APPENDIX P: GROUNDWATER IMPACT ASSESSMENT

GROUNDWATER IMPACT ASSESSMENT
Deep Creek Quarry, Limeburners Creek, NSW

202011 Deep Creek Quarry Groundwater Impact Assessment

REPORT NO. 202011

GROUNDWATER ASSESSMENT
Deep Creek Quarry, Limeburners Creek, NSW

HYDROMINEX GEOSCIENCE

REPORT FOR IRONSTONE DEVELOPMENTS PTY LTD

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EXECUTIVE SUMMARY

This groundwater assessment provides an evaluation of the impact of the proposed quarry on the groundwater and surface water in the vicinity and other groundwater users in the area.

The quarry is to be developed within rhyolite subvolcanic rock emplaced within sandstone and siltstone sediments. The rhyolite has no primary porosity, with groundwater only present in discontinuous subvertical fractures. Sandstones and siltstones with some primary porosity, in addition to fracture porosity, overlie and underlie the rhyolite.

The fractures in the sediments and rhyolite allow direct recharge from rainfall (estimated in the Water Sharing Plan to be 4% of rainfall) and flow of groundwater through the proposed quarry area. The rhyolite and underlying sediments are interpreted to be under semi-confined to confined conditions and are unlikely to have porosity of more than a few percent associated with fractures in the rhyolite and fractures and some pores in the sandstone.

The proposed quarry is estimated to have a low inflow of groundwater, due to the low permeability rhyolite rock type, which is the target material for quarrying. The sandstone and siltstone units overlying the rhyolite are generally above the water table, so are not all water-bearing.

Quarrying operations in similar volcanic units in the same Water Sharing Plan area are recorded to be essentially dry, suggesting the proposed quarry development will be similar. The predicted low inflow of groundwater into the quarry will allow groundwater to accumulate in the base of the pit, where it will evaporate and be available for site activities, such as dust suppression.

Groundwater in the area of the proposed quarry has an Electrical Conductivity (EC) that is up to 10 times that in surface water ponds within the bed of deep Creek, within several hundred metres of the proposed quarry. In the creek the EC is low and in the order of 250 uS/cm. However, the groundwater is moderate-quality water, acceptable for some agricultural uses but not for potable water.

Unless there is contamination of groundwater in the quarry during excavation from explosive residues or hydrocarbons it is unlikely there would be an impact on the groundwater quality in the area.

Groundwater records on the BoM Groundwater Explorer show that the nearest registered groundwater bore is 35 m deep and located 2 km east southeast and downgradient of the site, 200 m west of The Bucketts Way road. This is listed as a stock bore. The next nearest registered bores are 4.3 and 6.2 km east and north northeast of the site, with depths of 66 and 53 m and used as a monitoring bore and a domestic bore respectively.

Aquatic Groundwater Dependant Ecosystems (GDE's) are restricted to the area around the Karuah River, 5 km east of the site, and are extremely unlikely to be impacted by activities of the proposed quarry site. The proposed quarry site is mapped as hosting moderate and low priority terrestrial GDE's (trees) determined from regional assessment. These consist of Hunter-Macleay Dry Sclerophyll Forests containing Spotted Gum and Broad-leaved Mahogany. The Deep Creek stream bed is mapped as an area of Weeping Lilly Pilly and Water Gum riparian vegetation of Northern Warm Temperate Rainforest. The two dry sclerophyll communities (PCT 1590 and PCT 1619) are not considered GDEs, based on ecological mapping. The creek line vegetation (1567 – Tallowood Brush Box Sydney Bluegum) is a wet sclerophyll community so it may be described as a “non-obligate GDE”. The Lilly Pilly Community may have some reliance on groundwater; however, this community isn’t mapped within the development site.

The principal uncertainty in the groundwater assessment is the potential heterogeneity in the fracturing of the rhyolite and surrounding sediments. Ongoing monitoring is recommended to better understand the response to rainfall of the groundwater level.

Groundwater inflows into the quarry have been estimated for Stages 1 to 3 and are considered most likely to be in the range of 8 to 51 ML/year, as the quarry is developed. Limited inflows are expected during Stage 1 (8-13 ML/year) and Stage 2 (22-32 ML/year), increasing to inflows in the order of 33-51 ML/year in Stage 3.

Appropriate storage and handling of hydrocarbons, any chemical products and site toilet and wastewater facilities will minimise the risk of groundwater and surface water contamination.

A Water Management Plan is required to cover the details of regular groundwater monitoring at site and the reporting of results and analysis of data. Interpretation and presentation of data will be required internally for the company and for reporting to government agencies.

TABLE OF CONTENTS

TABLE OF FIGURES

TABLE OF TABLES

GLOSSARY

AHD	Australian Height Datum
AIP	Aquifer Interference Policy
ANZECC	Australian and New Zealand Environment and Conservation Council Guidelines
BoM	Bureau of Meteorology
DCQ	Deep Creek Quarry
DPIE Water	Department of Planning Industry and Environment - Water Division
EA	Environmental Assessment
EPA	NSW Environmental Protection Agency
EP&A	Act Environment Planning and Assessment Act 1979
EPBC	Environment Protection and Biodiversity Conservation Act 1999
ESD	Ecological Sustainable Development
Hydrominex	Hydrominex Geoscience Pty Ltd
LEP	Local Environment Plan
LGA	Local Government Area
ML	Megalitres
NOW	NSW Office of Water
NRAR	Natural Resources Access Regulator
PEA	Preliminary Environmental Assessment
SEPP	State Environmental Planning Policy
SWL	Standing water Level – depth to groundwater below the reference level of measurement
TSS	Total Suspended Solids
WSP	Water Sharing Plan
m	Micrometres
µS/cm	Microsiemens/cm – measurement of electrical conductivity

1 SCOPE OF WORK

1.1 Site Access and Project Context

Ironstone Developments Pty Ltd (Ironstone Developments) intends to develop the Deep Creek Quarry at 279 Deep Creek Road, Limeburner’s Creek. The proposed quarry (the site) is located 45 km north northeast of Newcastle on Lots 48 DP753178 and Lot 472 DP1162208. The site is accessed from the Pacific Highway, 15 km north of Raymond, continuing along The Bucketts Way for 11.75 km, before turning left onto Deep Creek Road. Access to the site once operational will be via a dedicated private access road to the north of Deep Creek Road.

The quarry is planned to extract up to 500,000 tonnes/year of high value rhyolite rock for sale as aggregate and construction materials in the Hunter and Greater Sydney regions. The material is of interest to a significant number of end users, due to the resistance of the material and high grip in road applications.

The proposed quarry will be a State Significant Development, consistent with Clause 7 (1)(a) of Schedule 1 in the State Environmental Policy 2011 (State and Regional development SEPP). The quarry will cover an area of approximately 30 hectares. The pit floor will remain above the more acidic (lower pH) groundwater resources. The final landform will be grassed (floor) and vegetated (benches

This report has been prepared to support the project Environmental Impact Study (EIS) and provide details of groundwater investigation for potential impacts of the quarry operation. Figure 1.1 shows the location of the site relative to infrastructure and land use in the area.

1.2 Proposed Development

Quarry plan and sequencing

Ironstone Developments Pty Ltd plans to extract 500,000 tonnes/year of rhyolite rock for sale as aggregate and construction materials. The project is developed around a rhyolite unit interpreted to intrude into surrounding sandstones. A total of 11.8 million Tonnes of rhyolite resource has been defined at the site, comprising 930,000 cubic metres, enough to support quarry activities for up to 30 years, accounting for a variable extraction rate.

The quarry will begin at the base of an east-west trending ridge and will work up the hill in a westerly direction, progressively increasing the highwall height to reach the final extraction area shown by Figure 1.2. The low point for the quarry development is 37 m AHD, above the level of Deep Creek, at approximately 22 m AHD, to the east of the quarry development. A haul road will be developed to the base of the quarry, from a new entry road to the project area. The primary stockpile area for material will be in the base of the quarry, to minimise noise to the surrounding area from mining and crushing activities. Quarrying and processing aims to optimise resource recovery and satisfy planning and environmental constraints.

The quarry Stage 1 develops benches in the northern part of the extraction area. The Stage 2 development will expand the quarry further to the west and south. Vegetation will be maintained outside the immediate quarry area. Stage 3 increases the depth of the quarry and Stage 4 is the final quarry landform, extending slightly to the east.

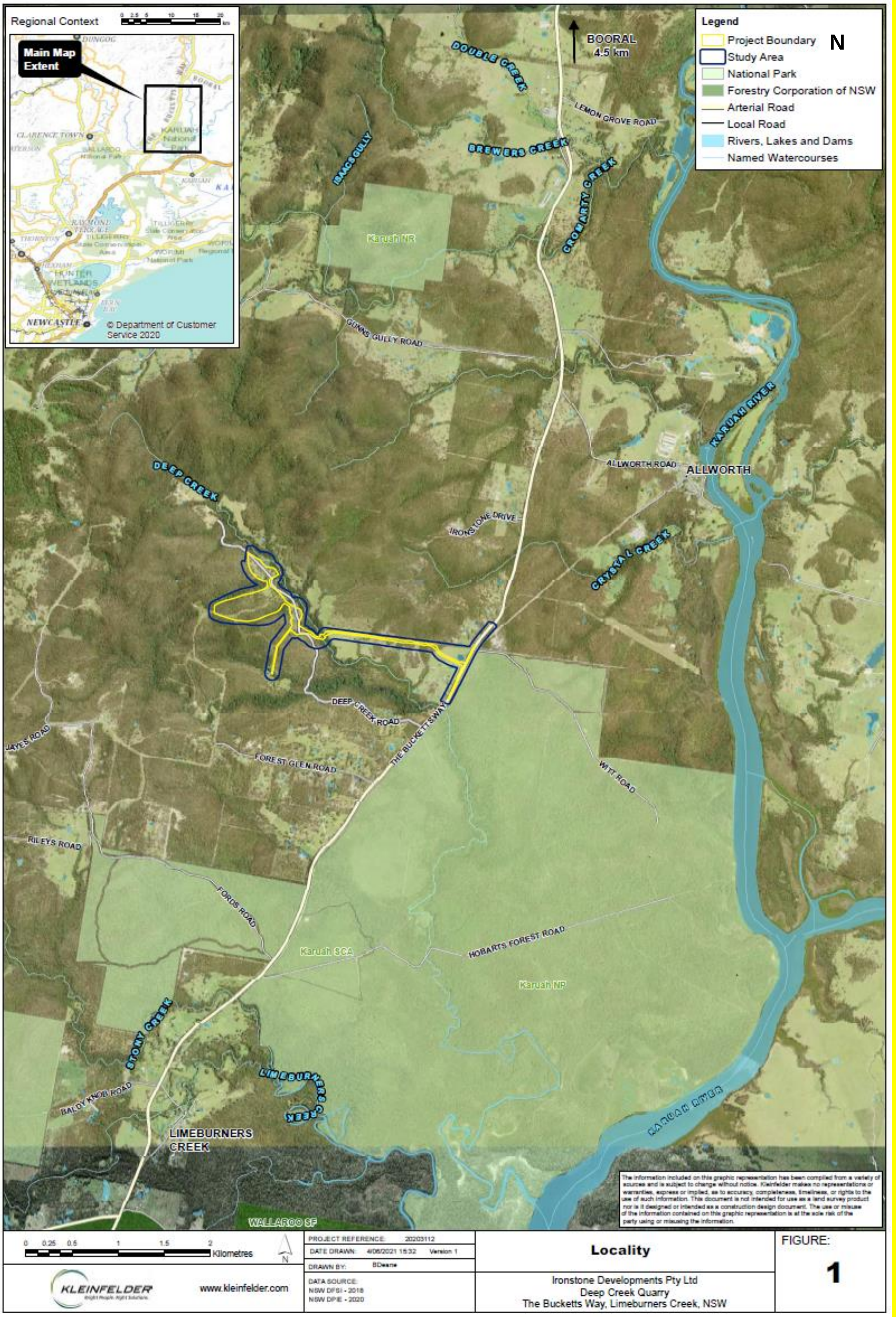

Figure 1.1: Proposed quarry location relative to nearby towns, cities and infrastructure

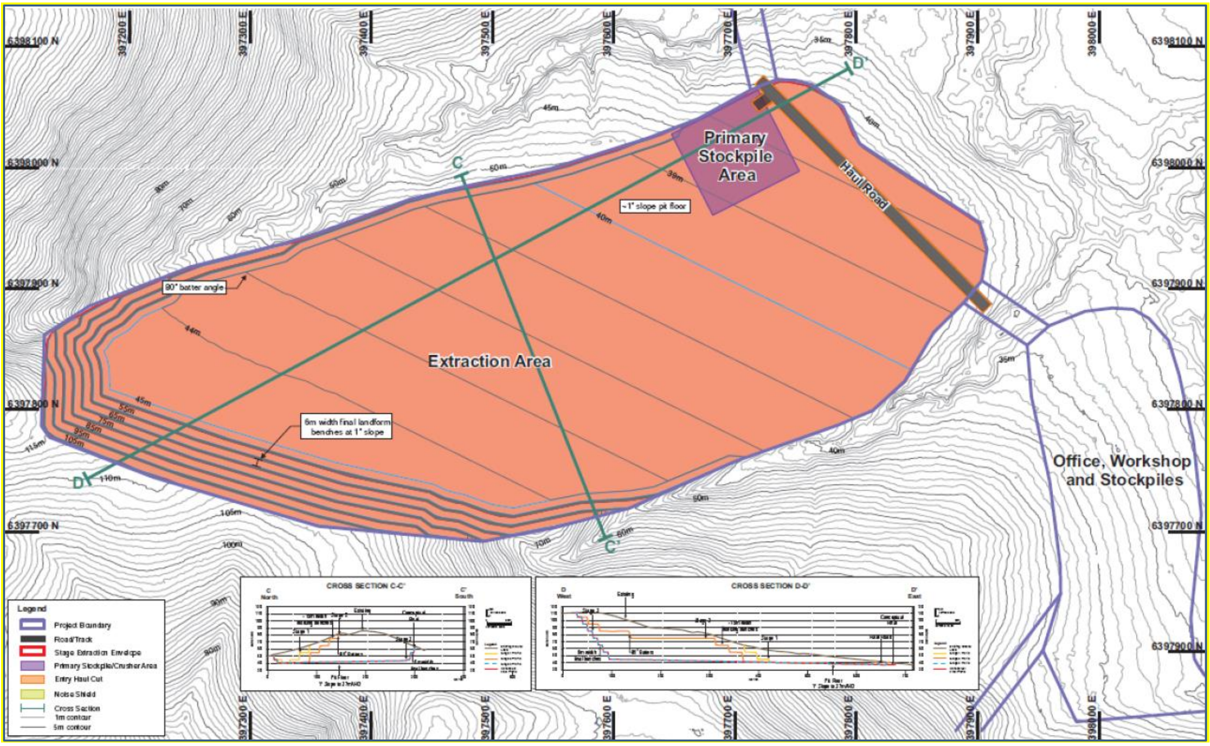

Figure 1.2: shows the proposed final quarry landform.

The quarry proposed by Ironstone Developments would be operated as a drill and blast operation, using the natural landform to minimise the noise and visual impact of the site, which is located in forest centred 2.2 kilometres from The Bucketts Way.

The proposed quarrying will involve several stages of work, as follows:

- Removing vegetation from surface to permit quarrying;
- Stripping and stockpiling the soil present at the site;
- Conventional drill and blast quarrying to extract the high value rhyolite and immediately adjacent sandstone;
- Maintaining topography at the eastern end of the quarry as a natural noise shield to minimise noise, with the quarry being developed beneath a ridgeline, to use the topography as a noise barrier;
- Development of sumps within the quarry to capture groundwater and surface water entering the quarry;
- Use of inflow water for dust reduction;
- Rehabilitation of the site.

The principal features of the site are shown in Figure 1.2, comprising:

- Stage 1 extraction along the northern side of the rhyolite resource;
- Stage 2 expansion of the quarry area to the south and west;
- Primary stockpile area, located at the eastern entry to the quarry where the processing plant with crusher and screens will be located;
- Offices, workshop and stockpiles, which are to be located out of the quarry 200 m to the southeast;
- Quarry sump, a local low point in the quarry used to collect any groundwater, surface water flow and rainfall runoff in the quarry;

- Sedimentation basins to collect sediment runoff in any surface water exiting the quarry. Basins would be located around the eastern end of the quarry, upslope of Deep Creek. Diversion drains would be developed to direct any runoff from the quarry area into the sedimentation basins;
- A main stockpile area approximately 200 m north of the quarry;
- Haul road, from the workshop and storage area to the quarry; and
- A new road alignment to The Bucketts Way for trucks leaving and entering the site, located on the northern extreme of Lot 551/DP1238818 and Lot 552/DP1238818. A new intersection 200 m south of Witt Road, would be developed to facilitate the primary quarry access.

1.3 Objectives

The objectives of the groundwater component of the EIS are to:

- Compile baseline information and document existing groundwater conditions, such as variations in the phreatic level, the groundwater flow direction and gradient;
- Establish the natural baseline variation in physical and chemical characteristics of the groundwater;
- Evaluate whether any risk of acid mine drainage exists, based on the results of drilling on site;
- Evaluate groundwater recharge at the site;
- Evaluate the risks of modification to the landform and groundwater drainage;
- Evaluate the effects of groundwater drainage due to quarrying on local and regional aquifers and any groundwater dependent ecosystems;
- Develop a conceptual model for the project area;
- Develop a numerical groundwater model for the area, to estimate the drawdown in the phreatic level due to quarrying, to determine the long-term post quarry impact of changes to the site landform;
- Assess potential impacts of the quarry development;
- Provide recommendations for monitoring and management of groundwater and develop a long-term groundwater monitoring plan, reporting and data collection protocol.

1.4 Activities Undertaken

Preparation of this report to address the different aspects of the site groundwater conditions and potential impacts related to quarry development include:

- Evaluation of the site geology and hydrogeology, groundwater recharge and discharge, aquifer yield characteristics and groundwater and surface water quality and the proposed quarry development plans;
- Evaluation of the baseline groundwater and surface water monitoring information for the site from the network that has been in place since 2014;
- Evaluation of whether groundwater dependent ecosystems are present;
- Evaluation of the relevant legislation and how the proposed development interacts with the legislation and relevant plans and guidelines;
- A review of other groundwater users in the vicinity of the site and information available on registered bores;
- Developing a conceptual groundwater model for the site, including the interaction with surface water;

- Developing an analytical groundwater model to simulate the impact of quarry operation and the final post closure landform;
- Preparation of a long-term monitoring program for the site.

2 REGULATORY CONTEXT

Relevant legislation is summarised in Table 2.1, with specific reference to key legislation outlined below in this section.

2.1 NSW State Groundwater Policy Framework Document

The NSW Groundwater Framework Policy document provides a clear NSW government policy direction on the ecologically sustainable management of the State's groundwater resources for the people of NSW. The groundwater policy framework was consulted in the evaluation of the groundwater situation at the proposed quarry site.

The focus of the Policy is on water below the ground surface in a geological structure or formation, and on the ecosystems from which these waters are recharged or into which they discharge. It provides for the better consideration of all issues which affect, or are likely to affect the condition and functioning of the resources of these areas including water chemistry, geology, aquifer recharge and discharge, and dependent ecosystems such as wetlands, lakes and streams, springs and seeps. It requires that careful consideration be given to all factors affecting the stability, vulnerability, and productivity of these systems.

The State Groundwater Policy is a framework policy designed to establish:

- Objectives and principles for groundwater management;
- A coordinated program for policy development, reporting and review;
- Tools for policy implementation; and
- Opportunities for information sharing.

The policy will guide the decision-making of State and local government, as well as landholders in their management and use of groundwater. It will influence the type and selection of management activities and resource development opportunities supported by the State's resource managers. Some actions required to prevent groundwater resource degradation may conflict with existing or potential economic development. In such cases the full costs and benefits of the social, economic and the environmental implications will need to be considered when making a decision on what can be fundamentally divergent uses for the groundwater resource.

Ecologically Sustainable Development has been adopted by this policy to provide a basis for the protection of the groundwater resources of New South Wales.

2.2 NSW State Groundwater Quality Protection Policy

The goal for the management of groundwater resources in New South Wales is to manage the State's groundwater resources so they can sustain environmental, social and economic uses for the people of NSW. The quarry development has been considered in terms of the NSW State Groundwater Quality Protection Policy, with this in mind.

It is the policy of the NSW Government to encourage the ecologically sustainable management of the State's groundwater resources, so as to:

- Slow and halt, or reverse any degradation of groundwater resources;
- Ensure sustainability of groundwater dependent ecosystems;

- Maintain the full range of beneficial uses of these resources;
- Maximise economic benefit to the Region, State and Nation.

The Groundwater Quality Protection Policy is specifically designed to protect valuable groundwater resources against pollution. This Policy, means the sustainability of groundwater resources and their ecosystem support functions will be given explicit consideration in resource management decision making.

NSW groundwater management policies and practices will be consistent with the aims of other national and State policies. These include:

- The National Strategy for Ecologically Sustainable Development (ESD);
- The Inter-Governmental Agreement on the Environment (IGAE);
- The National Water Quality Management Strategy (NWQMS);
- The Council of Australian Governments (COAG) water reform agenda;
- NSW Water Reforms; and
- NSW government policy directions for natural resource management.

The Policy objectives will be achieved by applying the management principles listed below:

1 All groundwater systems should be managed such that their most sensitive identified beneficial use (or environmental value) is maintained;
2. Town water supplies should be afforded special protection against contamination;
3. Groundwater pollution should be prevented so that future remediation is not required;
4. For new developments, the scale and scope of work required to demonstrate adequate groundwater protection shall be commensurate with the risk the development poses to a groundwater system and the value of the groundwater resource;
5. A groundwater pumper shall bear the responsibility for environmental damage or degradation caused by using groundwaters that are incompatible with soil, vegetation or receiving waters;
6. Groundwater dependent ecosystems will be afforded protection;
7. Groundwater quality protection should be integrated with the management of groundwater quantity;
8. The cumulative impacts of developments on groundwater quality should be recognised by all those who manage, use, or impact on the resource; and
9. Where possible and practical, environmentally degraded areas should be rehabilitated and their ecosystem support functions restored.

The following beneficial uses are defined under the policy:

- Ecosystem protection;
- Recreation and aesthetics;
- Raw water for drinking water supply;
- Agricultural water; and
- Industrial water.

2.3 NSW State Groundwater Quantity Management Policy

The objectives for managing groundwater quantity in NSW are outlined below and were considered with regards to the proposed quarry development:

- To achieve the efficient, equitable and sustainable use of the state’s groundwater;

- To prevent, halt, or reverse degradation of the State's groundwaters, and their dependent ecosystems;
- To provide opportunities for development which generate the most cultural, social and economic benefits to the community, region, State and nation, within the context of environmental sustainability; and
- To involve the community in the management of groundwater resources.

Principle 1

Total use of groundwater in a water source or zone will be managed within the sustainable yield, so that the groundwater is available for future generations, and dependent ecological processes remain viable.

Principle 2

Significant groundwater dependent ecosystems must be identified and protected. The Water Management Act 2000 requires specific environmental water provisions to be set for all the State's groundwater systems. This will be achieved by setting aside a part of the estimated long-term average yearly natural recharge to the aquifer.

Principle 3

Total licensed entitlements will not exceed 125% of the sustainable yield in currently over-allocated groundwater sources or zones. In many systems the current licensed entitlement is much more than the sustainable yield of the aquifer (or zone). Adjusting total entitlements to the sustainable yield, or within 25% of this, will give licence holders a clear understanding of their tradeable "right" to a proportion of the sustainable yield.

Principle 4

Groundwater access must be managed in such a way that it does not cause unacceptable local impacts. Principles 1, 2 and 3 relate to the "macro" management of a groundwater system or zone. However, neither the quantity of groundwater nor its quality are consistent across an area. In addition, groundwater dependent ecosystems are not evenly distributed across an aquifer. Licensed groundwater pumping also tends to cluster, rather than be spread evenly across an aquifer.

Principle 5

Artificial recharge of groundwater will be strictly controlled. The concept of artificial recharge of an aquifer is at times put forward to increase yield. This involves the enhanced recharge of an aquifer by an injection well or bore, or by spreading and holding water over the aquifer's recharge areas. However, either of these processes can harm the aquifer. Therefore, artificial recharge schemes will be strictly controlled to protect the intrinsic water quality of the aquifer and maintain aquifer permeability.

Principle 6

Landholders overlying an aquifer will have a basic right to access groundwater for domestic and stock purposes. The Water Management Act 2000 recognises a basic right of landholders overlying an aquifer to access groundwater for domestic and stock watering purposes.

Principle 7

Access to groundwater will be managed according to an established priority of use. The Water Management Act 2000 establishes a priority of access to the water that is available for extraction, after environmental water is provided.

2.4 NSW Groundwater Dependent Ecosystems Policy

The NSW State Groundwater Dependant Ecosystems Policy is a component policy of the NSW State Groundwater Policy Framework Document that aims to manage the State's groundwater resources so that they can sustain environmental, social and economic uses for the people of NSW. The original document was released by the then Department of Land and Water in 2002 and outlines the context of groundwater dependant ecosystems, their importance and recommendations on how they should be managed.

2.5 North Coast Fractured and Porous Rock Water Sharing Plan

The proposed quarry is located on the Newcastle 1:250,000 geological map within the North Coast Fractured and Porous Rock Water Sharing Plan. This covers a large area of northeastern NSW, with unregulated rivers and groundwater systems. This water sharing plan covers 13 fractured rock and porous rock groundwater sources.

The project is located in the south of the New England Fold Belt Coast Groundwater Source, close to the limit of the Permian age Sydney Basin sediments, that include important coal sequences. The New England Fold Belt area consist of sedimentary and volcanic rocks with porous and fracture porosity and permeability. Connectivity between fractured and porous rock aquifers and surface water is low to moderate, according to the Water Sharing Plan (WSP).

Groundwater in the area is used for basic land holder rights for stock and domestic consumption, with water extracted under these rights without a water supply works approval. Yields in the New England Fold Belt groundwater source are noted to be low, being around 1 L/s. Groundwater is typically recharged by direct rainfall infiltration.

2.5.1 The Water sharing plan context

The plan objectives are to:

a) protect, preserve, maintain and enhance the important high priority groundwater-dependent ecosystems of these groundwater sources;
b) protect, preserve, maintain and enhance the Aboriginal, cultural and heritage values of these groundwater sources;
c) protect basic landholder rights;
d) manage these groundwater sources to ensure equitable sharing between users;
e) provide opportunities for enhanced market-based trading of access licences and water allocations within environmental and system constraints;
f) provide water allocation account management rules which allow sufficient flexibility in water use;
g) contribute to the maintenance of water quality;
h) provide recognition of the connectivity between groundwater sources;

i) adaptively manage these groundwater sources;
j) 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).

Strategies developed for the plan include the need to:

a) establish performance indicators;
b) establish environmental water rules;
c) identify water requirements for basic landholder rights;
d) identify water requirements for access licences;
e) establish rules for the granting and amending of access licences and approvals;
f) establish rules that place limits on the availability of water for extraction;
g) establish rules for making available water determinations;
h) establish rules for the operation of water allocation accounts;
i) establish rules which specify the circumstances under which water may be taken;
j) establish access licence dealing rules; and
k) identify triggers for and limits to changes to the rules in this Plan.

This Plan recognises the effects of climatic variability on groundwater levels by provisions that manage the sharing of water within the limits of water availability on a long-term average annual basis and the priorities according to which water allocations are to be adjusted as a consequence of any reduction in the availability of water due to an increase in the average annual extraction against the long-term average annual extraction limit.

Relevant Legislation	Purpose
Legislation and plans	
NSW Water Management Act 2000	Water access and water sharing plans
NSW Water Act 1912 Plans	Drainage works and AIP activities
Water Sharing Plan for the North Coast Fractured and Porous Rock Groundwater Sources (2016) Policies	Quantification, access and management of water in a defined area
Water Policies	
NSW State Groundwater Policy Framework Document (1997)	Groundwater policy definition
NSW State Groundwater Dependent Ecosystems Policy (2002)	Definition and management of GDE's
NSW State Groundwater Quality Protection Policy (1998)	Water quality requirements
Draft NSW Groundwater Quantity Management Policy (2001)	
NSW Aquifer Interference Policy – (2012)	Definition and management of AIP activities
NSW Guidelines	
NSW Policy for Managing Access to Buried Groundwater Sources (2011) Guidelines	Management of aquifers
Guidelines for Controlled Activities (NOW, 2012)	Requirements for developments
Groundwater Monitoring and Modelling Plans – Information for prospective mining and petroleum exploration activities (NOW, 2014)	Guideline for extractive industries groundwater impacts
NSW Environment Protection Authority Guidelines for the Assessment & Management of Groundwater Contamination (EPA, 2007)	Guideline for groundwater contamination
National Guidelines	
Australian Groundwater Modelling Guidelines 2012 (Commonwealth)	Groundwater modelling guidelines for levels of modelling probability
National Water Quality Management Strategy Guidelines for Groundwater Protection in Australia (ARMCANZ/ANZECC, 2000)	Water protection analyte concentrations and trigger levels
Environment Australia: Environmental Flows Initiative technical report No.2 (2001)	Guideline on surface water flows for environment health

Table 2.1: Summary of relevant legislation

2.5.2 Plan water allowances

Estimating recharge for an entire groundwater source is not an exact science due to variations in geology, rainfall distribution and sources of recharge. Consequently, NSW Government Water Authorities (DPIE) have taken a precautionary approach to calculating recharge. Rainfall data is sourced from the Bureau of Meteorology model that used 1900-2011 average annual rainfall data from monitoring sites. Considering the different aquifers comprising the New England Fold Belt Coast groundwater source an overall rainfall recharge rate of 4% is applied.

The estimated average annual rainfall recharge for the New England Fold Belt Coast groundwater unit is estimated as 480,000 ML/year in the high environmental value areas and 1,500,000 ML/year in the non-high environmental value areas. This is well in excess of the total usage in this groundwater source of 35,468 ML/year, consisting of:

- 9,605 ML/year of Basic Landholder Rights;
- 14,840 ML/year of town water supply; and
- 11,023 ML/year of all other licenced entitlements.

High environmental value areas include National Parks, Nature Reserves, historic sites, Aboriginal sites, State conservation areas and karst conservation areas, and 100% of the recharge generated over these areas is reserved as planned environmental water.

Different rainfall recharge rates are used for different aquifer types due to their varying transmissivity characteristics.

Risk assessments have been conducted for the different groundwater sources in the plan, with environmental value weighed against the socio-economic dependence and consideration to actions that could be taken to mitigate the risk to environmental values. A risk rating was estimated as equal to the highest rating attained for any one criterion. Consideration was given to mitigation measures that can be applied through rules in the water sharing plan to reduce the impact of extraction on a groundwater source. However, none of the groundwater sources in the plan had mitigation measures applied, due to the relatively low initial risks. The New England Fold Belt Coast groundwater source was assessed as having a moderate aquifer risk and low socio-economic risk.

In coastal NSW, excluding upland alluvial and porous rock aquifers, the long-term average annual extraction limit (LTAAELs) is determined with consideration of current water requirements and estimated future water requirements. A separate upper extraction limit (UEL) is also included up to which the LTAAEL can be increased. The method for determining fractured rock LTAAELs is considered in the WSP to be conservative, whilst ensuring that future water requirements will be met. In the case of future estimates being less at plan development than what eventuates during the term of the plan, the LTAAEL can be amended up to the higher UEL.

The UEL is determined by summing the percentage of recharge potentially available for extraction generated over non-high environmental value areas (based on the sustainability Water Sharing Plan for the North Coast Fractured and Porous Rock Groundwater Sources: Background document 28 | NSW DPI Water, September 2016 index) and the percentage of recharge potentially available for extraction generated over high environmental value areas. For the New England Fold Belt Coast, the UEL is 375,000 ML/year, considerably more than the total groundwater usage of 35,468 ML/year.

The future requirements of water in the WSP include mining water requirements, in addition to agricultural and town water supply requirements, dewatering needs for construction and Basic Landholder Rights. Future estimated groundwater usage in the New England Fold Belt Coast source consists of:

- 1,000 ML/year for mining;
- 8,449.5 ML/year for agriculture;
- 7,500 ML/year for town water supply;
- 1,397.2 ML/year for residential and commercial dewatering; and
- 1,037.7 ML/year for Basic Landholder Rights.

Considering the current and projected future groundwater demand in the source area the long-term average annual extraction limit of the source has been set as 60,000 ML/year, as this is the approximate sum of the current and projected future water use, although well below the estimated UEL.

2.5.3 Water sharing rules

The Water Sharing Plan for the North Coast Fractured and Porous Rock Groundwater Sources establishes a framework for water sharing that defines:

- Environmental water provisions;
- Requirements for water for basic landholder rights;
- Requirements for water for extraction under access licences;
- Long-term average annual extraction limits and available water determinations for each groundwater source;
- Rules for granting access licences;
- Rules for water allocation accounts;
- Rules for water supply work approvals; and
- Access licence dealing rules to control the trade of water within or into other groundwater sources.

The plan identifies and protects water for environmental purposes in each groundwater source. This is defined as ‘planned environmental water’ and consists of water that is excluded from extraction and is reserved for the environment. Planned environmental water is delivered through reservation of:

- A portion of groundwater held in storage; and
- A portion of groundwater generated from recharge.

2.5.4 Water supply works approvals

In accordance with the principles of the WMA 2000, distance rules may be applied when granting or amending water supply works approvals and managing existing works. These rules take into account local impacts on other water users, contaminated sites, groundwater dependent ecosystems (GDEs) and groundwater dependent culturally significant sites. The rules are intended to prevent unacceptable or damaging levels of drawdown of water occurring in the local vicinity of other water users and significant sites.

2.5.5 Identification of high priority groundwater-dependent ecosystems

GDEs are ecosystems which have their species composition and natural ecological processes determined to some extent by the availability of groundwater. GDEs can include cave systems (karsts), springs, wetlands and groundwater-dependent endangered ecological communities.

GDE are identified through a desktop exercise assembling all known records of GDEs and includes interrogating known data bases, GIS records and other studies. New bores that are not used for basic rights cannot be located within 200 m of high priority GDE's or the outside perimeter of a National Park.

2.5.6 Plan extraction location limitations

To protect GDE's and other features the WSP requires minimum distances from new works approvals to be approved, with the following considerations:

- Minimise interference with neighbouring works;
- Locate works away from contaminated sites;
- Protect water levels that support high priority GDE's;
- Protect groundwater dependent culturally significant sites; and
- Manage surface and groundwater connectivity.

Existing works must have a water supply works approval, but are not required to make changes to the work to satisfy the distance rules for new works.

A water supply work approval must not be granted or amended to authorise the construction of a water supply work which is proposed to be located within:

- 200 metres of a water supply work (producing <20 ML/year, or 400 m for bores producing >20 ML/year) that is not used for Basic Water Rights;
- 200 metres of a water supply work that is not used for Basic Water Rights;
- 100 metres of the boundary of the landholding on which the water supply work is located, unless the owner of the landholding adjoining the boundary has provided consent in writing;
- 500 metres of a water supply work that is a local or major water utility bore;
- 500 metres of a departmental water monitoring bore.

However, it is noted that for State Significant Developments use, works and activity approvals are not required, with only the aquifer interference approval required.

2.5.7 Operation in accordance with the WSP requirements

The proposed quarry can operate in accordance with requirements of the North Coast Fractured and Porous Rock Water Sharing Plan. Incidental groundwater inflow into the quarry due to dewatering as the quarry progresses will be used on site for dust suppression and non-potable water in site infrastructure and not discharged directly to Deep Creek.

2.6 Groundwater Management and Aquifer Interference Policy

Activities which intersect or 'interfere with' an aquifer may involve:

- The extraction of groundwater that flows into a void to allow an activity to operate safely. This is often called dewatering, and the water extracted is often referred to as 'incidental take of groundwater'; and

- Other impacts resulting from the intersection of the aquifer, such as changes to groundwater flow paths and gradients, subsidence, compaction of the aquifer structure, and artificial aquifer recharge.

Volumes of water incidentally taken in the course of aquifer interference activities, such as the water intercepted during mining is regulated by the issue of an access licence under the Water Management Act (2000) and sufficient account volume to account for the incidental water taken during mining activities. Operators of mining activities are required to comply with the NSW Aquifer Interference Policy. For water sources not exposed at surface there is provision for the release of small volumes of water stored in these aquifers by a supplementary water (storage) access licence.

The Aquifer Interference Policy (NSW Office of Water, 2012) defines aquifer interference activities and how they are managed under licencing and approvals of the Water Management Act 2000. The policy deals with quarrying, mining excavation dewatering, aquifer injection activities, coal seam gas and other activities with the potential to contaminate groundwater or result in a loss of storage or result in structural damage to an aquifer.

Quarrying activities proposed for the site are defined as aquifer interference activities and evaluation of the impact during and post quarrying is required. This is addressed by development of an analytical model for the site that uses mathematical relationships to estimate groundwater inflows. Groundwater is removed from the fractured rock aquifer as part of quarrying activities. A small part of this groundwater is lost as moisture in aggregate transported off site, although the remainder of the water will be used for dust control on the site, will evaporate or be retained in water storage facilities constructed as part of the quarry infrastructure.

The Aquifer Interference Policy outlines Minimum Impact Considerations for different aquifer sources, with the North Coast Fractured and Porous Rock Groundwater Sources classified as Less Productive porous and fractured rock aquifers. The Minimum Impact Considerations are summarised in Table 2.2.

Water Table	Water Pressure	Water Quality
1. Less than or equal to 10% cumulative variation in the water table, allowing for typical climatic “post-water sharing plan” variations, 40m from any: (a) high priority groundwater dependent ecosystem; or (b) high priority culturally significant site; listed in the schedule of the relevant water sharing plan. A maximum of a 2m decline cumulatively at any water supply work.	**1.** A cumulative pressure head decline of not more than a 2m decline, at any water supply work.	**1.** Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40m from the activity.
2. If more than 10% cumulative variation in the water table, allowing for typical climatic “post-water sharing plan” variations, 40m from any: (a) high priority groundwater dependent ecosystem; or (b) high priority culturally significant site; listed in the schedule of the relevant water sharing plan if appropriate studies demonstrate to the Minister’s satisfaction that the variation will not prevent the long-term viability of the dependent ecosystem or significant site. If more than a 2m decline cumulatively at any water supply work then make good provisions should apply.	**2.** If the predicted pressure head decline is greater than requirement 1. above, then appropriate studies are required to demonstrate to the Minister’s satisfaction that the decline will not prevent the long-term viability of the affected water supply works unless make good provisions apply.	**2.** If condition 1 is not met then appropriate studies will need to demonstrate to the Minister’s satisfaction that the change in groundwater quality will not prevent the long-term viability of the dependent ecosystem, significant site or affected water supply works.

Table 2.2: Aquifer Interference Policy criteria

2.7 Water Licences

The proponent of the proposed quarry development does not currently hold any water access licence for water extraction or aquifer interference activities. This will be sought based on the outcomes of the analytical groundwater modelling, which is discussed in section 6 of the report.

Water usage by individual licence holders is managed through water allocation accounts. Water is credited to the account when an available water determination (AWD) is made at the start of the water year and debited as water is extracted throughout the year. A licence holder’s account is not permitted to go into debit.

The AWD for aquifer access licences in these groundwater sources will be 1 ML/unit share, unless a growth in use response is required. The AWD is used to manage growth in extractions above the LTAAEL. If growth is assessed to have increased more than 5% above the LTAAEL extraction limit over a 3-year period, AWDs may be reduced to less than 1 ML/unit share.

In the most recent version of the WSP for the New England Fold Belt source there is 24,532 ML/year of unassigned water.

Access licences may be granted in accordance with the categories defined under the WMA 2000 and the Water Management (General) Regulation 2011. Aquifer access licences may be granted in line with a controlled allocation order made in relation to any unassigned water in a groundwater source. This is done under section 65 of the WMA 2000.

In some groundwater sources unused water allocation may be carried over from one water year to the next. Carryover of unused water is permitted at the end of each water year in all groundwater sources in this water sharing plan. Carryover of up to 20% of account water is permitted from one year to the next.

Based on the results of the modelled groundwater inflows may reach **51 ML/year. However, as the inflow is estimated to increase by stage it is recommended** to obtain an initial licence for 20 ML/year under the Water Management Act (2000). The inflows into the quarry should be measured and quantified as best possible, to reconcile groundwater inflows with predictions. Given the increasing inflow between stages an increased licence volume can be sought to cover increased inflows during the life of the project.

2.8 Protection of Environment Operations (POEO) 1997

The Protection of the Environment Operations Act 1997 (POEO Act) is the main NSW environmental legislation covering water, land, air and noise pollution and waste management. Under Section 120 of the POEO Act it is illegal to pollute or cause or permit pollution of waters. Under the Act water pollution includes introducing litter, wash water, soil, debris, detergent, paint, cement slurry, building materials etc. into waters or placing such material where it is likely to be washed or blown into waters or the stormwater system or percolate into groundwater. The quarry will be required to attain an EPL under the POEO Act, however, with suitable controls impacts to groundwater are considered unlikely.

2.9 The ANZECC Guidelines

The ANZECC (2000) Australian and New Zealand Guidelines for Fresh and Marine Water Quality provides water quality trigger values for a range of purposes including irrigation, aquatic ecosystems, aquaculture, and recreational. The trigger values for protection of aquatic ecosystems are the relevant reference point for consideration of groundwater in the site area. Results from sampling of groundwater and surface water at the site are compared to the ANZECC guidelines in later sections of the report.

2.10 Australian (Commonwealth) Groundwater Modelling Guidelines 2012

The objective of the Australian groundwater modelling guidelines is to promote a consistent and sound approach to the development of groundwater flow and solute transport models in Australia. It builds on existing guidelines (Murray–Darling Basin Commission 2001). While it is acknowledged that the term groundwater modelling refers to a variety of methods, the guidelines focus on computer-based numerical simulation models. The guidelines should be seen as a point of reference and not as a rigid standard. They seek to provide direction on the scope and approaches common to modelling projects. It is recognised there are other approaches to modelling not covered in these guidelines and that such approaches may well be appropriate and justified in certain circumstances.

In the planning stage the modellers and key stakeholders should agree on various aspects of the model and the process leading to its development. The process should document the agreed modelling objectives and the model‘s intended use in contributing to or providing certain outcomes required by the larger project. The model confidence-level classification should be addressed at this stage.

The classification is a benchmark that illustrates the level of confidence in the model predictions and generally reflects the level of data available to support model development, and the manner in which the predictions are formulated.

Conceptualisation involves identifying and describing the processes that control or influence the movement and storage of groundwater and solutes in the hydrogeological system. The conceptualisation should consider the physical processes and resulting heads and flows of groundwater. In this regard it provides information on how the project is expected to impact on the groundwater and the surface water bodies that depend on groundwater.

The conceptual model must explain (qualitatively and quantitatively) all observed groundwater behaviour in the region. The guidelines encourage regular reassessment of the conceptual model at all stages of the project, with refinements made as other stages of the process suggest that these may be appropriate or necessary. In many cases the conceptual model may not be unique (i.e. different conceptual models can explain all observations) and it is encouraged to propose and maintain alternative conceptualisations for as long as possible through the modelling project.

The design and construction stage involves a series of decisions on how to best implement the conceptualisation in a mathematical and numerical modelling environment. The decisions required at this stage include selection of a numerical method and modelling software, selection of an appropriate model dimension, definition of a model domain and the spatial and temporal discretisations to be used in the model.

The guidelines encourage modellers to take a pragmatic approach to these issues and to explore simple modelling options where these may be appropriate. For example, **they encourage the consideration of two-dimensional (2D) rather than 3D models and consideration of steady state rather than transient models where these simpler approaches may be adequate to address the modelling objectives.**

This approach suggested in the guidelines has led to Hydrominex adopting a 2D analytical model for volume estimation for the project.

Because models simplify reality, their outputs are uncertain. Model outputs presented to decision-makers should include estimates of the goodness or uncertainty of the results. Linear methods for calculating uncertainty are less computationally intensive than non-linear methods. For many decisions, linear methods are sufficient to convey expectations of uncertainty. Presentation of uncertainty results, regardless of the methods used, should include a visual depiction that the model prediction is more than a single result or set of results, and a presentation of uncertainty that most directly addresses the decision of interest.

Model reporting encompasses documentation and communication of different stages of the model through a written technical document. The report should describe the model, all data collected and information created through the modelling process. The report should be accompanied by an archive of all the model files and all supporting data so the results presented in the report can, if necessary, be reproduced and the model used in future studies.

2.11 Guidelines for the Assessment & Management of Groundwater Contamination (NSW EPA)

It is considered unlikely that the proposed quarry will result in contamination of groundwater. However, it is noted that the NSW EPA has developed guidelines for the assessment and management of groundwater contamination, which outline a best-practice framework for assessing and managing contaminated groundwater in NSW.

- Elements of the guidelines include assessing groundwater contamination – outlining ways of identifying whether groundwater is contaminated and describing how to conduct preliminary and detailed assessments.
- Managing groundwater contamination – outlining ways of controlling groundwater contamination and identifying what remediation is needed to resolve it.
- Cleaning up contaminated groundwater – describes a clean-up hierarchy including when it is essential to clean up so natural background water quality is restored and when clean-up to the extent practicable is acceptable.
- The regulatory involvement in managing groundwater contamination.

2.12 Consideration of the Project SEARS

Elements of the sears relevant to the project are summarised in the following Table 2.3.

Groundwater Items Identified in the SEARS for Evaluation	Relevant Section
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;	In other documentation
Identification of any licensing requirements or other approvals under the Water Act 1912 and/or Water Management Act 2000;	Section 2
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);	Section 6
A description of the measures proposed to ensure the development can operate in accordance with the requirements of any relevant WSP or water source embargo;	Sections 2, 7
An assessment of any likely flooding impacts of the development;	In other documentation
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;	Section 7
An assessment of the likely impacts of the development on aquifers, watercourses, riparian land, water-related infrastructure, and other water users;	Section 7
A detailed description of the proposed water management system (including sewage, wastewater and stormwater), **water monitoring program,** erosion and sediment control measures, and other measures to mitigate surface and groundwater impacts; and	In other documentation, Section 8
Include a detailed consideration of any potential impacts on sensitive downstream receiving environments, including the Karuah River.	Section 7

Table 2.3: Summary of SEARS points relating to water, with items in bold addressed in this report with the relevant sections noted

3 SITE IDENTIFICATION AND SETTING

3.1 Location

The site is located on the western side of The Bucketts Way road, 45 km north northeast of Newcastle at 279 Deep Creek Road, Limeburner’s Creek. The site is located on Lot 48 DP753178 and Lot 472 DP1162208, within the Mid Coast Council area and covers an area of 30 ha (Figure 3.1) on the west side of Deep Creek.

The site is mostly forested and undeveloped. The rhyolite is present at surface along the spine of the ridge trending west through the quarry. There is a network of tracks through the area. A significant portion of the site is forested.

3.2 Topography and Drainage

The site steepens to the west, from below 30 m around Deep Creek (26 m, at its closest to the quarry pit) to 120 m up the ridge west of the highest extension of the quarry, which will reach approximately 115 m AHD.

Low-lying flat areas are located in the east of the Site, above Deep Creek. The lowest level of the quarry is to be 37 m AHD.

3.3 Flood Potential

Deep Creek meanders through the incised drainage and is not noted to flow regularly, but opens into an area of flat land to the east of the site.

Detailed flood modelling was undertaken by Engeny to estimate the existing flood conditions within Deep Creek, as well as estimate the potential changes to flooding in response to the proposed quarry development. The modelling indicates that flooding is generally confined to the main channel of Deep Creek, with only a small out of bank floodplain about 100 m wide. The quarry, stockpile area, and infrastructure area are all located outside of the modelling 1% AEP flood extent

Two dams and an in-pit sediment dam are planned to manage runoff from the quarry. Diversion drains will be constructed to direct water around the quarry infrastructure.

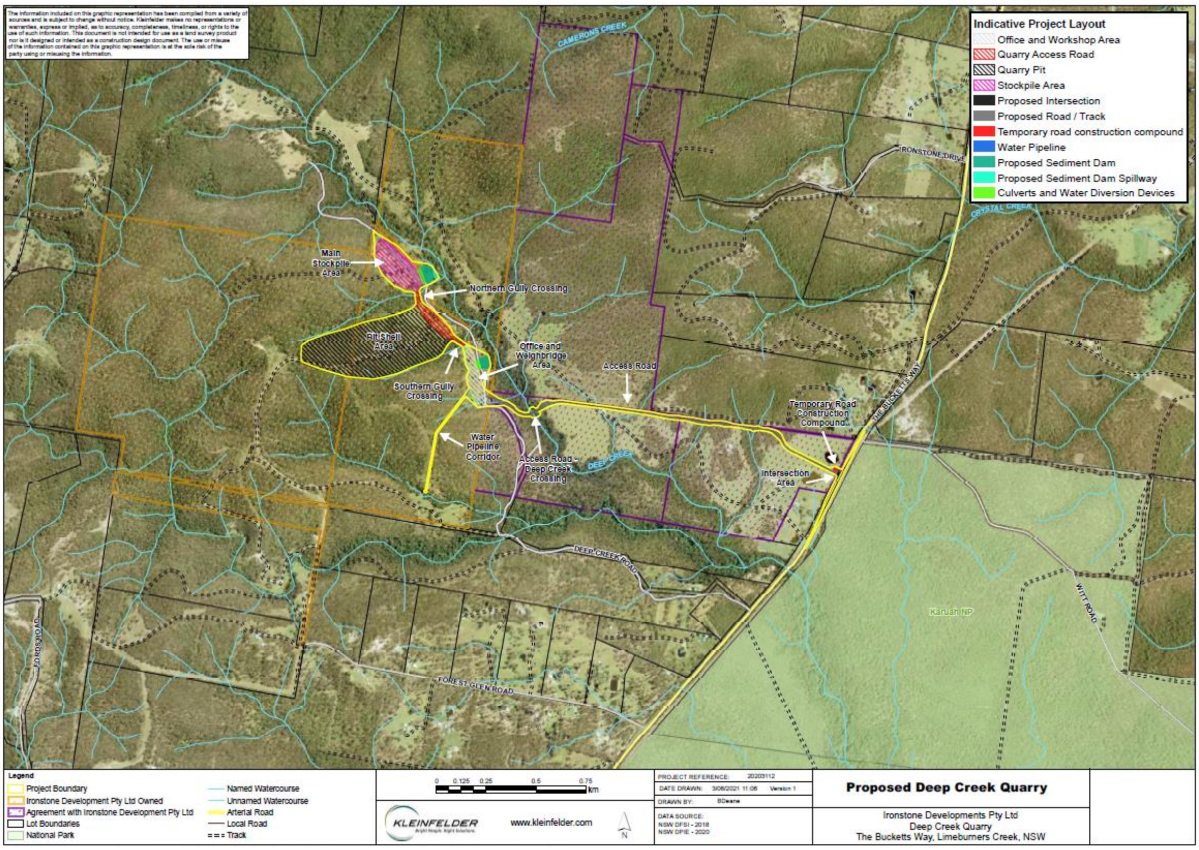

Figure 3.1: Location of the proposed quarry and infrastructure of the Deep Creek property

4 GEOLOGICAL AND HYDROLOGICAL ENVIRONMENT

4.1 Geological Setting

4.1.1 Regional geology

The quarry site is located west of The Bucketts Way, north of the Pacific Highway. The NSW Seamless geology map (Figure 4.1) shows a unit of the Carboniferous Paterson Volcanics (Curp) described as terrestrial volcaniclastic or pyroclastic rock that are in the age range of 330.9-323.2 million years. This unit trends approximately 080 degrees, down the ridge where it is identified in geological mapping at the site. This unit is within the Mount Johnstone (upper) sandstone unit (Cutj_s on the geology map), which consists of Carboniferous terrestrial sediments which are poorly constrained in age and interpreted to be between 358.9 and 298.9 million years.

On the Newcastle 1:100,000 geological sheet the Deep Creek Quarry site is described to be underlain by the Italia Road Formation, which forms part of the Kings Hill Group. The unit is described as containing lithic sandstones, shale, coal, chert, ignimbrites and tuffs. The site is located close to where younger Permian Sydney Basin sediments containing coal sequences overlie these older rocks. The depositional environment during this period of Australia’s development consisted of very cold conditions with glaciers, little flora and significant volcanic activity.

Neogene alluvium is mapped in the area around Deep Creek, with this general unit dating to within the last 23 million years. This unit is overlain by Quaternary alluvium, directly associated with the active drainage channels, with alluvium up to 2.6 million years old. The older alluvium becomes more extensive towards the Karuah River.

There are a number of other quarries which are developed in the general area, which are extracting volcanic materials for aggregate and other use. These quarries are developed on similar volcanic bodies, such as in the Nerong Volcanics in the Karuah area (Cook, 2018), where there are several operating quarries.

4.1.2 Local geology

The proposed quarry site is dominated by a west to east sloping ridge, with moderately steep slopes to the north and south. The highest point is located in the western portion of the site at 116m AHD, with lowest point to the east at 37m AHD, significantly above the elevation of Deep Creek at approximately 22-33 m AHD along the frontage to the quarry project.

The geology at the site was characterised by a number of activities to define with reasonable certainty the distribution of the target unit, which is a pale coloured rhyolite (Figure 4.2). This is a rock with high silica content, that is fine grained, compact, hard and has high resistance to abrasion and a high grip factor for use in road applications. The methodology to evaluate the local geology consisted of:

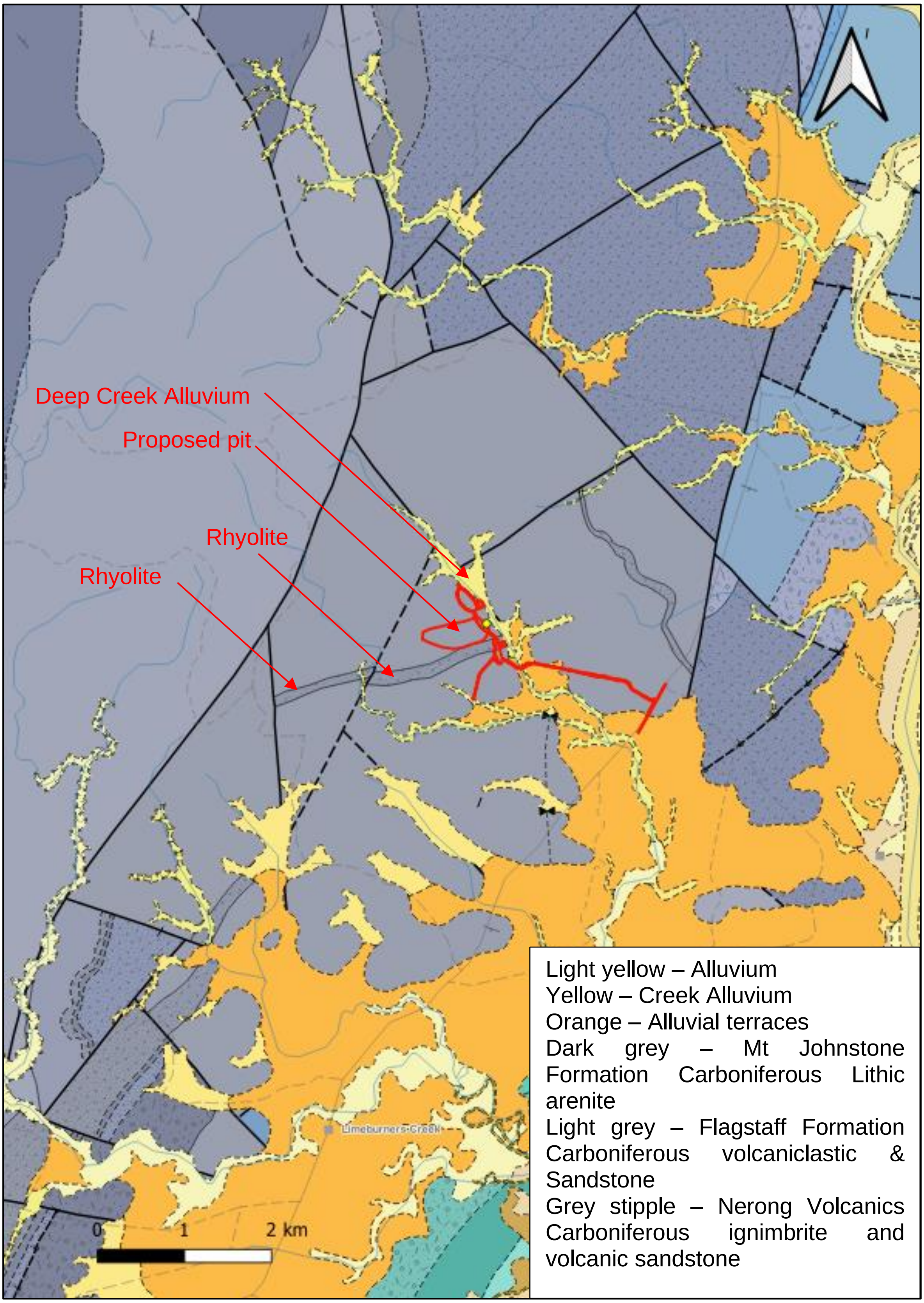

Figure 4.1: Local geology from the NSW seamless geology map. Red line is proposed pit, stockpile and infrastructure areas, including a new access road from The Bucketts Way. Note the mapped rhyolite does not correspond with the proposed quarry location and actual rhyolite outcrops

Figure 4.2: Rhyolite intrusive rock, showing limited fracturing below the surface zone and minimal iron staining

- Geological mapping of the site surface on a 50 m grid over the area, which has moderate outcrop, to determine the distribution of the rhyolite unit and adjacent rock types (differentiation of rock types shown in Figure 4.3):
- Locating drill sites and undertaking diamond drilling, to obtain rock cores for evaluation of the rock type, quality and relationships between the different geological units;
- Photographing and documenting the drill core and studying the core in detail to take samples for geotechnical assessment;
- Undertaking a resource estimate, based on the drilling undertaken, to determine the tonnage of rhyolite rock which could potentially be extracted, to develop a conceptual mine plan.

The target volcanic rock is described as rhyolite to rhyodacite or trachyte to quartz trachyte, consisting of fresh orange pink to cream hard blocky outcrop, with feldspar laths set in a fine ground mass. A coarser grained variant is described as pegmatite, consisting of subangular to subrounded opaque and clear quartz grains, with 10% muscovite to 1 mm size, with minor clay from weathering and an orangey pink colour.

The rhyolitic unit is noted to correspond to steep slopes, with hard arenites (sandstones) occurring as rounded boulder fields. Little to no outcrop is present on flat or gentle slopes. The eastern side of the proposed quarry area has no visible outcrop, but test pits have identified decomposed rhyolite. The coarser grained “pegmatitic” rhyolite is located on the northern side of the body.

It appears that around the contact with the rhyolite the sediments have been “cooked” and what has been described as “altered volcanics” is present along the contact between sediments and the volcanics. Drilling has defined sediments overlying the rhyolite in many of the drill holes (i.e. DDH7, DDH18, DDH7), with drill holes terminated in the rhyolite, except DDH7, which intersects sediments after an interval of approximately 60 m of rhyolite (Figure 4.4). Towards the eastern end of the ridge the overlying sediments appear to have been eroded. It is not clear if the rhyolite unit is a volcanic flow or high-level intrusion. Regardless of the morphology of the rhyolite unit drilling and mapping has confirmed there is a considerable tonnage of the unit at the site.

A range of geotechnical test-work was carried out at the site, with definition of a broad range of geotechnical and rock strength characteristics for the rhyolite and surrounding sediments. This included physical characteristics, such as particle density, particle size distribution, polished aggregate friction value Atterberg limits and uniaxial compressive rock strength. The rhyolite is noted to be hard to very hard, with between 1 and 10 fractures per metre. Fractures are generally tight and rough, with only occasional carbonate infill and occasional iron staining. Chemical characteristics such as chloride and sulphate content were also determined as between 0.001 and 0.003% chloride and 0.017 and 0.080 % sulphate. The general lack of significant oxidation halos around fractures suggests the iron content of the rock is low and the potential content of sulphides such as pyrite is likely to be low.

The sediments that the rhyolite occurs within are a sequence of fine to medium grained sandstone and conglomerate, with relatively rounded pebbles.

Drilling has shown that the soil overburden at the site is generally in the order of 1 m, but extends up to 2.5 m in drill hole DDH18. Weathered sandstone, siltstone or claystone is present below the soil with thicknesses from 0 to 6.8 m across the four drill holes in the centre of the deposit (DDH7, DDH17, DDH18 and DDH19). Below this depth unweathered sedimentary rock continues or the rhyolite is directly encountered. The deepest drill hole (DDH7) drilled through the rhyolite and encountered fresh sandstone, siltstone and claystone beneath the unit.

While the total hard rock resource within the proponent’s landholding is considerably larger than that proposed, in order to focus the quarry on the highest value rhyolite product, a resource of approximately 12 million tonnes (MT) is proposed to be extracted.

The pit location has been partially cleared for agricultural purposes and logging, the shallow depth of the target resource in this area allows for a reduced amount of overburden. While alternate areas of resource are present within the wider land owned by the proponent, the adopted resource area is considered to have the highest resource value and can be extracted with the lowest possible environmental impacts.

4.1.3 Drilling investigations

Drilling was supervised for the proponent by Mr Tim Mullaney, representing Ironstone Developments Pty Ltd. Drilling was undertaken by Total Drilling, with the first phase of drilling conducted from 19th-28th August 2013, with a second phase between 17th March and 7th April 2014. Most of the holes are in the order of 50 m deep and remain in the rhyolite. Hole DDH07 (Figure 4.3 and 4.4) was drilled through sandstone and claystone from surface, into the top of the rhyolite at 6.8 m, exiting the rhyolite into sediments at 68 m (at 32 m AHD, approximately 9 m below the quarry floor), with the lower sediments comprising carbonaceous claystone and occasional sandstone bands to 70.2 m, continuing in grey sandstone to the base of the hole at 72 m.

Drilling confirmed the competent nature of the rhyolite rock. Core was recovered, photographed and described with regard to hardness and colour. Samples were taken to evaluate the suitability of the material for different saleable products. A summary of the drill hole locations, depths and elevations is provided in Table 4.1, with drill hole locations shown in Figure 4.3 in the immediate area of the proposed quarry, and Figure 4.4, showing the cross section along line B-B' shown in Figure 4.3. Four of the drill holes are reported to have been converted to piezometers, for monitoring of the groundwater levels.

4.1.4 Petrographic evaluation

Petrographic analysis of selected core samples was undertaken following the drilling evaluation. This confirmed mineralogical variation between Trachyte, Quartz Trachyte, Rhyolite and Rhyodacite from the drill cores, with primary feldspar content varying between 38 and 85% and quartz content varying between 3 and 30%.

4.1.5 Fracture analysis

Observations of the drill holes were made, with zones of structural disruption noted, consisting of faulted or broken ground. Broken zones were marked by core loss in some locations. These are where groundwater would be expected to flow through the rock, considering that it is a volcanic rock without a porous matrix. The rhyolite encountered in drilling is oxidised through much of the depth of the proposed pit, with brown oxidation stains observed on the drill core. Natural fractures in the rhyolite appear to be predominantly in the range of 30 to 45 degrees from the vertical. Many of the other fractures may be induced by the drilling and storage in core trays and observations suggest that drillers breaks have not all been marked.

The fault zones identified in information from DDH01 through DDH09 are generally < 1 m across. Correlation between the fault and broken zones was not possible between the vertical drill holes. Black carbonaceous zones were noted to be present in the sediments underlying and above the rhyolite unit.

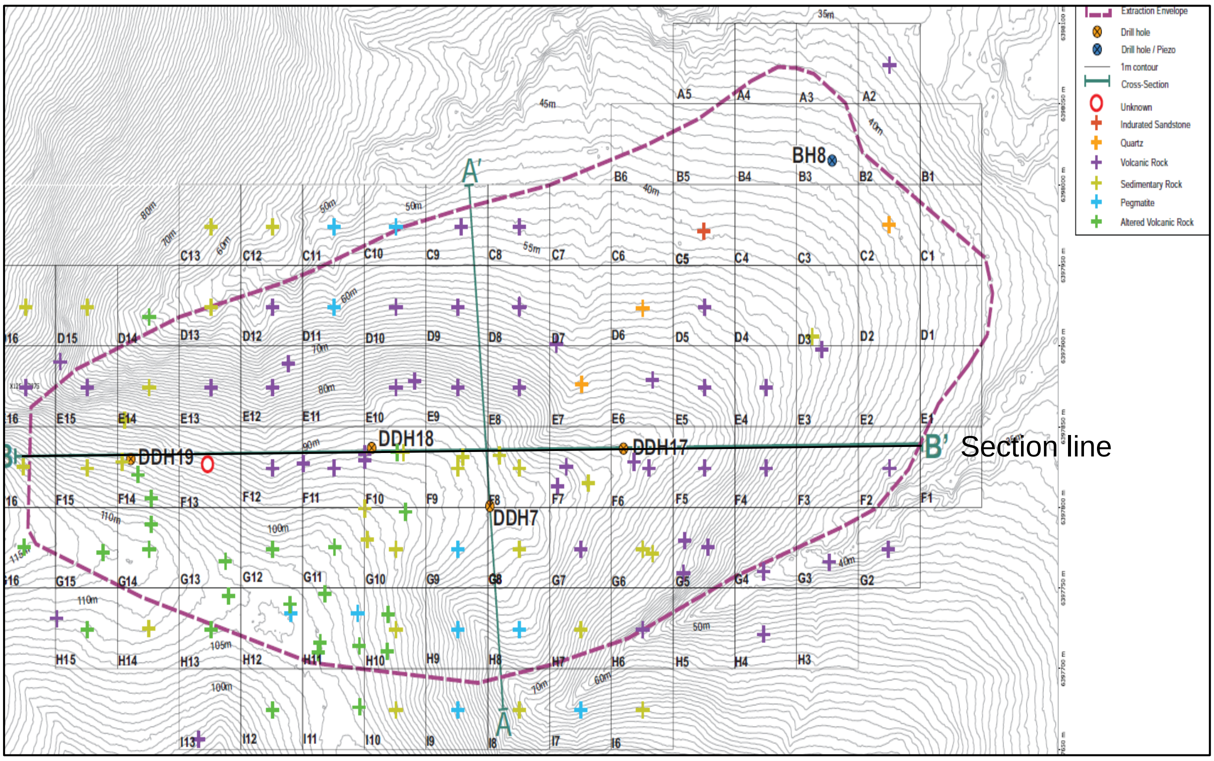

Figure 4.3: Site outcrop geology map coloured by rock type with observations, drill holes and proposed pit outline

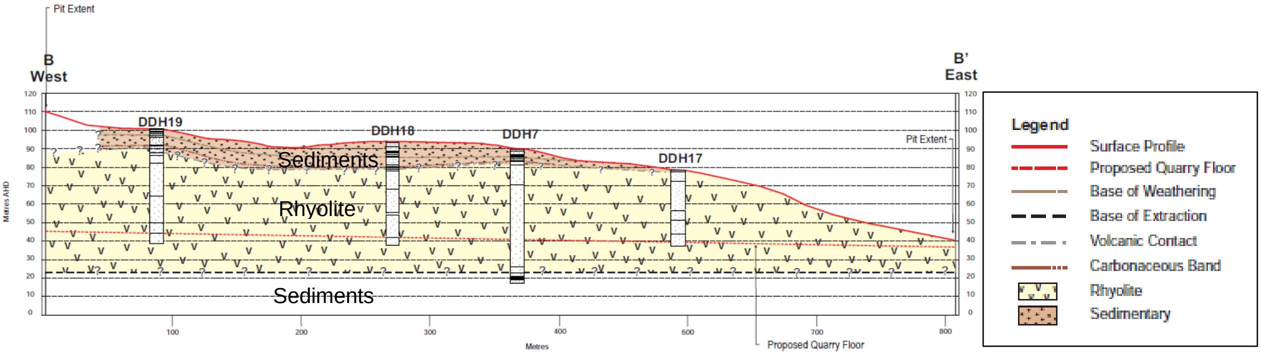

Figure 4.4: Cross section along line B-B', showing the distribution or rocks in the quarry

4.2 Climatic Data

Basic meteorological data for different periods is available from the Mill Dam Falls in Clarence Town, Dungog Post Office, and the Stroud Post Office, with rainfall and some maximum and minimum temperature data. More detailed data is available for the Williamtown RAAF weather station that is located approximately 30 km south from the site, with results summarised in Table 4.2 below. The climate in the area is warm temperate, with mild winters and warm summers. The temperature ranges from the coldest month of July, to the warmest in January at the Williamtown station.

Drill Hole	Hole Type	Depth (m)	Collar RL AHD	EastingGDA94z55	Northing_GDA94z55	Monitoring status
DDH01	Diamond Drill Hole	38.9	145	396976	6397907	
DDH02	Diamond Drill Hole	59.15	110	397456	6397535	
DDH03	Diamond Drill Hole	39	85	397273	6397148	
DDH04	Diamond Drill Hole	54	42.5	397647	6397095	Piezometer
DDH05	Diamond Drill Hole	51.2	108	396987	6397385	
DDH06	Diamond Drill Hole	33.2	106.5	397336	6397742	
DDH07	Diamond Drill Hole	72.05	90	397502	6397800	
DDH08	Diamond Drill Hole	15	40	397776	6398013	Piezometer
DDH09	Diamond Drill Hole	56.97	45.1	397431	6397208	
DDH17	Diamond Drill Hole	39.6	77.7	397618	6397829	Piezometer
DDH18	Diamond Drill Hole	55.7	92.5	397400	6397834	
DDH19	Diamond Drill Hole	62.4	101.5	397203	6397829	Piezometer
DH1	Percussion Drill Hole	n/a	83	397313	6397163	
DH2	Percussion Drill Hole	n/a	90	397169	6397153	
DH3	Percussion Drill Hole	n/a	100	396965	6397450	
DH4	Percussion Drill Hole	n/a	120	397052	6397776	
DH5	Percussion Drill Hole	n/a	105.5	397278	6397757	
DH6	Percussion Drill Hole	n/a	110	397376	6397649	

Table 4.1: List of drill holes in the project area, with DDH07, 08, 17, 18 and 19 within the proposed open pit

4.2.1 Rainfall

The average rainfall for the site is in the order of 800 to 1000 mm/year, based on data from the surrounding rainfall stations (Table 4.1). The highest rainfall is in January, February, March and June, with significant rainfall monthly throughout the year (BOM Williamstown weather station 061078 with data from 1942 to present and other stations).

4.2.2 Temperature

Temperature information is available for less sites than rainfall data. The average monthly temperature at the Williamstown weather station varies between a high of 28.3 degrees in January and a low of 17.2 °C in July. At the Dungog Post Office weather station, the mean maximum temperature is noted to vary between 26.9 °C (lowest) and 34 °C (highest) in January and 17 °C (lowest) and 19.8 °C (highest) in June.

4.2.3 Evaporation

Monthly total evaporation rates are around 1,400 mm/year (based on the BOM evaporation map of Australia), indicating only a slight excess of evaporation over rainfall.

The scaling of evaporation pan data for larger water bodies requires the use of a conversion factor, which is typically in the order of 0.7 (reference) and requires consideration of the albedo (reflectance) effects. Information from the Williamstown RAAF base indicated daily evaporation of 4.8 mm/day from 41 years of data, for approximately 1750 mm/year.

Average actual evapotranspiration data from national maps prepared by the Bureau of Meteorology indicate evapotranspiration averages around 800 mm/year.

4.2.4 Climate Change

Government agencies in Australia have been evaluating the potential implications of climate change in Australia. The Climate Futures Tool (climatechangeinaustralia.gov.au) provides estimates of potential climate conditions.

All the climate models (19) indicate rainfall intensity of storm events is likely to increase. Spring rainfall is likely to decrease, whereas autumn rainfall is likely to increase. However, the increased rainfall intensity and seasonal change is unlikely to have a significant impact on groundwater recharge over the life of the project.

4.3 Surface Hydrology

There is no specific information regarding surface water hydrology at the site. The site is located on the southwestern side of Deep Creek. The Creek is noted to run only periodically following periods of significant rainfall. Outside these periods the creek contains discontinuous pools of water and these largely dry up during summer. The bed of the creek is a mixture of sandy material and organic material and the creek line is generally extensively vegetated, including with species such as Lantana.

Areas of high soil moisture, that appear to be seeps, were noted near the road traversing the base of the area near where the haul road is planned. This suggests there is some shallow groundwater discharge to surface in this area. There is interpreted to be groundwater discharge into Deep Creek as base flow, which potentially explains the extended presence of water in the creek bed. The proposed quarry is likely to result in some discharge within the pit that previously discharged at lower topographic levels.

The Creek is not known to be a water source for stock or domestic use in the near vicinity of the proposed quarry. Monitoring points in the creeks surrounding the site and at groundwater bores is shown in Figure 4.5.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Rainfall mm - Clarence Town (Prince St) 1895-2020													
Mean	104.3	111.5	122.9	100.4	86.6	101.6	68.3	60.3	62.1	68.1	78.2	99.3	1063.7
Median	80.1	87.5	103	76.9	70.3	75.9	52.4	41.2	47	52.4	65.7	82.3	1050.5
Highest	523.3	512	511.4	639.8	427.8	592.4	307.1	472.7	333.4	281.1	354.2	365.2	1734.2
Rainfall mm - Medowie Post Office 1908-1943													
Mean	88.7	80.8	108.6	133.9	127.8	96.7	119.3	59.3	82.7	75.8	59.5	115.5	1155.5
Median	94	72.2	88.1	112.3	104.4	88.7	102.8	46.5	73.6	44.7	56.5	109.3	1157.7
Highest	206.2	318.5	324.8	398.8	489.8	375.8	367.2	181.5	221.8	286.9	224.3	451.7	1600.8
Rainfall mm - Dungog Post Office 1961-1990													
Mean	107.7	111.8	112.9	83.4	74.6	86.5	54.9	51.2	55.8	68.4	77.2	100.4	982.2
Median	97.1	85.2	94.1	64.8	55.9	59.7	45.4	31.8	39.2	51.5	63.2	89.8	979.8
Highest	446.9	538.4	426	451.8	365.4	493.8	236.8	409.4	212.8	322.4	318.3	266.8	1666.1
Rainfall mm - Nelson Bay (Nelson Head) 1881-2020													
Mean	99.8	112.5	117.7	129.3	149.6	159	135.6	101.5	89.7	77.9	79.6	92	1339
Median	82.6	85.7	92.9	102.8	121.3	132.5	112.6	79.6	74.4	68.4	68.3	73.2	1280.5
Highest	559.7	530.8	401.8	493.8	632	607.6	615.9	630.6	311.9	297	264.3	334.3	2335.9
Rainfall mm - Williamstown RAAF 1942-2020													
Mean	98.3	117.8	120.7	109.8	108.6	125.2	70.3	73.2	60.6	73.5	81.9	77.5	1118
Median	90.8	85.4	123.9	94.5	95.5	90.1	51	46.8	48.3	66.6	68.9	64.1	1103.7
Highest	325.4	599.6	398.5	361.2	235.5	318.4	168.4	212.2	155.1	237.5	181.5	238	1793.7
Rainfall mm - SILO Proposed Quarry Site September 2020													
Mean	101.3	124.6	136.3	107.1	68.0	125.1	68.6	51.1	61.2	66.0	108.1	90.0	1107.4
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Average**
Temperature ^{o}C - Dungog Post Office - Mean Maximum													
Lowest	26.9	26.4	24.9	23.5	19.4	17	17.3	17.9	19.8	23.3	25.9	27.8	23.9
Highest	34	31.1	29.3	27.4	23.6	19.8	20.2	20.8	25.2	28	31.4	31.3	24.8
Temperature ^{o}C Williamstown RAAF													
Mean	28.3	27.7	26.4	23.8	20.4	17.7	17.2	18.8	21.5	23.8	25.6	27.4	23.2
Highest monthly mean	33.3	31	28.5	26.3	23.1	19.9	19.5	21.9	25.7	27.1	28.6	30.8	26.3
Lowest monthly mean	24.4	24.9	23.8	21.7	18.8	15.9	15.5	17	18.5	20.9	22.7	23.8	20.7
SILO Proposed Quarry Site September 2020													
Maximum T ^{o}C	29.3	28.2	26.6	23.9	20.6	17.6	17.6	18.9	22.1	24.3	26.2	27.7	23.6
Minimum T ^{o}C	19.1	18.6	17.4	14.1	10.6	9.1	7.6	7.8	10.5	12.9	15.5	17.2	13.4
Evaporation mm	183.5	143.5	117.8	85.3	68.1	49.4	60.0	86.8	119.0	144.0	158.9	175.7	1392.1

Table 4.2: Climatic data relevant to the site

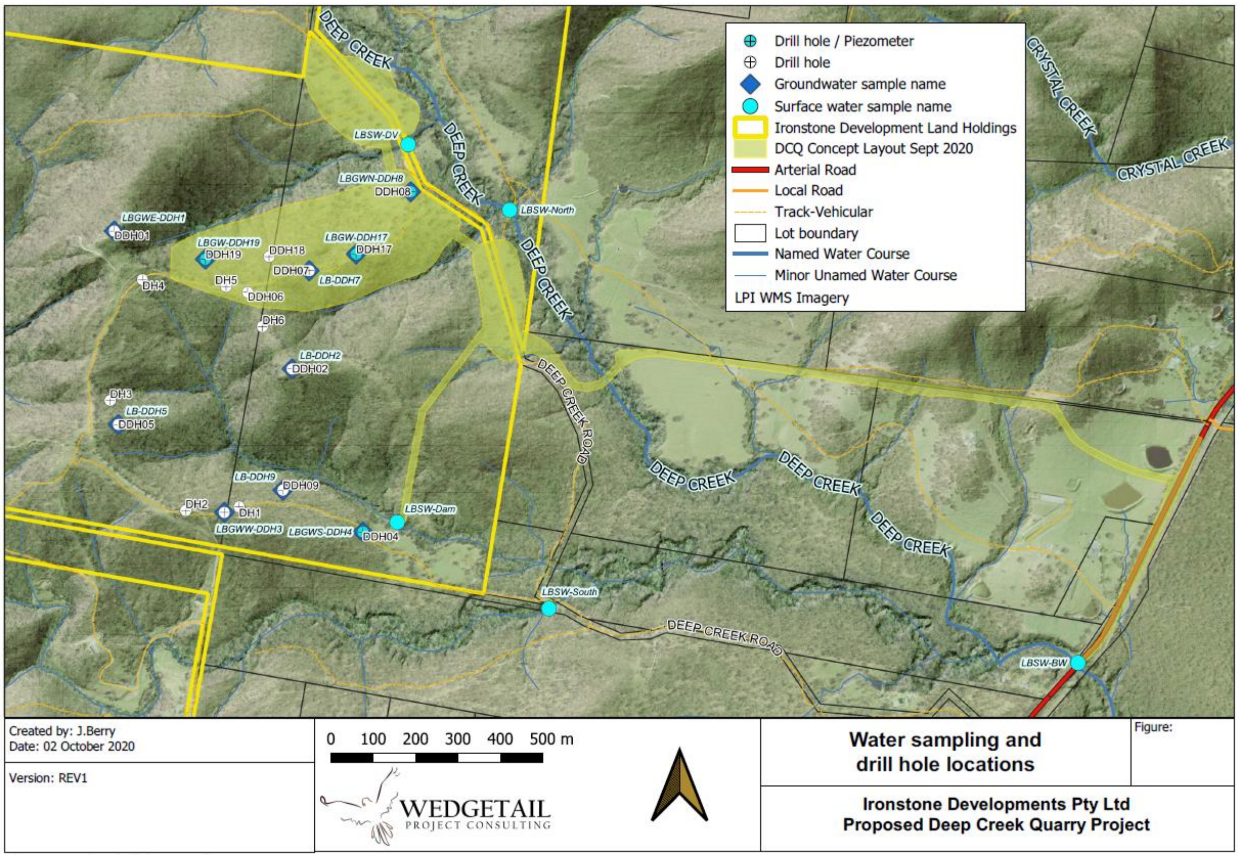

Figure 4.5: Groundwater and surface water sampling locations, within the properties owned by Ironstone Developments, showing the access road and proposed development area

4.4 Hydrogeology

4.4.1 Regional hydrogeological interpretation

The North Coast Porous and Fractured Aquifers comprise aquifers that potentially have dual porosity but in general are considered to have low porosity and groundwater storage. Other quarries are present in the general area around Newcastle, such as at Karuah South where volcanic rock is being quarried. Investigations show that the volcanic rocks in that area have low water storage and release when quarried, with quarry operation essentially dry.

The fractured and porous rock aquifers in the area around the site are expected to discharge groundwater into the Karuah River, with potential discharge into creek systems feeding into the river. The area around the site consists of forest, with some cleared land on the south and eastern side of the proposed quarry site.

4.4.2 Site Hydrogeology and Groundwater Level Analysis

During the drilling of the diamond holes for resource definition and estimation no groundwater ingress was noted, with the holes drilled on the ridge sloping to the east. Monitoring wells were not installed in all the holes, with well construction for wells monitored shown in Table 4.3. The monitoring wells and drill holes were subsequently sampled for groundwater levels and quality, beginning in 2014. The location of groundwater and surface water points is shown in Figure 4.5, with groundwater levels relative to the AHD height datum shown in Figure 4.6 and Table 4.4. Groundwater monitoring from 2014 to early 2017 showed essentially constant groundwater levels, but since this time all wells have shown a decline in water level, with the most abrupt noted in the most recent measurements of DDH19 (Figure 4.7). As there has been no development at the site it is unclear whether this is related to the extended drought period leading up to the winter of 2020. Over the period of monitoring bores have shown variations of generally less than 2 m in water level.

Not all the holes drilled are active as monitoring wells, as some wells have become blocked (casing was not installed) and measurements of water level are not believed to be reliable. Some of these holes provided initial water quality samples or groundwater levels.

Evaluation of the groundwater levels indicates the groundwater gradient is towards the east and Deep Creek, mirroring the topography. However, monitoring information is located along the ridge and the linear location of wells limits the certainty in the groundwater contours.

The bores extend to depths of 15 to 72.5 m below ground surface, depending on surface topography. Only DDH8 was installed with PVC pipe at the time of permeability testing. Standpipes have subsequently been installed in the more recent 2018 diamond drill holes. The elevation of monitoring well standpipes was confirmed with topography developed for the site from the NSW ELVIS elevation data repository, and found to be within 2 metres of the surveyed elevations.

Drill Hole	Depth	Screen length	Screen m bgl	Comments
DDH04	54	21	15-36	Gravel pack with 1 m bentonite seal over the screen section
DDH08	15	9	6-15	3 m backfill at top of hole over 5 m of bentonite over gravel pack
DDH17	39.6	24	9-33	9 m blank pipe with gavel over 1 m bentonite, over 24 m of screen. Base at RL42 m. Proposed pit floor. 1 m bentonite plut and 6 m gravel backfill at base of the hole
DDH19	62.4	36	17-53	17 m blank pipe with gravel and 1 m bentonite seal, over 36 m slotted pipe and 1 m bentonite plug at base over 9 m of gravel backfill. Base of screen at RL45 m

Table 4.3: Well construction for wells that have been monitored from 2014 and 2018 onward

Drill Hole	Depth below surface m	Hole Collar Elevation m AHD	SWL Elevation m AHD
DDH02	36.95	110	**73.05**
DDH04	12.83	42.5	**29.67**
DDH08	12.92	40	**27.08**
DDH17	23.85	77.7	**53.85**
DDH19	24.45	101.5	**77.05**

Table 4.4: Groundwater levels measured on 26 February 2019, or nearest date when not measured on that date

4.4.3 Porosity and permeability characteristics

Observations at surface suggest that the rhyolite is relatively unfractured. Drilling shows that the rhyolite can be recovered in drill core in 1 m sticks, although there are generally several fractures per metre observed in the drill core (although some may be induced during the drilling and storage in core trays). The fractures per metre vary between approximately 1 and 5. The sandstone and siltstone units overlying the rhyolite show a higher degree of fracturing than the rhyolite.

A previous investigation of the site was carried out by Groundwater Exploration Services (GES), who undertook low volume pumping tests in open diamond drill holes and one 50 mm diameter PVC monitoring well that was installed in the diamond drilling holes on the site. Data was collected from pumping and recovery tests in five wells. These provide an indicative summary of the physical properties of the rock to be extracted, which showed that hydraulic conductivity is extremely low (Table 4.5, Figure 4.8). No information was obtained on aquifer storage, as the holes were not conducive to longer term or higher volume pumping tests. The GES report is attached in Appendix A. Attempts to measure permeability characteristics in additional drill holes were prevented by blockages in the holes.

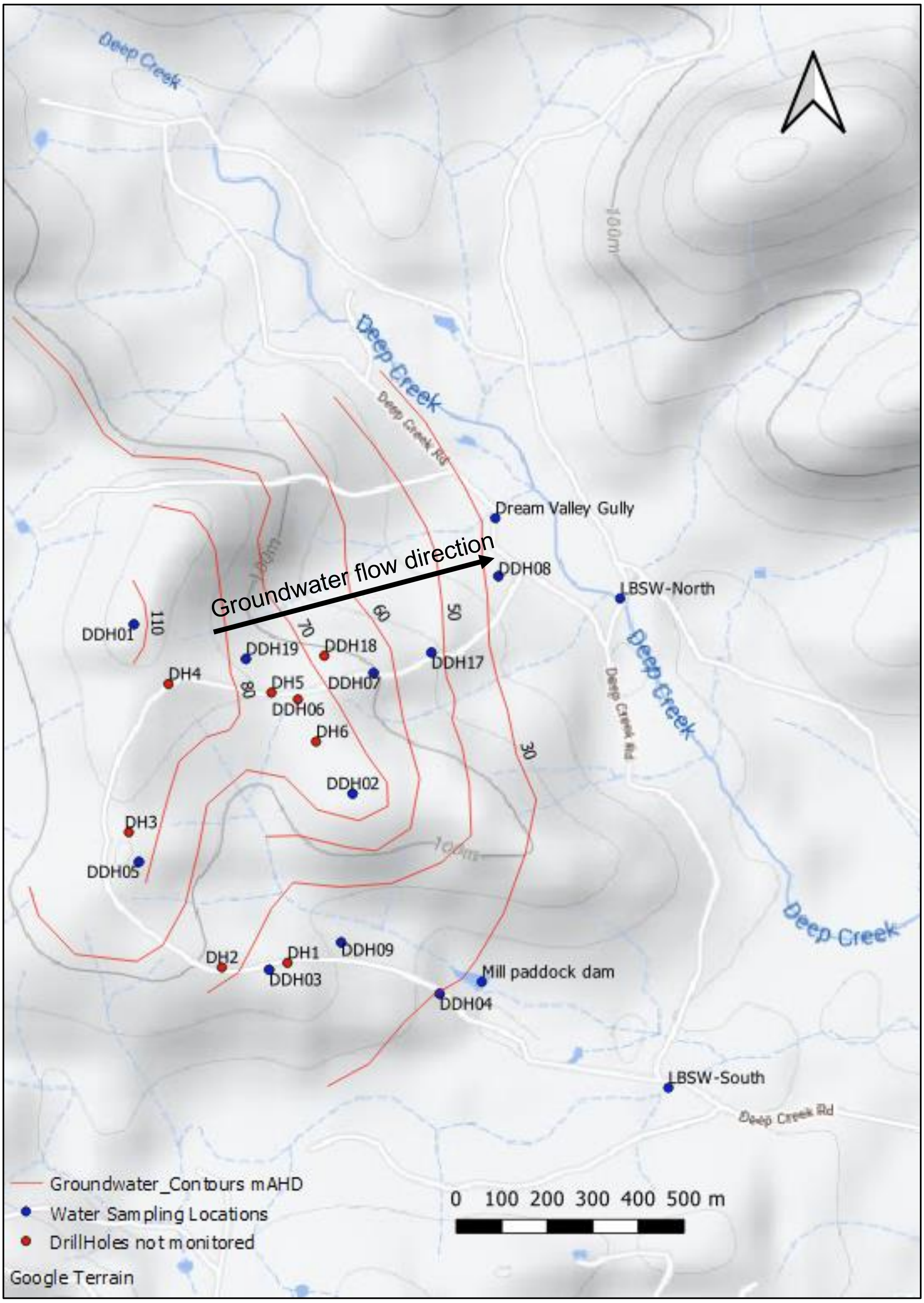

Figure 4.6: Interpreted contours (m AHD) of groundwater level in wells on the 26 February 2019

Although the rhyolite does not have primary porosity minor amounts of groundwater are likely to be hosted in joint fractures and small fault planes within the rock, which has undergone folding and faulting over time. The fractures and fault planes provide discontinuous pathways for infiltration and flow of groundwater. Groundwater hosted in the rhyolite and surrounding sediments is considered to be under semi-confined to confined aquifer conditions. The sediments over and underlying the rhyolite may contain groundwater in the primary porosity in sandstones and fractures, although limited information is available from these units. At 27 m AHD water in DDH08 is likely to be within the sandstone, which correlates with lower pH levels. The specific yield refers to the portion of the total porosity that can be extracted by pumping (or draining). This is likely to be very small, in the order of several percent.

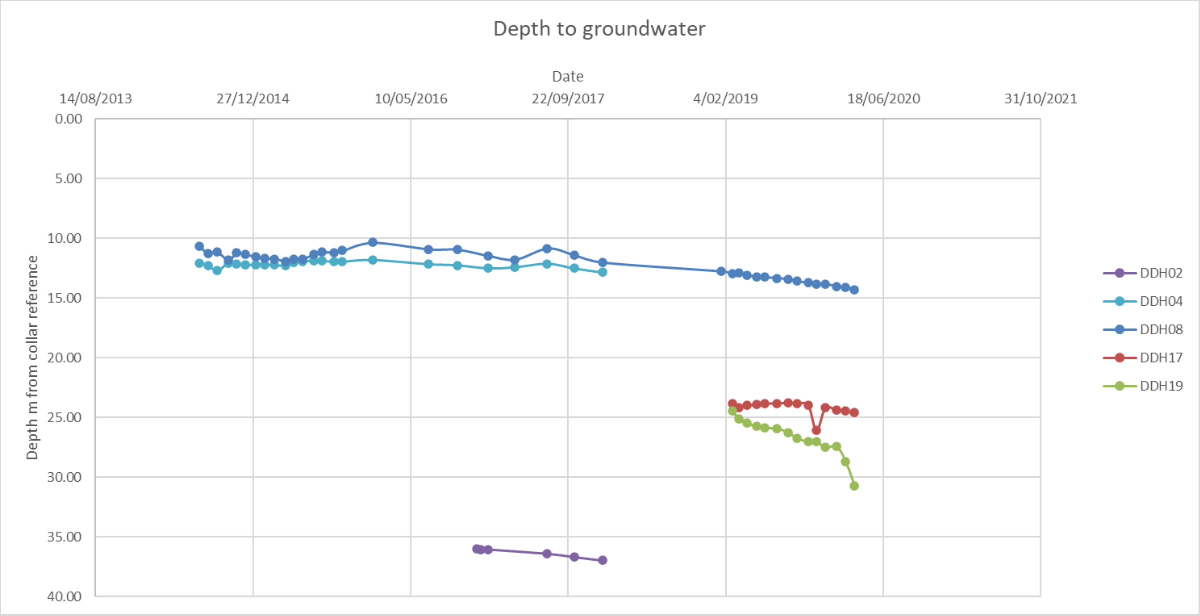

Figure 4.7: Groundwater monitoring data from 2014 to 2020 from monitoring wells

Information from other hard rock quarries extracting volcanic rocks in the district, such as the Karuah South quarry (Cook, 2018), indicates they operate under dry conditions, with little or no groundwater inflow into the quarry pit. Hydraulic conductivity determined by Coffey (2012), mentioned in Cook (2018) showed hydraulic conductivity of the rhyodacite unit was determined as 5 x 10^{-6} to 9 x10^{-6} m/s, which they note is consistent with crystalline igneous rocks. Those observations suggested that groundwater flow is insignificant at that site and evaporation is likely to overcome groundwater inflow into the quarry pit.

Hole	Standing Water level below surface	Hydraulic Conductivity (m/day)	Depth	Screen
DDH02	35.86	1 x 10^{-5}	~40	Open hole
DDH04	11.86	2.75 x 10^{-3}	~54	21 m from 15 m. Gravel pack & bentonite seal
DDH05	22.45	1 x 10^{-5}	~105	Open hole
DDH07	8.09	3 x 10^{-10}	72.05	Open hole
DDH09	7.99	1.3 x 10^{-2}	~60	Unknown

Table 4.5: Hydraulic conductivity measurements on site by GES (2018) in January 2017

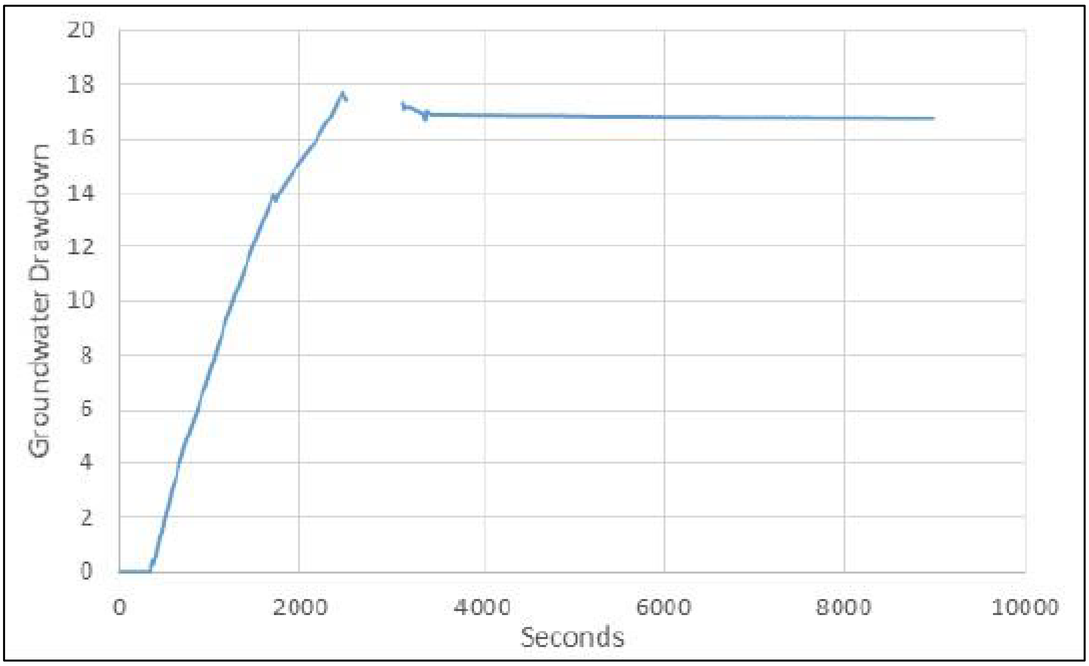

Figure 4.8: DDH07 pumping and recovery test, showing a lack of recovery in the well

4.4.4 Aquifer recharge

Aquifer recharge occurs from rainfall that infiltrates into fractures in the rocks and from infiltration of water at surface as local overland flow towards drainages. DPIE Water in the Water Sharing Plan assign a value of 4% of rainfall for recharge of aquifer units and recharge in the specific area is likely to be in the range of 1 to 5% of rainfall, values also considered by Cook (2018) for the South Karuah quarry site.

4.4.5 Aquifer discharge

The surface and groundwater systems in the vicinity of the site show different chemical characteristics, discussed under groundwater quality below.

Some natural discharge of shallow groundwater is expected to occur to Deep Creek, as a result of topography and potential higher permeability near surface. Deep Creek typically flows only after significant rain events (based on monitoring carried out for the project since 2014). Following periods of rain, water remains in pools. These pools potentially reflect discharge of some shallow groundwater into the drainage, however the water quality parameters such as EC and pH do not support significant discharge of groundwater. Vegetation along Deep Creek in the vicinity of the proposed quarry is not considered to constitute groundwater dependent ecosystems, based on the ecological assessment completed for the project.

4.4.6 Groundwater Dependent Ecosystems

Groundwater will flow within fractures and faults in the rhyolite, and pores and fractures within the underlying and overlying sandstone. Flow will depend on the size and orientation of fractures in the rhyolite and in the sediments over and underlying the rhyolite a combination of flow through primary pores and through fractures.

Groundwater Dependent Ecosystems are classified as terrestrial or aquatic (related to rivers and lakes). GDE mapping is carried out by national and state agencies and information is available as GIS map layers outlining areas with different dependencies. In the vicinity of the proposed quarry the following GDE's are identified:

- Extensive spotted Gum and Broad Leaved mahogany dry Sclerophyll forest – generally classified as moderate potential GDE's. These are present surrounding and including the site area (where based on regional mapping a small area is classified as low potential GDE);
- Red bloodwood / Smooth Barked Apple heathy woodlands, generally classified as moderate potential GDE's, extending south of the proposed quarry site;
- Weeping Lilly Pill /Water Gum riparian warm temperate rain forest, classified as high potential GDE's along Deep Creek;
- Estuarine wetlands developed around the Karuah River, 5 km south of the site, where aquatic GDE's are noted in national mapping.

Deep Creek potentially receives some shallow groundwater discharge, however water quality information from pools along Deep Creek shows these are substantially fresher water than the groundwater upgradient in the project area, suggesting at most a minor contribution to the Deep Creek alluvium from the bedrock groundwater to the west.

4.4.7 Other groundwater users

Other groundwater users in the area (black dots on Figure 4.9) consist of sparse stock and domestic users around the site, based on review of the Bureau of Meteorology Groundwater Explorer groundwater data. Limited information is available on most bores, with essentially no information on the standing water level and water quality data. A summary of bore details is provided in Table 4.6.

Groundwater records on the BoM Groundwater Explorer show that the nearest registered groundwater bore is 35 m deep, located 2 km east southeast and downgradient of the site, 200 m west of The Bucketts Way road. This is listed as a stock bore. The next nearest registered bores are 4.3 and 6.2 km east and north northeast of the site, with depths of 66 and 53 m and uses as a monitoring bore and a domestic bore respectively.

HydroID	Hydro Code	Depth	Distance km	Type	Easting	Northing	Elevation AHD	Works ID
10053707	GW052378	35.1	2	Stock and Domestic	399579	6397099	26.74	200076450
10107579	GW202804	66	4.3	Monitoring	402112	6399032	n/a	1000195549
10030674	GW050664	51.8	6.2	Water Supply	400791	64034563	n/a	200076448

Table 4.6: Registered groundwater bores in the vicinity of the project, coordinates in GDA94Z56

4.4.8 Sensitive groundwater receptors

Sensitive groundwater receptors can include municipal and private water supply wells and groundwater dependent ecosystems and permitted sites for Aboriginal water use. Evaluation of the area suggests there are no sensitive receptors in the immediate vicinity of the site. The Karuah National Park and Nature Reserve are a significant distance from the proposed quarry and well beyond any groundwater impacts.

4.4.9 Groundwater and surface water quality

Monitoring is ongoing at the site. Monitoring of physical and chemical characteristics has been undertaken on some bores since 2014, with results shown in Figures 4.10 to 4.12. This shows that:

- Four of the bores that have been monitored show similar pH in the range of 6.1 to 7.2. These bores are located along the rhyolite ridge;

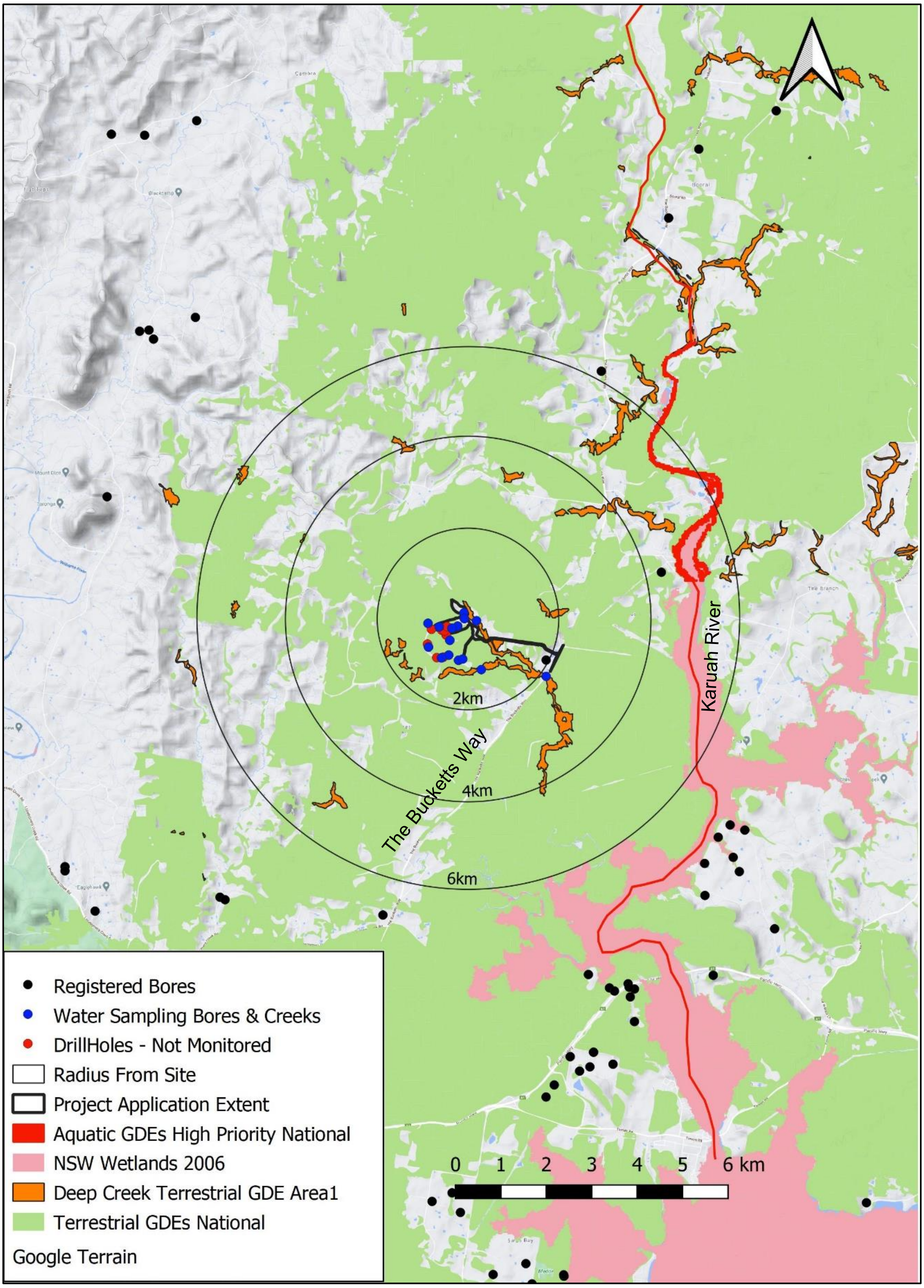

Figure 4.9: The location of the project relative to registered groundwater bores and mapped terrestrial and aquatic GDE's

- Bore DDH8 at the eastern end of the proposed quarry site at an elevation of 45 m has a distinctly lower pH in the range of 3.6 to 4.6;
- Bore DDH2, located 150 m south of the proposed quarry pit has an intermediate pH of 5-5.3;
- Electrical conductivity in wells measured in the field varies between 0.45 mS/cm and 3.77 mS/cm, with most samples between 1 and 2.5, varying over time. Wells behave differently and there is not a consistent pattern between the holes.

With regards to surface water monitoring:

- Four sites have been monitored since 2014, with most measurements made from pools that have remained after rain events;
- pH of the sampling sites varied between 5.44 and 7.91, with one exception. pH values were predominantly between pH 6 and 7, with the highest values for the dam site;
- Electrical conductivity at three of the sampling sites is typically around 0.2 mS/cm, with the LBSW-North point returning samples with results up to 1 mS/cm.
- Although the surface water pH is similar to most of the groundwater samples the surface water has a notably lower EC, with groundwater approximately an order of magnitude more concentrated.

Laboratory analysis of samples from 2014 to 2020 were analysed at NATA accredited ALS laboratories. The samples were taken with a bailer or (for surface water samples) collected directly into a bottle. Analyses show that for:

Surface Water

- pH of the surface water samples varies between 6.2 and 7, corresponding to the majority of the field measurements;
- EC of the surface samples 0.142 and 0.342 mS/cm, broadly consistent with field measurements;
- Major cations and anion concentrations are all low and phosphate, nitrate and nitrite values are all less than the ANZECC guideline values;
- Aluminium consistently exceeds the ANZECC 95% guideline values, with occasional exceedances for zinc, copper and cadmium;
- Surface water and groundwater values are compared in Figures 4.12 and 4.14.

Groundwater

- Exceedances for groundwater samples were more extensive, with EC and pH commonly outside the ANZECC values;
- Groundwater samples show exceedances for Aluminium, arsenic, cadmium, chromium, copper, lead, nickel and zinc;
- Groundwater in DDH08 is notably lower pH, at around 4, than the other bores which are generally between pH 6 and 7.5 (with the exception of DDH02, which is around pH 5). The lower pH in DDH08 is considered likely to reflect the presence of shaley material in this drill hole. This drill hole is located in the extreme east of the quarry and drills into the foot wall of the rhyolite unit, into sediments including shales. The quarry is designed to remain in the base of the rhyolite unit and to avoid intercepting lower quality groundwater from this unit below the base of the rhyolite unit. Quarry

operations should monitor the water quality and the intersection of any material during quarrying that is not the target rhyolite unit.

Field and laboratory chemistry shows groundwater and surface water conductivity, metal and nutrient contents are sufficiently different that groundwater is probably not contributing a large volume of water to Deep Creek, based on the results of sampling since 2014. Groundwater major ion concentrations are typically at least 10 times those of surface water analyses.

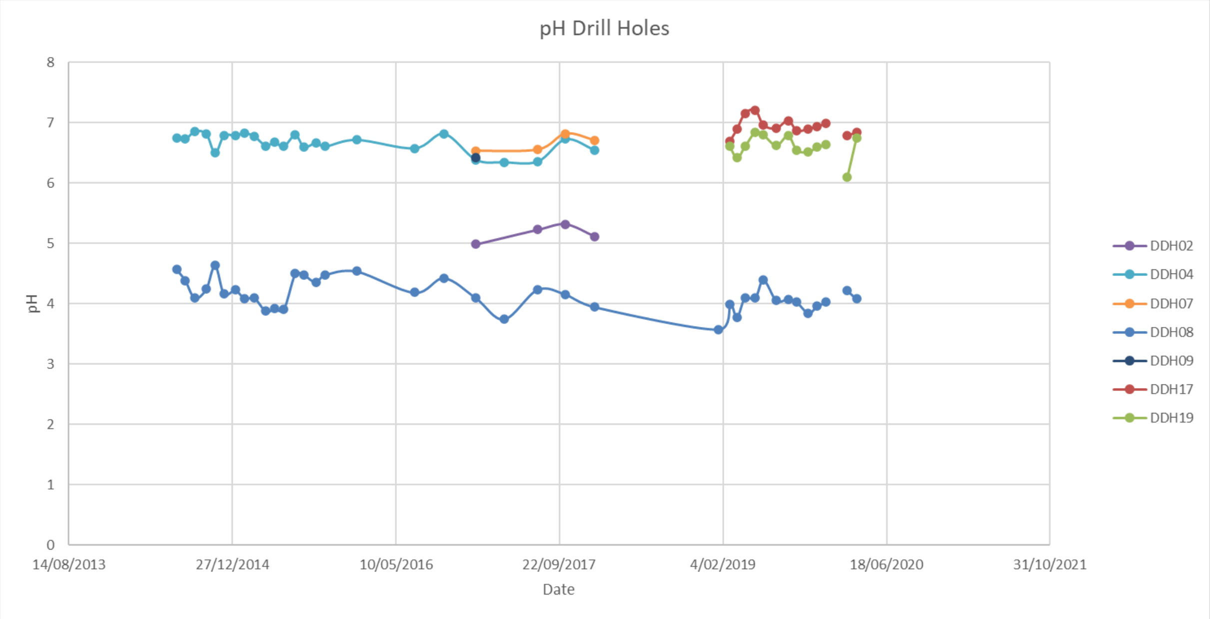

Figure 4.10: Groundwater bores pH measurements over time

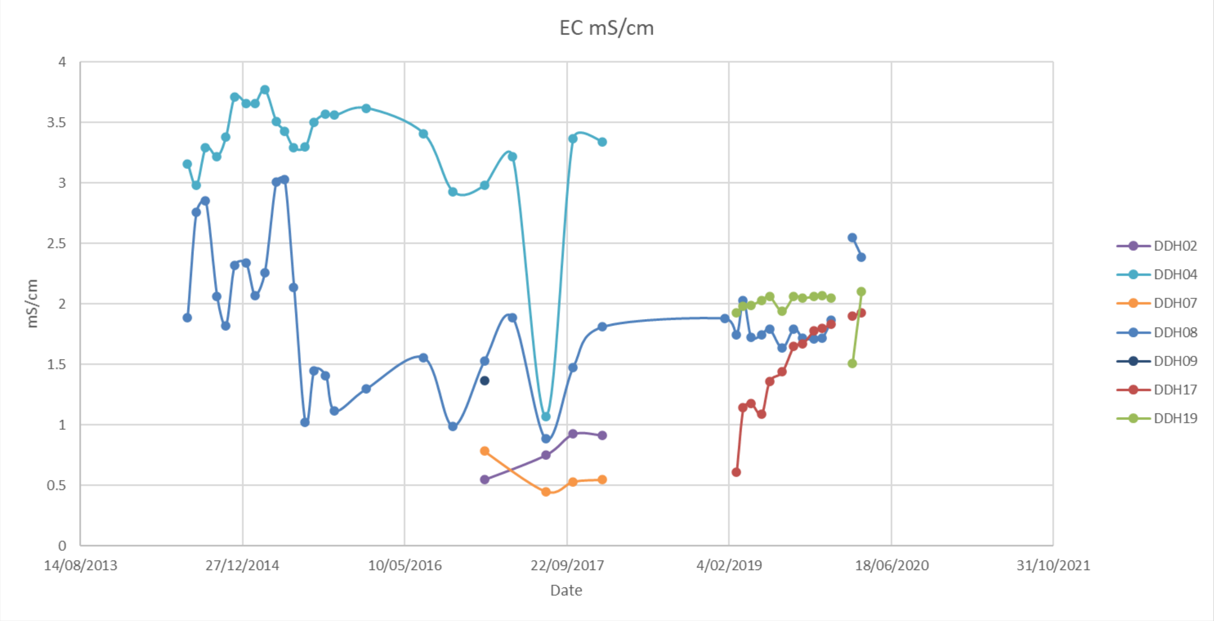

Figure 4.11: Electrical conductivity of groundwater bores over time

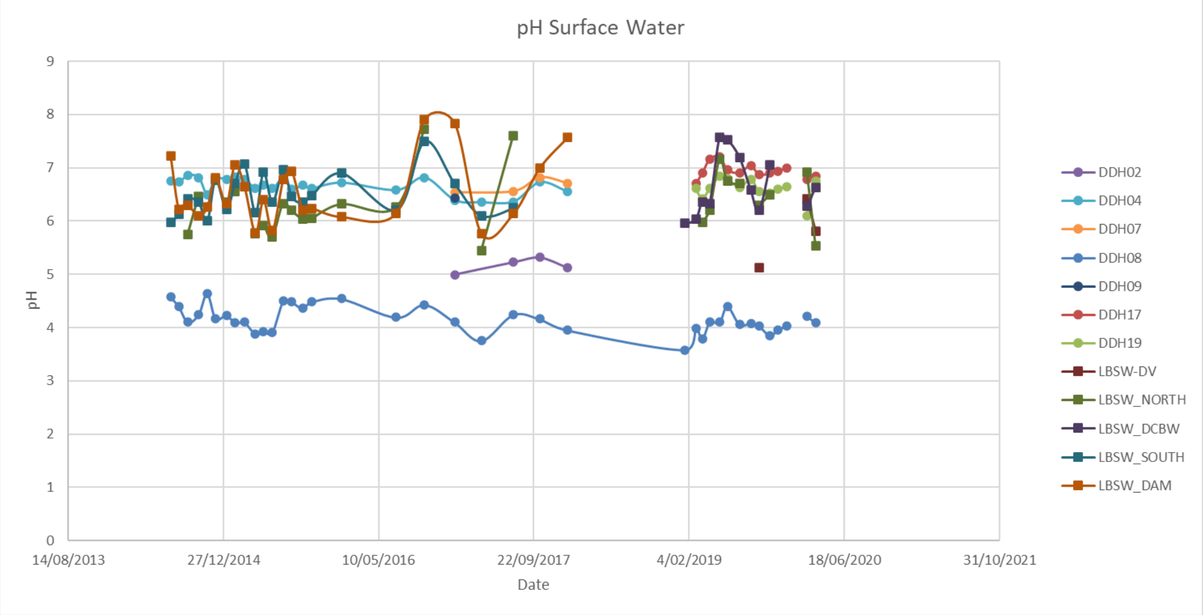

Figure 4.12: pH measurements of surface water compared with groundwater

4.4.10 Hydrogeochemical classification

Groundwater sampled when permeability testing was undertaken in 2017 was analysed for a range of major elements and metals. This information was compared to the ANZECC 2000 water quality guidelines and plotted on a Piper diagram (Figure 4.13), to evaluate the differences in water quality between water sample locations and to evaluate recharge and discharge processes. Recent groundwater recharge typically plots closer to the left-hand apex of the diamond field in the Piper diagram, with more evolved groundwater further from recharge sources located further to the right in the diamond field. Typically, Cl and SO4 increasing along the groundwater flow path.

Wells DDH5 and DDH7 show high bicarbonate relative to chloride, which generally indicates a higher relative groundwater recharge component relative to the other samples. Wells DDH02, DDH04 and DDH09 show more evolved groundwater characteristics, suggesting less groundwater recharge is occurring at those sites.

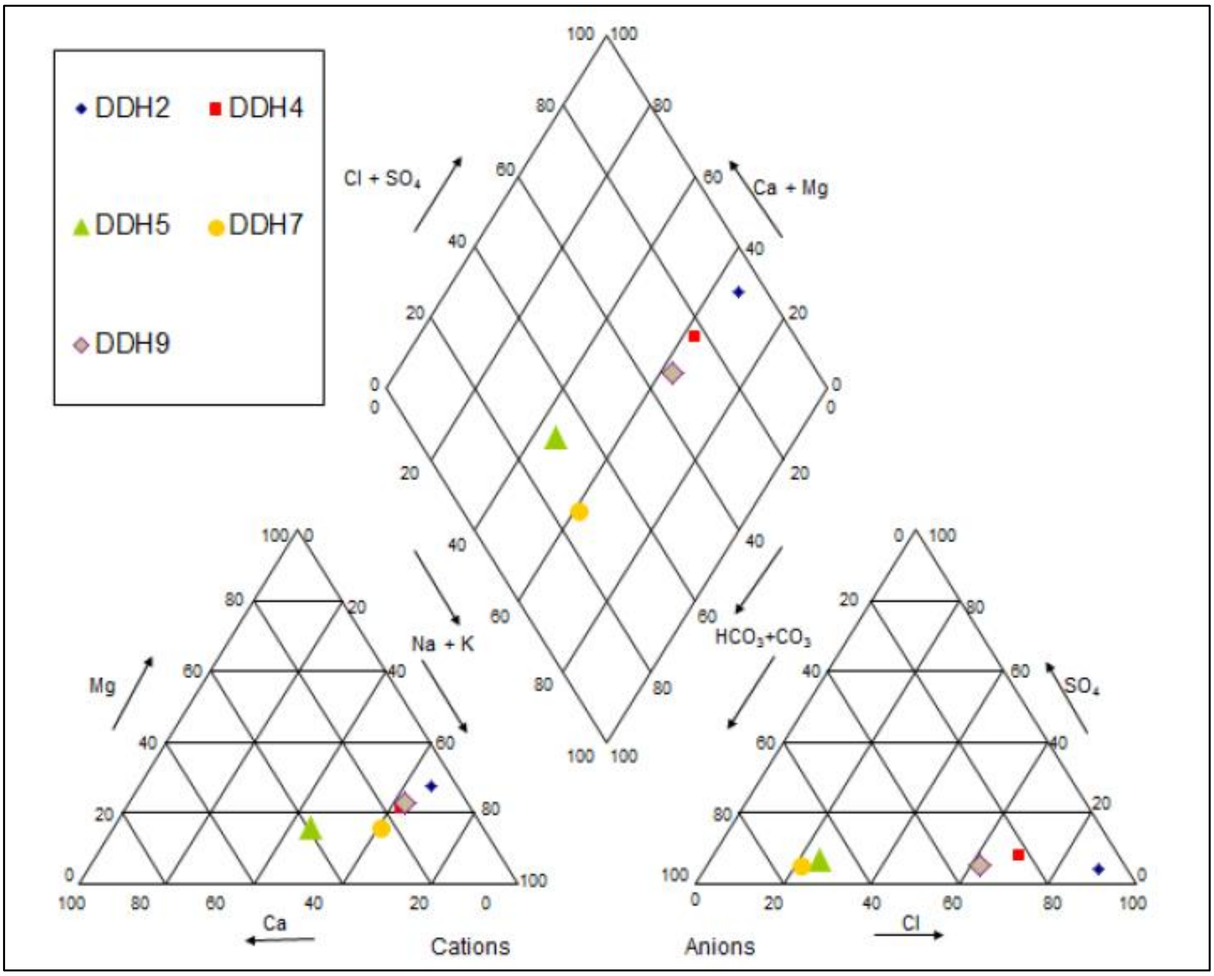

Figure 4.13: Piper diagram, showing relative compositions of groundwater wells

4.4.11 Acid mine drainage risk

Analyses of sulphur in groundwater varies between 2 and 39 mg/l in all bores, except for DDH01 (up to 62 mg/l and located 100 m west of the proposed quarry pit) and DDH2 (up to 185 mg/l, located 100 m south of the proposed quarry pit). Analyses of sulphate in the groundwater were 124 mg/l or less in all holes except DDH01 (to 225 mg/l) and DDH02 (to 634 mg/l).

pH measurements were made on core samples from DDH01 through DDH09 and pH values were between 6.1 and 9.2, with all but DDH02 between pH 8.8 and 9.2.

No observations of sulphide minerals were made in the core. Whole rock analyses of intervals of drill core from holes within the proposed quarry pit, including DDH07 – (composite 10.0m to 67.0m), DDH18 – (composite 13.4m to 36.5m) and DDH19 – (composite 13.4m to 49.5m) returned low sulphate values of 0.017 to 0.047%. On the basis of the low sulphur and sulphate contents in the rhyolite and groundwater it is considered there is a low probability of significant sulphide minerals being present and a low probability of acid mine drainage development.

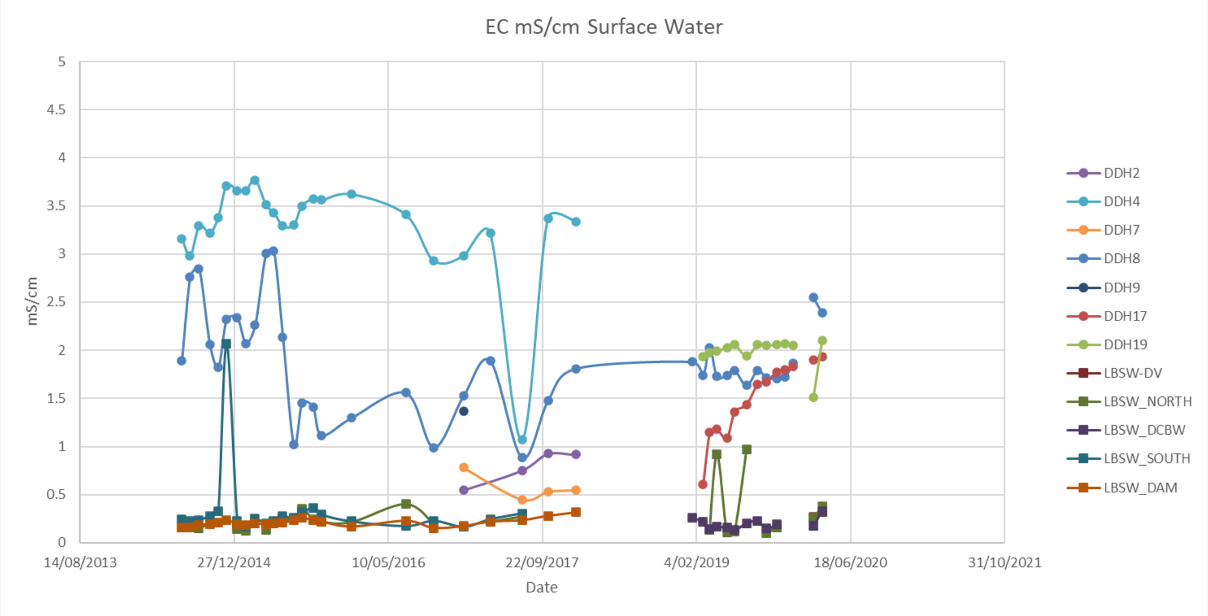

Figure 4.14: Electrical conductivity of surface water compared with groundwater

4.4.12 Site water balance

The current site water balance was estimated by Engeny using the GoldSim modelling package, and is based on the conceptual water management system for the site (refer to the Engeny report), including the proposed progression of quarrying activities. The model includes representations of:

Water sources:

- Direct rainfall onto dam/water storage surfaces.
- Runoff from natural, rehabilitated and disturbed catchment areas.
- Groundwater inflow to quarry.
- External water supplies.

Losses:

- Evaporation from dams and the quarry pit.
- Water lost to product.
- On-site dust suppression (haul roads and stockpiles).
- Discharges.

This report provides the anticipated groundwater inflow to the quarry for use within the Site Water Balance developed in the Engeny Report 2021.

Analyte		Anions and Cations															Alkalinity						Inorganics		
Analyte		Sodium	Calcium	Magnesium	Potassium	Total Sulfur	Sulphate	Chloride	Fluoride	Total Phosphorus	Nitrite + Nitrate as N	Total Nitrogen as N	Total Kjeldahl Nitrogen as N	Total Cations	Total Anions	Ionic Balance	Bicarbonate Alkalinity as CaCO3	Carbonate Alkalinity as CaCO3	Hydroxide Alkalinity as CaCO3	Total Alkalinity as CaCO3	Total Hardness as CaCO3	Electrical Conductivity @ 25°C	Total Dissolved Solids	Total suspended solids	pH
Units		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	meq/L	meq/L	%	mg/L	mg/L	mg/L	mg/L	mg/L	µS/cm	mg/L	mg/L	pH units
Trigger Values[1]		-	-	-	-	-	-	-	-	20	15	250	-	-	-	-	-	-	-	-	-	30-350	-	-	6.5 - 8.0
Sample Name	Sample Date																								
BHGWE-DDH1	10-Oct-14	112	5.0	6.0	2.0	29	110	85	0.6	-	-	-	-	5.67	5.89	1.94	60	< 1.0	< 1.0	60	37	601	391	102	7.19
	06-Jul-16	189	12	14	2.0	62	225	138	0.3	3.12	1.88	15	13	10	11	3.46	108	< 1.0	< 1.0	108	88	984	640	8,130	6.76
BHGWW-DDH3	10-Oct-14	194	29	58	6.0	121	404	286	< 1.0	-	-	-	-	16	17	2.82	42	< 1.0	< 1.0	42	311	1,760	1,140	1,660	6.0
	08-Jul-15	281	22	50	5.0	98	324	373	0.5	4.48	0.05	12	12	18	18	0.37	21	< 1.0	< 1.0	21	261	1,830	1,190	5,330	5.38
	06-Jul-16	258	38	77	4.0	185	634	276	0.7	8.99	0.02	19	19	20	22	4.86	28	< 1.0	< 1.0	28	412	1,950	1,270	15,500	5.48
	05-Oct-16	212	37	80	5.0	154	398	240	0.9	-	-	-	-	18	16	6.22	32	< 1.0	< 1.0	32	422	1,900	1,240	9,690	5.63
	10-Jan-17	202	33	74	6.0	142	410	249	0.7	-	-	-	-	17	16	1.88	25	< 1.0	< 1.0	25	387	1,610	1,050	14,300	5.45
	18-Jul-17	193	24	52	5.0	118	352	240	0.5	9.45	0.03	26	26	14	15	2.02	24	< 1.0	< 1.0	24	274	1,680	1,090	10,500	5.45
	11-Oct-17	222	30	66	6.0	132	346	300	0.7	-	-	-	-	17	17	0.61	64	< 1.0	< 1.0	64	347	1,680	1,090	7,020	5.84
	09-Jan-18	128	14	32	4.0	75	195	169	0.5	-	-	-	-	9.0	9.11	0.58	14	< 1.0	< 1.0	14	167	987	642	199	5.65
LB DDH7-1	19-Dec-16	70	31	8.0	6.0	2.0	2.0	31	0.3	-	-	-	-	5.4	4.75	6.41	192	< 1.0	< 1.0	192	122	509	331	360	6.72
LB DDH7-2	19-Dec-16	81	28	10	9.0	3.0	4.0	40	0.3	-	-	-	-	5.97	5.41	4.98	210	< 1.0	< 1.0	210	128	584	380	4,630	6.86
LB-DDH2	20-Dec-16	71	6.0	17	10	3.0	10	172	0.2	0.09	0.09	1.0	0.9	5.04	5.46	3.97	20	< 1.0	< 1.0	20	85	580	377	2,240	5.41
LB-DDH5	20-Dec-16	75	58	14	3.0	6.0	20	55	0.1	0.44	0.02	1.4	1.4	7.38	7.14	1.67	259	< 1.0	< 1.0	259	202	682	443	636	6.76
LB-DDH7	20-Dec-16	-	-	-	-	-	-	-	-	1.57	0.02	5.6	5.6	-	-	-	-	-	-	-	-	-	-	-	-
LB-DDH9	20-Dec-16	183	37	36	7.0	13	32	284	0.7	2.13	0.03	8.6	8.6	13	14	3.3	258	< 1.0	< 1.0	258	241	1,310	852	20,400	7.22
LBGW-DDH2	18-Jul-17	100	8.0	20	16	2.0	4.0	226	0.2	0.71	0.16	2.3	2.1	6.8	6.94	0.97	24	< 1.0	< 1.0	24	102	944	614	1,970	5.58
	11-Oct-17	105	11	26	17	2.0	5.0	274	0.2	-	-	-	-	7.69	8.51	5.07	34	< 1.0	< 1.0	34	134	840	546	1,190	5.75
	09-Jan-18	96	8.0	23	16	2.0	5.0	253	0.2	-	-	-	-	6.88	7.68	5.52	22	< 1.0	< 1.0	22	115	830	540	74	5.48
LBGW-DDH7	10-Jan-17	110	43	14	7.0	2.0	1.0	52	0.4	0.57	< 0.01	2.8	2.8	8.26	7.98	1.73	325	< 1.0	< 1.0	325	165	841	547	730	7.07
	18-Jul-17	41	41	4.0	4.0	1.0	< 1.0	41	0.2	0.02	0.04	0.6	0.6	4.26	4.43	1.98	164	< 1.0	< 1.0	164	119	540	351	24	6.88
	11-Oct-17	47	55	5.0	5.0	2.0	1.0	41	0.2	-	-	-	-	5.33	4.95	3.64	189	< 1.0	< 1.0	189	158	464	302	15	7.33
	09-Jan-18	44	51	4.0	4.0	2.0	2.0	39	0.2	-	-	-	-	4.89	4.86	0.33	186	< 1.0	< 1.0	186	144	486	316	15	6.96
LBGWN-DDH8	09-Oct-14	287	7.0	56	17	4.0	15	651	0.4	-	-	-	-	18	19	2.2	< 1.0	< 1.0	< 1.0	< 1.0	248	2,200	1,430	348	4.35
	08-Jul-15	180	3.0	32	10	12	39	341	0.2	0.23	0.19	0.5	0.3	11	10	2.04	< 1.0	< 1.0	< 1.0	< 1.0	139	1,210	786	1,300	4.58
	06-Jul-16	229	4.0	38	10	7.0	24	479	0.2	0.12	0.08	0.4	0.3	14	14	1.71	< 1.0	< 1.0	< 1.0	< 1.0	166	1,570	1,020	996	4.35
	05-Oct-16	151	2.0	26	8.0	9.0	29	298	0.2	-	-	-	-	9.01	9.01	0.01	< 1.0	< 1.0	< 1.0	< 1.0	112	1,170	760	134	4.77
	10-Jan-17	215	3.0	48	12	7.0	25	490	0.3	-	-	-	-	14	14	2.08	< 1.0	< 1.0	< 1.0	< 1.0	205	1,670	1,080	83	4.06
	18-Jul-17	141	1.0	17	7.0	13	34	242	0.1	0.1	0.09	0.6	0.5	7.76	7.57	1.22	2.0	< 1.0	< 1.0	2.0	72	1,050	682	486	4.89
	11-Oct-17	197	2.0	36	9.0	10	29	438	0.2	-	-	-	-	12	13	4.42	< 1.0	< 1.0	< 1.0	< 1.0	153	1,340	871	554	4.24
	09-Jan-18	280	2.0	49	15	11	28	493	0.3	-	-	-	-	17	15	7.07	< 1.0	< 1.0	< 1.0	< 1.0	207	1,700	1,100	560	4.18
LBGWS-DDH4	09-Oct-14	430	110	78	14	25	90	753	0.8	-	-	-	-	31	34	4.86	551	< 1.0	< 1.0	551	596	3,420	2,220	108	6.95
	08-Jul-15	556	125	93	16	34	105	766	0.8	0.02	0.09	0.5	0.4	39	34	6.37	504	< 1.0	< 1.0	504	695	3,550	2,310	25	6.91
	06-Jul-16	523	106	79	12	34	123	805	0.7	0.23	0.01	0.4	0.4	35	35	0.86	509	< 1.0	< 1.0	509	590	3,480	2,260	830	6.73
	05-Oct-16	516	122	88	14	30	76	780	0.7	-	-	-	-	36	32	5.61	436	< 1.0	< 1.0	436	667	3,740	2,430	338	7.17
	20-Dec-16	505	114	91	15	39	124	817	0.8	-	-	-	-	36	35	1.27	451	< 1.0	< 1.0	451	659	3,450	2,240	966	7.06
	18-Jul-17	199	46	18	8.0	8.0	18	129	0.2	0.13	0.01	1.2	1.2	13	12	4.51	377	< 1.0	< 1.0	377	189	1,390	904	519	6.68
	11-Oct-17	473	112	78	13	31	74	779	0.9	-	-	-	-	33	34	1.3	514	< 1.0	< 1.0	514	601	3,120	2,030	708	7.11
	09-Jan-18	466	100	64	12	28	92	689	0.5	-	-	-	-	31	32	2.44	552	< 1.0	< 1.0	552	513	3,050	1,980	1,020	6.9
LBSW-DAM	09-Oct-14	24	2.0	4.0	2.0	2.0	7.0	49	< 0.1	-	-	-	-	1.52	1.73	-	10	< 1.0	< 1.0	10	21	203	132	< 5.0	6.46
	08-Jul-15	32	4.0	6.0	2.0	2.0	6.0	52	< 0.1	0.02	< 0.01	0.5	0.5	2.14	1.83	-	12	< 1.0	< 1.0	12	35	238	155	9.0	6.48
	06-Jul-16	19	2.0	3.0	3.0	2.0	4.0	31	< 0.1	0.03	< 0.01	0.8	0.8	1.25	1.26	-	15	< 1.0	< 1.0	15	17	153	99	14	6.22
	05-Oct-16	23	2.0	4.0	3.0	1.0	3.0	33	< 0.1	-	-	-	-	1.51	1.21	-	11	< 1.0	< 1.0	11	21	171	111	< 5.0	6.74
	10-Jan-17	28	2.0	4.0	3.0	< 1.0	3.0	37	< 0.1	-	-	-	-	1.72	1.36	-	13	< 1.0	< 1.0	13	21	186	121	< 5.0	7.04
	18-Jul-17	31	4.0	5.0	2.0	3.0	6.0	51	< 0.1	0.02	0.01	0.6	0.6	2.01	1.74	-	9.0	< 1.0	< 1.0	9.0	30	244	159	< 5.0	6.28
	11-Oct-17	37	4.0	5.0	6.0	3.0	6.0	57	0.1	-	-	-	-	2.37	1.97	-	12	< 1.0	< 1.0	12	30	262	170	< 5.0	6.67
	09-Jan-18	32	4.0	5.0	3.0	2.0	5.0	52	< 0.1	-	-	-	-	2.08	1.83	-	13	< 1.0	< 1.0	13	30	270	176	18	6.73
LBSW-NORTH	09-Oct-14	23	4.0	4.0	3.0	2.0	< 10	46	< 0.1	-	-	-	-	1.6	1.72	-	21	< 1.0	< 1.0	21	26	214	139	< 5.0	6.63
	08-Jul-15	29	5.0	5.0	2.0	2.0	4.0	53	0.1	0.02	< 0.01	0.5	0.5	1.97	1.86	-	14	< 1.0	< 1.0	14	33	244	159	< 5.0	6.21
	06-Jul-16	16	5.0	3.0	3.0	4.0	7.0	23	< 0.1	0.06	< 0.01	1.0	1.0	1.27	1.19	-	20	< 1.0	< 1.0	20	25	142	92	32	6.29
	05-Oct-16	21	5.0	4.0	4.0	1.0	< 1.0	32	< 0.1	-	-	-	-	1.59	1.3	-	20	< 1.0	< 1.0	20	29	184	120	< 5.0	6.69
	18-Jul-17	38	6.0	5.0	3.0	3.0	6.0	59	< 0.1	0.02	< 0.01	0.6	0.6	2.44	2.07	-	14	< 1.0	< 1.0	14	36	295	192	< 5.0	6.22
LBSW-SOUTH	09-Oct-14	29	7.0	6.0	2.0	2.0	6.0	66	< 0.1	-	-	-	-	2.16	2.65	-	33	< 1.0	< 1.0	33	42	285	185	< 5.0	6.65
	08-Jul-15	35	8.0	6.0	2.0	1.0	9.0	51	< 0.1	0.02	< 0.01	0.6	0.6	2.47	2.14	-	26	< 1.0	< 1.0	26	45	260	169	< 5.0	6.67
	06-Jul-16	18	5.0	4.0	2.0	6.0	18	27	< 0.1	0.03	< 0.01	0.5	0.5	1.41	1.46	-	16	< 1.0	< 1.0	16	29	160	104	9.0	6.15
	05-Oct-16	28	7.0	6.0	2.0	< 1.0	< 1.0	42	< 0.1	-	-	-	-	2.11	1.74	-	28	< 1.0	< 1.0	28	42	241	157	< 5.0	6.8
	10-Jan-17	21	4.0	4.0	2.0	2.0	10	20	< 0.1	-	-	-	-	1.49	1.21	-	22	< 1.0	< 1.0	22	26	154	100	< 5.0	6.84
	18-Jul-17	43	7.0	7.0	2.0	5.0	11	62	< 0.1	0.01	0.01	0.5	0.5	2.85	2.3	-	16	< 1.0	< 1.0	16	46	342	222	< 5.0	6.43

Notes:

- - Not analysed

< - Less than laboratory limit of reporting

LOR - Laboratory limit of reporting

mg/L - Milligrams per litre

µS/cm - Microsiemens per centimeter

Bold indicates a detection above the laboratory limit of reporting

Criteria:

[1] Australian and New Zealand Environment and Conservation Council (ANZECC) - National Water Quality Management Strategy Guidelines using NSW Upland Rivers & 95% Protection Values

Table 4.7: Groundwater & surface water major ions compared to the ANZECC 2000 guidelines, items in pink showing exceedance of the criteria – locations in Figure 4.5

Analyte		Metals										
		Aluminum	Arsenic	Cadmium	Chromium	Copper	Iron	Lead	Mercury	Nickel	Selenium	Zinc
Units		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Trigger Values[1]		0.055	0.013	0.0002	0.001	0.0014	-	0.0034	0.0006	0.011	0.011	0.008
Sample Name	Sample Date											
BHGWE-DDH1	10-Oct-14	**0.08**	< 0.001	< 0.0001	< 0.001	**0.003**	< 0.05	< 0.001	< 0.0001	**0.001**	< 0.01	< 0.005
	06-Jul-16	**0.06**	< 0.001	**0.0001**	< 0.001	< 0.001	**0.12**	< 0.001	< 0.0001	< 0.001	< 0.01	**0.019**
BHGWW-DDH3	10-Oct-14	**0.22**	< 0.001	**0.0002**	< 0.001	**0.003**	**15**	< 0.001	< 0.0001	**0.048**	< 0.01	**1.81**
	08-Jul-15	**0.29**	< 0.001	< 0.0001	< 0.001	< 0.001	**6.16**	< 0.001	< 0.0001	**0.048**	< 0.01	**0.198**
	06-Jul-16	**0.31**	< 0.001	**0.0004**	< 0.001	< 0.001	**4.99**	< 0.001	< 0.0001	**0.088**	< 0.01	**0.396**
	05-Oct-16	**0.64**	< 0.001	**0.0007**	< 0.001	**0.001**	**1.58**	< 0.001	< 0.0001	**0.086**	< 0.01	**0.435**
	10-Jan-17	**1.52**	< 0.001	< 0.0001	**0.002**	**0.002**	**1.06**	< 0.001	< 0.0001	**0.052**	< 0.01	**0.12**
	18-Jul-17	**0.28**	< 0.001	**0.0003**	< 0.001	**0.001**	**7.18**	< 0.001	< 0.0001	**0.061**	< 0.01	**0.179**
	11-Oct-17	**0.11**	< 0.001	< 0.0001	< 0.001	**0.001**	**28**	< 0.001	< 0.0001	**0.061**	< 0.01	**0.701**
	09-Jan-18	**0.12**	< 0.001	< 0.0001	< 0.001	**0.002**	**0.07**	< 0.001	< 0.0001	**0.024**	< 0.01	**0.088**
LB DDH7-1	19-Dec-16	**0.22**	**0.022**	< 0.0001	**0.005**	**0.014**	**1.05**	**0.002**	< 0.0001	**0.002**	< 0.01	**0.005**
LB DDH7-2	19-Dec-16	**0.51**	**0.026**	< 0.0001	**0.006**	**0.017**	**1.31**	**0.006**	< 0.0001	**0.007**	< 0.01	**0.082**
LB-DDH2	20-Dec-16	**0.15**	< 0.001	**0.0003**	< 0.001	**0.001**	< 0.05	< 0.001	< 0.0001	**0.011**	< 0.01	**0.083**
LB-DDH5	20-Dec-16	**0.04**	**0.01**	< 0.0001	**0.001**	**0.002**	**0.66**	**0.003**	< 0.0001	**0.006**	< 0.01	< 0.005
LB-DDH9	20-Dec-16	**0.01**	**0.037**	< 0.0001	< 0.001	< 0.001	**0.17**	< 0.001	< 0.0001	**0.004**	< 0.01	< 0.005
LBGW-DDH2	18-Jul-17	**0.12**	< 0.001	**0.0012**	< 0.001	**0.001**	**0.05**	< 0.001	< 0.0001	**0.012**	< 0.01	**0.098**
	11-Oct-17	**0.15**	< 0.001	**0.0013**	< 0.001	**0.002**	< 0.05	< 0.001	< 0.0001	**0.014**	< 0.01	**0.155**
	09-Jan-18	**0.09**	< 0.001	**0.0012**	< 0.001	**0.001**	< 0.05	< 0.001	< 0.0001	**0.013**	< 0.01	**0.09**
LBGW-DDH7	10-Jan-17	**0.12**	**0.015**	< 0.0001	**0.004**	**0.009**	**0.94**	**0.007**	< 0.0001	**0.003**	< 0.01	< 0.005
	18-Jul-17	**0.11**	< 0.001	< 0.0001	< 0.001	< 0.001	**0.64**	< 0.001	< 0.0001	**0.001**	< 0.01	**0.013**
	11-Oct-17	**0.12**	< 0.001	< 0.0001	< 0.001	< 0.001	**0.78**	< 0.001	< 0.0001	**0.001**	< 0.01	**0.022**
	09-Jan-18	**0.06**	< 0.001	< 0.0001	< 0.001	< 0.001	**0.46**	< 0.001	< 0.0001	**0.001**	< 0.01	**0.012**
LBGWN-DDH8	09-Oct-14	**1.75**	**0.002**	< 0.0001	< 0.001	**0.01**	**5.16**	**0.007**	< 0.0001	**0.019**	< 0.01	**0.327**
	08-Jul-15	**0.7**	< 0.001	< 0.0001	< 0.001	**0.004**	**1.06**	**0.002**	< 0.0001	**0.008**	< 0.01	**0.143**
	06-Jul-16	**0.91**	< 0.001	< 0.0001	< 0.001	**0.008**	**0.1**	**0.004**	< 0.0001	**0.008**	< 0.01	**0.188**
	05-Oct-16	**0.66**	< 0.001	< 0.0001	< 0.001	**0.009**	< 0.05	**0.004**	< 0.0001	**0.006**	< 0.01	**0.142**
	10-Jan-17	**1.19**	< 0.001	< 0.0001	< 0.001	**0.009**	< 0.05	**0.006**	< 0.0001	**0.01**	< 0.01	**0.204**
	18-Jul-17	**0.37**	< 0.001	< 0.0001	< 0.001	**0.005**	**0.06**	**0.002**	< 0.0001	**0.004**	< 0.01	**0.127**
	11-Oct-17	**1.03**	< 0.001	< 0.0001	< 0.001	**0.008**	**0.05**	**0.006**	< 0.0001	**0.007**	< 0.01	**0.165**
	09-Jan-18	**1.31**	**0.002**	< 0.0001	< 0.001	**0.011**	**0.06**	**0.007**	< 0.0001	**0.01**	**0.01**	**0.195**
LBGWS-DDH4	09-Oct-14	< 0.01	**0.039**	< 0.0001	< 0.001	< 0.001	**8.06**	< 0.001	< 0.0001	< 0.001	< 0.01	**0.007**
	08-Jul-15	< 0.01	**0.039**	< 0.0001	< 0.001	< 0.001	**2.14**	< 0.001	< 0.0001	< 0.001	< 0.01	< 0.005
	06-Jul-16	< 0.01	**0.03**	< 0.0001	< 0.001	< 0.001	**0.97**	< 0.001	< 0.0001	< 0.001	< 0.01	< 0.005
	05-Oct-16	< 0.01	**0.014**	< 0.0001	< 0.001	< 0.001	**0.14**	< 0.001	< 0.0001	< 0.001	< 0.01	< 0.005
	20-Dec-16	< 0.01	**0.022**	< 0.0001	< 0.001	< 0.001	**0.94**	< 0.001	< 0.0001	< 0.001	< 0.01	**0.006**
	18-Jul-17	**0.14**	**0.031**	< 0.0001	**0.001**	< 0.001	**1.31**	**0.001**	< 0.0001	**0.001**	< 0.01	< 0.005
	11-Oct-17	< 0.01	**0.027**	< 0.0001	< 0.001	< 0.001	**0.33**	< 0.001	< 0.0001	< 0.001	< 0.01	**0.11**
	09-Jan-18	< 0.01	**0.007**	< 0.0001	< 0.001	< 0.001	**0.42**	< 0.001	< 0.0001	< 0.001	< 0.01	**0.006**
LBSW-DAM	09-Oct-14	**0.4**	**0.001**	< 0.0001	< 0.001	< 0.001	**0.86**	< 0.001	< 0.0001	< 0.001	< 0.01	< 0.005
	08-Jul-15	**0.29**	< 0.001	< 0.0001	< 0.001	< 0.001	**0.5**	< 0.001	< 0.0001	< 0.001	< 0.01	**0.007**
	06-Jul-16	**0.87**	< 0.001	< 0.0001	< 0.001	< 0.001	**1.02**	< 0.001	< 0.0001	< 0.001	< 0.01	< 0.005
	05-Oct-16	**0.52**	< 0.001	< 0.0001	< 0.001	< 0.001	**0.74**	< 0.001	< 0.0001	< 0.001	< 0.01	< 0.005
	10-Jan-17	**0.06**	**0.001**	< 0.0001	< 0.001	< 0.001	**0.27**	< 0.001	< 0.0001	< 0.001	< 0.01	< 0.005
	18-Jul-17	**0.49**	< 0.001	< 0.0001	< 0.001	< 0.001	**0.74**	< 0.001	< 0.0001	< 0.001	< 0.01	< 0.005
	11-Oct-17	**0.09**	< 0.001	< 0.0001	< 0.001	**0.002**	**0.46**	< 0.001	< 0.0001	< 0.001	< 0.01	**0.052**
	09-Jan-18	**0.02**	**0.001**	< 0.0001	< 0.001	< 0.001	**0.18**	< 0.001	< 0.0001	< 0.001	< 0.01	< 0.005
LBSW-NORTH	09-Oct-14	**0.37**	**0.002**	< 0.0001	< 0.001	**0.001**	**1.1**	< 0.001	< 0.0001	< 0.001	< 0.01	**0.006**
	08-Jul-15	**0.58**	**0.001**	< 0.0001	< 0.001	< 0.001	**1.55**	< 0.001	< 0.0001	< 0.001	< 0.01	< 0.005
	06-Jul-16	**2.59**	**0.001**	< 0.0001	< 0.001	< 0.001	**2.24**	< 0.001	< 0.0001	< 0.001	< 0.01	< 0.005
	05-Oct-16	**0.91**	**0.002**	< 0.0001	< 0.001	< 0.001	**2.32**	< 0.001	< 0.0001	< 0.001	< 0.01	< 0.005
	18-Jul-17	**0.3**	**0.002**	< 0.0001	< 0.001	< 0.001	**2.21**	< 0.001	< 0.0001	< 0.001	< 0.01	**0.005**
LBSW-SOUTH	09-Oct-14	**0.15**	< 0.001	< 0.0001	< 0.001	**0.001**	**0.39**	< 0.001	< 0.0001	< 0.001	< 0.01	**0.01**
	08-Jul-15	**0.88**	< 0.001	< 0.0001	< 0.001	< 0.001	**0.94**	< 0.001	< 0.0001	< 0.001	< 0.01	< 0.005
	06-Jul-16	**2.22**	< 0.001	**0.0002**	< 0.001	< 0.001	**1.18**	< 0.001	< 0.0001	< 0.001	< 0.01	**0.013**
	05-Oct-16	**0.44**	**0.001**	< 0.0001	< 0.001	< 0.001	**0.8**	< 0.001	< 0.0001	< 0.001	< 0.01	< 0.005
	10-Jan-17	**1.37**	**0.002**	< 0.0001	< 0.001	< 0.001	**1.86**	< 0.001	< 0.0001	< 0.001	< 0.01	< 0.005
	18-Jul-17	**0.27**	**0.001**	< 0.0001	< 0.001	< 0.001	**0.72**	< 0.001	< 0.0001	< 0.001	< 0.01	< 0.005

Notes:
- - Not analysed
< - Less than laboratory limit of reporting
mg/L - Milligrams per litre
Bold indicates a detection above the laboratory limit of reporting

Criteria:

[1] Australian and New Zealand Environment and Conservation Council (ANZECC) - National Water Quality Management Strategy Guidelines using NSW Upland Rivers & 95% Protection Values

Table 4.8: Groundwater & surface water major ions compared to the ANZECC 2000 guidelines, items in pink showing exceedance of the criteria – locations in Figure 4.5

5 CONCEPTUAL HYDROGEOLOGICAL MODEL

The conceptual groundwater model for the site is outlined below, with a visual representation in Figures 5.1 and 5.2.

- Groundwater infiltration occurs through the thin soil profile and directly into the outcropping sandstone and fractured rhyolite in the area of the proposed quarry and upslope to the west. Recharge is low in general and is estimated by DPIE to be in the order of 4%.
- Groundwater is hosted in pores and fractures within the sandstone and within fractures in the rhyolite unit. Groundwater flows through the site area towards the east and lower topographic areas upgradient of the Karuah River.
- Groundwater is moderately deep, in the order of 10 to 35 m below surface, with the proposed quarry extending to approximately 70 m below ground surface, depending on location within the proposed quarry.
- The hydraulic conductivity in the proposed quarry site is very low, based on permeability testing and observations of the drill core.
- Groundwater in the sandstone and rhyolite is derived from rainwater infiltration, and is generally within 1 pH unit of neutral, and is relatively low EC (0.5 to 3.5 mS/cm). Longer groundwater residence times are likely in the deeper groundwater.
- Groundwater in bore DDH08 at the eastern end of the proposed quarry site has a pH of around 4. This is thought to represent the presence of shaley units near the base of this hole, beneath the rhyolite and sandstone. The quarry is designed so the base remains in the rhyolite, above the shaly units, limiting interaction and possible future discharge of groundwater from the underlying shaley units.
- Some shallow groundwater and interflow probably discharges to Deep Creek east of the proposed quarry site. However, the water quality from sampling of surface water suggests groundwater discharge to the creek is probably relatively minor, as the water in pools in the creek is considerably lower EC than the groundwater in the rhyolite and sandstone.
- Excavation of the quarry will result in some inflow of groundwater into the quarry pit, although this is expected to be relatively minor, considering the relatively low porosity and permeability of the sediments and rhyolite.
- The quarry occupies only a small part of the catchment for Deep Creek, and is effectively limited to a ridge line between two ephemeral creeks. The groundwater intercepted within the proposed quarry area is unlikely to be an important part of overall groundwater discharge to Deep Creek.
- The rhyolite does not have any appreciable sulphide content, hence there is not considered an acid mine drainage risk from quarrying this material.

5.1 Pre-Development / Current Conditions

Currently some shallow groundwater is likely to discharge to Deep Creek. However, the low EC values of the creek water quality data suggest the groundwater component is minor.

5.2 Conditions During Operation

During operation groundwater interflow through the thin soil profile will discharge into the quarry pit, as will groundwater from fractures and porous sediments that are intersected in quarrying operations. This groundwater will be used for activities on site, such as dust control on roads, limiting flow of this intercepted groundwater to Deep Creek.

5.3 Post Development Conditions

Post development groundwater will continue to discharge into the quarry excavation, where it will be collected in sumps at low points and be allowed to evaporate. The final landform of the quarry will minimise any groundwater flow from the quarry to the creek and will avoid intersecting groundwater from the lower pH unit below the rhyolite to maintain the best possible long term groundwater quality in the quarry.

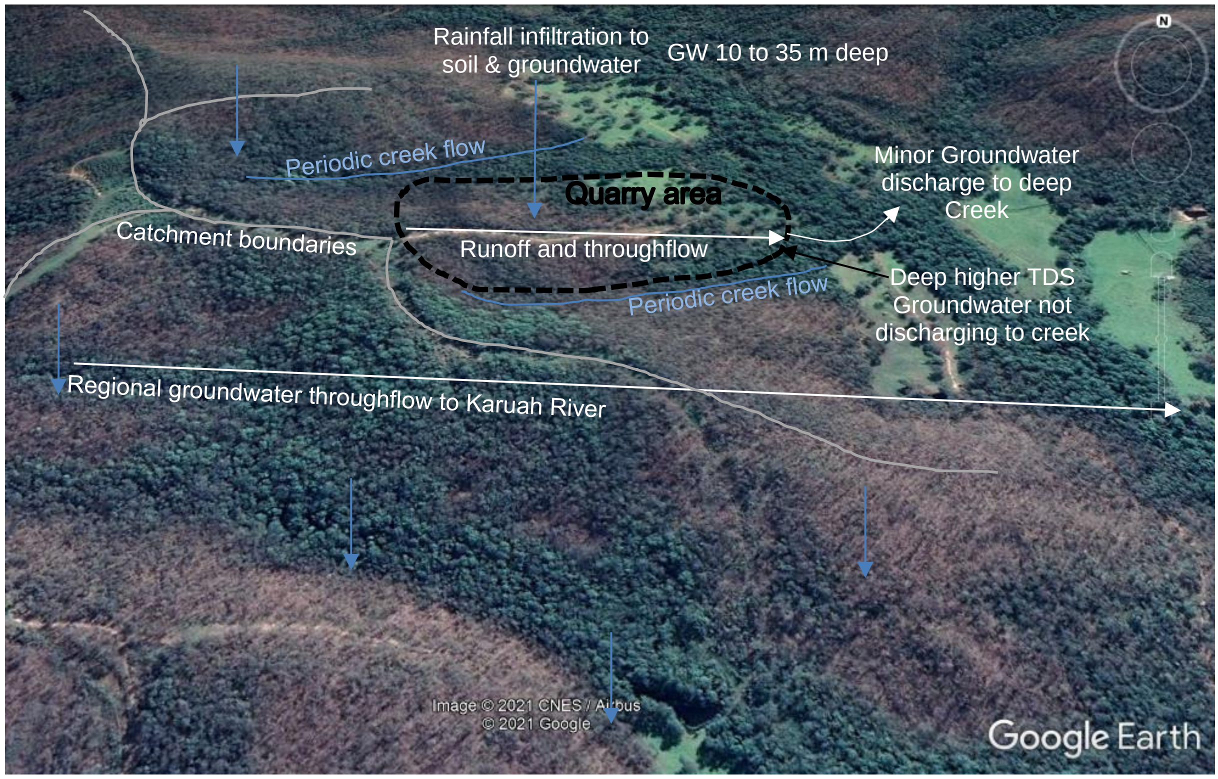

Figure 5.1: Conceptual model elements shown on a Google Earth image of the project area

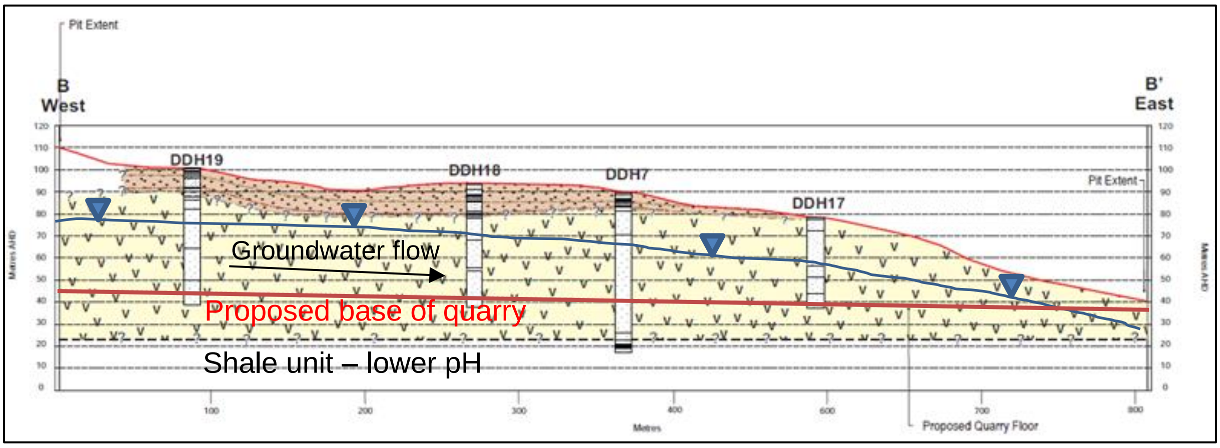

Figure 5.2: West-East cross section looking north through the quarry area, showing the water table in blue and the base of the quarry in red, overlying the interpreted shale unit intersected in DDH7

6 ESTIMATION OF GROUNDWATER INFLOWS

6.1 Estimation Approach

The objective is to develop an estimate of groundwater inflow into the open pit development and evaluate the range in potential inflows by testing the estimate with different input parameters. Because there is relatively sparse data available and the inflows are expected to be low, compared to unconsolidated or consolidated porous sediments, an analytical groundwater model has been used rather than a numeric groundwater model using a software package, such as Modflow. The model considers inflows from Stages 1 through 3.

Important assumptions of the conceptual model are:

- Lowering the water table by open pit development will decrease the saturated thickness of rock materials providing pit inflow.
- In addition to seepage from the pit walls, significant seepage will also occur through the pit bottom.
- The rock formation is semi-infinite below the pit and there is no impermeable boundary at depth. In reality the pit is designed to not reach the shaly unit underlying the base of the rhyolite, where monitoring suggests the groundwater is lower quality. The underlying shale and sandstone sequence is likely to be more fractured and have primary and fracture porosity, in comparison to the rhyolite. These units have been subject to permeability testing around the pit area.
- Steady state flow conditions exist near the quarry pit. This assumption is reasonable, considering the time frame of the quarry development.

The estimation has been made with the analytical model developed by Marinelli and Niccoli (Groundwater, Vol 38. No 2. March-April 2000, p 311-314), who developed the analytical model to take account of seepage through the walls and also the floor of a quarry and built on earlier work by other investigators. Their model includes a separate analytical model for both the quarry walls and the base of the quarry, referred to Zone 1 and Zone 2 respectively.

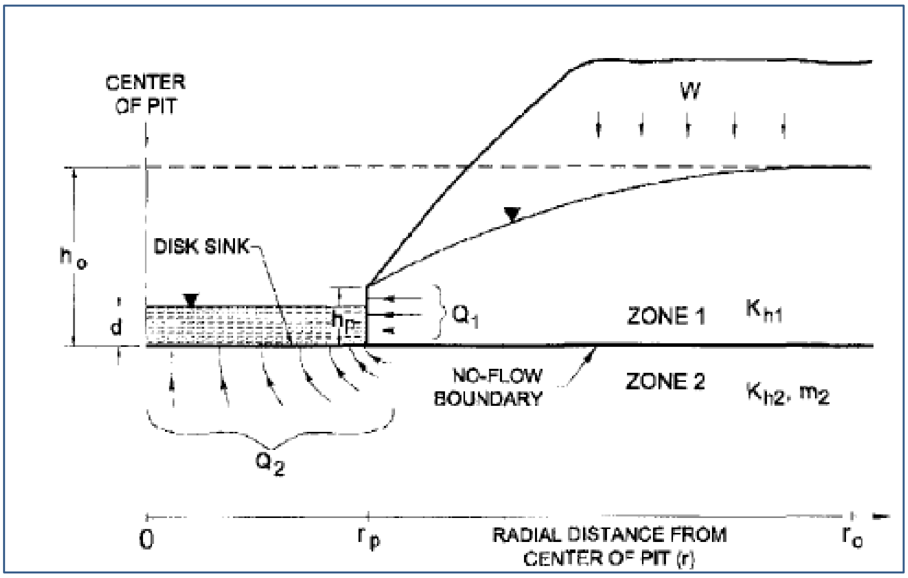

Figure 6.1: Analytical model developed by Marinelli and Niccoli (2000) for pit inflow estimates

Variables used in the model are as follows:

- K_h Horizontal Hydraulic conductivity range
- K_v Vertical hydraulic conductivity (scenarios used with 1:1 to horizontal and 1:10)
- m_2= Sqrt (Kh2/Kv2)
- r_p Effective pit radius
- r_o Radius of influence - maximum extent of cone of depression from centre of the pit
- h_o Original saturated thickness (variable and approximate)
- h_p Saturated thickness above base of Zone 1 at r_p from the centre of the pit
- W Recharge flux (from rain infiltration) mm/year converted to m/second
- d Height of pond above pit floor (if a pond is present)

Zone 1 – Pit Walls

Specific assumptions of the analytical model include:

- Pit walls are approximated as a circular cylinder
- Groundwater flow is horizontal, with the Dupuit-Forchheimer approximation used to account for changes in saturated thickness due to depression of the water table;
- The static pre-mining water table is approximately horizontal;
- Uniformly distributed recharge is distributed across the site from surface infiltration. All recharge within the radius of influence of the cone of depression is assumed to be captured by the pit;
- Groundwater inflow towards the pit is axially symmetric.

Zone 1 inflow is defined as $Q_1 = W*pi*(r_o^2-r_p^2)$

Zone 2 – Base of the Pit

The analytical solution is based on steady state flow to one side of a circular disk sink of constant and uniform drawdown. The sink represents the bottom of the pit. The solution is based on the following assumptions:

- Hydraulic head is initially uniform and hydrostatic throughout Zone 2. Initial head is equal to the elevation of the initial water table in Zone 1;
- The disk sink has a constant hydraulic head equal to the elevation of the pit lake water surface (if present). If the pit is completely dewatered the disk sink head is equal to the elevation of the pit bottom.
- Flow to the disk sink is three dimensional and axially symmetrical.
- Materials within Zone 2 are anisotropic and the principal coordinate direction for hydraulic conductivity are horizontal and vertical.

Zone 2 inflow (through the base of the pit) is defined as $Q_2 = 4r_p*(K_h/m_2)*(h_o-d)$

6.2 Inflow Estimation

The dimension of the quarry pit at full development (i.e. Stage 3, Stage 4, has minimal additional disturbance) is approximately 300 x 700 metres, aligned approximately east-west along a ridge, with small creeks to the north and south of the pit. The analytical model for simulation of the quarry inflows requires the use of a circular pit shape as a simplification. Consequently, the area of the pit at the different stages was converted to a circular diameter with equivalent area to the pit at that time. A diameter of 450 m was selected as an approximation for the pit at full development, with an effective pit radius of 225 m used for the estimation. The Stage 1 pit radius is estimated at equivalent to 115 m, Stage 2 at 160 m and the Stage 3 pit at 225 m radius. Stage 4 involves a slight eastern extension in the lower part of the pit, and for inflow purposes the pit radius is considered equivalent to that of Stage 3.

- The groundwater level in piezometer DDH08, closest to the eastern end, and topographically lowest part of the pit is typically 10 to 12 m below surface, declining to almost 15 m below surface during the drier years of 2019 to 2020.
- Monitoring from holes DDH17 and DDH19 in the centre and west of the planned pit area respectively are in the order of 25 to 30 m below surface.
- The development of the pit ranges from a high point of 110 m AHD, to a base at 37 m, for a difference in elevation slightly more than 70 m.
- The groundwater level across the pit area is hence assigned a base value of 30 m for the thickness of the saturated unit from the phreatic surface to the base of the pit (ho in the analytical model – see Figure 6.1). This is, of course, variable over the pit area due to the topography, but this is considered a reasonable simplification.

The seepage estimates have been estimated with a range of parameters to assess the potential range of inflows, based on different parameters applied. The equation developed by Marinelli and Niccoli (2000) was used as a check on the parameters being used for h_p (the seepage face height), K_h the hydraulic conductivity and r_o the distance from the pit that is dewatered. Evaluation of these parameters in this equation provided a check against the known thickness of the saturated zone across the quarry area, which is considered to be in the order of 30 m thick.

$$h_o = \sqrt{h_p^2 + \frac{W}{K_{h1}}\left[r_o^2 \ln\left(\frac{r_o}{r_p}\right) - \frac{(r_o^2 - r_p^2)}{2}\right]}$$

Figure 6.2: Analytical equation relating initial saturated thickness to the diameter of drawdown and hydraulic conductivity

The calculations and estimation of seepage are presented in Appendix 2 and summarised in Table 6.1 below. This considers a staged inflow into the pit, with inflows differing based around the size of the pit and the saturated thickness of rock in the area excavated.

	SCENARIOS STAGE 1				
	UNITS	**LOW**	**MIDDLE**	**HIGH**	**PREFERRED**
ZONE 1 Calculation					
$Q_1 = W*pi*(r_o^2-r_p^2)$	**m^3/s**	6.7253E-05	0.00019726	0.000732221	1.96E-04
	m^3/year	2,121	6,221	23,091	6,192
	ML/year	2	6	23	6
ZONE 2 Calculation		Kh:KV 1:1			
	m^3/s	2.51E-07	5.15E-04	1.37E-03	2.07E-04
	m^3/year	8	16,240	43,274	6,528
	ML/year	0	16	43	7
		Kh:KV 10:1			
$Q_2 = 4r_p*(K_h/m_2)*(h_o-d)$	**m^3/s**	7.93E-08	1.63E-04	4.34E-04	6.55E-05
	m^3/year	3	5,136	13,685	2,064
	ML/year	0	5	14	2
TOTAL seepage Zones 1&2 (K_h = 10 K_v scenario)	**ML/year**	**2**	**11**	**37**	**8**
TOTAL seepage Zones 1&2 (K_h = K_v scenario)	**ML/year**	**2**	**22**	**66**	**13**

	SCENARIOS STAGE 2				
	UNITS	**LOW**	**MIDDLE**	**HIGH**	**PREFERRED**
ZONE 1 Calculation					
$Q_1 = W*pi*(r_o^2-r_p^2)$	**m^3/s**	0.0001046	0.00053555	0.001665634	5.36E-04
	m^3/year	3,299	16,889	52,527	16,889
	ML/year	3	17	53	17
ZONE 2 Calculation		Kh:KV 1:1			
	m^3/s	7.22E-07	1.45E-03	3.85E-03	4.80E-04
	m^3/year	23	45,587	121,472	15,137
	ML/year	0	46	121	15
		Kh:KV 10:1			
$Q_2 = 4r_p*(K_h/m_2)*(h_o-d)$	**m^3/s**	2.28E-07	4.57E-04	1.22E-03	1.52E-04
	m^3/year	7	14,416	38,413	4,787
	ML/year	0	14	38	5
TOTAL seepage Zones 1&2 (K_h = 10 K_v scenario)	**ML/year**	**3**	**31**	**91**	**22**
TOTAL seepage Zones 1&2 (K_h = K_v scenario)	**ML/year**	**3**	**62**	**174**	**32**

		SCENARIOS STAGE 3			
	UNITS	**LOW**	**MIDDLE**	**HIGH**	**PREFERRED**
ZONE 1 Calculation					
$Q_1 = W*pi*(r_o^2-r_p^2)$	**m^3/s**	0.000272396	0.00079446	0.002935655	7.94E-04
	m^3/year	8,590	25,054	92,579	25,054
	ML/year	9	25	93	25
ZONE 2 Calculation		Kh:KV 1:1			
	m^3/s	1.02E-06	2.03E-03	5.42E-03	8.10E-04
	m^3/year	32	64,107	170,820	25,544
	ML/year	0	64	171	26
		Kh:KV 10:1			
$Q_2 = 4r_p*(K_h/m_2)*(h_o-d)$	**m^3/s**	3.21E-07	6.43E-04	1.71E-03	2.56E-04
	m^3/year	10	20,272	54,018	8,078
	ML/year	0	20	54	8
TOTAL seepage Zones 1&2 (K_h = 10 K_v scenario)	**ML/year**	**9**	**45**	**147**	**33**
TOTAL seepage Zones 1&2 (K_h = K_v scenario)	**ML/year**	**9**	**89**	**263**	**51**

Table 6.1: Summary of Possible seepage scenarios (scenarios include variation in Kv) progressively increasing from Stage 1 through Stage 2 and Stage 3 pits

Table 6.1 presents a range of seepage scenarios with different inputs for each of the three pit stages. Two scenarios are provided for seepage through the pit floor, one with K_h=K_v and the other with K_h=10K_v. The table outlines the range of case for the pit at different stages of development, from the small Stage 1 pit, to the Final Stage 3 pit. The preferred estimate is considered to be the more likely inflow volume, considering the range of parameters applied.

- Considering a moderate hydraulic conductivity, based on the measurements available, and the K_h=10K_v case the preferred inflow estimate for the final Stage 3 pit is approximately 33 ML/year.
- In the K_h=10K_v case the range of potential inflows is in the range of 9 to 147 ML/year. However, given the lowest hydraulic conductivity was in the rhyolite unit it is likely the seepage will be at the low end of this range.
- In the K_h=K_v case the range of potential inflows is larger. **The preferred inflow estimate is 51 ML/year**, with a range of 9 to 263 ML/year.

Considering the input variables, it is likely inflows into the quarry are in the range of 8 to 51 ML/year over the life of the quarry.

However, until quarrying intersects the groundwater surface groundwater inflows will be minor and most water reporting to the pit will be from rain and overland runoff.

Groundwater seepage is expected to be towards the low end of the estimates, given the pit is elongate in an east-west direction and lies between two ephemeral drainages, to which groundwater will naturally drain. These drainages occur outside the north and south limits of the Stage 3 pit.

Note that as the depth to the standing water level in the centre of the quarry area is in the range of 25 to 30 m below surface it is likely Stage 1 and much of Stage 2 quarry development will have relatively little groundwater inflow, as the material being quarried is essentially in the unsaturated zone.

As quarrying progresses deeper and excavates below the water table, then groundwater inflows are likely to increase, until reaching an equilibrium through dewatering as the quarry reaches its final extent.

6.3 Sensitivity to Input Parameters

Seepage through Zone 1 (the walls) is sensitive to:

- The hydraulic conductivity – the most sensitive parameter.
- The radius of dewatering r_o, measured from the centre of the pit. This value has been approximately constrained by applying values to the equation in Figure 6.2 and iterating them to evaluate their impact – suggesting a value with a radius of 250 to 500 m from the centre of the pit at the different stages of development is applicable for r_o, to fit with the observed saturated thickness above the pit floor.

Seepage through Zone 2 (the floor) is sensitive to:

- The hydraulic conductivity – again the most sensitive parameter.
- The relationship between vertical and horizontal hydraulic conductivity. If these are assigned to be equal there is a much larger predicted inflow than if the standard relationship of $K_h=10K_v$ is applied.

Seepage estimates should be re-evaluated as the quarry progresses, and more information becomes available. This groundwater can be used for operational requirements at the site. However, it would not be available for construction as early excavation is likely to be dry.

7 GROUNDWATER IMPACT ASSESSMENT

7.1 Potential to Change Physical and Chemical Parameters of Groundwater

The proposed quarrying activities are considered unlikely to affect the physical and chemical parameters of groundwater, as the quarry is quarrying the lower end of a ridge and quarrying will not require the use of chemicals other than standard explosives for blasting. Quarrying is considered unlikely to result in pH changes, changes to groundwater EC or mobilisation of metals, or acid mine drainage.

The limited groundwater inflow into the proposed quarry is predicted to be low flow from fractures, with relatively low salinity non-toxic groundwater diluted by rainwater once drained into the proposed quarry. Storage for groundwater inflows would be constructed at the eastern end of the quarry. The chemistry of groundwater discharge in the final quarry void would tend to the composition of rainwater, due to dilution by rainwater.

Potential contamination sources during quarry operations would be associated with hydrocarbon leaks from refuelling equipment or mobile earthmoving equipment, and spills in fuel (and limited chemical) storage facilities and the mechanical workshop proposed for the quarry. Extraction operations would require some fuel storage on site in adequately bunded areas to retain any spilled fuel and prevent infiltration into fractures in the rock.

Appropriate plans for the workshop and fuel storage and transportation areas and an effective water management plan and control measures would significantly reduce the risk of environmental impacts.

Any septic tanks for on-site toilet facilities will require installation to NSW and national standards, to minimise any risk of effluent infiltration into groundwater.

The storm water retention areas at the site should be designed to minimise risk of discharge to Deep Creek, where the water quality objectives correspond to the ANZECC values for NSW Upland Rivers and 95% Protection Values (with values from site sampling and ANZECC trigger values in Table 4.8). It is acknowledged that the groundwater in most of the wells exceeds these guidelines for electrical conductivity and is outside the pH range, as well as exceeding the concentrations for a collection of the metals. The surface water monitoring locations are within the ANZECC levels, with the exception of pH, aluminium and zinc.

There is not envisaged to be a significant impact on the groundwater as a result of the quarry intersecting flows and causing groundwater discharge into the pit, rather than some natural discharge to Deep Creek and other discharge further down gradient to the east towards the Karuah River.

7.2 Impact on Groundwater Dependent Ecosystems (GDEs)

Identified terrestrial GDE's are located throughout the area around and including the site, based on mapping and classification by Government Agencies. These correspond to Spotted Gum and Broad Leaf Mahogany Dry Sclerophyll Forests of the Hunter-Macleay area through the proposed quarry site. Red Bloodwood / Smooth-barked Apple heathy woodlands are also extensive in the general area.

Deep Creek is assessed as a separate GDE referred to as Weeping Lilly Pilly / Water Gum Riparian warm temperature rainforest. Deep Creek is one of many drainages in the area with the same assessed GDE. This GDE is mapped beginning adjacent to the proposed quarry and stockpile area, and continues down Deep Creek, continuing to the east of The Bucketts Way. The quarry area would only occupy a small area adjacent to this GDE.

Five kilometres to the east aquatic GDE's are present along the Karuah River, recorded in assessment by NSW and National government agencies. These GDE's are down gradient of the site, with the sub-catchment hosting the proposed quarry site only a very small portion of the overall catchment supplying runoff to the Karuah River and associated GDE's. The Karuah River is not likely to be a significant recipient of groundwater discharge from the quarry area.

The proposed quarry area is located, between two creeks. Groundwater investigations have shown that the rocks to be quarried have low hydraulic conductivity and groundwater storage. Evaluation of surface water and groundwater shows that the water quality is distinct and groundwater contribution to Deep Creek is likely to consist of limited shallow interflow discharge to the creek and limited discharge of deeper groundwater in bedrock fractures.

Consequently, quarry operations are not expected to have any significant impact on GDE's in the area.

7.3 Local Surface Water

Surface water sampling was carried out by the proponent, with samples analysed at ALS laboratories showing the groundwater intersected in the quarry area and the surface water in Deep Creek have different characteristics. The surface water has a lower EC, compared to the groundwater and the pH is higher.

Limited connection is interpreted between the fractured rock groundwater in the proposed quarry site and surface water in Deep Creek. Groundwater discharge into the quarry is not envisaged to be a significant impact on the surface water in Deep Creek or on any adjacent riparian land. Water in the creek is considered to mostly accumulate following significant flow events in the creek. The quarry is designed to retain inflows from groundwater seepage, so this can be used on site for dust suppression and site infrastructure that does not require potable water. In the event of overflow of groundwater from the quarry pit this would be due to extreme storm event run-off, which would dilute the groundwater and contribute to more regional inflows to Deep Creek. Water quality in the quarry and Deep Creek will be monitored regularly as part of the proposed quarry operation.

7.4 Impact on Existing Bores

Registered groundwater bores are located 2 km or more from the site, with only 3 within 6 km. The nearest bores are separated from the area of the proposed quarry development by surface water drainages. The proposed quarry is expected to intersect only local groundwater flow and it is concluded the Project will not adversely impact any neighbouring registered bores.

The aquifer in the proposed quarry site and surrounds is considered to be low yielding, with discontinuous fractures that are disconnected from the surface water system.

The groundwater drawdown due to quarry operation is unlikely to extend more than several hundred metres from the proposed quarry. Following quarry closure groundwater seepage into the pit would continue, with the groundwater evaporating in the quarry pit, or becoming diluted with surface water and discharging to Deep Creek, particularly in very wet conditions. Consequently, quarrying operations and incidental groundwater discharge into the proposed quarry pit will not cause any impact to the known registered bores in the area around the site.

7.5 Impact on Cultural Sites

There are no known cultural sites which could be affected by changes to the groundwater environment during or post quarrying.

7.6 Predicted Groundwater Inflows to the Quarry

Fractures are observed within the rhyolite and underlying sandstone and siltstone units. However, these are likely to be discontinuous and with limited connection to Deep Creek. Other quarrying operations north of Newcastle in similar rock types have exhibited essentially dry conditions over the quarrying operations (Cook, 2018) and it is expected the proposed quarry will be largely dry, with groundwater draining from fractures in the walls of the quarry.

An assessment of inflow to the quarry has been made using an analytical groundwater solution that was developed for quarries and mining operations and evaluates inflows through the floor and walls of a pit.

It is suggested a Water Access Licence is applied for to cover the quarry operating conditions, allowing for a 51 ML WAL, to cover groundwater seepage into the quarry, and the utilisation of inflow groundwater or groundwater obtained from any possible bore installation, for dust suppression on the site. The water resources on site are covered by the Water Sharing Plan for the North Coast Fractured and Porous Rock Groundwater Sources, and there are sufficient unallocated licences available in the WSP.

7.7 Groundwater Level and Quality Monitoring Program

Monitoring of groundwater levels will continue in parallel with development and operation of the proposed quarry, building on the groundwater monitoring from 2014 to the present. Replacement monitoring sites (i.e. DDH01, DDH02 or newly constructed wells) will be used to replace wells within the quarry outline that will be decommissioned as quarrying progresses.

The water level will be monitored with manual water level measurements and data loggers, with periodic water quality sampling. Additional monitoring wells may be required through the life of the quarry where groundwater observations are not consistent with expectations.

Water quality will continue to be monitored at the existing groundwater monitoring sites and surface water sites, to establish whether changes in groundwater quality occur during the life of the quarry operation.

7.8 Site Rehabilitation and Modified Landform

Following completion of the proposed quarry operations groundwater will continue to discharge into the quarry pit and evaporate, with no significant impact of the quarry development considered to occur on the surrounding area.

7.9 Risk Matrix

Risk item	Risk rating	Rational
Risk of change in groundwater levels to GDE's	Low	Groundwater is >10 m below surface in much of the proposed quarry. Limited discharge to Deep Creek likely based on EC and pH data. GDE's in area are principally tree species, with other tree species along Deep Creek
Risk of timing in change of groundwater fluctuations to GDE's	Low	Some seasonal fluctuation in groundwater but generally > 10 m over most of the site.
Risk of changing base flow conditions on GDE's	Low	Quarry will only intercept a small amount of the regional groundwater in the vicinity of Deep Creek. Water chemistry suggests groundwater discharge to Deep Creek is minor
Risk of acid mine drainage or iron contamination	Low	Analyses from investigation of the rhyolite in the quarry area indicate it has a low sulphur content and is a felsic rock with low iron content
Risk of changing physical and chemical conditions of the water source	Low	Local groundwater "catchment" is small. Groundwater seepage into quarry will evaporate or be stored and used for onsite activities. Discharge to Deep Creek will only occur in major rainfall/flood events, where there is major dilution by rainfall
Risk of change in the beneficial use of the water source	Low	Groundwater will be intercepted and evaporated or used on site. Groundwater up and down gradient along the creek line will be unaffected. Minor risk from petroleum product or lubricant spills from quarry machinery
Risk of causing impacts on other groundwater users	Low	Other groundwater users are more than 2 km from the site and are not known to be significant groundwater extractors. Groundwater in this area is relatively low productivity
Risk of impacting cultural sites	Low	There are no known cultural sites which could be affected by changes to the groundwater environment during or post mining

Table 7.1: Summary of major risk items and rational for the risk rating

8 RECOMMENDATIONS

8.1 Monitoring

The objectives of monitoring groundwater are to:

- Evaluate changes in groundwater levels in response to quarrying, to refine the analytical groundwater estimate of inflows into the pit (taking account of rainfall and surface water inflows).
- Evaluate the water quality of the groundwater inflows to the pit and their subsequent dilution by rainfall, prior to discharge from the quarry.

Monitoring would allow modification to the WAL volume to reflect actual inflows. Monitoring would also confirm the quality of groundwater entering the pit and the quality of water that would discharge to Deep Creek following rainfall dilution.

- Continued monitoring of the current groundwater network (DDH2, 4, 8, 17 and 19) is recommended prior to and during quarry operations, to evaluate drawdown in the groundwater level associated with quarry operation. This should continue with a period of post-closure monitoring. Recommended monitoring activities and frequencies are outlined in Table 8.1.
- As wells within the quarry are likely to be destroyed during quarry operations it is recommended that additional existing wells are added to the monitoring network (such as DDH01, if possible) and new wells are added to compensate for loss of wells within the quarry. These wells should be constructed as purpose-built monitoring wells, with the top of the well-sealed so there is no infiltration of rainfall or run-off between the PVC pipe and annulus of the well. In particular wells should provide information on groundwater quality between the quarry and Deep Creek.
- A dedicated monitoring well should be installed down gradient of the petroleum storage area, to monitor for hydrocarbon contamination of groundwater.
- Water levels and water quality should be measured during the first year of operations on a monthly basis, followed by quarterly monitoring.
- It is recommended data loggers are installed in wells at least during the first year of quarry operations to better understand the drawdown cone developing due to quarrying.
- Water quality monitoring should consist of the analytes and frequencies outlined in Table 8.2.
- A rain gauge should be installed on site and rainfall measurements made throughout the life of the quarry operation for comparison with surface and groundwater data.
- A database should be maintained with manual water level measurements and measurements from data loggers. Data should be reviewed and plotted at least quarterly, to confirm the quality of the measurements.
- Given the natural background groundwater conditions at the quarry site show exceedances of the ANZECC 2000 95% levels for NSW Upland Rivers for many of the metals and some other parameters the selection of trigger values for future reporting needs to be carefully selected.

A groundwater management plan should be developed for the site when it is operating.

Monitoring	Monitoring Activity	Monitoring Frequency	Objective
Water level	Manual dip measurements and data loggers	At least monthly measurements and monthly downloads of loggers sampling every 6 hours	Designed to collect useful information on drawdown associated with quarry operation and recharge from rain
Water quality	Samples from monitoring wells and surface water sites	Take samples quarterly, to compare with pre-quarrying data. Review data after 3 years to re-evaluate the samplign frequency	Designed to detect any change in groundwater and surface water chemistry that could be related to quarry operations
Rainfall	Automated rainfall measurements	Measurement of rainfall with <0.5 mm sensitivity	Designed to collect comprehensive rainfall data for comparison with other data sources

Table 8.1: Recommended monitoring activities and frequency

Recommended Analytes and Sampling Frequency			
Cations		**Petroleum hydrocarbons suite (TPH & BTEX)**	Quarterly
Sodium (Na)	Quarterly	**pH**	Monthly initially, then quarterly
Potassium (K)	Quarterly	**Electrical Conductivity**	Monthly initially, then quarterly
Magnesium (Mg)	Quarterly	**Metals**	
Calcium (Ca)	Quarterly	Aluminum	Quarterly
Ammonia (NH4)	Quarterly	Arsenic	Quarterly
Anions		Cadmium	Quarterly
Chloride (Cl)	Quarterly	Chromium	Quarterly
Sulphate (SO4)	Quarterly	Copper	Quarterly
Carbonate alkalinity (as CaCO3)	Quarterly	Iron	Quarterly
Bicarbonate alkalinity (as CaCO3)	Quarterly	Lead	Quarterly
Total alkalinity (as CaCO3)	Quarterly	Mercury	Quarterly
Total Phosphorus	Quarterly	Nickel	Quarterly
Nitrite + Nitrate as N	Quarterly	Selenium	Quarterly
Total Nitrogen as N	Quarterly	Zinc	Quarterly
Total Kjeldahl Nitrogen as N	Quarterly		

Table 8.2: Recommended analytes and frequency of sampling during quarrying operations

8.2 Analysis

Water level and water quality data should be analysed following each quarterly sampling round and plotted to evaluate trends in the data that may correlate with rainfall and climatic conditions or with development of the quarry site. This information will be useful for management of groundwater and minimising discharge to Deep Creek.

8.3 Reporting

Reporting for the operating quarry Water Management Plan (WMP) should contain the following information:

- Presentation and analysis of water levels in groundwater monitoring wells.
- Presentation and analysis of groundwater physical and chemical parameters and changes over time.
- Presentation of rainfall data and the possible correlations with groundwater and surface water measurements.
- Monthly information should be presented in internal reports and in reporting to government agencies.

Reporting should include:

- A map showing the location of sites in the monitoring network.
- Rainfall data and annual variations.
- Graphs showing changes in groundwater level over time (hydrographs), comparing results between monitoring wells and with rainfall data.
- Tables and graphs showing changes in groundwater chemistry, identifying any trends and comparison with ANZECC values and other values which may be relevant trigger values for monitoring and reporting.
- Measurement and recording of inflows into the quarry and evaluation against predictions.
- Conclusions from monitoring and any suggested modifications to the monitoring network.

9 SUMMARY

- This groundwater assessment provides an evaluation of the impact of the proposed quarry on the groundwater in the vicinity and other groundwater users.
- The quarry is to be developed on a rhyolite unit that was emplaced within sandstone and siltstone sediments. The rhyolite has no primary porosity, with groundwater only present in discontinuous subvertical fractures. Sandstones and siltstones with some primary porosity, in addition to fracture porosity, overlie the rhyolite and ae below the rhyolite and the quarry floor.
- The fractures in the sediments and rhyolite allow direct recharge from rainfall (estimated at a regional scale in the Water Sharing Plan to be 4% of rainfall) and movement of groundwater within the quarry area. The rhyolite and underlying sediments are interpreted to be under semi-confined to confined conditions and are unlikely to have porosity of more than a few percent associated with fractures.
- The proposed quarry is estimated to have a low inflow of groundwater, due to the low permeability rhyolite rock type which is the target material for quarrying. The sandstone and siltstone units overlying the rhyolite are generally above the water table, so are not all water-bearing.
- Quarrying operations in similar volcanic units in the same Water Sharing Plan area are recorded to be essentially dry, suggesting the proposed quarry development will be very similar.
- The low inflow of groundwater to the quarry will allow groundwater to accumulate in the base of the pit, where it will be available for site activities, such as dust suppression.
- Groundwater in the area around the proposed quarry has an EC that is up to 10 times that in surface water ponds within the bed of deep Creek, where the EC is low and in the order of 250 uS/cm. However, the groundwater is still relatively high-quality water, acceptable for agricultural use but not as potable water.
- Unless there is contamination of groundwater in the quarry during excavation from explosive residues or hydrocarbons it is unlikely there would be an impact on the groundwater quality in the area.
- Groundwater records on the BoM Groundwater Explorer show that the nearest registered groundwater bore is 35 m deep and located 2 km east southeast and downgradient of the site, 200 m west of The Bucketts Way road. This is listed as a stock bore. The next nearest registered bores are 4.3 and 6.2 km east and north northeast of the site, with depths of 66 and 53 m and uses as a monitoring bore and a domestic bore respectively. Quarry groundwater drawdown and associated activities are not expected to impact these users.
- Aquatic GDE’s are restricted to the area around the Karuah River, 5 km east of the site, and are extremely unlikely to be impacted by activities of the proposed quarry site. The proposed quarry site is mapped as hosting moderate and low priority GDE’s determined from regional assessment. These consist of Hunter-Macleay Dry Sclerophyll Forests containing Spotted Gum and Broad-leaved Mahogany. The Deep Creek stream bed is an area of Weeping Lilly Pilly and Water Gum riparian vegetation of Northern Warm Temperate Rainforest. This is classified as a high potential GDE, based on regional studies.
- The principal uncertainty in the groundwater assessment is the potential heterogeneity in the fracturing of the rhyolite and surrounding sediments. Ongoing monitoring is recommended to better understand the response to rainfall of the groundwater level.

- Groundwater inflows into the quarry have been estimated by stage and are considered most likely to be in the range of 8 to 51 ML/year, increasing as the quarry is developed.
- Appropriate storage and handling of hydrocarbons, any chemical products and site toilet and wastewater facilities will minimise the risk of groundwater contamination.
- A Water Management Plan is required to cover the details of regular groundwater monitoring at site and the reporting of results and analysis of data. Interpretation and presentation of data will be required internally for the company and for reporting to government agencies.

Report prepared by Hydrominex Geoscience Pty Ltd
Principal Hydrogeologist Murray Brooker
7/09/21

REGISTERED PROFESSIONAL GEOSCIENTIST
AUSTRALIAN INSTITUTE OF GEOSCIENTISTS
MURRAY BROOKER
RPGeo No: 10086

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11 LIMITATIONS

This report was prepared by Hydrominex Geoscience and has the following limitations:

- The specific instructions received from project manager Wedgetail Project Consulting, for client Ironstone Developments Pty Ltd on the project t
- May not be relied upon by any third party not named in this report for any purpose except with the prior written consent of Hydrominex Geoscience
- This report comprises the formal report, documentation sections, tables, figures and appendices as referred to in the index to this report and must not be released to any third party or copied in part without all the material included in this report for any reason;
- The report only relates to the site referred to in the scope of works being located at Limeburners Creek, NSW (“the site”);
- The report relates to the site as at the date of the report as conditions may change thereafter due to natural processes and/or site activities;
- No warranty or guarantee is made in regard to any other use than as specified in the scope of works and only applies to the depth tested and reported in this report;
- Fill, soil, groundwater and rock to the depth tested on the site may be fit for the use specified in this report. Unless it is expressly stated in this report, the fill, soil and/or rock may not be suitable for classification as clean fill if deposited off site; and

11.1 GENERAL LIMITATIONS

11.1.1 SCOPE OF SERVICES

The work presented in this report is prepared by Hydrominex in response to the specific scope of works requested by and approved by the client. It cannot be relied on by any other third party for any purpose except with our prior written consent. The client may distribute this report to other parties and in doing so warrants that the report is suitable for the purpose it was intended for. However, any party wishing to rely on this report should contact us to determine the suitability of this report for their specific purpose.

11.1.2 DATA SHOULD NOT BE SEPARATED FROM THE REPORT

This report is provided inclusive of all documentation sections, limitations, tables, figures and appendices and should not be provided or copied in part without all supporting documentation for any reason, as this may lead to misinterpretation.

11.1.3 SUBSURFACE CONDITIONS ARE NOT CONSTANT

Subsurface conditions related to groundwater exhibit natural and anthropogenic change. Site conditions vary with time and analysis cannot cover every analyte or contaminant that could possibly be present at the site. Field observations, field measurements and professional judgement increases the probability of identifying contaminated soil and or groundwater at the site. Under no circumstances can it be considered that these findings represent the actual condition of the site at all points in time or in all locations geographically.

Environmental studies identify the sub-surface conditions only at the points of sampling and when they are taken. Actual conditions vary between sampling locations differ and no sub-surface sampling program, irregardless of the extent, can show what is present below the ground surface. The actual boundaries between materials may be far more gradual or abrupt than an assessment indicates. Actual conditions in areas not sampled may differ from those predicted and this cannot be anticipated. However, steps can be taken to help minimize the impact.

11.1.4 CONSISTENCY IN DATA COLLECTION

Advice and interpretation are provided on the basis that subsequent site work will be undertaken by Hydrominex. This will maintain consistency in how data is collected and interpreted, conduct additional tests that may be necessary and recommend relevant solutions to issues encountered on site. Third parties may misinterpret our reporting and we cannot be responsible for how the information in this report is used or interpreted.

11.1.5 LIMIT OF LIABILITY

This study has been carried out to a particular scope of works at a specified site and should not be used for any other purpose. This report is provided on the condition that Hydrominex disclaims all liability to any person or entity other than the client in respect of anything done or omitted to be done and of the consequence of anything done or omitted to be done by any such person in reliance, whether in whole or in part, on the contents of this report.

Furthermore, Hydrominex disclaims all liability in respect of anything done or omitted to be done and of the consequence of anything done or omitted to be done by the client, or any such person in reliance, whether in whole or any part of the contents of this report of all matters not stated in the brief outlined in Hydrominex’s proposal number and according to Hydrominex’s general terms and conditions and special terms and conditions.

To the maximum extent permitted by law, we exclude all liability of whatever nature, whether in contract, tort or otherwise, for the acts, omissions or default, whether negligent or otherwise for any loss or damage whatsoever that may arise in any way in connection with the supply of services. Under circumstances where liability cannot be excluded, such liability is limited to the value of the purchased service.

12 APPENDICES

APPENDIX A GES HYDRAULIC CONDUCTIVITY EVALUATION

LIMEBURNERS CREEK QUARRY PROJECT

Preliminary Aquifer Testing

FOR

WOODBURY CIVIL

By

Groundwater Exploration Services Pty Ltd

January 2017

TABLE OF CONTENTS

TABLES

FIGURES

1 INTRODUCTION

The Limeburners Creek Quarry Project is located approximately 15 kilometres north of the Pacific Highway along the Buckets Way within the Mid-Coast Regional Council Local Government Area (LGA).

In 2013 and 2014, investigation holes were drilled with a drill and blast rig and fully cored HQ rotary diamond core drilling method. One of these DH4 had 50mm PVC screen installed while all others have remained as open holes. **Figure 1** shows the relative location of these drill holes.

The site includes variable terrain with elevations from 35m to 145m AHD with Late Carboniferous geology including felsic volcanics, lithic Sandstones, shale, coal, ignimbrites and tuffs.

Groundwater Exploration Services was asked to investigate the drill holes and undertake testing to determine hydrogeological physical properties of the host geology.

Figure 1: Aerial Photo Showing Drillhole Location

2 AQUIFER TESTING

Where possible, access to these investigative drill holes was made with a low flow submersible pump to gain access to a groundwater quality sample and also test response to pumping. Groundwater level loggers were used to gather water level response to the low rates of pumping and analysis has been undertaken using a variety of empirical methods. Given the nature of the bores and the rate and time of pumping, these results provide an indicative overview of the physical properties of the sites geology. Table 1 presents a summary of test results which are further discussed in the following sections.

Curve matching of the tests undertaken are shown Appendix A.

Table 1: Summary of Test Results

Site	SWL	Hydraulic Conductivity (m/day)
DDH2	35.86	1×10^{-5}
DDH4	11.86	2.75×10^{-3}
DDH5	22.45	1×10^{-5}
DDH7	8.09	3×10^{-10}
DDH9	7.99	1.3×10^{-2}

2.1 DDH1

DDH1 also located on high ground was blocked at approximately 7m below ground level (bgl) and was not sampled.

2.2 DDH2

DDH2 is located on a ridge and is approximately 40m in depth although dipping the bore drill hole revealed caving had left the drill hole open to approximately 37m. Standing water level (SWL) was measured at 35.86m bgl.

A low low submersible pump was installed to just below the water table and pumped for a short time enabling groundwater quality sampling. A logger installed on the pump recorded a small recovery which was analysed using Bower-Rice slug test empirical method.

Hydraulic conductivity was assessed to be 1×10^{-5}m/day.

2.3 DDH4

DDH4 is located at low elevation on the project area. It is the only drill hole on site that has been converted to a monitoring bore using installed 50mm PVC slotted screen and bore casing. SWL was at 11.86m bgl. Bore depth is 54m with 21m of slotted screen installed in an alternating 3m screen, 3m blanks from 15m depth. The bore is gravel packed from 14.5m and sealed to surface with bentonite.

Figure 2 shows the drawdown and recovery profile for DDH4 which returned a more conventional profile to test pumping. A leaky aquifer model was used to gain an estimated transmissivity of 1.1×10^{-1} m^2/day. For the 40m of saturation, this is equal to a hydraulic conductivity of 2.75×10^{-3} m/day

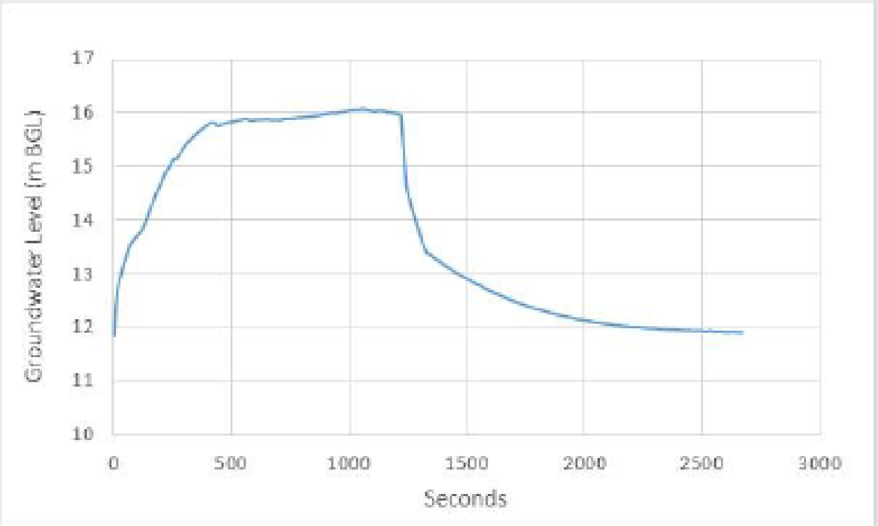


Figure 2: Drawdown and Recovery Profile for DDH4

2.4 DDH5

DDH5 is located in lower terrain where exposed volcanics at surface.

DDH5 was drilled to 105m and it is unknown what depth the drill hole is open to, as there is likely to be some caving. The hole is open to at least 60m.

SWL is 22.45mbg and the low flow sampling pump was installed to 35m depth.

Figure 3 shows the drawdown characteristics. Simular to conditions found at DDH7, most of the drawdown represents bore volume removal. Recovery is negligible over the monitored period.

Analysis of hydraulic conductivity therefore again focuses on the recovery period using slug test analytical methods for confined conditions using the Bower-Rice solution, results in a hydraulic conductivity of 1.1 x 10^{-5} m/day.

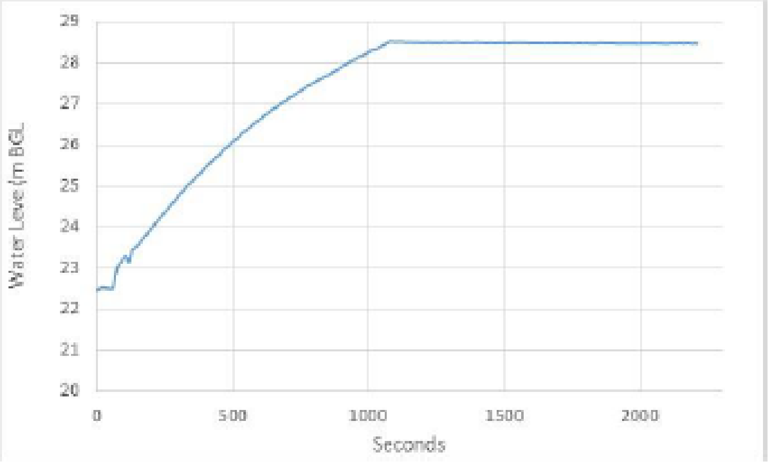


Figure 3: Drawdown Profile for DDH5

2.5 DDH7

DDH7 is an open hole 72m in depth with a short section of surface casing. Standing water level is 8.09m below ground level (bgl) which also marked the depth that tree roots have invaded the borehole.

A low flow submersible was installed and pumped at a rate of between 0.1 and 0.15 L/sec until pump capability limited further drawdown. The pump was removed and a logger reinstalled to capture recovery. **Figure 4** shows the drawdown from pumping the column of water in the HQ drill hole and subsequent lack of recovery following a short break in the data. Recovery is very slow and drawdown merely empties the bore volume without accepting any significant groundwater. Analysis of hydraulic conductivity focuses on the recovery period using slug test analytical methods for confined and unconfined conditions including Bower-Rice and Hvorslev solutions, all returning similar results of 3 x 10^{-10} m/day.

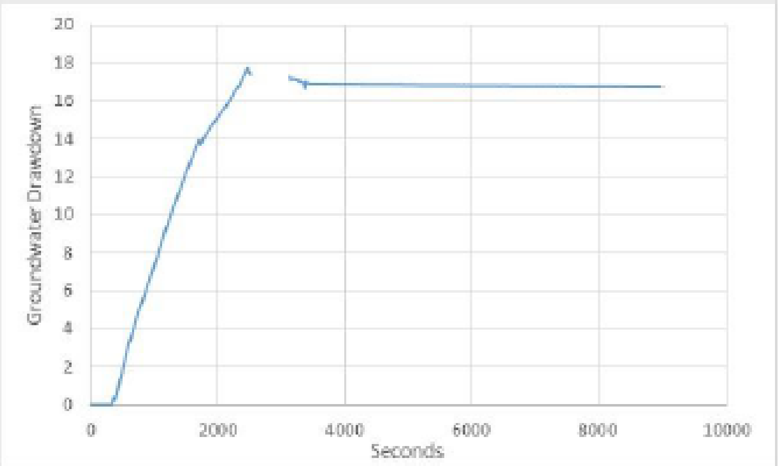


Figure 4: Drawdown Profile for DDH7

2.6 DDH9

DDH9 is also located at low elevation within the project area. The SWL at the time of testing was 7.99m below ground level. A blockage of bentonite which was mobile prevented installation of the low flow submersible with any significant depth below the water table and the bentonite initially restricted the pump and then disabled the pump after 12 minutes of pumping. However, the limited test time data is presented in Figure 5. Analysis of this curve was undertaken using a leaky aquifer model (Hantush) providing an estimated transmissivity of 5.2 x 10^{-1} m^2/day. Given there is uncertainty as to what connectivity within the bore is given that in contains a failed bentonite seal, an arbitrary 40m of the drilled depth of 60m has been used to ascertain a hydraulic conductivity of 1.3 x 10^{-2} m/day.

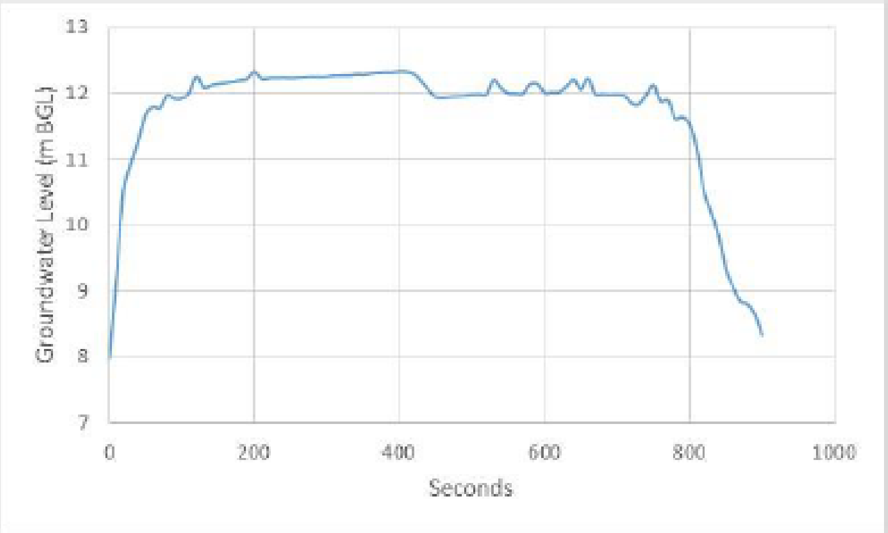


Figure 5: Drawdown and Recovery Profile for DDH9

3 GROUNDWATER QUALITY

The exploration drill holes were sample for water quality. Water quality data obtained is summarised in **Table 2.** Water samples were collected for laboratory testing of a comprehensive suite of analytes which includes:

- pH, EC and total dissolved solids (TDS);
- Major cations and anions; and
- Dissolved and total metals.

The laboratory analysis was undertaken by ALS Environmental, a NATA-accredited laboratory based in Sydney.

Table 2: Groundwater Quality Analytical Test Results

Site		DDH4	DDH7	DDH5	DDH2	DDH9
Electrical Conductivity @ 25°C	µS/cm	3450	574	682	580	1310
Total Dissolved Solids (Calc.)	mg/L	2240	373	443	377	852
Total Hardness as CaCO3	mg/L	659	124	202	85	241
Hydroxide Alkalinity as CaCO3	mg/L	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	mg/L	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	mg/L	451	236	259	20	258
Total Alkalinity as CaCO3	mg/L	451	236	259	20	258
Sulfate as SO4 - Turbidimetric	mg/L	124	11	20	10	32
Chloride	mg/L	817	42	55	172	284
Calcium	mg/L	114	30	58	6	37
Magnesium	mg/L	91	12	14	17	36
Sodium	mg/L	505	86	75	71	183
Potassium	mg/L	15	10	3	10	7
Aluminium	mg/L	<0.01	0.23	0.04	0.15	0.01
Arsenic	mg/L	0.022	0.03	0.01	<0.001	0.037
Cadmium	mg/L	<0.0001	<0.0001	<0.0001	0.0003	<0.0001
Chromium	mg/L	<0.001	0.005	0.001	<0.001	<0.001
Copper	mg/L	<0.001	0.014	0.002	0.001	<0.001
Lead	mg/L	<0.001	0.006	0.003	<0.001	<0.001
Nickel	mg/L	<0.001	0.005	0.006	0.011	0.004
Selenium	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc	mg/L	0.006	0.008	<0.005	0.083	<0.005
Iron	mg/L	0.94	0.91	0.66	<0.05	0.17
Mercury	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Fluoride	mg/L	0.8	0.4	0.1	0.2	0.7
Nitrite + Nitrate as N	mg/L	----	0.02	0.02	0.09	0.03
Total Kjeldahl Nitrogen as N	mg/L	----	5.6	1.4	0.9	8.6

Site		DDH4	DDH7	DDH5	DDH2	DDH9
Total Nitrogen as N	mg/L	----	5.6	1.4	1	8.6
Total Phosphorus as P	mg/L	----	1.57	0.44	0.09	2.13
Total Anions	meq/L	34.6	6.13	7.14	5.46	13.8
Total Cations	meq/L	35.5	6.48	7.38	5.04	12.9
Ionic Balance	%	1.27	2.79	1.67	3.97	3.3

Piper plots can provide indications of the recharge-discharge processes, and also allow a comparison of water samples derived from different environments within the hydrological cycle. Recently-recharged water tends to plot closer to the left-hand apex of the diamond field in the Piper diagram, and waters further from the source of recharge closer to the right-hand side.

Figure 5 illustrates a Piper Diagram which shows that groundwater from the five sampled drill holes is variable. Two distinct groundwater types can be seen particularly with respect to anion concentrations. DDH7 and DDH5 show high bicarbonate with respect to chloride which generally indicates a higher relative recharge component in comparison to other samples. DDH2, DDH4 and DDH9 by comparison show more mature groundwater characteristics with higher relative chloride concentrations.

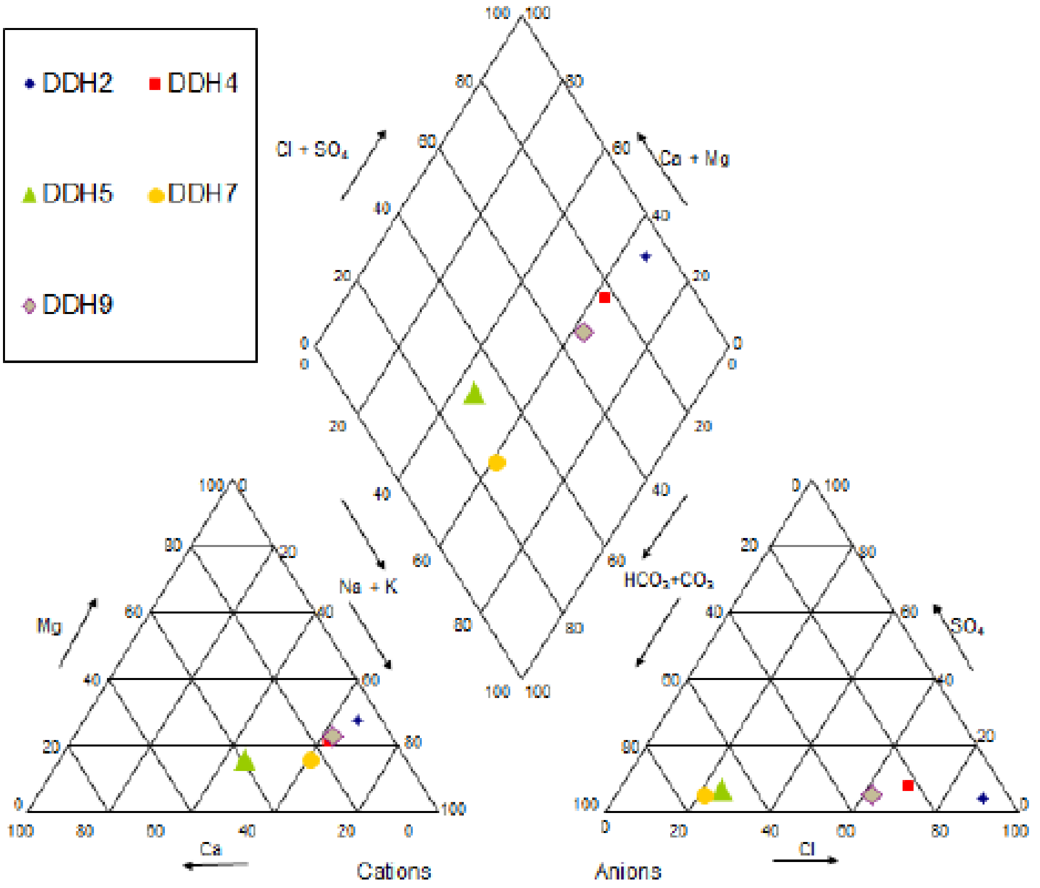


Figure 6: Piper Diagram

4 DISCUSSION

GES was requested to assess groundwater investigation holes suitability for undertaking basic aquifer testing with the intent of gaining some understanding of the hydrogeological physical properties of the proposed quarry site and to gain some indication of potential groundwater inflows to a quarry excavation. As drilling of these investigation holes occurred in 2013 / 2014, some deterioration can be assumed and invasion of tree roots, bentonite seal and or drilling muds present and bore caving have impacted all of the open holes.

The fully core drilling to date has shown that the geology includes very hard indurated felsic volcanics, lithic sandstones, and other metasediments. Drill core photos show zones of intense fracturing but also zones where fracture frequency is quite sparse. There is little to no alluvium within the project area and any groundwater resource will exists within the fracture frocks that make up the targeted geological aggregate resource.

Access to five resource investigation holes and successfully pumped in order to retrieve a groundwater quality sample and with the use of groundwater loggers, drawdown response to pumping was also undertaken. However it should be noted that the pump used was very low flow and which was not intended to place an aquifer under pumping stress for any significant length of time.

Groundwater levels range from 8m to 36m in those investigation holes accessed and although no contour surfaces are presented, it is apparent that a large proportion of the aggregate resource is unsaturated.

Testing of the resource investigation / delineation drill holes has shown variable permeability. Given the age of the drill holes and the assumed weathering and the low flow nature of the tests which were undertaken, the resulting drawdown responses have not provided "classical " drawdown responses making it difficult to use curve matching techniques to analyse hydraulic conductivities. However the pump tests have provided reasonable indicative results.

In DDH5 and DDH7, hydraulic conductivities were so low that pumping merely depleted the stored drill hole water column and recoveries were very slow indicating that there is little in the way of storage from connected fractures in these locations.

In DDH2, DDH4 and DDH9, some reaction to pumping was apparent although these where not stressed to any degree with the low flow pump used, yield was higher enough in all cases to cause drawdown to the pump intake levels or to pump lift capacity highlighting the low interconnectivity of joint structures in these fractured rock aquifers.

Groundwater quality results show two distinct water types. A high bicarbonate apparently younger type from DDH5 and DDH7 in comparison to the high chloride and apparently more mature groundwater of the other three sampled drill holes. DDH5 and DDH7 also show similar very low hydraulic conductivity results which indicate that the lithology in that area which is saturated is essentially an aquitard. The high bicarbonate signature may indicate inundation of the bores by surface water given they are essentially open holes. Continuous water level monitoring may be able to add to conceptualisation of the groundwater system and the anomaly of these two sites.

DDH2, DDH4 and DDH9 wave groundwater signatures with a higher relative chloride content which is more consistent with what may be expected in a mature landscape. However there is still a noteworthy concentration of bicarbonate ion all bores except DDH2 to suggest that rainfall recharge plays a significant part in the groundwater system across this site.

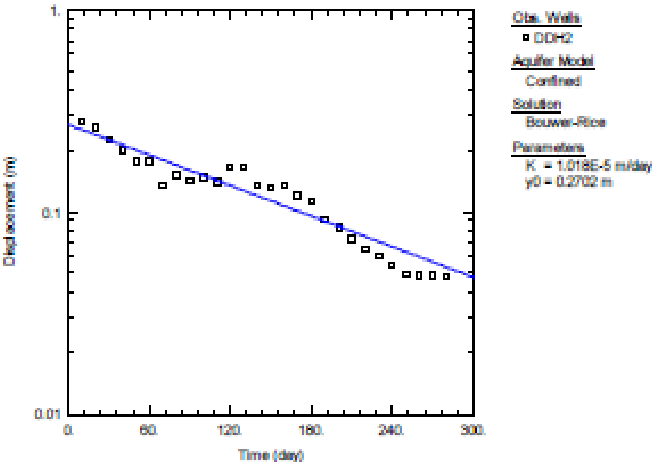
As note earlier, although access to groundwater from these open holes was achieved, it would be beneficial to retrofit PVC screen and casing into these if longer term monitoring should be a required consideration. If not for operational monitoring reasons, then it may certainly be useful for temporal base line conditions that are important considerations during an approval process.

APPENDIX A

AQUIFER TEST CURVE MATCHING

11

DDH2



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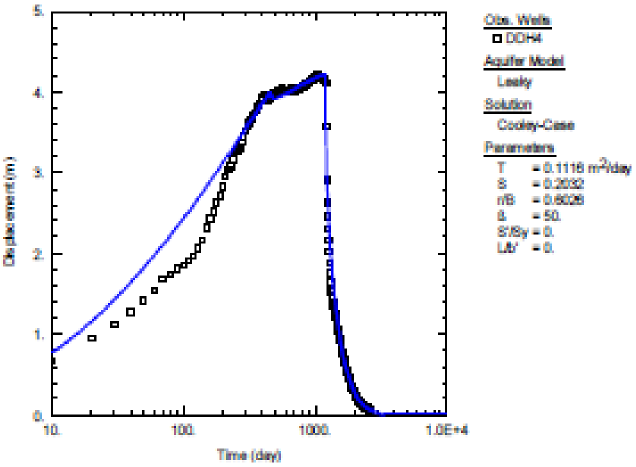
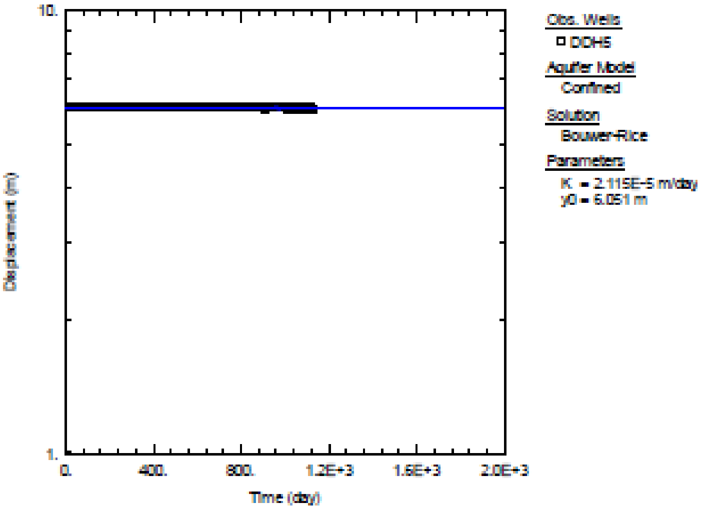
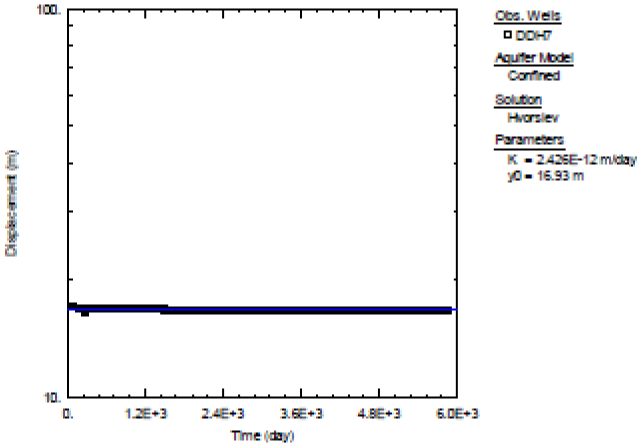


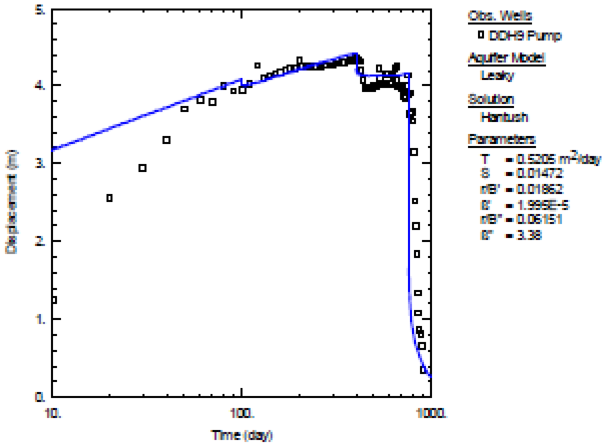
DDH5



DDH7


100.
10.
Displacement (m)
0.
1.2E+3
2.4E+3
3.6E+3
4.8E+3
6.0E+3
Time (day)
Obs. Wells
DDH7
Aquifer Model
Confined
Solution
Hvorslev
Parameters
K = 2.426E-12 m/day
y0 = 16.93 m

DDH9


5.
4.
3.
2.
1.
0.
Displacement (m)
10.
100.
1000.
Time (day)
Obs. Wells
DDH9 Pump
Aquifer Model
Leaky
Solution
Hantush
Parameters
T = 0.5205 m2/day
S = 0.01472
r/B' = 0.01862
ß' = 1.995E-5
r/B" = 0.06151
ß" = 3.38

APPENDIX B SEEPAGE ESTIMATE

DEFINITION OF VARIABLES	*STAGE 1*		RANGES		
VARIABLE	UNITS	LOW	MIDDLE	HIGH	PREFERRED
86400	Seconds/day				
31536000	Seconds/year				
K_h Horizontal Hydraulic conductivity range	Lowest in the centre of intrusive				
1.50E-07	m/s	5.79E-11	7.53E-08	1.50E-07	3.00E-08
1.16E-10	m/s				
3.47E-15	m/s				
K_h Average of higher values					
7.53E-08	m/s				
K_v Average of higher values		As 10% of horizontal			
7.53E-09	m/s	5.79E-12	7.53E-09	1.50E-08	3.00E-09
K_v Equivalent to Kh		5.79E-11	7.53E-08	1.50E-07	3.00E-08
m_2= Sqrt (Kh^2/Kv^2) for 10:1 case	unitless	3.16E+00	3.16E+00	3.16E+00	3.16E+00
m_2= Sqrt (K_h^2/K_v^2) for 1:1 case	unitless	1.00E+00	1.00E+00	1.00E+00	1
r_p Effective pit radius	m	114	114	114	***115***
r_p^2 effective pit radius squared	m^2	12996	12996	12996	13225
r_o Radius of influence - maximum extend of cone of depression	m	200	250	400	***250***
r_o^2 Effective radius influence squared	m^2	40000	62500	160000	62500
h_o Original saturated thickness (variable and approx)	m	10	15	20	***15***
h_p Saturated thickness above base of Zone 1 at rp	m	5	10	10	***10***
Pi	unitless	3.141592654	3.14159265	3.141592654	3.141592654
W Recharge flux (from rain infiltration)	m/s	7.92745E-10	1.2684E-09	1.58549E-09	1.27E-09
d Height of pond above pit floor	m	0.5	0	0	0
			SCENARIOS STAGE 1		
	UNITS	LOW	MIDDLE	HIGH	PREFERRED
ZONE 1 Calculation					
$Q_1 = W*pi*(r_o^2-r_p^2)$	m^3/s	6.7253E-05	0.00019726	0.000732221	1.96E-04
	$m^3/year$	2,121	6,221	23,091	6,192
	ML/year	2	6	23	6
ZONE 2 Calculation		Kh:KV 1:1			
	m^3/s	2.51E-07	5.15E-04	1.37E-03	2.07E-04
	$m^3/year$	8	16,240	43,274	6,528
	ML/year	0	16	43	7
		Kh:KV 10:1			
$Q_2 = 4r_p*(K_h/m_2)*(h_o-d)$	m^3/s	7.93E-08	1.63E-04	4.34E-04	6.55E-05
	$m^3/year$	3	5,136	13,685	2,064
	ML/year	0	5	14	2
TOTAL seepage Zones 1&2 (K_h = 10 K_v scenario)	**ML/year**	**2**	**11**	**37**	**8**
TOTAL seepage Zones 1&2 (K_h = K_v scenario)	**ML/year**	**2**	**22**	**66**	**13**

DEFINITION OF VARIABLES	*STAGE 2*		RANGES		
VARIABLE	UNITS	LOW	MIDDLE	HIGH	PREFERRED
86400	Seconds/day				
31536000	Seconds/year				
K_h Horizontal Hydraulic conductivity range	Lowest in the centre of intrusive				
1.50E-07	m/s	5.79E-11	7.53E-08	1.50E-07	3.00E-08
1.16E-10	m/s				
3.47E-15	m/s				
K_h Average of higher values					
7.53E-08	m/s				
K_v Average of higher values		As 10% of horizontal			
7.53E-09	m/s	5.79E-12	7.53E-09	1.50E-08	3.00E-09
K_v Equivalent to Kh		5.79E-11	7.53E-08	1.50E-07	3.00E-08
m_2= Sqrt (Kh^2/Kv^2) for 10:1 case	unitless	3.16E+00	3.16E+00	3.16E+00	3.16E+00
m_2= Sqrt (K_h^2/K_v^2) for 1:1 case	unitless	1.00E+00	1.00E+00	1.00E+00	1
r_p Effective pit radius	m	160	160	160	***160***
r_p^2 effective pit radius squared	m^2	25600	25600	25600	25600
r_o Radius of influence - maximum extend of cone of depression	m	260	400	600	***400***
r_o^2 Effective radius influence squared	m^2	67600	160000	360000	160000
h_o Original saturated thickness (variable and approx)	m	20	30	40	***25***
h_p Saturated thickness above base of Zone 1 at rp	m	5	15	20	***15***
Pi	unitless	3.141592654	3.14159265	3.141592654	3.141592654
W Recharge flux (from rain infiltration)	m/s	7.92745E-10	1.2684E-09	1.58549E-09	1.27E-09
d Height of pond above pit floor	m	0.5	0	0	0
	SCENARIOS STAGE 2				
	UNITS	LOW	MIDDLE	HIGH	PREFERRED
ZONE 1 Calculation					
$Q_1 = W*pi*(r_o^2-r_p^2)$	m^3/s	0.0001046	0.00053555	0.001665634	5.36E-04
	$m^3/year$	3,299	16,889	52,527	16,889
	ML/year	3	17	53	17
ZONE 2 Calculation		Kh:KV 1:1			
	m^3/s	7.22E-07	1.45E-03	3.85E-03	4.80E-04
	$m^3/year$	23	45,587	121,472	15,137
	ML/year	0	46	121	15
		Kh:KV 10:1			
$Q_2 = 4r_p*(K_h/m_2)*(h_o-d)$	m^3/s	2.28E-07	4.57E-04	1.22E-03	1.52E-04
	$m^3/year$	7	14,416	38,413	4,787
	ML/year	0	14	38	5
TOTAL seepage Zones 1&2 (K_h = 10 K_v scenario)	ML/year	3	31	91	22
TOTAL seepage Zones 1&2 (K_h = K_v scenario)	ML/year	3	62	174	32

DEFINITION OF VARIABLES	RANGES				
VARIABLE	UNITS	LOW	MIDDLE	HIGH	PREFERRED
86400	**Seconds/day**				
31536000	**Seconds/year**				
K_h Horizontal Hydraulic conductivity range	**Lowest in the centre of intrusive**				
1.50E-07	**m/s**	5.79E-11	7.53E-08	1.50E-07	3.00E-08
1.16E-10	**m/s**				
3.47E-15	**m/s**				
K_h Average of higher values					
7.53E-08	**m/s**				
K_v Average of higher values		**As 10% of horizontal**			
7.53E-09	**m/s**	5.79E-12	7.53E-09	1.50E-08	3.00E-09
K_v Equivalent to Kh		5.79E-11	7.53E-08	1.50E-07	3.00E-08
m_2= Sqrt (Kh^2/Kv^2) for 10:1 case	**unitless**	3.16E+00	3.16E+00	3.16E+00	3.16E+00
m_2= Sqrt (K_h^2/K_v^2) for 1:1 case	**unitless**	1.00E+00	1.00E+00	1.00E+00	1
r_p Effective pit radius	**m**	225	225	225	***225***
r_p^2 effective pit radius squared	**m^2**	50625	50625	50625	50625
r_o Radius of influence - maximum extend of cone of depression	**m**	400	500	800	***500***
r_o^2 Effective radius influence squared	**m^2**	160000	250000	640000	250000
h_o Original saturated thickness (variable and approx)	**m**	20	30	40	***30***
h_p Saturated thickness above base of Zone 1 at rp	**m**	5	15	25	***10***
Pi	**unitless**	3.141592654	3.14159265	3.141592654	3.141592654
W Recharge flux (from rain infiltration)	**m/s**	7.92745E-10	1.2684E-09	1.58549E-09	1.27E-09
d Height of pond above pit floor	**m**	0.5	0	0	0
	SCENARIOS STAGE 3				
	UNITS	**LOW**	**MIDDLE**	**HIGH**	**PREFERRED**
ZONE 1 Calculation					
$Q_1 = W*pi*(r_o^2-r_p^2)$	**m^3/s**	0.000272396	0.00079446	0.002935655	7.94E-04
	m^3/year	8,590	25,054	92,579	25,054
	ML/year	9	25	93	25
ZONE 2 Calculation		Kh:KV 1:1			
	m^3/s	1.02E-06	2.03E-03	5.42E-03	8.10E-04
	m^3/year	32	64,107	170,820	25,544
	ML/year	0	64	171	26
		Kh:KV 10:1			
$Q_2 = 4r_p*(K_h/m_2)*(h_o-d)$	**m^3/s**	3.21E-07	6.43E-04	1.71E-03	2.56E-04
	m^3/year	10	20,272	54,018	8,078
	ML/year	0	20	54	8
TOTAL seepage Zones 1&2 (K_h = 10 K_v scenario)	**ML/year**	**9**	**45**	**147**	**33**
TOTAL seepage Zones 1&2 (K_h = K_v scenario)	**ML/year**	**9**	**89**	**263**	**51**