Wedgerock Pty Ltd

ABN: 15 099 038 123

Karuah South Quarry

Groundwater Assessment

Prepared by

Larry Cook Consulting Pty Ltd

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Groundwater Assessment

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Please note: All Figures in this document are presented in colour on the electronic version supplied on the USB or downloaded from the DPE Website.

CONTENTS

CONTENTS

Page

CONTENTS

Page

ANNEXURES

FIGURES

TABLES

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EXECUTIVE SUMMARY

Larry Cook Consulting Pty Ltd has been commissioned by R.W. Corkery & Co. Pty Limited on behalf of Wedgerock Pty Ltd ("the Applicant") to prepare this Groundwater Assessment including hydrogeological field investigations and office-based studies for the proposed Karuah South Quarry ("the Project"), Blue Rock Close, Karuah, NSW.

It is proposed to develop and operate a hard rock quarry on the southern side of Lot 11 in DP1024564 ("the Site"). The target resource is rhyodacite ignimbrite belonging to the Nerong Volcanics with extraction achieved by conventional drill and blast, load and haul and processing methods to produce up to 600000tpa of quarry products. Two indicative stages of extraction moving from south to north are proposed over 25 years. The results of surface water studies indicate that sufficient water for use in Project-related activities can be collected on site.

The Site is located approximately 40 km north of Newcastle and 4km northeast of Karuah, Central Coast NSW.

This Groundwater Impact Assessment provides an assessment of the local and regional hydrogeology centred on the Site, and the potential impacts on the groundwater system and environment that may be associated with the Project.

The Site is located within the Water Sharing Plan for the North Coast Fractured and Porous Rock Groundwater Sources (the WSP).

The SEARs require a detailed assessment of potential environmental impacts of the Project including:

- potential impacts including any cumulative impacts on the quality and quantity of existing surface and groundwater resources, including the impacts on existing user entitlements, affected licensed water users and basic landholder rights, groundwater-dependent and groundwater-sensitive ecosystems;
- an adequate and secure water supply for the Project;
- identification of any licensing requirements or other approvals under the *Water Act 1912* and/or *Water Management Act 2000* and demonstration that the Project is consistent with the relevant access and trading rules within the Water Sharing Plan for the North Coast Fractured and Porous Rock Groundwater Sources;
- a description of the measures that would be implemented to avoid, minimise, mitigate, offset, managed and/or monitor the impacts of the Project; and
- an assessment of the potential to intercept and/or impact groundwater and predicted dewatering volumes, water quality and disposal/retention methods. This would need to address the requirements of relevant policy including the Aquifer Interference Policy.

The Site is underlain by the Nerong Volcanics, a dominantly dense terrestrial rhyodacitic ignimbrite. The rhyodacitic deposit in the local area is broadly tabular in shape which is consistent with the mode of formation – an aerially extensive, blanket-type ignimbrite-style eruption emanating from a nearby volcano/s.

The Nerong Volcanics is disconformably overlain by the Karuah Formation and the Booti Booti Sandstone and conformably overlies the Conger Formation and Boolambayte Formation. The stratigraphic sequence beneath the Site dips gently to the south-southeast.

The results of resource drilling within and surrounding the Site indicates a minimum 42m thickness of rhyodacite which dips to the south. The top 1m to 5m of this tabular body is strongly weathered.

The southern part of the Site drains to the estuarine Yalimbah Creek system ultimately flowing into the Karuah River.

Groundwater is associated with secondary geological defects that have dissected the crystalline rock mass. The rhyodacite does not have any primary porosity, therefore the groundwater occurrence is associated with discontinuous sub-vertical 'sheet like' fractures and shear zones. These defects provide a discontinuous potential fluid pathway for percolating rainfall. The fractured rhyodacite aquifers are interpreted to be under semi-confined to confined hydrogeological conditions. Enhanced hydraulic conductivity may be associated with the occurrence of relatively open joints and fractures or in areas containing a high density of fracturing and/or intersecting fractures/faults.

Although structural discontinuities likely exist in the local area, the evidence from many years of rhyodacite extraction in the Karuah Quarry immediately north of the Site indicates the existence of 'dry' quarry conditions, i.e. little or no groundwater inflow to the extraction area. This suggests that groundwater flow in this aquifer is insignificant and/or the evaporative potential is greater than any groundwater inflow into the pit.

Aquifer recharge is primarily by way of excess precipitation (rainfall), in particular the water that infiltrates fractured rhyodacite which is not lost through evapotranspiration. The demonstrable relative impervious nature of the rhyodacite resource with overprinted secondary defects suggests that the recharge proportion from rainfall is likely between approximately 1 % and 5 %.

The surface water and groundwater systems in the vicinity of the Site are considered to be disconnected. However, natural discharge of shallow groundwater (interflow) may occur on the Site as a result of topography and the relatively permeable "boulder strewn" scree materials that has developed on the Site (contact springs). It is anticipated that a small proportion of rainfall would percolate through this relatively permeable material which overlies the less permeable rhyodacite.

Although the discharges from these contact springs are interpreted to vary in response to seasonal and climatic factors, anecdotal evidence indicates that they are low volume semi-permanent flows.

The hydraulic conductivity values of the rhyodacite aquifer depends on the orientation, interconnectivity, frequency and size of any secondary defects as the result of structural deformation. Crystalline igneous rocks typically have very low to zero primary porosity and zero primary permeability. The typical value for hydraulic conductivity of a rhyodacite, without major structural deformation and fracturing, is predicted to be less than 1×10^{-6} m/s. Aquifer testing carried out by Coffey on the rhyodacite aquifer of the Karuah East Quarry varied between 5×10^{-6} m/s and 9×10^{-6} m/s.

A district search for data and information for registered boreholes held by WaterNSW in their computerised on-line database revealed that there are no registered bores either on the Site or within a three-kilometre radius. However, a search of the Bureau of Meteorology's Groundwater Explorer identified one production bore (GW201611), approximately 3km northwest of the Site (refer **Section 10.3**). The lack of bores in the vicinity of the Project supports the hypothesis that fractured hard rock aquifer has low yields.

A network of four monitoring bores (piezometers) were constructed within former resource drill holes in the proposed extraction area. Baseline measurements of water level were collected in the four piezometers. Automated fully calibrated 'Greyhound' water level sensors and loggers with a telemetry function were installed in the four piezometers in order to collect 'real time' baseline water level data.

In summary, the hydrographs for the four piezometers generally reveal a relatively static water level with no apparent correlation with rainfall during the 7-month monitoring period. Standing water levels ranged from 7.10 m to 26.58 m Below Ground Level. The elevations of the piezometric surface ranged from 21.92 m to 42.10 m AHD. This data supports the hypothesis that the fractured rhyodacite aquifer is discontinuous and semi-confined to confined.

Baseline groundwater sampling and analysis was carried out in the four piezometers with the objective of establishing a baseline set of water quality data for the fractured rhyodacite aquifer system. In summary, the groundwater is slightly acidic, low salinity with moderate to high buffering capacity. Trace to low levels of total metals were recorded. The ion compositions indicate that the groundwater is Sodium Chloride type. The hydrochemical signature of the rhyodacite aquifer is interpreted to be typical of a rainfall-dominant groundwater system which suggests that the discrete discontinuous sub-vertical fractures that dissect the rhyodacite rock mass are likely limited in extent and provide preferential, but discontinuous, groundwater pathways for percolated rainfall

Potential groundwater impacts may include impacts to the local and regional groundwater system, water supply bores including any proximal neighbouring bores, GDEs and culturally significant sites that are dependent on groundwater.

The hydrogeological investigations indicate that the local direction of groundwater flow is to the south broadly mimicking the topography. The results for water level monitoring indicate that the rhyodacite aquifer system is discontinuous and under semi-confined to confined conditions.

The elevation of the base of the extraction area is approximately 20m AHD. This suggests that groundwater may be intersected in the lower parts of the extraction area at different stages over the life of the Project. However, the operational Karuah Quarry located immediately north of the extraction area is observed to be 'dry' even though sub-vertical fractures and shear zones (secondary defects) are mapped in the walls of the extraction area. The relatively 'low-yielding' aquifer system is therefore considered to be associated with discrete discontinuous sub-vertical fractures that dissect the rhyodacite rock mass and provide preferential, but discontinuous, groundwater pathways for percolated rainfall. Based on the existing hydrogeological conditions in the existing Karuah Quarry and the relatively 'low-yielding' fracture aquifer system it is concluded that minor amounts of groundwater may flow into the proposed extraction area.

Whilst review of WaterNSW records identified that there are no registered bores within 3km of the Site, a search of the Bureau of Meteorology's Groundwater Explorer identified a production bore (GW201611), approximately 3km northwest of the Site (refer **Section 10.3**). However, due to the up gradient location of this bore and the depth of the screened interval it is therefore concluded that the Project will not adversely impact any neighbouring registered bores.

The results of surface water studies reveal that overland flow is largely discharged to longitudinal drainage infrastructure located along the alignment of Blue Rock Close. This infrastructure discharges into significant cross drainage associated with the nearby Pacific Highway. Groundwater flow within the rhyodacite aquifer predominantly occurs within secondary defects (fractures and shear zones) which are recharged from rainfall infiltration. These fracture systems are discontinuous and considered to be disconnected from watercourses.

Any groundwater inflow into the extraction area is predicted to be 'low flow', 'low salinity', non-toxic and effectively diluted by rainwater. That is, the chemistry of any residual water retained in the final void would be dominated by rainwater.

Potential contamination sources in extractive industry operations may be associated with hydrocarbon leaks from mining equipment, refuelling operations and spills in fuel (and chemical) storage facilities and the mechanical workshop on the Site. The nature of the extraction operations is such that limited fuels and hydrocarbon products would be stored on the Site. Implementation of an appropriate workshop plan, fuel storage plan and water management plan with effective control measures would significantly reduce the risk of any adverse environmental impacts.

No Groundwater Dependent Ecosystems (GDEs) or Groundwater Sensitive Ecosystems (GSEs) have been identified on the Site or within close proximity. It is therefore concluded that it is highly unlikely that potential contaminants could reach this environmental receptor. Implementation of effective control and management measures would further reduce the risk of any adverse environmental impacts.

Having regard to the presence of a semi-confined to confined fractured rock aquifer system beneath the proposed extraction area, the key parameters for assessing minimal impact considerations for the Project are the potential adverse impacts from the extraction area on water pressure and water quality. However, as the only registered groundwater user in the vicinity of the Project (GW201611) is situated approximately 3km from the extraction area, in a different geologic unit (quartz dominant lithic sand, silt, gravel and clay) to that in which the extraction area is situated and within which groundwater flow is typically limited to secondary defects, it is considered that the minimal impact considerations relating to water pressure would not be met.

Furthermore, the location of the extraction area and baseline groundwater chemistry indicates there is no evidence to suggest that a significant change in water quality would result from any aquifer interference activity.

The main uncertainties in the groundwater assessment are considered to be the degree of heterogeneity of the hard rock aquifer system on the local scale. In order to increase the understanding of the rhyodacite aquifer system and assess any impacts, an ongoing program of water level and water quality monitoring as well as the recording of any groundwater extraction (pit inflows), and reporting of these data would be required.

Groundwater monitoring and reporting strategies would constitute an important part of a Water Management Plan to be developed prior to the commencement of operations. A suggested outline for a monitoring and reporting strategy is provided.

Strategies to minimise the risks and uncertainties related to any potential impacts from the Project would depend on progressive monitoring results throughout the life of the Quarry. Strategies to mitigate any risks may include acquisition of additional water licences or exploring possible offsets.

The factors affecting the rate of inflow of any groundwater into an extraction void are the size, shape, location, rate of excavation and the hydrogeological properties of the host rock, in particular the effective permeability of the crystalline rhyodacitic ignimbrite (Nerong Volcanics).

The rate of inflow of groundwater into the progressively developed extraction area will also be controlled by local geologic and structural elements.

Although secondary defects are known to exist in the rhyodacite aquifer, the evidence from many years of extraction in the Karuah Quarry indicates the existence of 'dry' quarry conditions. As a result, it is anticipated that it will not be necessary for the Operator to secure a water access licence, however, the results of monitoring on any flows and volumes entering the expanding quarry should be assessed and reported to DoI - Water If and when they occur. Should it be established that sustained inflows are occurring, the Operator would arrange for a water access licence to cover groundwater inflow, at a volume agreed upon with DoI – Water.

The proposed quarry operation would be largely a 'dry' operation. The results of the surface water studies indicate that sufficient water for use in Project-related activities can be collected on-site. It is understood that there are no plans to apply to WaterNSW for a water supply work on the Site for any make-up water as all water collected for Project-related use would be accounted for under the maximum harvestable rights provisions of the *Water Management Act 2000*.

The important and dynamic interrelationship between surface water, groundwater systems and land use in the hydrologic cycle of landscapes is recognised. Subsequently, a strategy for the management of monitoring data and in-house and regulatory reporting is proposed as part of a Water Management Plan (WMP) that would be developed by the Operator, approved by DPE and implemented. A suggested approach is provided.

Automated measurements of groundwater level should be continued in the established monitoring network in order to build on the existing database. An ongoing long-term program of regular water level measurements (and manual readings) and water quality sampling and analysis in the strategically-designed monitoring network is recommended in order to collect additional hydrogeological data. Monitoring data would be statistically analysed to establish any natural variation in water levels and water quality in piezometers. The recommended on-site monitoring network is provided.

It is recommended that sampling and analysis of groundwater quality in the four piezometers should be carried out on a quarterly (3 monthly) basis for an initial period of 24 months. In this way, analysis of the results would establish any trends in water quality and establish any natural variation. It is recommended that the water quality data is reviewed every year to ensure only meaningful data is being collected. In the event data from the piezometers and observations in the extracted areas indicate little groundwater is present, the monitoring program should be curtailed or abandoned.

A recommended protocol for data management and reporting would be incorporated in the WMP.

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1. INTRODUCTION

1.1 STATEMENT

Larry Cook Consulting Pty Ltd (Larry Cook Consulting) was commissioned by R. W. Corkery & Co. Pty Limited on behalf of Wedgerock Pty Ltd ("the Applicant"), to undertake a Groundwater Impact Assessment including hydrogeological field investigations and office-based studies with regard to the groundwater resources beneath and surrounding Lot 11 in DP1024564, 61 Blue Rock Close, Karuah New South Wales (the Site).

It is proposed to extract and process the known hard rock resource (rhyodacitic ignimbrite) of the Site to produce a range of aggregates and other construction materials for use in the Hunter and Greater Sydney Metropolitan Regions.

This Groundwater Impact Assessment report was prepared for inclusion in the Environmental Impact Statement prepared by R. W. Corkery & Co. Pty Limited to support the development application for the Karuah South Quarry Project ("the Project"). The application for the Project would be made as a State Significant Development in accordance with Clause 7 (1)(a) of Schedule 1 of State Environmental Policy (State and Regional Development) 2011 (State and Regional Development SEPP).

1.2 SCOPE OF WORK AND OBJECTIVES

This report provides an assessment of the local and regional hydrogeology centred on the Site, and the potential impacts on the groundwater system that may be associated with the proposed hard rock extraction operations of the Project.

The objectives of this hydrogeological assessment are to:

- establish and assess local and regional hydrogeological conditions;
- establish the existing groundwater utilisation in the area surrounding the Site;
- estimate recharge volumes in the area centred on the Site;
- carry out baseline analytical testing to characterise the groundwater;
- develop a conceptual hydrogeological model;
- assess any potential impacts of the extraction of hard rock on local and regional aquifer systems, local and regional water tables, any down-gradient groundwater dependent ecosystems (GDEs), groundwater chemistry and local water users;
- provide recommendations including operational safeguards, mitigation measures and contingency planning; and
- propose a long-term groundwater monitoring program, and reporting and database management protocols.

1.3 THE SITE

The Project would be constructed and operated on the southern section of Lot 11, DP1024564, (the Site). The Site is approximately 21 hectares (ha) and is located approximately 40 kilometres (km) north of Newcastle and 4 km northeast of Karuah (refer **Figure 1**)

The Site is located immediately south of the Karuah Hard Rock Quarry and southwest of the Karuah East Quarry, both owned and operated by Hunter Quarries Pty Ltd.

A topographic plan over the Site is presented in **Figure 2**.

The Site straddles the southern facing slope of a prominent hill. The highest point of the Site is on the central eastern boundary of Lot 11 DP 1024564 (139 m Australian Height Datum (AHD)). The lowest elevation of the Site is approximately 12m AHD on the southern boundary.

2. DESCRIPTION OF PROPOSED HARD ROCK EXTRACTION OPERATIONS

The proposed extraction area, as shown on **Figure 3**, has been defined based upon the occurrence of the underlying hard rock resource. An estimated 10 million tonnes of fresh rock and 1.25 million tonnes of weathered rock have been identified within the proposed extraction area.

The Project would utilise conventional drill and blast, load and haul and processing methods to produce up to 600 000tpa of quarry products. These products would principally be used for road pavement products, concrete and sealing aggregates, pre-coat products, gabion, armour rock, decorative gravel, crusher fines and select fill. Extraction would be undertaken in a staged manner, that is, over two stages with each stage comprising three sub-stages. Production during the initial stages of extraction would be lower with production gradually ramped up in the years following site establishment. It is expected that extraction would continue for a period of approximately 25 years following Project commencement.

It is noted that both extraction and processing operations have been designed to optimise the recovery of resource whilst satisfying environmental and Site constraints.

The principal components of the Project are shown in **Figure 3** and summarised as follows.

- **Extraction Area - Stage 1**
  The Stage 1 extraction area would cover approximately 4.9ha with its footprint typically between approximately 30m AHD and 75m AHD (to a floor with an elevation of 8m AHD).
- **Extraction Area - Stage 2**
  The Stage 2 extraction area would cover approximately 5.9ha with its footprint typically between 75m AHD and 120m AHD (to a sloping floor from an elevation of 8m to 12m AHD).
- **Quarry Infrastructure Area**
  The Quarry infrastructure area would be located on the southern side of the extraction area and would incorporate the product stockpiling area, mobile processing plant and ancillary components area.

Figure 1 Locality Plan

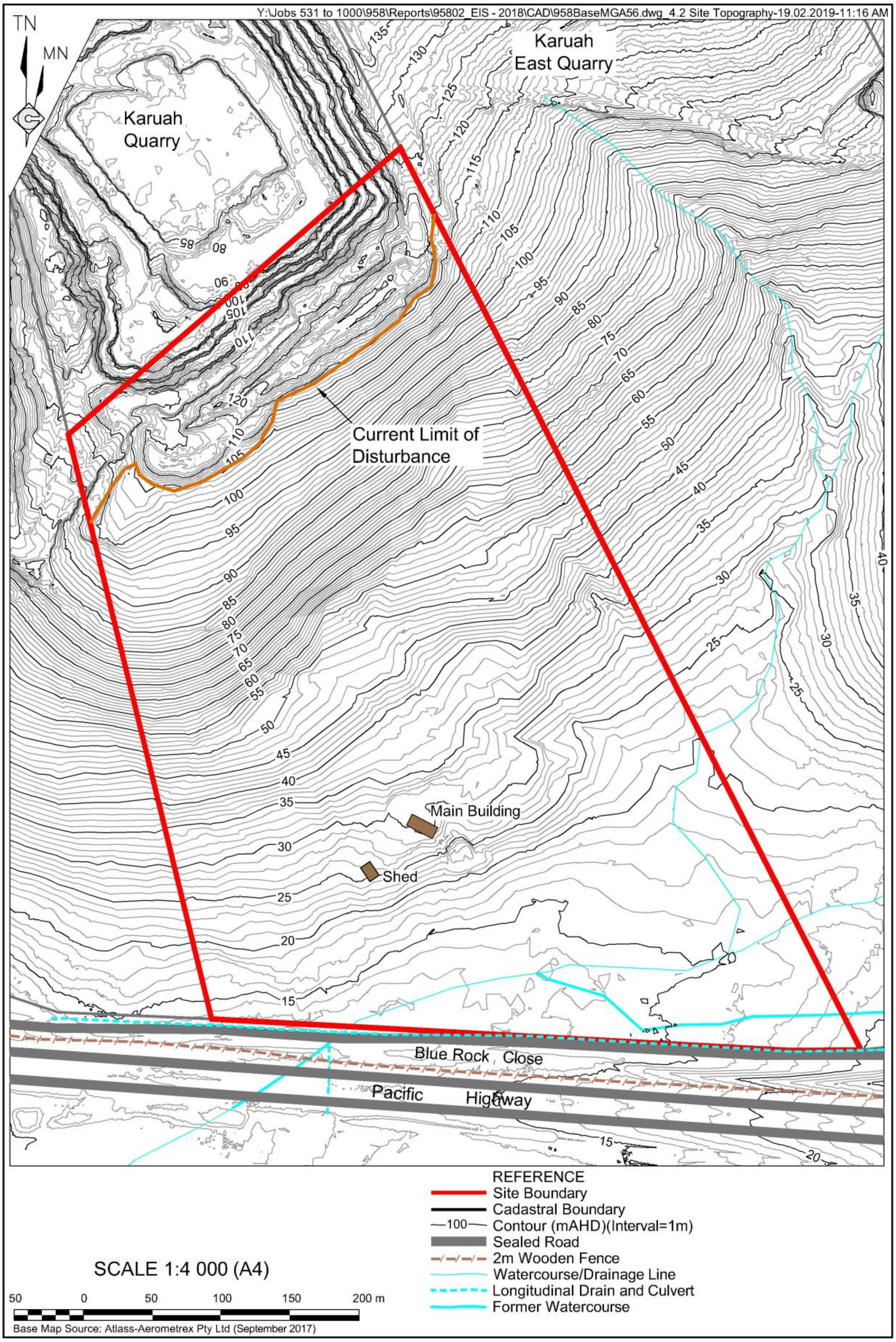


Figure 2 Site Topography

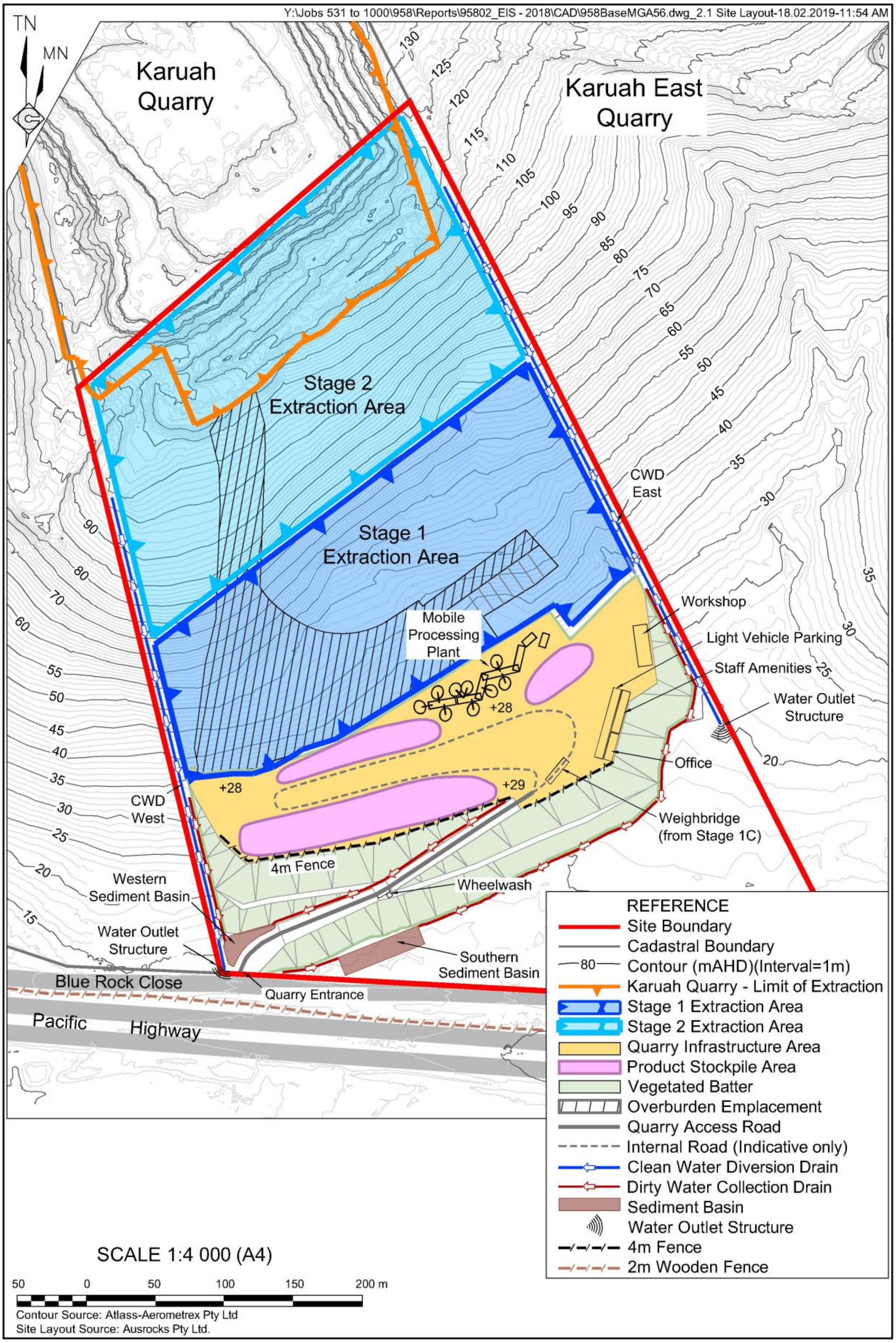


Figure 3 Indicative Site Layout

- **Product Stockpiling Area**
  The product stockpiling area would be located on the northern section of the Quarry infrastructure area during Stage 1. This area would be expanded to cover northern, southern and western portions of the quarry infrastructure area during Stage 2 (see **Figure 3**).
- **Mobile Processing Plant**
  The mobile processing plant would incorporate a range of crushers and screens and would be located on the western section of the quarry infrastructure area during Stage 1. During Stage 2 (see **Figure 3**), the mobile processing plant would be relocated to the eastern section of the Quarry infrastructure area to minimise product haulage distances.
- **Internal Roads**
  A network of roads to provide access for off-road haul trucks between the extraction and processing area.
- **Quarry Access Road**
  The inclined, sealed section of road extending from the Quarry entrance to the southern side of the Quarry infrastructure area.
- **Sediment Basins**
  Two sediment basins (Western and Southern), each with a with pre-treatment pond, would be constructed to collect sediment laden runoff from the disturbed sections of the Quarry; The western sediment basin would be located at the southwestern toe of the Quarry infrastructure area pad, north of the Quarry access road, whilst the southern sediment basin would be situated along the southern toe of the Quarry infrastructure area pad / Quarry access road. Perimeter drains along the toe of the Quarry infrastructure area pad would collect runoff from the batter slopes of the pad and direct it to either of these sediment basins.
- **Diversion Drains**
  Two clean water diversion (CWD) drains (CWD East and CWD West) would be constructed to direct runoff from undisturbed areas upslope of the extraction area. Bunding and/or contour drains would intercept runoff from the upslope undisturbed catchments, preventing it from entering the extraction area and directing this runoff to either of the clean water diversion drains which in turn would flow towards Yalimbah Creek.

The overall footprint of the operation would be kept as small as possible during all stages of operation, with vegetation and soil removed immediately prior to the progressive extension of operations. Progressive rehabilitation would be undertaken as soon as practicable following disturbance.

Quarry products would be despatched by road using the existing road network with access to the Site via a new entrance to Lot 11 DP 1024564 from Blue Rock Close. The location of the Quarry Entrance would be close to the existing entrance to the property and would be constructed to accommodate with quad-dog trailers and semi-trailers.

3. RELEVANT GOVERNMENT PLANS, LEGISLATION, POLICIES AND GUIDELINES

3.1 INTRODUCTION

The legislation, plans, policies and guidelines relevant to the Project are listed in **Table 1**.

Table 1
Relevant Legislation, Plans, Policies and Guidelines

Legislation
NSW Water Management Act 2000
NSW Water Act 1912
Plans
Water Sharing Plan for the North Coast Fractured and Porous Rock Groundwater Sources (2016)
Policies
NSW State Groundwater Policy Framework Document (1997)
NSW State Groundwater Dependent Ecosystems Policy (2002)
NSW State Groundwater Quality Protection Policy (1998)
Draft NSW Groundwater Quantity Management Policy (2001)
NSW Aquifer Interference Policy – (2012)
NSW Policy for Managing Access to Buried Groundwater Sources (2011)
Guidelines
Guidelines for Controlled Activities (NOW, 2012)
Groundwater Monitoring and Modelling Plans – Information for prospective mining and petroleum exploration activities (NOW, 2014)
Australian Groundwater Modelling Guidelines 2012 (Commonwealth)
NSW Environment Protection Authority Guidelines for the Assessment & Management of Groundwater Contamination (EPA, 2007)
National Water Quality Management Strategy Guidelines for Groundwater Protection in Australia (ARMCANZ/ANZECC, 2000)
Environment Australia: Environmental Flows Initiative technical report No.2 (2001)

3.2 THE WATER SHARING PLAN FOR THE NORTH COAST FRACTURED AND POROUS ROCK GROUNDWATER SOURCES

The Site is located within the Water Sharing Plan (WSP) for the North Coast Fractured and Porous Rock Groundwater Sources.

The WSP is made under the *Water Management Act 2000* which provides the mechanism for the control and management of groundwater resources within NSW and applies to those areas of NSW that have WSPs in place. The WSP commenced on 1 July 2016 and applies until July 2026.

The water sharing rules of the WSP allocate water for the environmental needs of the groundwater sources, directs how water is shared among different water users and provides rules for protecting the environment, extractions, managing licence holder's water accounts and water trading (water dealing).

The objectives of the WSP, as gazetted, are to:

a) protect, preserve, maintain and enhance the high priority groundwater dependent ecosystems and important river flow dependent ecosystems of these groundwater sources,

b) protect, preserve and maintain the integrity of aquifers in these groundwater sources,

c) protect, preserve, maintain and enhance the Aboriginal, cultural and heritage values of these groundwater sources,

d) contribute to the sustainable and integrated management of the water cycle across these groundwater sources,

e) protect basic landholder rights,

f) manage these groundwater sources to ensure equitable sharing between users,

g) provide opportunities for market-based trading of access licences and water allocations within sustainability and system constraints,

h) provide security and certainty for the life of the plan to stakeholders that utilise groundwater resources,

i) provide water allocation account management rules which allow sufficient flexibility to encourage responsible use of available water,

j) contribute to the maintenance of water quality,

k) provide recognition of the connectivity between surface water and groundwater,

l) adaptively manage these groundwater sources,

m) contribute to the environmental and other public benefit outcomes identified under the Water Access Entitlements and Planning Framework in the *Intergovernmental Agreement on a National Water Initiative (2004)* (the NWI),[1] and

   – be given statutory recognition and have at least the same degree of security as water access entitlements for consumptive use and be fully accounted for,

   – be defined as the water management arrangements required to meet the outcomes sought, including water provided on a rules basis or held as a water access entitlement, and

   – if held as a water access entitlement, may be made available to be traded (where physically possible) on the temporary market, when not required to meet the environmental and other public benefit outcomes sought and provided such trading is not in conflict with these outcomes.

[1] Under the NWI, water that is provided by NSW to meet agreed environmental and other public benefit outcomes as defined within relevant WSP.

3.2.1 Water Licensing

Water access licensing ensures that the amount of water taken from each water source does not exceed the extraction limit set in the WSP. Water licences (including aquifer access licences) are required to account for the water taken from both groundwater and surface water sources through aquifer interference activities regardless of its quality. A licence with sufficient water allocation (entitlement) must be held to account for all take of water, both during the life of a Project such as extraction and for any ongoing take after the aquifer interference activity has ceased. Further, under Section 2.2 of the Aquifer Interference Policy (AIP), *"Where there is ongoing take of water, the licence holder must retain a water licence for the period until the system returns to equilibrium or surrender it to the Minister."* Allocations issued under a licence generally state the number of "share components" the holder of the licence is entitled to take from the resource with one share component representing a specified volumetric unit. It is noted that, in this assessment share components are referred to as ML/year.

The total volume of water to be taken from each water source as a result of the aquifer interference activity must be determined before development consent can be granted. Importantly, a water licence is required whether water is taken directly from a groundwater or surface water source for consumptive use or whether it is taken incidentally (indirectly) by the aquifer interference activity such as induced flow from a connected groundwater or surface water source by the aquifer interference activity such as extraction. Incidental water take can result from intentional dewatering of aquifer as a result of groundwater inflows to the extraction area but also includes the volume of groundwater inflow to voids that results in evaporative losses where the void intersects the water table.

3.3 AQUIFER INTERFERENCE POLICY

3.3.1 Introduction

The NSW Aquifer Interference Policy (AIP) was released by the NSW government in September 2012. The AIP provides an explanation of the water licensing and impact assessment processes for aquifer interference activities under the *Water Management Act 2000* and other relevant legislation. The AIP details the way in which the respective Government Agency, tasked with managing NSW water resources, assesses projects to determine their potential impacts on groundwater resources. There are three key components of the AIP, namely:

1. all water taken must be properly accounted for;
2. the aquifer interference activity must address specific minimal impact considerations for any potential impacts on the water table, water pressure levels and water quality; and
3. planning for measures in the event that the actual impacts are greater than predicted including a contingency for monitoring.

3.3.2 Minimal Impact Considerations

The groundwater source in the area of the Site is a "**Porous and Fractured Rock Water Source**". In regard to the minimal impact considerations for Aquifer Interference Activities, under the AIP, the groundwater source category for the hard rock resource in the Site is interpreted to be **"Less Productive"**.

The minimal impact considerations and thresholds documented in Table 1 of the AIP for this type of groundwater source are provided in **Table 2**.

Table 2
Minimal Impact Considerations - NSW Aquifer Interference Policy

Water Sharing Plan	North Coast Fractured and Porous Rock Groundwater Sources		
Groundwater Source	Porous and Fractured Rock		
Source Category	Less Productive		
	Maximum Impacts Considered Acceptable		
	Water Table	**Water Pressure**	**Water Quality**
Water Supply Work	≤ 2m cumulative water level decline unless make good provisions	≤ 2m cumulative water level decline unless studies can demonstrate that the activity would not prevent the long-term viability of the water supply work or make good provisions	Not detailed
GDE/CSS	≤ 10% cumulative variation in the measured water table level in the first year of the WSP at a distance of 40m from a GDE or CSS unless studies can demonstrate that the activity would not prevent the long-term viability of the GDE or CSS.	Not detailed	Not detailed
Aquifer Interference Activity	Not detailed	Not detailed	No change in beneficial use category of the groundwater source >40m from activity unless studies can demonstrate that change in groundwater quality would not prevent the long-term viability of any GDE, CSS or water supply work

GDE: Groundwater Dependent Ecosystem

CSS: Culturally Significant Site

4. SECRETARY'S ENVIRONMENTAL ASSESSMENT REQUIREMENTS

The key groundwater issues identified within the relevant Secretary's Environmental Assessment Requirements (SEARs) are summarised in **Table 3** together with reference to where each requirement is addressed in this document. The requirements were prepared by the Department of Planning and Environment (DPE) following consultation with, and submissions from, relevant government agencies.

Table 3

Coverage of Environmental Assessment Requirements Relating to Groundwater

Page 1 of 3

Agency / Organisation	Relevant Requirement	Relevant Section(s)
Department of Planning and Environment 02/11/17	• a detailed site water balance, including a description of site water demands, water disposal methods (inclusive of volume and frequency of any water discharges), water supply infrastructure and water storage structures;	Refer to Surface Water Assessment (RWC, 2018)
	• identification of any licensing requirements or other approvals under the *Water Act 1912* and/or *Water Management Act 2000*;	13.1, 13.2 & 13.3
	• demonstration that water for the construction and operation of the development can be obtained from an appropriately authorised and reliable supply in accordance with the operating rules of any relevant Water Sharing Plan (WSP);	13.2
	• a description of the measures proposed to ensure the development can operate in accordance with the requirements of any relevant WSP;	13.3
	• an assessment of the likely impacts on the quality and quantity of existing surface and groundwater resources, including a detailed assessment of proposed water discharge quantities and quality against receiving water quality and flow objectives;	10.2, 10.5, 10.7 & 12
	• an assessment of the likely impacts of the development on aquifers, watercourses, riparian land, water-related infrastructure, and other water users; and	10.2, 10.3, 10.4, 10.6, 10.7 & 11.1.1
	• a detailed description of the proposed water management system (including sewage), water monitoring program and other measures to mitigate surface and groundwater impacts;	14.1, 14.2.1, 14.2.2 &12
DPI – Crown Lands and Water Division 20/10/17	The identification of an adequate and secure water supply for the life of the project. Confirmation that water can be sourced from an appropriately authorised and reliable supply. This is to include an assessment of the current market depth where water entitlement is required to be purchased.	13.2
	Assessment of impacts on groundwater 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.	10, 11.1.1, 12 & 14
	Proposed groundwater monitoring activities and methodologies.	14.2.1 & 14.2.2
	Consideration of relevant policies and guidelines.	3.2, 2.3 & 11.1

Table 3 (Cont'd)
Coverage of Environmental Assessment Requirements Relating to Groundwater

Page 2 of 3

Agency / Organisation	Relevant Requirement	Relevant Section(s)
Environment Protection Authority 20/10/17	**Background Conditions** • Describe existing groundwater quality. An assessment needs to be undertaken for any water resource likely to be affected by the proposal. Issues to be discussed should include but are not limited to: – a description of any impacts from existing industry or activities on water quality	9.3, 10.2, 10.5, 10.7 & 12
	– an outline of baseline groundwater information, including, for example, depth to water table, flow direction and gradient, groundwater quality, reliance on groundwater by surrounding users and by the environment historic river flow data	9.1, 9.2, 9.3 & 10.3
	• State any locally specific objectives, criteria or targets which have been endorsed by the NSW Government.	N/A
	Impact Assessment • Describe the nature and degree of impact that any proposed discharges will have on the receiving environment.	10.4, 10.6, 11 & 11.1.1
	• Assess impacts against the relevant ambient water quality outcomes. Demonstrate how the proposal will be designed and operated to: – protect the Water Quality Objectives for receiving waters where they are currently being achieved; and	10.4, 10.6, 11 & 11.1.1
	– contribute towards achievement of the Water Quality Objectives over time where they are not currently being achieved.	14.1
	• Assess impacts on groundwater and groundwater dependent ecosystems.	10, 11
	Monitoring • Describe how predicted impacts will be monitored and assessed over time.	14.1, 14.2, 14.4, 14.5 & 14.6
	Monitoring Programs The EIS should include a detailed assessment of any water monitoring required during the construction and on-going operation of the site to ensure that the development achieves a satisfactory level of environmental performance. The evaluation should include a detailed description of the monitoring locations, sample analysis methods and the level of reporting proposed.	14.1, 14.2, 14.4, 14.5 & 14.6
Office of Environment & Heritage 25/10/17	The EIS must map the following features relevant to water including: • Groundwater.	7.4, 7.5, 8 & 9
	• Groundwater dependent ecosystems.	7.5.3 & 10.6
	• Proposed intake and discharge locations.	Refer to Surface Water Assessment (RWC, 2018)

Table 3 (Cont'd)
Coverage of Environmental Assessment Requirements Relating to Groundwater

Page 3 of 3

Agency / Organisation	Relevant Requirement	Relevant Section(s)
Office of Environment & Heritage 25/10/17 (Cont'd)	• The EIS must describe background conditions for any water resource likely to be affected by the development, including: a) Existing groundwater.	7.4, 7.5, 9.1, 9.2 & 9.3
	c) 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.	10.3, 10.4, 10.6, 11 & 11.1.1
	d) 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.	Refer to Surface Water Assessment (RWC, 2018)
	• The EIS must assess the impacts of the development on water quality, including: a) The nature and degree of impact on receiving waters for both surface and groundwater, demonstrating how the development protects the Water Quality Objectives where they 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.	10.54, 10.6, 10.9 & 11.1 Refer to Surface Water Assessment (RWC, 2018)
	b) Identification of proposed monitoring of water quality.	14.2.2
	• The EIS must assess the impact of the development on hydrology, including: c) Effects to downstream water-dependent fauna and flora including groundwater dependent ecosystems.	10.4, 10.6, 10.9 & 11.1 Refer to Surface Water Assessment (RWC, 2018)
	e) Changes to environmental water availability, both regulated/licensed and unregulated/rules-based sources of such water.	13.1, 13.2 & 13.3
Department of Planning and Environment 02/11/17	**Environmental Planning Instruments, Policies, Guidelines & Plans**	
	NSW State Groundwater Policy Framework Document (NOW)	3.1
	NSW State Groundwater Quality Protection Policy (NOW)	3.1
	NSW State Groundwater Quantity Management Policy (NOW)	3.1
	NSW Aquifer Interference Policy 2012 (NOW)	3.1, 3.3
	Office of Water Guidelines for Controlled Activities (2012)	3.1
	Groundwater Monitoring and Modelling Plans – Information for prospective mining and petroleum exploration activities (NOW)	3.1
	Australian Groundwater Modelling Guidelines 2012 (Commonwealth)	N/A
	National Water Quality Management Strategy Guidelines for Groundwater Protection in Australia (ARMCANZ/ANZECC)	3.1
	Guidelines for the Assessment & Management of Groundwater Contamination (EPA)	3.1

5. METHODOLOGY

The methodology employed in meeting the objectives identified in Section 1.2 and the Secretary's Environmental Assessment Requirements in Section 4 included a comprehensive combination of literature review, data collection and field assessments.

Specifically, the assessment comprised the following.

- Research and collation of the results of any previous geological, hydrogeological and environmental investigations within 2 to 3 km from the boundary of the proposed extraction area.
- Examination and detailed interpretation of recent NSW government colour aerial photographs taken over the district, and remotely sensed data historically produced Wedgerock Pty Ltd by Geo Spectrum (Australia Pty Ltd).
- A review of recent and historic published geological mapping of the district at various scales including 1:250 000 and 1:100 000. This review incorporated a review of relevant unpublished geological documents.
- A review of data and information for registered/licensed boreholes in the district held by the WaterNSW.
- Establishing and assessing local and regional hydrogeological and hydrological conditions. Assessment of aquifer type, aquifer distribution, recharge estimates, groundwater recharge areas and discharge areas (springs), aquifer yields, groundwater quality, determination of groundwater hydraulic gradient and direction of groundwater flow.
- Assembly of baseline water level and water quality data sets.
- Collection and submission of groundwater samples to a NATA-registered laboratory for specific testing of a designed suite of analytes.
- Identifying the nature of the surface water system on and surrounding the Site to establish the interaction between surface water and groundwater.
- Identifying correct groundwater utilisation in the local area, including the location and details of any registered and possibly unregistered neighbouring bores, purposes and water entitlements.
- Establishment of a groundwater monitoring network within the Site.
- Develop a conceptual hydrogeological model.
- Establish indicative aquifer characteristics for the Site.
- Assessment of the potential impacts of the extraction on local and regional aquifer systems, local and regional water tables, any groundwater dependent ecosystems (GDEs), groundwater chemistry and local groundwater users.
- Recommendations including mitigation measures and contingency planning.
- Preparation of a long-term monitoring program for the Site and data logger maintenance plan to be incorporated in future Management Plans should development consent be granted for the Project.

- Development of a protocol for in-house groundwater data management and statutory reporting.
- Compilation of potential groundwater impacts including results of investigations, prediction of any impacts and mitigation measures.

6. PREVIOUS HYDROGEOLOGICAL INVESTIGATIONS

A groundwater study and groundwater impact assessment was undertaken by Coffey Geotechnics in 2012 for the Karuah East Quarry Project, the most recently-approved hard rock (rhyodacite ignimbrite) quarry northeast of the Site.

The groundwater study (Coffey, 2012) established:

- the hydrogeological setting;
- potential groundwater related issues such as pit inflows, discharge water quality and potential sources of groundwater contamination;
- the existence of any on-site and surrounding registered bores;
- a network of monitoring bores in order to measure baseline water levels and collect water samples;
- groundwater chemistry;
- hydraulic conductivity values for the rhyodacite ignimbrite (estimated from hydraulic testing);
- long-term monitoring and mitigation measures;
- possible impacts on any groundwater dependent ecosystems (GDEs); and
- potential impacts of the quarry on the local groundwater system during extraction operations and post closure.

Coffey (2012) concluded:

- groundwater flow in the local aquifer predominantly occurs within fractures (secondary porosity);
- recharge of the fractured rock system is via precipitation (rainfall);
- the groundwater system is disconnected from the surface water system;
- groundwater flow mimics the local topography. That is, the groundwater is interpreted to flow from higher to lower elevations;
- a search within a 3 km radius of the Karuah East Quarry did not identify any registered bores;
- groundwater has not been intercepted in the Karuah Hard Rock Quarry that is proximal to the Karuah East Quarry and the Site and located in the same geological unit;

- the low-yielding and low-permeability nature of the hard rock aquifer system would result in a low potential for any impacts on groundwater resources and, as a consequence, no impact to local standing water levels was anticipated; and
- the Karuah East Quarry would not lead to any significant impacts to groundwater users with respect to water quality or volume and no sensitive groundwater receivers would be impacted due to the extraction operations.

Subsequently, Coffey (2012) recommended:

- monitoring of the volume (if any) of all water pumped from the extraction area and clarification of whether any of the water removed is groundwater; and
- implementation of a Water Management Plan that incorporates provision for ongoing monitoring and reporting of groundwater encountered at the Site.

7. LOCAL SETTING

7.1 GEOLOGY

7.1.1 Regional Geology

NSW government regional geological mapping indicates that the Site is underlain by a sequence of volcanics and interbedded tuffaceous and clastic sedimentary rocks deposited during the Carboniferous Period (approximately 360 to 300 million years ago). The principal geological unit in the Karuah district is the Nerong Volcanics which is primarily comprised of an aerially extensive tabular body of rhyodacitic ignimbrite. The Nerong Volcanics are located in the Myall Structural Block which is a subdivision of the Tamworth Belt which in turn forms part of the southern New England Fold Belt. The Nerong Volcanics are disconformably overlain by the Karuah Formation and the Booti Booti Sandstone and conformably overlies the Conger Formation and the Boolambayte Formation. The stratigraphic sequence beneath the Site dips at various gradients to the south-southeast.

The Nerong Volcanics are extracted in the adjoining quarries to produce a range of aggregates and other construction materials. In the local area, the Nerong Volcanics occur in a broadly tabular shape which is consistent with its mode of formation, i.e. a really extensive, blanket-type ignimbrite-style eruption emanating from a nearby volcano or volcanoes. The relative homogeneity of the unit in the Karuah district supports its consideration as a regionally significant resource.

7.1.2 Local Geology

The local geology is shown in **Figure 4**.

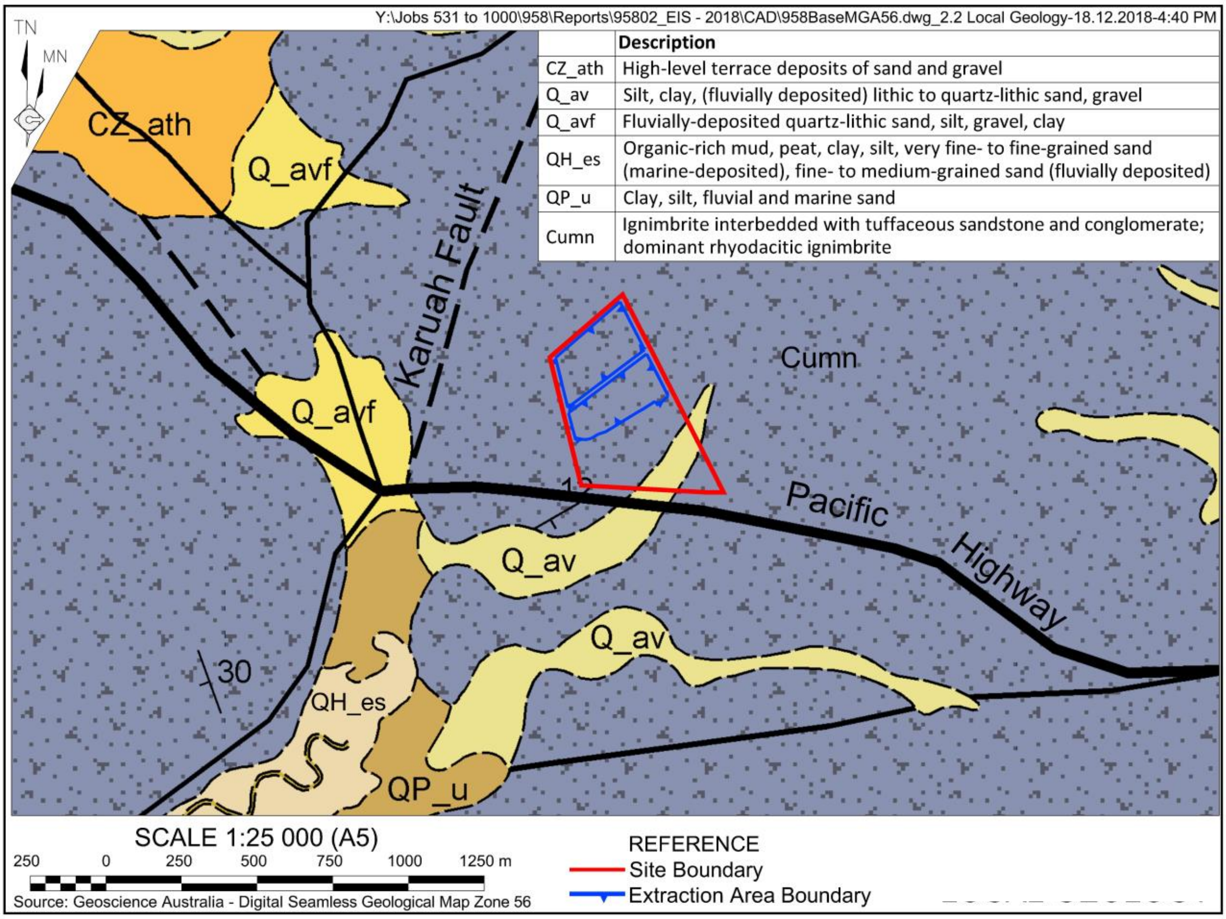


Figure 4 Local Geology

The Site is underlain by the Nerong Volcanics, a dominantly dense terrestrial rhyodacitic ignimbrite. The rhyodacitic deposit in the local area is broadly tabular in shape which is consistent with the mode of formation – an aerially extensive, blanket-type ignimbrite-style eruption emanating from a nearby volcano/s.

The Nerong Volcanics is disconformably overlain by the Karuah Formation and the Booti Booti Sandstone and conformably overlies the Conger Formation and Boolambayte Formation. The stratigraphic sequence beneath the Site dips gently to the south-southeast.

The most informed surface geological mapping over the local area centred on the quarries is inferred mapping undertaken by Douglas Geotechnics in 2010 (Douglas Geotechnics, 2012) as part of an Environmental Assessment (EA) for the then proposed hard rock Karuah East Quarry (Karuah East Quarry Pty Ltd). The inferred geology and interpreted lineaments are annotated in **Figure 5**. A north-northeasterly trending fault which separates the Carboniferous Nerong Volcanics to the east and undifferentiated Carboniferous sedimentary rocks to the west.

Aerial Photo – *Geospectrum* (2008) Inferred Geology after Coffey Geotechnics (2012)

FIGURE 5
INFERRED SURFACE GEOLOGY

The results of a nine-hole resource drilling program on the Site on behalf of the Applicant (**Figure 6**), drilling by Hunter Quarries in the Karuah Quarry and recent geological observations in the Karuah Quarry indicates a minimum 42m thickness of rhyodacite which dips to the south. The top 1m to 5m of this tabular body is strongly weathered. Interbeds of sandstone, conglomerate and volcaniclastic (tuffaceous) siltstone between 3m to 5m in thickness have also been reported in the Karuah Quarry, although no interbeds were intersected during resource drilling within the adjoining Karuah East Quarry Site (Coffey Geotechnics, 2012).

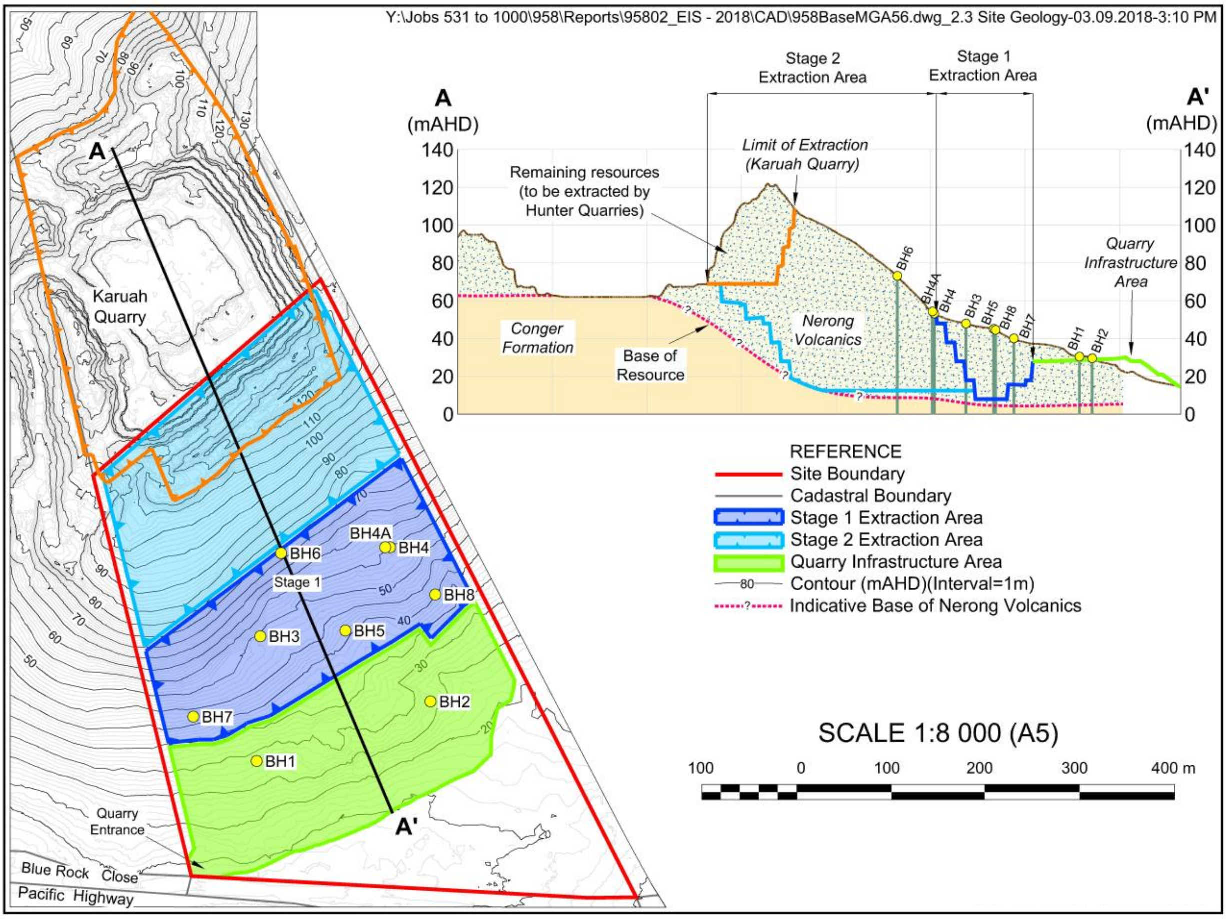


Figure 6 Site Geology

Geological mapping by Coffey Geotechnics in 2010 (Coffey Geotechnics, 2012), in the then existing Karuah Quarry, revealed the existence of a 5 m-wide shear zone within the southern bench that exhibits intense sub-vertical fracturing. Igneous dykes were also identified within Coffey (2012) revealed the existence of a 5m-wide shear zone within the southern bench in the Karuah Quarry that exhibits intense sub-vertical fracturing. Igneous dykes were also identified in the walls of the extraction area. The inferred locations of the shear zones and dykes are shown in **Figure 5**.

An inferred east-northeast trending geological structure, possibly a fault dissects the Site (**Figure 5**). This inferred geological structure is sub-parallel to the dykes mapped by in the Karuah Quarry.

7.2 CLIMATE

Climate data has been sourced from the Bureau of Meteorology's (BoM) Nelson Bay (Nelson Head) (BoM ID 061054) weather station which is situated approximately 18km southeast of the Site – 1881 to present. Whilst rainfall data collection commenced in 1881, temperature data collection for this station only commenced in 1914.

Monthly evaporation data was processed using information sourced from the Scientific Information for Land Owners (SILO) database, managed by the Queensland Department of Environment and Science (DES). The program uses historic Bureau of Meteorology datasets and interpolation techniques to generate continuous daily time step synthetic climate data for any given location in Australia. The SILO dataset for the period 1 January 1889 to 13 September 2018 was generated for the Site (Latitude -32.65, Longitude 152.00) on 14 September 2018.

Climate data sourced from the above stations is presented in **Table 4**.

Table 4
Climate Data

	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
Temperature (C°) – Nelson Head (BoM ID 074037) (1914 to present)													
Mean maximum temperature	27.3	27	25.9	23.6	20.8	18.2	17.5	18.9	21.4	23.2	24.7	26.1	22.9
Mean minimum temperature	18.9	19.1	17.8	15.3	12.4	10.2	9.1	9.9	12	14.1	16	17.7	14.4
Rainfall (mm) – Nelson Head (BoM ID 074037) (1881 to present)													
Mean rainfall	100.5	111.3	117.5	129.4	150.2	157.9	137.5	101.7	89.2	77.9	80.2	93.2	1343.6
Highest rainfall	559.7	530.8	401.8	493.8	632	607.6	615.9	630.6	311.9	297	264.3	334.3	2335.9
Lowest rainfall	2.5	0	3.6	0	7.9	6.2	0	0.8	1.5	0	0	5.8	416.6
Highest daily rainfall	155.7	257.8	217.7	168	225	148.1	137.2	130	208.3	74.9	191.8	191.5	257.8
Evaporation (mm) – SILO (1889 to present) – Morton's Shallow Lake													
Mean monthly evaporation	181.9	144.7	128.6	95.4	70.4	59.4	67.9	93.4	122	149.7	161.2	189.3	1510

7.3 SURFACE WATER

Surface water studies have been carried out by R.W. Corkery & Co. (RWC, 2018). The studies incorporated a detailed site water balance as required by NSW Department of Planning and Environment. Overland flow is largely discharged to longitudinal drainage infrastructure located along the alignment of Blue Rock Close. This stormwater infrastructure discharges into cross drainage infrastructure associated with the Pacific Highway.

Surface water discharge south of the Pacific Highway is via indistinct drainage pathways prior to entry into Yalimbah Creek, approximately 600 m west of the Site, this area is identified as a wetland under the Great Lakes LEP 2014 and listed as a coastal wetland under the Draft NSW Coastal Management SEPP.

7.4 HYDROGEOLOGY

A review of published geological maps combined with recent field observations, knowledge of the geology of the district and experience in these hydrogeological settings indicates that principally, one type of water-bearing zone (aquifer) exists beneath the Site hard rock aquifer. This aquifer is associated with the relative thick rhyodacite resource belonging to the Nerong

Volcanics and the immediately underlying the sequence of interbedded Carboniferous sedimentary rocks of the Karuah formation. A description of the groundwater system in the sedimentary rocks underlying the rhyodacite resource is provided for completeness although it is recognised that extraction operations for the proposed quarry would not intersect the underlying sedimentary sequence.

These aquifer systems are described as follows.

1. Although the rhyodacite does not have any primary porosity, groundwater occurrence may be associated with secondary defects such as discontinuous sub-vertical ‘sheet like’ fractures and shear zones that have been imposed as the rhyodacite has been subjected to several phases of progressive deformation (folding, thrusting and faulting) over an extended period. These defects dissect the rock mass and provide a discontinuous potential fluid pathway for percolating rainfall. The various geological mapping campaigns carried out by NSW government geologists over the district have provided testimony to that structural history.

   The fractured rhyodacite aquifers are interpreted to be under semi-confined to confined hydrogeological conditions.

   Enhanced hydraulic conductivity may be associated with the occurrence of relatively open joints and fractures or in areas containing a high density of fracturing and/or intersecting fractures/faults.

   Although structural discontinuities likely exist in the local area, the evidence from many years of rhyodacite extraction in the Karuah Quarry immediately north of the Site indicates the existence of ‘dry’ quarry conditions, i.e. little or no groundwater inflow to the extraction area. This suggests that groundwater flow in this aquifer is insignificant and/or the evaporative potential is greater than any groundwater inflow into the pit.

2. Confined ‘Dual porosity’ aquifers possibly associated with the underlying sedimentary rock formation - the Conger Formation and Boolambayte Formation. These are:

   ‘primary aquifers’ hosted by relatively porous units within the Carboniferous sedimentary rock sequence - sub-horizontal relatively porous and stacked layers (beds) of more porous units, for example sandstone with increased primary permeability, in contrast to less permeable interbedded sedimentary units such as siltstone and shale. These primary aquifers provide the main aquifer storage in these rocks; and

   ‘secondary aquifers’ associated with pervasive, sub-vertical, semi-continuous to continuous tectonically-imposed structural discontinuities such as fractures and joints with secondary ‘enhanced’ permeabilities. These rock defects have dissected the rock mass and may also include other features such as sub-horizontal bedding partings and stress relief structures.

As the Project is principally concerned with the extraction of the rhyodacite resource, no interception of the underlying dual porosity aquifer system is proposed and impacts to this system are not considered further in this assessment.

7.4.1 Aquifer Recharge

Aquifer recharge is primarily by way of excess precipitation (rainfall). However, the demonstrable relative impervious nature of the rhyodacite resource with overprinted secondary defects suggests that the recharge proportion from rainfall is likely between approximately 1 % and 5 %.

7.4.2 Aquifer Discharge

As previously noted, the surface water and groundwater systems in the vicinity of the Site are disconnected. However, natural discharge of shallow groundwater (interflow) may occur on the Site as a result of topography and the relatively permeable “boulder strewn” scree materials that has developed on the Site. It is anticipated that a small proportion of rainfall would percolate through this relatively permeable material which overlies the less permeable rhyodacite.

By definition, these shallow groundwater systems are springs. The existence of a “contact” spring requires that below the subsurface, the percolating water encounters a low-permeability zone and is unable to continue to percolate downward as fast as it is supplied at the surface. As a result, the water spreads laterally until it intersects the land surface where erosion has lowered the topography to the water’s level (e.g., on the side of a gully, hill or valley).

Although the discharges from these contact springs are interpreted to vary in response to seasonal and climatic factors, anecdotal evidence indicates that they are low volume semi-permanent flows. These water features can, in some areas, (for example flat-lying sandstone sequences in the Sydney Basin), support ecosystems (Groundwater Dependent Ecosystems (GDEs)). However, no GDEs have been identified on the Site as a result of these groundwater investigations or in the fauna and flora investigations (EcoPlanning, 2018).

7.5 GROUNDWATER-SURFACE WATER INTERACTION

Groundwater flow predominantly occurs within the discontinuous secondary defects (fractures and shear zones) of the rhyodacite aquifer which are recharged from rainfall precipitation. The fractured rhyodacite aquifer is under semi-confined to confined conditions and considered to be disconnected from any watercourses.

7.5.1 Aquifer Properties

7.5.1.1 Hydraulic Conductivity

The hydraulic conductivity values of the rhyodacite “aquifer” depends on the orientation, interconnectivity, frequency and size of any secondary defects as the result of structural deformation. Crystalline igneous rocks typically have very low to zero primary porosity and zero primary permeability.

The typical value for hydraulic conductivity of a rhyodacite, without major structural deformation and fracturing, is predicted to be less than approximately 10^{-6} m/s (Domenico and Schwartz, 1990). Falling head aquifer tests carried out by Coffey on the rhyodacite aquifer beneath the Karuah East Quarry in (Coffey, 2012) varied between 5 x 10^{-6} m/s and 9 x 10^{-6} m/s. Structural deformation generally increases the permeability of a rock mass, and may impart a higher ratio of vertical to horizontal hydraulic conductivity when deformation is largely along sub-vertical features (secondary permeability). Weathering of the igneous rock mass can also result in an increase in permeability. As the result of weathering of the rock mass, the number and size of secondary defects can increase.

7.5.2 Specific Yield

Specific yield is an important aquifer storage parameter. However, this is predominantly mainly in aquifers with primary porosity. For the purposes of conceptual hydrogeological model development, the specific yield of the rhyodacite aquifer depends on the nature of the secondary defects (refer to Section 6.1.2). The specific yield of secondary defects can be as high as 95% of the defect volume depending on defect dilation (and the influence of capillary forces) and defect intersection.

7.5.3 Groundwater Dependent Ecosystems

No Groundwater Dependent Ecosystems (GDEs) or Groundwater Sensitive Ecosystems (GSEs) have been identified on the Site or within close proximity. However, the Site is approximately 1.1 kilometres northeast of the Yalimbah Creek system that host SEPP 14 wetlands. An assessment of the potential for any impacts of the Project on the GDEs or GSEs is provided in Section 10.6.

7.5.4 Groundwater Availability and Utilisation

Whilst review of WaterNSW records identified that there are no registered bores within 3km of the Site, a search of the Bureau of Meteorology's Groundwater Explorer identified a production bore (GW201611), approximately 3km northwest of the Site (refer **Section 10.3**). The lack of bores in the vicinity of the Project supports the hypothesis that fractured hard rock aquifer has low yields.

8. MONITORING BORES

A network of four strategically-positioned groundwater monitoring bores was established on the Site. The monitoring network utilises four of nine hard rock resource drill holes sunk in two exploration campaigns commissioned in 2009 and 2015.

The locations of these nine drill holes are shown in **Figures 5** and **7**. Drill holes BH3, BH4, BH7 and BH8 were relocated, using a geotechnical drilling rig (Nealings Drilling Services) and equipped with 50 mm-diameter Class 18 PVC casing, Class 18 PVC screen, acid-washed gravel pack and bentonite seal, and constructed for use as piezometers.

Details of the four monitoring bores (piezometers) are provided in **Table 5**.

Table 5
Register of Groundwater Monitoring Bores

	Coordinates (MGA Zone 5)		Elevation Ground Level (m AHD)	Depth of Hole (m BGL)	Piezometer Details							
					Elevation TOC (m AHD)	Stickup (m AGL)	SWL 24.10.18 (m BGL)	Elevation SWL (m AHD)	Blank Casing 50 mm uPVC		Screen 50 mm uPVC	
Monitoring Site	Easting (m)	Northing (m)							From (m)	To (m)	From (m)	To (m)
BH 3	0406622	6389254	49.20	40.67	49.88	0.68	7.10	42.10	-0.68	34.67	34.67	40.67
BH 4	0406759	6389348	55.10	40.70	55.75	0.65	26.58	28.52	-0.65	49.10	49.10	55.10
BH 7	0406551	6389169	42.80	40.15	43.48	0.65	13.65	29.15	-0.65	34.15	34.15	40.15
BH 8	0406807	6389298	39.20	33.67	39.98	0.78	17.28	21.92	-0.78	27.67	27.67	33.67

Reference: AHD: Australian Height Datum; TOC: Top Of Collar
BGL: Below Ground Level; SWL: Standing Water Level
AGL: Above Ground level; PVC: Poly(vinyl chloride)

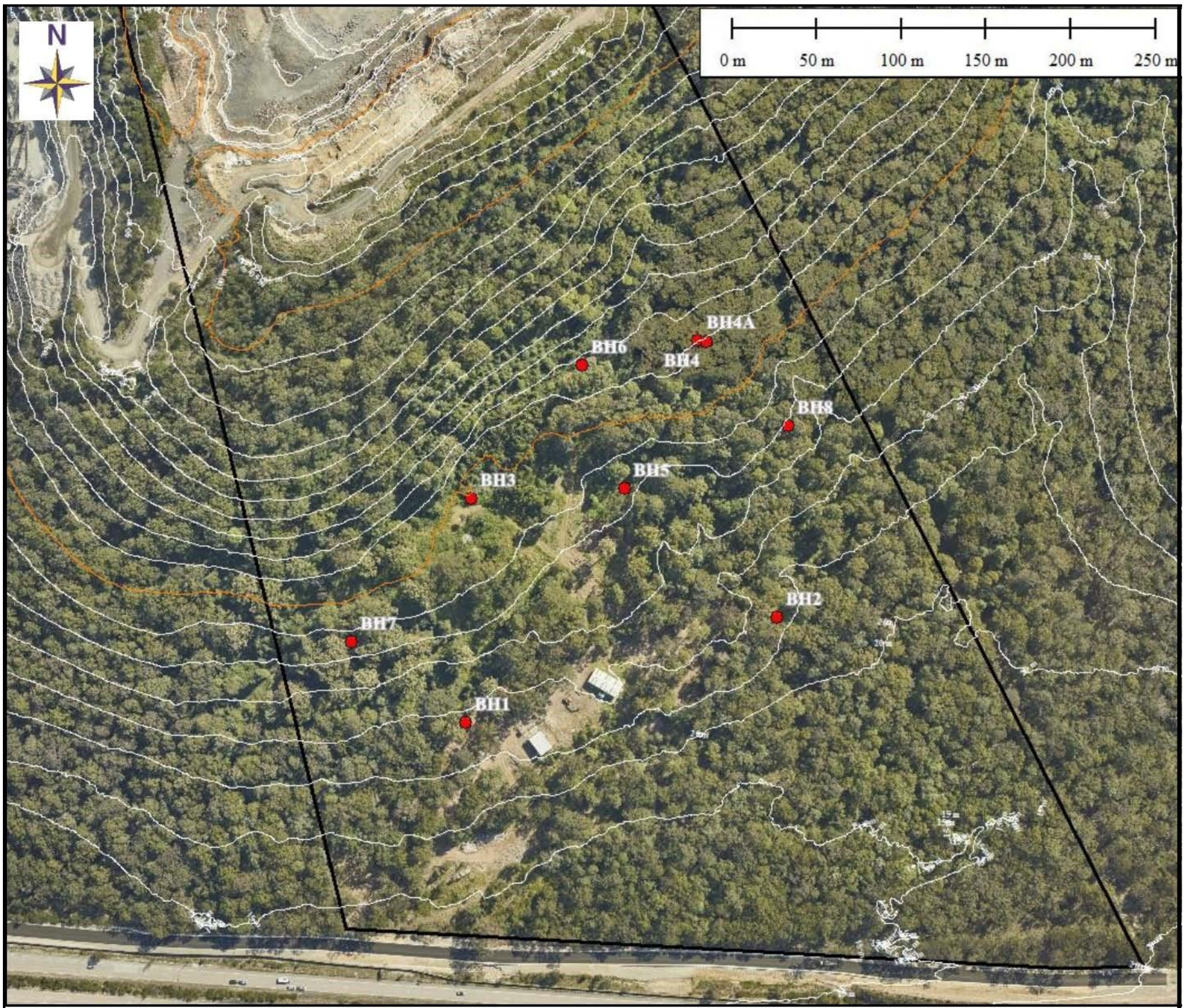


FIGURE 7
LOCATIONS OF DRILL HOLES

9. AQUIFER CHARACTERISTICS

9.1 WATER LEVEL MEASUREMENTS, DIRECTION OF GROUNDWATER FLOW AND HYDRAULIC GRADIENT WITHIN THE SITE

9.1.1 Introduction

Automated fully calibrated 'Greyhound' water level sensors and loggers with a telemetry function were installed in four piezometers (BH3, BH4, BH7 and BH8) in April 2018 in order to collect 'real time' baseline water level data. The specifications and calibration data for the 'Greyhound' pressure transducer sensors are provided in **Appendix A**. The sensors are programmed to measure water levels at a frequency of one reading every four hours.

9.1.2 Water Level Monitoring April 2018 – November 2018

A composite set of hydrographs showing standing water level for the four piezometers bores equipped with 'real time' water level sensors are presented in **Figure 8**. A composite set of hydrographs showing the elevation of water level are presented in **Figure 9**. Daily rainfall amounts acquired from the Bureau of Meteorology weather station Nelson Bay (Station 061054) are also shown.

In summary, the hydrographs for piezometers BH 4, BH 7 and BH 8 reveal a relatively static water level with no apparent correlation with rainfall during the 7-month monitoring period. However, the piezometric level recorded in BH 3 reveals fluctuations and a general rise between early and late June 2018. This is shown on **Figure 9** as a gradual decline in water level recorded between late June and early October 2018. The water level is then observed to rise between early and late October 2018 in response to a 44 mm rainfall event over two days on 5th and 6th October 2018 the water level then gradually drops towards the end of the monitoring period. It is noted that the water level in BH 3 did not respond to a 26 mm rainfall event on 4th September 2018.

Standing water levels recorded in monitoring bores BH 3, BH 4, BH 7 and BH 8 on 24th October 2018 (refer to **Table 5**) ranged from 7.10 m below ground level in BH 3 to 26.58 m in BH 4. The elevations of the piezometric surface ranged from 21.92 m AHD in BH 8 to 42.10 m AHD in BH 3. This data supports the hypothesis that the fractured rhyodacite aquifer is discontinuous and semi-confined to confined.

9.2 AQUIFER TESTING

An attempt was made to carry out short-term pumping tests in the four piezometers to establish a set of representative aquifer parameters including hydraulic conductivity and transmissivity. However, none of the piezometers could sustain continuous periods of pumping (<1hr). This supports the hypothesis that the rhyodacite aquifers are low yielding.

Hydraulic conductivity testing was carried out by Coffey in monitoring bores at the Karuah East Quarry in 2012. The monitoring bores intersected the same rhyodacite (Nerong Volcanics) as that delineated in the Site.

Coffeys' (2012) results indicated the hydraulic conductivity of the rhyodacite aquifer varied from 5×10^{-6}m/s to 9×10^{-6}m/s which is consistent with published values for crystalline igneous rocks with no primary porosity.

9.3 GROUNDWATER QUALITY TESTING

9.3.1 Introduction

Baseline groundwater sampling and analysis was carried out in the four piezometers in October 2018. The objective of the groundwater sampling and water quality analysis was to establish a baseline set of water quality data for the rhyodacite aquifer system.

The details and results of the groundwater sampling and analysis carried in 2018 are documented in the following sections.

Figure 8 Hydrographs (SWL) April 2018 – November 2018

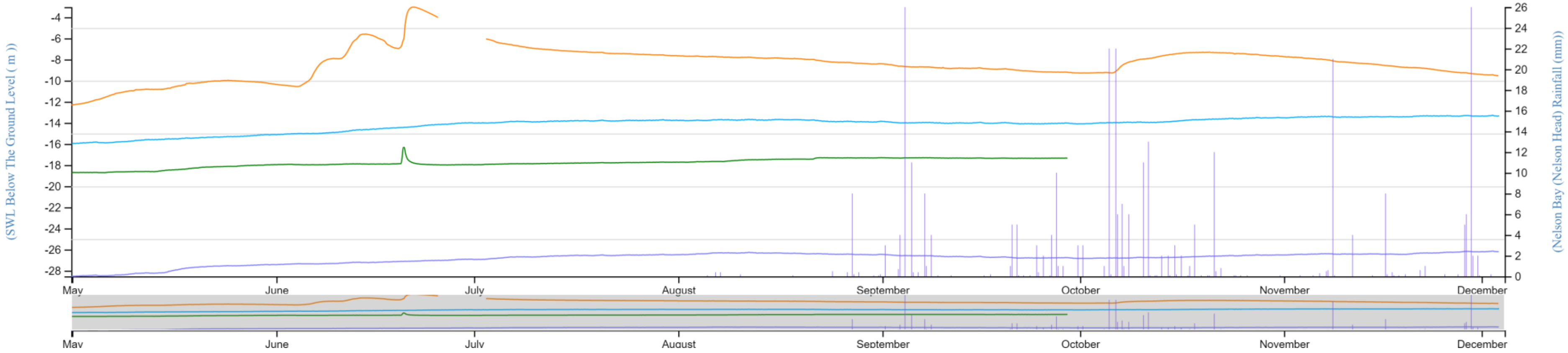
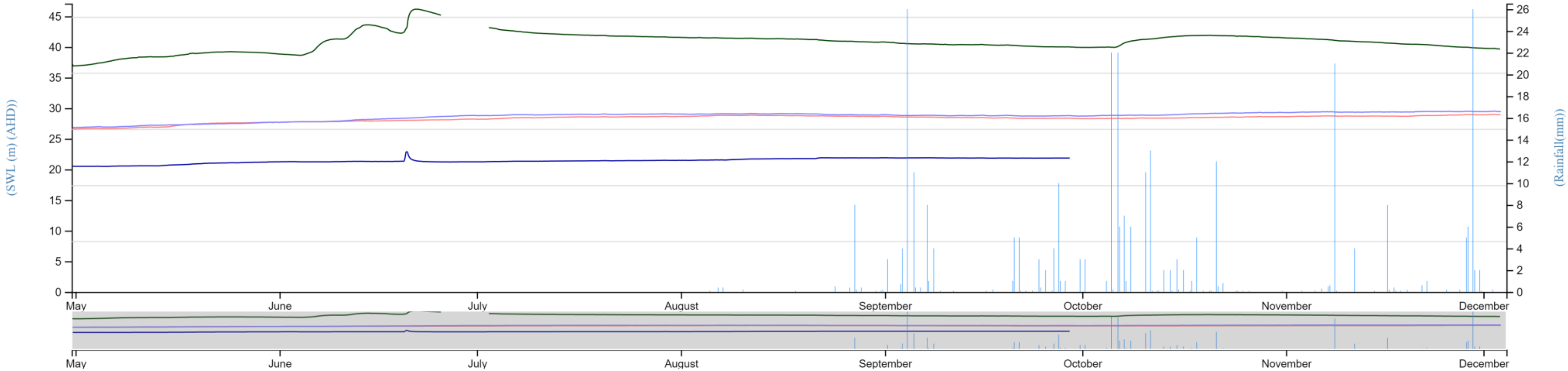


Figure 9 Hydrographs (AHD) April 2018 – November 2018



9.3.2 Sampling

Groundwater samples were collected from the piezometers using a bladder (low flow) pump. Upon collection, samples were stored in laboratory-supplied sample bottles and immediately placed in a chilled esky and submitted to a NATA accredited laboratory (Envirolab Services Chatswood) for analysis.

9.3.3 Analytical Results

The analytical results are summarised in **Table 6**. A copy of the laboratory certificate and Chain Of Custody (COC) documentation are provided in **Annexure B**.

Table 6
Groundwater Quality Monitoring Results – Karuah South Quarry

Analyte	Unit	Practical Quantification Limit (PQL)	Piezometers			
			BH 3	BH 4	BH 7	BH 8
pH (lab)	pH Units		5.9	6.7	6.8	6.1
Electrical Conductivity (lab)	µS/cm	1	270	480	510	330
Total Dissolved Solids (TDS)	mg/L	5	160	310	310	200
Nitrate (as N)	mg/L	0.005	0.21	0.57	0.20	0.64
Nitrite (as N)	mg/L	0.005	<0.005	<0.005	<0.005	<0.005
Cations						
Calcium (Ca)	mg/L	0.5	5.2	17	30	9.0
Potassium (K)	mg/L	0.5	1.3	1.3	3.0	3.8
Sodium (Na)	mg/L	0.5	42	82	65	55
Magnesium (Mg)	mg/L	0.5	4.7	7.1	8.8	3.6
Anions						
Chloride (Cl)	mg/L	1	58	92	87	63
Bicarbonate (HCO^3)	mg/L	5	24	54	87	28
Total Metals						
Carbonate Alkalinity ($CaCO^3$)	mg/L	5	<5	<5	<5	<5
Hydroxide Alkalinity (OH^-) (as $CaCO^3$)	mg/L	5	<5	<5	<5	<5
Total Alkalinity (as $CaCO^3$)	mg/L	5	24	54	87	28
Sulphate (SO^4)	mg/L	1	9	20	23	24
Arsenic (As)	µg/L	1	<1	<1	<1	<1
Cadmium (Cd)	µg/L	0.1	<0.1	<0.1	<0.1	<0.1
Chromium (Cr)	µg/L	1	<1	<1	<1	1
Copper (Cu)	µg/L	1	<1	<1	2	3
Lead (Pb)	µg/L	1	<1	<1	<1	<1
Mercury (Hg)	µg/L	0.05	<0.05	<0.05	<0.05	<0.05
Nickel (Ni)	µg/L	1	1	2	2	2
Zinc (Zn)	µg/L	1	7	15	150	200
Iron (Fe)	µg/L	10	25	49	31	640

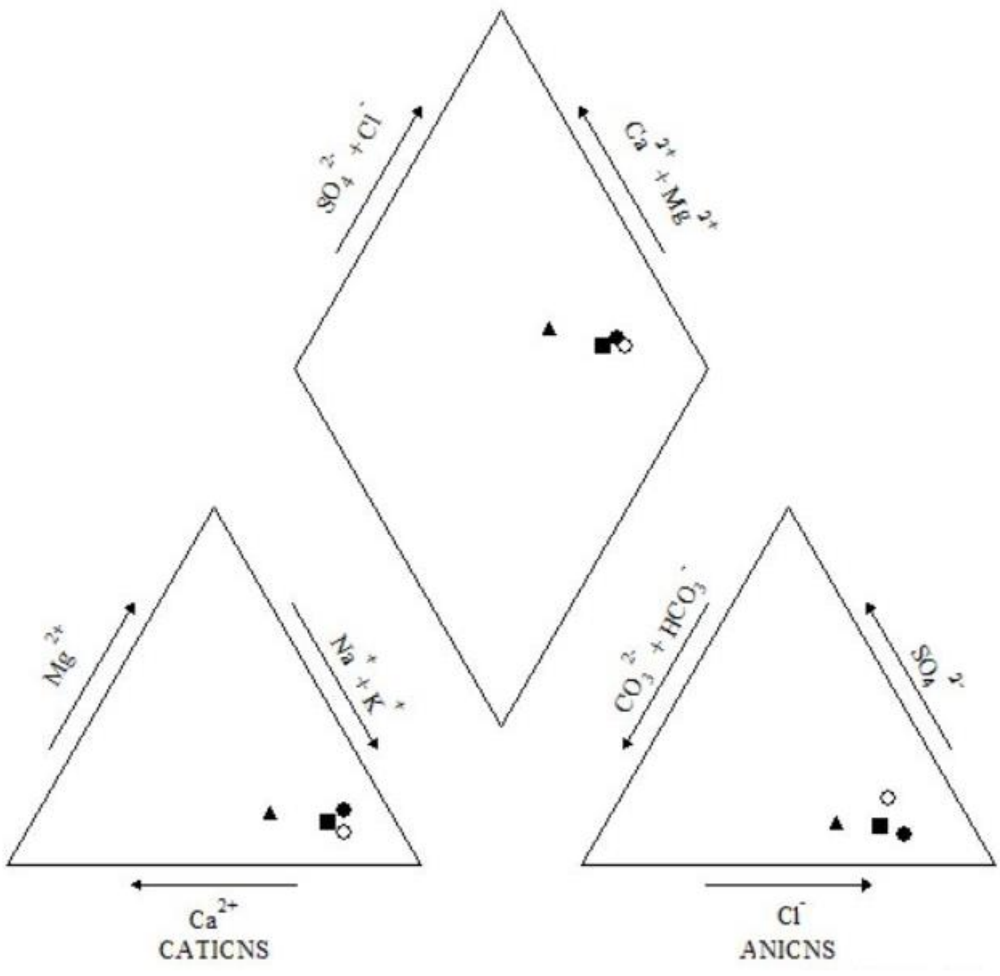
In summary:

- The results for pH are all slightly acidic with values ranging from 5.9 in BH 3 to 6.8 in BH 7.
- Laboratory measurements of electrical conductivity (EC) (270 to 510 µS/cm EC). The EC levels are reflected in the recorded concentrations of sodium and chloride, i.e. rainfall dominant source.
- all samples returned levels of carbonate alkalinity and hydroxide alkalinity less than the Practical Quantification Limit (PQL).
- concentrations of total alkalinity range from 24 to 87 mg/L which indicates a moderate to high buffering capacity.
- concentrations of total metals were either less than the PQL or at trace levels. The exception are low levels of zinc and iron.

9.3.4 Hydrochemical Classification

The major ion proportions for the four water samples are plotted on a Piper diagram (trilinear plot) in order to characterise the chemistry of the groundwater. The plot is shown in **Figure 10.**

Figure 10 Piper Diagram – Groundwater Karuah South Quarry



The ion compositions indicate that the groundwater is grouped into **Sodium Chloride** type as listed in **Table 7**. The hydrochemical signature of the rhyodacite aquifer is interpreted to be typical of a rainfall-dominant groundwater system which suggests that the discrete discontinuous sub-vertical fractures that dissect the rhyodacite rock mass are likely limited in extent and provide preferential, but discontinuous, groundwater pathways for percolated rainfall.

Table 7
Hydrochemical Classification of Site Groundwater

Bore	**Hydrochemical Classification**
BH 3	Sodium Chloride
BH 4	Sodium Chloride
BH 7	Sodium Chloride
BH 8	Sodium Chloride

10. ASSESSMENT OF POTENTIAL GROUNDWATER IMPACTS

10.1 INTRODUCTION

Potential groundwater impacts may include impacts to the local and regional groundwater system, water supply bores including any proximal neighbouring bores, GDEs and culturally significant sites that are dependent on groundwater. Thresholds for minimal impact considerations have been developed for the AIP and relate to impacts on groundwater table and pressure, and to groundwater and surface water quality.

Five potential impacts associated with the Project are listed below and discussed in the following sections.

- Local and regional groundwater system;
- Local groundwater users;
- Local creek flow;
- Groundwater chemistry; and
- Groundwater Dependent Ecosystems

10.2 LOCAL AND REGIONAL GROUNDWATER SYSTEM

The hydrogeological investigations indicate that the local direction of groundwater flow is to the south broadly mimicking the topography.

The elevations of the piezometric surface recorded in the piezometers in October 2018 range from 21.92m to 42.10m AHD (see **Table 5**).

The results for water level monitoring, collected from the four piezometers, indicate that the rhyodacite aquifer are discontinuous and under semi-confined to confined conditions.

The elevation of the base of the extraction area designed by Ausrocks is approximately 12m AHD. This suggests that groundwater may be intersected in parts of the Quarry at different stages over the life of the Project. However, the operational Karuah Quarry located immediately north of the extraction area is observed to be 'dry' even though sub-vertical fractures and shear zones (secondary defects) are mapped in the quarry walls. Minor seeps are documented in the Karuah Quarry by Coffey (2012).

The relatively 'low-yielding' aquifer system is therefore considered to be associated with discrete discontinuous sub-vertical fractures that dissect the rhyodacite rock mass and provide preferential, but discontinuous, groundwater pathways for percolated rainfall.

Based on the existing hydrogeological conditions in the existing Karuah Quarry and the relatively 'low-yielding' fracture aquifer system, it is concluded that minor amounts of groundwater may flow into the proposed quarry and/or would effectively evaporate on the exposed rock faces within the extraction area.

Groundwater monitoring and reporting strategies would constitute an important part of a Water Management Plan to be developed prior to the commencement of operations. A suggested outline for a monitoring, data management and reporting strategy is provided in Sections 14.2, 14.3 and 14.5.

10.3 LOCAL GROUNDWATER USERS

A district search for data and information for registered boreholes held by WaterNSW revealed that there are no registered bores within a 3-km radius of the Site. However, a search of the Bureau of Meteorology's Groundwater Explorer identified a production bore (GW201611), approximately 3km northwest of the Site, refer **Figure 1**. The work summary for this bore (refer **Annexure C**), indicates that the purpose of the bore is commercial and that it is situated within a fluvially deposited, quartz-lithic sand, silt, gravel and clay lithology. The screen of this bore is situated between 48m and 60m below ground surface. Review of local elevation data indicates that the top of the screen of this bore is therefore approximately 35m below the floor of the proposed extraction area. Subsequently, as GW201611 is situated in a different geological unit, up-gradient of the proposed extraction area and well below the maximum depth of the proposed extraction area, it is concluded that the Project will not adversely impact any neighbouring registered bores.

10.4 LOCAL CREEK FLOW

Surface water studies have been carried out for the Project by R.W. Corkery & Co. Pty Ltd. Overland flow is largely discharged to longitudinal drainage infrastructure located along the alignment of Blue Rock Close. This infrastructure discharges into significant cross drainage associated with the Pacific Highway.

Groundwater flow within the rhyodacite aquifer predominantly occurs within secondary defects (fractures and shear zones) which are recharged from rainfall infiltration. These fracture systems are discontinuous and considered to be disconnected from watercourses.

10.5 GROUNDWATER QUALITY

Any groundwater inflow into the extraction area is predicted to be 'low flow', 'low salinity', non-toxic and effectively diluted by rainwater. That is, the chemistry of any residual water retained in the final void would be dominated by rainwater.

Potential contamination sources in extractive industry operations may be associated with hydrocarbon leaks from mobile earthmoving equipment, refuelling operations and spills in fuel (and chemical) storage facilities and the mechanical workshop on the Site. The nature of the extraction operations is such that limited fuels and hydrocarbon products would be stored on the Site. Implementation of an appropriate workshop plan, fuel storage plan and water management plan with effective control measures would significantly reduce the risk of any adverse environmental impacts.

Whilst review of WaterNSW records identified that there are no registered bores within 3km of the Site, a search of the Bureau of Meteorology's Groundwater Explorer identified a production bore (GW201611), approximately 3km northwest of the Site (refer **Section 10.3**). However, due to the up gradient location of this bore and the depth of the screened interval, it is also concluded that the proposed extraction area is predicted not to impact on the chemistry of the groundwater quality of any neighbouring bore.

10.6 GROUNDWATER DEPENDENT ECOSYSTEMS

No Groundwater Dependent Ecosystems (GDEs) or Groundwater Sensitive Ecosystems (GSEs) have been identified on the Site (refer to EcoPlanning, 2018) or within close proximity. However, the Site is approximately 1.1 kilometres northeast of the Yalimbah Creek system that host SEPP 14 wetlands. Coffey (2012) made reference to this wetland system in their groundwater impact assessment for the Karuah East Quarry development. Coffey flagged the potential risk of contaminants to migrate down gradient to the wetlands with a note that the extent of dissolved phase groundwater contaminant plumes migrating from potential contaminant source/s from small sites rarely exceeds 100 metres. It is therefore concluded that it is highly unlikely that potential contaminants could reach this environmental receptor. Implementation of effective control and management measures would further reduce the risk of any adverse environmental impacts.

10.7 ASSESSMENT OF THE PROJECT

Having regard to the presence of a semi-confined to confined fractured rock aquifer system beneath the proposed extraction area, the key parameters for assessing minimal impact considerations for the Project are the potential adverse impacts from the extraction area on water pressure and water quality.

However, whilst there is one (GW201611) registered groundwater user within 3km of the Site (refer **Figure 1**), this bore is situated within a different geological unit and is fitted with a screened interval well below the floor of the proposed extraction area (refer **Annexure C**). Therefore, as groundwater flow in the fractured rock aquifer is typically limited to secondary defects, it is considered that the minimal impact considerations relating to water pressure would not be met.

Furthermore, the location of the extraction area and baseline groundwater chemistry indicates there is no evidence to suggest that a significant change in water quality would result from any aquifer interference activity.

10.8 RISKS AND UNCERTAINTIES

The main uncertainties in the groundwater impact assessment are considered to be the degree of heterogeneity of the rhyodacite aquifer system on the local scale. In order to increase the understanding of the rhyodacite aquifer system and assess any impacts, an ongoing program of water level and water quality monitoring as well as the recording of any groundwater extraction (pit inflows), and reporting of these data would be required.

Groundwater monitoring and reporting strategies would constitute an important part of a Water Management Plan to be developed prior to the commencement of operations. A suggested outline for a monitoring and reporting strategy is provided in Sections 14.2 to 14.5.

10.9 STRATEGIES TO MINIMISE ANY RISKS

Strategies to minimise the risks and uncertainties related to any impacts would depend on progressive monitoring results throughout the life of the Quarry. Strategies to mitigate any risks may include acquisition of additional water licences or exploring possible offsets.

11. GROUNDWATER DEPENDENT ECOSYSTEMS

As documented in Section 10.6, no Groundwater Dependent Ecosystems (GDEs) or Groundwater Sensitive Ecosystems (GSEs) have been identified on the Site. However, the Site is approximately 1.1 kilometres northeast of the Yalimbah Creek system. It is considered highly unlikely that potential contaminants can reach the environmental receptor. The stormwater management infrastructure for the Project (RWC, 2018) provide 'industry best practice' water and sediment management. The stormwater management devices and infrastructure associated with the recent upgrade of Blue Rock Close and the Pacific Highway effectively intercept and truncate the natural overland flow pathways and the headwaters of Yalimbah Creek. Implementation of an appropriate Water Management Plan with effective control measures would further reduce the risk of any adverse environmental impacts.

11.1 SECRETARY'S ENVIRONMENTAL ASSESSMENT REQUIREMENTS

The Secretary's Environmental Assessment Requirements (SEARs) relevant to this groundwater impact assessment are summarised in **Table 3** together with reference to where each requirement is addressed in this document. The SEARs specify the key biodiversity issues required to be addressed through a detailed assessment of the potential impact of the proposed development on Groundwater Dependent Ecosystems (GDEs), riparian resource, threatened species and their habitats and native vegetation.

The key documents relevant to this assessment are the NSW State Groundwater Dependent Ecosystems Policy (NSW Government 2002) and the Water Sharing Plan for the North Coast Fractured and Porous Rock Groundwater Sources (2016).

11.1.1 Potential Impacts on Yalimbah Creek

Yalimbah Creek is located approximately 1.1 km southwest of the Site. As documented in Section 10.4 the stormwater management infrastructure associated with Blue Rock Close and the Pacific Highway effectively disrupts the headwaters of the Yalimbah Creek system. Provided all proposed management measures are implemented, there is low potential for contaminants from the Site to migrate down gradient to any wetlands. It is concluded that it is therefore, highly unlikely that potential contaminants can reach this system. Implementation of an appropriate water management plan with effective control measures would further reduce the risk of any adverse environmental impacts.

12. INFLOW OF GROUNDWATER INTO PIT VOID

The factors affecting the rate of inflow of any groundwater into an extraction void are the size, shape, location, rate of excavation and the hydrogeological properties of the host rock, in particular the effective permeability of the crystalline rhyodacitic ignimbrite (Nerong Volcanics).

The rate of inflow of groundwater into the progressively developed extraction area will also be controlled by local geologic and structural elements.

As documented in Section 7.5.1, the rhyodacite aquifer does not exhibit any primary porosity. Groundwater occurrence in the aquifer is associated with secondary defects such as discontinuous fractures and shear zones. Sub-vertical dykes are also known to occur in the geological unit. These secondary defects may provide limited potential fluid pathways and conduits and enhanced hydraulic conductivity may occur, associated with areas containing a high density of intersecting secondary defects.

Although secondary defects exist in the local area, the evidence from many years of extraction in the Karuah Quarry immediately north of the extraction area indicates the existence of 'dry' quarry conditions. This suggests that groundwater flow in the rhyodacite aquifer is insignificant and/or the evaporative potential in the area is greater than any groundwater inflow into the pit.

Notwithstanding this, ongoing monitoring of any groundwater inflow should be undertaken to enable assessment of any sustained flows and volumes potentially discharging into the extraction area.

13. WATER ACCESS LICENSING

13.1 PREDICTED QUARRY GROUNDWATER INFLOW

Although secondary defects are known to exist in the rhyodacite aquifer, the evidence from many years of extraction in the Karuah Quarry immediately north of the extraction area indicates the existence of 'dry' quarry conditions. As a result, it is anticipated that it will not be necessary for the Operator to secure a water access licence, however, the results of monitoring on any flows and volumes entering the expanding quarry will be assessed and reported to DoI - Water If and when they occur. Should it be established that sustained inflows are occurring, the Operator would arrange for a water access licence to cover groundwater inflow, at a volume agreed upon with DoI – Water.

13.2 SUPPLEMENTARY MAKE-UP WATER

The proposed quarry operation would be largely a 'dry' operation. Surface water studies including a detailed site water balance were carried out (RWC, 2018), the water balance indicate that sufficient water for use in Project-related activities can be collected on-site. It is understood that there are no plans to apply to WaterNSW for a water supply work on the Site for any make-up water as all water collected for Project-related use would be accounted for under the maximum harvestable rights provisions of the *Water Management Act 2000*.

13.3 CURRENT APPROVALS AND LICENCES – THE SITE

The water resources of the Site are covered by the Water Sharing Plan for the North Coast Fractured and Porous Rock Groundwater Sources. There are no registered bores on the Site and no current work approvals or licences exist.

14. IMPACT MITIGATION STRATEGIES

14.1 INTEGRATED APPROACH TO WATER MANAGEMENT

The important and dynamic interrelationship between surface water, groundwater systems and land use in the hydrologic cycle of landscapes is recognised. Hence, a strategy for the management of monitoring data and in-house and regulatory reporting is proposed as part of a Water Management Plan (WMP) that would be developed by the Operator, approved by DPE and implemented. A suggested approach is provided in the following sub-sections.

14.2 GROUNDWATER MONITORING PROGRAM

14.2.1 Water Level Monitoring

Automated measurements of groundwater levels should be continued in the established monitoring network in order to build on the existing database. An ongoing long-term program of regular water level measurements (and manual readings) and water quality sampling and analysis in the strategically-designed monitoring network is recommended in order to collect additional hydrogeological data.

Monitoring data would be statistically analysed to establish any natural variation in water levels and water quality in piezometers. The recommended on-site monitoring network is listed in **Table 8**.

Table 8
Recommended Monitoring Bore Network

Bore	Bore Type	Monitoring Type
BH 3	On-site Monitoring Bore	Water level measurements and water quality testing
BH 4	On-site Monitoring Bore	Water level measurements and water quality testing
BH 7	On-site Monitoring Bore	Water level measurements and water quality testing
BH 8	On-site Monitoring Bore	Water level measurements and water quality testing

As extraction operations progress and the characteristics of the groundwater is better understood, the monitoring network may need to be supplemented in the longer term with additional monitoring bores being established as existing monitoring bores are removed. The final locations of additional monitoring bores, if required, would be subject to approval from DoI - Water following consultation.

It is noted that measurements of water level are currently collected using automated water level sensors/data loggers and recorders (with telemetry) in four piezometers bores with the data being uploaded on a regular basis.

Manual measurements of water level should be collected on a two to three monthly basis in the piezometers to provide calibration of the automatically collected data.

14.2.2 Water Quality Monitoring

It is recommended that sampling and analysis of groundwater quality in the four piezometers should be carried out on a quarterly (3 monthly) basis for an initial period of 24 months. In this way, analysis of the results would establish any trends in water quality and establish any natural variation. Careful analysis and progressive assessment of the results may lead to the reduction of the number of analytes determined and the frequency of sampling. A set of indicator analytes can be developed which would alert the Quarry Manager of any significant changes in water quality that may require action. The recommended list of analytes and tests for quarterly sampling is provided in **Table 9**. It is recommended that the water quality data is reviewed every year to ensure only meaningful data is being collected.

Table 9
Recommended List of Analytes and Tests

Page 1 of 2

Tests and TDS
pH
Electrical Conductivity (EC)
Total Dissolved Solids (TDS)

Table 9 (Cont'd)
Recommended List of Analytes and Tests

Page 2 of 2

Cations
Sodium (Na)
Calcium (Ca)
Potassium (K)
Magnesium (Mg)
Ammonia (NH4-N)
Anions
Chloride (Cl)
Sulphate (SO4)
Carbonate Alkalinity (as CaCO3)
Bicarbonate Alkalinity (as CaCO3)
Hydroxide Alkalinity (OH^-) as CaCO3)
Total Alkalinity (as CaCO3)
Metals
Arsenic (As)
Cadmium (Cd)
Chromium (Cr)
Copper (Cu)
Lead (Pb)
Zinc (Zn)
Nickel (Ni)
Iron (Fe)

14.2.3 Rainfall Monitoring

During operations, rainfall data would be collected on the Site, this data would be collated in an electronic database for evaluation with the groundwater and surface water data.

A recommended monitoring program is provided in **Table 10**.

14.3 DATA MANAGEMENT

The recommended protocol for data management would be incorporated in the WMP. A suggested protocol is summarised as follows.

- The water level data downloaded from the water level data loggers in the monitoring bores is presently imported into an electronic database or spreadsheet via telemetry and viewed weekly to ensure the operational integrity of the sensors. This process would ensure that a progressive record of the data is stored and maintained, and the integrity/quality of the data can be checked on a regular basis.

- Maintain the existing electronic water quality database
- Develop and maintain Site rainfall database.

Table 10
Recommended Monitoring Program

Monitoring Type	Activity	Sample Frequency	Comment
Water Level	Automatic water level measurements using data logger in monitoring bores (Telemetry)	• 1 sample every 4 hours	This sample frequency is designed to provide adequate, real time water level data, optimise the logger battery life and optimise logger memory.
Water Quality	Groundwater sampling and analysis of four monitoring bores	• *Initial* 3-monthly (1 sample per bore) for 24 months • *Assess* data after 24 months	This sample frequency is designed to provide adequate water quality data to detect any significant changes in groundwater chemistry.
Rainfall	Automatic rainfall measurements in *tipping bucket rain gauge* data logger on site	• *Continuous* logging at every 0.2 mm tip with time/date recorded	This sample frequency is designed to provide adequate, real time good quality rainfall data, optimise the logger battery life and optimise logger memory.

14.4 DEVELOPMENT OF TRIGGER LEVELS

It is recognised that any significant decrease in water level and/or changes in water quality in monitoring bores and monitoring sites may be a consequence of a number of factors including but not necessarily limited to reduced rainfall and aquifer recharge or interference from extraction operations.

The development of a set of trigger levels over time is considered an important component of on-going long-term assessment of any potential impacts from extraction operations on the local groundwater system and environment.

In the event that the established trigger water levels in monitoring bores are ‘exceeded’ and an impact is indicated, action would include an immediate assessment of rainfall data and water level fluctuations in other monitoring bores to establish trends and ascertain whether there is a correlation or otherwise with quarrying.

Any mitigation measures would depend on the degree of fluctuations in water levels in the monitoring bores, and the assessment of the significance of any impacts. Additional mitigation measures may need to be developed depending on the nature and degree of any impacts that may be revealed at the end of the review stages.

14.5 REPORTING

A protocol for reporting would be incorporated in a WMP. A suggested protocol for reporting is summarised as follows:

- All water level data and any groundwater quality monitoring results should be recorded, collated and duly reported in-house on at least a six-monthly basis for the first 12 months then on an annual basis. The data should be reviewed annually with the aim to assess any changes in water levels or groundwater chemistry and identify reasons for the changes if they occur. The monitoring schedule should be reviewed annually and changed if deemed appropriate by the hydrogeological consultant.
- Annual review of the results of the statistical analysis of monitoring data in order to detect any imminent or occurring impacts.
- A complete set of results of the production and monitoring program including a review and assessment of the statistical analysis should be formally reported in the Quarry's Annual Review for circulation to relevant government agencies including DoI - Water.

The report should include but not necessarily limited to:

- a figure showing the locations of the monitoring bore network
- a set of hydrographs;
- rainfall data correlations;
- progressive assessment of any trends in water level fluctuations;
- analytical results and progressive assessment of any trends in water quality;
- progressive assessment of any statistical trends; and,
- conclusions and recommendations

14.6 MITIGATION OF ANY IMPACTS TO NEIGHBOURING WATER USERS

Whilst review of WaterNSW records identified that there are no registered bores within 3km of the Site, a search of the Bureau of Meteorology's Groundwater Explorer identified a production bore (GW201611), approximately 3km northwest of the Site and up gradient (refer **Section 10.3**). However, if there were a scientifically and independently demonstrated significant impact on any neighbouring water users surrounding the Site, for example, a fall in bore water level, bore performance (bore yield) or water quality that can, with the available scientific data, be attributed to hard rock extraction operations, the following 'make good' options are presented for consideration in a WMP subject to any agreement/s between the property owner and the Applicant.

- Supply groundwater supplies to the property/s with a minimum flow equivalent to the measured and documented losses with water quality commensurate with the present bore supply, or better.
- Deepen the affected bore, if feasible.

- Drill a new test bore for the owner in order to replace or improve the bore yield of the existing registered bore. The water quality must be similar to the existing bore water quality or suitable for the intended purpose.
- Agree to another arrangement mutually acceptable to the property owner and the Applicant.

15. CONCLUSIONS

- This Groundwater Impact Assessment provides an assessment of the local and regional hydrogeology centred on the Site, and the potential impacts on the groundwater system and environment that may be associated with the Project.
- Groundwater is associated with secondary geological defects that have dissected the crystalline rock mass. The rhyodacite does not have any primary porosity, therefore the groundwater occurrence is associated with discontinuous 'low yielding' sub-vertical 'sheet like' fractures and shear zones. These defects provide a discontinuous potential fluid pathway for percolating rainfall. The fractured rhyodacite aquifers are interpreted to be under semi-confined to confined hydrogeological conditions.
- The proposed quarry operation is largely a 'dry' operation. The results of the surface water studies indicate that sufficient water for use in Project-related activities can be collected on-site. It is understood that there are no plans to apply to WaterNSW for a water supply work on the Site for any make-up water as all water collected for Project-related use would be accounted for under the maximum harvestable rights provisions of the Water Management Act.
- Although structural discontinuities likely exist in the local area, the evidence from many years of rhyodacite extraction in the Karuah Quarry indicates the existence of 'dry' quarry conditions, i.e. little or no groundwater inflow to the extraction area. This suggests that groundwater flow in this aquifer is insignificant and/or the evaporative potential is greater than any groundwater inflow into the pit.
- The elevation of the base of the extraction area is approximately 20m AHD. This suggests that groundwater may be intersected in parts of the Quarry at different stages over the life of the Project. However, the operational Karuah Quarry is observed to be 'dry' even though sub-vertical fractures and shear zones (secondary defects) are mapped in the quarry walls. The relatively 'low-yielding' aquifer system is therefore considered to be associated with discrete discontinuous sub-vertical fractures that dissect the rhyodacite rock mass and provide preferential, but discontinuous, groundwater pathways for percolated rainfall. Based on the existing hydrogeological conditions in the existing Karuah Quarry and the relatively 'low-yielding' fracture aquifer system it is concluded that minor amounts of groundwater may flow into the proposed quarry.
- Any groundwater inflow into the extraction area is predicted to be 'low flow', 'low salinity', non-toxic and effectively diluted by rainwater. That is, the chemistry of any residual water retained in the final void would be dominated by rainwater.

- Whilst review of WaterNSW records identified that there are no registered bores within 3km of the Site, a search of the Bureau of Meteorology's Groundwater Explorer identified a production bore (GW201611), approximately 3km northwest of the Site and up gradient (refer **Section 10.3**). It is therefore concluded that the Project will not adversely impact any neighbouring registered bores. It is concluded that the minimal impact considerations relating to water pressure would not be met.
- Furthermore, the location of the extraction area and baseline groundwater chemistry indicates there is no evidence to suggest that a significant change in water quality would result from any aquifer interference activity.
- No Groundwater Dependent Ecosystems (GDEs) or Groundwater Sensitive Ecosystems (GSEs) have been identified on the Site or within close proximity. It is concluded that it is highly unlikely that potential contaminants could reach this environmental receptor. Implementation of effective control and management measures would further reduce the risk of any adverse environmental impacts.
- The results of surface water studies reveal that overland flow is largely discharged to longitudinal drainage infrastructure and significant cross drainage. It is concluded that these control measures significantly reduce the potential impact on the estuarine Yalimbah Creek system.
- Although secondary defects are known to exist in the rhyodacite aquifer, the evidence from many years of extraction in the Karuah Quarry indicates the existence of 'dry' quarry conditions. As a result, it is anticipated that it will not be necessary for the Operator to secure a water access licence, however, the results of monitoring on any flows and volumes entering the expanding quarry will be assessed and reported to DoI - Water If and when they occur. Should it be established that sustained inflows are occurring, the Operator would arrange for a water access licence to cover groundwater inflow, at a volume agreed upon with DoI – Water.
- The main uncertainties in the groundwater impact assessment are considered to be the degree of heterogeneity of the hard rock aquifer system on the local scale. In order to increase the understanding of the rhyodacite aquifer system and assess any impacts, an ongoing program of water level and water quality monitoring as well as the recording of any groundwater extraction (pit inflows), and reporting of these data would be required.
- Groundwater monitoring and reporting strategies would constitute an important part of a Water Management Plan to be developed prior to the commencement of operations.
- The nature of the extraction operations is such that limited fuels and hydrocarbon products would be stored on the Site. Implementation of an appropriate workshop plan, fuel storage plan and water management plan with effective control measures would significantly reduce the risk of any adverse environmental impacts.

- Strategies to minimise the risks and uncertainties related to any potential impacts from the Project would depend on progressive monitoring results throughout the life of the Quarry. Strategies to mitigate any risks may include acquisition of additional water licences or exploring possible offsets.
- A strategy for the management of monitoring data and in-house and regulatory reporting is proposed as part of a Water Management Plan (WMP) that would be developed by the Operator, approved by DPE and implemented.

16. REFERENCES

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For and on Behalf of

Larry Cook Consulting

Larry Cook MSc (Hydrogeology and Groundwater Management)

Hydrogeologist

GLOSSARY OF TERMS

ALLUVIUM--Unconsolidated clay, silt, sand, or gravel deposited during recent geologic time by running water in the bed of a watercourse or on its floodplain.

ANISOTROPY--condition of having different properties in different directions.

AQUICLUDE--A saturated geologic unit that is incapable of transmitting significant quantities of water under ordinary hydraulic gradients.

AQUIFER--A geologic formation (or one or more geologic formations) that is porous enough and permeable enough to transmit water at a rate sufficient to feed a spring or a well. An aquifer transmits more water than an aquitard. A saturated permeable geologic unit that can transmit significant quantities of water under ordinary hydraulic gradients.

AQUIFER SYSTEM--heterogeneous body of interbedded permeable and poorly permeable material that functions regionally as a water-yielding unit; it comprises two or more permeable beds separated at least locally by confining beds that impede vertical groundwater movement but do not greatly affect the regional hydraulic continuity of the system; includes both saturated and unsaturated parts of permeable materials.

AQUIFER YIELD--Maximum rate of withdrawal that can be sustained by an aquifer. See YIELD.

AQUITARD--A part of a geologic formation (or one or more geologic formations) that is of much lower permeability than an aquifer and would not transmit water at a rate sufficient to feed a spring or for economic extraction by a well. A saturated geologic unit that transmits water in quantities insufficient for economic use.

BEDROCK--The solid rock that underlies any unconsolidated sediment or soil.

BICARBONATE--The anionic constituent HCO3 that has a single negative charge as dissolved in water. Nearly all of the alkalinity in water is composed of bicarbonate. An alkalinity value (reported as mg/L CaCO3) for a water can be converted to the equivalent bicarbonate concentration in mg/L by multiplying by 1.219.

BOUNDARY CONDITION--mathematical expression of a state of the physical system that constrains the equations of the mathematical model.

CALCIUM--The element Ca that occurs as a cation with a double positive charge when dissolved in water; the major dissolved constituent constituting hardness in water.

CALIBRATION (model application)--process of refining the model representation of the hydrogeologic framework, hydraulic properties, and boundary conditions to achieve a desirable degree of correspondence between the model simulation and observations of the ground-water system.

CARBONATE--The anionic constituent CO3 that has two negative charges as dissolve din water or present in a mineral.

CASING RADIUS--Radius of unperforated portion of well casing.

CHLORIDE--The anionic form of the element chlorine (Cl) that has a single negative charge as dissolved in water.

CLAY--A very fine grained material, smaller than silt (clay has a diameter of less than 1/256 mm). Clay is formed by the weathering and breaking down of rocks and minerals.

CONCEPTUAL MODEL--interpretation or working description of the characteristics and dynamics of the physical system.

CONE OF DEPRESSION--A cone-shaped depression in the water table around a well or a group of wells. The cone is created by withdrawing groundwater more quickly than it can be replaced.

CONFINED AQUIFER--An aquifer that is bounded above and below by confining layers. Because of the pressure created in a confined aquifer, the water level in a well drilled into a confined aquifer would rise above the top of the aquifer and, in some instances, above the land's surface. An aquifer with upper and lower boundaries consisting of aquicludes.

CONTACT SPRING--A type of gravity spring whose water flows to the land surface from permeable rocks that are underlain by less permeable rocks, preventing the downward movement of water.

DEPTH TO WATER--The depth of the water table below the earth's surface.

DISCHARGE--Movement of groundwater from the subsurface to the land surface, usually from a spring or to a marsh, river, or watercourse.

DISCHARGE AREA--An area where groundwater is lost naturally from an aquifer through springs, seeps, or hydraulic connection to other aquifers. The water leaving the aquifer is called discharge.

DOMESTIC USE--Water used for drinking and other purposes by a household such as from a rural well.

DOUBLE-POROSITY FRACTURED AQUIFER--An aquifer represented by a double porosity system consisting of low-permeability, primary porosity blocks and high-permeability, secondary porosity fissures.

DOWNGRADIENT--In reference to the movement of groundwater, the "downstream" direction from a point of reference (e.g. a well).

DRAWDOWN--Lowering of the ground-water surface or the piezometric pressure caused by pumping, measured as the difference between the original ground-water level and the current pumping level after a period of pumping. Change in water level relative to static condition due to pumping or slug withdrawal during an aquifer test.

ELEVATION HEAD--see hydraulic head.

EPHEMERAL FLOW--when water flows in a channel only after precipitation.

FAULT--A fracture or break in underground rock usually resulting from tectonic stresses along which one or both sides move. Movement along faults may produce earthquakes; most faults are relatively minor with movement involving only a few feet.

FINITE-DIFFERENCE METHOD--numerical technique for solving a system of equations using a rectangular mesh representing the aquifer and solving for the dependent variable in a piece-wise manner.

FINITE-ELEMENT METHOD--numerical technique for solving a system of equations using an irregular triangular or quadrilateral mesh representing the aquifer and solving for the dependent variable in a continuous manner.

FLUX--refers to the rate of flow; it is the quantity of material or energy transferred through a system or a portion of a system in a unit time and is called mass flux. If the moving matter is a fluid, the flux may be measured as volume of fluid moving through a system in a unit time and is called volume flux. For most applications, we desire to know the flux per unit area of a system rather than the flux of the entire system; the flux per unit area is called the flux density.

FORMATION--A body of rock identified by physical characteristics and stratigraphic position and mappable at the earth's surface or traceable in the subsurface. The formation is the fundamental unit in lithostratigraphic classification. Formations can be subdivided into members or lumped together into groups.

GEOLOGY--The study of the earth, what it's made of, and how it changes over time.

GEOLOGIC STRUCTURES--Features produced by deformation or displacement of the rocks, such as folds, faults, and fractures.

GRAVEL PACK--Coarse sand and gravel placed in the annular space between the borehole and the well casing in the vicinity of the well screen. The purpose of the gravel pack is to minimize the entry of fine sediment into the well, stabilize the borehole, and allow the flow of groundwater into the well.

GROUNDWATER--Underground water that is generally found in the pore space of rocks or sediments and that can be collected with wells, tunnels, or drainage galleries, or that flows naturally to the earth's surface via seeps or springs.

GROUND-WATER-FLOW MODEL--application of a mathematical model to represent a site-specific ground-water flow system.

GROUND-WATER FLOW SYSTEM--set of ground-water flow paths with common recharge and discharge areas. Flow systems are dependent on both the hydrogeologic characteristics of the soil/rock material and landscape position. Areas of steep or undulating (hummocky) relief tend to have dominant local-flow systems (discharging in nearby topographic lows such as a pond or watercourse) Areas of gently sloping or nearly flat relief tend to have dominant regional-flow systems (discharging at much greater distances than local systems in major basin topographic lows or oceans.)

GROUND-WATER HYDROGRAPH--see hydrograph.

GROUND-WATER STORAGE--(1) quantity of water in the saturated zone, or (2) water available only from the storage as opposed to capture.

HARDNESS—(1) Water-quality parameter that indicates the level of alkaline salts, principally calcium and magnesium, and expressed as equivalent calcium carbonate ($CaCO_3$). Hard water is commonly recognized by the increased quantities of soap, detergent, or shampoo necessary to lather. (2) In mineralogy, the degree of hardness of a mineral is an aid in identification. Geologists have assigned numbers to the hardness of several minerals; in this hardness scale, softer minerals are assigned a low mineral and the harder minerals a higher number.

HEAD--see hydraulic head.

HEAD LOSS--see hydraulic head.

HECTARE (ha)--One hectare equals 2.47 acres. One square kilometre equals 100 hectares. One square mile equals 259 hectares.

HETEROGENEOUS--material property that varies with the location within the material. See also homogeneous.

HOMOGENEOUS--material is homogeneous if its hydrologic properties are identical everywhere.

HYDRAULIC CONDUCTIVITY--Factor of proportionality in Darcy's equation relating flow velocity to hydraulic gradient having units of length per unit of time. A property of the porous medium and the fluid (water content of the medium). The volume of water moving through a unit area of aquifer perpendicular to the direction of flow in unit time under a unit hydraulic gradient.

HYDRAULIC GRADIENT--slope of the water table or potentiometric surface. The change is static head per unit of distance in a given direction. If not specified, the direction generally is understood to be that of the maximum rate of decrease in head.

HYDRAULIC HEAD OR (STATIC) HEAD--Height that water in an aquifer can raise itself above an (arbitrary) reference level (or datum), and is generally measured in feet. When a borehole is drilled into an aquifer, the level at which the water stands in the borehole (measured with reference to a horizontal datum such as sea level) is, for most purposes, the hydraulic head of water in the aquifer. This term defines how much energy water possesses. Groundwater possesses energy mainly by virtue of its elevation (elevation head) and of its pressure (pressure head). See also hydrostatic head. When groundwater moves, some energy is dissipated and therefore a head loss occurs.

HYDRAULICALLY CONNECTED--A condition in which groundwater moves easily between aquifers that are in direct contact. An indication of this condition is that the water levels in both aquifers are approximately equal.

HYDROGEOLOGY--The study of groundwater and its relationship to geology. Also sometimes known as geohydrology.

HYDROGRAPH--graph showing stage, flow, velocity, or other characteristics of water with respect to time. A watercourse hydrograph commonly shows rate of flow; a ground-water hydrograph shows water level or head.

HYDROLOGIC BUDGET OR BALANCE--Accounting of the inflow to, outflow from, and storage in a hydrologic unit such as a watercourse basin, aquifer, soil zone, lake, or reservoir; the relationship between evaporation, precipitation, runoff, and the change in water storage, expressed by the hydrologic equation.

HYDROLOGIC CYCLE--The complete cycle that water can pass through, beginning as atmospheric water vapour, turning into precipitation and falling to the earth's surface, moving into aquifers or surface water, and then returning to the atmosphere via evapotranspiration.

HYDROLOGY--The study of the characteristics and occurrence of water, and the hydrologic cycle. Hydrology concerns the science of surface water and groundwaters, whereas hydrogeology principally focuses on groundwater.

HYDROSTATIC HEAD--height above a standard datum of the surface of a column of water or other liquid that can be supported by the (hydro) static pressure at a given point.

HYDROSTATIC PRESSURE--Pressure exerted by water at any given point in a body of water at rest.

IGNEOUS ROCK--Rock that forms when a hot liquid (magma) cools and hardens.

IRRIGATION USE--Water applied to the soil surface by centre pivots, ditches or other means, or to the soil subsurface by tubes to add to the water available for plant growth.

ISOTROPIC--said of a medium whose properties are the same in all directions. See anisotropy.

JOINT--In geologic terms, a natural fracture, usually vertical, in a rock. Joints are common in limestone, and caves usually form along joints and bedding planes.

LEAKY AQUIFER--An aquifer with upper and lower boundaries of one aquitard and one aquiclude or two aquitards.

LITHOLOGY--(1) The description of rocks on the basis of physical characteristics, such as colour and mineral composition. (2) The physical character of a rock.

MAGNESIUM--The cationic form of the element magnesium (Mg) that has a double positive charge as dissolved in water; along with calcium, a major dissolved constituent constituting hardness in water.

MAGNESIUM-BICARBONATE TYPE--The constituents with the largest concentrations in this type of water are calcium (Ca) and bicarbonate (HCO3).

MAJOR DISSOLVED CONSTITUENTS--The substances in largest concentration that are dissolved in waters are calcium, magnesium, sodium, bicarbonate, chloride, sulphate, and silica, although nitrate can sometimes be a major constituent.

mg/L--Milligrams of a substance dissolved in one litre of water. The value is essentially the same as a part per million in freshwater because one litre of distilled water weighs one million milligrams (one kilogram).

MILLIGRAMS PER LITRE (mg/L)--Milligrams per litre of water. This measure is equivalent to parts per million (ppm).

MODEL--Assembly of concepts in the form of mathematical equations that portray understanding of a natural phenomenon.

MODELLING--Investigative technique that uses a mathematical or physical representation of a system or theory that accounts for all or some of its known properties. Models are often used to test the effects of changes of system components on the overall performance of the system.

MONITORING WELL--Non-pumping well used primarily for drawing water-quality samples; also for measuring ground-water levels.

NATURAL RECHARGE--Naturally occurring water added to an aquifer. Natural recharge generally comes from snowmelt and precipitation or storm runoff.

NUMERICAL METHODS--set of procedures used to solve the equations of a mathematical model in which the applicable partial differential equations are replaced by a set of algebraic equations written in terms of discrete values of state variables at discrete points in space and time. There are many numerical methods. Those in common use in ground-water models are the finite-difference method, the finite-element method, the boundary-element method, and the analytical-element method.

NUMERICAL MODEL--model that uses numerical methods to solve the governing equations of the applicable problem.

OBSERVATION WELL--non-pumping well used primarily for observing the elevation of the water table or the piezometric pressure; also to obtain water-quality samples.

OUTCROP--That part of a rock unit that is exposed at the earth's surface.

PARTS PER MILLION (ppm)--See milligrams per litre.

PERCHED WATER TABLE--Water table of a relatively small ground-water body lying above the general ground-water body.

PERCHING HORIZON--A relatively impermeable (i.e., incapable of transmitting fluids) lens or layer of clay or bedrock in otherwise permeable sediments that slows or prevents the downward movement of water.

PERENNIAL FLOW--year-round flow.

PERIOD--A unit of geologic time. Several periods make up an era.

PERMEABLE--Permeability is a measure of the ease with which a fluid would move through a porous material (e.g., sand and gravel or rock). A geologic unit is permeable if groundwater moves easily through it.

PERMEABILITY--(1) Ability of a material (generally an earth material) to transmit fluids (water) through its pores when subjected to pressure or a difference in head. Expressed in units of volume of fluid (water) per unit time per cross section area of material for a given hydraulic head; (2) description of the ease with which a fluid may move through a porous medium; abbreviation of intrinsic permeability. It is a property of the porous medium only, in contrast to hydraulic conductivity, which is a property of both the porous medium and the fluid content of the medium.

pH--measure of the relative acidity or alkalinity of water. Defined as the negative log (base 10) of the hydrogen ion concentration. Water with a pH of 7 is neutral; lower pH levels indicate an increasing acidity, while pH levels above 7 indicate increasingly basic solutions.

PIEZOMETER--small-diameter well open at a point or short length in the aquifer to allow measurement of hydraulic head at that point or short length. An open-ended pipe installed in an aquifer to measure hydraulic head at a specific depth.

PIEZOMETRIC PRESSURE--pressure corresponding to the height to which water would rise in an observation well penetrating an aquifer.

PIEZOMETRIC SURFACE--surface defined by a pressure head and position (elevation above a standard datum, such as sea level). For an unconfined aquifer, it is equal to the elevation of the water table. For a confined aquifer, it is equal to the elevation to which water would rise in a well penetrating and open to the aquifer. This term is now replaced by potentiometric surface.

POROSITY--Fraction of bulk volume of a material consisting of pore space. Porosity determines the capacity of a rock formation to absorb and store groundwater. The ratio of void volume to total volume in an unconsolidated material.

POROUS--Geologically, this term describes rock that permits movement of fluids through small, often microscopic openings, much as water moving through a sponge. Porous rocks may contain gas, oil, or water.

POTENTIOMETRIC SURFACE--Imaginary surface representing the static head of groundwater and defined by the level to which water would rise in a well. The water table is a particular potentiometric surface.

PRECIPITATION--Water in some form that falls from the atmosphere. It can be in the form of liquid (rain or drizzle) or solid (snow, hail, sleet).

QUARTZ--An important rock-forming mineral, crystalline silica (SiO2) occurs either in transparent hexagonal crystals or in crystalline or cryptocrystalline masses. Quartz is the commonest mineral next to feldspar and forms the majority of most sands. It is widely distributed in igneous, sedimentary, and metamorphic rocks. It has a hardness of 7 on the Mohs scale.

RECHARGE--The replenishment of groundwater in an aquifer. It can be either natural, through the movement of precipitation into an aquifer, or artificial-the pumping of water into an aquifer.

RECHARGE AREA--A geographic area where water enters (recharges) an aquifer. Recharge areas usually coincide with topographically elevated regions where aquifer units crop out at the surface. In these areas infiltrated precipitation is the primary source of recharge. The recharge area may also coincide with the area of hydraulic connection where one aquifer receives flow from another adjacent aquifer.

SAFE YIELD--(1) Rate of surface-water diversion or ground- water extraction from a basin for consumptive use over an indefinite period of time that can be maintained without producing negative effects; (2) the annual extraction from a ground-water unit which would not, or does not, exceed the average annual recharge; ii. so lower the water table that permissible cost of pumping is exceeded; iii. so lower the water table as to permit intrusion of water of undesirable quality; or iv. so lower the water table as to infringe upon existing water rights; (3) the attainment and maintenance of a long-term balance between the amount of groundwater withdrawn annually and the annual amount of recharge; (4) the maximum quantity of water that can be guaranteed from a reservoir during a critical dry period. Synonymous to firm yield.

SALINE WATER--Water containing more than 10,000 parts per million (ppm) of dissolved solids of any type. Brackish water contains between 1,000 and 10,000 ppm of dissolved solids.

SALINITY--The total quantity of dissolved salts in water, usually measured by weight in milligrams per litre (mg/L) or parts per million (ppm). The upper limit for freshwater is 1,000 mg/L; natural seawater has a salinity of approximately 35,000 mg/L.

SAND--A rock fragment or mineral particle smaller than a granule and larger than a coarse silt grain. Its diameter ranges from 1/16 to 2 mm.

SATURATED THICKNESS--The vertical thickness of an aquifer that is full of water. The upper surface is the water table. The height of the hydrogeologically defined aquifer unit in which the pore spaces are filled (saturated) with water. For the High Plains aquifer and similar unconfined, unconsolidated aquifers, the saturated thickness is equal to the difference in elevation between the bedrock surface and the water table. The predevelopment saturated thickness is based on the best available estimate of the elevation of the water table prior to human alteration by groundwater pumping. Vertical distance measured from the top of an aquifer (confining layer or water table) to the base of the aquifer.

SATURATED ZONE--That portion of soil or an aquifer in which all of the pore space is filled with water.

SEEP--A discharge of water that "oozes out of the soil or rock over a certain area without distinct trickles or rivulets" (from H. Bouwer, 1978, Groundwater Hydrology: New York, McCraw-Hill, 480 p.).

SIMULATION--in ground-water-flow modelling, one complete execution of a ground-water-modelling computer program, including input and output.

SODIUM--The cationic form of the element sodium (Na) that has a single positive charge as dissolved in water.

SPECIFIC DISCHARGE--for groundwater, the rate of discharge of groundwater per unit area measured at right angles to the direction of flow.

SPECIFIC RETENTION--ratio of the volume of water that a given body of rock or soil would hold against the pull of gravity to the volume of the body itself. It is usually expressed as a percentage. Compare with field capacity.

SPECIFIC STORAGE--volume of water released from or taken into storage per unit volume of the porous medium per unit change in head. It is the three-dimensional equivalent of storage coefficient or storativity, and is equal to storativity divided by aquifer saturated thickness. The volume of water released from storage by a unit volume of confined aquifer per unit decline in hydraulic head.

SPECIFIC YIELD--The quantity of water given up by a unit volume of a substance when drained by gravity. The volume of water released from storage per unit surface area of an unconfined aquifer per unit decline of the water table.

SPRING--A place where groundwater flows naturally from the earth into a body of surface water or onto the land surface, at a rate sufficient to form a current.

STEADY-STATE FLOW--characteristic of a flow system where the magnitude and direction of specific discharge are constant in time at any point.

STORATIVITY or STORAGE COEFFICIENT--volume of water released per unit area of aquifer and per unit drop in head. Storage coefficient is a function of the compressive qualities of water and matrix structures of the porous material. A confined aquifer's ability to store water is measured by its storage coefficient. Storativity is a more general term encompassing both or either storage coefficient and/or specific yield. The volume of water released from storage per unit surface area of a confined aquifer per unit decline in hydraulic head.

SUBSURFACE--Underground. Below the earth's surface.

SUBSURFACE WATER--all water below the land surface, including soil moisture, capillary fringe water in the vadose zone, and groundwater.

SULPHATE--The anionic constituent SO4 that has two negative charges as dissolved in water.

SURFACE WATER--Water found at the earth's surface, usually in watercourses or lakes.

SUSTAINABLE YIELD--volume of groundwater that can be extracted annually from a groundwater basin without causing adverse effects.

TOPOGRAPHIC MAP--A map that shows natural human-made features of an area using contour lines (lines of equal elevation) to portray the size, shape, and elevation of the features.

TOPOGRAPHY--Physical features, such as hills, valleys, and plains that shape the surface of the Earth.

TOTAL DISSOLVED SOLIDS (TDS)--The total quantity of minerals (salts) in water, usually measured by weight in milligrams per litre (mg/L) or parts per million (ppm).

TRANSMISSIVITY--flow capacity of an aquifer measured in volume per unit time per unit width. Equal to the product of hydraulic conductivity times the saturated thickness of the aquifer. Transmissivity is the rate of flow under a unit hydraulic gradient through a cross-section of aquifer having a unit width and full saturated thickness. Also expressed as the product of hydraulic conductivity times saturated thickness.

TRIASSIC PERIOD--The interval of geologic time between approximately 248.2 and 205.7 million years ago.

UNCONFINED AQUIFER--An aquifer that is not bounded above by an aquitard; water levels in wells screened in an unconfined aquifer coincide with the elevation of the water table. An aquifer with an unrestricted (free) upper boundary and an impermeable lower boundary (aquiclude).

UPGRADIENT--In reference to the movement of groundwater, the "upstream" direction from a point of reference (e.g., a well).

VADOSE ZONE--unsaturated (not completely filled with water) zone lying between the earth's surface and the top of the groundwater. Also known as unsaturated zone and zone of aeration.

VOID--pore space or other openings in rock. The openings can be very small to cave size and are filled with water below the water table.

WATER BALANCE--A mathematical construction that shows the amount of water leaving and entering a given watershed or aquifer.

WATER QUALITY--physical, chemical, and biological characteristics of water and how

WATERSHED--The area drained by a single watercourse or river.

WATER TABLE--A fluctuating demarcation line between the unsaturated (vadose) zone and the saturated (phreatic) zone that forms an aquifer. It may rise or fall depending on precipitation (rainfall) trends. The water table is semi parallel to the land surface above but is not always a consistent straight line. Because of impervious beds of shale, etc., local water tables can be perched above the area's average water table.

WELL--A vertical excavation into an underground rock formation.

WELLBORE RADIUS--Radius of well boring (adjacent to well intake or screen).

WELL SCREEN--A slotted section of pipe usually placed in the borehole adjacent to the main aquifer unit or units that supplies the well with water.

WELL YIELD--Maximum pumping rate that can be supplied by a well without drawing the water level in the well below the pump intake. See YIELD.

YIELD--amount of water that can be supplied from a reservoir, aquifer, basin, or other system during a specified interval of time. This time period may vary from a day to several years depending upon the size of the system involved.

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Appendices

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Annexure A

Specifications 'Greyhound' Water Level Sensor

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Sensor Description

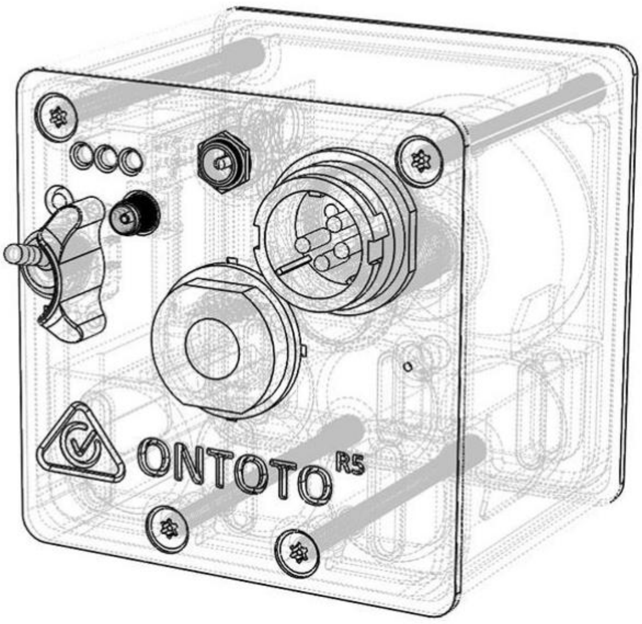
Holykell branded sensor
Model HPT604
P/N 60427HGS17E11CWN1040
Pressure range 0-20m $H2O$, Accuracy ≤ ± 0.5% FS

Typical Installation

Ontoto

The Greyhound

Ground Water Remote Telemetry Data Logging



- 3G/4G LTE data and SMS connectivity.
- Optional LoRa available (Long Range Radio)
- Level and optional data stored and backed up in flash memory on board prior to emailing as CSV attachment.
- The default configuration has 4hour sample intervals and weekly reporting frequencies.
- User customisable send-to email field in config.txt file.
- Remotely configurable smartphone App or Web Portal
- Strong and durable casing to protect the internal hardware.
- The standard vandal resistant aerial.
- Tamper proof screws restrict access to the internal componentry
- A tested range of higher gain aerials available to suit the geography of your location.
- Class leading battery life, powered by Duracell Ultra alkaline long-life batteries (safe for air freight)3-5 years battery life, user serviceable
- Optional Lithium battery for extended life and temperature range + 85 deg C
- Optional solar / battery for higher reporting frequency
- Optional Pulse input (IE tipping bucket rain gauge, flow).
- Industry standard Modbus sensor interface, and SD-12 to support a range of senor configurations.
- Quick and easy retrofit into existing infrastructure.

Annexure B

Laboratory Certificate Water Quality Testing and Chain of Custody

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CERTIFICATE OF ANALYSIS 204038

Client Details

Client	Larry Cook Consulting
Attention	Larry Cook
Address	PO Box 8146, Tumbi Umbi, NSW, 2261

Sample Details

Your Reference	Larry Cook - Wedgerock
Number of Samples	4 water
Date samples received	26/10/2018
Date completed instructions received	26/10/2018

Analysis Details

Please refer to the following pages for results, methodology summary and quality control data.

Samples were analysed as received from the client. Results relate specifically to the samples as received.

Results are reported on a dry weight basis for solids and on an as received basis for other matrices.

Report Details

Date results requested by	02/11/2018
Date of Issue	23/11/2018

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Accredited for compliance with ISO/IEC 17025 - Testing. **Tests not covered by NATA are denoted with ***

Results Approved By
Jaimie Loa-Kum-Cheung, Senior Chemist
Priya Samarawickrama, Senior Chemist

Authorised By

Jacinta Hurst, Laboratory Manager

Envirolab Reference: 204038
Revision No: R00

ACCREDITED FOR TECHNICAL COMPETENCE

Client Reference: Larry Cook - Wedgerock

Miscellaneous Inorganics					
Our Reference		204038-1	204038-2	204038-3	204038-4
Your Reference	UNITS	BH 3	BH 4	BH 7	BH 8
Date Sampled		24/10/2018	24/10/2018	24/10/2018	24/10/2018
Type of sample		water	water	water	water
Date prepared	-	26/10/2018	26/10/2018	26/10/2018	26/10/2018
Date analysed	-	26/10/2018	26/10/2018	26/10/2018	26/10/2018
pH	pH Units	5.9	6.7	6.8	6.1
Electrical Conductivity	µS/cm	270	480	510	330
Total Dissolved Solids (grav)	mg/L	160	310	310	200
Nitrate as N in water	mg/L	0.21	0.57	0.20	0.64
Nitrite as N in water	mg/L	<0.005	<0.005	<0.005	<0.005

Client Reference: Larry Cook - Wedgerock

Ion Balance					
Our Reference		204038-1	204038-2	204038-3	204038-4
Your Reference	UNITS	BH 3	BH 4	BH 7	BH 8
Date Sampled		24/10/2018	24/10/2018	24/10/2018	24/10/2018
Type of sample		water	water	water	water
Date prepared	-	26/10/2018	26/10/2018	26/10/2018	26/10/2018
Date analysed	-	26/10/2018	26/10/2018	26/10/2018	26/10/2018
Calcium - Dissolved	mg/L	5.2	17	30	9.0
Potassium - Dissolved	mg/L	1.3	1.3	3.0	3.8
Sodium - Dissolved	mg/L	42	82	65	55
Magnesium - Dissolved	mg/L	4.7	7.1	8.8	3.6
Hydroxide Alkalinity (OH^-) as $CaCO_3$	mg/L	<5	<5	<5	<5
Bicarbonate Alkalinity as $CaCO_3$	mg/L	24	54	87	28
Carbonate Alkalinity as $CaCO_3$	mg/L	<5	<5	<5	<5
Total Alkalinity as $CaCO_3$	mg/L	24	54	87	28
Sulphate, SO4	mg/L	9	20	23	24
Chloride, Cl	mg/L	58	92	87	63
Ionic Balance	%	5.0	10	5.0	7.0

Client Reference: Larry Cook - Wedgerock

HM in water - total					
Our Reference		204038-1	204038-2	204038-3	204038-4
Your Reference	UNITS	BH 3	BH 4	BH 7	BH 8
Date Sampled		24/10/2018	24/10/2018	24/10/2018	24/10/2018
Type of sample		water	water	water	water
Date prepared	-	29/10/2018	29/10/2018	29/10/2018	29/10/2018
Date analysed	-	29/10/2018	29/10/2018	29/10/2018	29/10/2018
Arsenic-Total	µg/L	<1	<1	<1	<1
Cadmium-Total	µg/L	<0.1	<0.1	<0.1	<0.1
Chromium-Total	µg/L	<1	<1	<1	1
Copper-Total	µg/L	<1	<1	2	3
Lead-Total	µg/L	<1	<1	<1	<1
Mercury-Total	µg/L	<0.05	<0.05	<0.05	<0.05
Nickel-Total	µg/L	1	2	2	2
Zinc-Total	µg/L	7	15	150	200
Iron-Total	µg/L	25	49	31	640

Client Reference: Larry Cook - Wedgerock

Method ID	Methodology Summary
Inorg-001	pH - Measured using pH meter and electrode in accordance with APHA latest edition, 4500-H+. Please note that the results for water analyses are indicative only, as analysis outside of the APHA storage times.
Inorg-002	Conductivity and Salinity - measured using a conductivity cell at 25°C in accordance with APHA latest edition 2510 and Rayment & Lyons.
Inorg-006	Alkalinity - determined titrimetrically in accordance with APHA latest edition, 2320-B.
Inorg-018	Total Dissolved Solids - determined gravimetrically. The solids are dried at 180+/-10°C.
Inorg-040	The concentrations of the major ions (mg/L) are converted to milliequivalents and summed. The ionic balance should be within +/- 10% ie total anions = total cations +/-10%.
Inorg-055	Nitrate - determined colourimetrically. Soils are analysed following a water extraction.
Inorg-055	Nitrite - determined colourimetrically based on APHA latest edition NO2- B. Soils are analysed following a water extraction.
Inorg-081	Anions - a range of Anions are determined by Ion Chromatography, in accordance with APHA latest edition, 4110-B. Alternatively determined by colourimetry/turbidity using Discrete Analyer.
Metals-020	Determination of various metals by ICP-AES.
Metals-021	Determination of Mercury by Cold Vapour AAS.
Metals-022	Determination of various metals by ICP-MS.

Client Reference: Larry Cook - Wedgerock

QUALITY CONTROL: Miscellaneous Inorganics						Duplicate			Spike Recovery %	
Test Description	Units	PQL	Method	Blank	#	Base	Dup.	RPD	LCS-W1	[NT]
Date prepared	-			26/10/2018	[NT]	[NT]	[NT]	[NT]	26/10/2018	[NT]
Date analysed	-			26/10/2018	[NT]	[NT]	[NT]	[NT]	26/10/2018	[NT]
pH	pH Units		Inorg-001	[NT]	[NT]	[NT]	[NT]	[NT]	102	[NT]
Electrical Conductivity	µS/cm	1	Inorg-002	<1	[NT]	[NT]	[NT]	[NT]	105	[NT]
Total Dissolved Solids (grav)	mg/L	5	Inorg-018	<5	[NT]	[NT]	[NT]	[NT]	107	[NT]
Nitrate as N in water	mg/L	0.005	Inorg-055	<0.005	[NT]	[NT]	[NT]	[NT]	98	[NT]
Nitrite as N in water	mg/L	0.005	Inorg-055	<0.005	[NT]	[NT]	[NT]	[NT]	113	[NT]

Client Reference: Larry Cook - Wedgerock

QUALITY CONTROL: Ion Balance					Duplicate				Spike Recovery %	
Test Description	Units	PQL	Method	Blank	#	Base	Dup.	RPD	LCS-W1	[NT]
Date prepared	-			26/10/2018	[NT]	[NT]	[NT]	[NT]	26/10/2018	[NT]
Date analysed	-			26/10/2018	[NT]	[NT]	[NT]	[NT]	26/10/2018	[NT]
Calcium - Dissolved	mg/L	0.5	Metals-020	<0.5	[NT]	[NT]	[NT]	[NT]	109	[NT]
Potassium - Dissolved	mg/L	0.5	Metals-020	<0.5	[NT]	[NT]	[NT]	[NT]	119	[NT]
Sodium - Dissolved	mg/L	0.5	Metals-020	<0.5	[NT]	[NT]	[NT]	[NT]	113	[NT]
Magnesium - Dissolved	mg/L	0.5	Metals-020	<0.5	[NT]	[NT]	[NT]	[NT]	109	[NT]
Hydroxide Alkalinity (OH^-) as $CaCO_3$	mg/L	5	Inorg-006	<5	[NT]	[NT]	[NT]	[NT]	[NT]	[NT]
Bicarbonate Alkalinity as $CaCO_3$	mg/L	5	Inorg-006	<5	[NT]	[NT]	[NT]	[NT]	[NT]	[NT]
Carbonate Alkalinity as $CaCO_3$	mg/L	5	Inorg-006	<5	[NT]	[NT]	[NT]	[NT]	[NT]	[NT]
Total Alkalinity as $CaCO_3$	mg/L	5	Inorg-006	<5	[NT]	[NT]	[NT]	[NT]	98	[NT]
Sulphate, SO4	mg/L	1	Inorg-081	<1	[NT]	[NT]	[NT]	[NT]	117	[NT]
Chloride, Cl	mg/L	1	Inorg-081	<1	[NT]	[NT]	[NT]	[NT]	99	[NT]

Client Reference: Larry Cook - Wedgerock

QUALITY CONTROL: HM in water - total						Duplicate			Spike Recovery %	
Test Description	Units	PQL	Method	Blank	#	Base	Dup.	RPD	LCS-W4	204038-2
Date prepared	-			29/10/2018	1	29/10/2018	29/10/2018		29/10/2018	29/10/2018
Date analysed	-			29/10/2018	1	29/10/2018	29/10/2018		29/10/2018	29/10/2018
Arsenic-Total	μg/L	1	Metals-022	<1	1	<1	<1	0	103	103
Cadmium-Total	μg/L	0.1	Metals-022	<0.1	1	<0.1	<0.1	0	103	102
Chromium-Total	μg/L	1	Metals-022	<1	1	<1	<1	0	97	96
Copper-Total	μg/L	1	Metals-022	<1	1	<1	<1	0	99	97
Lead-Total	μg/L	1	Metals-022	<1	1	<1	<1	0	99	98
Mercury-Total	μg/L	0.05	Metals-021	<0.05	1	<0.05	[NT]		104	[NT]
Nickel-Total	μg/L	1	Metals-022	<1	1	1	1	0	107	97
Zinc-Total	μg/L	1	Metals-022	<1	1	7	7	0	104	101
Iron-Total	μg/L	10	Metals-022	<10	1	25	24	4	105	97

Client Reference: Larry Cook - Wedgerock

Result Definitions	
NT	Not tested
NA	Test not required
INS	Insufficient sample for this test
PQL	Practical Quantitation Limit
<	Less than
>	Greater than
RPD	Relative Percent Difference
LCS	Laboratory Control Sample
NS	Not specified
NEPM	National Environmental Protection Measure
NR	Not Reported

Quality Control Definitions	
Blank	This is the component of the analytical signal which is not derived from the sample but from reagents, glassware etc, can be determined by processing solvents and reagents in exactly the same manner as for samples.
Duplicate	This is the complete duplicate analysis of a sample from the process batch. If possible, the sample selected should be one where the analyte concentration is easily measurable.
Matrix Spike	A portion of the sample is spiked with a known concentration of target analyte. The purpose of the matrix spike is to monitor the performance of the analytical method used and to determine whether matrix interferences exist.
LCS (Laboratory Control Sample)	This comprises either a standard reference material or a control matrix (such as a blank sand or water) fortified with analytes representative of the analyte class. It is simply a check sample.
Surrogate Spike	Surrogates are known additions to each sample, blank, matrix spike and LCS in a batch, of compounds which are similar to the analyte of interest, however are not expected to be found in real samples.
Australian Drinking Water Guidelines recommend that Thermotolerant Coliform, Faecal Enterococci, & E.Coli levels are less than 1cfu/100mL. The recommended maximums are taken from "Australian Drinking Water Guidelines", published by NHMRC & ARMC 2011.	

Client Reference: Larry Cook - Wedgerock

Laboratory Acceptance Criteria

Duplicate sample and matrix spike recoveries may not be reported on smaller jobs, however, were analysed at a frequency to meet or exceed NEPM requirements. All samples are tested in batches of 20. The duplicate sample RPD and matrix spike recoveries for the batch were within the laboratory acceptance criteria.

Filters, swabs, wipes, tubes and badges will not have duplicate data as the whole sample is generally extracted during sample extraction.

Spikes for Physical and Aggregate Tests are not applicable.

For VOCs in water samples, three vials are required for duplicate or spike analysis.

Duplicates: >10xPQL - RPD acceptance criteria will vary depending on the analytes and the analytical techniques but is typically in the range 20%-50% – see ELN-P05 QA/QC tables for details; <10xPQL - RPD are higher as the results approach PQL and the estimated measurement uncertainty will statistically increase.

Matrix Spikes, LCS and Surrogate recoveries: Generally 70-130% for inorganics/metals; 60-140% for organics (+/-50% surrogates) and 10-140% for labile SVOCs (including labile surrogates), ultra trace organics and speciated phenols is acceptable.

In circumstances where no duplicate and/or sample spike has been reported at 1 in 10 and/or 1 in 20 samples respectively, the sample volume submitted was insufficient in order to satisfy laboratory QA/QC protocols.

When samples are received where certain analytes are outside of recommended technical holding times (THTs), the analysis has proceeded. Where analytes are on the verge of breaching THTs, every effort will be made to analyse within the THT or as soon as practicable.

Where sampling dates are not provided, Envirolab are not in a position to comment on the validity of the analysis where recommended technical holding times may have been breached.

Measurement Uncertainty estimates are available for most tests upon request.

To: Envirolab Services Pty Ltd
12 Ashley Street
Chatswood NSW 2147

CHAIN OF CUSTODY

Date: 25.10.18 Page: 1 of 1

REPORT TO: Larry Cook
COMPANY: Larry Cook Consulting
ADDRESS: PO Box 8146
TUMBI UMBI NSW 2261

INVOICE TO: Larry Cook
COMPANY: Larry Cook Consulting
ADDRESS: PO Box 8146
TUMBI UMBI NSW 2261

Telephone: 0428 884645
Email: larrycookconsulting@gmail.com

ANALYSIS REQUIRED

	Client Sample ID	Sample Date	Matrix	pH, EC, TDS	CATIONS (calc)	ANIONS	NITRATE NITRITE	8 METALS	TOTAL IRON
1	BH 3	24.10.18	WATER	✓	✓	✓	✓	✓	✓
2	BH 4	↓	↓	✓	✓	✓	✓	✓	✓
3	BH 7	↓	↓	✓	✓	✓	✓	✓	✓
4	BH 8	↓	↓	✓	✓	✓	✓	✓	✓

Envirolab
12 Ashley St
Chatswood NSW 2067
Ph: (02) 9910 6200
Job No: 204038
Date Received: 26/10/18
Time Received: 09:00
Received By: TN
Temp: Cool/Ambient 09.5°C
Cooling: Ice/Icepack
Security: Intact/Broken/None

Project ID	Relinquished By:	Date/Time	Received By:	Date/Time
WEDGEROCK	LARRY COOK		ELS T.Nguyen	26/10/18 0900
	Relinquished By:	Date/Time	Received By:	Date/Time
	Relinquished By:	Date/Time	Received By:	Date/Time

Comments:

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Annexure C

Work Summary GW201611

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WaterNSW

Work Summary

GW201611

Licence:

Licence Status:

Authorised Purpose(s):
Intended Purpose(s): COMMERCIAL

Work Type: Bore
Work Status: Supply Obtained
Construct.Method: Rotary Air
Owner Type: Private

Commenced Date:
Completion Date: 10/11/2004

Final Depth: 60.00 m
Drilled Depth: 60.00 m

Contractor Name: Country to Coast Drilling
Driller: Leon Frederick Hook
Assistant Driller: Stuart

Property:
GWMA:
GW Zone:

Standing Water Level (m): 23.500
Salinity Description:
Yield (L/s): 2.500

Site Details

Site Chosen By:

	County	Parish	Cadastre
Form A:	GLOUCESTER	CARRINGTON	50//1036893
Licensed:			

Region: 20 - Hunter
River Basin: 209 - KARUAH RIVER
Area/District:

CMA Map: 9232-1N
Grid Zone:
Scale:

Elevation: 0.00 m (A.H.D.)
Elevation Source: Unknown

Northing: 6391185.000
Easting: 404605.000

Latitude: 32°36'45.9"S
Longitude: 151°58'59.7"E

GS Map: -
MGA Zone: 56
Coordinate Source: GIS - Geogra

Construction

Negative depths indicate Above Ground Level; C-Cemented; SL-Slot Length; A-Aperture; GS-Grain Size; Q-Quantity; PL-Placement of Gravel Pack; PC-Pressure Cemented; S-Sump; CE-Centralisers

Hole	Pipe	Component	Type	From (m)	To (m)	Outside Diameter (mm)	Inside Diameter (mm)	Interval	Details
1		Hole	Hole	0.00	0.50	195			Rotary Air
1		Hole	Hole	0.50	60.00	175			Down Hole Hammer
1		Annulus	Bentonite	7.00	8.00	175	140		
1	1	Casing	Steel - Erw	0.00	42.00	140	124		Seated on Bottom, Welded
1	1	Casing	Steel Stainless 304	42.00	48.00	142	124		Seated on Bottom, Welded
1	1	Opening	Slots - Vertical	48.00	60.00	142		0	Casing - Hand Sawn Slot, Stainless Steel 304, SL: 200.0mm, A: 1.00mm

Water Bearing Zones

From (m)	To (m)	Thickness (m)	WBZ Type	S.W.L. (m)	D.D.L. (m)	Yield (L/s)	Hole Depth (m)	Duration (hr)	Salinity (mg/L)
55.00	60.00	5.00	Unknown	23.50		2.50		01:00:00	1700.00

Drillers Log

From (m)	To (m)	Thickness (m)	Drillers Description	Geological Material	Comments
0.00	0.10	0.10	Topsoil	Topsoil	
0.10	0.50	0.40	Clay, tan	Clay	
0.50	55.00	54.50	Sandstone, hard, red	Sandstone	
55.00	60.00	5.00	Sandstone, water bearing	Sandstone	

Remarks

10/11/2004: Form A Remarks:
Nat Carling, 27-Apr-2012; Coordinates based on location map provided with the Form-A.

*** End of GW201611 ***

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