespread damage to rehabilitation areas.

Table 15: Rehabilitation domain rehabilitation objectives.

Rehabilitation Domain Name	Functional Objective	Rehabilitation Phase					
		Decommissioning	**Landform Establishment**	**Growth medium Development**	**Ecosystem and Land Use Establishment**	**Ecosystem and Land Use Sustainability**	**Relinquishment**
Primary Domains							
1. Infrastructure Area	Safe, stable, free-draining and non-polluting landform. Suitable for rehabilitation to native woodland. Select infrastructure retained to facilitate continued site access and support post-mining land use.	Infrastructure not required for post-mining use decommissioned and demolished. Contamination assessment completed, with contamination and contaminant sources removed or managed.	Landform slopes <10º or assessed as geotechnically stable. Accessible for rehabilitation, and suitable for rehabilitation to native woodland or post-mining land use. Surface free-drains to sediment control structure, with no ponding or significant erosion.	See secondary domains: A - Native Woodland Area, for the majority of the rehabilitated Infrastructure area, or F - Infrastructure, for residual access roads and residual post-mining structures			
2. Waste Lime Storage / Emplacement Area	Safe, stable and non-polluting encapsulation of waste lime materials.	No (wind or water) migration of waste material from emplacement area. Area capped with 1.5m of inert overburden to prevent risk of future exposure.	Capped emplacement surface merges seamlessly with adjacent landform, sheds water and drains to sediment control structure. Landform suitable for rehabilitation to native woodland.	See secondary domain A - Native Woodland Area			
3. Water Management Areas	Receive and store water for operational use, or temporarily hold surface catchment run-off for sediment control purposes.	Water management structure not required for post-mining use decommissioned and backfilled or demolished.	Water management structures to remain post mining assessed as geotechnically stable, meeting water quality	See secondary domain E - Water Management			

Rehabilitation Domain Name	Functional Objective	Rehabilitation Phase					
		Decommissioning	Landform Establishment	Growth medium Development	Ecosystem and Land Use Establishment	Ecosystem and Land Use Sustainability	Relinquishment
			requirements, and meeting selected land use function.				
4. Overburden Emplacement Areas	Stable, safe, free draining and non-polluting landform capable of sustaining a native woodland vegetation community.	Emplaced landform generally matches maximum RL and contours shown in relevant MOP / RMP plans.	Slopes reshaped to designed contours and gradients < 1:3 to 1:6. Benches and drainage structures incorporated and functioning as designed. Landforms shed water, and drain to sediment control structures. Landform surfaces accessible and able to be rehabilitated.	See secondary domain A - Native Woodland Area			
5. Stockpiled Material Areas	Temporary storage of stockpiled materials within infrastructure areas (raw materials, processed materials and waste materials).	Infrastructure demolished and potentially contaminating materials removed / scalped. Compacted surface layers ripped or capped to ensure nearsurface material compatible with rehabilitation.	Landforms shed water, and drain to sediment control structures. Landform surface merges seamlessly with adjacent landform, is accessible and able to be rehabilitated.	See secondary domain A - Native Woodland Area			
6. Open Cut Void	Void landforms safe, stable and non-polluting. Void preferentially available for overburden emplacement or	Slopes and benches shaped to match stability criteria presented in Table 17. All sources of potential	Ramps, slopes and benches determined as stable from geotechnical assessment. Void provides water capture, temporary	See secondary domains: C – Final void, general safety and stability treatment for the residual void, or D - Visual screening, for the void perimeter and in-void vegetation screens			

Rehabilitation Domain Name	Functional Objective	Rehabilitation Phase					
		Decommissioning	Landform Establishment	Growth medium Development	Ecosystem and Land Use Establishment	Ecosystem and Land Use Sustainability	Relinquishment
	short-term water detention.	contamination removed. Safe access to void maintained, while unauthorised access controlled.	holding (and potentially filtration treatment) capacity. Void perimeter and upper benches accessible and suitable for vegetation establishment.				
7. Rehabilitation Areas	Native woodland community of variable density and function enhancing slope stability and visual amenity.	Ongoing monitoring and maintenance	Variable, but generally safe, stable, non-polluting, and conforming to adjacent landscape.	See secondary domain B – Trees over Grass			
Secondary Domains							
A - Native woodland areas	Resilient and self-sustaining native woodland community providing slope stability, biodiversity enhancement and visual amenity.	See relevant primary domains: 1. Infrastructure Area 2. Waste Lime Storage / Emplacement Area 4. Overburden Emplacement Areas, or 5. Stockpiled Material Areas		Where used, topdressing material (meeting EC, pH and ESP criteria) placed as per erosion risk: *Low risk:* 10cm depth topdressing material. *Mod risk:* 10cm depth good quality topsoil. *High risk*: Rock / soil mulch. Or suitable ameliorant (i.e. OGM) used as per industry leading practice.	Vegetation established, with species mix reflecting species composition of open native woodland. Controls implemented to prevent interference with rehabilitated areas. Monitoring program expanded to ensure representative coverage.	Vegetation community composition (including key species) and structure developing towards reference site as per LFA monitoring. Evidence of reproduction (setting viable seed, flowering or F1 plants establishing).	Sufficient monitoring evidence to indicate woodland community exhibiting essential ecosystem processes, landform stabilisation, habitat enhancement and visual screening.

Rehabilitation Domain Name	Functional Objective	Rehabilitation Phase					
		Decommissioning	Landform Establishment	Growth medium Development	Ecosystem and Land Use Establishment	Ecosystem and Land Use Sustainability	Relinquishment
B - Trees over Grass – landform stability	Resilient and self-sustaining vegetation community, promoting visual screening, landform stability and erosion control.	See primary domain 7. Rehabilitation Areas		Where used, topdressing material (meeting EC, pH and ESP criteria) placed as per erosion risk: *Low risk:* 10cm depth topdressing material. *Mod risk:* 10cm depth good quality topsoil. *High risk*: Rock / soil mulch. Or suitable ameliorant (i.e. OGM) used as per industry leading practice.	Vegetation established, with species mix reflecting species composition of open native woodland. Controls implemented to prevent interference with rehabilitated areas. Monitoring program expanded to ensure representative coverage.	Vegetation community composition (including key species) and structure developing towards reference site as per LFA monitoring. Evidence of reproduction (setting viable seed, flowering or F1 plants establishing).	Sufficient monitoring evidence to indicate woodland community exhibiting essential ecosystem processes, landform stabilisation, habitat enhancement and visual screening.
C - Final void	Resilient and self-sustaining native dominated tree / shrub community (where vegetation establishment achievable) providing landform stability and habitat value.	See primary domain 6. Open Cut Void		Inert weathered material used to establish growth medium on non-flooded flat surfaces. Or suitable ameliorant (i.e. OGM) used as per industry leading practice.	Native grass, shrub and tree species established on non-flooded level surfaces.	Diverse native woodland tree and shrub community developing, with no evidence of vegetation failure or widespread premature senescence. Evidence of reproduction observed.	Sufficient monitoring evidence to indicate diverse native woodland community essential exhibiting ecosystem processes and landform stabilisation and habitat enhancement.
D - Visual screening	Resilient and self-sustaining dense to moderately dense native woodland vegetation community, with mid-storey and	See primary domain 6. Open Cut Void		As for C- Final void	Native grass, shrub and tree species (with key canopy and mid-storey species) established on void perimeter	Visual screening vegetation moderately dense to dense, with no evidence of vegetation failure or widespread	Sufficient monitoring evidence to indicate diverse native woodland community exhibiting essential ecosystem

Rehabilitation Domain Name	Functional Objective	Rehabilitation Phase					
		Decommissioning	Landform Establishment	Growth medium Development	Ecosystem and Land Use Establishment	Ecosystem and Land Use Sustainability	Relinquishment
	canopy providing visual screening.				and upper benches and ramps.	premature senescence. Evidence of reproduction observed.	processes, landform stabilisation and visual screening.
E - Water management	Receive and store water for selected post-mining land use, or temporarily hold surface catchment run-off for sediment control purposes.	See primary domain 3. Water Management Area		Placement of 10 cm of topdressing material (meeting EC, pH and ESP criteria) on outer batters of dams, drains or other infrastructure slopes with high erosion risk.	Erosion control groundcover vegetation established on water management infrastructure slopes. No trees to be established where roots may penetrate and compromise water holding / carrying capability of structures.	Mix of tree and shrub species establishing and groundcover > 70% for erosion control. No evidence of vegetation failure. Water management structure inspected periodically and assessed as functional. Significant water holding structures assessed periodically as safe and geotechnically stable.	Sufficient monitoring evidence to indicate groundcover vegetation resilient and self-sustaining and providing landform stabilisation function. Water management structures assessed as necessary, functional, safe and stable. Arrangements made to meet ongoing management requirements.

Table 16: Provisional completion criteria developed from 2018-2023 MOP.

Rehabilitation Element	Indicator	Criteria
Landform Stability	Slope Gradient	▪ Where the slopes are steeper than 10°, additional water management structures will be utilised (as required). ▪ Where hostile material is present and exposed, the landform is capped with a minimum of 1.5m of inert material and be free draining.
	Erosion Control	▪ Erosion control structures are installed at intervals commensurate with the slope of the landform. ▪ Dimensions and frequency of occurrence of erosion rills and gullies are generally no greater than that in reference sites that exhibit similar landform characteristics.
	Surface Water Drainage	▪ Use of contour banks and diversion drains to direct water into stable areas or sediment control basins. ▪ All landforms will be free draining except where specific structures (i.e. dams) have been constructed for the storage of water as required for sediment and erosion control or some post mining land-use.
Topsoil	Salinity (Electrical Conductivity)	▪ Soil salinity content is <0.6 dS/m.
	pH	▪ Soil pH is between 5.5 and 8.5.
	Sodium Content	▪ Soil Exchange Sodium Percentage (ESP) is <15%.
	Nutrient Cycling	▪ Nutrient accumulation and recycling processes are occurring as evidenced by the presence of a litter layer, mycorrhizae and / or other microsymbionts. Adequate macro and micro-nutrients are present.
Vegetation	Land Use	▪ Area accomplishes and remains as healthy native woodland
	Surface Cover	▪ Minimum of 70% vegetative cover is present (or 50% if rocks, logs or other features of cover are present).
	Species Composition	▪ Subject to proposed land use, comprise a mixture of native trees, shrubs and grasses representative of regionally occurring woodland where possible
	Resilience to Disturbance	▪ Established species survive and / or regenerate after disturbance. ▪ Weeds do not dominate native species after disturbance or after rain. Pests do not occur in substantial numbers or visibly affect the development of native plant species.
	Sustainability	▪ Species are capable of setting viable seed, flowering or otherwise reproducing. Evidence of second generation of shrub and understorey species. ▪ Vegetation develops and maintains a litter layer evidenced by a consistent mass and depth of litter over subsequent seasons. ▪ No evidence of premature die back or senescence.
Fauna	Vertebrate Species	▪ Representation of a range of species characteristics from each faunal assemblage group (e.g. reptiles, birds, mammals), present in the ecosystem type, based on pre-mine fauna lists and sighted within the three-year period preceding mine closure. ▪ The number of vertebrate species does not show a decrease over a number of successive seasons prior to mine closure.
	Invertebrate Species	▪ Presence of representatives of a broad range of functional indicator groups involved in different ecological processes.
	Habitat Structure	▪ Typical food, shelter and water sources required by the majority of vertebrate and invertebrate inhabitants of that ecosystem type are present, including: a variety of food plants; evidence of active use of habitat provided during rehabilitation such as nest boxes, and logs and signs of natural generation of shelter sources including leaf litter.
Water Quality		▪ As per water quality trigger values presented in Project Surface Water Assessment and regulatory limits.
Safety		▪ Risk assessment has been undertaken in accordance with relevant guidelines and Australian Standards and risks reduced to levels agreed with the stakeholders.

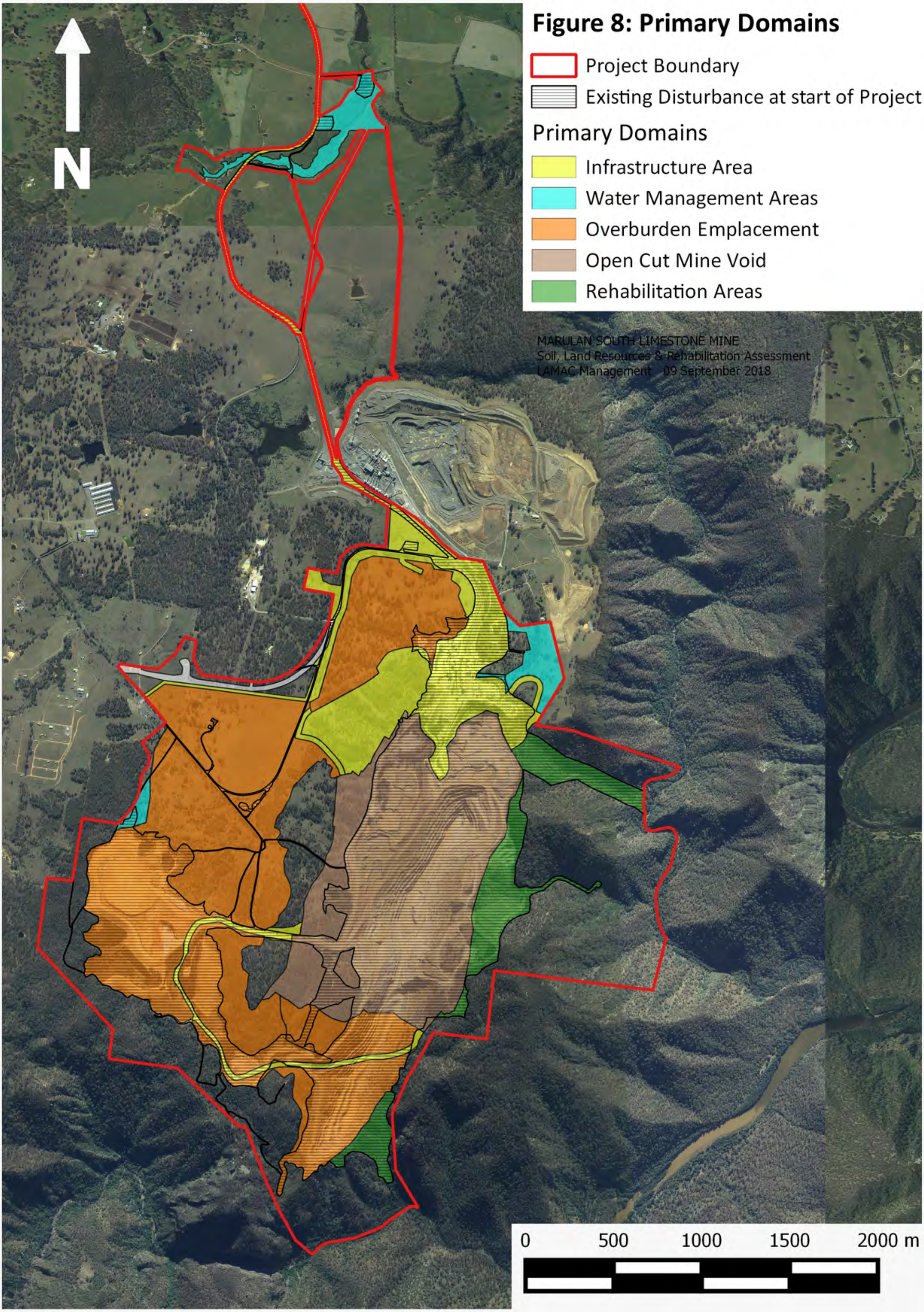


Figure 8: Primary Domains

Figure 9: Secondary Domains

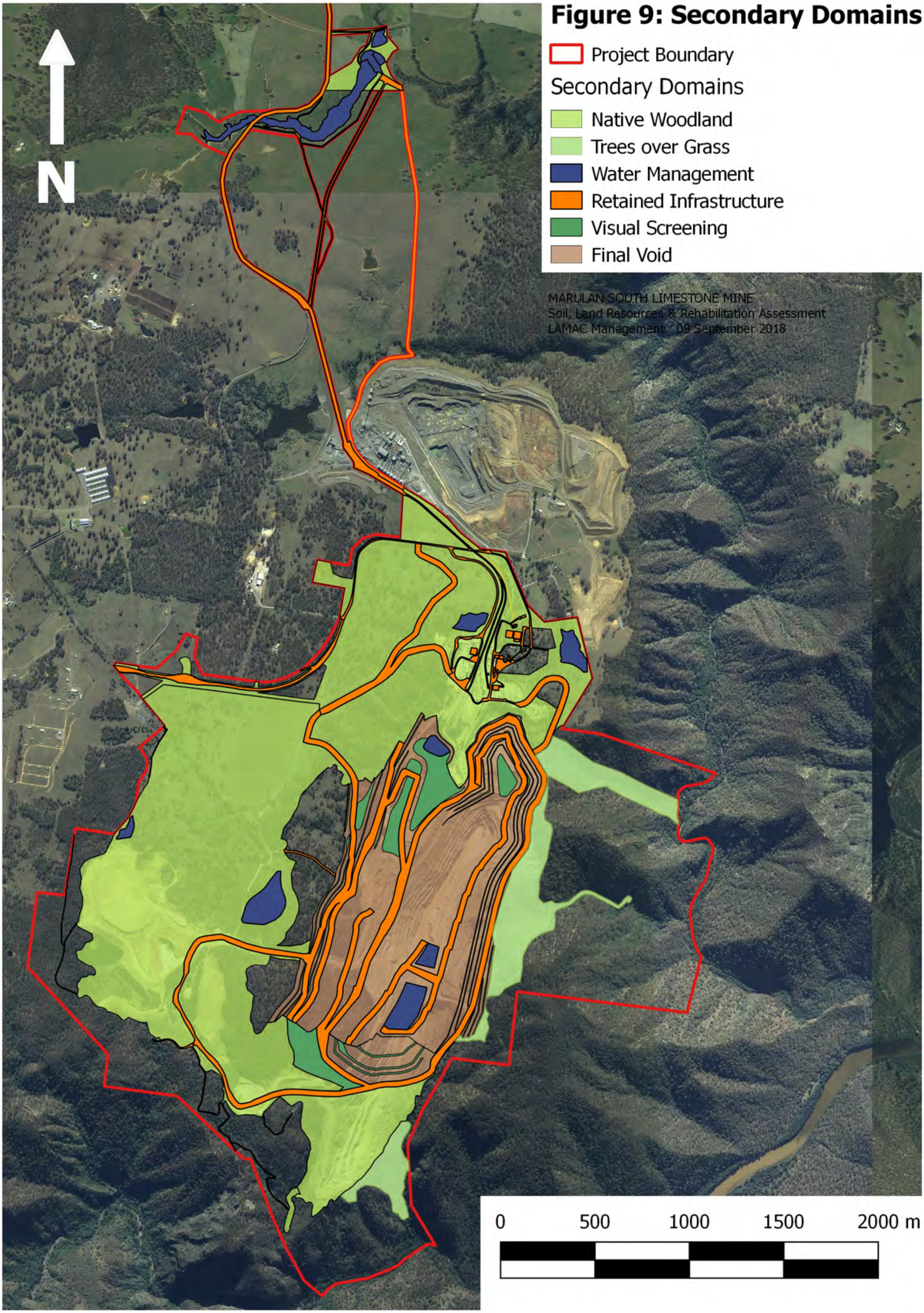


Figure 10: 3D visualisation of final landform (end of Stage 4) from Bungonia Lookdown

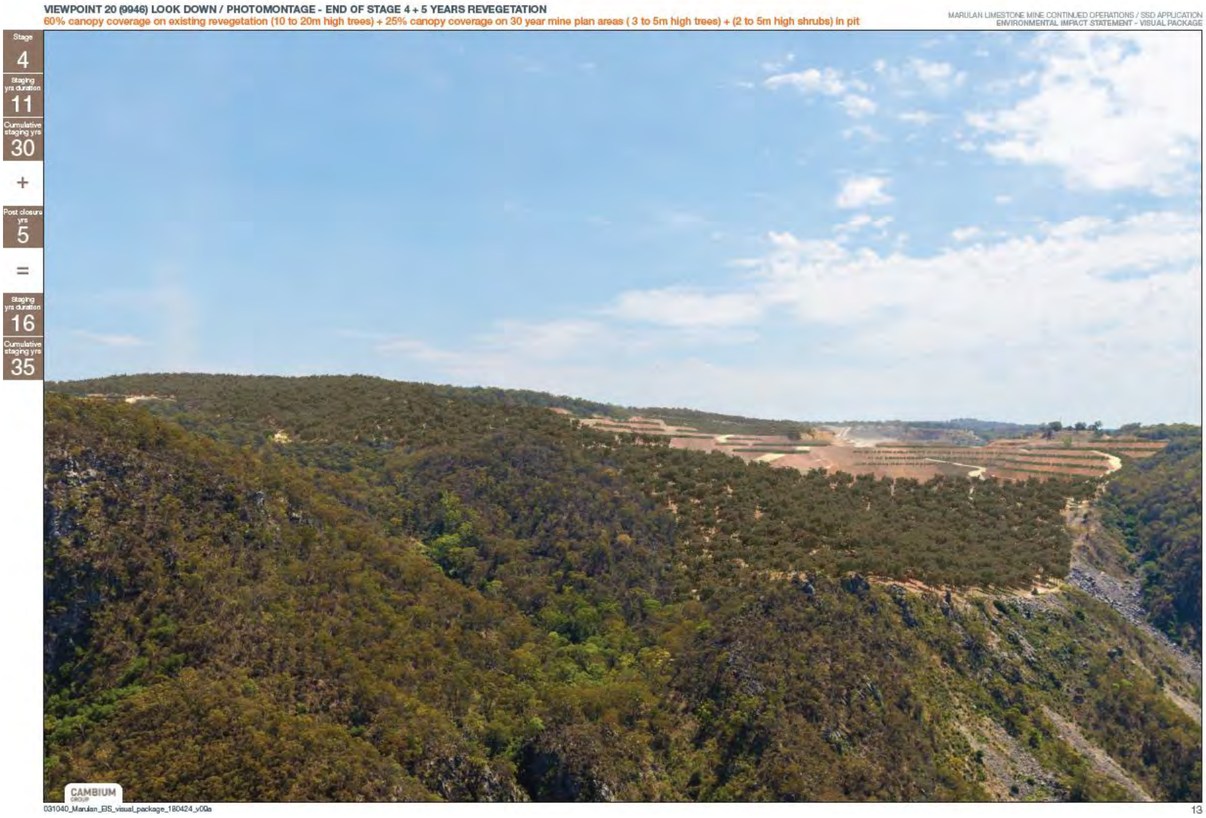


Figure 11: 3D visualisation of final rehabilitation (end of Stage 4 plus five years) from Bungonia Lookdown

4.5. Proposed Rehabilitation Method

Rehabilitation of mining-disturbed land is proposed as part of Project activities, with the majority of rehabilitation being completed progressively during Stages 1 – 3, as overburden emplacements reach final design limits. Other areas, such as infrastructure and the open cut pit, will be required until end of mine life (end of Stage 4), and will be rehabilitated during post-mining decommissioning works. Staging plans for scheduled Project disturbance and rehabilitation are presented in **Appendix 3**.

The standard methodology proposed for each phase of rehabilitation across Project-related land disturbance is discussed in Section 4.5.1, along with variations proposed to address domain-specific issues and requirements. These proposed rehabilitation methods represent leading industry practice for comparatively sized mine sites, and should result in the successful establishment of vegetated landforms that meet selected rehabilitation objectives and are suitable for proposed post-mining land uses.

The methods outlined are general, and final rehabilitation methodology will be determined during detailed rehabilitation planning, in consultation with experienced rehabilitation specialists (within Boral, or external) and in response to field monitoring and trials.

4.5.1. Standard Rehabilitation Methodology

4.5.1.1. Decommissioning

The decommissioning phase will involve the disconnection and removal of utilities and services, and the decommissioning, demolition and removal of infrastructure not required to support post mining land uses.

The footprint of decommissioned infrastructure will be cleared of structures and foreign material including scrap metal, bitumen, concrete and potentially contaminated material. Detailed contamination assessment and remediation will also occur during this phase, along with the removal of residual waste products.

The site will be secured to ensure public safety.

4.5.1.2. Landform Establishment

Landform establishment consists of re-contouring completed mine landforms, such as overburden emplacements, to the selected final landform design as indicated in the Stage 4 design. Reshaping will result in a stable landform, incorporating slopes, benches and drainage features that blend in with the surrounding natural topography. For overburden emplacements, this consists of three main activities – bulk shaping, final trim and drainage construction. The final mine void treatment is considered separately.

Bulk Shaping

Overburden transported from the open cut during mining will generally be placed according to the approximate shape of the developing, final emplacement design. The outside slopes of the WOBE and NOBE will generally be reshaped to gradients of between 15% (1:6) and 20% (1:5) and are considered moderate erosion risk due to their moderate gradient, elevation (up to RL 655) and potential visibility from surrounding vantage points. Emplacement upper surfaces are considered low risk erosion due to their lower gradients, and will be re-contoured to a slightly domed shape to promote visual relief consistent with adjacent natural topography, avoid surface ponding and facilitate drainage.

The SOBE, is assessed as the highest erosion risk landform due to its steep gradients, proximity to Bungonia Creek and Bungonia National Park, and prominence when viewed from the Bungonia Lookdown. Once reshaped, the landform will extend from RL350 to RL635, and consist of slope gradients up to 33% (1:3) with 10m wide benches approximately 15 to 20 m in elevation to reduce slope length, provide emplacement stability and facilitate access for further rehabilitation treatment.

During emplacement and bulk reshaping, material exhibiting hostile characteristics (such as acidity, excessive alkalinity, salinity or sodicity) will be identified, placed at depth and covered with at least two metres of inert material, isolating it from future vegetation root zones preventing exposure during bulk reshaping.

Drainage
Until an adequate vegetation cover is established, heavy rainfall may cause erosion and soil loss from reshaped mine landform surfaces. To reduce erosion potential, primarily from the outer slopes of overburden emplacements, slope length will be reduced by the construction of graded banks that intercept and divert water off the slopes. These banks will report to protected drop structures (grass or rock lined) that drain water safely from the landform, to a series of sediment detention and water storage structures. Hydrological engineers have been engaged by Boral to assess surface water management requirements for the Project, including design of overburden emplacement drainage, and sediment control structures. Hydrological assessment findings and erosion / sediment control specifications are presented in the Marulan South Limestone Mine Continued Operations Project Surface Water Assessment (Advisian, 2018).

Final trim
Once bulk reshaping and drainage construction is completed, reshaped surfaces will be subject to final trim, ripping and (where required) rock raking. The final trim smooths out any wash-outs, rough edges, temporary access tracks, locally steep topography and prepares the surface for revegetation. Ripping loosens up any near surface strata compacted during placement, aiding root penetration during vegetation establishment. Ripping, where safe and practical, should be done along the contour to reduce erosion potential. Rock-raking removes large surface rocks, uncovered during ripping, that may impede subsequent rehabilitation works.

On the higher risk steep batters (slope gradients exceeding approximately 26% or 1:3.7), rehabilitation machinery access will be limited to the benches, and inter-bench slopes will need to be contour-notched with a long reach excavator (instead of contour ripping) to provide surface texture. Alternatively, contour-notching can be achieved by dozer blade, with dozers working up / down slope.

For the decommissioned Infrastructure Area, and other relatively level surfaces where minimal bulk reshaping will be required, final trim should incorporate sufficient local relief to avoid uniform, straight or completely level surfaces, merge seamlessly with the surrounding topography, avoid unintentional ponding and ensure controlled runoff of surface water.

Final Void
As the surfaces and slopes consist mainly of consolidated limestone rock, and the landform is internally draining, landform establishment for the final void varies significantly from the standard methodology. The Project groundwater assessment (AGE, 2018) and surface water assessment (Advisian, 2018) investigated the hydrological impacts of Project activities, including the impacts associated with the open cut void and modelling of long term water balance in the residual open cut void. It is predicted that the void will only temporarily hold water, and is highly unlikely to fill or overtop Void water quality is predicted to be moderately alkaline. Therefore erosion and drainage

control is not as a significant risk requiring management such as the adjacent overburden emplacements.

Geochemical characterisation (RGS 2015) included in the ground water assessment (AGE 2018) did not identify any potentially hostile geological strata, nor has any been encountered during mining to date. However, water quality sampling and testing in accordance with the site water monitoring programme will continue to assess pit water quality.

Mine void slopes have been assessed by a suitably qualified geotechnical engineer and will be treated as per recommendations provided in the geotechnical assessment report (PSM, 2018) to minimise slope failure risk. Bench and inter-ramp slopes are currently designed considering the angles recommended in **Table 17**.

Table 17: Recommended void slope design (PSM, 2018).

UNIT	BENCH SLOPE ANGLE	BENCH HEIGHT	BERM WIDTH	INTER-RAMP SLOPE ANGLE
Extremely Weathered Sediments	50°	15m	9m	35°
Eastern & Western Sediments	60°	15m	9m	40°
Highly Weathered Limestone*	65°	15m	8m	45°
Eastern Limestone East wall North of 614 7300 N	65°	15m	8m	45°
Eastern Limestone elsewhere to above	75°	15m	7m	54°

For those areas outlined in Section 4.1.2, where revegetation is proposed as part of void treatment, surfaces should be ripped or notched (where safe and practical to do so) to de-compact surface material, promote root growth and enhance water infiltration.

4.5.1.3. Growth Medium Establishment

The establishment of a vegetation community, especially groundcover species, is essential in reducing erosion of sloping landforms. A significant contributor to the successful vegetation establishment is the careful development of a good quality growth medium layer.

Growth medium refers to the surface layer of inert, fertile material established over less suitable material to facilitate improved vegetation establishment. Typically, this layer consists of natural topsoil material (A1 horizon) stripped ahead of ground disturbance, but may consist of subsoils, organic mulches, weathered geological strata, or even geochemically suitable overburden material as a rock mulch.

Topsoil Availability

Where possible, the growth medium layer should consist of the loamy A1 horizon topsoil stripped ahead of Project related disturbance, and the steep slopes of the SOBE should be the priority for use of stripped natural topsoil. Topsoil, or alternative growth media, will be placed and spread to a depth of 10cm, with the exception of proposed drop-structure locations.

As discussed in Section 3.2.4 and summarised in **Table 11**, it is estimated that a maximum of approximately 215,510 m^3 of topsoil material is available for stripping ahead of Project ground disturbance.

As a gross Project topsoil balance, it is recommended that 70,000 m^3 of this material be reserved for use in top-dressing the 70 ha (at 10cm depth) high erosion risk SOBE slopes, leaving approximately 145,510 m^3 for use on the moderate erosion risk outside slopes of the NOBE and WOBE. These emplacement outer slopes cover 117 ha, which will result in a topsoil demand of 117,000 m^3 if spread to 10cm depth. This will leave approximately 28,580 m^3 surplus topsoil material for use on lower gradient slopes. Opportunities for topsoil savings may result from drop structures and vehicle access tracks, which will not require topsoil placement, and lower gradient slopes could be used to trial alternate surface cover material. On the steeper inter-bench slopes of the SOBE, an approximately 2:3 mix of soil and competent coarse rock may also be used as a surface mulch to assist in protecting slopes from erosion, while providing a medium for seed germination. Where this soil / rock is used, it will also reduce the volume of topsoil required.

Alternative Growth Media

An overall topsoil deficit will require alternative material to establish a growth medium across lower gradient emplacement surfaces and the relatively level gradients of the Infrastructure domain.

Due to the lower erosion risk associated with the internally draining final mine void, it is also unlikely that topsoil will be required for establishment of a growth medium. However, sufficient weathered overburden material should be available (following geochemical characterisation to ensure suitability) to allow for spreading over bench areas proposed for revegetation establishment. This material should be ripped, or notched, to create seedbed micro-relief and promote infiltration.

The two most likely sources of alternative growth medium materials are decomposed granite from Peppertree Quarry and a rocky weathered shale material from mine overburden. Inspections of existing rehabilitation indicated that the rocky weathered shale resulted in good tree germination rates, but the decomposed granite was more useful at establishing groundcover vegetation (with a more sparse tree stem density). This assists with selection of most appropriate material, with groundcover establishment being of greater importance for erosion protection on slopes, while the rocky weathered shale material may be of more benefit in establishing a woodland vegetation community on low gradient emplacement surfaces, final void benches and the Infrastructure Area.

Where growth media is sourced from deeper regolith strata (such as decomposed granite or rocky weathered shale), the material is likely to be deficient in the soil nutrients and biological processes required for successful soil development and sustainable plant growth. Incorporation of a readily available composted organic material, such as Organic Growth Medium (OGM), may compensate for these deficiencies and assist homogenise plant establishment results across a range of variable materials. Any growth medium material not assessed in this SLRRA (or material stockpiled for more than five years), whether sourced internally or externally, should be subject to a basic characterisation program to ensure suitability and identify amelioration requirements.

Growth Media Management

Ameliorants, if required, should be applied to the trimmed overburden surface prior to growth media establishment. At a minimum, gypsum should be applied at a rate of approximately 5-10 t/ha to assist in treating sodic, poorly structured or heavy clay material. If access restrictions prevent surface application, ameliorants can be mixed with the proposed growth medium material before placement and spreading.

Once the growth media layer is established, it should not be excessively trafficked in order to prevent compaction. To reduce material loss from wind and water erosion, the period between establishment and seeding should also be minimised. Where a discrete growth media layer is established, it should be lightly contour tined or disc cultivated along the contour to create a "key" between media and underlying spoil. This creates micro-relief that promotes infiltration. Best results will be obtained by ripping when the material is moist and when undertaken immediately prior to sowing. Where slope angle precludes the safe use of dozers, the surface should be deeply notched by dozer blade or digger bucket.

On the steeper inter-bench slopes of the SOBE, where slope gradient prevents paddock dumping and spreading of growth medium material, windrow placement of suitable material at the top of the batter should be undertaken. Dozer pushing from the top, or pulling down with a long reach excavator from the bottom, can then be undertaken to spread soil evenly across the slope. The same mobile plant can contour-notch the spread material to achieve surface roughness prior to sowing.

As a deficit of good quality topsoil is predicted for the Project rehabilitation activities, it is important that a good topsoil management strategy be implemented to ensure topsoil is not lost, degraded or wasted before being used where it is most needed.

Opportunities for direct topsoil placement will be prioritised in the scheduling of topsoil stripping operations. Direct placement increases soil biological and physical health, greatly increasing its value in rehabilitation. Early in the Project life, as overburden emplacements are being developed, temporary stockpiling of topsoil will be unavoidable. However, as operations progress and scheduling allows, final landform slopes should be reshaped to allow for direct placement.

At the beginning of each planning / reporting year, growth medium requirements will be estimated for rehabilitation programs in the upcoming year, and adequate topsoil or topdressing resources allocated to meet that requirement. Appropriate material will be selected, based on proximity of stockpiles to rehabilitation area, age and quality of topsoil, vegetation community type at the topsoil source (i.e. native grassland or native woodland) compared to selected rehabilitation outcomes, and direct placement opportunities.

If the stockpiled topsoil is old (greater than five years) an assessment of topsoil quality should be undertaken. Such an assessment may include visual inspection, field testing or laboratory analysis to determine whether the material is still usable, and whether application of supplements and / or ameliorants may be required. Sufficient evidence of a stockpile's loss of inherent value will need to be recorded, and approved by the Site Manager, before a stockpile was spoiled or abandoned.

A topsoil inventory (or register) will be maintained to ensure tracking of topsoil stripping, stockpiling and usage. This inventory should be updated at least annually via a topsoil survey and balance. It is useful to complete the topsoil survey / balance towards the end of the reporting year, to allow for inclusion of the updated balance in an Annual Environmental Management Report or Annual Rehabilitation Report. The survey / balance should generally include the:

- Survey (ground survey or aerial) of all new or modified topsoil stockpiles;
- Calculation of stockpile volumes, and balance against topsoil recovery and usage for the reporting year;
- Verification of topsoil stockpile volume reductions, by checking against rehabilitation areas completed for the reporting year;
- Balance of topsoil inventory, against predicted topsoil requirements, for the remainder of the;
    - MOP period, and

  - o Mine operational life.
- Inspection of all topsoil stockpiles, to assess stockpile integrity and identify maintenance actions required, such as weed spraying, new signage, and erosion control.

Management recommendations for recovery and stockpiling of topsoil, as part of rehabilitation operations onsite, are presented in **Appendix 5**.

4.5.1.4. Ecosystem and Land Use Establishment

The major benefits of rehabilitating mining-disturbed land (such as improved erosion control, increased biodiversity value, agricultural productivity or visual screening) result from the successful re-establishment of a diverse and sustainable vegetation cover. A landscape as topographically and climatically variable as the Project site may require several complementary revegetation techniques to achieve successful vegetation establishment. There is no single-option solution for revegetation and, as indicated in **Appendix 4**, numerous strategies have been trialled historically within the Project site. The relative advantages of the relevant revegetation techniques, as they pertain to rehabilitation within the Project site, are discussed in the following sub-sections.

As with all revegetation programs, careful planning and preparation will greatly increase the likelihood of success. The existing site wide weed control program will be extended into newly established rehabilitation to assess and, where required, treat weeds before vegetation establishment. Weed treatment is currently undertaken by contractors and may include chemical or mechanical weed control. Residual soil herbicides should be avoided as they can persist in soil and kill young trees.

Except where a surface rock mulch is proposed, ground preparation activities such as deep ripping, surface cultivation or notching of slopes will be undertaken before vegetation establishment. Rip lines and other forms of cultivation should always run parallel to the slope contour to avoid channelized gullying.

Direct seeding

Direct seeding is usually the most effective and cost-efficient method of vegetation establishment. Project rehabilitation areas will generally be seeded manually (by hand) or mechanically (tractor / dozer and spreader). Supplementary methods may be used where required, such as aerial seeding (by fixed wing or rotary wing aircraft) for remote areas, or hydroseeding / hydromulching for difficult to access slopes or where rapid vegetation establishment is important.

Direct seeding usually results in establishment of vegetation that exhibits greater density (stems/ha) and species diversity, and requires less post-establishment maintenance (including watering) than other methods. Vegetation established via direct seeding is also usually more climatically tolerant and resilient, and will usually out-grow tube stock vegetation in the long term.

The relatively harsh climate and topography of the Project site will require careful consideration when choosing a seed mix. Any rehabilitation and revegetation strategy needs to refer to relevant flora and fauna studies and previous rehabilitation performance when compiling a species list. Many variations have been trialled previously, and examples of typical seed mixes (native woodland and erosion control) that performed well are presented in **Appendix 6**. These are not definitive, and should be reviewed in response to revegetation monitoring and performance.

For native woodland rehabilitation, a seeding rate of 5 - 7 kg/ha will be applied after mixing with fertiliser and / or a bulking agent. In areas adjacent to conservation reserves, this rate may need to be increased to offset losses from native / pest herbivores. The mix is typically in the ratio of approximately 40% shrub seed and 60% tree seed. A light cover crop of sterile annual groundcover species should also be sown in conjunction with native seed in order to assist early soil stabilisation.

Surface water management structures, such as contour benches and grass-lined drains, should be sown with pasture species at a rate of 50-60 kg/ha to encourage rapid groundcover establishment.

Hydroseeding (and hydromulching)
Hydro-mulching (potentially supplemented by tube stock planting) is the recommended method for high erosion-risk steep slopes where equipment access is limited to benches and where rapid establishment of a vegetation cover is essential for landform stability. Hydroseeding is a specialist technique usually requiring engagement of contractors, with cost efficiency highly dependent on proximity to good quality water required as an ingredient for the spray emulsion. Where small areas require rapid vegetation establishment, an on-site hydro-seeding machine is available for use. However, for larger areas, a hydro-seeding contractor is recommended. Hydro-mulching should be undertaken immediately after site preparation (contour ripping or notching by excavator or dozer blade) when the surface is still freshly scarified.

Tube Stock
Revegetation by tube stock planting is particularly useful where specific species are required in a specific location, such as visual screens, windbreaks or filling existing vegetation gaps. Tube stock revegetation can also be used to supplement existing rehabilitation, where species composition requirements for targeted vegetation communities have not been achieved. However, tube stock planting will generally only be used as a supplementary revegetation method, due to the increased establishment and maintenance requirements relative to seeding.

Although initial growth may be rapid, tube stock require greater management input to establish, including ground ripping (for decompaction and water capture), manual planting, watering or irrigation, weed control and protection from browsing. Greater care also needs to be taken when scheduling tube stock planting, as seedlings are more susceptible to extreme heat, cold or dry conditions. Over the long term, vegetation established via seeding usually displays greater diversity, resistance to disease, resilience following disturbance, tolerance of climatic variability, and (despite the head-start experienced by tube stock) faster growth rates.

When sourcing tube stock, smaller seedlings should be selected as they have lower maintenance requirement and are not as prone to weather extremes. Hardened tube stock (given survival watering only and exposed to weather in nursery) should be used to assist with conditioning plants prior to planting.

Cleared Vegetation and Seedbank
Topsoil stripped from woodland areas ahead of Project-related disturbance will generally contain a natural seedbank in the top 3 – 5 cm. This seedbank can be useful for vegetation re-establishment, especially where direct placement of topsoil is possible. Native trees and shrubs have also been known to re-establish from roots and saplings transported with stripped topsoil. Where feasible, direct placement of topsoil, and integration of cleared vegetation debris, will be practiced during the disturbance of woodland areas.

The existing program of seed collection from onsite stands of remnant native vegetation will also be continued, to provide a source of seed for use in rehabilitation.

Biodiversity value in rehabilitated native woodland vegetation can also be increased by recovering trees with hollows (and other potential habitat features including logs, stumps, stags and boulders) during clearing and placing these features on rehabilitated land. This requires a considerable degree of prior planning to execute well, but does encourage early faunal colonisation of rehabilitated areas.

Where native woodland vegetation is to be cleared for Project development, the area will be assessed for potential habitat resources available for potential recovery. Concurrently, areas that may potentially benefit from the inclusion of these resources will also be assessed. An evaluation will be made regarding the feasibility and overall benefit of recovering and re-using those resources in the rehabilitated landscape.

4.5.1.5. Ecosystem and Land Use Sustainability

Once new areas of rehabilitation are established, the existing regime of assessment and maintenance will be expanded to incorporate those areas, to determine whether revegetated landforms and communities are developing towards meeting the selected success criteria and, if not, identify what remedial actions may be required to re-establish that development pathway.

To ensure the immediate protection of newly rehabilitated areas, adequate signage, fencing and barriers will be established to isolate those areas from unintentional interference. Administrative safeguards have also been integrated into the mine planning process to ensure rehabilitation is not disturbed.

The existing rehabilitation monitoring program, as outlined in Section 4.4.1.1 will be used to assess existing and future rehabilitation areas. As well as formal monitoring, regular inspections of new rehabilitation are undertaken until vegetation cover is sufficiently established. Inspections identify areas of concern and required remedial works such as weed and pest control, repair of wash-outs and gullies, or supplementary planting.

Livestock grazing is not a selected post-mining land use for the Project area and livestock have been excluded from rehabilitated land, which will assist vegetation to properly establish prior to introduction of grazing pressures. However, if grazing of rehabilitation was proposed in the future, controlled grazing trials should first be established to determine suitability before any grazing being introduced more widely or permanently.

Eastern Batters

The rehabilitated steep slopes to the east of the open cut mine void (Bryces Overburden Emplacement and Barbers Creek Overburden Emplacement) were identified during the Project preliminary risk assessment as representing a potential high risk of failure due to slope steepness and surface water drainage contributing to slope erosion on both emplacements. Geotechnical assessments of slope stability and failure potential for both emplacements were subsequently completed (PSM, 2015; PSM, 2017), which identified that mass movement or failure of the existing eastern slopes is unlikely. However, gullies on the lower slopes indicate a self-propagating cycle of erosion, undercutting and slumping.

The initial SLRRA investigated remedial options for increasing general vegetation cover across the existing Eastern Batter overburden emplacement slopes, as a means of reducing runoff and promoting greater erosion control. However, following an incident in 2018, Boral has entered into discussions with NSW EPA and DPE-DRG regarding the development of a remediation strategy for managing erosion on these overburden emplacements.

4.5.1.6. Relinquishment

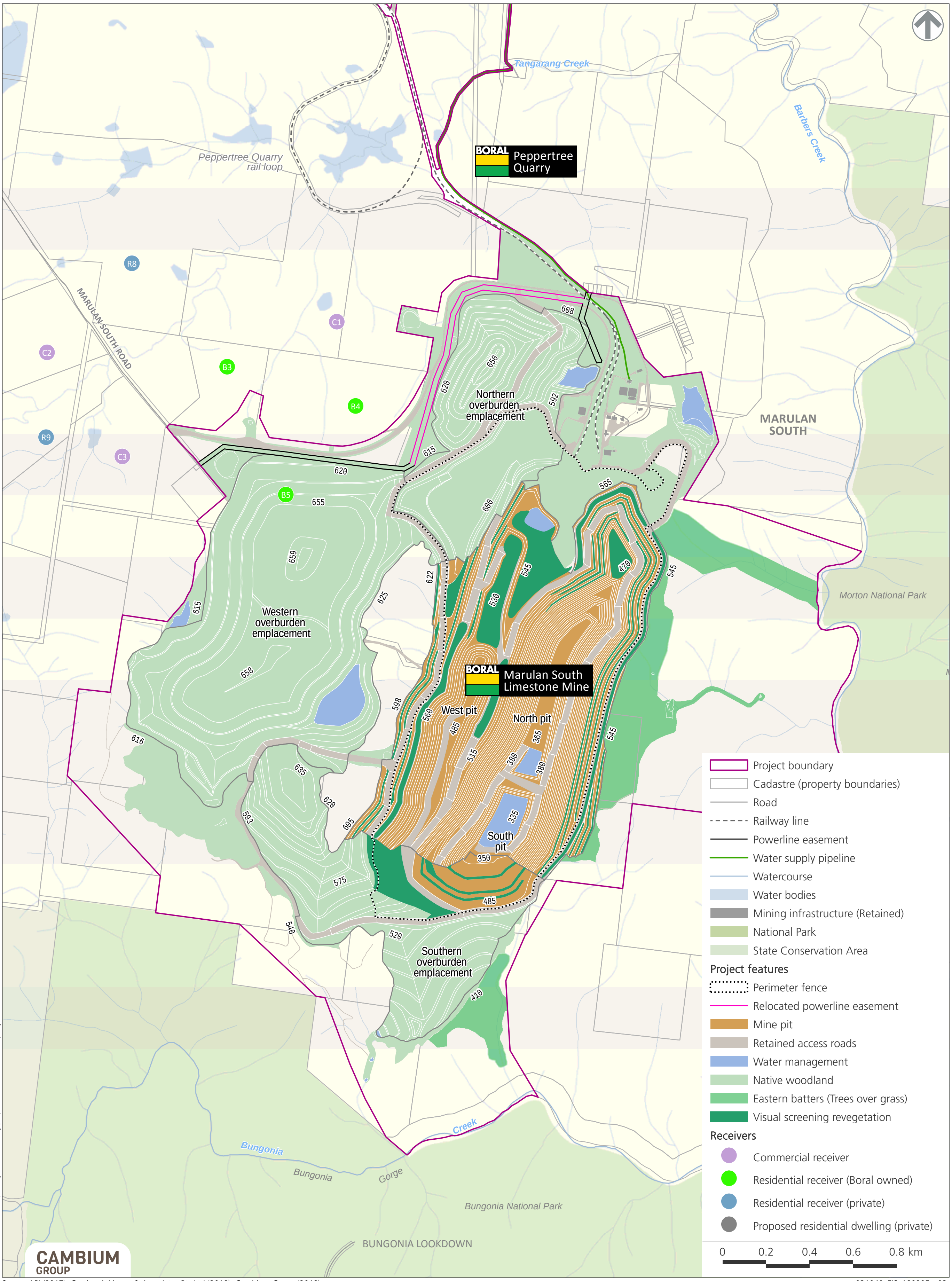
While it is likely that the Project area will be used for further resource development post the 30-year Project period, as discussed in Section 4.1, individual sections of rehabilitation within the site may be assessed as having reached the Relinquishment phase towards the latter stages of the Project life.

Once monitoring indicates rehabilitated areas are well into the Ecosystem and Land Use Sustainability phase, and on the right development trajectory to meeting all general and domain-specific success criteria, as presented in the MOP / RMP, then consideration for an application to DPE-DRG will be made to initiate the relinquishment process. Sufficient evidence will be compiled to demonstrate how the rehabilitation under relinquishment application (a) meets the success criteria, and (b) is suitable for the agreed post-mining land use.

Figure 12

The Project - Final landform

MARULAN SOUTH LIMESTONE MINE CONTINUED OPERATIONS - SSD APPLICATION
ENVIRONMENTAL IMPACT STATEMENT

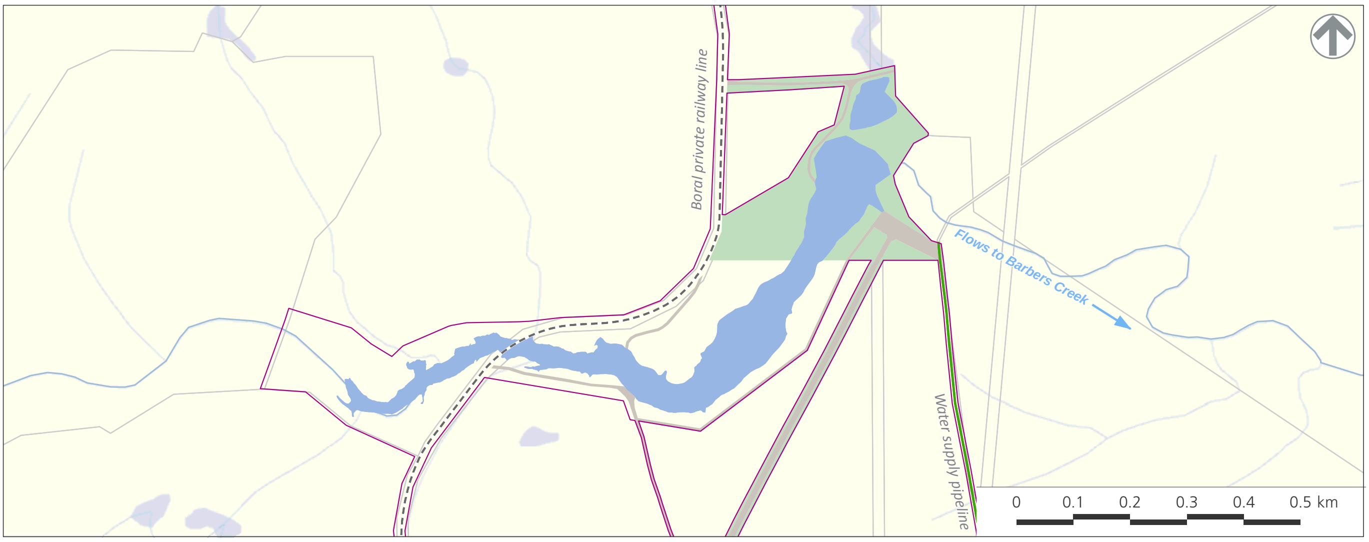


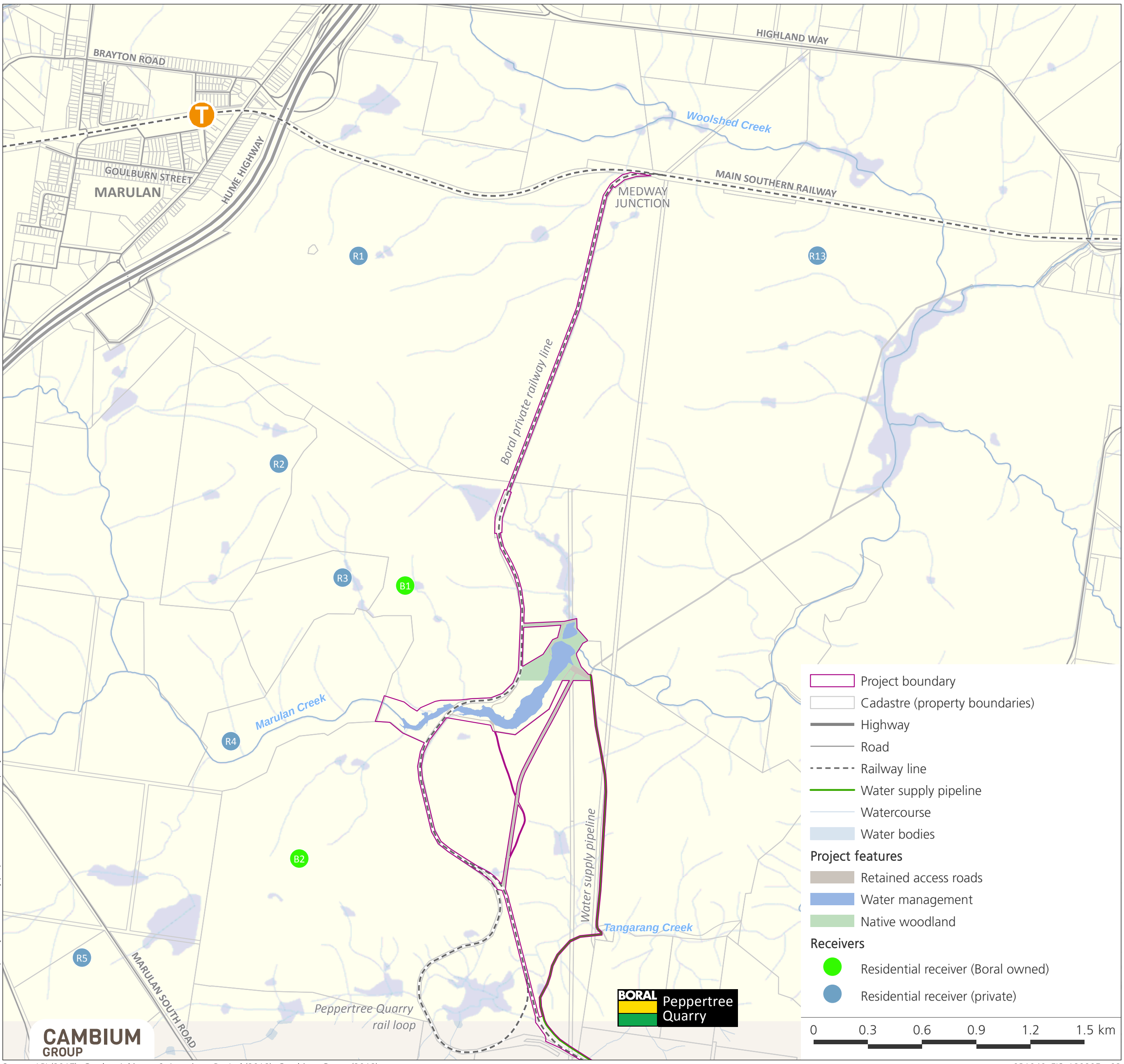
Source: LPI (2017), Gordon Atkinson & Associates Pty Ltd (2018), Cambium Group (2018).

031040_EIS_180905_v03

Figure 13
The Project - Final landform (Marulan Creek Dam)

MARULAN SOUTH LIMESTONE MINE CONTINUED OPERATIONS - SSD APPLICATION
ENVIRONMENTAL IMPACT STATEMENT





Source: LPI (2017), Gordon Atkinson & Associates Pty Ltd (2018), Cambium Group (2018).

031040_EIS_180905_v02

5. Conclusion

This report outlines the findings of the SLRRA completed for proposed Project activities. The SLRRA consisted of a soils and land capability assessment of the existing Project site, and an assessment of existing and proposed rehabilitation. An assessment of the Project site against BSAL verification criteria was also completed.

The SLRRA identified no particularly hostile soils, subsoils or overburden material in the proposed disturbance footprint that would require special management. Six soil landscape units within the Project site were identified and mapped, consisting of:

- 143.5 ha Sodosols (Red / Brown);
- 11.5 ha Kurosols, Brown;
- 119.9 ha Tenosols (Bleached-Orthic / Brown-Orthic);
- 229.0 ha Tenosols / Rudosols (Steep Slopes);
- 2.5 ha Rudosols (Alluvial); and
- 340.0 ha Disturbed / Anthroposols

Topsoil stripping depths of 10cm were recommended for the Sodosol and Tenosol soil landscape units within the southern section of the assessment area, and 15cm for Sodosol soils within the northern section of the assessment area and Kurosols within the southern section of the assessment area. 215,510 $m^{208,}$ of good quality topsoil was identified as available for stripping within the Project site. Potential alternate top-dressing materials were also identified, if required.

No BSAL was identified within the Project site (which was certified by DP&E in consultation with OEH, by issuing a Site Verification Certificate dated 17 November 2015), and impact on existing agricultural resources is expected to be minor. Land Capability Classes of land within the Project site are summarised below as:

- 155 ha Class V: Moderate to low capability land;
- 120 ha Class VII: Very low capability land;
- 231 ha Class VIII: Extremely low capability land; and
- 340 ha Not Assessed: Mining disturbed land.

Section 4 of this SLRRA outlined the conceptual Project rehabilitation and mine closure strategy, post-mining land use, conceptual final landform design and strategic rehabilitation considerations.

The rehabilitation and mine closure strategy anticipates that operations could continue beyond the initial 30-year Project period with a further 110 million tonnes of limestone available for mining. As continuation of mining following the 30-year Project life is a likely option, post mining land is currently considered in conceptual terms, particularly in regard the mine void. Further development of final land use over the Project life will be guided by regulatory approvals and consultation with local interested parties.

The 30-year mine development considers both “above ground” and “in-pit” options for overburden emplacement to achieve a balance between resource utilisation and long term environmental considerations - especially visual impacts of the rehabilitated landform. At the end of Project reshaped emplacements (which will occupy approximately 242 ha of the total 598 ha disturbance footprint) will be the likely final landforms, even if mining should continue past the current 30-year Project life.

The post mining land use goal for the overburden emplacements is the re-establishment and development of native woodland vegetation communities that reflect the existing ecological communities identified in the Project biodiversity assessment (Niche, 2018)

If mining were to cease towards the end of the proposed 30-year Project life, potential post-mining use options for the final 156 ha mine void include:

(a) temporary water storage;

(b) landfill / backfill capacity, including additional overburden emplacement or metropolitan infrastructure projects; or

(c) potential recreation area consistent with adjacent State administered conservation and recreation areas.

A conceptual final landform design has been developed as detailed in Section 4.1.2 to guide the post mining land use planning process and assist in the development of rehabilitation objectives.

An assessment of historic rehabilitation at the site also identified several key constraints to establishing rehabilitation within the Project site, including:

- *Soil pH conditions*: The overall limited availability of topsoil material suitable for use in rehabilitation is exacerbated by elevated pH levels exhibited in the overburden materials used as growth medium layers to date. This has impeded the successful development of a growth medium layer that can support rehabilitation.
- *Steep slopes*: Although overburden emplacements have been designed to mimic adjacent natural steep slopes, landform steepness has contributed to rehabilitation establishment issues in some emplacements, leading to potential derivative impacts of erosion and downstream water quality impacts.
- *Climate*: Highly variable and irregular climatic conditions hinder rehabilitation development. Such conditions include hot summers, cold winters and periodic droughts. It is important to plan towards rehabilitation in the traditional windows of Spring and Autumn, but allow flexibility in long term rehabilitation planning to allow for drought periods.
- *Water supply*: Rehabilitation success has been impacted upon by water shortages following good initial germination. Irrigation trials have been set up previously, with mixed success.
- *Environment*: Local environmental factors resulting from mine location have impeded rehabilitation establishment. Such factors include browsing by herbivorous pests such as goats and rabbits, native macropod species, as well as weed competition.

For planning purposes, proposed rehabilitation areas within the Project site were grouped into primary and secondary rehabilitation domains, consisting of:

Primary Domains (operational land management units)

1. Infrastructure Area;
2. Waste Lime Storage / Emplacement Area;
3. Water Management Areas;
4. Overburden Emplacement Areas;
5. Stockpiled Material Area;
6. Open cut Mine void); and
7. Rehabilitation Areas.

Secondary Domains (rehabilitation management land units)

A – Native Woodland Areas
B – Trees over Grass – landform stability
C – Final Mine Void
D – Visual Screening
E – Water Management
F – Infrastructure

Rehabilitation objectives for each rehabilitation domain were outlined in **Table 15**, for each of the rehabilitation phases:

1. Decommissioning;
2. Landform Establishment;
3. Growth Medium Development;
4. Ecosystem and Land Use Establishment
5. Ecosystem and Land Use Sustainability; and
6. Relinquishment.

Provisional completion criteria (developed from the 2018-2023 MOP) are included as presented in **Table 16**.

Rehabilitation methodology was recommended for each of these rehabilitation domains, with native woodland being recommended as the predominant final vegetation cover, with 327 ha being rehabilitated to this community. Vegetation will also be established around the perimeter, and on the upper benches, of the final void primarily for visual screening purposes. The proposed SOBE was identified as potentially the highest erosion risk rehabilitation domain, due to the moderately steep slopes and proximity to sensitive receptors such as Bungonia Creek and adjacent publicly administered conservation areas.

5.1. Recommendations

The following rehabilitation objectives were recommended as applicable to all rehabilitation domains.

- Rehabilitated land will be geotechnically stable and will not present a greater safety hazard than surrounding land to land-users, public, livestock and native fauna accessing or transiting the post-mining area.
- Land capability will, at a minimum, be returned to a class similar to that existing prior to Project commencement (Class V, VII or VIII).
- Except for mine void, mined land will be visually compatible with the surrounding natural landscape.
- Rehabilitated landforms will be designed to shed water without causing excessive erosion or increasing downstream pollution.
- Rehabilitated landforms will not negatively impact visual amenity for nearby residents and users of conservation reserves.

These general objectives were supplemented by objectives specific to each rehabilitation domain, which will be used to derive detailed specific rehabilitation progress indicators and completion criteria, for inclusion in subsequent site MOP / RMP.

Subject to local constraints, topsoil resources identified in the soil assessment should be stripped and handled with care to minimise the expected deficit in topsoil material. Any alternative top-dressing material sourced to address this topsoil deficit should be characterised through geochemical assessment before being used in rehabilitation.

The proposed SOBE should be the priority for rehabilitation planning and resource allocation, including topsoil placement. Given the access and slope constraints, specialised techniques have been recommended to rehabilitate this emplacement.

A geotechnical investigation of the Eastern Batters identified that, while mass movement failure was not likely, management works will be required to manage the existing erosion gullies on these emplacements. A remedial management strategy for the existing Eastern Batters is subject to continuing discussions with state regulatory authorities.

With careful management, adequate land resources should be recoverable from within the proposed area of Project disturbance to successfully rehabilitate the final landform, meet the rehabilitation objectives and achieve the proposed final land use.

5.2. Limitations

This report has been prepared for Boral to meet the assessment objectives and scope described in the report. Responsibility will not be accepted for any other use, or user.

The findings and recommendations presented are based on conditions observed and information reviewed at the time of assessment. Conditions may change subsequently and responsibility is not accepted for any such changes.

The findings and recommendations presented are based on conditions observed at specific locations and sites, according to assessment scope and methodology. Conditions at other parts of the site may be different from those observed.

This report was prepared based on Project information provided by Boral and other EIS assessment companies. Liability is not accepted for inaccurate conclusions or recommendations caused by errors or omissions in that information.

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Appendix 1 – Geology Samples Laboratory Report

Department of Primary Industries
Soil Conservation Service

SOIL TEST REPORT

Scone Research Centre

REPORT NO:	SCO15/032R1
REPORT TO:	Lachlan Crawford LAMAC Management Pty Ltd 33 Lerra Road Windella NSW 2320
REPORT ON:	Four soil samples
PRELIMINARY RESULTS ISSUED:	Not issued
REPORT STATUS:	Final
DATE REPORTED:	16 March 2015
METHODS:	Information on test procedures can be obtained from Scone Research Centre

TESTING CARRIED OUT ON SAMPLE AS RECEIVED
THIS DOCUMENT MAY NOT BE REPRODUCED EXCEPT IN FULL

SR Young

SR Young
(Laboratory Manager)

SOIL CONSERVATION SERVICE
Scone Research Centre

Report No: SCO15/032R1
Client Reference: Lachlan Crawford
LAMAC Management Pty Ltd
33 Lerra Road
Windella NSW 2320

Lab No	Method	P7B/2 Particle Size Analysis (%)					P8A/2	P9B/2	C6A/2	C1A/5	C2A/4	C2B/4	
	Sample Id	clay	silt	f sand	c sand	gravel	D%	EAT	OC (%)	EC (dS/m)	pH	pH Cacl$_2$	Texture
1	03A	12	13	24	26	25	5	n/a	0.11	0.07	8.7	7.1	Loam
2	05-1/2	14	25	13	11	37	55	2(1)	0.02	0.16	8.7	7.3	Silty loam
3	06-1/2	8	13	22	8	49	4	6	0.06	1.61	8.2	7.4	Loam
4	08-2	40	18	11	10	21	0	6	0.22	0.43	6.2	5.8	Clay

n/a – not available

END OF TEST REPORT

Appendix 2 – BSAL Assessment Report and Site Verification Certificate

MARULAN SOUTH LIMESTONE MINE CONTINUED OPERATIONS PROJECT

Assessment of Biophysical Strategic Agricultural Land (BSAL)

LAMAC Management, October 2015

Document Control

Document Title	Marulan South Limestone Mine Continued Operations Project – BSAL Assessment
General Description	Assessment of Project site against BSAL verification criteria

Rev No	Date	Description	By	Checked
0	06 September 2015	Draft	L.Crawford	N.Hattingh
1	10 October 2015	Final	L.Crawford	D.McKenzie

TABLE OF CONTENTS

1. Introduction

The Marulan South Limestone Mine (the mine) is an existing open cut mining operation situated in Marulan South, 10 km southeast of Marulan village and 35 km east of Goulburn, within the Goulburn Mulwaree Local Government Area in the Southern Tablelands of NSW.

Limestone mining and lime manufacturing has occurred on the site since 1875, with the current mine having been in continuous operation since 1953. The mine has produced up to 3.38 million tonnes of limestone and lime-based products per year for the cement, steel, agricultural, construction and commercial markets. The mine is owned and operated by Boral Cement Limited (BCL).

The mine currently operates under Consolidated Mining Lease (CML) 16, Environment Protection Licence 944, a combination of development consents issued by Goulburn Mulwaree Council and continuing use rights. BCL is seeking approval for continued operations at the site through a development application for a State Significant Development (SSD) including a 30 year mine plan, associated overburden emplacement areas and a mine water supply dam (hereafter referred to as 'the Project').

LAMAC Management Pty Ltd has been engaged by BCL to undertake a soils, land and rehabilitation assessment, as part of the SSD approval process. A component of the SSD approval process is the completion of a Biophysical Strategic Agricultural Land (BSAL) verification assessment in support of a Site Verification Certificate (SVC) application for the Project area.

This BSAL assessment report has been prepared in accordance with the *Interim Protocol for Site Verification and Mapping of Biophysical Strategic Agricultural Land* (NSW Government 2013) (interim protocol).

1.1. Project Area

The mine is located in a rural area bordered by extractive industry (Peppertree Quarry) to the north, Bungonia National Park and State Conservation Area to the South, Morton National Park to the East and an agricultural lime facility, fireworks storage facility and Turkey farm to the west.

The mine is situated on the edge of a plateau, approximately 560 m above the deeply incised Shoalhaven River. The terrain bordering the mine to the east and south-west is very steep with limited accessibility, characteristic of limestone environments. The land to the west and north-west of the mine (on which the BSAL assessment area is largely situated) consists of flat to undulating plateau landforms.

Local tributary gullies drain the Project area in an easterly and southerly direction to Barbers and Bungonia Creeks, which discharge into the Shoalhaven River further to the east.

The BSAL assessment area is described in greater detail in Section 3.1.

1.2. BSAL Process

The NSW government introduced a *Gateway Process* in 2013 to protect high value agricultural land from potential mining development impacts. The Gateway Process requires BSAL to be identified, and potential impacts assessed, before a development application can be lodged for mining and petroleum projects.

Under the *State Environmental Planning Policy (Mining, Petroleum Production and Extractive Industries) Amendment (Resource Significance) 2013* (Mining SEPP amendment), the Gateway process applies to the following State Significant Development located wholly or partially on BSAL:

- State significant mining development that requires a new mining lease;
- Extraction of a bulk sample of more than 20,000 tonnes of coal or any mineral ore (ie. State significant mining exploration activity);
- State significant petroleum development that requires a new petroleum production lease;
- State significant petroleum exploration activity;
- Excluding any associated development, such as linear infrastructure, outside the area of a proposed mining or production lease.

The NSW government has mapped BSAL at a regional scale to assist with preliminary identification of BSAL during project planning. Regardless of whether a project area has been regionally mapped as BSAL or not, project proponents may apply for a SVC, which certifies that a project area does not meet BSAL criteria and is, therefore, exempt from the Gateway process. Applications for SVC must be accompanied by a BSAL assessment report completed in accordance with the interim protocol.

Under clause 17A of the Mining SEPP amendment, only those parts of a project area requiring a new mining lease (under the *Mining Act 1992*) are subject to the Gateway Process. Project development on existing mining leases, or on land not proposed for a mining lease, is not subject to, BSAL assessment or the Gateway Process.

2. Method

This assessment followed the initial steps outlined in Section 5 of the interim protocol to verify the presence of BSAL. These steps consisted of:

Step 1: Identify the project area which will be assessed for BSAL;
Step 2: Confirm access to a reliable water supply;
Step 3: Choose the appropriate approach to map the soils information; and
Step 4: Risk Assess the project area with respect to the proposed development.

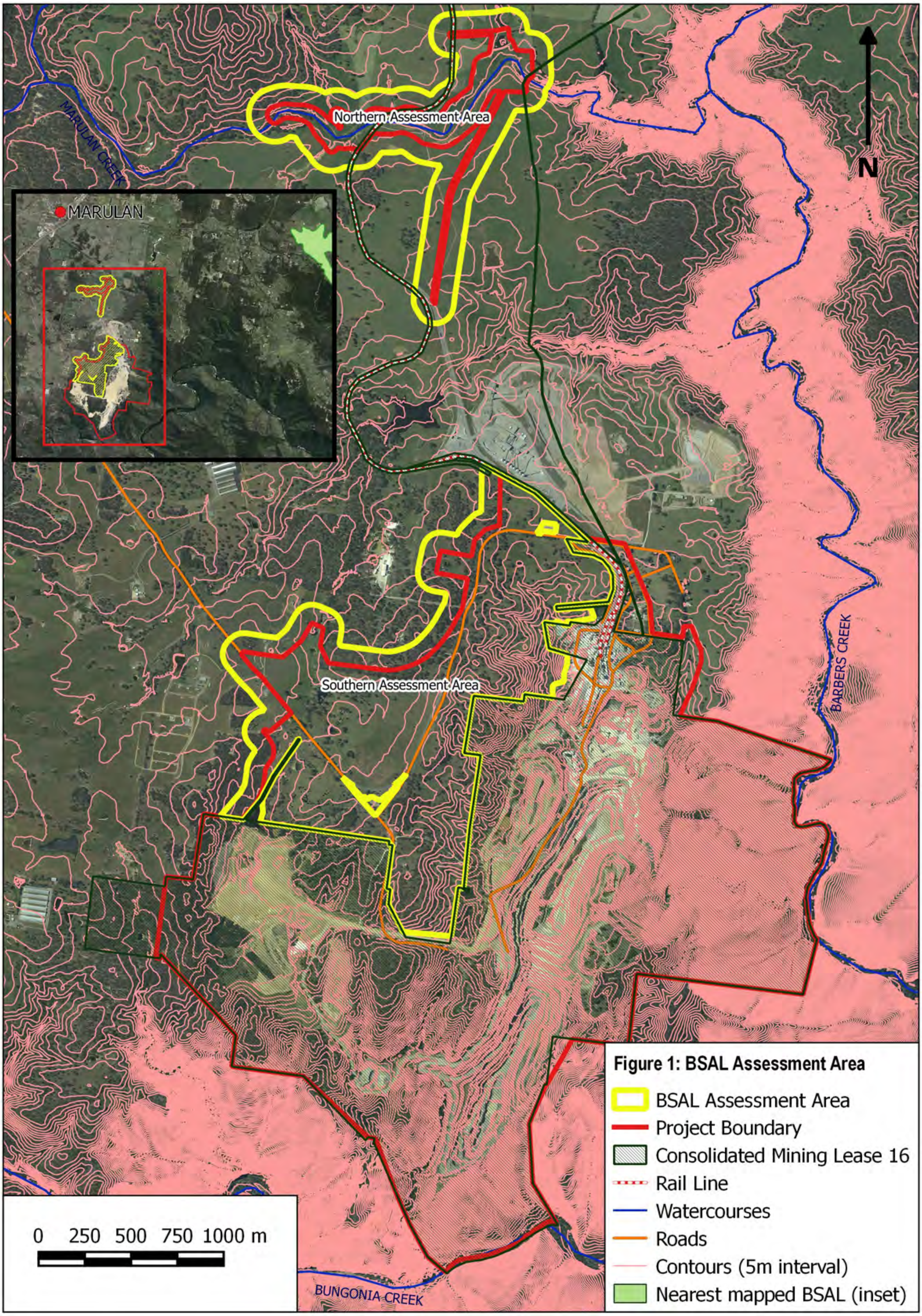
The methods used to complete these steps are presented in the following sections.

2.1. Assessment Area Definition

For the purposes of this BSAL assessment, the Project has been separated into two areas, referred to as the *Northern assessment area* and *Southern assessment area*, and are shown on Figure 1.

The Northern assessment area includes a proposed water supply dam for the Project on Marulan Creek, approximately 3km north of the mine. The Northern assessment area is defined by the likely maximum inundation level, and possible surface disturbance area resulting from the construction of the dam, including two proposed haul roads to facilitate construction access. The interim protocol also requires a 100m buffer zone around the proposed Project area to be included in the BSAL assessment area. Including this 100m buffer zone, the Northern assessment area is 94 ha.

The Southern assessment area includes land within the proposed Project boundary for the continued open cut mine operations, but excluding land within CML 16 and other areas subject to historic disturbance. The Southern assessment area was delineated by the maximum proposed surface disturbance footprint required for continued operations of the mine including expansion of the open cut pit, out of pit overburden emplacement and the construction or realignment of associated infrastructure such as Marulan South Road. Including the 100m buffer zone, the Southern assessment area is 226 ha. Therefore the total BSAL assessment area is 320 ha. The 100m buffer zone to the Project boundary required under the interim protocol represents 102 ha, or 32% of the total assessment area.



N
MARULAN
MARULAN CREEK
Northern Assessment Area
Southern Assessment Area
BARBERS CREEK
BUNGONIA CREEK
0 250 500 750 1000 m
Figure 1: BSAL Assessment Area
BSAL Assessment Area
Project Boundary
Consolidated Mining Lease 16
Rail Line
Watercourses
Roads
Contours (5m interval)
Nearest mapped BSAL (inset)

2.2. Access to Water

The interim protocol requires a property to have a reliable water supply to be classified as BSAL land.

Rainfall records are available from the Bureau of Meteorology Station at Marulan (George St) (Station 70063), located approximately 6km to the northwest of the Project Area. Rainfall data from this station indicates Annual Mean Rainfall of 709mm for the period July 1894 to May 2015. This meets the BSAL criteria for reliable water supply of rainfall of 350mm or more per annum (9 out of 10 years).

2.3. Assessment Approach

The BSAL assessment areas are situated on land owned by Boral and access was possible to both areas. Therefore, soils and landscape were assessed against BSAL verification criteria using on-site assessment.

2.4. Risk assessment

A risk assessment was completed to identify potential impact on agricultural/land resources and determine the appropriate scale of investigation. The methodology for the risk assessment followed the process outlined in the *Guideline for Agricultural Impact Statements at the Exploration Stage* (DTIRIS, 2012). This process assesses risk based on the probability of impact occurring, and the expected consequence of that impact. The interim protocol indicates that soil sampling densities can range between:

- 1 site per 25 – 400 ha for low risk; and
- 1 site per 5 – 25 ha for high risk.

Determination of appropriate investigation scale, based on risk assessment outcomes, is outlined below. Detailed risk assessment results are presented in Appendix 1.

Northern Assessment Area

Of the 94 ha investigated in the Northern assessment area, 18 ha is predicted to be impacted by the Project. This includes approximately 10 ha of inundation (at maximum dam capacity as defined by the 598m AHD contour) and up to 8 ha of disturbance related to dam construction. This 18 ha was assessed as being moderate to high risk of impact to agricultural resources. The remaining 76 ha of land within the Northern assessment area, was assessed as having a low risk of impact as it is located outside of the Project disturbance footprint. A survey density of 1 detailed site per 30 ha, with the priority of effort being centred on the high risk zone, was selected for the Northern assessment area.

Southern Assessment Area

Of the 226 ha investigated in the Southern assessment area, approximately 169 ha is predicted to be impacted by the Project. This includes approximately 164 ha of overburden emplacement and approximately 5 ha in the construction or realignment of roads and the development of the Road Sales Stockpile Area. This 169 ha is assessed as being a high risk of impact to agricultural resources. The remaining 57 ha of land within the Southern assessment area was assessed as having a low risk of impact as it is located outside of the Project disturbance footprint. An investigation density of approximately 1 detailed site per 20 ha was selected for the Southern assessment area.

2.5. Soils and Landscape Assessment

Following the completion of the four initial BSAL verification steps, an investigation of the assessment areas was undertaken to identify and map soil types, and compare soil and landscape properties with the BSAL verification criteria presented in the interim protocol. The assessment consisted of two main components: the preliminary assessment and the field assessment.

The soil and landscape assessment was completed in accordance with the requirements of the interim protocol, and following the methodology presented in Part 5 of *Guidelines for Surveying Soil and Land Resources* (McKenzie *et al*. 2008). Soil and landscape attributes were characterised using the terminology described in the *Australian Soil and Land Survey Field Handbook* (National Committee on Soil and Terrain 2009), and soil profiles were classified according to the *Australian Soil Classification* (Isbell 2002) (ASC).

2.5.1. Personnel

The planning and assessment work for this BSAL investigation was undertaken by Lachlan Crawford of LAMAC Management. Lachlan is an environmental consultant with 20 years' experience in land resource management and disturbed land rehabilitation, including numerous soil and land resource assessments for mining projects in NSW and QLD.

David McKenzie (Certified Professional Soil Scientist, Stage 3, Soil Science Australia and 'CPSS Competent in Australian Soil Survey') was engaged to audit the approach, quality and accuracy of the work completed as part of the BSAL assessment.

2.5.2. Preliminary Assessment

Before commencing the field assessment, a preliminary assessment was undertaken to produce a preliminary soil and landscape map. This assessment involved the following sources of information.

- Surface Geology Mapping (online Atlas of NSW, NSW Land & Property Information);
- Regional BSAL mapping (NSW Government 2014);
- Land and Soil Capability mapping (Office of Environment and Heritage 2013);
- Soils and landscape information contained in BCL documents;
- Aerial photography and LIDAR imagery provided by BCL; and
- Soil profile and landscape information contained in the Soil and Land Information System (SALIS), accessed via eSPADE spatial viewer.

No detailed soil mapping covers the assessment area; however, *Soil Landscapes of the Goulburn 1:250 000 sheet* (Hird, 1991) maps soil landscape units to within 800 m of the western boundary of the assessment area and was referenced for background information.

During the preliminary assessment, land within the assessment area of slope greater than 10 percent was identified using Light Detection and Ranging (LIDAR) imagery provided by BCL. Detail on the slope analysis methodology is provided in Appendix 2.

Provisional site locations for soil investigation were allocated during the preliminary assessment, based on the information discussed above.

2.5.3. Field Assessment

2.5.3.1. Reconnaissance Inspection

An inspection of the assessment areas was undertaken on the 7 April 2015 to finalise and mark out the soil investigation site locations selected during the preliminary assessment. Likely exclusion areas were identified during this inspection, based on the BSAL criteria relating to rock outcropping, surface rock fragments and gilgai presence.

2.5.3.2. Test Pits

Thirteen test pits (Sites 1 to 14, excluding Site 10) were excavated to 1.4m, or until refusal on weathered bedrock, to facilitate detailed soil profile description. Test pit locations were selected to provide even and representative coverage of the assessment areas, according to the selected investigation densities discussed in Section 2.4.

The proposed Site 10 was not investigated, as it was located within the existing CML 16 boundary.

Landscape features surrounding each test pit were photographed and described including:

- Site identification and location;
- Excavation method and depth;
- Landuse and vegetation cover;
- Slope gradient;
- Microrelief; and
- Rock outcropping.

Soil profiles were photographed and sampled, with soil profiles being described in accordance with the requirements of the interim protocol. The following soil profile attributes were recorded for each location.

- Horizon identification and lower boundary depth;
- Horizon boundary distinctiveness;
- Horizon colour and mottling;
- Field texture;
- Soil structure/ pedality;
- Field pH (using Raupach test kit);
- Soil moisture and drainage conditions;
- Coarse fragments and segregations;
- Root presence;
- Dispersion and slaking in deionised water; and
- Lower horizon carbonate presence (effervescence with 1M HCL).

Several test pits had been hand-excavated to the upper boundary of the B horizon as part of an archaeological assessment being undertaken across the Project area. Several of these pits were inspected during the field assessment, with near surface soil horizons being assessed. As these pits were only 30 cm deep, they did not meet interim protocol requirements for check sites, and are not designated as such. However, these archaeological test pits (ATP) were used, along with other surface observations (such as road, creek and erosion cuttings) to assist with delineation of soil unit boundaries. Test Pits ATP 18 and ATP 38, in particular, were used to confirm soil type along the proposed Marulan Creek Dam southern construction access road. Photographs of ATP 18 and 38 are included in Appendix 3, with locations shown on Figure 3.

2.5.3.3. Laboratory Analysis

Sixty-three soil samples were collected from test pit horizons and sent for analysis to the NATA (National Association of Testing Authorities) registered NSW Soil Conservation Service Laboratory, Scone NSW.

Samples were typically collected from depth intervals 0-5cm; 5-15cm; 15-30cm; 30-60cm; and, 60-100cm. However, minor variations in sampling interval depths did occur to ensure samples did not cross horizon boundaries.

Samples were analysed for:

- Soil pH (1:5 soil:water or 1:5 soil:$CaCl_2$);
- Electrical conductivity (EC 1:5, and calculation of ECe);
- Cation Exchange Capacity (CEC);
- Exchangeable cations for calculation of exchangeable sodium percentage (ESP) and Ca:Mg ratio; and
- Seven samples that indicated moderate to high dispersion in field testing were also tested for EAT including:
  - Site 1: 30-60 cm;
  - Site 4: 30-48 cm;
  - Site 6: 9-15 cm;
  - Site 7: 32-60 cm;
  - Site 8: 8-15 cm;
  - Site 8: 15-30 cm; and
  - Site 14: 15-30 cm.

Tabulated analytical results are included in Appendix 4, and the laboratory analysis report is included as Appendix 5.

2.5.3.4. Mapping and BSAL Verification

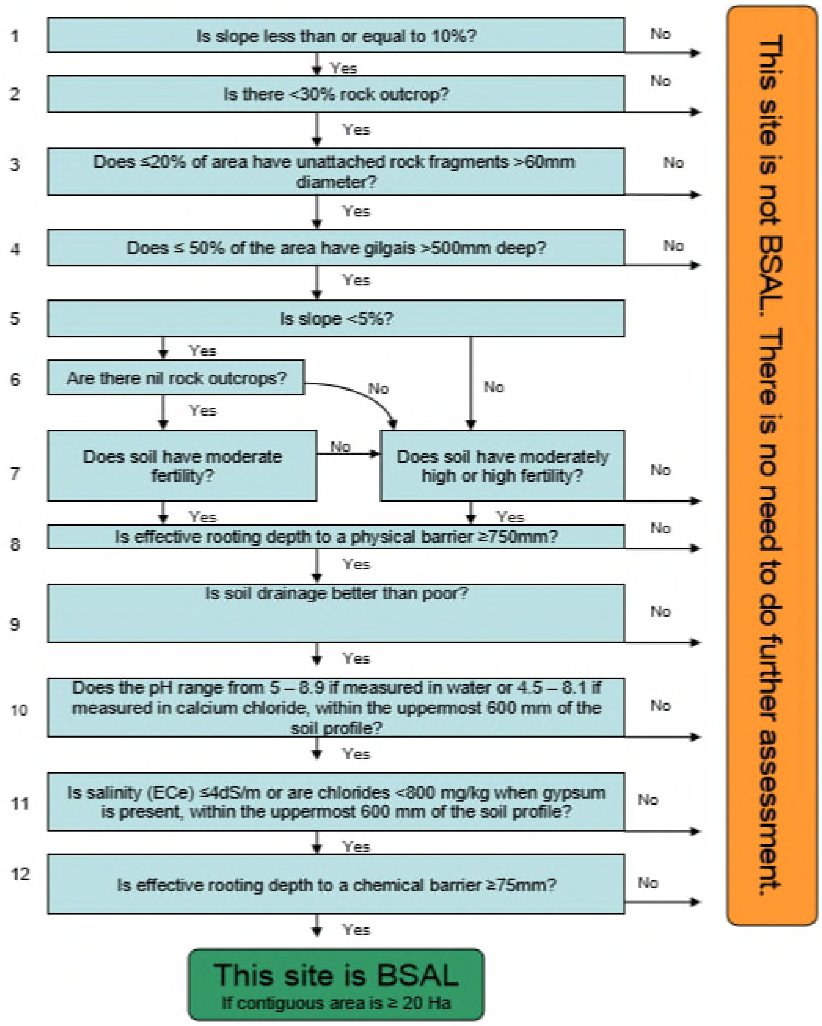
The interim protocol presents ten criteria for verifying the presence of BSAL, as shown in Figure 2, with the minimum area for BSAL being 20 ha. If soils or landform (of area > 20 ha) does not meet any one of these criteria, it is not considered BSAL.

Exclusion mapping based on the first criterion (land gradient > 10% slope) was undertaken during the preliminary assessment, and potential for exclusion due to criteria 2 to 4 (rock outcrop, surface rock fragments and gilgai) was assessed during the field assessment.

Soil profile and landscape attributes recorded during the field assessment were used to:

a) Classify soil type, using the ASC, to Family level;
b) Map soil types within the assessment areas; and
c) Compare soil and landscape attributes against BSAL verification criteria.

Figure 2: Twelve criteria presented in interim protocol to verify presence of BSAL.



3. Assessment Results

3.1. Preliminary Assessment

The following background information on soils and landscape within the assessment areas was noted during the preliminary assessment from the sources outlined in Section 2.5.2.

3.1.1. Geology

The Northern assessment area overlies the Glenrock Granodiorite intrusion. The majority of the Southern assessment area overlies a Silurian-Devonian geology unit known as the Bungonia Limestone formation, consisting of interbedded fossiliferous shale, sandstone, limestone and siltstone. Weathered granodiorite bedrock was also encountered in the far south and east of the Southern assessment area.

3.1.2. Landscape

Land and Soil Capability mapping (OEH 2013) indicates that the flat to undulating plateau that comprises the majority of the Northern and Southern assessment areas is considered *Class V: Severe Limitations - land not capable of sustaining high impact landuses without special management*. The eastern margins of the Southern assessment area, consisting of moderately steep upper slopes, are mapped as *Class VII: Extremely severe limitations – land incapable of sustaining most landuses*. The far eastern corner of the Northern assessment area, consisting of extremely steep and rocky upper slopes is mapped as *Class VIII: Extreme limitations – land incapable of sustaining any landuses*.

Slope exclusion mapping, derived from aerial photography and LIDAR imagery and prepared in accordance with the methodology presented in Appendix 2, indicates that approximately 6.9 ha (7%) of the Northern assessment area has a slope gradient greater than 10 percent. Approximately 37.7 ha (17%) of the Southern assessment area has a slope gradient greater than 10 percent. This slope exclusion mapping is presented in Figures 3 and 4.

3.1.3. Soils

A review of the background soils information listed in Section 2.5.2 indicates that texture contrast soils are dominant within the BSAL assessment area. An assessment of topsoil suitability for use in post-mine rehabilitation identified the dominant soil types in the south and east of the Southern assessment area as Yellow Duplex and Red Duplex soils (GSS Environmental, 2010).

Regional mapping of ASC soil types (accessed via eSPADE) within the BSAL assessment area identifies the following soil landscape associations:

- Kurosols, natric – lower slopes, flats and drainage depressions within the Southern assessment area;
- Sodosols – mid-slopes, upper-slopes and crests within the Northern and Southern assessment areas; and
- Rudosols/Tenosols – steep slopes in east margins of the Southern assessment area.

The SALIS database (accessed via eSPADE) identified two recorded soil profiles in the vicinity of the assessment areas. Although neither of these eSPADE soil profiles included laboratory analyses, they did include detailed descriptions. The profiles included:

Location	***ASC Classification***
50m east of northeast boundary of Southern assessment area	Brown Chromosol, - Haplic, thin, slightly gravelly, loamy, clayey, deep
350m northwest of western boundary of Southern assessment area	Brown Sodosol, -, -, thin, non-gravelly, loamy, clayey, deep

3.1.4. Mapped BSAL and Critical Industry Clusters

The 2014 BSAL mapping of NSW indicates that the nearest mapped BSAL is approximately 7.5 km to the northeast of the assessment areas. The nearest mapped BSAL land is shown on Figure 1.

Critical Industry Clusters (CIC) are concentrations of highly productive agricultural industries located within the NSW Upper Hunter, such as the equine (horse) and viticulture (wine) industries. The NSW government has mapped CIC, and potential Project impacts on CIC are assessed as part of the Gateway Process.

As CIC mapping covers only the NSW Hunter Valley, approximately 300km north of the assessment areas, mapped CIC are of no relevance to this assessment.

3.2. Field Assessment

Soil profiles at each of the 13 sites were classified according to the ASC, to Family level. Soil attributes observed during field assessment are presented in Appendix 4. The soil types identified are shown in Table 1, to Subgroup level. From these soil classifications, three soil units were identified within the assessment areas, consisting of:

- 87 ha (Northern assessment area) and 138 ha (Southern assessment area) of Brown/Red Sodosols (dominant)/ Brown Chromosol (minor) associated with mid to upper slopes across both the Northern and Southern assessment areas;
- 38.6 ha of Brown-Orthic/ Bleached-Orthic Tenosols associated with the crests and steep eastern slopes of the ridgeline in the south and east of the Southern assessment area; and
- A minor area (12.5 ha) of Brown Kurosol associated with the lower slopes, flats and depressions in the central part of the Southern assessment area.

Based on assessment of archaeological test pits ATP 18 and 38, which were exposed as deep as the upper boundary of the B horizon, soils along the proposed Marulan Creek Dam, southern construction access road within the Northern assessment area were identified as texture contrast soils, consistent with the Red Sodosols observed at nearby Site 01. On this basis, the Brown/Red Sodosol soil unit extended across the entire Northern assessment area.

The typical attributes of these soil units are described in Section 3.5, with mapped soil units shown on Figure 3.

Soil profile descriptions have been submitted via the eDIRT online data entry portal for inclusion in the SALIS database. Acknowledgements of successful submission of soil profiles are included in Appendix 6. These soil profiles will be available for viewing on the eSPADE online access.

3.3. BSAL Presence

The soil and landscape attributes of each site were compared against the BSAL verification criteria presented in the interim protocol. As indicated in Table 1, none of the 13 sites met all the BSAL criteria. Limiting factors for each soil landscape unit are discussed in Section 3.4 and major limiting factors for BSAL are shown in Figure 4.

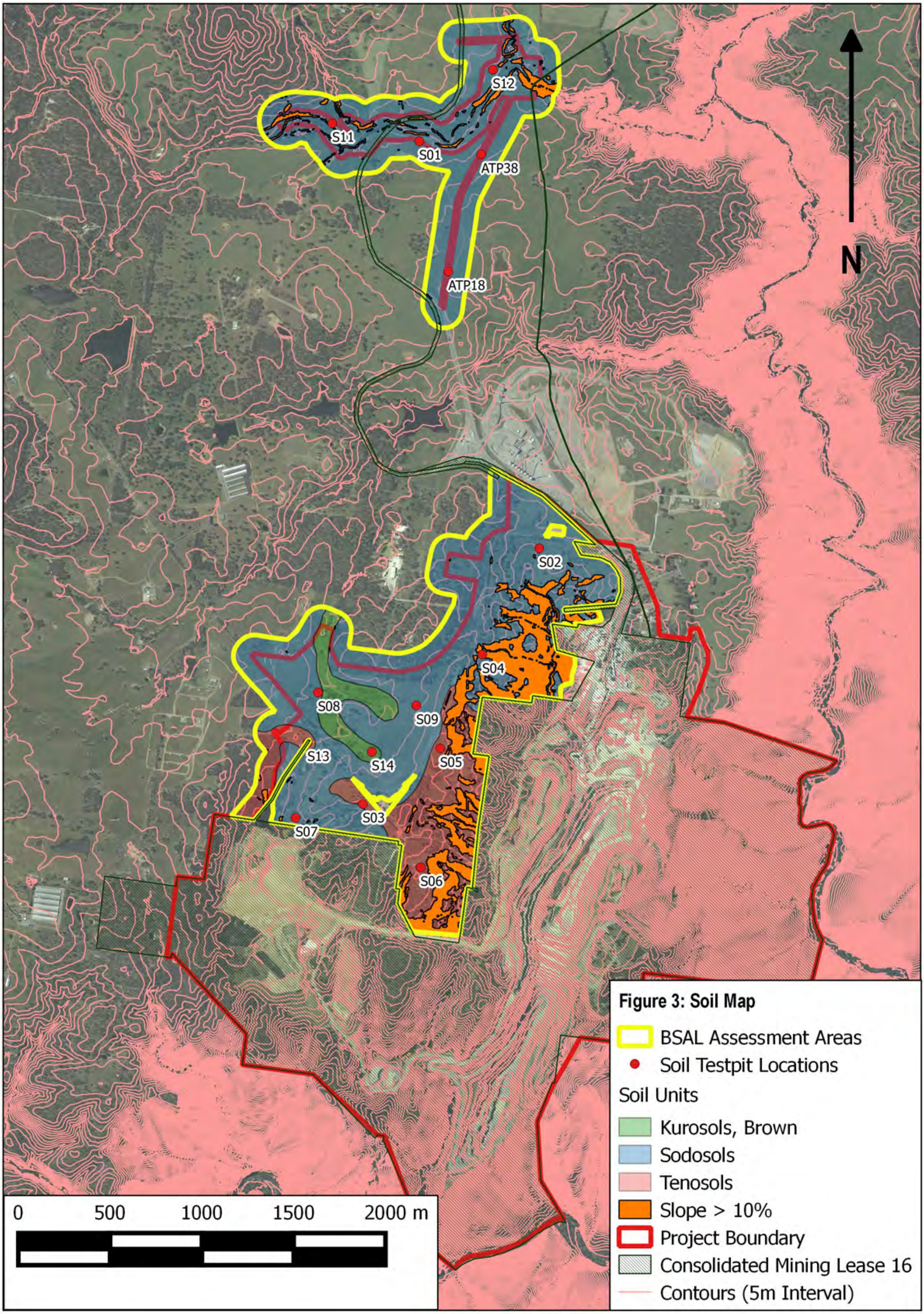
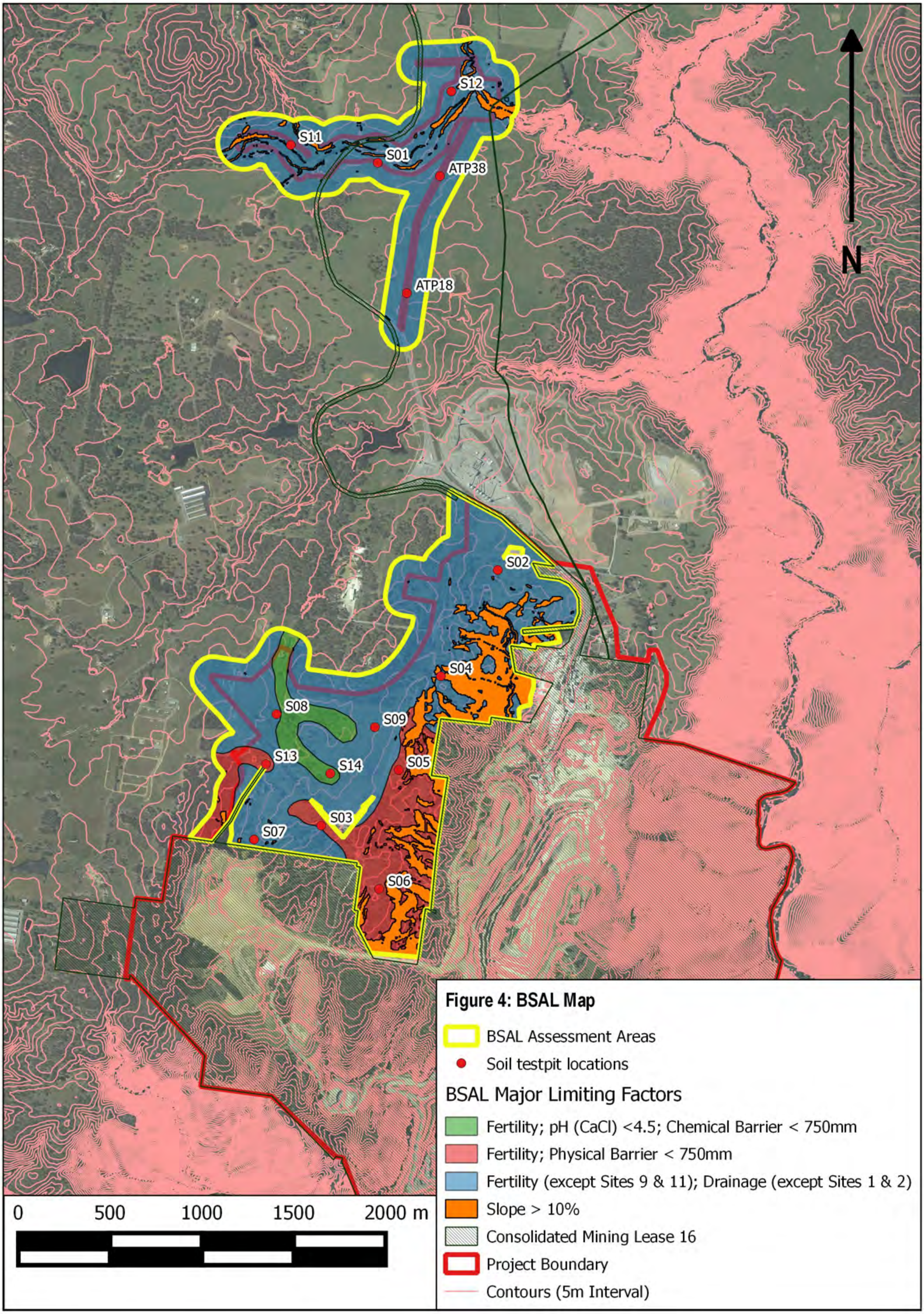

N
S12
S11
S01
ATP38
ATP18
S02
S04
S08
S09
S13
S14
S05
S03
S07
S06
0
500
1000
1500
2000 m
Figure 3: Soil Map
BSAL Assessment Areas
Soil Testpit Locations
Soil Units
Kurosols, Brown
Sodosols
Tenosols
Slope > 10%
Project Boundary
Consolidated Mining Lease 16
Contours (5m Interval)

Table 1: BSAL Verification Summary

Site Number	Inspection Site Type	Australian Soil Classification (to ASC Family)					1. Is slope < 10%?	2. Is there < 30% Rock Outcrop?	3. < 20% unattached Rock Fragments > 60mm?	4. Does < 50% have Gilgais >500mm deep?	5. Is Slope <5%?	6. Are there nil rock outcrops?	7a. Does Soil Have Moderate fertility?	7b. Does soil have Moderately High or High fertility?	8. Is effective rooting depth to a physical barrier >750mm?	9. Is drainage better than poor?	10. Is pH (CaCl2) between 4.5 and 8.1 in upper most 600mm?	11. Is salinity (ECe) < 4 dS/m in uper most 600mm?	12. Is effective rooting depth to a chemical barrier >750mm?	Is the Site BSAL?
		Subgroup	Great Group	Suborder	Order	Family														
1	Detailed	Eutrophic	Subnatric	Red	Sodosol	Medium, non-gravelly, loamy, clayey, moderate	Yes	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	No
2	Detailed	Eutrophic	Mottled-Subnatric	Brown	Sodosol	Medium, non-gravelly, loamy, clayey, moderate	Yes	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	No
3	Detailed	Basic	Ferric	Bleached-Orthic	Tenosols	Medium, non-gravelly, loamy, clay loamy, shallow	Yes	Yes	Yes	Yes	Yes	Yes	No	No	50% Fe nodule layer at 30-41cm	Red mottle 30% & distinct	No	Yes	pH 4.3 at 41-60cm	No
4	Detailed	Eutrophic	Mottled-Subnatric	Brown	Sodosols	Medium, non-gravelly, loamy, clayey, shallow	Yes	Yes	Yes	Yes	No	N/A	N/A	No	Yes	Grey mottle 30% & distinct	No	Yes	pH 4.4 at 30-48cm	No
5	Detailed	Basic	Paralithic	Brown-Orthic	Tenosol	Thick, slightly gravelly, loamy, clayey, shallow	Yes	Yes	Yes	Yes	Yes	Yes	No	No	50% weath sandstone at 60cm	Yes	Yes	Yes	Yes	No
6	Detailed	Basic	Paralithic	Bleached-Orthic	Tenosol	Medium, slightly gravelly, loamy, clayey, shallow	Yes	Yes	Yes	Yes	Yes	Yes	No	No	60% weath granite at 60cm	Grey mottle 30% & distinct	Yes	Yes	Yes	No
7	Detailed	Magnesic	Mottled-Subnatric	Red	Sodosol	Thick, non-gravelly, loamy, clayey, moderate	Yes	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Y.br. mottle 20% & distinct	Yes	Yes	Ca:Mg ratio < 0.1 at 60cm	No
8	Detailed	Eutrophic	Mottled-Subnatric	Brown	Sodosol	Medium, non-gravelly, loamy, clayey, moderate	Yes	Yes	Yes	Yes	Yes	Yes	No	No	Yes	R.Br. mottle 40% & distinct	Yes	Yes	Yes	No
9	Detailed	Bleached-Mottled	Mesotrophic	Brown	Chromosol	Thick, non-gravelly, loamy, clayey, moderate	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Red mottle 40% & distinct	Yes	Yes	Ca:Mg ratio < 0.1 at 60cm; pH 4.3	No
11	Detailed	Mottled-Sodic	Eutrophic	Brown	Chromosol	Medium, non-gravelly, clay loamy, clayey, deep	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Grey mottle 50% & distinct	Yes	Yes	Yes	No
12	Detailed	Eutrophic	Mottled-Subnatric	Brown	Sodosol	Thick, non-gravelly, loamy, clayey, deep	Yes	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Grey mottle 20% & distinct	Yes	Yes	Yes	No
13	Detailed	Basic	Paralithic	Brown-Orthic	Tenosol	Medium, slightly gravelly, clay loamy, clayey, moderate	Yes	Yes	Yes	Yes	Yes	Yes	No	No	70% weath granite at 70cm	Yes	Yes	Yes	Yes	No
14	Detailed	Bleached-Sodic	Mesotrophic	Brown	Kurosol	Thick, non-gravelly, loamy, clayey, moderate	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes	pH 4.4 at 45-60cm	No



N
S12
S11
S01
ATP38
ATP18
S02
S04
S08
S09
S13
S14
S05
S03
S07
S06
Figure 4: BSAL Map
BSAL Assessment Areas
Soil testpit locations
BSAL Major Limiting Factors
Fertility; pH (CaCl) <4.5; Chemical Barrier < 750mm
Fertility; Physical Barrier < 750mm
Fertility (except Sites 9 & 11); Drainage (except Sites 1 & 2)
Slope > 10%
Consolidated Mining Lease 16
Project Boundary
Contours (5m Interval)
0
500
1000
1500
2000 m

3.4. Soil Units Identified in Assessment Area

Soil Unit: Sodosol, Red/ Brown		
Representative Dominant Sites:	1 & 7 (Red) 2, 4, 8and 12(Brown)	
Minor Sites	9 & 11 (Brown Chromosol)	
Typical Soil Profile	A1: 0-11 – Very dark grey loam, very weak angular-blocky, rough-faced, peds 30-40mm, moist, nil gravel	
	A2: 11-21 – Yellowish brown, sandy loam, weak polyhedral, rough faced peds, 20-40mm, moist, nil gravel	
	B2: 21-95 – Light olive brown heavy clay, apedal massive, moist, increasing weathered bedrock fragments	
	B/C: 95- >140 – weathered bedrock	Soil Profile Site: 2 (Brown Sodosol)
Roots:	Fine, few to 44cm	
Landscape Association:	Mid to upper slopes	
Landuse:	Low density sheep grazing	
BSAL Status and limiting factors: Not BSAL. Fertility *Moderately Low* at all sites except 9 and 11. Indicators of poor drainage (such as distinct mottling) at all sites except Sites 1 and 2. Site 4 has pH ($CaCl_2$) of 4.4 at < 600mm depth which also represents a chemical barrier at <750 mm depth. Site 9 has pH of 4.3 at <600mm depth and Ca:Mg ratio < 0.1 at < 750mm depth.		Landscape Site: 4

<table>
<tr><td colspan="3">Soil Unit: Tenosol, Bleached-Orthic / Brown-Orthic</td></tr>
<tr><td>Representative Dominant Sites:</td><td>3 & 6 (Bleached-Orthic)</td><td rowspan="5">


</td></tr>
<tr><td>Co-dominant Sites:</td><td>5 & 13 (Brown-Orthic)</td></tr>
<tr><td rowspan="3">Typical Soil Profile</td><td>A1: 0-11 – Dark brown sandy loam, weak angular-blocky, rough-faced, peds 10-30mm, moist, 0-10% gravel</td></tr>
<tr><td>B2: 11-60 – Yellowish brown heavy clay, apedal massive</td></tr>
<tr><td>B/C: 60- >95 – weathered bedrock</td></tr>
<tr><td></td><td></td><td>Soil Profile Sites: 6 & 13</td></tr>
<tr><td>Roots:</td><td>Fine, few to 58cm</td><td rowspan="4"></td></tr>
<tr><td>Landscape Association:</td><td>Crests and steep slopes</td></tr>
<tr><td>Landuse:</td><td>Mine buffer land</td></tr>
<tr><td colspan="2" rowspan="2">BSAL status and limiting factors:
Not BSAL.
Fertility Moderately Low at all sites.
Physical barrier (typically high proportion of weathered bedrock fragments) at <750 mm depth at all sites;
Site 3 has pH ($CaCl_2$) of 4.3 at < 600mm depth, which also represents a chemical barrier at <750 mm depth.
Indicators of poor drainage at Sites 3 and 6.</td></tr>
<tr><td>Landscape Site: 3</td></tr>
</table>

<table>
<tr><td colspan="3">Soil Unit: Kurosol, Brown</td></tr>
<tr><td>Representative Sites:</td><td>14</td><td rowspan="4">
</td></tr>
<tr><td rowspan="4">Typical Soil Profile</td><td>A1: 0-12 – Dark greyish brown sandy loam, weak polyhedral, rough-faced, peds 10-20mm, moist, nil gravel</td></tr>
<tr><td>A2: 12-44 – Light yellowish brown, sandy clay loam, weak polyhedral, rough faced peds, 20-30mm, moist, 20% ironstone nodules</td></tr>
<tr><td>B2: 44-65 – Yellowish brown medium clay, weak polyhedral to platy peds, 5-10mm, moist, 5% weathered bedrock fragments</td></tr>
<tr><td>B/C: 65- >110 – weathered bedrock</td><td>Soil Profile Site: 14</td></tr>
<tr><td>Roots:</td><td>Fine, few to 57cm</td><td rowspan="4"></td></tr>
<tr><td>Landscape Association:</td><td>Flats and drainage depressions</td></tr>
<tr><td>Landuse:</td><td>Low density sheep grazing</td></tr>
<tr><td colspan="2" rowspan="2">BSAL status and limiting factors:
Not BSAL.
Fertility ranking Moderate.
Site 14 has pH ($CaCl_2$) of 4.4 at
< 600 mm depth, which also represents a chemical barrier at <750 mm depth.
Indicators of poor drainage (bleached A2 horizon) at Site 14.</td></tr>
<tr><td>Landscape Site: 14</td></tr>
</table>

4. Conclusion

The BSAL assessment was completed in June- July 2015. The BSAL assessment area, consisting of the Northern assessment area and Southern assessment area, totalled 320 ha. The BSAL assessment was undertaken in accordance with the requirements of the interim protocol. No BSAL was identified within the BSAL assessment area.

5. References

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Appendix 1 - Risk Assessment

A risk assessment of potential impact to agricultural land was completed for the proposed Project disturbance areas. The assessment utilised the Risk Ranking matrix presented in Table A1, and probability and consequence descriptions presented in Tables A2 and A3, respectively. These risk ranking criteria are taken from the *Guideline for Agricultural Impact Statements at the Exploration Stage* (DTIRIS, 2012). A summary of the assessment findings are presented in Table A4.

Table A1: Risk ranking matrix.

Consequence / PROBABILITY	A Almost Certain	B Likely	C Possible	D Unlikely	E Rare
1. Severe and/or permanent damage. Irreversible impacts	A1 high	B1 high	C1 high	D1 high	E1 medium
2. Significant and /or long term damage. Long term mgt implications. Impacts difficult or impractical to reverse.	A2 high	B2 high	C2 high	D2 medium	E2 medium
3. Moderate damage and/or medium-term impact to agricultural resources or industries. Some ongoing mgt implications which may be expensive to implement. Minor damage or impacts over the long term.	A3 high	B3 high	C3 medium	D3 medium	E3 medium
4. Minor damage and/or short-term impact to agricultural resources or industries. Can be managed as part of routine operations	A4 medium	B4 medium	C4 low	D4 low	E4 low
5. Very minor damage and minor impact to agricultural resources or industries. Can be effectively managed as part of normal operations	A5 low	B5 low	C5 low	D5 low	E5 low

where:

= low risk

= medium risk

= high risk

Table A2: Risk probability class descriptions

Level	Descriptor	Description
A	Almost Certain	Common or repeating occurrence
B	Likely	Known to occur or it has happened
C	Possible	Could occur or I've heard of it happening
D	Unlikely	Could occur in some circumstances but not likely to occur
E	Rare	Practically impossible or I've never heard of it happening

Table A3: Risk consequence class descriptions

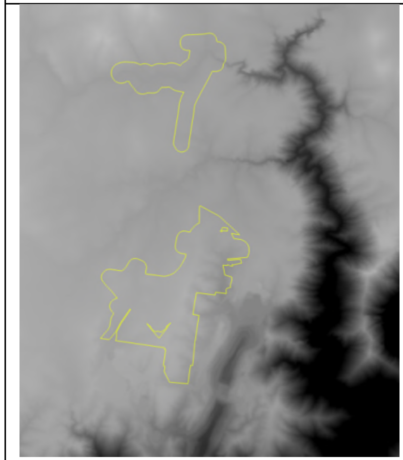
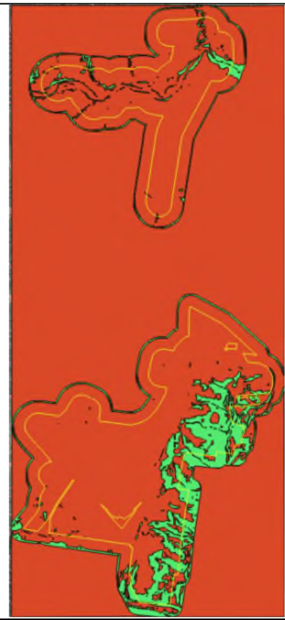
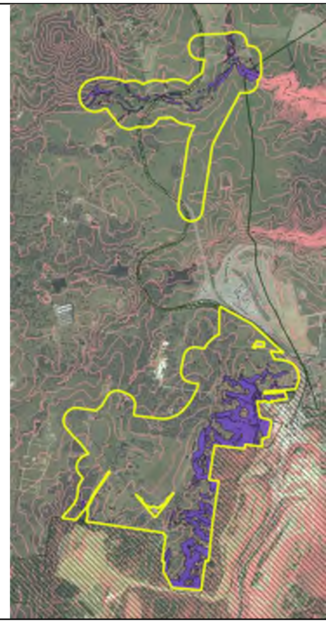
Level: 1	Severe Consequences	Example of Implications
Description	Severe and/or permanent damage to agricultural resources, or industries Irreversible Severe impact on the community	Long term (eg 20 years) damage to soil or water resources Long term impacts (eg 20 years) on a cluster of agricultural industries or Important agricultural lands
Level: 2	**Major Consequences**	**Example of Implications**
Description	Significant and/or long-term impact to agricultural resources, or industries Long-term management implications Serious detrimental impact on the community	Water and / or soil impacted, possibly in the long term (eg 20 years) Long term (eg 20 years) displacement / serious impacts on agricultural industries
Level:3	**Moderate Consequences**	**Example of Implications**
Description	Moderate and/or medium-term impact to agricultural resources, or industries Some ongoing management implications Minor damage or impacts but over the long term.	Water and/ or soil known to be affected, probably in the short – medium term (eg 1-5 years) Management could include significant change of management needed to agricultural enterprises to continue.
Level: 4	**Minor Consequences**	**Example of Implications**
Description	Minor damage and/or short-term impact to agricultural resources, or industries Can be effectively managed as part of normal operations	Theoretically could affect the agricultural resource or industry in short term, but no impacts demonstrated Minor erosion, compaction or water quality impacts that can be mitigated. For example, dust and noise impacts in a 12 month period on extensive grazing enterprises.
Level: 5	**Negligible Consequences**	**Example of Implications**
Description	Very minor damage or impact to agricultural resources, or industries Can be effectively managed as part of normal operations	No measurable or identifiable impact on the agricultural resource or industry

Table A4: Risk ranking for proposed Project disturbance activities.

Assessment Area	Existing Environment	Proposed Disturbance	Area (ha)	Probab-ility	Conse-quence	Risk Ranking
Northern	Cleared land used for livestock grazing. Low undulating rises along creek bed (Land Capability Class V). Steeply incised gully towards eastern margin (Land Capability Class VIII).	Construction of dam at eastern end of area and access roads.	8	A	2/3	High
		Dam inundation area	10	A	2	High
		Buffer zone	76	D	5	Low
Southern	Predominantly cleared land used as mine buffer land in the east and for livestock grazing in the west. Gentle slopes and flats in the west ((Land Capability Class V). Moderate to steep slopes in the east (Land Capability Class VII).	Overburden emplacements	164	A	1	High
		Infrastructure: realignment of Marulan South Rd and drainage infrastructure.	5	A	1	High
		Buffer Zone	57	C	5	Low

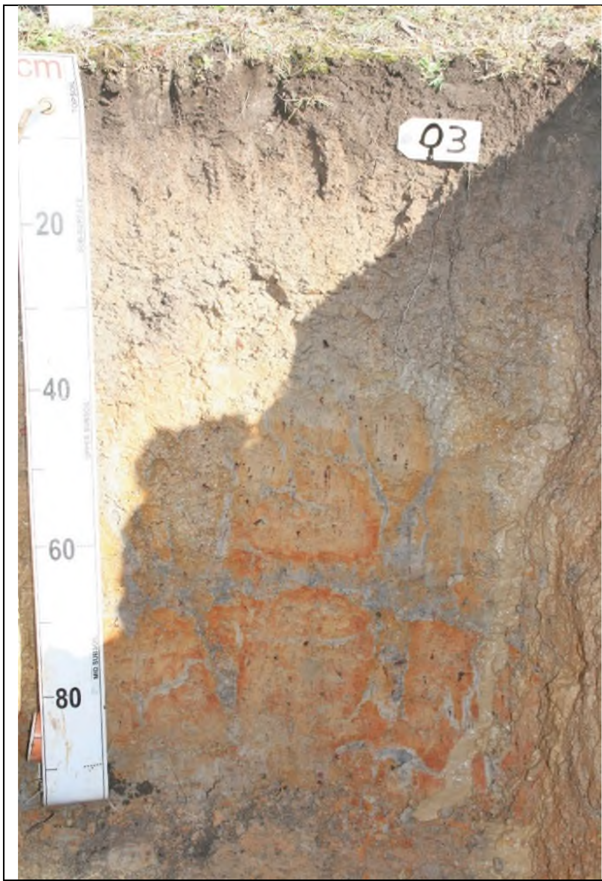
Appendix 2 – Slope Analysis

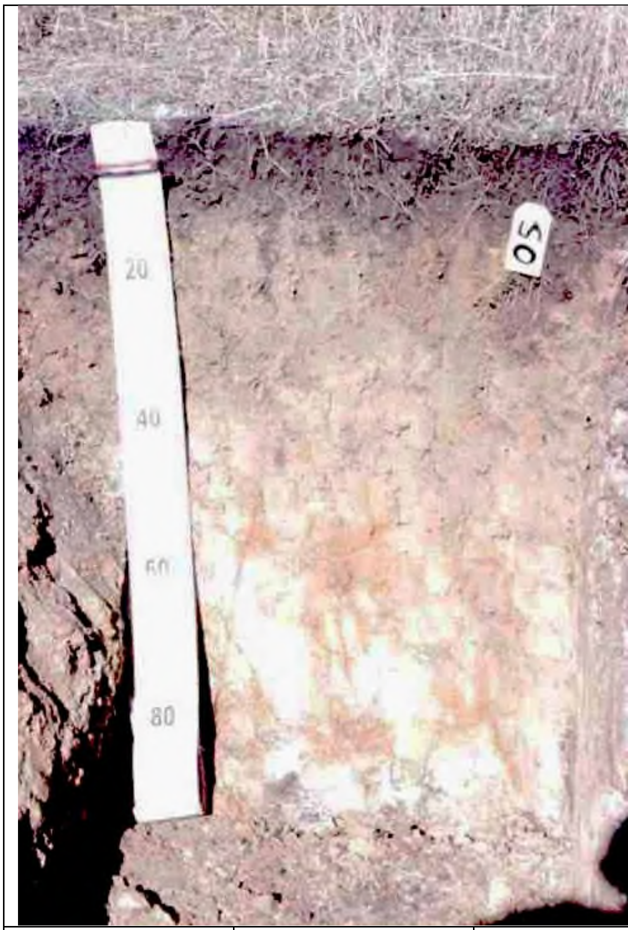
An analysis of terrain within the BSAL assessment areas was undertaken to identify slope gradient greater than ten percent (10%), and exclude those areas from further assessment. LIDAR imagery of the assessment areas was collected in November 2014, and processed using QGIS as described below.

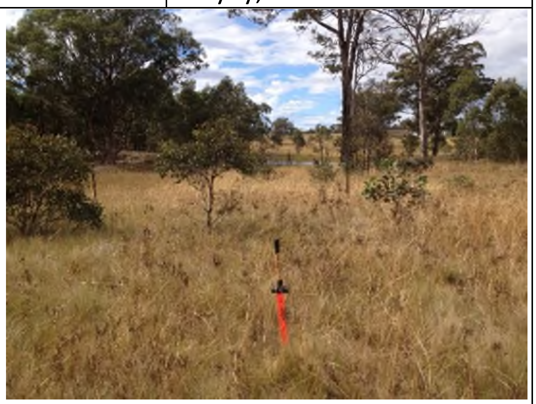
Step 1	**Step 2**	**Step 3**	**Step 4**	**Step 5**
				
LIDAR imagery of Project area displayed as raster layer in QGIS, with vector polygons of BSAL assessment areas shown in yellow.	LIDAR image clipped to 100m buffer around BSAL assessment areas and analysed for slope using QGIS *Terrain Analysis*, giving a range of 0-25% slope within the area.	QGIS *Raster Calculator* used to identify areas of slope greater than 10% (white areas).	Raster image converted to vector polygons, with brown areas representing slope less than 10%, and green showing areas greater than 10% slope.	Polygons clipped to BSAL assessment areas, with purple polygons representing those areas with slope greater than 10%.

Appendix 3 – Test Pit Photographs

<table>
<tr><th colspan="3">Soil Profile</th><th colspan="2">Landscape</th></tr>
<tr><td colspan="3">
</td><td colspan="2"></td></tr>
<tr><td>1. Eutrophic</td><td>Subnatric</td><td>Red</td><td>Sodosol</td><td>Medium, non-gravelly, loamy, clayey, moderate</td></tr>
<tr><td colspan="3">
</td><td colspan="2"></td></tr>
<tr><td>2. Eutrophic</td><td>Mottled-Subnatric</td><td>Brown</td><td>Sodosol</td><td>Medium, non-gravelly, loamy, clayey, moderate</td></tr>
</table>

				
3. Basic	Ferric	Bleached-Orthic	Tenosols	Medium, non-gravelly, loamy, clay loamy, shallow
				
4. Eutrophic	Mottled-Subnatric	Brown	Sodosols	Medium, non-gravelly, loamy, clayey, shallow

<table>
<tr><td colspan="3">
</td><td colspan="2"></td></tr>
<tr><td>5. Basic</td><td>Paralithic</td><td>Brown-Orthic</td><td>Tenosol</td><td>Thick, slightly gravelly, loamy, clayey, shallow</td></tr>
<tr><td colspan="3">
</td><td colspan="2"></td></tr>
<tr><td>6. Basic</td><td>Paralithic</td><td>Bleached-Orthic</td><td>Tenosol</td><td>Medium, slightly gravelly, loamy, clayey, shallow</td></tr>
</table>

				
7. Magnesic	Mottled-Subnatric	Red	Sodosol	Thick, non-gravelly, loamy, clayey, moderate
				
8. Eutrophic	Mottled-Subnatric	Brown	Sodosol	Medium, non-gravelly, loamy, clayey, moderate

<table>
<tr><td colspan="3">
</td><td colspan="2"></td></tr>
<tr><td>9. Bleached-Mottled</td><td>Mesotrophic</td><td>Brown</td><td>Chromosol</td><td>Thick, non-gravelly, loamy, clayey, moderate</td></tr>
<tr><td colspan="3">
</td><td colspan="2"></td></tr>
<tr><td>11. Mottled-Sodic</td><td>Eutrophic</td><td>Brown</td><td>Chromosol</td><td>Medium, non-gravelly, clay loamy, clayey, deep</td></tr>
</table>

12. Eutrophic	Mottled-Subnatric	Brown	Sodosol	Thick, non-gravelly, loamy, clayey, deep

13. Basic	Paralithic	Brown-Orthic	Tenosol	Medium, slightly gravelly, clay loamy, clayey, moderate

14. Bleached-Sodic	Mesotrophic	Brown	Kurosol	Thick, non-gravelly, loamy, clayey, moderate

ATP 18	Surface Observation: Dark brown loam over reddish brown clay (texture contrast profile)

ATP 38	Surface Observation: Dark brown loam over yellowish brown clay (texture contrast profile)

Appendix 4 – Soil Profile Descriptions

Site ID	Hori-zon	Lower Boundary Depth (cm)	Boundary Distinct.	Colour (Munsell)	Mottles			Texture	Structure			Fabric	Consist-ence	Field pH	HCl Test	Dispersion (10 min in water)	Roots		Mois-ture	Coarse Fragments		
					Col	%	Contrast		Ped Type	Size (mm)	Grade						Size	Abun-dance		%	Size (mm)	Lithology
1	A1	20	Clear	10YR 3/2	-	-	-	SCL	AB	20-30	Weak	Rough ped	Weak	5	-	1	1	1	Moist	2	2-5	Not identified
1	B2	58	Diffuse	5YR 4/6	Grey	5	Faint	HC	Mass-ive	-	-	Earthy	Firm	6	-	3	1	0.5 (58cm)	Moist	nil	-	-
1	C	>140	-	10YR 6/6	Grey/red	5	Faint	HC	Mass-ive	-	-	Earthy	-	7.5	N	Slake	-	-	Mod. Moist	50-90	-	Granod-iorite
2	A1	11	Abrupt	10YR 3/1	-	-	-	L	AB	40	Weak	Rough ped	Very Weak	6	-	0	1	1	Very Moist	nil	-	-
2	A2	21	Abrupt	10YR 5/3	-	-	-	SL	Poly-hedral	20-40	Weak	Rough ped	Weak	6	-	1	1	1	Very Moist	nil	-	-
2	B21	57	Gradual	2.5Y 5/3	Grey	20-30	Distinct	HC	Massive	-	-	Earthy	Firm	6	-	1	1	0.5 (45cm)	Moist	nil	-	-
2	B22	95	Diffuse	7.5YR 4/6	-	-	-	MC	Poly-hedral	40-60	Weak	Rough ped	Strong	7.5	-	0	-	-	Moist	10	2-5	Sand-stone
2	B3	>140	-	(multi)	-	-	-	MC	AB	10-20	Weak	Rough ped	-	-	N	-	-	-	Mod. Moist	30	2-5	Sand-stone
3	A1	11	Clear	10YR 3/2	-	-	-	L	AB	30-50	Weak	Rough ped	Weak	6	-	0	1	1	Moist	nil	-	-
3	A21	30	Clear	10YR 5/3	Red	5	Faint	SL	Poly-hedral	40-70	Weak	Rough ped	Very Weak	6	-	1	1	1	Wet	nil	-	-
3	A2c	41	Clear	10YR 5/3	-	-	-	SL	Aped	-	-	Sandy	Loose	5.5	-	0	-	-	Wet	50-90	5	ironstone
3	B21	65	Diffuse	10YR 6/6	Red/grey	30	Distinct	CLS	Platy	50	Weak	Rough ped	Firm	5	N	0	-	-	Mod. Moist	20	6-20	Sand-stone
3	B22	>90	-	10YR 6/6	Grey	20	Distinct	CLS	Platy	50	Weak	Rough ped	Weak	-	-	-	-	-	Mod. Moist	60	6-20	Sand-stone
4	A1	11	Clear	10YR 3/2	-	-	-	L	AB	5-10	Weak	Rough ped	Very Weak	7.5	-	0	1	2	Moist	-	-	-
4	A2	28	Clear	2.5Y 5/2	Red	5	Faint	SL	Poly-hedral	5-10	Weak	Rough ped	Very Weak	7	-	0	1	1	Wet	10	5	Sand-stone
4	B21	48	Diffuse	10YR 5/6	Grey/red	30	Distinct	HC	Poly-hedral	30-50	Weak	Rough ped	Firm	5.5	N	2	3	0.5	Moist	20	20	Sand-stone
4	B3	>120	-	(multi)	-	-	-	MHC	AB	20-40	Weak	Rough ped	Firm	5.5	N	1	-	-	Moist	50-90	6-20	Sand-stone
5	A11	13	Clear	10YR 3/2	-	-	-	SCL	Crumb	3-5	Weak	Rough ped	Very Weak	7.5	-	0	1	3	Moist	2	2-5	Sand-stone
5	A12	38	Clear	10YR 5/4	-	-	-	CLS	Poly-hedral	5-10	Weak	Rough ped	Very Weak	7	-	0	1	1	Moist	5-10	2-5	Sand-stone
5	B3	60	Diffuse	7.5YR 6/6	-	-	-	LMC	Poly-hedral	30-50	Weak	Rough ped	Weak	5	N	1	1	0.5 (53cm)	Mod. Moist	50-90	6-20	Sand-stone

Site ID	Hori-zon	Lower Boundary Depth (cm)	Boundary Distinct.	Colour (Munsell)	Mottles			Texture	Structure			Fabric	Consist-ence	Field pH	HCl Test	Dispersion (10 min in water)	Roots		Mois-ture	Coarse Fragments		
					Col	%	Contrast		Ped Type	Size (mm)	Grade						Size	Abun-dance		%	Size (mm)	Lithology
5	C	>90	-	(multi)	-	-	-	LMC	Massive	-	-	Sandy	-	-	N	-	1	2	Dry	>90	6-20	Sand-stone
6	A1	9	Clear	10YR 2/2	-	-	-	L	Poly-hedral	30-50	Weak	Rough ped	Very Weak	7	-	1	1	1	Moist	10	5-20	ironstone
6	A2	17	Abrupt	10YR 6/3	-	-	-	SL	Poly-hedral	10-20	Weak	Rough ped	Very Weak	6	-	2	1	1	Very Moist	10	50-100	ironstone
6	B21	44	Diffuse	5YR 4/6	Grey	30	Distinct	MHC	Massive	-	-	Earthy	Firm	7.5	-	1	4	1	Moist	30	6-20	ironstone
6	B3	>60	-	5YR 4/4	-	-	-	MHC	Massive	-	-	Earthy	Strong	-	N	-	-	-	Mod. Moist	60	6-20	Granod-iorite
7	A1	11	Clear	10YR 3/3	-	-	-	L	AB	10-30	Weak	Rough ped	Weak	6	-	0	1	1	Moist	nil	-	-
7	A2	32	Abrupt	10YR 5/4	-	-	-	SL	AB	30-50	Weak	Rough ped	Very Weak	6	-	1	1	1 (22cm)	Wet	10	5-10	ironstone
7	B21	64	Diffuse	5YR 5/8	Yellow Brown	20	Distinct	MC	Massive	-	-	Earthy	Firm	5.5	N	2	-	-	Moist	5	5-10	Weath. Sedi-mentary
7	B3	>100	-	5YR 5/3	Grey	5	Faint	MC	Massive	-	-	Earthy	Firm	-	-	-	-	-	Moist	40	5-10	Weath. Sedi-mentary
8	A1	8	Clear	10YR 3/3	-	-	-	L	Poly-hedral	10-20	Weak	Rough ped	Very Weak	6.5	-	1	1	1	Moist	nil	-	-
8	A2	15	Abrupt	10YR 5/3	-	-	-	SL	Poly/ lentic	5-10	Weak	Rough ped	Weak	7.5	-	2	1	1	Wet	10	5-20	ironstone
8	B21	65	Diffuse	7.5YR 5/6	Red Brown	40	Distinct	MC	Poly/ lentic	50-70	Weak	Rough ped	Firm	5.5	-	2	1	0.5 (28cm)	Mod. Moist	10	5-20	Weath. Sedi-mentary
8	B3	>85	-	(multi)	-	-	-	MC	Poly/ lentic	30-50	Weak	Rough ped	Firm	-	N	-	-	-	Mod. Moist	>70	5-20	Sedi-mentary
9	A1	11	Gradual	10YR 3/2	-	-	-	SL	Poly-hedral	10-30	Weak	Rough ped	Weak	7	-	0	1	1	Moist	nil	-	-
9	A2	32	Clear	10YR 5/4	-	-	-	SCL	Poly-hedral	5-20	Weak	Rough ped	Weak	6	-	1	1	0.5	Wet	10	2-5	ironstone
9	B21	85	Diffuse	10YR 6/4	Orang e	40	Distinct	MC	Poly/ lentic	30-50	Weak	Rough ped	Weak	5	-	0	-	-	Moist	10	2-5	ironstone
9	C	>120	-	-	-	-	-	LMC	Massive	-	-	Sandy	-	-	-	-	-	-	Mod. Moist	>70	6-20	Sand-stone
11	A1	17	Clear	10YR 2/2	-	-	-	CL	SB	20-30	Weak	Rough ped	Weak	5.5	-	1	1	1	Moist	-	-	-
11	B21	45	Clear	10YR 3/3	Grey	50	Distinct	MC	AB	30-50	Weak	Rough ped	Weak	5.5	-	1	1	1	Moist	-	-	-
11	B22	100	Gradual	2.5Y 4/2	Yellow Brown	5	Faint	MHC	Massive	-	-	Earthy	Firm	6	-	0	-	-	Moist	-	-	-
11	B3	130	Clear	2.5Y 6/2	Yellow Brown	30	Prom-inent	MHC	Poly-hedral	30-50	Weak	Rough ped	Firm	7.5	N	0	-	-	Moist	>70	6-20	Granod-iorite
11	C	>140	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Dry	>90	6-20	Granod-iorite
12	A1	13	Gradual	10YR 4/2	-	-	-	SL	AB	20-50	Weak	Rough ped	Weak	5.5	-	0	1	1	Mod. Moist	-	-	-

Site ID	Hori-zon	Lower Boundary Depth (cm)	Boundary Distinct.	Colour (Munsell)	Mottles			Texture	Structure			Fabric	Consist-ence	Field pH	HCl Test	Dispersion (10 min in water)	Roots		Mois-ture	Coarse Fragments		
					Col	%	Contrast		Ped Type	Size (mm)	Grade						Size	Abun-dance		%	Size (mm)	Lithology
12	A2	42	Clear	10YR 6/2	Yellow Brown	5	Faint	SL	Poly-hedral	15	Weak	Rough ped	Very Weak	5.5	-	0	1	1	Moist	-	-	-
12	B21	95	Diffuse	10YR 5/6	Grey	20	Distinct	HC	Massive	-	-	Earthy	Firm	6	-	1	-	-	Moist	-	-	-
12	B22	>120	-	7.5YR 4/2	-	-	-	MHC	Poly/ lentic	30-70	Weak	Rough ped	Weak	7.5	N	2	-	-	Moist	-	-	-
13	A1	13	Clear	10YR 3/4	-	-	-	CL	AB	20-30	Weak	Rough ped	Weak	6	-	1	1	1	Moist	5	5	Not evident
13	B21	64	Gradual	7.5YR 5/6	Grey	10	Distinct	MHC	Massive	-	-	Earthy	Firm	5.5	-	1	1	1 (47cm)	Moist	5	6-20	Granod-iorite
13	C	>80	-	10YR 6/8	multi	-	-	HC	Poly-hedral	30-50	Weak	Rough ped	Firm	5.5	N	1	-	-	Mod. Moist	>70	2-6	Granod-iorite
14	A1	12	Clear	10YR 3/2	-	-	-	SL	Poly-hedral	10-20	Weak	Rough ped	Weak	6	-	0	1	1	Moist	-	-	-
14	A2	44	Clear	2.5Y 6/3	-	-	-	SCL	Poly/ lentic	20-30	Weak	Rough ped	Weak	6	-	2	1	1	Moist	20	6-20	ironstone
14	B21	75	Gradual	10YR 5/4	Orange	10	Distinct	MC	Poly/ platy	5-10	Weak	Rough ped	Firm	5.5	-	0	1	1 (57cm)	Moist	5	6-20	Weath. Sedi-mentary
14	B3	>110	-	(multi)	Red	40	Prominent	LMC	Platy	10-20	Weak	Rough ped	Weak	5.5	N	0			Moist	60	6-20	Weath. Sedi-mentary

Appendix 5 – Laboratory Analysis Report

SOIL TEST REPORT

Scone Research Centre

REPORT NO:	SCO15/131R1
REPORT TO:	Lachlan Crawford Lamac Management Pty Ltd 22 Lerra Road Windella NSW 2320
REPORT ON:	Sixty Three soil samples
PRELIMINARY RESULTS ISSUED:	Not issued
REPORT STATUS:	Final
DATE REPORTED:	19 August 2015
METHODS:	Information on test procedures can be obtained from Scone Research Centre

TESTING CARRIED OUT ON SAMPLE AS RECEIVED
THIS DOCUMENT MAY NOT BE REPRODUCED EXCEPT IN FULL

SR Young
(Laboratory Manager)

Scone Research Centre, PO Box 283 Scone 2337, 709 Gundy Road Scone 2337
Ph: 02 6545 1666, Fax: 02 6545 2520

SOIL CONSERVATION SERVICE
Scone Research Centre

Report No: SCO15/131R1

Client Reference: Lachlan Crawford
Lamac Management Pty Ltd
22 Lerra Road
Windella NSW 2320

Lab No	Method	P9B/2	C1A/5	C2A/4	C2B/4	C5A/4 CEC & exchangeable cations (me/100g)						
	Sample Id	EAT	EC (dS/m)	pH	pH ($CaCl_2$)	CEC	Na	K	Ca	Mg	Al	Texture
1	1 : 0-5	nt	0.06	6.7	6.0	14.3	0.2	0.4	9.0	2.3	nt	Sandy loam
2	1 : 5-15	nt	0.03	6.5	5.6	13.2	0.3	0.3	6.0	2.1	nt	Sandy clay loam
3	1 : 20-30	nt	0.03	7.0	5.6	29.6	1.3	0.4	10.3	12.1	nt	Heavy clay
4	1 : 30-60	3(2)	0.03	7.8	6.2	26.2	1.8	0.3	8.1	10.6	nt	Heavy clay
5	2 : 0-5	nt	0.05	7.2	6.5	14.9	0.4	0.6	10.4	1.8	nt	Sandy loam
6	2 : 5-11	nt	0.03	6.9	6.1	12.1	0.4	0.4	6.6	1.6	nt	Sandy loam
7	2 : 11-15	nt	0.01	6.8	5.8	4.4	0.5	0.4	1.8	1.2	nt	Sandy loam
8	2 : 21-30	nt	0.13	6.9	5.9	30.9	2.3	0.4	5.8	18.2	nt	Heavy clay
9	2 : 30-57	nt	0.27	7.0	6.0	33.5	3.6	0.5	3.9	21.5	nt	Heavy clay
10	2 : 60-100	nt	0.37	8.0	6.8	35.8	4.5	0.4	3.5	22.0	nt	Medium clay
11	3 : 0-5	nt	0.04	6.8	6.0	12.2	0.6	0.4	8.7	1.5	nt	Loam
12	3 : 5-11	nt	0.02	6.6	5.8	9.3	0.2	0.3	6.1	1.4	nt	Loam
13	3 : 15-30	nt	<0.01	7.0	6.0	4.8	0.2	0.3	2.4	1.4	nt	Sandy loam
14	3 : 41-60	nt	0.01	5.5	4.3	4.2	0.2	0.3	0.8	2.4	1.5	Sandy loam
15	4 : 0-5	nt	0.06	8.1	7.5	13.2	0.2	0.7	10.9	1.5	nt	Loam

SOIL CONSERVATION SERVICE
Scone Research Centre

Report No: SCO15/131R1
Client Reference: Lachlan Crawford
Lamac Management Pty Ltd
22 Lerra Road
Windella NSW 2320

Lab No	Method	P9B/2	C1A/5	C2A/4	C2B/4	C5A/4 CEC & exchangeable cations (me/100g)						
	Sample Id	EAT	EC (dS/m)	pH	pH ($CaCl_2$)	CEC	Na	K	Ca	Mg	Al	Texture
16	4 : 5-10	nt	0.05	8.0	7.2	11.8	0.2	0.6	9.3	1.4	nt	Loam
17	4 : 15-30	nt	0.01	7.8	6.9	4.5	0.1	0.4	3.0	1.1	nt	Sandy loam
18	4 : 30-48	2(1)	0.08	5.9	4.4	19.9	1.5	0.5	2.7	10.4	0.9	Heavy clay
19	4 : 60-100	nt	nt	nt	nt	nt	nt	nt	nt	nt	nt	nt
20	5 : 0-5	nt	0.08	7.5	7.0	18.3	0.1	1.0	14.1	1.8	nt	Loam
21	5 : 5-13	nt	0.06	7.4	6.8	15.1	0.1	1.1	11.6	1.8	nt	Sandy clay loam
22	5 : 15-30	nt	0.03	6.9	6.0	7.4	0.1	0.7	3.8	1.4	nt	Sandy clay
23	5 : 30-60	nt	0.02	5.6	4.5	8.0	0.1	0.9	2.2	1.7	3.1	Medium clay
24	6 : 0-5	nt	0.04	7.5	6.8	16.2	0.1	0.8	12.1	1.9	nt	Loam
25	6 : 9-15	3(2)	0.02	7.2	6.3	5.8	0.2	0.3	3.4	2.2	nt	Sandy loam
26	6 : 17-30	nt	0.05	8.0	6.7	22.5	0.5	0.5	7.9	8.5	nt	Heavy clay
27	6 : 30-44	nt	0.06	8.0	6.8	19.2	0.6	0.5	5.6	9.1	nt	Heavy clay
28	6 : 44-60	nt	0.07	8.0	6.7	21.7	1.0	0.5	3.3	13.1	nt	Heavy clay
29	7 : 0-5	nt	0.04	6.1	5.3	12.3	0.2	0.5	5.9	2.9	<0.5	Loam
30	7 : 5-11	nt	0.02	6.1	5.1	10.3	0.2	0.4	4.9	2.7	<0.5	Loam

SOIL CONSERVATION SERVICE
Scone Research Centre

Report No: SCO15/131R1
Client Reference: Lachlan Crawford
Lamac Management Pty Ltd
22 Lerra Road
Windella NSW 2320

Lab No	Method	P9B/2	C1A/5	C2A/4	C2B/4	C5A/4 CEC & exchangeable cations (me/100g)						
	Sample Id	EAT	EC (dS/m)	pH	pH ($CaCl_2$)	CEC	Na	K	Ca	Mg	Al	Texture
31	7 : 15-30	nt	0.01	6.3	5.1	6.9	0.2	0.3	2.7	2.4	<0.5	Loam
32	7 : 32-60	2(1)	0.04	5.8	4.6	20.8	1.3	0.4	0.8	13.5	0.9	Medium clay
33	8 : 0-5	nt	0.03	6.8	6.1	8.0	0.3	0.4	5.1	1.2	nt	Loam
34	8 : 8-15	2(1)	0.01	7.1	6.1	7.0	0.4	0.1	1.4	1.6	nt	Sandy loam
35	8 : 15-30	2(2)	0.10	6.3	5.1	24.3	2.3	0.2	3.6	14.3	<0.5	Medium clay
36	8 : 30-60	nt	0.12	6.3	5.1	22.0	2.6	0.2	2.6	14.2	<0.5	Medium clay
37	8 : 65-85	nt	nt	nt	nt	nt	nt	nt	nt	nt	nt	nt
38	9 : 0-5	nt	0.03	7.3	6.6	8.1	0.3	0.2	6.9	1.4	nt	Loam
39	9 : 5-11	nt	0.03	7.1	6.4	6.8	0.3	0.1	4.9	1.3	nt	Sandy loam
40	9 : 15-30	nt	0.01	6.7	5.8	6.4	0.4	0.1	2.4	1.7	nt	Sandy clay
41	9 : 32-60	nt	0.01	5.7	4.9	9.8	0.5	0.1	3.5	3.7	2.4	Light clay
42	9 : 60-85	nt	0.01	5.2	4.3	10.6	0.5	0.1	0.2	3.8	7.4	Light clay
43	11 : 0-5	nt	0.07	6.5	5.9	19.7	0.5	1.0	12.2	5.7	nt	Clay loam
44	11 : 5-15	nt	0.03	6.2	5.3	15.8	0.6	0.3	8.6	5.6	<0.5	Clay loam
45	11 : 17-30	nt	0.02	6.1	4.9	22.6	1.0	0.3	8.2	8.9	0.6	Medium clay

SOIL CONSERVATION SERVICE
Scone Research Centre

Report No: SCO15/131R1
Client Reference: Lachlan Crawford
Lamac Management Pty Ltd
22 Lerra Road
Windella NSW 2320

Lab No	Method	P9B/2	C1A/5	C2A/4	C2B/4	C5A/4 CEC & exchangeable cations (me/100g)						
	Sample Id	EAT	EC (dS/m)	pH	pH ($CaCl_2$)	CEC	Na	K	Ca	Mg	Al	Texture
46	11 : 30-60	nt	0.03	6.5	5.2	26.8	1.3	0.3	8.5	11.8	<0.5	Heavy clay
47	11 : 60-100	nt	0.09	7.1	5.9	28.8	1.8	0.4	9.1	13.6	nt	Heavy clay
48	12 : 0-5	nt	0.04	6.2	5.5	5.9	0.5	0.2	2.4	0.8	nt	Sandy loam
49	12 : 5-15	nt	0.04	5.9	5.1	5.2	0.4	0.1	5.3	1.2	<0.5	Sandy loam
50	12 : 17-30	nt	0.02	5.8	4.8	5.2	0.5	0.1	1.1	0.6	<0.5	Sandy loam
51	12 : 42-60	nt	0.11	6.8	5.7	23.6	1.9	0.2	7.1	11.8	nt	Heavy clay
52	12 : 60-100	nt	0.08	7.7	6.4	20.3	1.7	0.1	5.5	9.9	nt	Heavy clay
53	13 : 0-5	nt	0.04	6.6	5.7	22.4	0.6	0.8	10.3	8.8	nt	Light clay
54	13 : 5-13	nt	0.04	6.2	5.4	22.5	1.0	0.3	9.4	11.0	<0.5	Medium clay
55	13 : 17-30	nt	0.04	5.9	4.7	37.9	1.7	0.1	7.1	23.4	1.0	Heavy clay
56	13 : 42-60	nt	0.05	5.9	4.6	36.1	2.2	0.1	3.1	24.8	1.1	Heavy clay
57	13 : 60-80	nt	nt	nt	nt	nt	nt	nt	nt	nt	nt	nt
58	14 : 0-5	nt	0.02	7.2	6.4	8.3	0.4	0.1	6.1	1.0	nt	Sandy loam
59	14 : 5-12	nt	0.01	6.9	6.1	6.8	0.4	0.1	4.2	0.9	nt	Sandy loam
60	14 : 15-30	2(1)	<0.01	6.7	5.8	4.1	0.4	<0.1	1.6	0.6	nt	Sandy clay loam

SOIL CONSERVATION SERVICE
Scone Research Centre

Report No: SCO15/131R1
Client Reference: Lachlan Crawford
Lamac Management Pty Ltd
22 Lerra Road
Windella NSW 2320

Lab No	Method	P9B/2	C1A/5	C2A/4	C2B/4	C5A/4 CEC & exchangeable cations (me/100g)						
	Sample Id	EAT	EC (dS/m)	pH	pH ($CaCl_2$)	CEC	Na	K	Ca	Mg	Al	Texture
61	14 : 30-44	nt	<0.01	6.6	5.6	1.2	0.4	<0.1	1.5	0.7	nt	Sandy clay loam
62	14 : 45-60	nt	0.01	5.4	4.4	14.4	0.7	<0.1	2.5	4.3	6.7	Medium clay
63	14 : 60-100	nt	0.01	5.2	4.1	10.5	0.7	0.1	0.3	2.5	4.4	Light clay

nt = not tested

END OF TEST REPORT

Appendix 6 – Acknowledgement of Soil Profile submission via eDIRT

Tue 6/10/2015 11:02 AM

edirt.admin@environment.nsw.gov.au

PROD: Profile has been approved.

To lachlan@lamac.com.au

Dear eDIRT user:

1 profile has been approved.

Survey: Marulan South Limestone Mine Continued Operations Project (1005318), Site location: 50m sth of Marulan Creek. 220m east of rail line, profile number: 1
Comment provided: Survey 'Marulan South Limestone Mine Continued Operations Project (1005318)' has been set up, please use this for any future profiles in same survey.

Regards
The eDIRT system

This is a system generated email, please do not reply.

For additional help about eDIRT and browser selection visit The Electronic Digital Infield regolith tool (eDIRT) web page.

This email is intended for the addressee(s) named and may contain confidential and/or privileged information.
If you are not the intended recipient, please notify the sender and then delete it immediately.
Any views expressed in this email are those of the individual sender except where the sender expressly and with authority states them to be the views of the NSW Office of Environment and Heritage.

PLEASE CONSIDER THE ENVIRONMENT BEFORE PRINTING THIS EMAIL

Tue 6/10/2015 11:03 AM

edirt.admin@environment.nsw.gov.au

PROD: Profile has been approved.

To lachlan@lamac.com.au

Dear eDIRT user:

1 profile has been approved.

Survey: Marulan South Limestone Mine Continued Operations Project (1005318), Site location: 60 m south of Marulan South Road, profile number: 2
Comment provided: Survey 'Marulan South Limestone Mine Continued Operations Project (1005318)' has been set up, please use this for any future profiles in same survey.

Regards
The eDIRT system

This is a system generated email, please do not reply.

For additional help about eDIRT and browser selection visit The Electronic Digital Infield regolith tool (eDIRT) web page.

This email is intended for the addressee(s) named and may contain confidential and/or privileged information.
If you are not the intended recipient, please notify the sender and then delete it immediately.
Any views expressed in this email are those of the individual sender except where the sender expressly and with authority states them to be the views of the NSW Office of Environment and Heritage.

PLEASE CONSIDER THE ENVIRONMENT BEFORE PRINTING THIS EMAIL

Tue 6/10/2015 11:04 AM

edirt.admin@environment.nsw.gov.au

PROD: Profile has been approved.

To lachlan@lamac.com.au

Dear eDIRT user:

1 profile has been approved.

Survey: Marulan South Limestone Mine Continued Operations Project (1005318), Site location: 100m south of Marulan South Road, profile number: 3
Comment provided: Survey 'Marulan South Limestone Mine Continued Operations Project (1005318)' has been set up, please use this for any future profiles in same survey.

Regards
The eDIRT system

This is a system generated email, please do not reply.

For additional help about eDIRT and browser selection visit The Electronic Digital Infield regolith tool (eDIRT) web page.

Tue 6/10/2015 11:04 AM

edirt.admin@environment.nsw.gov.au

PROD: Profile has been approved.

To lachlan@lamac.com.au

Dear eDIRT user:

1 profile has been approved.

Survey: Marulan South Limestone Mine Continued Operations Project (1005318), Site location: 100m east of Marulan South Road, profile number: 4
Comment provided: Survey 'Marulan South Limestone Mine Continued Operations Project (1005318)' has been set up, please use this for any future profiles in same survey.

Regards
The eDIRT system

This is a system generated email, please do not reply.

For additional help about eDIRT and browser selection visit The Electronic Digital Infield regolith tool (eDIRT) web page.

Tue 6/10/2015 11:05 AM

edirt.admin@environment.nsw.gov.au

PROD: Profile has been approved.

To lachlan@lamac.com.au

Dear eDIRT user:

1 profile has been approved.

Survey: Marulan South Limestone Mine Continued Operations Project (1005318), Site location: 60 east of Marulan South Road, profile number: 5
Comment provided: Survey 'Marulan South Limestone Mine Continued Operations Project (1005318)' has been set up, please use this for any future profiles in same survey.

Regards
The eDIRT system

This is a system generated email, please do not reply.

For additional help about eDIRT and browser selection visit The Electronic Digital Infield regolith tool (eDIRT) web page.

Tue 6/10/2015 11:05 AM

edirt.admin@environment.nsw.gov.au

PROD: Profile has been approved.

To lachlan@lamac.com.au

Dear eDIRT user:

1 profile has been approved.

Survey: Marulan South Limestone Mine Continued Operations Project (1005318), Site location: 500m south east of Marulan South Road, profile number: 6
Comment provided: Survey 'Marulan South Limestone Mine Continued Operations Project (1005318)' has been set up, please use this for any future profiles in same survey.

Regards
The eDIRT system

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For additional help about eDIRT and browser selection visit The Electronic Digital Infield regolith tool (eDIRT) web page.

Tue 6/10/2015 11:06 AM

edirt.admin@environment.nsw.gov.au

PROD: Profile has been approved.

To lachlan@lamac.com.au

Dear eDIRT user:

1 profile has been approved.

Survey: Marulan South Limestone Mine Continued Operations Project (1005318), Site location: 380m south west of Marulan South Road, profile number: 7
Comment provided: Survey 'Marulan South Limestone Mine Continued Operations Project (1005318)' has been set up, please use this for any future profiles in same survey.

Regards
The eDIRT system

This is a system generated email, please do not reply.

For additional help about eDIRT and browser selection visit The Electronic Digital Infield regolith tool (eDIRT) web page.

Tue 6/10/2015 11:06 AM

edirt.admin@environment.nsw.gov.au

PROD: Profile has been approved.

To lachlan@lamac.com.au

Dear eDIRT user:

1 profile has been approved.

Survey: Marulan South Limestone Mine Continued Operations Project (1005318), Site location: 150m north east of Marulan South Road, profile number: 8
Comment provided: Survey 'Marulan South Limestone Mine Continued Operations Project (1005318)' has been set up, please use this for any future profiles in same survey.

Regards
The eDIRT system

This is a system generated email, please do not reply.

For additional help about eDIRT and browser selection visit The Electronic Digital Infield regolith tool (eDIRT) web page.

Tue 6/10/2015 11:07 AM

edirt.admin@environment.nsw.gov.au

PROD: Profile has been approved.

To lachlan@lamac.com.au

Dear eDIRT user:

1 profile has been approved.

Survey: Marulan South Limestone Mine Continued Operations Project (1005318), Site location: 140m west of Marulan South Road, profile number: 9
Comment provided: Survey 'Marulan South Limestone Mine Continued Operations Project (1005318)' has been set up, please use this for any future profiles in same survey.

Regards
The eDIRT system

This is a system generated email, please do not reply.

For additional help about eDIRT and browser selection visit The Electronic Digital Infield regolith tool (eDIRT) web page.

Tue 6/10/2015 11:08 AM

edirt.admin@environment.nsw.gov.au

PROD: Profile has been approved.

To lachlan@lamac.com.au

Dear eDIRT user:

1 profile has been approved.

Survey: Marulan South Limestone Mine Continued Operations Project (1005318), Site location: 250m north west of rail line, profile number: 11
Comment provided: Survey 'Marulan South Limestone Mine Continued Operations Project (1005318)' has been set up, please use this for any future profiles in same survey.

Regards
The eDIRT system

This is a system generated email, please do not reply.

For additional help about eDIRT and browser selection visit The Electronic Digital Infield regolith tool (eDIRT) web page.

Tue 6/10/2015 11:09 AM

edirt.admin@environment.nsw.gov.au

PROD: Profile has been approved.

To lachlan@lamac.com.au

Dear eDIRT user:

1 profile has been approved.

Survey: Marulan South Limestone Mine Continued Operations Project (1005318), Site location: 180m east of railway, profile number: 12
Comment provided: Survey 'Marulan South Limestone Mine Continued Operations Project (1005318)' has been set up, please use this for any future profiles in same survey.

Regards
The eDIRT system

This is a system generated email, please do not reply.

For additional help about eDIRT and browser selection visit The Electronic Digital Infield regolith tool (eDIRT) web page.

Tue 6/10/2015 11:10 AM

edirt.admin@environment.nsw.gov.au

PROD: Profile has been approved.

To lachlan@lamac.com.au

Dear eDIRT user:

1 profile has been approved.

Survey: Marulan South Limestone Mine Continued Operations Project (1005318), Site location: 60m southwest of Marulan South Road, profile number: 13
Comment provided: Survey 'Marulan South Limestone Mine Continued Operations Project (1005318)' has been set up, please use this for any future profiles in same survey.

Regards
The eDIRT system

This is a system generated email, please do not reply.

For additional help about eDIRT and browser selection visit The Electronic Digital Infield regolith tool (eDIRT) web page.

Tue 6/10/2015 11:11 AM

edirt.admin@environment.nsw.gov.au

PROD: Profile has been approved.

To lachlan@lamac.com.au

Dear eDIRT user:

1 profile has been approved.

Survey: Marulan South Limestone Mine Continued Operations Project (1005318), Site location: 170m north of Marulan South Road, profile number: 14
Comment provided: Survey 'Marulan South Limestone Mine Continued Operations Project (1005318)' has been set up, please use this for any future profiles in same survey.

Regards
The eDIRT system

This is a system generated email, please do not reply.

For additional help about eDIRT and browser selection visit The Electronic Digital Infield regolith tool (eDIRT) web page.

Appendix 7 – CPSS Project Audit Comments

9 October 2015

Lachlan Crawford
Director
LAMAC Management Pty Ltd

SOILmgt

P.O. Box 2171
ORANGE NSW 2800

ph: (02) 6361 1913
f: (02) 6361 3268
e: david.mckenzie@soilmgt.com.au

www.soilmgt.com.au
ABN 37 076 676 616

COMMENTS REGARDING LAMAC MANAGEMENT'S BIOPHYSICAL STRATEGIC AGRICULTURAL LAND VERIFICATION ASSESSMENT', MARULAN SOUTH LIMESTONE PROJECT, OCTOBER 2015

Dear Lachlan

In April 2015, you invited me to carry out a technical review for LAMAC Management. It was associated with the 'Biophysical Strategic Agricultural Land (BSAL) Verification Assessment' for Boral's Marulan South Limestone Project near Goulburn, NSW. I have 38 years experience as a soil scientist. My qualifications include a PhD (soil physics) from University of Sydney and a MScAg degree (soil chemistry & agronomy) from University of New England. I have 'Certified Professional Soil Scientist (Stage 3)' and 'CPSS Competent in Australian Soil Survey' accreditation from Soil Science Australia, and I am a 'Chartered Scientist' with British Society of Soil Science.

My half day in the field with you on 30.6.15 allowed me to examine your soil description and sampling techniques in soil pits, and to discuss my experiences with BSAL assessment in northern NSW. It was clear that you had a good understanding of soil and landscape processes. Although you were out of practice with soil surveying procedures, I was impressed by your ability to quickly refine your techniques to suit the landscape conditions at Marulan South.

In addition to this brief field meeting, I enjoyed our recent phone and email discussions regarding your report, map preparation and soil data entry via eDIRT. Your clear writing style was appreciated. I note that my comments were taken on board by you.

The information presented in your report has convinced me that declarable areas of BSAL almost certainly do not exist within the Marulan South study area.

Yours sincerely

Dr David McKenzie
Soil Science Consultant
Soil Management Designs

Site Verification Certificate
Marulan South Limestone Mine

Part 4AA, Division 3 of *State Environmental Planning Policy (Mining, Petroleum Production and Extractive Industries) 2007*

Pursuant to clause 17C(1) of the *State Environmental Planning Policy (Mining, Petroleum Production and Extractive Industries) 2007*, I determine the application made by Boral Cement Limited by issuing this certificate.

I certify that in my opinion, having regard to the criteria in the *Interim protocol for site verification and mapping of biophysical strategic agricultural land*, the land specified in Schedule 1 is not Biophysical Strategic Agricultural Land.

The reasons for forming the opinion on each of the relevant criteria are contained in Schedule 2.

Secretary
Date certificate issued: 17.11.15

This certificate will remain current for 5 years from the date of issue.

SCHEDULE 1

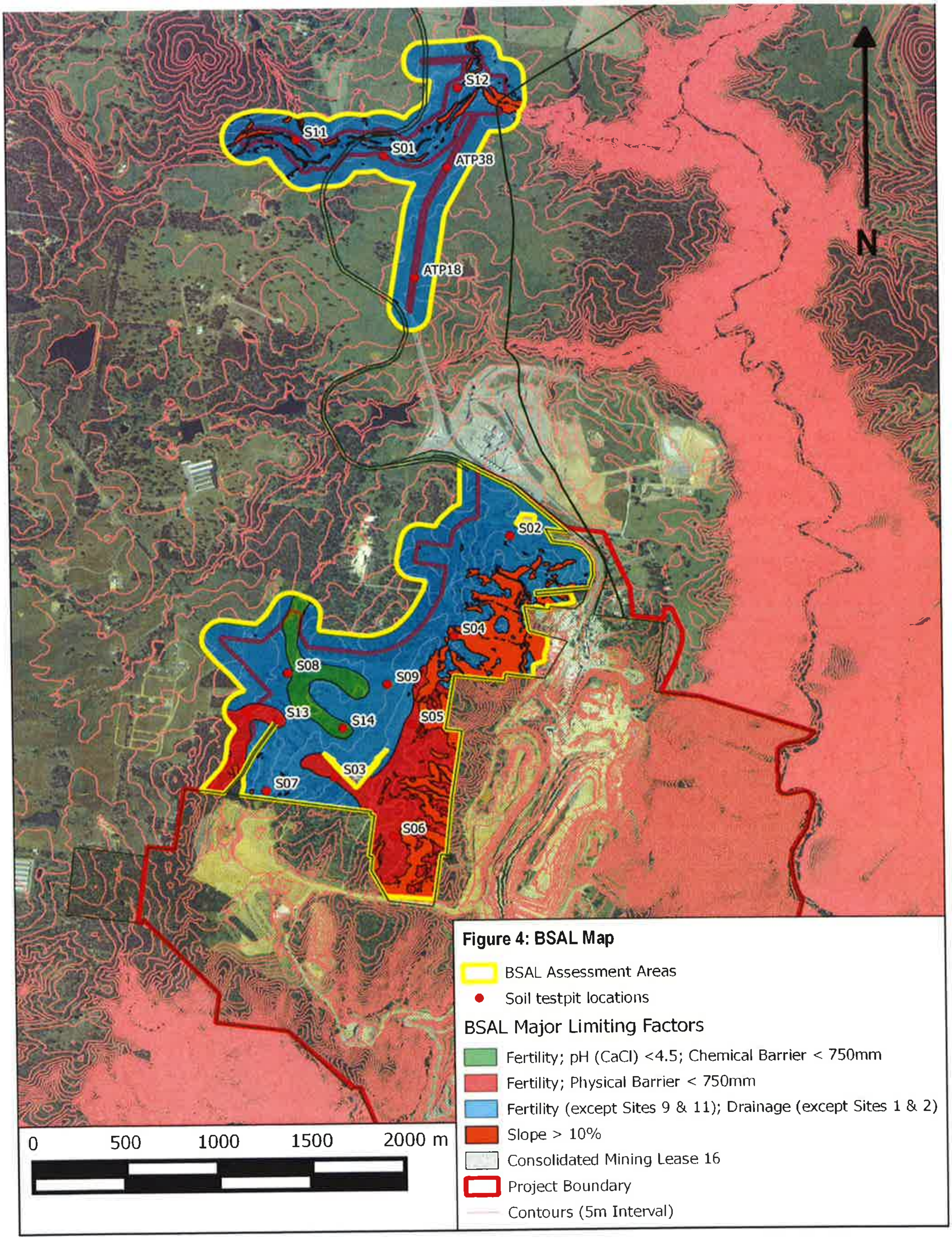


Figure 4: BSAL Map

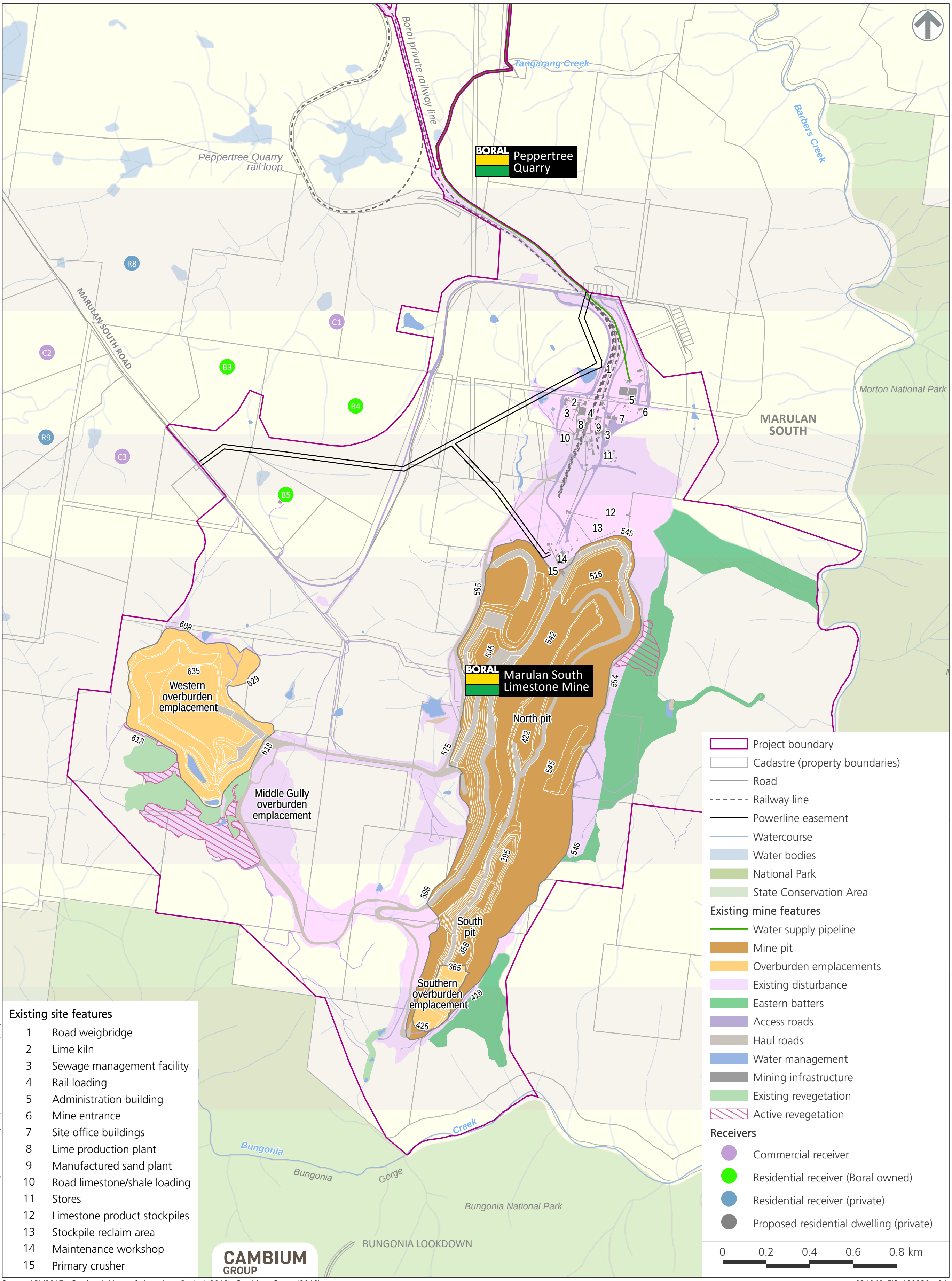
SCHEDULE 2

Relevant criteria	Consideration
Soil type	The site comprises soil landscapes that are of low fertility or have poor drainage, and does not meet the BSAL criteria.

Appendix 3 – Project Staging Plans

Existing operations - Stage 0

MARULAN SOUTH LIMESTONE MINE CONTINUED OPERATIONS - SSD APPLICATION
ENVIRONMENTAL IMPACT STATEMENT

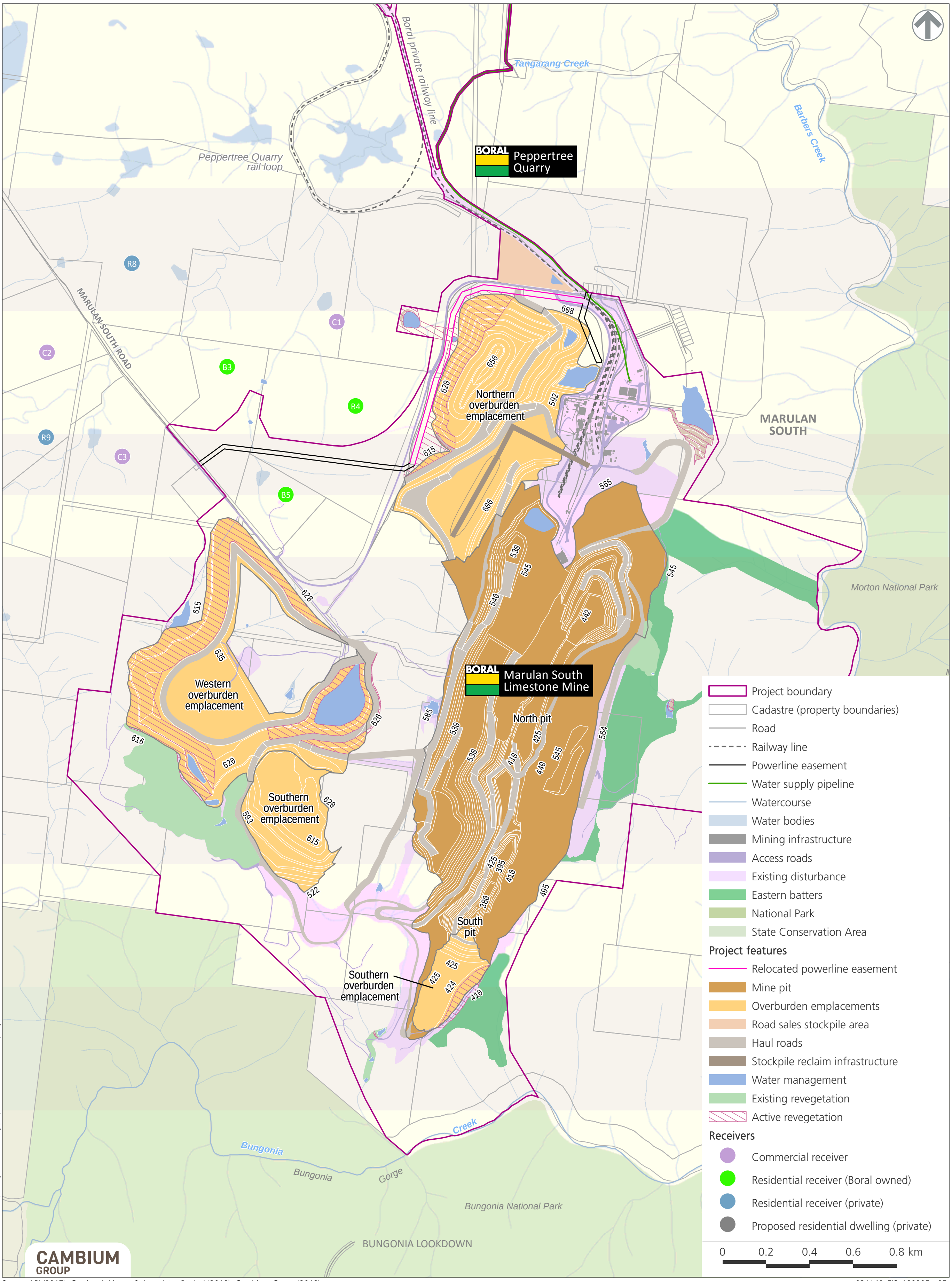


Source: LPI (2017), Gordon Atkinson & Associates Pty Ltd (2018), Cambium Group (2018).

031040_EIS_180830_v04

The Project - Stage 1 (5 years)

MARULAN SOUTH LIMESTONE MINE CONTINUED OPERATIONS - SSD APPLICATION
ENVIRONMENTAL IMPACT STATEMENT



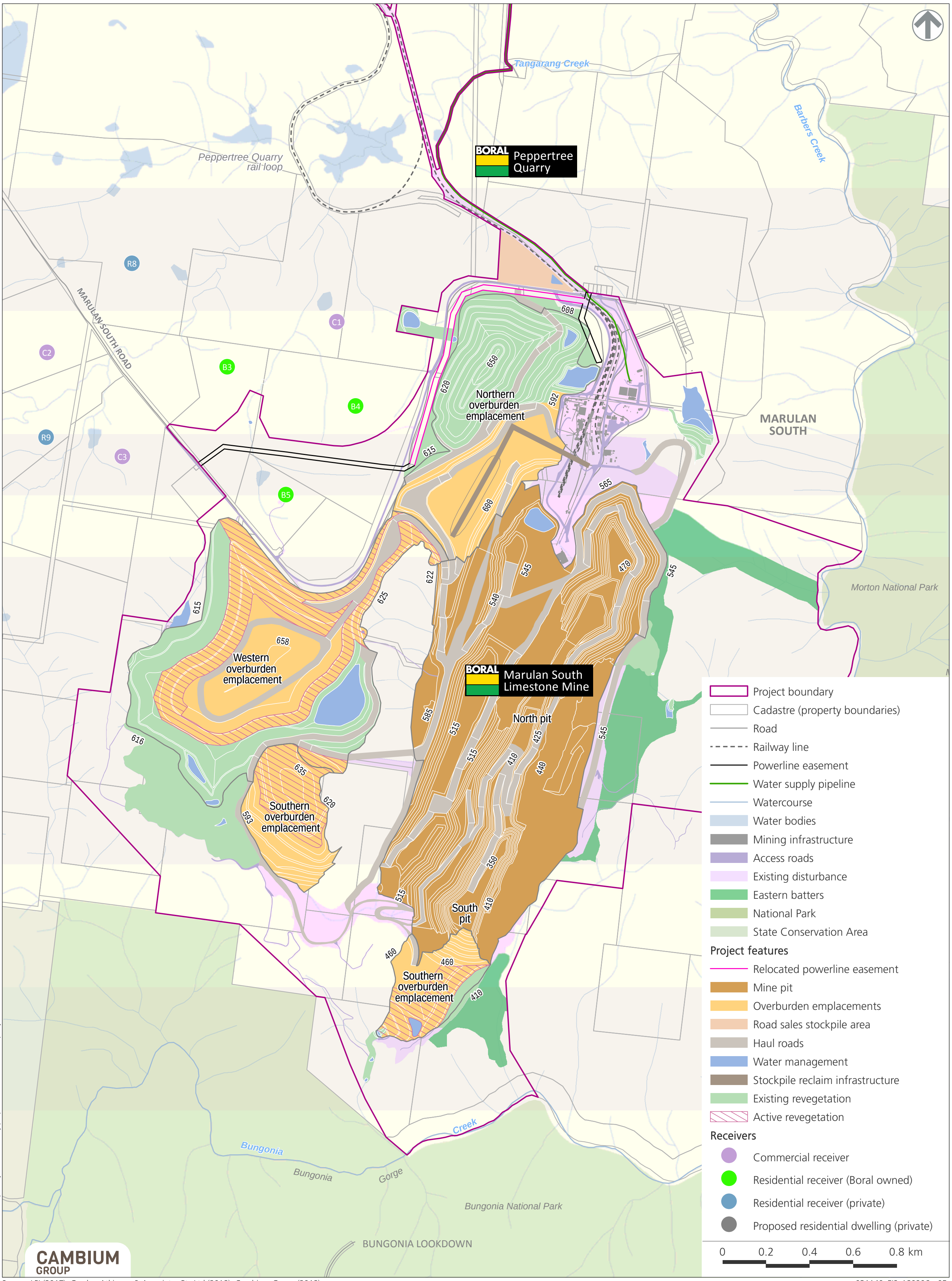
CAMBIUM GROUP

Source: LPI (2017), Gordon Atkinson & Associates Pty Ltd (2018), Cambium Group (2018).

031140_EIS_180905_v05

The Project - Stage 2 (8 years)

MARULAN SOUTH LIMESTONE MINE CONTINUED OPERATIONS - SSD APPLICATION
ENVIRONMENTAL IMPACT STATEMENT

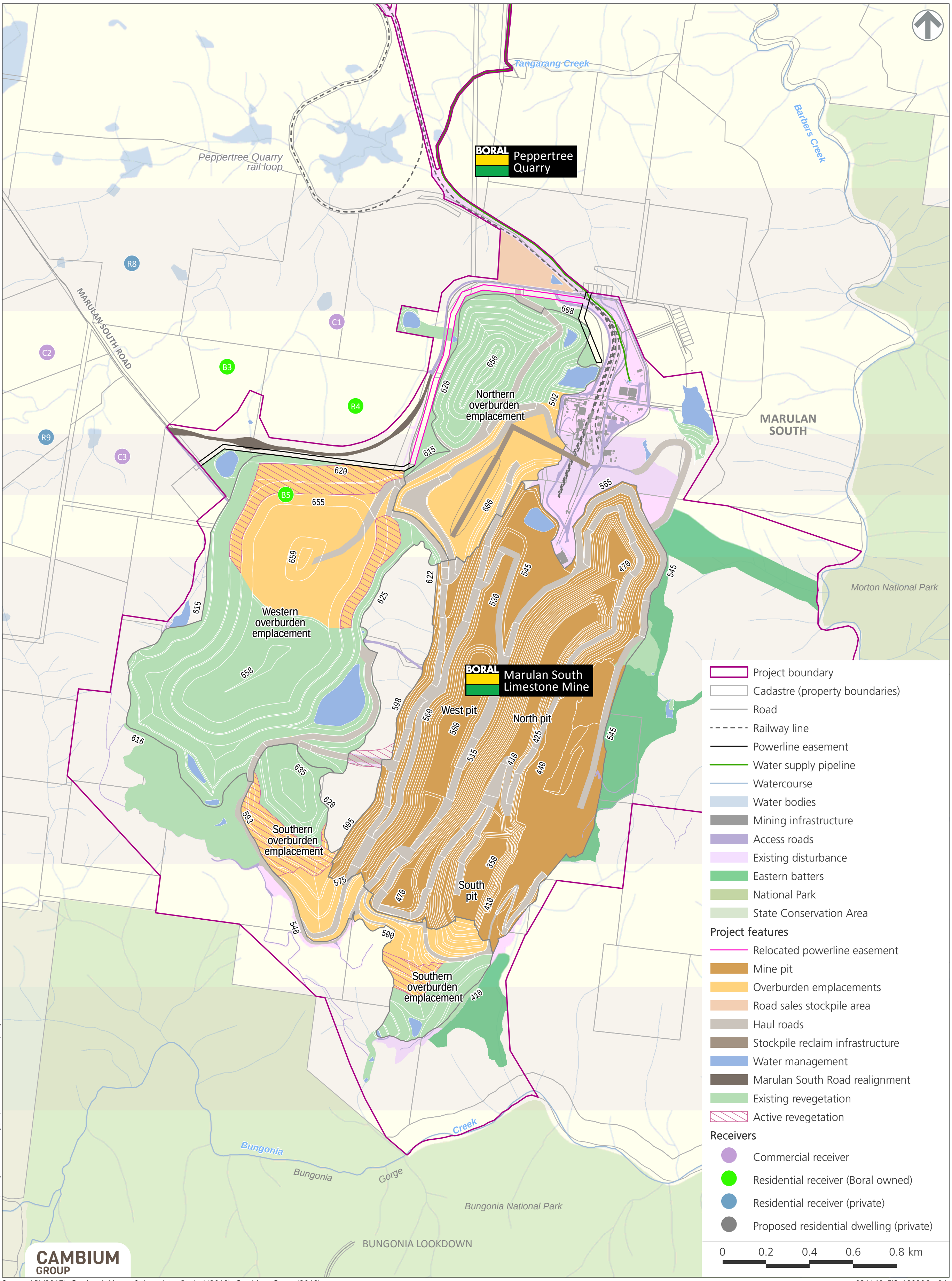


Source: LPI (2017), Gordon Atkinson & Associates Pty Ltd (2018), Cambium Group (2018).

031140_EIS_180906_v05

The Project - Stage 3 (6 years)

MARULAN SOUTH LIMESTONE MINE CONTINUED OPERATIONS - SSD APPLICATION
ENVIRONMENTAL IMPACT STATEMENT

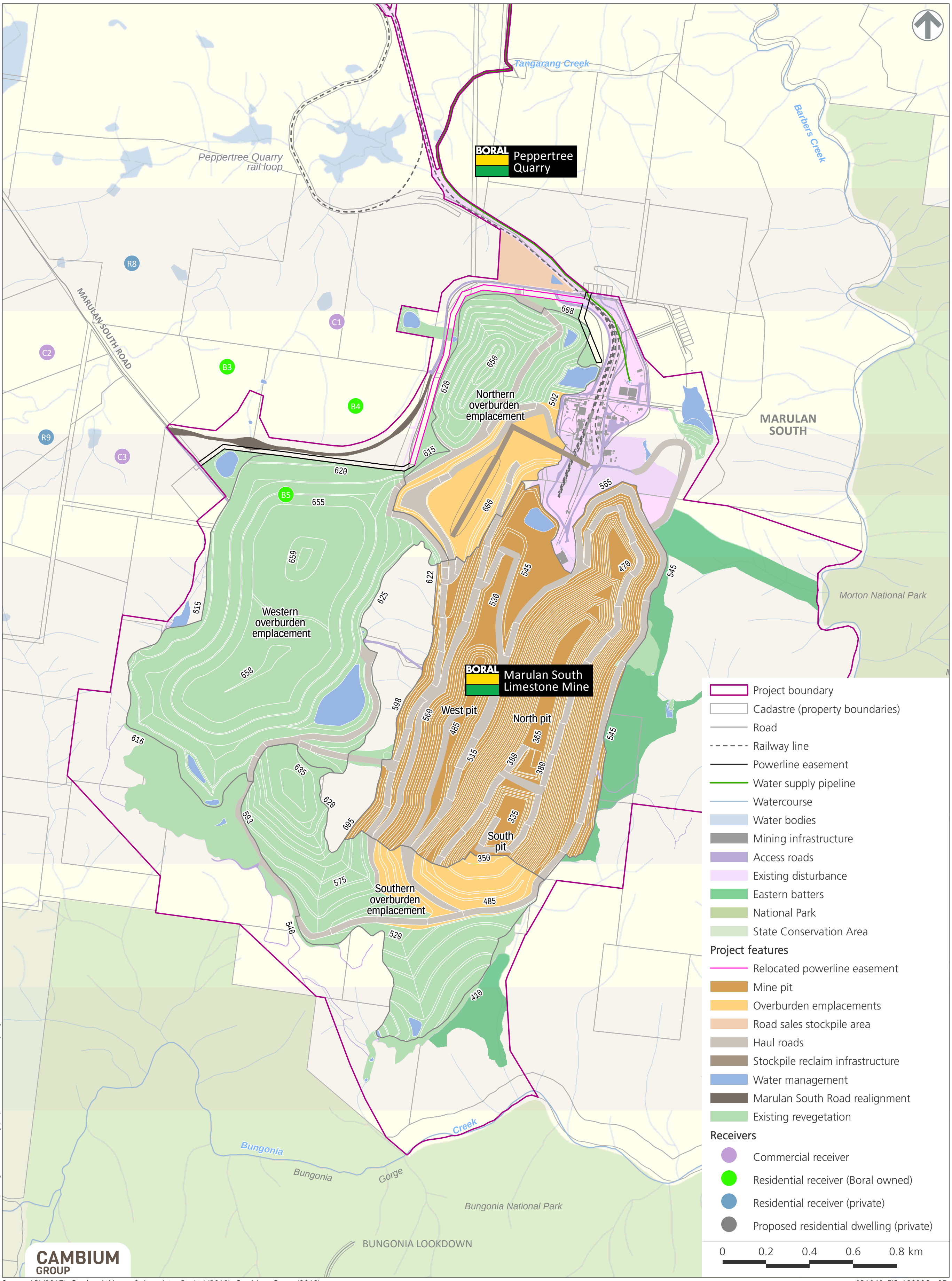


Source: LPI (2017), Gordon Atkinson & Associates Pty Ltd (2018), Cambium Group (2018).

031140_EIS_180906_v04

The Project - Stage 4 (11 years)

MARULAN SOUTH LIMESTONE MINE CONTINUED OPERATIONS - SSD APPLICATION
ENVIRONMENTAL IMPACT STATEMENT



CAMBIUM GROUP

Source: LPI (2017), Gordon Atkinson & Associates Pty Ltd (2018), Cambium Group (2018).

031040_EIS_180906_v05

Appendix 4 – Rehabilitation History

Existing rehabilitation areas within the Project site include:

Western (Main Gully) Overburden Emplacements

- A variety of revegetation methods were used to initially establish grass cover to stabilise the southern slopes in the mid-1980s.
- During 2003 the area, following the removal of a widespread Serrated Tussock invasion was direct seeded with a variety of tree and shrub species in conjunction with Greening Australia. In addition areas of the lower, flat waste emplacement were similarly revegetated.
- In 2005 a nominal 2 ha trial area was deep ripped and then seeded with a recommended seed mix under the guidance of revegetation specialists GSS Environmental and in association with the Site Environmental Officer. At first the trial appeared successful with large numbers of natives germinating only to be "burnt off" as a hot, dry and windy weather pattern emerged. A "second germination round" did not eventuate as hoped in 2006 / 07.
- Further trials conducted in late 2008 included both drill and direct seeding of 1 to 2 ha areas adjacent to the 2005 trial plots and hydro-mulching areas of both Main and Middle Gully emplacement.
- In late 2013 –early 2014, a total area of eight hectares was directly sown with tree seed. The principal objective of tree seeding was to re-establish native forest on these areas. To this effect seed of a range of locally occurring tree, shrub and groundcover, including native grasses was used.

Bryce's Gully Overburden Emplacement

- The rehabilitation area, occupying approximately 5.3 ha, was originally contoured and benched approximately 25-35 years ago to look similar to the surrounding topography. It is very steep, rocky and free draining and therefore retains little moisture. It has been grassed to help prevent erosion. Mixed tube stock containing wattles, gums and she-oaks were planted. Of the original trees planted about 60% survived the first year however under drought conditions further plants were lost with only about 10% of the original planting surviving.
- The first three benches were planted out again in 2005 with tube stock and water retaining crystals as well as a slow release fertilizer. Some 400 trees and shrubs were planted on the benches in 2005. Of these 400 trees about 50% survived helping to re-establish bushland corridors and to stabilize the first three benches reducing erosion and subsequent sediment release into creeks below.

PML 18

- An old mullock dump area of approximately 11 ha with similar characteristics as Bryces Emplacement but has been irrigated using a dripper irrigation system. Gums, wattles and she-oaks were planted as tube stock. Out of approximately 2,000 trees planted a loss of about 19% was incurred. Losses in this area have been replaced with mixed tube stock and the area is now fully fenced to keep feral and native animals out. Although revegetation progress is encouraging the area will require ongoing maintenance supported by additional plantings.

Barbers Creek Emplacement

- This emplacement occupies an area of approximately 11 ha and is located on the Eastern Batters. Some grassed revegetation has assisted in stabilising north facing benched slopes but the majority of the area remains unvegetated due to steepness of existing slopes that are subject to movement and slippage.

Eastern Batters (south)

- Trees of mixed species have been planted with black she-oaks being the dominant species. An initial loss of 15% occurred in the first year, with that figure increasing to a total of approximately 40% in the year 2003 to 2004, primarily due to dry conditions. The trees that have survived are healthy.
- At the end of 2005 over half of this area was deep ripped and seeded using the same method as the trial plots within the Western Emplacement with guidance from GSS Environmental. Success to date has been limited due to drought conditions, insect attack and feral animals including rabbits and goats.

South-East South Pit Revegetation Trial Area

- This trial commenced in September 2004. An area of approximately 1.3 hectares was prepared and planted in November – December 2004 with local species using seed ball and tube stock planting methods. Direct seeding trials have also been conducted on benches within this area during 2005 in addition to natural revegetation that has been observed to occur.

Freddy's Hill is located adjacent to Marulan South Road

- This area of tube stock revegetation developed in 1998 occurred in "in-situ" soil and amongst large stones or rocks that came to the surface when the area was deep ripped. The area had previously been grazed but improved considerably when grazing was stopped with large numbers of native ground covers re-establishing as well as native grasses. The mulch from establishing trees has also helped. The use of water retaining crystal has assisted tube stock plantings. Some weeds still persist in this area but will be slowly reduced as the tube stock establish. Native birds are starting to nest there and native reptiles are also present, including lizards. The area is naturally revegetating but monitoring will be maintained to record the fauna that are re-establishing habitat.

Marulan South Village

- Revegetation of the former Marulan South Village commenced during 1999 to 2002 and has become progressively more established with good evidence of natural re-vegetation. Some trees and shrubs are still small but have survived drought conditions. Good rainfall will definitely boost revegetation within this area that has a very good soil depth and structure and an established grass cover. Tree watering was conducted in the first six months of planting. Two years on trees have survived with only mowing of the grass that surrounds them required and minor maintenance. This area is considered re-vegetated with only maintenance plantings as required.

North-western Buffer Zone "Weather Station Paddock"

- Tree screen plantings and trials have been conducted directly north of the Western Emplacement area The "T-1" buffer zone was originally direct and drill seeded by Greening Australia in 2005.
- During 2008 the area was re-seeded and expanded to include approximately 10km of rip lines in length. Continued attempts to revegetate this area during the MOP period is considered important in establishing tree screens that provide a "northern" visual barrier to the advancing Western Emplacement and in the creation of a natural corridor for native fauna.

Appendix 5 – Topsoil Management Recommendations

Topsoil Stripping

Topsoil stripping involves the separate removal of topsoil from the surface, prior to deeper excavation or ground disturbance. The depth of topsoil recovered is dependent on the quality and depth of the material. Topsoil recovery according to the recommended stripping depth is essential. Stripping shallower than the identified depth will result in lost topsoil resource, and stripping deeper than the identified depth could result in the contamination of the topsoil resource with poor quality, or hostile, subsoil material.

During topsoil stripping operations, direct placement of excavated topsoil onto re-shaped areas is preferred to stockpiling, to avoid rehandling and reduce the potential for topsoil degradation or loss. If a re-shaped surface is not available, the topsoil will be stockpiled. The following controls shall be observed when undertaking these actions.

- Stripping depths and limits (including areas of no recovery), are to be marked (pegged or taped) and adhered to during stripping operations.
- Stripping operators shall be experienced in topsoil work, or otherwise be closely supervised, to ensure topsoil stripping depths are adhered to.
- Care is to be taken during topsoil stripping to avoid structural degradation of soils – taking particular care to avoid excessive compaction (i.e. avoid re-handling, limit stripping activities in wet conditions, and prevent heavy equipment trafficking over in situ soil material).
- Potential generation of dust will be considered in planning of topsoil stripping, with weather conditions, water truck availability, potential downtime and alternate standby tasks being key planning considerations.
- Soils should be stripped in a slightly moist condition and should not be stripped in either a dry or wet condition, thus reducing deterioration in topsoil quality and dust generation.

Location of Topsoil Stockpiles

- Topsoil stockpiles should not be located in the path of planned, or potential projects or operations. A long-term perspective should be adopted during this planning (preferably life-of-mine) and organisation-wide consultation should be undertaken during this process. Rehandling of topsoil is expensive and detrimental to topsoil quality.
- The planned final rehabilitation location for the topsoil should be considered when locating the stockpile (i.e. where it is to be used for rehabilitation). Haulage requirements (distance and volume) to get it to the stockpile location, and how it will be recovered from that stockpiled location and transported to that final destination should also be considered.
- Stockpiles should:
    - not be placed on excessively steep landform, that will increase erosion and potentially hamper recovery.
    - not be placed adjacent to, or amongst, existing woodland vegetation, that will potentially cause topsoil loss or damage to remnant vegetation.
    - not be placed on active overburden emplacements, until the final RL has been achieved at the proposed stockpile location.
    - be located away from edges of emplacements, ramps, dams, drains and pits, where future recovery may be constrained, increasing cost or planning complexity.
    - be aligned so as to reduce their susceptibility to wind erosion, especially if placed on top of elevated overburden emplacements.

  - not be located in, across or adjacent to watercourses or drainage lines with potential to flow.
  - not be located on flat and / or low-lying areas susceptible to flooding.

Stockpile Construction and Management

Where direct placement of topsoil is not possible, the period of topsoil stockpiling should be minimised to reduce the detrimental effects of storage on topsoil quality, especially topsoil structure, aeration and permeability, native seed bank viability, and biological activity levels in material stockpiled greater than one metre deep. Where topsoil stockpiling is likely to exceed three months, the following measures should be followed.

- The proposed stockpile pad should be stripped, cleared of surface rocks and vegetation, and isolated from local drainage, with nearby weed infestations treated, if required.
- As a general rule, a maximum stockpile depth of 3 m will be maintained.
- Seed stockpiles as soon as possible with a sterile annual cover crop species (e.g. oats or millet). A rapid growing and healthy annual crop sward provides sufficient competition to minimize the emergence of undesirable weed species.
- Topsoil will be block tipped. Under no circumstances will topsoil be tipped over a tip head or a second lift of block tip be used.
- Stockpiles should be trimmed and graded to ensure they shed water, to avoid pooling or waterlogging.
- Stockpile surfaces should be left coarsely textured to minimise erosion until vegetation is established, and avoid surface compaction and surface sealing.
- Every effort will be made to avoid equipment trafficking over topsoil stockpiles. Stockpiles should be isolated from adjacent operations and accidental vehicle access (by berm, ditch, substantial fence, bollards, old electricity poles, etc), and clearly identified by a sign to reduce the likelihood of interference.
- Following construction, stockpiles will be surveyed and recorded on mine plans. This information will be recorded on the topsoil stockpile register, along with other relevant data pertaining to each stockpile.
- Prior to re-spreading stockpiled material onto reshaped overburden emplacements (particularly onto designated tree seeding areas), an assessment of weed infestation on stockpiles should be undertaken to determine if individual stockpiles require herbicide application and / or "scalping" of weed species prior to spreading.

Maintenance of existing stockpiles

- On an annual basis, the stockpiles should be inspected for erosion, vegetation cover health, weed infestation and other general degradation or interference.
- Maintenance and remedial works will be scheduled, as needed. Such maintenance or remedial works may include:
  - repair of erosion (i.e. regrading of eroded areas), diversion of drainage paths and de-silting of sediment control structures;
  - slashing, re-seeding or supplementary planting;
  - application of fertiliser to address nutrient deficiency;
  - application of lime or gypsum to control pH and improve soil structure;
  - replacing signage and access barriers;
  - bushfire management activities; and
  - weed and pest animal control measures.

- If stockpiles are borrowed from, but not completely removed, the excavated face will need to be re-shaped to ensure water shedding and stockpile stability, and re-sewn with a protective cover crop. Those stockpiles will also need to be ear-marked for re-survey as part of the annual topsoil survey.
- For long-term stockpiles, a strict timetable of weed control and maintenance fertilizing is required as part of the stockpile management program.

Appendix 6 – Recommended Revegetation Seed Mix

1. Recommended Revegetation Seed Mix (Global Soil Systems, 2012)

Native Grasses & Ground Cover Species	Overstorey / Canopy Species
Themeda	*Eucalyptus agglomerata*
Microleana stipoides	*E. blakelyi*
Hardenbergia violacea	*E. bridgesiana*
Chloris truncate	*E. cinerea*
Austrodanthonia caespitosa	*E. dives*
	E. eugenoides
	E. globoidea
Understorey to Mid-Storey Species	*E. goniocalyx*
	E. macrorhyncha
Acacia falciformis	*E. mannifera*
A. decurrens	*E. melliodora*
A. implexa	*E. oblique*
A. mearnsii	*E. oblonga*
A. parramattensis	*E. punctata*
A. rubida	*E. piperita*
A. ulicifolia	*E. radiata*
Bursaria spinosa	*E. rossii*
Dodonaea cuneata	*E. sclerophylla*
Indigofera australis	*E. sieberi*
Lomandra longifolia	*E. tereticornis*
Pittosporum undulatum	*E. viminalis*
	Allocasuarina littoralis

2. Recommended Hydro-seeding mix (Global Soil Systems, 2012)

Erosion Control / Grassland Species	Rate (kg/ha)
Goulburn Sub clover (*Trifolium subterraneum cv. Goulburn)*	4
Dixie Crimson clover (Trifolium incarnatum cv. Dixie)	2
Haifa white clover (Trifolium repens cv. Haifa)	2
Tahora white clover (Trifolium repens cv. Tahora)	2
Fitzroy (Lolium perenne)	5
Australian II Phalaris (Phalaris aquatica cv. Australian II)	5
Kingston Rye (Lolium perenne cv. Kingston)	5
Currie Cocksfoot (Dactylis glomerate cv. Currie)	1.5
Rye Corn (Secale cereal)	20
Couch (Cynodon dactylon)	5
Japanese millet (Echinochloa esculenta)	10

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