# Hydrogeological Assessment

## Calingiri Copper Project
## Caravel Minerals

**Revision No 1**
**July 2018**

pendragon environmental solutions

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Leaders in Environmental Practice

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## Report

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| **Author(s):** | Ryan Lawrence, Fanie de Lange and Carel van der Westhuizen |
| **Client:** | Caravel Mineral |
| **Contact:** | Peter Pring |
| **Synopsis:** | This document details groundwater investigations at the Calingiri Copper Project, undertaken in accordance with Department of Water Operational Policy No. 5.12 – Hydrogeological Reporting associated with a Groundwater Well Licence. Although no level of assessment has been set yet, this document complies with a level H2 assessment. |

## Document Control

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| 1 | 25 July 2018 | Ryan Lawrence, Fanie de Lange, Carel van der Westhuizen | Taryn Wren |

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# Table of Contents

## Figures



## Tables

## Appendices

Appendix A: Search Data.

Appendix B: Bore Drilling and Testing Completion Records.

Appendix C: Water Quality Data and Laboratory Certificates.

# Executive Summary

## Scope of Works

Pendragon Environmental Solutions was requested by Caravel Minerals to undertake a desk study assessment of groundwater at their Calingiri Copper Project. This brief was subsequently extended to include drilling into known paleo valleys near the proposed new processing plant to assess the water bearing potential of these paleo valleys. It was agreed that reporting will comply with a H2 level of hydrogeological assessment as outlined in Operational Policy No. 5.12 - Hydrogeological Reporting associated with a Groundwater Well Licence (Department of Water, 2009).

A license to drill exploratory bores under Section 26D of the Rights in Water and Irrigation Act 1914 was lodged with the Department of Water and Environmental Regulation (DWER). DWER subsequently advised that this application is not required as the property is in an unproclaimed water resource area.

## Objectives

In addition to undertaking the preliminary investigation into the water bearing potential of the paleo valleys, this document details a hydrogeological assessment pertaining to the potential for impacts by mining on environmental factors including terrestrial environmental quality, hydrological processes, inland waters environmental quality and rehabilitation and decommissioning. The primary objectives are to ensure that the quality of land, soils, sediment and surface and ground water are maintained to protect environmental values and existing and potential future uses and to facilitate decommissioning and closure in an ecologically sustainable manner.

## Salient Findings

The geology of the area comprises paleo channel sediments within and underlain by granite/gneiss bedrock which has been faulted and intruded by dykes of dolerite. The primary aquifers are:

- sediments confined to paleo channels or valleys; and
- weathered/fractured granite-gneiss bedrock, faulted in places and intruded by near-vertical dykes of dolerite.

Preliminary investigations were undertaken to assess the paleo valleys but the underlying faulted and intruded bedrock utilising the overlying paleo channels as a source for recharge has yet to be investigated. Ground water was encountered in paleo channel sediments between 5m and 45m with yields varying between 0.1L/s and 4.8L/s from 100mm diameter bores. Preliminary assessments suggest that larger yields in the range between 10L/s and 20L/s are possible and sustainable. Utilising the current range of hydraulic parameters (T values between 30m$^2$/day and 900m$^2$/day and a S value of 0.002), the cone of drawdown may extend between 7km and 10km from the plant site at an abstraction rate of 100L/s.

Recharge to the paleo channels was estimated at 6mm/a or 1.6% of the mean annual rainfall which may constrain groundwater exploitation as a large area will be required to sustain bore and aquifer yields over the long term.

Ground water has elevated concentrations of Total Dissolved Solids (between 1,900mg/L and 5,000mg/L), predominantly Chloride and Sodium, which often exceed the Australian Drinking Water Guidelines, and to a lesser extent Sulfate. The heavy metals Arsenic, Cadmium, Chromium, Lead, Selenium, Iron and Mercury are absent in groundwater. Concentrations of Aluminium, Copper, Nickel and Zinc generally exceed the

ANZECC Fresh Water guidelines for most if not all species protection levels but are well below the drinking water guideline.

With the current layout of mine infrastructure and provided that construction employs best practice, it seems unlikely that mining and processing at the Calingiri Copper Project will impact any GDE's and subterranean fauna seems to be absent.

The primary impacts of mining and processing pertain to:

- The potential for impacts to soils, sediment, surface and ground water resources.
- Potential seepage from mine impoundments such as ROM pads, stockpiles and plant water infrastructure, WRDs and the TSF: mounding underneath and downstream thereof impacting groundwater quality.
- Groundwater abstraction and mine influx: receding ground water levels across mining area and beyond may impact local and/or regional water supplies.
- Exposure of sulfide-bearing materials in open pit excavations during mining and subsequent rehabilitation and closure.
- Open pit sinks and/or lakes post closure.

Whilst the impacts appear to be acceptable and manageable, appropriate site specific management of mining, waste rock and tailings disposal and ground water abstraction will be required to ensure that there is no impact on the receiving environment.

More drilling, and testing and sampling are required across the area in order to develop the conceptual model to a level of higher confidence and higher resolution regarding geological heterogeneities. Piezometric heads need to be measured across the area to be able to determine the aquifer(s) within the system as well as their interaction and boundaries.

**Recommendations**

Consideration should be given to:

- Undertake a census of all available surface and ground water sources within the mine tenements.
- Refine the mine water requirement to define the extent of further groundwater supply investigations.
- Utilise geophysical techniques to delineate aquifers and locate future drilling targets.
- Groundwater monitoring in accordance with this document.
- Further drilling, testing and sampling to not only investigate the paleo channel aquifers but also the faulted/fractured and intruded underlying granite/gneiss.

# 1. Introduction

## 1.1 Scope of Work

Pendragon Environmental Solutions was requested by Caravel Minerals to undertake a desk study assessment of groundwater at their Calingiri Copper Project (Figure 1.1). This brief was subsequently extended to include drilling into known paleo valleys near the proposed new processing plant to assess the water bearing potential of these paleo valleys. It was agreed that reporting will comply with a H2 level of hydrogeological assessment as outlined in Operational Policy No. 5.12 - Hydrogeological Reporting associated with a Groundwater Well Licence (Department of Water, 2009).

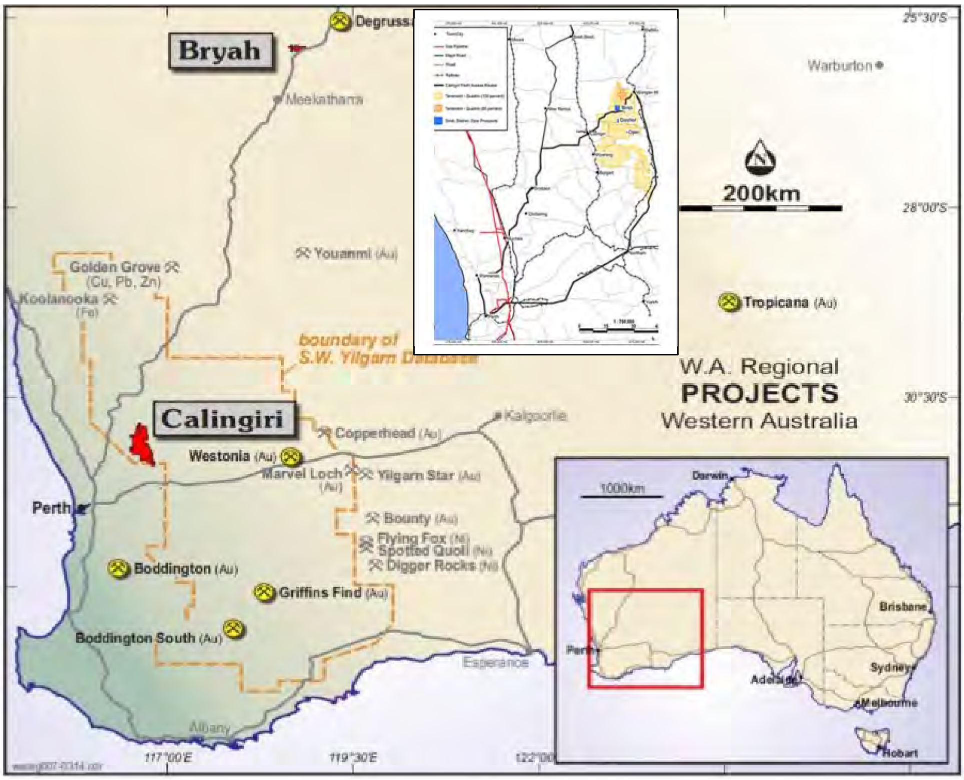



**Figure 1.1: Location of the Calingiri Copper Project.**

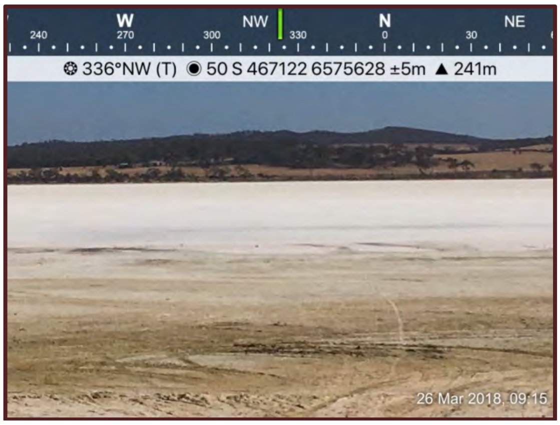
A license to drill exploratory bores under Section 26D of the Rights in Water and Irrigation Act 1914 was lodged with the Department of Water and Environmental Regulation (DWER). DWER subsequently advised that *this application is not required as the property is in an unproclaimed water resource area; the well can be drilled without a license* (email dated 19/02/2018). Nevertheless, bores were constructed to the standards outlined in the Minimum Construction Requirements for Water Bores in Australia (National Uniform Drillers Licensing Committee, 2012).

## 1.2 Objectives

This document details the hydrogeological assessment pertaining to the potential for impacts by mining on environmental factors including Terrestrial Environmental Quality, Hydrological Processes, Inland Waters Environmental Quality and Rehabilitation and Decommissioning (EPA, 2015). The primary objectives are to ensure that the quality of land, soils, sediment and surface and ground water is maintained to protect environmental values and existing and potential future uses and to facilitate decommissioning and closure in an ecologically sustainable manner.

## 1.3 Project Description

The proposed Calingiri Copper Project is located some 120km north-east of Perth, 13km south-west of the township of Wongan Hills and some 3km south-west of Lake Ninan in the northern Wheatbelt of Western Australia. Lake Ninan, at the head of the Mortlock River (North), covers an area of almost 700ha of reserve land.




Lake Ninan (view from south to north).


Calingiri-Wongan Hills Road crossing Mortlock River east of Lake Ninan.

The Department of Parks and Wildlife (DPAW) manages the 259ha A Class Reserve for the conservation of fauna and flora (vested 1963) and the Recreation Reserve (245ha) is managed by the Shire of Wongan-Ballidu. The lake, along with many wetlands in Western Australia, was impacted by water logging and increased salinity. It is affected by the activities in the catchment which extends north as far as Bindi Bindi and consequently, the water in the lake can be up to six times more saltier than the sea, fish species once found are no longer consistently present and the numbers and variety of bird species are reduced due to the absence of food in the lake. There are no other potential ground water dependent ecosystems within the mining area.

Access to the Calingiri Copper Project is via the Calingiri-Wongan Hills road or the Great Eastern Highway and Goomalling Road. The project is accessible year round via the sealed road network with local access via gazetted gravel roads. Rail infrastructure, used for grain, provides access to the ports of Fremantle and Kwinana.

The project, currently the subject of a feasibility study, is considered *a world class copper resource having a large resource* (*844kt Copper and 17kt Molybdenum,* Caravel Minerals March 2018*) and low (1:1) strip ratio with processing by means of conventional flotation*. *Environmental, social, tenure and infrastructure are low risk with low technical risk and no native title issues.* Caravel Minerals intends employing an advanced bulk ore sorting technology to optimise mill feed grades with lower plant throughput and consequently markedly lower power and water consumption and tailings requirements. The project has an initial life of 21 years at 15Mtpa.

Conventional opencast mining will take place at three locations: Bindi, Dasher and Opie (Figure 1.2); these deposits all contain Copper (Cu), Molybdenum (Mo), Silver (Ag) and Gold (Au). Processing will be by means of crushing (with ore stockpiling), grinding and flotation to yield a concentrate for metal recovery. Waste rock will be placed in rock dumps near the open pits. The Calingiri mineralisation is characterised by a relatively simple mineralogy. All the copper is in the form of chalcopyrite with pyrite the only other significant sulphide (cpy: py variable 3:1 to 1:1). All sulphides, including molybdenite, are relatively coarse grained. The gangue is dominantly silicates (quartz, feldspar, epidote, chlorite and garnet) with minor magnetite

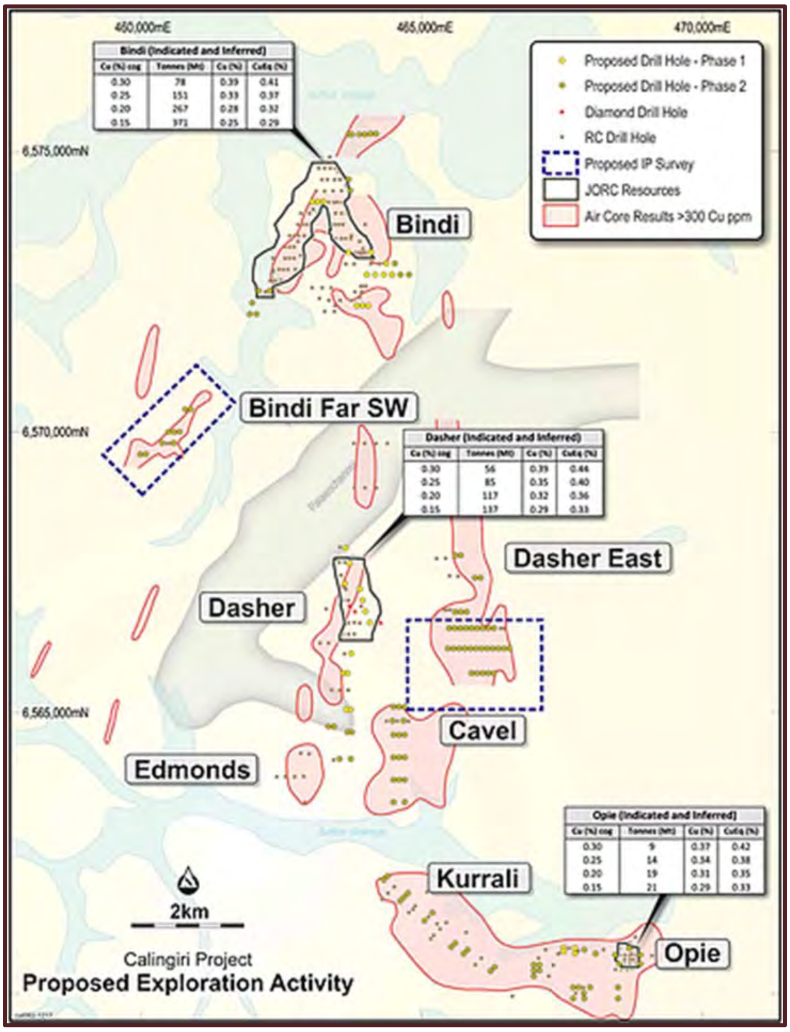



**Figure 1.2: Location of the Bindi, Dasher and Opie Prospects and Open Pits.**

The Tailings Storage Facility (TSF) at Bindi, adjacent to the processing plant, will be progressively developed over the life of mine with conventional sub areal deposition forming long beaches with water returned to the process plant for reuse from a central decant. The final TSF will have 4 cells of 300ha each, each cell having a diameter of around 1,950m i.e. the final TSF will cover an area of 1,200ha, 3.9km by 3.9km. The cells will be operated in pairs.

Water supply options include the large paleo channel located close to the Bindi and Dasher Prospects (refer Figure 1.2). Additional supplies are further afield.

The Bindi mineral resource has a cumulative strike of 3,700m, a plan width of 200m (Bindi West) and 350m (Bindi East) and depth extent of 360m below surface. The resource has an overall flat lying geometry, except in the west where it dips to the west under a hanging wall fault zone. The Dasher Mineral Resource has a strike extent of 1,500m, a plan width of 170m and depth extent of 490m below surface with an average dip of 45 degrees to the east. The Opie Mineral Resource has a strike extent of 250m, a plan width of 400m and depth extent of 250m below surface with a shallow northerly dip.

There is a saprolitic weathering layer between 5m and 50m thick (at Bindi and 45m and 35m respectively at Dasher and Opie), immediately below which the mineralisation is developed. All of the reported resources relate to sulphide mineralisation which is developed within a very consistent gneissic unit. All the resources remain open in a number of directions (Figure 1.3).

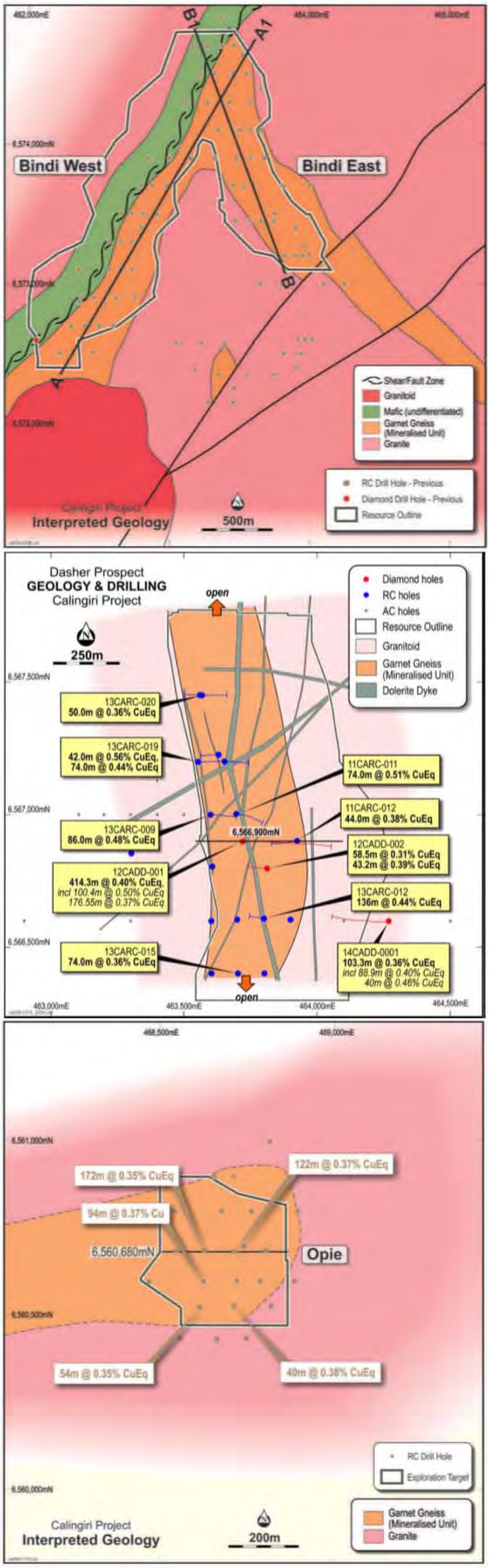



**Figure 1.3: Location of the Bindi, Dasher and Opie Prospects and Open Pits.**

Caravel Minerals (Quadrio Resources Pty Ltd) holds twelve Exploration Licences and one Prospecting Licence and owns 80% of Tenement E70/2343 held by Geodex Resources Pty Ltd Table 1.1 and Figure 1.4). All tenements are on privately owned land (excluded from this assessment).

**Table 1.1: Calingiri Copper Project Tenements.**

| Tenement Number | Holder | Tenement Area (ha) | Legal Area [Blocks] | Status | Grant Date |
|---|---|---|---|---|---|
| E70/2788 | Bindi and Dasher Open Pits and Waste Rock Dumps; Processing Plant and Tailings Storage Facility | 27,616 | 70 | Live | 6/03/2007 |
| E70/2789 | Opie Open Pit and Waste Rock Dump | 14,070 | 35 | Live | 11/08/2006 |
| E70/3680 | Exploration | 4,018 | 10 | Live | 23/11/2009 |
| E70/3755 | Exploration | 2,009 | 5 | Live | 15/04/2010 |
| P70/1593 | Exploration | 157 | 116 | Live | 10/02/2011 |
| E70/3674 | Bindi Open Pits and Waste Rock Dumps | 2,277 | 6 | Live | 15/11/2010 |
| E70/4517 | Exploration | 802 | 2 | Live | 26/08/2013 |
| E70/4476 | Exploration | 2,140 | 6 | Live | 19/08/2013 |
| E70/4675 | Exploration | 799 | 2 | Live | 12/01/2015 |
| E70/4674 | Exploration | 22,993 | 58 | Live | 14/01/2015 |
| E70/4676 | Exploration | 803 | 3 | Live | 11/03/2015 |
| E70/4732 | Exploration | 3,215 | 8 | Live | 11/08/2015 |
| E70/4746 | Exploration | 4,024 | 10 | Live | 31/08/2015 |
| E70/2343 | Exploration | 2,407 | 6 | Live | 30/05/2001 |

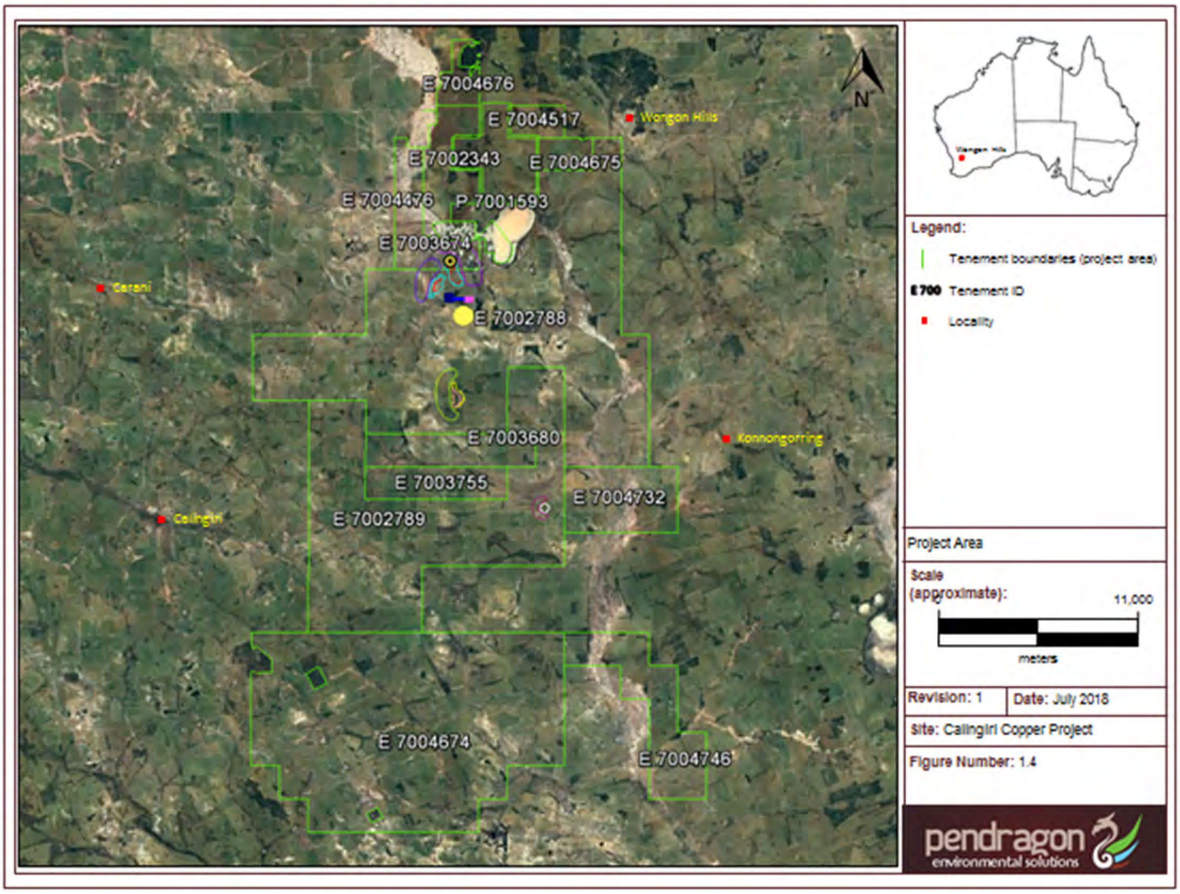



**Figure 1.4: Tenements and Mine Infrastructure.**

# 2. Climate

The area has a Mediterranean warm and temperate climate with dry hot summers and mild winters. Rain falls (Table 2.1 and Figure 2.1) mostly in the winter and average 388mm/a. It is the most important variable that impacts productivity and land degradation and arises from two general climatic systems: southern frontal systems, which pass from west to east; and rain from tropical air with a general pattern that tends to be a mosaic of wet and dry localities, which shifts from year to year. The growing season rainfall from April to October accounts for 75% of the average annual rainfall.

**Table 2.1: Climatic Data (Wongan Hills Weather Station 008137, Bureau of Meteorology, 2018).**

| Statistics | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Mean Temperature (°C)** | | | | | | | | | | | | | |
| Maximum | 34.6 | 34.1 | 30.9 | 26.5 | 21.6 | 18.2 | 17.0 | 17.9 | 20.7 | 25.2 | 29.2 | 32.5 | 25.7 |
| Minimum | 17.9 | 18.2 | 16.4 | 13.4 | 9.9 | 7.7 | 6.6 | 6.7 | 7.6 | 10.1 | 13.2 | 15.8 | 12.0 |
| **Mean Rainfall and Evaporation (mm)** | | | | | | | | | | | | | |
| Mean Rainfall (mm) | 15.5 | 15.4 | 20.7 | 22.4 | 51.6 | 69.4 | 69.3 | 51.6 | 29.8 | 19.6 | 12.4 | 10.0 | 388.2 |
| Highest rainfall (mm) | 134.6 | 110.5 | 165.8 | 81.3 | 187.9 | 220.2 | 174.4 | 131.1 | 97.3 | 121.6 | 60.3 | 71.4 | 675.4 |
| Highest daily rainfall (mm) | 71.6 | 79.8 | 81.3 | 61.7 | 63.5 | 69.6 | 86.2 | 34.3 | 37.1 | 53.2 | 38.6 | 57.2 | 86.2 |
| Mean number of rain days | 2.1 | 2.3 | 2.9 | 4.9 | 8.8 | 12.3 | 13.5 | 12.2 | 8.6 | 5.9 | 3.4 | 2.0 | 78.9 |
| Days of rain ≥ 25mm | 0.2 | 0.2 | 0.2 | 0.1 | 0.3 | 0.4 | 0.3 | 0.1 | 0.0 | 0.0 | 0.0 | 0.1 | 1.9 |
| Daily Evaporation | 11.6 | 10.6 | 8.6 | 5.5 | 3.4 | 2.3 | 2.1 | 2.6 | 3.8 | 5.9 | 8.4 | 10.3 | 6.3 |
| Daily Evaporation obtained from the Wongan Hills Res. Station 008138; 41 years, 1965 to 2013. | | | | | | | | | | | | | |

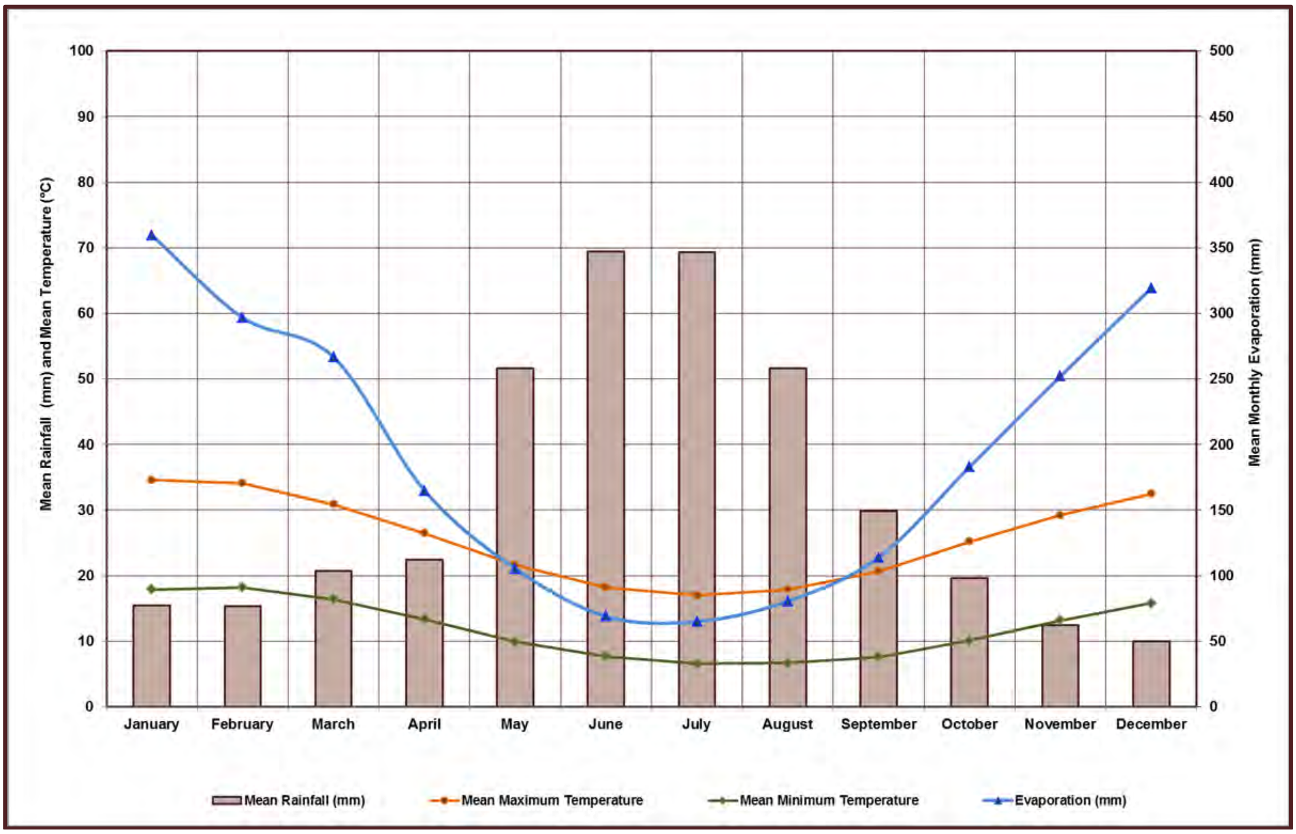



**Figure 2.1: Monthly Climatic Data.**

Since evaporation (averaging at about 2,276mm/a) exceeds rainfall (averaging at about 388mm/a) by almost six times, there is a water deficit across the region (Table 2.1). December, January and February are the hottest months with average maximum temperatures around 34°C. The lowest temperatures occur in winter, between June and September, when average maximum temperatures are below 20°C and average minimum temperatures are around 7°C (Table 2.1 and Figure 2.1).

# 3. Hydrogeology

## 3.1 Geology

The Calingiri Project is located in the south-western corner of the Archaen Yilgarn craton comprising granitic, volcanic and sedimentary rocks. The Calingiri mineralised trend extends south of the Wongan Hills Greenstone Belt (host to the Ninan mineralisation) into an area dominated by granite and granite-gneiss (hosts to the Bindi, Dasher and Opie deposits).

The mineralisation at Bindi, Dasher and Opie is of a common style: it comprises chalcopyrite, pyrite, Molybdenite and magnetite, disseminated within coarse-grained quartz-feldspar-garnet-biotite gneiss of granitic origin. The garnet-biotite gneiss and associated mineralisation typically forms tabular zones in the order of 50m to 150m thick, up to 200m, through the core of the main prospects. The sulphide mineralisation is developed in fresh bedrock generally at depths between 5m and 50m beneath a regolith cover of *in situ* saprolitic clays blanketed by a variable 1m to 10m layer of sand and gravel beneath a thin soil horizon.

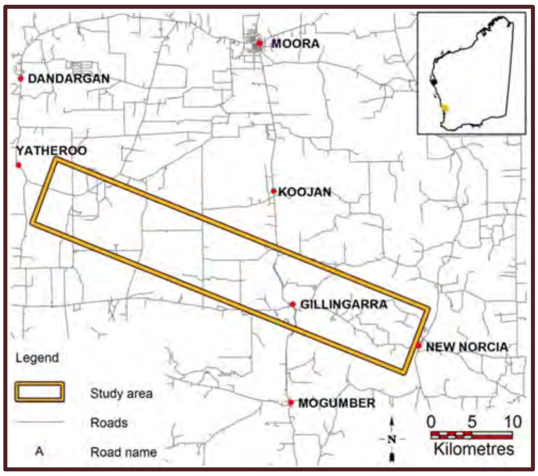
The mineralised zones at Dasher and Opie dip moderately to the east and north respectively, while the Bindi mineralisation appears to be folded resulting in the Bindi West (west dipping) and Bindi East (dip currently uncertain) components. Drilling identified lenses of amphibolite at all prospects and some post-mineralisation granite and pegmatite intrusions. Post-mineralisation dykes of dolerite are common.

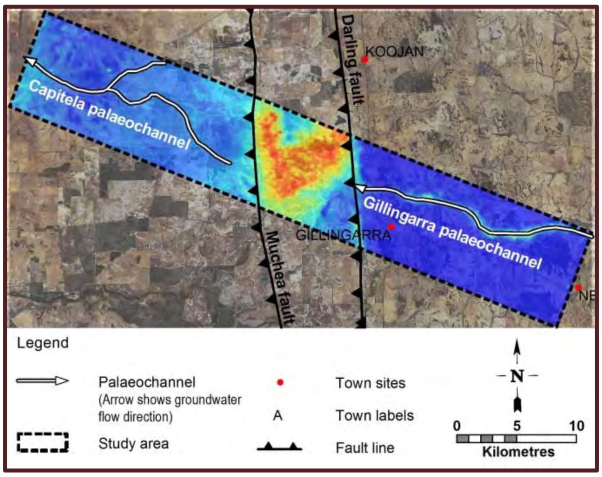
## 3.2 Local and Regional Aquifers

Local aquifers comprise relatively shallow paleo-channels between 5m and 50m thick. Faults, fracture systems and dykes of dolerite intruded into the host gneiss and granite bedrock, usually considered impermeable, form weathered and fractured rock aquifers at depth. Alluvial streambed aquifers are generally absent, sediments in creeks and drainage lines are thin, less than 2m thick.

Regional aquifer assessments include the groundwater investigations at West Midlands/Koojan-Gillingarra (Capitela) by the Agriculture and Food Division of the Department of Primary Industries and Regional Development, The Mapping and Water Management Project, funded through the Royalties for Regions program, identified groundwater resources for irrigated agriculture or livestock water supplies in the Capitela Valley (Department of Agriculture and Food Western Australia, DAFWA, 2008) and discovered a 10km long surficial paleo channel in the Perth Basin about 20km west of the Midlands Road. In 2009 DAFWA investigated spreading salinity in the Gillingarra-Koojan Catchment 30km south of Moora: *significant increases in salinity at some locations, causing loss of agricultural land, death of eucalypt woodlands and damage to the Midlands Road and rail line, might be caused by groundwater discharge from a paleo channel extending east towards New Norcia. To some extent, the paleo channel sediments discovered west of the Darling Fault in 2008 in the Capitela Valley aligned with the surmised paleo channel from New Norcia to Gillingarra. However, it was not clear whether the eastern and western sections of those separate channels were connected and one of the aims of the project was to investigate that possibility by means of airborne electromagnetic geophysical surveys (AEM) followed by drilling (mud rotary) to install a system of monitoring bores and a production bore and aquifer test pumping to determine the hydraulic parameters of the aquifer.*

The AEM survey across a rectangular area about 50km long and 7km wide, extending from New Norcia in the east to Yathroo in the west, located a paleo channel 125m to 130m below ground in granite bedrock. Whilst it was presumed that the paleo channel continues westward, it is possible the paleo channel sediments in the west are not linked to the paleo channel in the east (DAFWA, 2018).




Paleo channel sediments extend to 197m below surface some 6km north-west of New Norcia, significantly deeper than other paleo channels in the vicinity (generally no deeper than 100m below surface and more typically between 40m and 50m deep). Further to the west where the paleo channel crosses the Gillingarra-Glentromie Road, the paleo channel sediments extend to a depth of 192m. Aquifer testing at a constant discharge rate of 8L/s resulted in water level drawdown to 32m with subsequent recovery to more than 90% within 5 minutes. The bore yielded water with an Electrical Conductivity of 300mS/m or Total Dissolved Solids less than 1,700mg/L. DAFWA indicated that whilst *water in the upper parts of the palaeochannel aquifer is very fresh, further analysis is needed to determine how far the fresh water extends*.

## 3.3 Groundwater Occurrences and Recharge Potential

Most of the eastern Wheatbelt is situated on an Archaean craton with a flat landscape underlain by predominantly igneous rocks. Intrusions by dolerite dykes and more recent deformation by major faults, minor faults, and shear zones, have resulted in a strongly structurally controlled basement-aquifer complex. Aeolian, colluvial, fluviatile and lacustrine sediments overlie deeply weathered saprolite. The groundwater regime is a complex fractured-rock and regolith system through which water is transported slowly (DAFWA, 2007) with three main aquifer types: sedimentary (paleo channels), saprolite and fractured crystalline basement. Owing to the costs of drilling and high salinity of most groundwater, few bores were drilled to determine the hydraulic properties of the fractured basement aquifer system; the potential of these aquifers depends on the density of fractures, degree of connectivity and whether the fractures are open or filled with clay minerals but is likely to possess low porosity and high permeability.

Bedrock is generally overlain by alluvial deposits (soil) and regolith of markedly variable thicknesses, developed *in situ* by weathering of the underlying granite. The transition zone between unweathered bedrock and the overlying saprolite is often more permeable than the bulk of the saprolite.

The salt-river system and salt lakes of the Wheatbelt are dominated by chains of salt lakes, generally following the paths of the older paleo drainage system. They rarely flow as an interconnected system due to low seasonal rainfall, high evaporation rates and shallow lake profiles but rather act as a series of evaporation sumps to surface run-off.

Groundwater levels have risen following clearing of native vegetation; fluctuations characterised by a few distinct patterns (DAFWA, 2007):

- Seasonal fluctuation in the lower reaches of catchments where aquifers have direct hydraulic contact with creeks: water levels rise during winter and fall during summer in response to rainfall.
- Monotonically rising water levels in the upper reaches of catchments where water levels are relatively deep and rates of recharge are high. The rate of rise ranges from 0.2m/a to 0.5m/a.
- Continuously rising water levels with seasonal fluctuations in mid-slope areas; the water levels normally exhibit a sinusoidal pattern with a rising trend.
- Continuously falling water levels with seasonal fluctuations in catchments where re-vegetation occurred; in the Merredin catchment water levels declined by about 2m over five years.

Very little is known about the hydraulic and yield characteristics of the aquifers in close proximity to and underlying the Calingiri Copper Project. Detailed assessments of exploration drilling data (Caravel Minerals, 2018) revealed that groundwater was encountered in sands (paleo channels), fractures and in dolerite. Comments recorded by Caravel during exploratory drilling included:

- Bores *abandoned/terminated* due to *water* ingress, or *too much* water to continue or *too wet* or *excess water*.
- Water at (depth)m and very wet sample.
- Strong water flow and significant water.
- Hit groundwater/aquifer/paleo channel sands (running, collapsing), fresh/saline/salty water.
- Hit (small) fracture, abundant water flow and/or massive water.
- Water from fracture in dolerite.

The exploration database (refer Figure 3.1) indicated that some 44 of the 132 bores encountered groundwater between 100m and 250m depth. The remaining 88 bores encountered groundwater between 3m and 100m below surface averaging 42m with a standard deviation of 26m.

It seems that interconnectivity between aquifers, ground water storage and recharge potential would be limited (in quantity and also in lateral extent), controlled by irregular paleo and weathering/ fracture/fault systems and intrusions, low and predominantly determined by secondary porosity and hydraulic conductivity coupled with the presence of and constraints by geological barriers. The depth

to ground water excludes ground water discharge into drainage lines and creeks (interconnectivity between ground and surface water) and consequently ground water dependent ecosystems.

Preliminary estimates of the hydraulic parameters of the sediments in the paleo channels and fractured/intruded bedrock aquifers are:

- Aquifer Transmissivity T ($m^2$/day): less than 1 and between 10 and 100
- Aquifer Storativity S (dimensionless): less than 0.0005
- Recharge (% of mean annual precipitation, MAP): <3, if any, up to 6 in high rainfall years

Since the area has low rainfall with erratic seasonal distribution and high potential evaporation, recharge will be limited to a few events exceeding 25mm each year (Table 2.1).

## 3.4 Local Ground Water Trends

There are no hydrographs for bores at the Calingiri Copper Project; local ground water trends are therefore unknown.

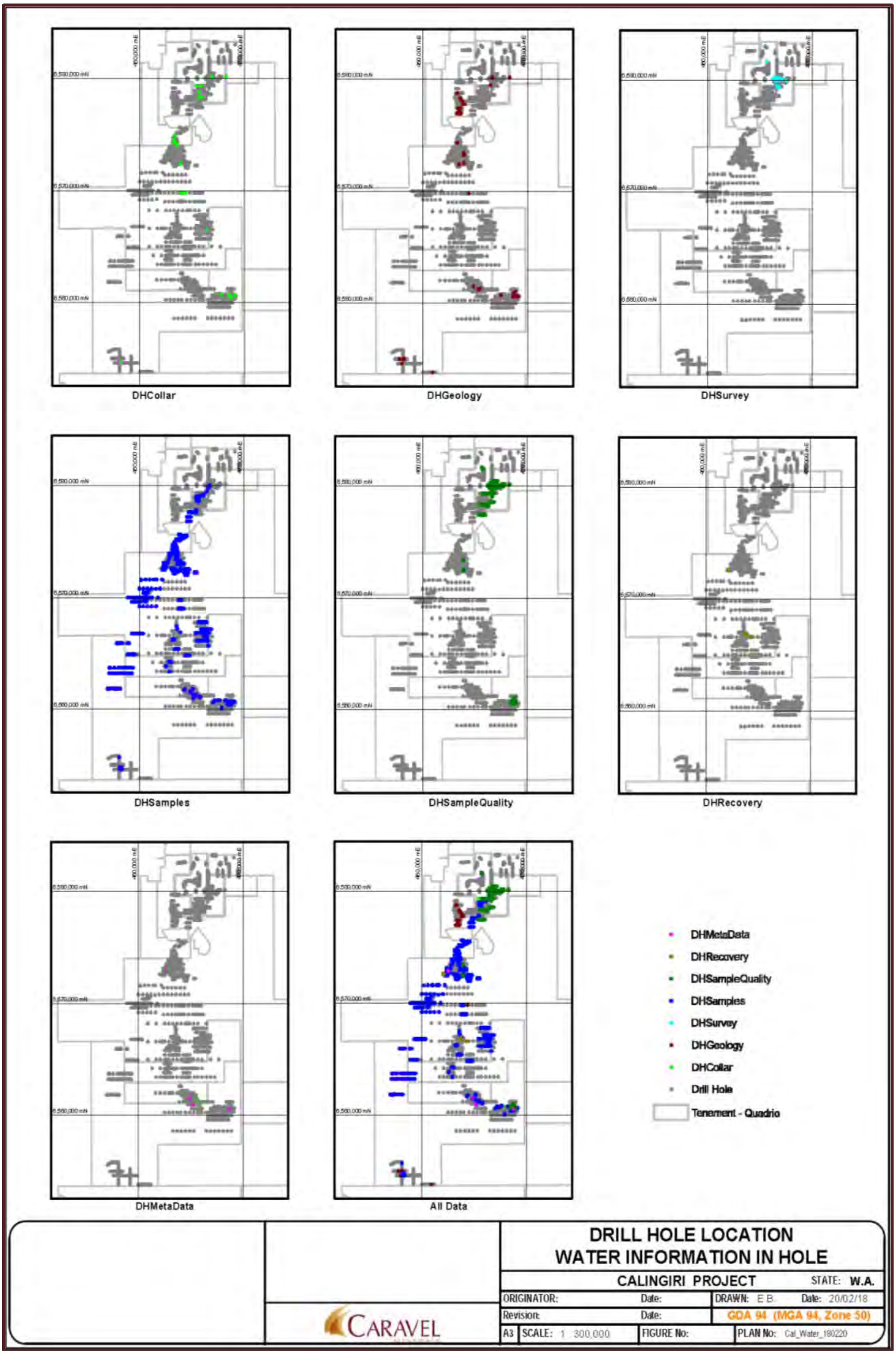



**Figure 3.1: Water in Exploration Bores.**

## 3.5 Bore Construction

A bore drilling program, primarily aimed at the paleo channel south of the proposed new plant at Bindi, including bore testing and water quality sampling, was to be implemented between March 2018 and April 2018. The objectives and scope of work for these preliminary hydrogeological investigations, constraint by both budget and time (availability of land prior to the planting season), included:

- Drill and construct small diameter (165mm drilling with 100mm solid casings and screens across the water bearing zones) ground water bores in accordance with the Minimum Construction Requirements for Water Bores in Australia (National Water Commission, 2012).
- Implement bore tests in accordance with Australian Standard AS 2368-1990 Test Pumping of Water Wells to ascertain the extent of aquifers and their characterization in terms of their hydraulic parameters and consequently the extent of the zone that may be impacted by mining. Undertake short-term 12-hour constant-rate discharge tests followed by recovery once the bores were constructed and fully developed:
  - The duration of discharge pump tests may vary between 12 hours and a maximum of 24 hours depending on the preliminary estimated bore yields attained during bore drilling/development.
  - The final number of bores to be tested will be decided upon following estimations of airlift yields on completion of drilling/development.
  - If airlift yields are low (<0.50L/s), falling/rising head tests will be undertaken by either pump-out and/or injection of water into the bore whilst the water level drawdown or rise is measured. Conventional slug tests by inserting a slug of known volume may also be undertaken.
- Undertake surveys of ground water levels to ascertain regional and local flow directions and velocities.
- Obtain ground water samples to ascertain the ambient quality of ground water.
- Obtain ground water samples for determining recharge characteristics by means of natural isotopes.
- Interpret and assess field and laboratory data gathered during the above programs to ascertain potential preferential pathways and enable a prediction of the potential impacts of mining and processing on the surrounding and downstream environments.

Indicative bore locations and details pertaining to construction/development of bores and subsequent testing appear in Table 3.1 and Figure 3.2.

**Table 3.1: Proposed Bore Locations.**

| Site ID | Zone | Coordinates | | Indicative Depth (m) | Anticipated Ground Water Level (mbgl) |
|---|---|---|---|---|---|
| | | Easting | Northing | | |
| **Bindi Paleo Channel (Refer Program of Work: 72163); Tenement E70/2788** | | | | | |
| PWB001 | 50J | 465,835 | 6,572,235 | up to 50 | 5 - 10 |
| PWB002 | | 465,670 | 6,571,760 | | |
| PWB003 | | 466,170 | 6,571,710 | | |
| PWB004 | | 466,070 | 6,571,190 | | |
| PWB005 | | 465,595 | 6,570,555 | | |
| PWB006 | | 466,465 | 6,570,475 | | |
| PWB007 | | 466,700 | 6,571,190 | | |
| PWB008 | | 467,595 | 6,571,140 | | |
| PWB009 | | 468,675 | 6,571,230 | | |
| PWB010 | | 469,415 | 6,571,295 | | |
| PWB011 | | 469,445 | 6,570,535 | | |

| Site ID | Zone | Coordinates | | Indicative Depth (m) | Anticipated Ground Water Level (mbgl) |
|---|---|---|---|---|---|
| | | Easting | Northing | | |
| PWB012 | 50J | 468,620 | 6,570,345 | up to 50 | |
| PWB013 | | 467,585 | 6,570,340 | | |
| PWB014 | | 467,565 | 6,569,820 | | |
| PWB015 | | 468,500 | 6,569,815 | | |
| PWB016 | | 469,475 | 6,569,825 | | |
| **Opie (Refer Program of Work: 71063); Tenement E70/2789** | | | | | |
| PDH096 | 50J | 468,450 | 6,560,680 | up to 50 | 5 - 10 |
| PDH098 | | 468,900 | 6,560,520 | | |
| PDH099 | | 468,520 | 6,560,520 | | |
| PDH100 | | 467,890 | 6,560,000 | | |
| PDH104 | | 467,100 | 6,560,400 | | |
| PDH106 | | 467,000 | 6,560,400 | | |
| PDH108 | | 467,000 | 6,560,300 | | |

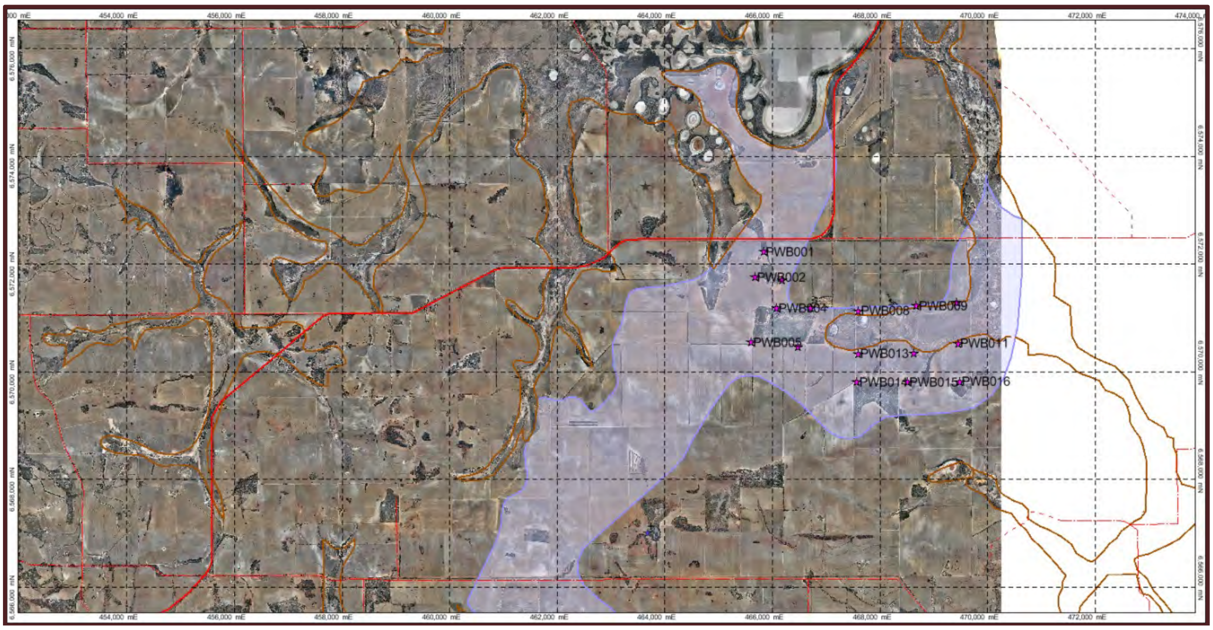



**Figure 3.2: Proposed Bore Locations, Bindi Paleo Channel.**

The final number of bores, locations, depths, construction/development and completion requirements, pump testing and sampling will be determined during the drilling program. Key geological and hydrogeological parameters to be collected during the drilling and pump testing programs include:

- Drilling logs to record the geological formations. The soils and geological formations encountered, changes in lithology and mineralogy, evidence of structural formations, water strike depths and approximate water yields, etc. will be recorded on a simple but accurate drill log. Where possible soil/rock samples would be taken at regular depths (e.g. every meter) and described during the drilling process. If needed, some of the solid samples will be tested for their mineralogical and geochemical properties.
- Depth and nature of water strikes, pending drilling method (RC or mud rotary).
- Approximate airlift yields.
- Details of well installation (length of casings, well-screen, thickness of gravel pack and seal materials such as bentonite, etc.) and bore development.
- Samples for water quality assessment. *In situ* (field) measurements will include: pH, EC, TDS, Salinity, Temperature, Dissolved Oxygen, Oxidation Reduction Potential including observations

such as odour, colour, etc.). NATA accredited laboratory analytical assessments of the water samples will include:

- Total Alkalinity (Talk, mg/L).
- Total Acidity (TAc, mg/L).
- Major anions (Cl, $SO_4$, $CO_3$/$HCO_3$, $NO_3$-N; mg/L).
- Major cations (Ca, Mg, Na and K; mg/L).
- Dissolved metals (Al, As, B, Cd, Cr, Cu, Fe, Mn, Ni, Pb, Zn, Fe; µg/L).
- Nutrients (Ammonia, Nitrite, Nitrate, Total Kjeldahl Nitrogen, Total Nitrogen, Reactive Phosphorus and Total Phosphorus).

- Samples for isotope assessment.

# 4. Existing Ground Water Use

## 4.1 Ground Water Licences

The Calingiri Copper Project falls within an unproclaimed groundwater area in which licences in terms of Section 26D (*constructing a well* and/or *taking of water*) of the Rights in Water and Irrigation Act 1914 are not required.

## 4.2 Ground Water Use

Large proportions of dryland farms in Western Australia receiving less than 600mm average rain suffer from water supply problems in the form of shortages, poor quality or combinations of these two factors (DAFWA, 2007). The Farm Water Plan of 1994 (Farm Water Strategy Group, 1994) indicated that *the north-eastern and eastern wheatbelt is where the greatest difficulty for development of reliable on-farm water supplies is experienced.*

Water supplies are described as either low quality (livestock) or high quality (domestic) sources. Low quality water from dams and bores is generally used for livestock and gardens as well as laundry and toilet facilities. High quality water from rain water harvesting (tanks or excavated earth tanks or dams) and bores is used for drinking, domestic purposes (roughly 150L/person/day including amenities) and for specific needs such as crop spraying. Domestic water constitutes less than 15% of that used in agriculture.

There are at many unlicensed ground water bores across the project area (WIR Database search dated 28th February 2018, Appendix A). However, the data is old and contain no information on aquifer types, bore depths and yields and/or groundwater quality. Nevertheless, groundwater levels are between the surface and 27.43m deep averaging 5.35m.

## 4.3 Groundwater Dependent Ecosystems (GDEs)

Ground water dependant ecosystems (GDEs) are ecosystems which have their species composition and their natural ecological processes determined by ground water (ARMCANZ and ANZECC, 1996). This also refers to ecosystems that may vary in the degree of their dependency on ground water, from having no apparent dependency through to being entirely dependent on it.

The decision making criteria (Table 4.3) for assessing the presence or absence of GDEs for this investigation are:

**Table 4.1: Criteria for Discerning GDEs.**

| Environmental Aspect | Criteria | Indicators of Ground Water Dependence |
|---|---|---|
| **Level 1. Locate zones with potentials for ground water dependence** | | |
| Potential for ground water fed systems | Status of inundation, submergence, seeps and springs, ground water aquifers, geology and topography | Soil and surface/ground water surveys indicate water (inundation/submergence/seeps/springs) or close (dampness) to the surface which vegetation can readily tap into or there is potential for expression of this water to the surface based on geology and topography. |

| Environmental Aspect | Criteria | Indicators of Ground Water Dependence |
|---|---|---|
| **Level 2. Assess specific areas where ground water dependence potential is high** | | |
| Indications of water: (inundation/ submergence/seeps/ springs) or close (dampness) to the surface | Soil moisture<br>Expression of ground water<br>Source of surface water<br>Refer to vegetation criteria | Greater than 15% following at least 7 days of no rain.<br>Shallow ground water levels, extent of ponding or flowing (frequency, rainfall relationship)<br>Drainage/topographic characteristics<br>Surface/ground water quality characteristics<br>Refer to vegetation structure |
| Vegetation Characteristics | Vegetation structure<br>Plant species composition | Structure (large trees) suggests reliance on a long term available water source.<br>Species composition suggests a dependence on a shallow ground water table.<br>Presence of species dependent on (near) permanent water. |

GDEs are defined as *natural ecosystems that require access to ground water to meet all or some of their water requirements so as to maintain their ecological functions*. A time dimension (Smith *et al*., 2006) may be added to then define GDEs as *ecosystems that rely wholly or partially on ground water to maintain an adequate level of ecosystem function and maintenance of community composition over multiple generations of the longest lived species within the community.*

Six types of GDEs are conventionally recognised in Australia:

- Terrestrial vegetation that relies on the availability of shallow groundwater.
- Wetlands such as paperbark swamp forests and mound springs ecosystems.
- River base flow systems where ground water discharge adds to stream flow.
- Aquifer and cave ecosystems where life exists independent of sunlight.
- Terrestrial fauna, both native and introduced, that rely on ground water as a source of drinking water.
- Estuarine and near shore marine systems, such as some coastal mangroves, salt marshes and sea grass beds, which rely on the submarine discharge of ground water.

A preliminary assessment suggests that none of these are present at the Calingiri Copper Project. Base flow is not readily evident and riparian and terrestrial vegetation which may have some form of reliance on ground water appears to be absent. Field observations revealed open expressions of the groundwater level (with excessive salinity) and an ephemeral surface water regime in which streams dry out completely each year early in the dry season.

GDEs in proximity to Wongan Hills include (GDE Atlas, 15th June 2018):

- Aquatic ecosystems that rely on the surface expression of groundwater which includes surface water ecosystems which may have a groundwater component, such as rivers, wetlands and springs: unclassified potential GDEs (national assessment), refer Figure 4.1 overleaf.
- Terrestrial ecosystems that rely on the subsurface presence of groundwater which includes all vegetation ecosystems: unclassified potential GDEs (national assessment), refer Figure 4.2.
- Subterranean ecosystems, including cave and aquifer ecosystems were not mapped.

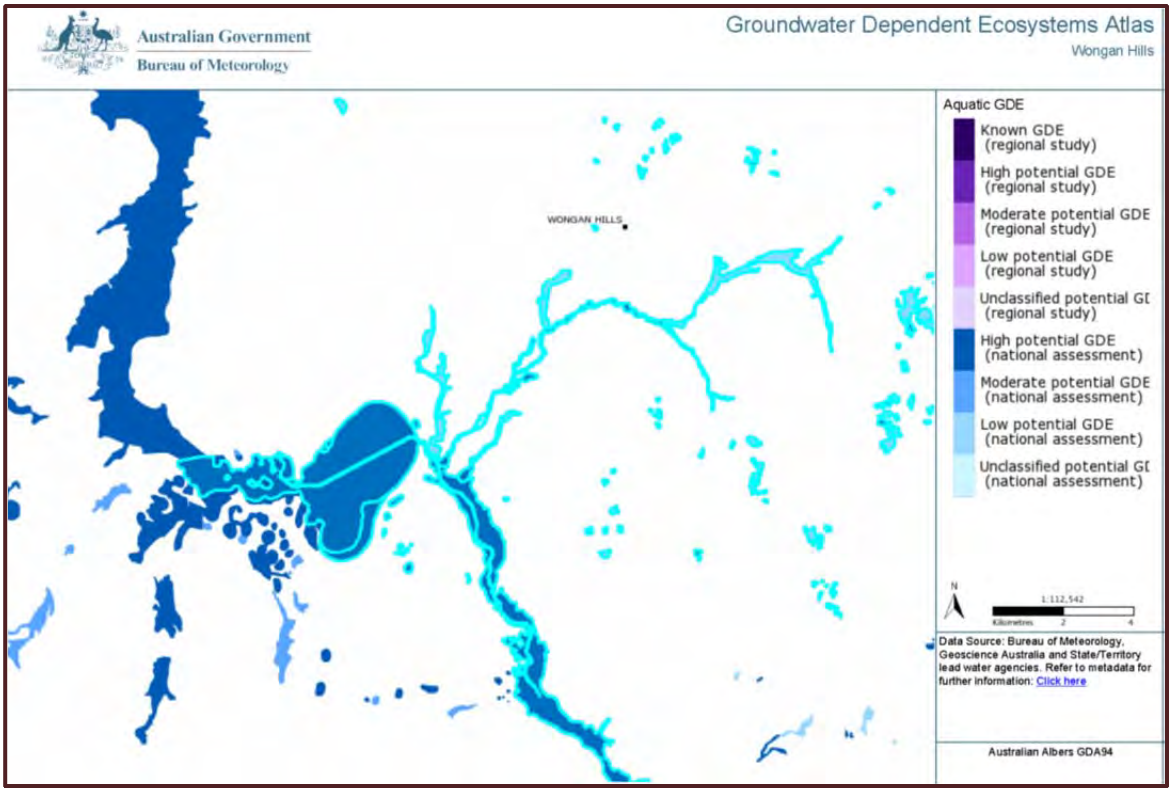



**Figure 4.1: Aquatic Ecosystems.**

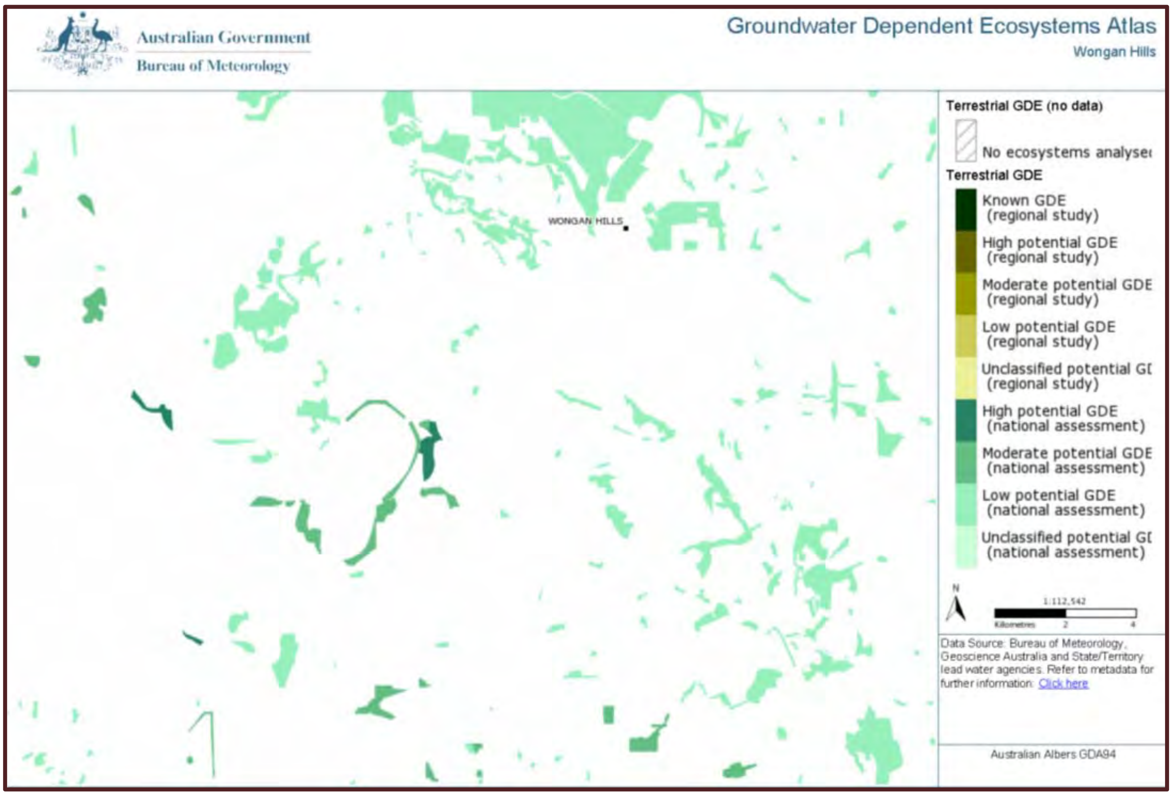



**Figure 4.2: Terrestrial Ecosystems.**

With the current layout of mine infrastructure and provided that construction employs best practice, it seems unlikely that mining and processing at the Calingiri Copper Project will impact any of the GDE's.

# 5. Ground Water Investigations

## 5.1 Bore Drilling

Several groundwater investigative bores were constructed between March 2018 and April 2018 to obtain information pertaining to the ground water bearing and hydraulic characteristics of the paleo channels west of the proposed Bindi processing plant (Figure 5.1) and at Opie (Figure 5.2).


**Figure 5.1: Bore Locations at Bindi** (process plant in blue and TSF in yellow).


**Figure 5.2: Bore Locations at Opie** (11km due south of Bindi).

The bores were constructed in accordance with the Minimum Construction Requirements for Water Bores in Australia (National Uniform Drillers Licensing Committee, 2012). Drilling employed reverse circulation and mud rotary techniques followed by installing PVC solid casings and slotted screens across the primary water bearing zones. The bore annulus between the PVC screen and bore wall were filled with coarse sand (gravel pack) and a polymer grout to ground level to prevent surface water entering the bore. Bores were developed subsequently by airlift and Wellclean (which is used in the development and cleanup of water bores to break down the viscosity of the bentonite mud and disperses cake that was formed on the walls of the drill hole, promoting rapid and effective clean up).

During drilling, samples of the drill cuttings were obtained, where possible, at 1m intervals, washed, sieved and used to prepare detailed lithological descriptions and bore construction logs. Detailed bore completion reports with details of casings and screens, surveyed coordinates and elevations, and, where possible, lithological descriptions, changes in moisture content and the depths at which water was encountered, ground water levels, airlift yields and observations made during drilling and construction appear in Appendix B. A summary of the more pertinent construction and hydrogeological details appear in Table 5.1.

Drilling encountered fine to medium and coarse gravels and sand, often interspersed in clays. Since the investigation aimed at determining the yield and hydraulic characteristics of the paleo channel sediments, drilling was stopped once bedrock was encountered. Earlier exploratory drilling encountered little, if any, groundwater in the underlying gneissic/granitic bedrock.

## 5.2 Bore and Aquifer Testing

Bore test pumping, constant rate discharge tests up to 12 hours in duration, was undertaken to ascertain the yield characteristics of the paleo channel sediments and to estimate their hydraulic parameters to undertake preliminary assessments of the potential long-term impacts of mine influx and ground water abstraction on the aquifer, receiving environment and surrounding users. It also allows a preliminary assessment of the availability and supply of water for mining and processing.

The test program was devised taking cognisance of bore construction and airlift yields, if available, measured on completion after bore development to obtain water qualities and to facilitate interpretation of aquifer properties, specifically hydraulic conductivity (K, m/d), transmissivity (T, $m^2$/d) and storativity (S, no dimensions). Bore test data (Appendix B) was provided by Orbit Drilling and interpreted by Pendragon Environmental Solutions making use of the FC Method software developed by the Institute for Groundwater Studies at the University of the Free State and the Department of Water Affairs in South Africa. These criteria and parameters contribute in determining the subsurface ground water environment and predicting its possible behaviour in future under different stresses and influences to construct a conceptual model (or numerical model) of the prevailing ground water flow regime including the presence of impermeable or recharge boundaries.

Bore testing involved monitoring the drawdown of the ground water level whilst keeping the abstraction rate constant. Drawdown and recovery data from constant rate tests are evaluated by making use of suitable interpretation methods (Kruseman and De Ridder, 1994 and Van Tonder, *et al.*, 2013) depending on knowledge regarding unconfined or confined aquifer conditions and whether the bore is situated in a porous or fractured medium. The duration of the constant rate test may be determined by the information and level of reliability required. It is common practice to run the test for a minimum of about eight hours for bores to be equipped with hand, solar or wind driven pumps, and for forty-eight to seventy-two hours for bores to be equipped with electricity or diesel driven pumps which are to be operated on a daily basis.

## Table 5.1: Summary of Bore Construction, Hydrogeological Details and Bore Testing.

| Summary of Bore Data | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Site/Location: Calingiri Copper Project | | | | | | | | | | | | | | | | |
| Bore Number | Location | | Elevation (mAHD) | Bore Depth | Casings/ Screens | Screen Interval | | Yield (Bore Test) | Duration | Drawdown | Recovery | TDS | Lithology/Aquifer Type | Groundwater Level | |
| | Latitude | Longitude | | | | | | | | | | | | | |
| | Zone 50J | | | | | from | to | | | | | | | | |
| | (mE) | (mN) | (mAHD) | (m) | (mbgl) | (mbgl) | (mbgl) | (L/s) | (hrs) | (m) - (%) | (%) | (mg/L) | - | (mbgl) | (mAHD) |
| New Investigative Bores | | | | | | | | | | | | | | | |
| Bindi Paleo Channel - Tenement | | | | | | | | | | | | | | | |
| 18CAWB001 | 465,180 | 6,571,750 | 259 | 45.0 | 0 - 45 | 0.0 | 41.0 | 4.8 | 12 | 1.90m - (4.4%) | 100% - 1min (residual s = 0) | 2,890 - 3,050 | Gravel. | 2.00 | 257.00 |
| 18CAWB002 | 465,670 | 6,571,700 | 255 | 40.0 | 0 - 34 | 0.0 | 34.0 | 4.5 | 12 | 5.80m - (16.7%) | 100% - 2min (residual s = 0) | 984 - 1,610 | Gravel. | 5.20 | 249.80 |
| 18CAWB003 | 466,170 | 6,571,710 | 245 | 36.0 | 0 - 36 | 0.0 | 36.0 | 2.0 | 1 min | 31.70m - (100%) | - | pumped dry | Gravel. | 4.30 | 240.70 |
| 18CAWB004 | 467,595 | 6,571,140 | 256 | 24.0 | - | - | - | - | - | - | - | - | Thin dry sand/gravel; bedrock. | - | - |
| 18CAWB005 | 467,585 | 6,570,340 | 235 | 46.0 | 0 - 46 | 0.0 | 46.0 | 1.0 | 5 | 26.85m - (60.2%) | 55% - 150min (residual s = 1.15m) | - | Clayey gravel. | 1.40 | 233.60 |
| 18CAWB006 | 467,565 | 6,569,820 | 231 | 34.0 | 0 - 21 | 0.0 | 21.0 | 1.0 | 1 | 9.59m - (31.0%) | 76% - 60min (residual s = 1.00m) | - | Clayey gravel. | 3.10 | 227.90 |
| Opie Paleo Channel - Tenement | | | | | | | | | | | | | | | |
| 18CARC027 | 467,734 | 6,560,805 | 229 | 132.0 | 0-24 | 18.0 | 24.0 | 1.8 | 8 | 18.35m - (93.1%) | 80% - 120min (residual s = 2.80m) | - | Sandy clay. | 4.30 | 224.70 |
| 18CARC028 | 467,906 | 6,560,782 | 246 | 66.0 | 0-42 | 30.0 | 42.0 | 2.0 | 1 min | 42.00m - (100%) | - | - | Sand and sandy clay | 0.00 | 246.00 |
| Notes | All bores (except B006 at 144mm DIA) drilled at 203mm DIA and fitted with 100mm DIA Class 9 PVC screens (9mm wallthickness). | | | | | | | | | | | | | | |
| | Screens: 100mmDIA uPVC Class 12 with 8 rows around screen, 37 banks on each row and 22 0.51mm slots on each bank. | | | | | | | | | | | | | | |

| Bore Number | Construction | Bore Testing |
|---|---|---|
| Bindi Paleo Channel - Tenement | | |
| 18CAWB001 | Drilled at 150mm to 48m, then cased with 100mm to 41mbgl; rounded gravel noted in drill cuttings. | - |
| 18CAWB002 | Drilled at 150mm to 40m, then cased with 100mm to 40mbgl; one length of 150mm solid PVC could not be removed; therefore slotted 100mm PVC to 36mbgl; rounded gravel noted in drill cuttings. | - |
| 18CAWB003 | Bore collapsing; site relocated 5m, drilled at 150mm and cased with 100mm slotted casing to 36m. | White foam affected water level measurements; pumped dry in <1min at 2L/s. |
| 18CAWB004 | Water encountered for 2m directly above solid rock. | Not tested; penetrated thin dry paleo sediments. |
| 18CAWB005 | Drilled to 41mm with 150mm, cased with 100mm to 32mbgl. | Bore was full of white foam which affected water level measurements; pumped dry in <1min at 2L/s; after redevelopment sustained 2L/s for 5hours. |
| 18CAWB006 | Drilled to 34 mm with 150mm, cased with 100mm to 21mbgl. | Bore was full of white foam which affected water level measurements; pumped dry in <1min at 2L/s; after redevelopment sustained 0.6L/s for 1hour; test abandoned due to drawdown. |

| Opie Paleo Channel - Tenement | | |
|---|---|---|
| 18CARC027 | Bore drilled to 140m+, drillers noted good water at 40mbgl maybe in a void; Asked to be cased to 60mbgl and left open with eth ambition of pumping at a depth of 40-50mbgl. Hole only cased to a depth of 28m; 4 tonnes of gravel added to bore to back fill. | Pumped at 2L/s. |
| 18CARC028 | Drilled to 64mbgl. The aim was to install slotted pvc at 52-64m and 12-18m to target sandier materials. Casing only installed to 42m, comprised of slotted from 30-42 as bore collapsed. This meant that slotted casing was not located on the targeted zone; Bore was particularly heavy in clay. | Very small yield. |

## 18CAWB001

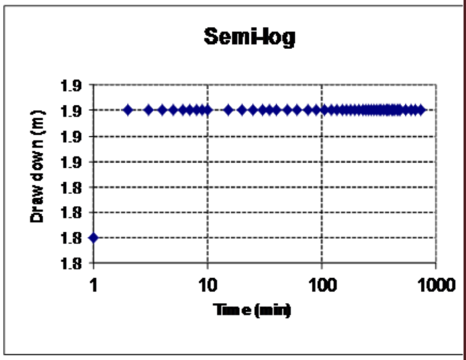
The very small drawdown measured during the test on Bore 18CAWB001, coupled with the almost immediate recovery of the water level after discharge testing, renders a reliable interpretation of the data difficult due to the predominant horizontal nature of the drawdown curves.

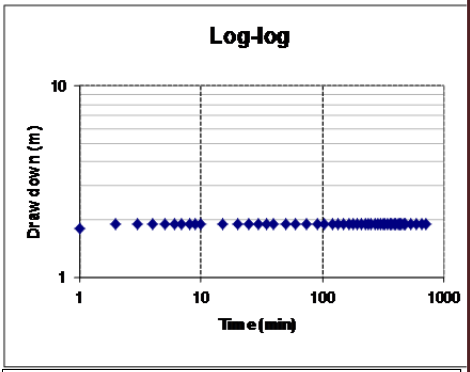
| | | | | | |
|---|---|---|---|---|---|
| Country: | Australia | Main | | Geology: | Gravel and sand; paleo channel |
| Region: | Wheatbelt | | | Depth of BH: | 45 |
| Owner: | Caravel Minerals | Diagnostic Plots | Derivative | Water strikes: | Saturated below 2mbgl |
| X-coord: | 465,180 | Sust_Q | | Date of Test: | 26/03/2018 |
| Y-coord: | 6,571,750 | | | Contractor: | Orbit Drilling |

CONSTANT RATE TEST DATA : enter values in cells which are coloured light yellow

| | | | | | | |
|---|---|---|---|---|---|---|
| Borehole: | CAWB001 | | | | AD= available drawdown for managing the borehole | |
| Distance from Rest WL to main water strike (m) = | 0 | $s_{max}$ = 1.9 | Recom AD = | 1.9 | AD = 40 | Time (y) = 5 |
| Q (l/s)= | 4.8 | Recovery data | | | T (m²/d) : Logan eq. | time = extrapolation time |
| | | | | | 266.3 | |

| t (min) | s (m) | avg s' | avg s" | avg T | avg S | Time t' | Res_s | t/t' | W rise | s' | Rec_T |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0.0 | | | | | 1 | 0 | 721 | 1.9 | | |
| 1 | 1.8 | | | | | | | ###### | ###### | ###### | |
| 2 | 1.9 | #NUM! | #NUM! | | | | | ###### | ###### | ###### | |
| 3 | 1.9 | #NUM! | #NUM! | 889.16 | 1.00E-06 | | | ###### | ###### | ###### | #DIV/0! |
| 4 | 1.9 | #NUM! | #NUM! | 889.16 | 1.00E-06 | | | ###### | ###### | ###### | #DIV/0! |
| 5 | 1.9 | #NUM! | #NUM! | 889.16 | 1.00E-06 | | | ###### | ###### | ###### | #DIV/0! |
| 6 | 1.9 | #NUM! | #NUM! | ####### | 1.00E-06 | | | ###### | ###### | ###### | #DIV/0! |
| 7 | 1.9 | 0.00 | #NUM! | ####### | 1.00E-06 | | | ###### | ###### | ###### | #DIV/0! |
| 8 | 1.9 | 0.00 | #NUM! | ####### | 1.00E-06 | | | ###### | ###### | ###### | #DIV/0! |
| 9 | 1.9 | #NUM! | #NUM! | ####### | 1.00E-06 | | | ###### | ###### | ###### | #DIV/0! |
| 10 | 1.9 | #NUM! | #NUM! | ####### | 1.00E-06 | | | ###### | ###### | ###### | #DIV/0! |
| 15 | 1.9 | #NUM! | #NUM! | ####### | 1.00E-06 | | | ###### | ###### | ###### | #DIV/0! |
| 20 | 1.9 | #NUM! | #NUM! | ####### | 1.00E-06 | | | ###### | ###### | ###### | #DIV/0! |
| 25 | 1.9 | #NUM! | #NUM! | ####### | 1.00E-06 | | | ###### | ###### | ###### | #DIV/0! |
| 30 | 1.9 | #NUM! | #NUM! | ####### | 1.00E-06 | | | ###### | ###### | ###### | #DIV/0! |
| 35 | 1.9 | #NUM! | #NUM! | ####### | 1.00E-06 | | | ###### | ###### | ###### | #DIV/0! |
| 40 | 1.9 | #NUM! | #NUM! | ####### | 1.00E-06 | | | ###### | ###### | ###### | #DIV/0! |
| 50 | 1.9 | #NUM! | #NUM! | ####### | 1.00E-06 | | | ###### | ###### | ###### | #DIV/0! |
| 60 | 1.9 | #NUM! | #NUM! | ####### | 1.00E-06 | | | ###### | ###### | ###### | #DIV/0! |
| 75 | 1.9 | #NUM! | #NUM! | ####### | 1.00E-06 | | | ###### | ###### | ###### | #DIV/0! |
| 90 | 1.9 | #NUM! | #NUM! | ####### | 1.00E-06 | | | ###### | ###### | ###### | #DIV/0! |
| 105 | 1.9 | #NUM! | #NUM! | ####### | 1.00E-06 | | | ###### | ###### | ###### | #DIV/0! |
| 120 | 1.9 | #NUM! | #NUM! | ####### | 1.00E-06 | | | ###### | ###### | ###### | #DIV/0! |
| 135 | 1.9 | #NUM! | #NUM! | ####### | 1.00E-06 | | | ###### | ###### | ###### | #DIV/0! |
| 150 | 1.9 | #NUM! | #NUM! | ####### | 1.00E-06 | | | ###### | ###### | ###### | #DIV/0! |
| 165 | 1.9 | #NUM! | #NUM! | ####### | 1.00E-06 | | | ###### | ###### | ###### | #DIV/0! |
| 180 | 1.9 | #NUM! | #NUM! | ####### | 1.00E-06 | | | ###### | ###### | ###### | #DIV/0! |
| 195 | 1.9 | #NUM! | #NUM! | ####### | 1.00E-06 | | | ###### | ###### | ###### | #DIV/0! |
| 210 | 1.9 | #NUM! | #NUM! | ####### | 1.00E-06 | | | ###### | ###### | ###### | #DIV/0! |
| 225 | 1.9 | #NUM! | #NUM! | ####### | 1.00E-06 | | | ###### | ###### | ###### | #DIV/0! |
| 240 | 1.9 | #NUM! | #NUM! | ####### | 1.00E-06 | | | ###### | ###### | ###### | #DIV/0! |
| 255 | 1.9 | #NUM! | #NUM! | ####### | 1.00E-06 | | | ###### | ###### | ###### | #DIV/0! |
| 270 | 1.9 | #NUM! | #NUM! | ####### | 1.00E-06 | | | ###### | ###### | ###### | #DIV/0! |
| 285 | 1.9 | #NUM! | #NUM! | ####### | 1.00E-06 | | | ###### | ###### | ###### | #DIV/0! |
| 300 | 1.9 | #NUM! | #NUM! | ####### | 1.00E-06 | | | ###### | ###### | ###### | #DIV/0! |
| 315 | 1.9 | #NUM! | #NUM! | ####### | 1.00E-06 | | | ###### | ###### | ###### | #DIV/0! |
| 330 | 1.9 | #NUM! | #NUM! | ####### | 1.00E-06 | | | ###### | ###### | ###### | #DIV/0! |
| 345 | 1.9 | #NUM! | #NUM! | ####### | 1.00E-06 | | | ###### | ###### | ###### | #DIV/0! |
| 360 | 1.9 | #NUM! | #NUM! | ####### | 1.00E-06 | | | ###### | ###### | ###### | #DIV/0! |
| 375 | 1.9 | #NUM! | #NUM! | ####### | 1.00E-06 | | | ###### | ###### | ###### | #DIV/0! |
| 390 | 1.9 | #NUM! | #NUM! | ####### | 1.00E-06 | | | ###### | ###### | ###### | #DIV/0! |
| 405 | 1.9 | #NUM! | #NUM! | ####### | 1.00E-06 | | | ###### | ###### | ###### | #DIV/0! |
| 420 | 1.9 | #NUM! | #NUM! | ####### | 1.00E-06 | | | ###### | ###### | ###### | #DIV/0! |
| 435 | 1.9 | #NUM! | #NUM! | ####### | 1.00E-06 | | | ###### | ###### | ###### | #DIV/0! |
| 450 | 1.9 | #NUM! | #NUM! | ####### | 1.00E-06 | | | ###### | ###### | ###### | #DIV/0! |
| 465 | 1.9 | #NUM! | #NUM! | ####### | 1.00E-06 | | | ###### | ###### | ###### | #DIV/0! |
| 480 | 1.9 | 0.00 | #NUM! | ####### | 1.00E-06 | | | ###### | ###### | ###### | #DIV/0! |
| 540 | 1.9 | #NUM! | #NUM! | ####### | 1.00E-06 | | | ###### | ###### | ###### | #DIV/0! |
| 600 | 1.9 | #NUM! | #NUM! | ####### | 1.00E-06 | | | ###### | ###### | ###### | #DIV/0! |
| 660 | 1.9 | #NUM! | #NUM! | ####### | 1.00E-06 | | | ###### | ###### | ###### | #DIV/0! |
| 720 | 1.9 | #NUM! | #NUM! | ####### | 1.00E-06 | | | ###### | ###### | ###### | #DIV/0! |



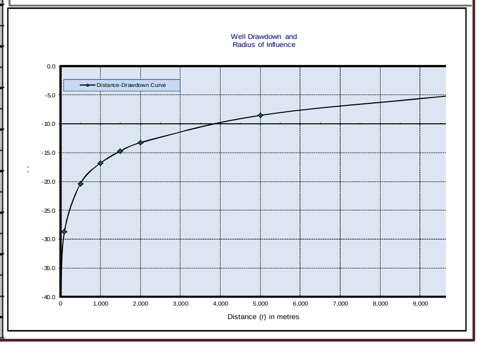




**Figure 5.3: Bore Test 18CAWB001.**

Approximate hydraulic parameters are: T value 889m²/day with S 1.6 x $10^{-3}$. It is clearly evident from the test data that this bore is capable of yielding far in excess of the 4.8L/s attained during testing considering the very small drawdown during testing. Using a radial flow model based on the Jacob Equation illustrates (Figure 5.3) that utilising the above hydraulic parameters and the available drawdown, may yield as much as 100L/s with a drawdown of 5m some 10km away after 5 years. However, it is unlikely that the paleo channels would extend radially for such large distances which would limit yield as a direct consequence of barriers which in turn would result in larger drawdowns. Nevertheless, it seems that yields in the order between 10L/s and 20 L/s could be more sustainable; the FC Method predicted a sustainable yield around 18 L/s.

## 18CAWB002

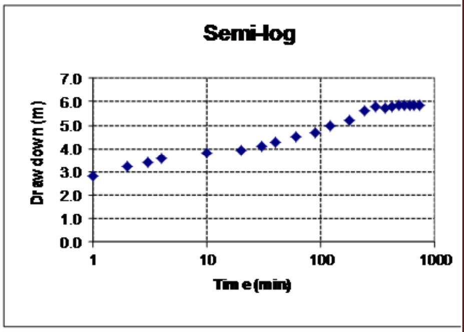
The test on Bore 18CAWB002 resulted in larger drawdowns but again almost immediate recovery of the water level after discharge testing.

| | | | | |
|---|---|---|---|---|
| Country: | Australia | Main | Geology: | Gravel and sand; paleo channel |
| Region: | Wheatbelt | | Depth of BH: | 40 |
| Owner: | Caravel Minerals | Diagnostic Plots / Derivative | Water strikes: | Saturated below 5mbgl |
| X-coord: | 465,670 | | Date of Test: | 27/03/2018 |
| Y-coord: | 6,571,700 | Sust_Q | Contractor: | Orbit Drilling |

CONSTANT RATE TEST DATA : enter values in cells which are coloured light yellow

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Borehole: | CAWB002 | | | | | AD= available drawdown for managing the borehole | |
| Distance from Rest WL to main water strike (m) = | 0 | $s_{max}$ = | 5.85 | Recom. AD = | 5.9 | AD = 35 | Time (y) = 5 |
| Q (l/s)= | 4 | Recovery data | | | | T ($m^2$/d) : Logan eq. 72.1 | time = extrapolation time |

| t (min) | s (m) | avg s' | avg s" | avg T | avg S | Time t' | Res_s | t/t' | Wl rise | s' | Rec_T |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 2.40 | | | | | 1 | 0.4 | 721 | 5.45 | | |
| 1 | 2.80 | | | | | 2 | 0.0 | 361 | 5.85 | ###### | |
| 2 | 3.20 | #NUM! | #NUM! | | | | | ###### | ###### | ###### | |
| 3 | 3.40 | #NUM! | #NUM! | 55.99 | 2.47E-04 | | | ###### | ###### | ###### | #DIV/0! |
| 4 | 3.55 | 0.79 | #NUM! | 93.22 | 2.47E-04 | | | ###### | ###### | ###### | #DIV/0! |
| 10 | 3.80 | 0.68 | 0.03 | 100.05 | 2.47E-04 | | | ###### | ###### | ###### | #DIV/0! |
| 20 | 3.90 | 0.79 | 0.42 | 86.16 | 2.47E-04 | | | ###### | ###### | ###### | #DIV/0! |
| 30 | 4.10 | 0.99 | 0.51 | 60.30 | 2.90E-04 | | | ###### | ###### | ###### | #DIV/0! |
| 40 | 4.30 | 1.20 | 0.41 | 50.38 | 1.05E-03 | | | ###### | ###### | ###### | #DIV/0! |
| 60 | 4.50 | 1.33 | 0.31 | 48.04 | 1.45E-03 | | | ###### | ###### | ###### | #DIV/0! |
| 90 | 4.70 | 1.51 | 0.39 | 44.79 | 2.20E-03 | | | ###### | ###### | ###### | #DIV/0! |
| 120 | 4.95 | 1.76 | 0.38 | 34.45 | 2.20E-03 | | | ###### | ###### | ###### | #DIV/0! |
| 180 | 5.22 | 1.97 | -0.08 | 29.96 | 2.20E-03 | | | ###### | ###### | ###### | #DIV/0! |
| 240 | 5.60 | 1.75 | -1.29 | 29.96 | 2.20E-03 | | | ###### | ###### | ###### | #DIV/0! |
| 300 | 5.80 | 1.12 | -2.48 | 29.96 | 2.20E-03 | | | ###### | ###### | ###### | #DIV/0! |
| 360 | 5.75 | 0.66 | -2.46 | 29.96 | 2.20E-03 | | | ###### | ###### | ###### | #DIV/0! |
| 420 | 5.80 | 0.46 | -2.61 | 29.96 | 2.20E-03 | | | ###### | ###### | ###### | #DIV/0! |
| 480 | 5.85 | #NUM! | #NUM! | 29.96 | 2.20E-03 | | | ###### | ###### | ###### | #DIV/0! |
| 540 | 5.85 | #NUM! | #NUM! | 29.96 | 2.20E-03 | | | ###### | ###### | ###### | #DIV/0! |
| 600 | 5.85 | #NUM! | #NUM! | ####### | 2.20E-03 | | | ###### | ###### | ###### | #DIV/0! |
| 660 | 5.85 | #NUM! | #NUM! | ####### | 2.20E-03 | | | ###### | ###### | ###### | #DIV/0! |
| 720 | 5.85 | #NUM! | #NUM! | ####### | 2.20E-03 | | | ###### | ###### | ###### | #DIV/0! |
| | | #NUM! | #NUM! | ####### | 2.20E-03 | | | ###### | ###### | ###### | #DIV/0! |
| | | #NUM! | #NUM! | ####### | 2.20E-03 | | | ###### | ###### | ###### | #DIV/0! |
| | | #NUM! | #NUM! | ####### | 2.20E-03 | | | ###### | ###### | ###### | #DIV/0! |
| | | #NUM! | #NUM! | ####### | 2.20E-03 | | | ###### | ###### | ###### | #DIV/0! |
| | | #NUM! | #NUM! | ####### | 2.20E-03 | | | ###### | ###### | ###### | #DIV/0! |
| | | #NUM! | #NUM! | ####### | 2.20E-03 | | | ###### | ###### | ###### | #DIV/0! |
| | | #NUM! | #NUM! | ####### | 2.20E-03 | | | ###### | ###### | ###### | #DIV/0! |
| | | #NUM! | #NUM! | ####### | 2.20E-03 | | | ###### | ###### | ###### | #DIV/0! |
| | | #NUM! | #NUM! | ####### | 2.20E-03 | | | ###### | ###### | ###### | #DIV/0! |
| | | #NUM! | #NUM! | ####### | 2.20E-03 | | | ###### | ###### | ###### | #DIV/0! |
| | | #NUM! | #NUM! | ####### | 2.20E-03 | | | ###### | ###### | ###### | #DIV/0! |
| | | #NUM! | #NUM! | ####### | 2.20E-03 | | | ###### | ###### | ###### | #DIV/0! |



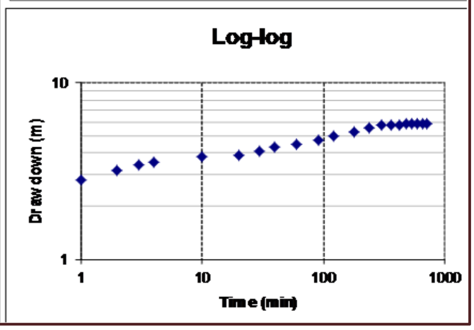




**Figure 5.4: Bore Test 18CAWB002.**

Approximate hydraulic parameters are: T value between 30m$^2$/day and 100m$^2$/day with an average S of 2.2 x $10^{-3}$; barrier boundaries are evident on the drawdown curves. Albeit lower hydraulic parameters at this location, it remains clearly evident from the test data that this bore is capable of yielding in excess of the 4.0L/s attained during testing. The radial flow model indicates that this bore may yield as much as 13L/s with a cone of dewatering of 7.5km after 5 years.

## Bores 18CAWB003, 18CAWB004 and 18CARC0028

Bore 18CAWB003 yielded very little water and was pumped dry almost immediately. Inspection of the lithological descriptions reveals that the bore penetrated some 30m of gravel (the same as Bores 1 and 2). Whilst the bore was redeveloped, it seems that construction and development remained problematic and potentially did not result in breaking down the bentonite wall cake.

Bore 18CAWB004 encountered only 10m of sand and gravel which appeared to be dry.

Bore 18CARC0028 encountered thin gravels overlying sand with clay increasing in content with depth. Bore construction was problematic and potentially did not achieve the desired outcome.

## 18CAWB005

The test on Bore 18CAWB005 resulted in larger drawdowns but again almost immediate recovery of the water level after discharge testing.

| | | | |
|---|---|---|---|
| Country: | Australia | Geology: | Gravel and sand; paleo channel |
| Region: | Wheatbelt | Depth of BH: | 46 |
| Owner: | Caravel Minerals | Water strikes: | Saturated below 2mbgl |
| X-coord: | 467,585 | Date of Test: | 6/04/2018 |
| Y-coord: | 6,570,340 | Contractor: | Orbit Drilling |

Main | Diagnostic Plots | Derivative | Sust_Q

CONSTANT RATE TEST DATA: enter values in cells which are coloured light yellow

Borehole: CAWB005

Distance from Rest WL to main water strike (m) = 0 | $s_{max}$= 26.9 | Recom. AD= 26.9

AD= available drawdown for managing the borehole

AD = 44 | Time (y) = 5

T ($m^2$/d) : Logan eq. 7.9 | time = extrapolation time

Q (l/s)= 2 | Recovery data

| t (min) | s (m) | avg s' | avg s" | avg T | avg S | Time t' | Res_s | t/t' | Wl rise | s' | Rec_T |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 3.10 | | | | | 1 | 15.0 | 301 | 11.85 | | |
| 2 | 5.40 | | | | | 2 | 13.0 | 151 | 13.85 | 4.07 | |
| 3 | 6.30 | 11.47 | 0.04 | | | 4 | 12.6 | 76 | 14.3 | 2.53 | |
| 4 | 8.20 | 11.68 | 0.12 | 2.65 | 2.35E-03 | 7 | 11.6 | 43.86 | 15.25 | 2.18 | 8.7 |
| 10 | 12.15 | 15.10 | 0.28 | 2.09 | 2.20E-03 | 10 | 11.8 | 31 | 15.1 | 8.64 | 4.9 |
| 20 | 18.70 | 17.13 | -0.31 | 1.66 | 2.20E-03 | 20 | 8.0 | 16 | 18.9 | 14.47 | 2.6 |
| 30 | 22.90 | 13.25 | -1.28 | 1.82 | 2.20E-03 | 30 | 4.7 | 11 | 22.11 | 15.01 | 2.7 |
| 40 | 23.64 | 6.96 | -1.75 | 4.52 | 2.20E-03 | 40 | 3.5 | 8.5 | 23.35 | 7.71 | 3.8 |
| 60 | 24.20 | 3.67 | -1.20 | 4.52 | 2.20E-03 | 60 | 2.4 | 6 | 24.46 | 5.11 | 6.1 |
| 90 | 24.50 | 2.89 | -0.07 | 4.52 | 2.20E-03 | 90 | 1.7 | 4.333 | 25.15 | 3.61 | 8.8 |
| 120 | 24.65 | 3.35 | #NUM! | 4.52 | 2.20E-03 | 120 | 1.3 | 3.5 | 25.54 | 2.51 | #DIV/0! |
| 180 | 25.75 | #NUM! | #NUM! | 4.52 | 2.20E-03 | 150 | 1.2 | 3 | 25.7 | ##### | #DIV/0! |
| 240 | 25.90 | #NUM! | #NUM! | 4.52 | 2.20E-03 | | | ##### | ##### | ##### | #DIV/0! |
| 300 | 26.85 | #NUM! | #NUM! | 4.52 | 2.20E-03 | | | ##### | ##### | ##### | #DIV/0! |
| | | #NUM! | #NUM! | 4.52 | 2.20E-03 | | | ##### | ##### | ##### | #DIV/0! |
| | | #NUM! | #NUM! | 4.52 | 2.20E-03 | | | ##### | ##### | ##### | #DIV/0! |
| | | #NUM! | #NUM! | 4.52 | 2.20E-03 | | | ##### | ##### | ##### | #DIV/0! |
| | | #NUM! | #NUM! | 4.52 | 2.20E-03 | | | ##### | ##### | ##### | #DIV/0! |
| | | #NUM! | #NUM! | 4.52 | 2.20E-03 | | | ##### | ##### | ##### | #DIV/0! |
| | | #NUM! | #NUM! | 4.52 | 2.20E-03 | | | ##### | ##### | ##### | #DIV/0! |
| | | #NUM! | #NUM! | 4.52 | 2.20E-03 | | | ##### | ##### | ##### | #DIV/0! |
| | | #NUM! | #NUM! | 4.52 | 2.20E-03 | | | ##### | ##### | ##### | #DIV/0! |
| | | #NUM! | #NUM! | 4.52 | 2.20E-03 | | | ##### | ##### | ##### | #DIV/0! |
| | | #NUM! | #NUM! | 4.52 | 2.20E-03 | | | ##### | ##### | ##### | #DIV/0! |
| | | #NUM! | #NUM! | 4.52 | 2.20E-03 | | | ##### | ##### | ##### | #DIV/0! |
| | | #NUM! | #NUM! | 4.52 | 2.20E-03 | | | ##### | ##### | ##### | #DIV/0! |
| | | #NUM! | #NUM! | 4.52 | 2.20E-03 | | | ##### | ##### | ##### | #DIV/0! |
| | | #NUM! | #NUM! | 4.52 | 2.20E-03 | | | ##### | ##### | ##### | #DIV/0! |
| | | #NUM! | #NUM! | 4.52 | 2.20E-03 | | | ##### | ##### | ##### | #DIV/0! |
| | | #NUM! | #NUM! | 4.52 | 2.20E-03 | | | ##### | ##### | ##### | #DIV/0! |
| | | #NUM! | #NUM! | 4.52 | 2.20E-03 | | | ##### | ##### | ##### | #DIV/0! |
| | | #NUM! | #NUM! | 4.52 | 2.20E-03 | | | ##### | ##### | ##### | #DIV/0! |
| | | #NUM! | #NUM! | 4.52 | 2.20E-03 | | | ##### | ##### | ##### | #DIV/0! |
| | | #NUM! | #NUM! | 4.52 | 2.20E-03 | | | ##### | ##### | ##### | #DIV/0! |
| | | #NUM! | #NUM! | 4.52 | 2.20E-03 | | | ##### | ##### | ##### | #DIV/0! |
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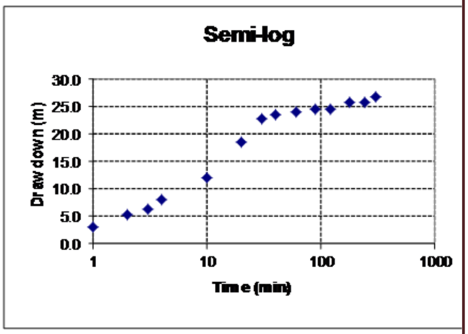


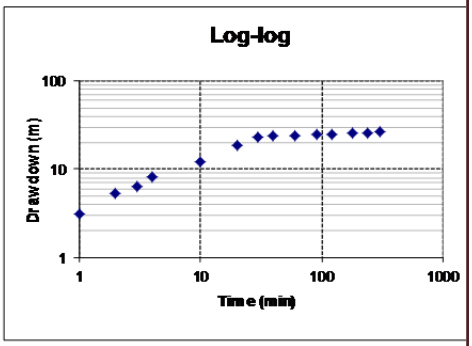


**Figure 5.5: Bore Test 18CAWB005.**

Approximate hydraulic parameters are: T value 8m$^2$/day with an average S of 2.2 x $10^{-3}$; barrier boundaries are evident on the drawdown curves. These much lower hydraulic parameters reflect the clayey gravels encountered at this location which impacted bore yields and consequently caused significant drawdown.

## 18CAWB006

The test on Bore 18CAWB006 yielded similar results than for Bore 5 and also encountered clayey gravels. The yield in this bore decreased from 1.0L/s at the start of the test to about 0.6L/s after 30 minutes.

It seems that the paleo channel across bores 4, 5 and 6 have a much higher clay content and thus do not contain sufficient groundwater to sustain discharge.

**18CARC027**

The test on Bore 18CARC027 resulted in larger drawdowns but again almost immediate recovery of the water level after discharge testing.

| | | | | |
|---|---|---|---|---|
| Country: | Australia | Main | Geology: | Gravel and sand; paleo channel |
| Region: | Wheatbelt | | Depth of BH: | 24 |
| Owner: | Caravel Minerals | Diagnostic Plots / Derivative | Water strikes: | Saturated below 4mbgl |
| X-coord: | 467,734 | | Date of Test: | 4/04/2018 |
| Y-coord: | 6,560,805 | Sust_Q | Contractor: | Orbit Drilling |

CONSTANT RATE TEST DATA : enter values in cells which are coloured light yellow

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Borehole: | CARC027 | | | | | | |
| Distance from Rest WL to main water strike (m) = | 0 | $s_{max}$= | 18.4 | Recom. AD= | 18.4 | | |
| AD= available drawdown for managing the borehole | | | | | | | |
| AD = | 20 | Time (y) = | 5 | | | | |
| T (m²/d) : Logan eq. | time = extrapolation time | | | | | | |
| 10.3 | | | | | | | |

Q (l/s)= 1.8 — Recovery data

| t (min) | s (m) | avg s' | avg s" | avg T | avg S | Time t' | Res_s | t/t' | Wl rise | s' | Rec_T |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.90 | | | | | 1 | 17.7 | 481 | 0.65 | | |
| 5 | 5.20 | | | | | 5 | 16.8 | 97 | 1.6 | 2.88 | |
| 10 | 6.05 | 2.52 | -0.76 | | | 10 | 14.5 | 49 | 3.85 | 13.54 | |
| 30 | 6.50 | 1.26 | -0.56 | 24.29 | 3.32E-06 | 20 | 8.6 | 25 | 9.75 | 11.46 | 4.4 |
| 60 | 6.70 | 0.97 | 0.24 | 24.29 | 3.32E-06 | 40 | 7.6 | 13 | 10.75 | 1.71 | #DIV/0! |
| 90 | 6.80 | 1.19 | 1.89 | 24.29 | 3.32E-06 | 120 | 7.2 | 5 | 11.15 | ##### | #DIV/0! |
| 120 | 6.90 | 2.83 | 3.98 | 13.01 | 1.32E-03 | | | ##### | ##### | ##### | #DIV/0! |
| 150 | 7.30 | 8.25 | 4.28 | 2.89 | 2.20E-03 | | | ##### | ##### | ##### | #DIV/0! |
| 180 | 7.65 | 20.35 | 2.91 | 1.09 | 2.20E-03 | | | ##### | ##### | ##### | #DIV/0! |
| 240 | 14.27 | 28.88 | 0.15 | 0.87 | 2.20E-03 | | | ##### | ##### | ##### | #DIV/0! |
| 300 | 16.35 | 23.18 | #NUM! | 0.87 | 2.20E-03 | | | ##### | ##### | ##### | #DIV/0! |
| 360 | 17.60 | #NUM! | #NUM! | 0.87 | 2.20E-03 | | | ##### | ##### | ##### | #DIV/0! |
| 420 | 18.24 | #NUM! | #NUM! | 0.87 | 2.20E-03 | | | ##### | ##### | ##### | #DIV/0! |
| 480 | 18.35 | #NUM! | #NUM! | 0.87 | 2.20E-03 | | | ##### | ##### | ##### | #DIV/0! |
| | | #NUM! | #NUM! | 0.87 | 2.20E-03 | | | ##### | ##### | ##### | #DIV/0! |
| | | #NUM! | #NUM! | 0.87 | 2.20E-03 | | | ##### | ##### | ##### | #DIV/0! |
| | | #NUM! | #NUM! | 0.87 | 2.20E-03 | | | ##### | ##### | ##### | #DIV/0! |
| | | #NUM! | #NUM! | 0.87 | 2.20E-03 | | | ##### | ##### | ##### | #DIV/0! |
| | | #NUM! | #NUM! | 0.87 | 2.20E-03 | | | ##### | ##### | ##### | #DIV/0! |
| | | #NUM! | #NUM! | 0.87 | 2.20E-03 | | | ##### | ##### | ##### | #DIV/0! |
| | | #NUM! | #NUM! | 0.87 | 2.20E-03 | | | ##### | ##### | ##### | #DIV/0! |
| | | #NUM! | #NUM! | 0.87 | 2.20E-03 | | | ##### | ##### | ##### | #DIV/0! |
| | | #NUM! | #NUM! | 0.87 | 2.20E-03 | | | ##### | ##### | ##### | #DIV/0! |
| | | #NUM! | #NUM! | 0.87 | 2.20E-03 | | | ##### | ##### | ##### | #DIV/0! |
| | | #NUM! | #NUM! | 0.87 | 2.20E-03 | | | ##### | ##### | ##### | #DIV/0! |
| | | #NUM! | #NUM! | 0.87 | 2.20E-03 | | | ##### | ##### | ##### | #DIV/0! |
| | | #NUM! | #NUM! | 0.87 | 2.20E-03 | | | ##### | ##### | ##### | #DIV/0! |
| | | #NUM! | #NUM! | 0.87 | 2.20E-03 | | | ##### | ##### | ##### | #DIV/0! |
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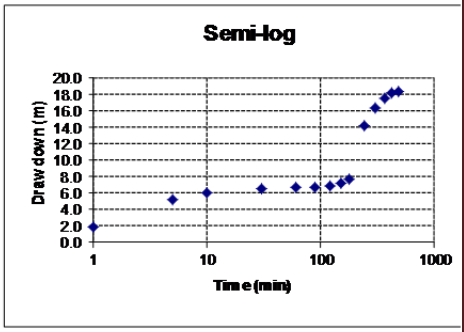
| | | #NUM! | #NUM! | 0.87 | 2.20E-03 | | | ##### | ##### | ##### | #DIV/0! |
| | | #NUM! | #NUM! | 0.87 | 2.20E-03 | | | ##### | ##### | ##### | #DIV/0! |
| | | #NUM! | #NUM! | 0.87 | 2.20E-03 | | | ##### | ##### | ##### | #DIV/0! |
| | | #NUM! | #NUM! | 0.87 | 2.20E-03 | | | ##### | ##### | ##### | #DIV/0! |
| | | #NUM! | #NUM! | 0.87 | 2.20E-03 | | | ##### | ##### | ##### | #DIV/0! |
| | | #NUM! | #NUM! | 0.87 | 2.20E-03 | | | ##### | ##### | ##### | #DIV/0! |



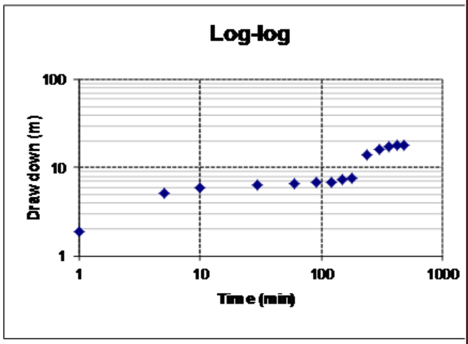




**Figure 5.6: Bore Test 18CARC027.**

Approximate hydraulic parameters for the sandy clays at this location are: T value 10m²/day with an average S of 2.2 x $10^{-3}$; barrier boundaries are evident on the drawdown curves and consequently caused significant drawdown towards the end of the test.

## 5.3 Ground Water Chemistry

### 5.3.1 Ground Water Quality

Samples of water were obtained subsequent to the drilling and testing program. A tabulated summary of the results and the detailed laboratory certificates may be found in Appendix C.

Field measurements of ground water quality reveal that pH is generally acidic and well below the Australian Drinking Water Guidelines. Total Dissolved Solids exceed the Australian Drinking Water Guidelines in all instances.

**Table 5.2: Field Measurements of Surface and Ground Water Quality.**

| | | Ground Water Level | pH | Temperature | Electrical Conductivity @ 25°C | Salinity | Total Dissolved Solids @ 25°C | Dissolved Oxygen | Oxidation Reduction Potential (ORP) |
|---|---|---|---|---|---|---|---|---|---|
| | **Units** | **mbgl** | **pH Unit** | **°C** | **µS/cm** | **ppt** | **mg/L** | **%** | **mV** |
| **ANZECC (2000)** | **Fresh Water (95%)** | **-** | **6.5-8.5** | **-** | **-** | **-** | **-** | **-** | **-** |
| **ADWG (2015, V3)** | **Aesthetic Value (AV)** | **-** | **6.5-8.5** | **-** | **-** | **-** | **600** | **>5** | **-** |
| **Date** | **Ground Water** | | | | | | | | |
| 13/04/18 | CAWB001 | 2.00 | **4.77** | 24.3 | 5,980 | - | **3,887** | 7.5 | - |
| 13/04/18 | CAWB002 | 5.30 | **5.15** | 24.1 | 2,950 | - | **1,918** | 7.5 | - |
| 13/04/18 | CAWB003 | 4.27 | **4.71** | 23.7 | 8,950 | - | **5,818** | 5.0 | - |
| 13/04/18 | CAWB005 | 1.40 | **5.72** | 23.5 | 8,120 | - | **5,278** | 5.8 | - |
| 13/04/18 | CAWB006 | 3.01 | **5.58** | 24.1 | 8,560 | - | **5,564** | **4.9** | - |
| 13/04/18 | CARC027 | 1.72 | **5.44** | 24.3 | 6,750 | - | **4,388** | 6.7 | - |
| 13/04/18 | CARC028 | 0.00 | **6.01** | 23.8 | 7,650 | - | **4,973** | 6.7 | - |
| | **Minimum** | **0.00** | **4.71** | **23.5** | **2,950** | **-** | **1,700** | **4.9** | **-** |
| | **Maximum** | **5.30** | **6.01** | **24.3** | **8,950** | **-** | **4,850** | **7.5** | **-** |
| | **Average** | **2.53** | **5.34** | **24.0** | **6,994** | **-** | **3,964** | **6.2** | **-** |
| **Note: Highlighted values exceed relevant guideline or trigger.** | | | | | | | | | |

Ground water has elevated concentrations of Total Dissolved Solids (generally well in excess of 600mg/L) and predominantly Chloride and Sodium, which often exceed the Australian Drinking Water Guidelines, and to a lesser extent Sulfate.

**Table 5.3: Concentrations of Major Ions in Ground Water.**

| | | Total Dissolved Solids @ 180°C | Total Hardness as $CaCO_3$ | Total Alkalinity as CaCO3 | Acidity as CaCO3 | Silicon as SiO2 | Sulfate as SO4 | Chloride | Calcium | Magnesium | Sodium | Potassium |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Units** | **(mg/L)** | | | | | | | | | | |
| **ADWG (2015, V3)** | **Health Value (HV)** | **-** | **-** | **-** | **-** | **-** | **500** | **-** | **-** | **-** | **-** | **-** |
| | **Aesthetic Value (AV)** | **600** | **200** | **-** | **-** | **-** | **250** | **250** | **-** | **-** | **180** | **-** |
| **DoH (2014)** | **Non-Potable Use** | **-** | **-** | **-** | **-** | **-** | **1,000** | **250** | **-** | **-** | **-** | **-** |
| **Date** | **Surface Water** | | | | | | | | | | | |
| 13/06/15 | Lake (pond) | **13,400** | **2,100** | 315 | - | - | 185 | **7,400** | 57 | 476 | **3,570** | 128 |
| **Date** | **Ground Water** | | | | | | 104 | | | | | |
| 13/04/18 | CAWB001 | **3,820** | **569** | 32 | - | - | **315** | **1,700** | 20 | 126 | **874** | 35 |
| 13/04/18 | CAWB002 | **1,830** | **270** | 17 | - | - | **282** | **795** | 9 | 60 | **385** | 14 |
| 13/04/18 | CAWB003 | **5,660** | **1,120** | 5 | - | - | **299** | **2,720** | 15 | 263 | **1,180** | 46 |
| 13/04/18 | CAWB005 | **5,150** | **985** | 5 | - | - | 198 | **2,460** | 12 | 232 | **1,180** | 41 |
| 13/04/18 | CAWB006 | **5,470** | **918** | 7 | - | - | **258** | **2,720** | 10 | 217 | **1,160** | 39 |
| 13/04/18 | CARC027 | **4,110** | **393** | 70 | - | - | 185 | **1,870** | 22 | 82 | **1,030** | 31 |
| 13/04/18 | CARC028 | **5,050** | **956** | 30 | - | - | 104 | **2,420** | 20 | 220 | **1,290** | 47 |
| | **Minimum** | **1,830** | 270 | 5 | **-** | **-** | 104 | **795** | 9 | 60 | **385** | 14 |
| | **Maximum** | **5,660** | 1,120 | 70 | **-** | **-** | **315** | **2,720** | 22 | 263 | **1,290** | 47 |
| | **Average** | **4,441** | 744 | 24 | **-** | **-** | 234 | **2,098** | 15 | 171 | **1,014** | 36 |
| **Note: Highlighted values exceed relevant guideline or trigger.** | | | | | | | | | | | | |

The heavy metals Arsenic, Cadmium, Chromium (except two small detections), Lead, Selenium, Iron (except two small detections) and Mercury are absent in groundwater. Concentrations of Aluminium, Copper, Nickel and Zinc generally exceed the ANZECC Fresh Water guidelines for most if not all species protection levels but are well below the drinking water guideline.

**Table 5.4: Concentrations of Heavy Metals in Ground Water.**

| | | Aluminium | Copper | Nickel | Zinc |
|---|---|---|---|---|---|
| | Units | mg/L | | | |
| ASC NEPM 1999 | GILs: Fresh water (95%) | 0.055 | 0.0014 | 0.011 | 0.008 |
| | GILs: Drinking Water | - | 2 | 0.020 | - |
| ANZECC (2000) | Fresh Water (80%) | 0.15 | 0.0025 | 0.017 | 0.031 |
| | Fresh Water (90%) | 0.08 | 0.0018 | 0.013 | 0.015 |
| | Fresh Water (95%) | 0.055 | 0.0014 | 0.011 | 0.008 |
| ADWG (2015, V3) | Health Value (HV) | | 2 | 0.02 | - |
| | Aesthetic Value (AV) | 0.2 | 1 | - | 3 |
| DoH (2014) | Non-Potable Use | 0.2 | 20 | 0.2 | 3 |
| Date | Ground Water | | | | |
| 13/04/18 | CAWB001 | <0.01 | 0.003 | 0.002 | <0.005 |
| 13/04/18 | CAWB002 | <0.01 | 0.002 | <0.001 | <0.005 |
| 13/04/18 | CAWB003 | 1.17 | 0.005 | 0.015 | 0.065 |
| 13/04/18 | CAWB005 | 0.35 | 0.026 | 0.007 | 0.036 |
| 13/04/18 | CAWB006 | 0.02 | 0.030 | 0.004 | 0.029 |
| 13/04/18 | CARC027 | <0.01 | 0.017 | 0.005 | 0.008 |
| 13/04/18 | CARC028 | <0.01 | 0.015 | 0.006 | 0.011 |
| | Minimum | 0.02 | 0.002 | 0.002 | 0.008 |
| | Maximum | 1.17 | 0.030 | 0.015 | 0.065 |
| | Average | 0.51 | 0.014 | 0.007 | 0.030 |
| Notes: Highlighted values exceed relevant minimum guideline or trigger. | | | | | |

Ground water is deficient in nutrients:

- Ammonia (as N) varies between 0.03mg/L and 0.06mg/L.
- Nitrite is absent and Nitrate (as N) varies between <0.01mg/L and 12.30mg/L averaging 3.53mg/L.
- Total Nitrogen (as N) varies between 1.0mg/L and 15.1mg/L averaging 3.99mg/L.
- Total Phosphorous varies between <0.05mg/L and 18.60mg/L averaging 6.35mg/L whilst Reactive Phosphorous varies between 0.02mg/L and 12.50mg/L averaging 2.31mg/L.

Excluding the elevated Nitrate in Bore B002, these concentrations are well below their respective assessment levels.

Graphical illustrations of surface and ground water chemistry indicate that:

## Piper Diagram

The Piper Diagram (Figure 5.7) allows for the graphical illustration of both anion and cation compositions on a single graph as percentages and is convenient for showing the mixing of waters from different sources and for visually describing the differences in major ion chemistry in groundwater flow systems. They also reveal similarities and differences among groundwater samples; those samples with similar qualities will tend to plot together as groups.

Figure 5.7 indicates that the surface and groundwater samples fall within the Na-Cl zone (water type) typical of marine or deep old stagnant ground waters receiving little if any recharge. There appears to be slight separations between the surface water sample and the groundwater samples with an additional separation with sample CARC027. Spatially sample CARC027 is approximately 11 km to the south of all the other samples (except CARC028 which is about 175 m to the east of CARC027). Although on a macro scale the differences could be considered negligible, reaching conclusions regarding recharge interactions might be with less confidence due to these minor discrepancies.

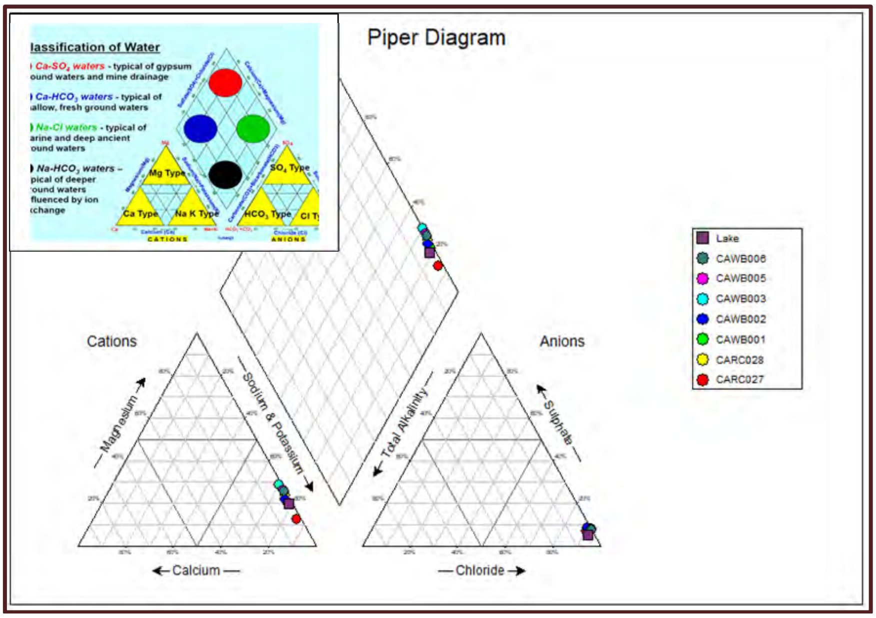



**Figure 5.7: Piper Diagram.**

**Expanded Durov Diagram**

A Durov Diagram is similar to a Piper Diagram in that relative percentages of the major ions (macro chemistry) are illustrated in nine different fields (Figure 5.8) each representing a different classification. All the samples at the Calingiri Project fall within the lowermost right corner indicative of a very old, stagnant water that has reached the end of the hydrogeological cycle (deserts, salty pans, etc.) or water that has moved a long time and/or distance through the aquifer and has undergone significant ion exchange during its migration to the surface. Too little information is currently available to make any comment with regard to the distance and duration.

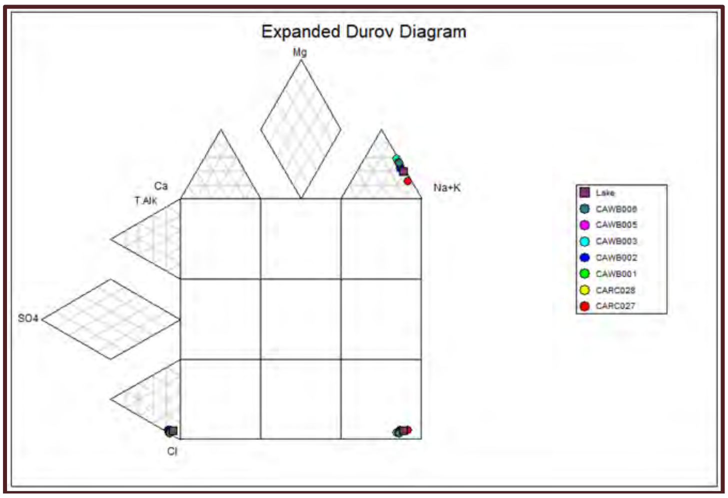



**Figure 5.8: Durov Diagram.**

**Stiff Diagram**

Stiff diagrams illustrate individual samples as a means to graphically compare the concentrations of selected anions and cations. The shapes of the diagrams quickly identify samples with similar compositions and are particularly useful when used for mapping to show the geographic locations of different water facies. In a Stiff Diagram, data is plotted as a polygon, with cations to the left and anions to the right. From Figure 5.9 it is evident that all the samples have a similar signature albeit at different scales; the surface water sample exhibits a more pronounced signature, while sample CAWB002 has the least pronounced signature although it is located closest to the surface water sample.

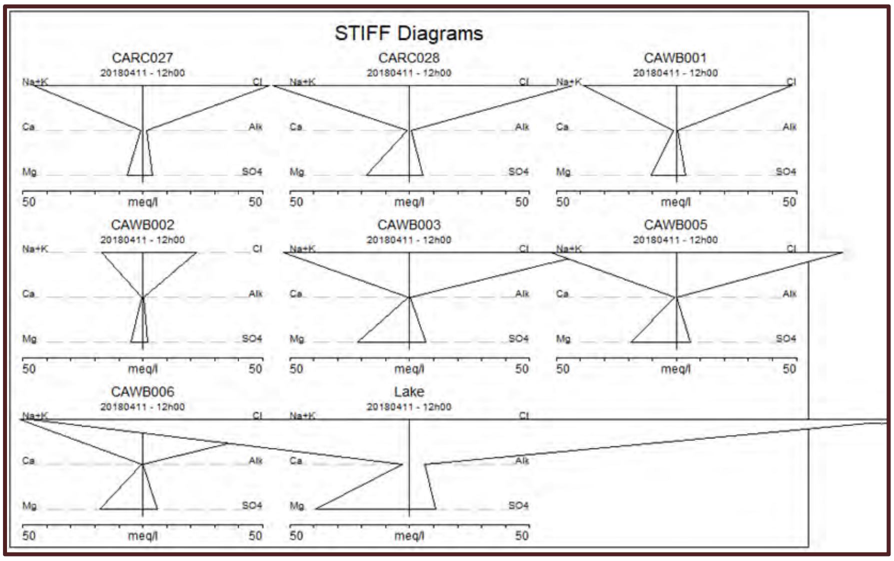



**Figure 5.9: Stiff Diagram.**

Taking due cognisance of the graphical illustrations it seems that the surface water sample is an expression of groundwater and that the larger salt content is due to evaporation.

## 5.3.2 Stable Isotope Analysis

Isotopes are atoms that have the same number of protons but a different number of neutrons. They can be divided into radioactive and stable isotopes. Radioactive isotopes undergo spontaneous breakdown of their nuclei to form other isotopes whilst stable isotopes do not break down spontaneously. Isotopes have a wide range of applications in physical as well as biological sciences. For the purpose of this investigation, the focus will be on stable isotopes and a way to interpret the results from analysis of these stable isotopes to assist us in describing and characterising the surface and near-surface groundwater regimes.

By making use of stable isotope fractionation, stable isotopes can be applied in environmental and geological studies due to changes in their isotopic ratios as part of their physical, chemical and biological interaction with their environment. Deuterium ($^{2}H$) and Oxygen 18 ($^{18}O$) are the two most common stable isotopes in the field of hydrogeology and are frequently used to determine the origin of a specific water sample or the residence time of a groundwater sample. It can also be used to compare different water samples to understand different processes involved and to assist in grouping samples together due to their specific characteristics.

Owing to a linear relationship between the $\delta^{18}O$ and $\delta^{2}H$ in precipitation that has not been evaporated

(Craig, 1961) a standard for comparison, the *Global Meteoric Water Line* (GMWL) can be described by the equation:

$$\delta D = 8\delta^{18}O + 10 \qquad \textit{Equation 1}$$

Equation 1 has been derived from precipitation data across the globe with an $R^2$ value of better than 0.95. This implies that the stable oxygen and hydrogen isotopes in water molecules are closely related and therefore the isotopic ratios and fractionations of the two elements are most often evaluated and reported together. It needs to be noted that if data is available, it is more appropriate to establish a *Local Meteoric Water Line* (LMWL) for comparison as in some instances this site-specific standard can vary significantly from the GMWL. In most cases the slope of the LMWL is in the range of 8 ± 0.5 but slopes between 5 and 9 are not that uncommon.

Deviations from the GMWL are caused by natural processes; therefore, water that has been subjected to evaporation or that has mixed with evaporated water will typically plot below the GMWL along lines that intersects it at the location of the original unevaporated composition of the water; evaporation lines with slopes in the range of 2 to 5 are common. Low temperature diagenetic reactions involving silicate hydrolysis can sometimes cause increases in the $\delta^{18}O$ and $\delta D$ values of waters.

At any given location, two primary factors control the isotopic signature of precipitation:

- the temperature of condensation of the precipitation; and
- the degree of rainout of the air mass (the ratio of water vapor that has already condensed into precipitation to the initial amount of water vapor in the air mass).

Evaporation from low-altitude oceans contributes most of the vapor in the atmosphere and consequently precipitation derived from this vapor is always enriched in D and $^{18}O$ relative to the vapor with the fractionation between the rain and vapor a function of condensation temperature. When clouds move inland, they become increasingly isotopically lighter as successive rain storms along its path cause the heavier isotopes to be depleted resulting in more negative $\delta$ values.

As groundwater is essentially recharged from precipitation in most systems, knowledge of the factors that control the isotopic compositions of precipitation before and after recharge makes it possible to use hydrogen and oxygen isotopes as tracers to identify water sources (origin) and processes. Regionally, isotopic compositions are controlled by several factors:

- **Altitude effect**: on the windward side of a mountain, the $\delta^{18}O$ and $\delta D$ values of precipitation decrease with increasing altitude. Typical gradients are -0.15‰ to -0.5‰ per 100m for $^{18}O$, and -1.5‰ to -4‰ per 100m for D. This pattern is often not observed in interior mountains, for snow, or on the leeward side of mountains.
- **Latitude effect**: The $\delta^{18}O$ and $\delta D$ values decrease with increasing latitude because of the increasing degree of *rain-out*.
- **Continental effect:** Isotopic ratios decrease inland from the coast.
- **Amount effect**: The greater the amount of rainfall, the lower the $\delta^{18}O$ and $\delta D$ values of the rainfall; this effect is not seen in snow.

At a given location, the seasonal variations in $\delta^{18}O$ and $\delta D$ values of precipitation and the weighted average annual $\delta^{18}O$ and $\delta D$ values of precipitation remain fairly constant from year to year. This is because the annual sequence of climatic conditions (temperatures, vapor source, direction of air mass movement, etc.) and range thereof remain more or less constant from one year to the other. Generally summer rain is isotopically heavier (more positive $\delta$ values) than winter rainfall. This is primarily caused by seasonal temperature differences but changes in moisture sources and storm tracks can also contribute to this observation.

Shallow groundwater usually reflects the local average of $\delta^{18}$O and δD values of precipitation but is modified to some extent by selective recharge and fractionation processes that may alter the $\delta^{18}$O and δD values of the precipitation before the water reaches the saturated zone (Gat and Tzur, 1967). Some of these processes include:

- Evaporation of rain during infiltration.
- Selective recharge.
- Interception of precipitation by the tree canopy.
- Exchange of infiltrating water with atmospheric vapor.

In the case of snow, various post-depositional processes, such as melting and subsequent infiltration of surface layers and evaporation, may alter the isotopic content of the snowpack, often leading to meltwater δ values that become progressively enriched (Stichler, 1987).

Table 5.5 summarises the stable isotope analysis on a surface and groundwater samples from the preliminary exploration bores. Figure 5.10 provides a general guide with regard to interpretation of stable water isotopes.

**Table 5.5: Stable Isotope Analytical Data.**

| Sample ID | Sample date | δD (‰) | $\delta^{18}$O (‰) |
|---|---|---|---|
| 18CAWB001 | 2018/04/27 | -25.7 | -4.73 |
| 18CAWB002 | 2018/04/27 | -24.9 | -4.27 |
| 18CAWB003 | 2018/04/27 | -26.1 | -4.78 |
| 18CAWB004 | 2018/04/26 | -25.5 | -4.61 |
| 18CAWB005 | 2018/04/26 | -26.9 | -4.96 |
| 18CAWB006 | 2018/04/26 | -25.0 | -4.17 |
| 18CARC026 | 2018/04/27 | -24.8 | -4.58 |
| 18CARC027 | 2018/04/27 | -25.3 | -4.70 |

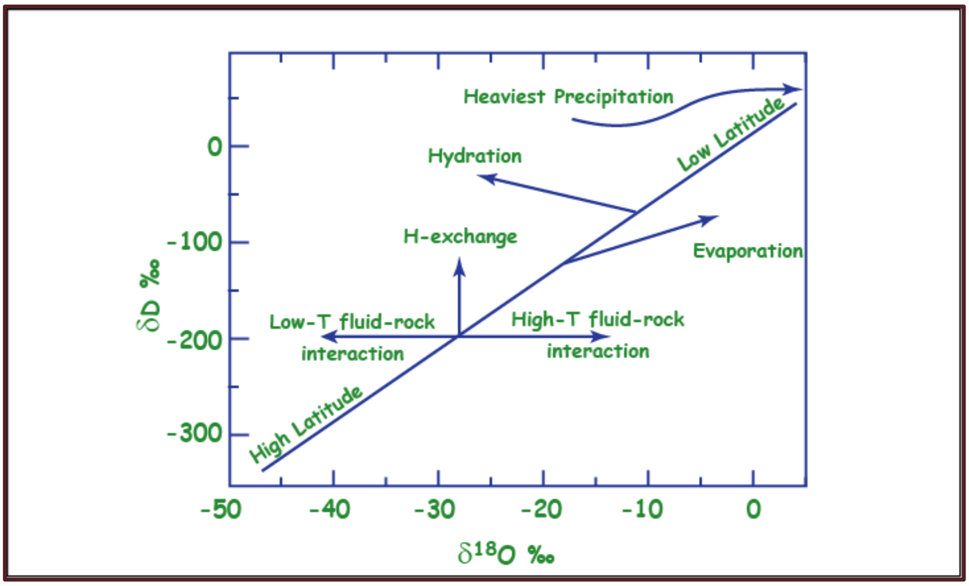



**Figure 5.10: General guide for $^{18}$O and $^{2}$H Interpretation.**

Figure 5.11 depicts the graphical representation of the isotope data against the GMWL, while Figure 5.12 represents the same data set against the LMWL (generated from information gleaned from Crosbie *et. al.*, 2012).

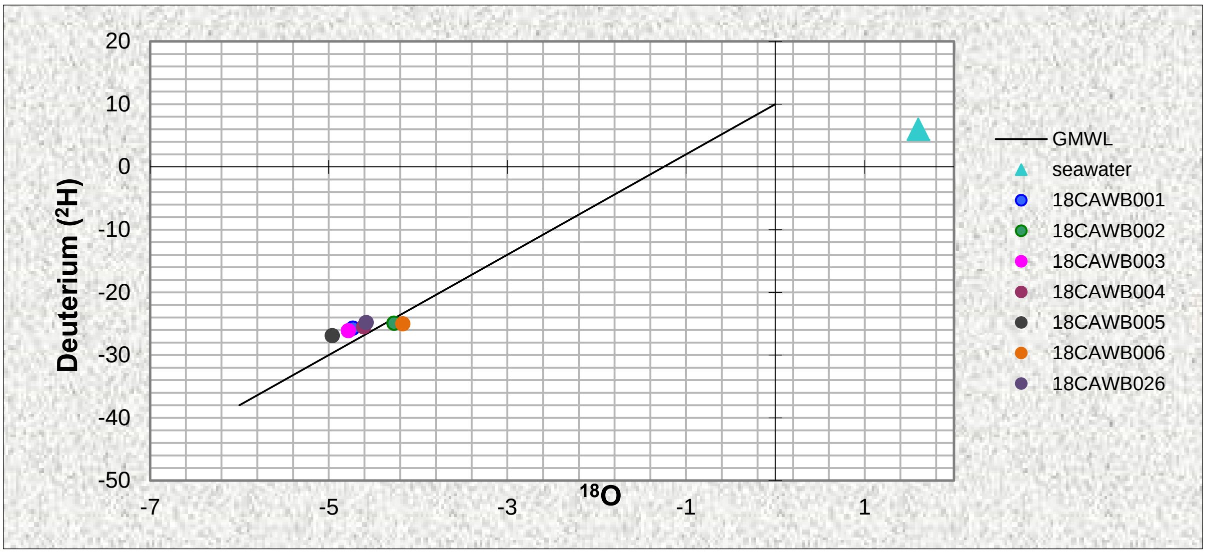



**Figure 5.11: Graphical Representation of Isotope Data vs the GMWL.**

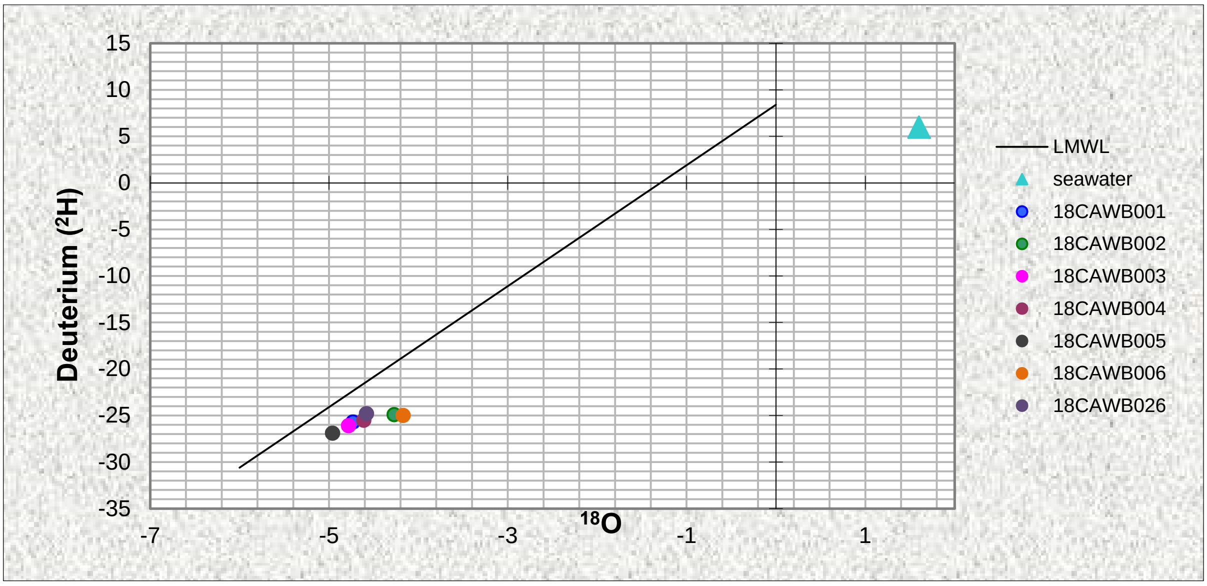



**Figure 5.12: Graphical Representation of Isotope Data vs the LMWL.**

The δD values range between -24.8‰ and -26.9‰ whilst the $\delta^{18}O$ values range between -4.17‰ and -4.96 ‰. It is evident that the values plot quite close to the standard (GMWL) which indicates that the relationship between the two parameters did not change significantly from where precipitation formed over the ocean to where recharge is occurring. Using the LMWL however, a distinct deviation to below the LMWL at a mean slope of 2.1 is apparent which fits within the acceptable range for evaporation. This evaporation effect could be indicative of slow infiltration rates that will in turn have an effect on the rate of recharge to the underlying aquifer(s).

The use of chloride as an environmental hydrologic tracer was first introduced in 1969 where groundwater recharge was determined in arid regions characterized by low relief and deep unsaturated zones. The chloride mass balance method (CMB method) involves quantifying the mass of chloride derived from precipitation to the aquifer system based on measuring the chloride concentration in precipitation and groundwater or estimating the amount of precipitation received from which an annual volume of groundwater recharge could be calculated (Aishlin, 2006). The use of the CMB method provides a practical low cost means for estimating groundwater recharge (van Tonder and Bean, 2003). In addition, the method for the saturated zone may be particularly useful in areas where groundwater levels do not fluctuate or data on groundwater levels are lacking (Adams, *et. al.*, 2004).

The use of CMB method to estimate groundwater recharge at the Calingiri Project is subject to the following assumptions (applicable to the methodology in general):

- Chloride concentration in the system and mean rainfall did not change over time i.e. it is assumed that the climate is stable (Kirchner, 2003).
- Chloride in the system is conservative (Aishlin, 2006) thereby assuming that the increase in chloride concentration is due to evapotranspiration losses only and that no additional chloride has been added by contamination from or leaching of overburden/bedrock (Woodford and Chevallier, 2002) and that bulk wet and dry fall are the only inputs of chloride to the system.
- The system is at steady state and no external surface and/or ground water inflows occur.
- No unmeasured runoff from the system occurs (Aishlin, 2006).
- Recharge moves vertically through the unsaturated zone (van Tonder and Bean, 2003), except where shallow sandy soils overlie less permeable sedimentary sequences on gently sloping terrain (Beekman and Xu, 2003).

In addition to the above assumptions, several limitations apply to the CMB method:

- The method should not be applied to areas underlain by evaporates or areas where up-coning or mixing of saline ground waters occurs.
- Use in fractured rock systems (Beekman and Xu, 2003). Groundwater flow in fractured rock aquifers tends to concentrate in the permeable fracture zones usually located in the bottoms of valleys (Sami, 2003).
- The method should be applied with great caution in areas close to the sea where rainfall chloride contents are highly variable (Beekman and Xu, 2003).
- The absence of long-term rainfall quality data (van Tonder and Bean, 2003).

Using the CMB method, recharge at the Calingiri Project is estimated at 6mm/a or 1.6% of the mean annual rainfall:

**Table 5.6: Summary of Cl-Method Estimation of Recharge.**

| | |
|---|---|
| Average rainfall (mm/a) | 388 |
| Cl in rain (mg/L) | 10.6 |
| Dry deposition Cl (mg/L) | 17.9 |
| Cl in groundwater or the unsaturated zone (mg/L) | 1,779 |
| **Average recharge (mm/a):** | **6** |
| **Recharge (% of mean annual rainfall):** | **1.6** |

In conclusion:

- Macro element analyses indicate a large concentration of salts in groundwater with larger concentrations in surface water (groundwater expressions) due to evaporation.
- The Piper Diagram indicates both surface and groundwater samples exhibit characteristics consistent with deep ancient waters. The mechanisms of interaction between surface and ground water could not be clearly established.
- The Durov Diagram confirms the above observations and indicates a water type that represent very old, stagnant water that has reached the end of the hydrogeological cycle or water that has moved a long time and/or distance through the aquifer and has undergone significant ion exchange.
- Stiff Diagrams indicate water types with the same characteristics but with a much more pronounced signature for surface water attributed to evaporation.
- Stable isotope data is consistent with vapor above the ocean when compared to the GMWL; however, when compared with the LMWL the samples, grouped in a narrow cluster, deviate with a trend line with a slope of just above 2, indicative of evaporation, consistent with what is observed with the chemical diagrams of the macro elements.
- Recharge is estimated using the CMB method at 1.6% of the average annual rainfall.
- A single data set is never ideal to reach conclusive results but the consistency in the results from all the different methods that was applied during this analysis, all indicate very low recharge probabilities with a definite evaporation component across the area.
- Although recharge to the paleo-channel is obvious, indications are that it does not occur at an advanced rate and precipitation undergoes evaporation impacted upon by chemical reactions along the pathway(s) towards the underlying aquifer(s).

# 6. Conceptual Ground Water Model

## 6.1 Introduction

This section presents a preliminary simplistic conceptual model of the aquifers at the Calingiri Copper Project. Numerical modelling has not been attempted due to a lack of sufficient data.

A conceptual model consists of a set of assumptions that describe the composition of the aquifer or ground water flow regime, based on field observations, measurement and interpretation of data. It can be regarded as a pictorial representation of the ground water flow regime and is frequently in the form of a simplified diagram or hydrogeological cross section. It defines the dimensions of a numerical model, how the grid is designed and how the grid is oriented and is an evolving hypothesis identifying important features, processes and events controlling fluid flow in a specific location. Assumptions that constitute a conceptual model should relate to the following:

- The flow regime.
- The matrix of the aquifer with reference to its homogeneity, heterogeneity, anisotropy and isotropy.

Homogeneity refers to if the hydraulic conductivity (K) is independent of position within a geologic formation. If K is dependent on position within a geologic formation, which is always the case in ground water systems, the formation is heterogeneous. In a homogeneous formation, $K_{(x, y, z)} = C$, C being a constant; whereas in a heterogeneous formation $K_{(x, y, z)} \neq C$. If the hydraulic conductivity (K) is independent of the direction of measurement at a point in a geologic formation, the formation is isotropic at that point. If K varies with the direction of measurement at a point in a geologic formation, the formation is anisotropic at that point.

Constructing a representative conceptual model and the degree of simplification in any particular case depends on available resources and information. Elements of a comprehensive conceptual model development process include:

- Geological formation and aquifer type.
- Boundary conditions.
- Ground water quality.
- Geometric structure of the system.

Although a conceptual model is by necessity a simplification of information, it should relate to the problem being addressed. The context in which the model is developed constrains the applicability of the model.

### 6.2 The Calingiri Conceptual Model

A simplified interpretation from bore completion records includes:

- The primary aquifers are:
  - sediments confined to paleo channels or valleys;
  - within and underlain by weathered/fractured granite-gneiss bedrock, faulted in places and intruded by near-vertical dykes of dolerite.

  Preliminary investigations were undertaken to assess the paleo valleys but the underlying faulted and intruded bedrock utilising the overlying paleo channels as a source for recharge has yet to be investigated.

Ground water was encountered in paleo channel sediments between 5m and 45m with yields varying between 0.1L/s and 4.8L/s from 100mm diameter bores. Preliminary assessments suggest that larger yields in the range between 10L/s and 20L/s are possible.

The hydraulic conductivities, $K_h$, of the paleo channel sediments fall within the range semi-permeable to permeable in the range between 1m/day and 10m/day. Vertical permeabilities, $K_v$, due to the near horizontally bedded nature of the strata, are considered to be one order of magnitude lower. The estimated T values vary between ~10m$^2$/day and ~889m$^2$/day with a storativity value around 0.002.

Recharge to the paleo channels was estimated at 6mm/a or 1.6% of the mean annual rainfall which may constrain groundwater exploitation as a large area will be required to sustain bore and aquifer yields over the long term.

Ground water has elevated concentrations of Total Dissolved Solids (between 1,900mg/L and 5,000mg/L), predominantly Chloride and Sodium, which often exceed the Australian Drinking Water Guidelines, and to a lesser extent Sulfate. The heavy metals Arsenic, Cadmium, Chromium, Lead, Selenium, Iron and Mercury are absent in groundwater. Concentrations of Aluminium, Copper, Nickel and Zinc generally exceed the ANZECC Fresh Water guidelines for most if not all species protection levels but are well below the drinking water guideline.

More drilling, and testing and sampling are required across the area in order to develop the conceptual model to a level of higher confidence and higher resolution regarding geological heterogeneities. Piezometric heads need to be measured across the area to be able to determine the aquifer(s) within the system as well as their interaction. Boundaries need to be investigated in more detail.

# 7. Assessment of Potential Impacts

This section details a preliminary identification of potential impacts to the aquifer, environment or other groundwater users, that may be caused by the proposed mining and processing, particularly disposal of waste rocks and tailings, mine influx and ground water abstraction. It is generally required to provide an evaluation of the potential extent of the cone of depression (impact of the proposed ground water abstraction and influx into the open pits) taking due cognizance of the aquifer parameters obtained from test pumping investigations or from other factual information.

Based on the results of limited groundwater investigation and assessment to date, the potential impacts of mining and processing, including abstraction of groundwater/mine influx, include:

- Receding ground water levels, deteriorating ground water quality and declining bore/aquifer yields.
- Potential acid mine drainage and sediment/salt loads.
- The aquifer/ground water resource including leakage from other aquifers.
- Other users (private and public) including GDEs and subterranean fauna, where and if present.
- The receiving environment.

The environmental factors (EPA, 2015) with reference to ground water include Hydrological Processes, Inland Waters Environmental Quality and Rehabilitation and Decommissioning. The primary objectives are to ensure that the quality of surface and ground water is maintained to protect environmental values, ecological and social, and existing and potential uses to facilitate decommissioning and closure in an ecologically sustainable manner. To achieve these objectives, appropriate management of mining, waste rock and tailings disposal and ground water abstraction/mine influx will be required.

The key risks for mining and processing pertain to:

- The potential for impacts to soils, sediment, surface and ground water resources by seepages, leachates and/or runoff from the process plant ROM pad and stockpiles, WRDs and the TSF containing potentially acid producing materials.
- Open pit mining: ground water influx, exposing sulfide-bearing materials in pit walls, water quality and pit lakes.
- Over exploitation of ground water resources by groundwater abstraction and mine influx.

## 7.1 Ground Water Levels

Ground water levels may be impacted by:

- Seepage from mine impoundments such as ROM pad, stockpiles and plant water infrastructure, WRDs and the TSF: mounding underneath and downstream thereof will cause a local rise in ground water levels and may impact groundwater quality.
- Open pit sinks and/or lakes post closure.
- Mine influx: receding ground water levels across mining area and beyond may impact local and/or regional water supplies.
- Ground water supply abstraction: receding ground water levels and declining yields across mining area and beyond may impact local and/or regional water supplies.

## 7.2 Ground Water Quality

Ground water quality may be impacted by:

- Infiltration/seepage from surface impoundments, the WRD's and TSF may impact on the quality of ground water beneath and within the vicinity of these structures.
- Open pit sinks and/or lakes post closure.
- Ground water abstraction: increasing acidity and salinity across mining area and beyond.

Receding groundwater levels may have a positive impact on soil salinity and groundwater quality.

## 7.3 Ground Water Yields

The impact of seepage and increased infiltration on ground water yields are considered negligible.

Ground water abstraction and mine influx will decrease ground water yields within the cone of influence due to mine influx/dewatering of the fractured bedrock.

## 7.4 Potential AMD and Sediment/Salt Loads

The key risks for mining and processing pertain to:

- The potential for impacts to soils, sediment, surface and ground water resources by seepages, leachates and/or runoff from the ROM pad and stockpiles, waste rock and tailings containing potentially acid producing materials. Whilst this risk is currently considered low, further investigation and assessment pertaining to soil and waste characterisation is required (Pendragon Environmental Solutions, 2018).
- Exposure of sulfide-bearing materials in open pit excavations during mining and subsequent remaining exposures as groundwater sinks and/or pit lakes.

## 7.5 Aquifer/Ground Water Resource

Ground water abstraction will cause rapidly declining ground water levels and consequently bore/aquifer yields.

Whilst ground water abstraction will retain potential water quality impacts within the cone of drawdown/mine influx, ground water qualities may deteriorate when ground water levels return to their pre-mining levels following rehabilitation and closure. Seepages of leachates from mining infrastructure may migrate downstream once ground water levels returned to their pre-mining levels.

## 7.6 Beneficial Use and the Receiving Environment

Beneficial uses and the receiving environment within the zone impacted by mining and processing include other groundwater users and GDEs and subterranean fauna if present.

Further isotope/water quality sampling will be required to ascertain whether the shallow paleo channel aquifers are interconnected with the underlying deep fractured aquifers. The underlying deep fractured aquifers may receive limited recharge, if any.

There seems to be no GDEs within the areas earmarked for mining and processing (to be confirmed by further investigation and assessment); hence the likely zone of impact of mining and processing is to be ascertained.

A desktop study assessment of stygofauna (EPA, 2013) to consider impacts of ground water abstraction/mine influx in a regional context and make conclusions about whether the area is likely to provide habitat for subterranean fauna indicated and/or to determine the level of survey and whether sampling is necessary, if any, indicated that stygofauna is unlikely to be present due to the salinity of groundwater within the area.

## 7.7 Summary of Impacts

A summary of the impacts, proposed management measures and controls and actions appear overleaf.

## Table 7.1: Summary of Impact Assessment.

| Impacts during Mining and Operations | Potential Risk | | | Proposed Management Measure and Control | Residual Risk | Action |
|---|---|---|---|---|---|---|
| | L | C | R | | | |
| **Surface Water and GDE's** | | | | | | |
| Infiltration/recharge, reduction in volume of surface water | L | Mi | Medium | Minimise disturbances/footprint, divert clean runoff. | Low | Incorporate in design.<br>Monitor water quality. |
| Deterioration of water quality in drainage lines | L | Mo | High | No discharge, contain dirty runoff, infiltration and seepage by design; provide pollution control measures including sufficient storage capacity. | | |
| Base flow, increase/decrease flow to potential GDEs, impact on biota | U | Mo | Medium | No discharge, contain dirty runoff, infiltration and seepage by design; provide pollution control measures including sufficient storage capacity. | Low | Incorporate in design.<br>Monitor water quality downstream of mine infrastructure. |
| **Ground Water Abstraction/Mine Influx** | | | | | | |
| Ground water level drawdown | A | Mo | High | Infiltration of mine influx to offset regional drawdown, abstraction at safe long term sustainable yields, spread production bores across mining area and manage abstraction to prevent over exploitation. | Low | Incorporate in design.<br>Provide additional monitoring bores.<br>Ground water monitoring: rates of influx/abstraction, water level drawdown and water quality |
| Bore/aquifer yield, mine influx | A | Mo | High | | | |
| Ground water quality | A | Mo | High | | | |
| Subterranean Fauna | Absent | | | | | |
| **Mine Infrastructure** | | | | | | |
| Infiltration/seepage from mining disturbances: potential AMD | L | Mi | Medium | Minimise disturbance areas; contain runoff. | | Incorporate in design.<br>Monitor surface and ground water quality |
| Seepage from WRDs, stockpiles, surface impoundments and tailings storage facility | L | Mo | High | Relative impermeable soils/formations, encapsulate and contain by design and engineering. | Low | Incorporate in design.<br>Monitor surface and ground water quality |
| **Residual Impact following Rehabilitation and Closure: Ground Water** | | | | | | |
| Ground water level drawdown | P | I | Low | Ground water levels will return to pre-mining levels. | Low | Ground water level monitoring until pre-mining levels are achieved<br>Remove abstraction equipment<br>Incorporate measures to curtail/ contain seepage from residual mine infrastructure such as waste rock dumps and tailings storage facility |
| Bore/Aquifer yield | U | I | Low | Cease abstraction and remove equipment. | Low | |
| Ground water quality | L | Mi | Medium | Contain seepage in a downstream direction in closure design. | Low | |

**Notes:** C denotes Consequence, L Likelihood and R Risk Rating.
Consequence: I - Insignificant, Mi – Minor, Mo – Moderate, Ma – Major and C – catastrophic.
Likelihood: R – Rare, U – Unlikely, P – Probable, L – Likely and A – Almost Certain.
Risk Categories: L – Low: acceptable, M – Medium: tolerable/acceptable – requires management, H – High: intolerable/unacceptable – requires high level of management; E – Extreme: unacceptable – discard activity.

# 8. Ground Water Monitoring

The proposed preliminary groundwater monitoring program aims at ascertaining pre-mining/ambient base-line groundwater levels and water quality for the subsequent determining the extent and severity of the subsequent impacts of mining and processing particularly with regard to mine influx, groundwater abstraction and disposal of wastes.

The bores drilled for investigative purposes thus far are suitable for ongoing monitoring (Figures 5.1 and 5.2). However, additional dedicated monitoring bores are to be provided during further ongoing investigations and upon completion of construction of mine infrastructure such as at the open pits, stockpiles at the process plant, waste rock dumps and the tailings storage facility.

The monitoring program is designed to adequately assess aquifer performance and determine any impact on surface and ground water quality, other users and/or the receiving environment. It is likely that several of the current locations will be relocated and/or discarded following further assessment on completion of the mining plan and schedule. The monitoring program will be expanded to also reflect relevant conditions of any pollution control license under the *Environmental Protection Act 1986*, if required and once available.

The proposed ground water monitoring frequency and analytes required to establish a sound environment baseline appears in Table 8.1.

**Table 8.1: Proposed Ground Water Monitoring Locations, Frequency and Analytes.**

| Monitoring Locations | Frequency | Measurements/Analytes |
|---|---|---|
| **Ground Water Monitoring Locations:**<br>Figures 5.1 and 5.2.<br>Additional locations are to be provided for:<br>▪ Open Pit Mining.<br>▪ Process Plant.<br>▪ Waste Rock Dumps.<br>▪ Tailings Storage Facility.<br>▪ Groundwater Abstraction. | **Continuous, when required** | Abstraction and influx rates and volumes, if any.<br>Rainfall.<br>Discharges from mining infrastructure, if any. |
| | **Quarterly** | **Field measurements:**<br>Depth to ground water level.<br>General field *in situ* (field) water quality measurements: pH, EC, TDS, Salinity, Temperature, Dissolved Oxygen, Oxidation Reduction Potential including observations such as appearance, odour, colour, etc.)<br>**Laboratory analyses:**<br>Total Alkalinity ($T_{alk}$, mg/L).<br>Total Acidity ($T_{ac}$, mg/L).<br>Major anions (Cl, $SO_4$, $CO_3$/$HCO_3$, $NO_3$-N; mg/L).<br>Major cations (Ca, Mg, Na and K; mg/L).<br>Dissolved metals (Al, As, B, Cd, Cr, Cu, Fe, Mn, Ni, Pb, Zn, Fe; µg/L). |
| **A full metal scan analysis will be undertaken for at least three sampling events and then periodically (e.g. annual) to confirm the proposed metal suite is appropriate for ongoing monitoring. Total metals analyses will also be undertaken at one monitoring site per sampling event as a quality control measure.**<br>**Water discharged, if any, shall have no visible surface films, oils and greases, Total Petroleum Hydrocarbons, litter or suspended matter.** | | |

Water quality data will be entered into an appropriate database and assessed against relevant water quality criteria and trigger values in order to immediately identify any potential impact as a consequence of mining and processing. Further investigation, if required, and remedial action will be undertaken promptly to address any potential water level and/or quality issues.

It is proposed that for ground water, the default Ground Water Investigation Levels (GILs) Schedule B1 National Environment Protection (Assessment of Site Contamination) Measure 1999 (amended in 2013) which combines the Australian Drinking Water Guidelines (NHMRC and NRMMC 2011) and the guidelines for 95 % species protection levels (hardness modified; ANZECC and ARMCANZ 2000) be adopted as trigger values for ground water quality (refer tabulations in Section 5.3: Ground Water Chemistry and Appendix C). Site-specific trigger values (and possibly for individual monitoring locations) are to be developed when there is sufficient data available from baseline monitoring and reference sites.

Monitoring data will be reported on and raw data provided at the required intervals and in agreed formats and will include an analysis of trends and comparisons with ambient water quality established prior to mining and appropriate water quality criteria and trigger values.

# 9. Management Approach

Whilst a preliminary impact assessment reveals that the potential risks appear to be acceptable and manageable, appropriate further site investigation and assessment are required to derive at specific management measures for mining and processing, waste rock and tailings disposal, mine influx into the open pits and well field ground water abstraction to ensure that there is no impact on the surrounding receiving environment. Caravel Minerals should prepare a Groundwater Management Plan.

# 10. Conclusions and Recommendations

## 10.1 Conclusions

The geology of the area comprises paleo channel sediments within and underlain by granite/gneiss bedrock which has been faulted and intruded by dykes of dolerite. The primary aquifers are:

- sediments confined to paleo channels or valleys; and
- weathered/fractured granite-gneiss bedrock, faulted in places and intruded by near-vertical dykes of dolerite.

Preliminary investigations were undertaken to assess the paleo valleys but the underlying faulted and intruded bedrock utilising the overlying paleo channels as a source for recharge has yet to be investigated. Ground water was encountered in paleo channel sediments between 5m and 45m with yields varying between 0.1L/s and 4.8L/s from 100mm diameter bores. Preliminary assessments suggest that larger yields in the range between 10L/s and 20L/s are possible and sustainable. Utilising the current range of hydraulic parameters (T values between 30m2/day and 900m2/day and a S value of 0.002), the cone of drawdown may extend between 7km and 10km from the plant site at an abstraction rate of 100L/s.

Recharge to the paleo channels was estimated at 6mm/a or 1.6% of the mean annual rainfall which may constrain groundwater exploitation as a large area will be required to sustain bore and aquifer yields over the long term.

Ground water has elevated concentrations of Total Dissolved Solids (between 1,900mg/L and 5,000mg/L), predominantly Chloride and Sodium, which often exceed the Australian Drinking Water Guidelines, and to a lesser extent Sulfate. The heavy metals Arsenic, Cadmium, Chromium, Lead, Selenium, Iron and Mercury are absent in groundwater. Concentrations of Aluminium, Copper, Nickel and Zinc generally exceed the ANZECC Fresh Water guidelines for most if not all species protection levels but are well below the drinking water guideline.

With the current layout of mine infrastructure and provided that construction employs best practice, it seems unlikely that mining and processing at the Calingiri Copper Project will impact any GDE's and subterranean fauna seems to be absent.

The primary impacts of mining and processing pertain to:

- The potential for impacts to soils, sediment, surface and ground water resources.
- Potential seepage from mine impoundments such as ROM pads, stockpiles and plant water infrastructure, WRDs and the TSF: mounding underneath and downstream thereof impacting groundwater quality.
- Groundwater abstraction and mine influx: receding ground water levels across mining area and beyond may impact local and/or regional water supplies.
- Exposure of sulfide-bearing materials in open pit excavations during mining and subsequent rehabilitation and closure.
- Open pit sinks and/or lakes post closure.

Whilst the impacts appear to be acceptable and manageable, appropriate site specific management of mining, waste rock and tailings disposal and ground water abstraction will be required to ensure that there is no impact on the receiving environment.

More drilling, and testing and sampling are required across the area in order to develop the conceptual model to a level of higher confidence and higher resolution regarding geological heterogeneities. Piezometric heads need to be measured across the area to be able to determine the aquifer(s) within the system as well as their interaction. Boundaries need to be investigated in more detail.

## 10.2 Recommendations

Consideration should be given to:

- Undertake a census of all available surface and ground water sources within the mine tenements.
- Refine the mine water requirement to define the extent of further groundwater supply investigations.
- Utilise geophysical techniques to delineate aquifers and locate future drilling targets.
- Groundwater monitoring in accordance with this document.
- Further drilling, testing and sampling to not only investigate the paleo channel aquifers but also the faulted/fractured and intruded underlying granite/gneiss.

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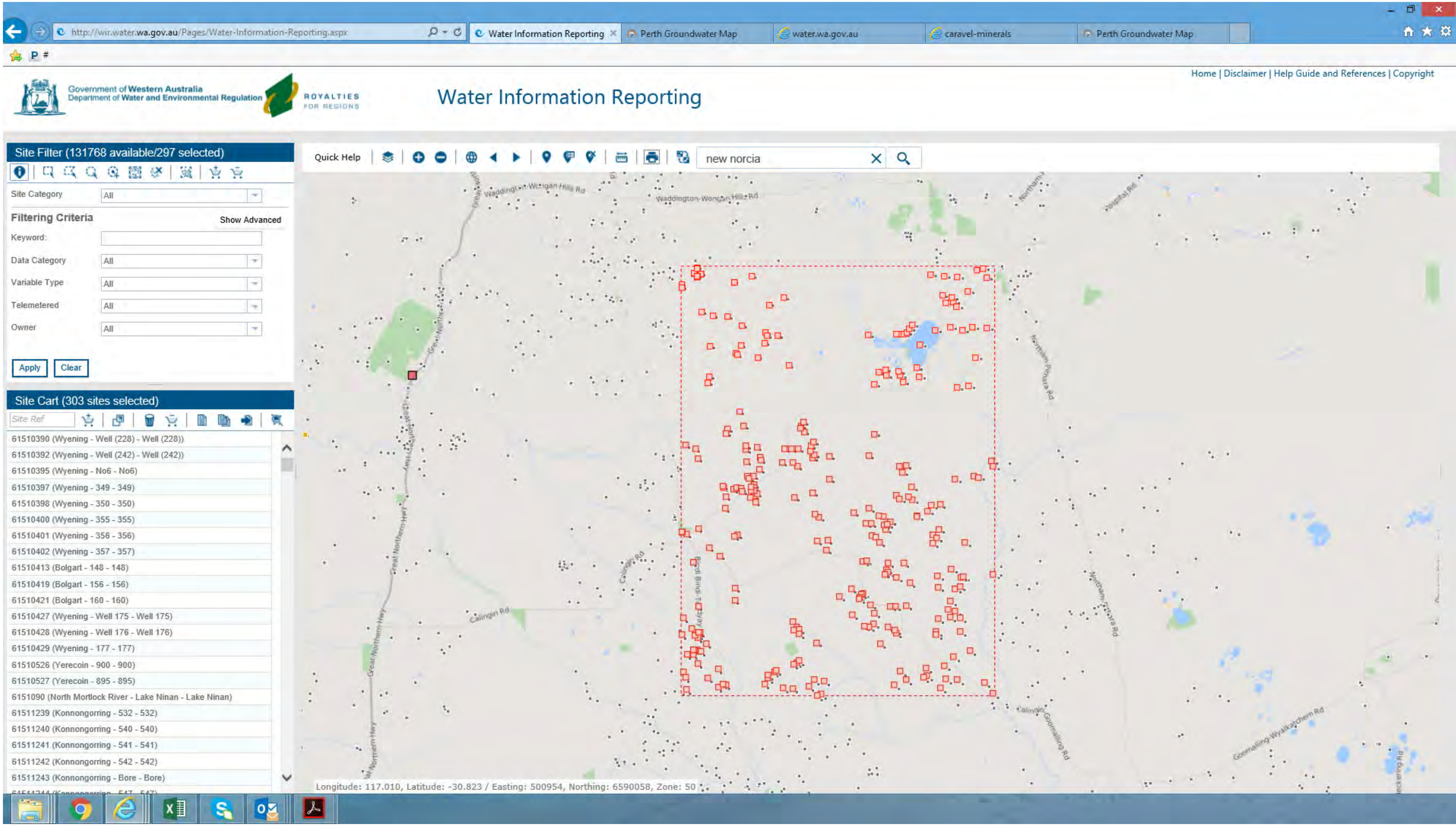
# Appendices

Appendix A: Search Data.

Appendix B: Bore Drilling and Testing Completion Records.

Appendix C: Water Quality Data and Laboratory Certificates.

# Appendix A: Search Data.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Department of Water and Environmental Regulation
ROYALTIES FOR REGIONS
Water Information Reporting
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Waddington-Wongan Hills Rd
Great Northern Hwy
Calingiri Rd
Northam-Pithara Rd
Goomalling-Wyalkatchem Rd
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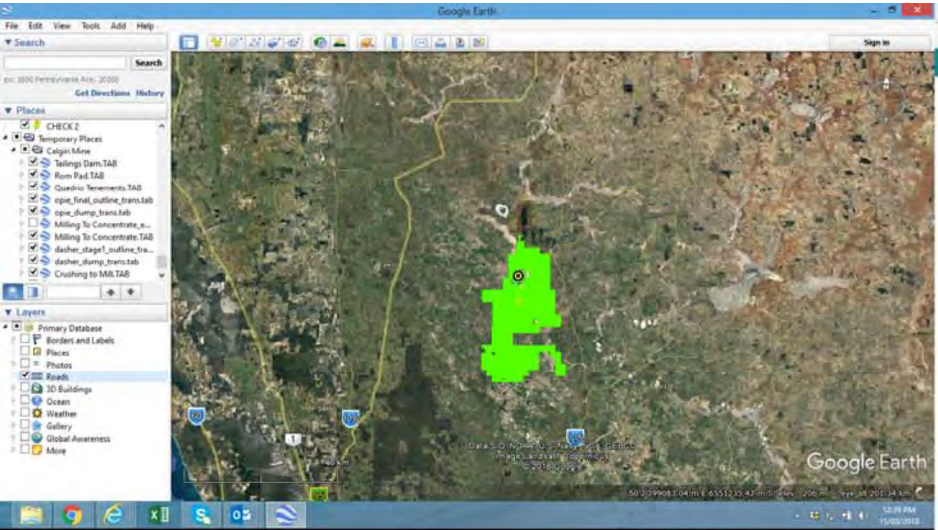
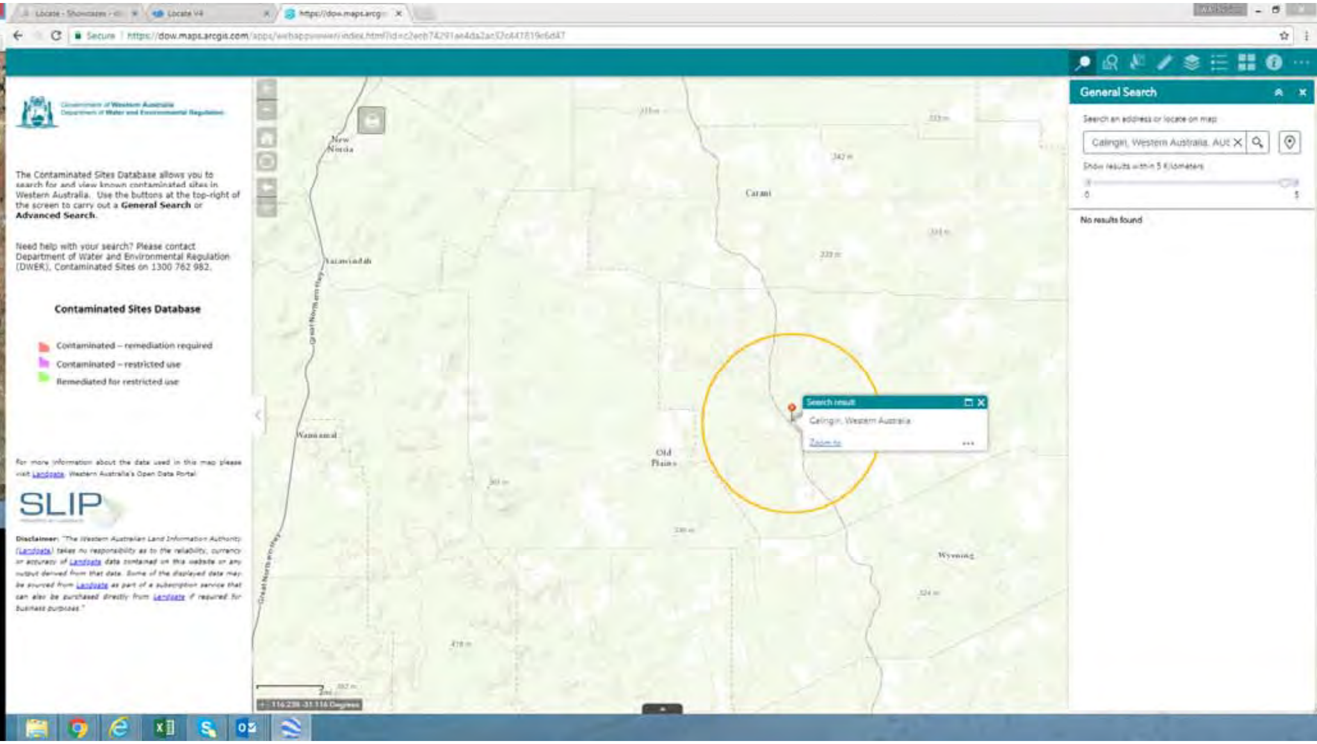
# Search radius 5km Calingiri town centre



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| 61716464 | 30/06/1965 00:00:00 | 20049564 | WA-G-<1996AQWADATA | 2136-2-SE-0025 | 0.51 | |
| 61719226 | 15/07/1988 10:30:00 | 2224568 | WA-S-SWRISHIST | 61719226 | | |
| 70210054 | 30/06/1988 00:00:00 | 20001045 | WA-G-<1996AQWADATA | 1742-4-SE-0087 | 6.09 | |
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| 70212131 | 1/01/1900 00:00:00 | 20000990 | WA-G-<1996AQWADATA | 1742-4-SE-0025 | 3.35 | |
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| | | | | **Minimum** | **0.00** | **0** |
| | | | | **Maximum** | **27.43** | **0** |
| | | | | **Average** | **5.35** | |

# Appendix B: Bore Drilling and Testing Completion Records.

www.pendragonenvironmental.com

Suite 2, Level 1, 464 Murray Street
Perth WA 6000
Tel No: (08) 9382-8286
email: info@pendragonenvironmental.com

| | | | |
|---|---|---|---|
| **Northing (mN):** | 465,180.00 | **Bore ID:** | **18CAWB001** |
| **Easting (mE):** | 6,571,750.00 | | |
| **Elevation (mAHD):** | 259.00 | | |
| **Zone:** | 50J | | |

| | | | | | |
|---|---|---|---|---|---|
| **Project:** | **Calingiri Project** | **Driller:** | **Orbit Drilling** | **Elevation (ToC, mAHD):** | **259.00** |
| **Reference:** | **PES18011** | **Method:** | **RC/Mud Rotary** | **Top of Casing (ToC, agl):** | **-** |
| **Client:** | **Caravel Minerals** | **Date Started:** | **13-March-2018** | **Depth to Ground Water (GWL, mbToC):** | **-** |
| | | **Date Completed:** | **13-March-2018** | **Depth to Ground Water (GWL, mbgl):** | **2.00** |
| | | **Logged:** | **RL** | **Ground Water Level (GWL, mAHD):** | **257.00** |

| Depth mbgl | Depth RL (m) | Moisture Content / Water Strike | Lithological Description | Observations and Remarks |
|---|---|---|---|---|
| 0.0 | 259.00 | | | |
| 1.0 | 258.0 | Dry to moist | | |
| 2.0 | 257.0 | Moist to wet | | |
| 3.0 | 256.0 | | | |
| 4.0 | 255.0 | | Gravelly SAND. | |
| 5.0 | 254.0 | | | |
| 6.0 | 253.0 | | | |
| 7.0 | 252.0 | | | |
| 8.0 | 251.0 | | | |
| 9.0 | 250.0 | | | |
| 10.0 | 249.0 | | | |
| 11.0 | 248.0 | | | |
| 12.0 | 247.0 | | | |
| 13.0 | 246.0 | | | |
| 14.0 | 245.0 | | | |
| 15.0 | 244.0 | | | |
| 16.0 | 243.0 | | | |
| 17.0 | 242.0 | | | |
| 18.0 | 241.0 | | | |
| 19.0 | 240.0 | | GRAVEL. | |
| 20.0 | 239.0 | | | |
| 21.0 | 238.0 | | | |
| 22.0 | 237.0 | | | |
| 23.0 | 236.0 | | | |
| 24.0 | 235.0 | | | |
| 25.0 | 234.0 | | | |
| 26.0 | 233.0 | | | |
| 27.0 | 232.0 | | | |
| 28.0 | 231.0 | | | |
| 29.0 | 230.0 | | | |
| 30.0 | 229.0 | | | |
| 31.0 | 228.0 | | Brown/red GRAVEL. | |
| 32.0 | 227.0 | | | |
| 33.0 | 226.0 | | | |
| 34.0 | 225.0 | | | |
| 35.0 | 224.0 | | | |
| 36.0 | 223.0 | | Clayey GRAVEL | |
| 37.0 | 222.0 | | | |
| 38.0 | 221.0 | | | |
| 39.0 | 220.0 | | | |
| 40.0 | 219.0 | | | |
| 41.0 | 218.0 | | | |
| 42.0 | 217.0 | | CLAY. | |
| 43.0 | 216.0 | | | |
| 44.0 | 215.0 | | | |
| 45.0 | 214.0 | | | |
| 46.0 | 213.0 | End of Hole | | Bedrock |
| 47.0 | 212.0 | | | |
| 48.0 | 211.0 | | | |
| 49.0 | 210.0 | | | |
| 50.0 | 209.0 | | | |

Bedrock

**Bore Construction Notes:**

Pilot hole drilled using RC to final depth.

Pilot hole reamed to 203mmDIA fitted with 100mmDIA UPVC casings/screens.

Solid casing/screen: 100mm DIA uPVC Class 9, 9mm wall thickness.

Screens: 100mmDIA uPVC Class 12 with 8 rows around screen, 37 banks on each row and 22 0.51mm slots on each bank.

Filter/gravel (> 5mmDIA) packs to surface top 0.5m grouted with foam.

| | | |
|---|---|---|
| **Bore Completion:** | Lockable Steel Riser | |
| **Bore Construction:** | Cement | |
| | Bentonite/Cement Grout | |
| | Gravel Pack | Type: Washed gravel >5mm |
| | Filter Sock | |
| **Bore Casing:** | Solid | Type: 100mm UPV |
| **Bore Screen:** | Screen | Type: 100mm UPV |
| | Ground Water Level | |

| | |
|---|---|
| **Date:** | 13-April-2018 |
| **pH:** | 4.77 |
| **Temperature ($^0$C):** | 24.3 |
| **Electrical Conductivity (dS/cm):** | 5,980 |
| **Total Dissolved Solids (mg/L):** | 3,300 |
| **Salinity (ppt):** | - |
| **Dissolved Oxygen (%):** | - |
| **Dissolved Oxygen (mg/L)** | 7.50 |
| **Oxidation Reduction Potential (ORP, mV):** | - |

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| | |
|---|---|
| Northing (mN): | 465,180.00 |
| Easting (mE): | 6,571,750.00 |
| Elevation (mAHD): | 259.00 |
| Zone: | 50J |

**Bore ID: 18CAWB002**

| | | | | | |
|---|---|---|---|---|---|
| **Project:** | **Calingiri Project** | **Driller:** | **Orbit Drilling** | **Elevation (ToC, mAHD):** | **255.00** |
| **Reference:** | **PES18011** | **Method:** | **RC/Mud Rotary** | **Top of Casing (ToC, agl):** | **-** |
| **Client:** | **Caravel Minerals** | **Date Started:** | **14-March-2018** | **Depth to Ground Water (GWL, mbToC):** | **-** |
| | | **Date Completed:** | **14-March-2018** | **Depth to Ground Water (GWL, mbgl):** | **5.30** |
| | | **Logged:** | **RL** | **Ground Water Level (GWL, mAHD):** | **249.70** |

| Depth mbgl | Depth RL (m) | Moisture Content / Water Strike | Lithological Description |
|---|---|---|---|
| 0.0 | 259.00 | | |
| 1.0 | 258.0 | Dry to moist | sandy GRAVEL. |
| 2.0 | 257.0 | | |
| 3.0 | 256.0 | | |
| 4.0 | 255.0 | | |
| 5.0 | 254.0 | Moist to wet (▼ water level) | |
| 6.0 | 253.0 | | Grey/light brown GRAVEL. |
| 7.0 | 252.0 | | |
| 8.0 | 251.0 | | |
| 9.0 | 250.0 | | |
| 10.0 | 249.0 | | |
| 11.0 | 248.0 | | |
| 12.0 | 247.0 | | |
| 13.0 | 246.0 | | |
| 14.0 | 245.0 | | |
| 15.0 | 244.0 | | |
| 16.0 | 243.0 | | |
| 17.0 | 242.0 | | |
| 18.0 | 241.0 | | |
| 19.0 | 240.0 | | |
| 20.0 | 239.0 | | |
| 21.0 | 238.0 | | |
| 22.0 | 237.0 | | |
| 23.0 | 236.0 | | |
| 24.0 | 235.0 | | |
| 25.0 | 234.0 | | |
| 26.0 | 233.0 | | |
| 27.0 | 232.0 | | |
| 28.0 | 231.0 | | |
| 29.0 | 230.0 | | |
| 30.0 | 229.0 | | |
| 31.0 | 228.0 | | Brown GRAVEL. |
| 32.0 | 227.0 | | |
| 33.0 | 226.0 | | |
| 34.0 | 225.0 | | |
| 35.0 | 224.0 | | Bedrock. |
| 36.0 | 223.0 | | |
| 37.0 | 222.0 | | |
| 38.0 | 221.0 | | |
| 39.0 | 220.0 | | |
| 40.0 | 219.0 | | End of Hole. |
| 41.0 | 218.0 | | |
| 42.0 | 217.0 | | |
| 43.0 | 216.0 | | |
| 44.0 | 215.0 | | |
| 45.0 | 214.0 | | |
| 46.0 | 213.0 | | |
| 47.0 | 212.0 | | |
| 48.0 | 211.0 | | |
| 49.0 | 210.0 | | |
| 50.0 | 209.0 | | |

Well Construction | Observations and Remarks

**Bore Construction Notes:**

Pilot hole drilled using RC to final depth.

Pilot hole reamed to 203mmDIA fitted with 100mmDIA UPVC casings/screens.

Solid casing/screen: 100mm DIA uPVC Class 9, 9mm wall thickness.

Screens: 100mmDIA uPVC Class 12 with 8 rows around screen, 37 banks on each row and 22 0.51mm slots on each bank.

Filter/gravel (> 5mmDIA) packs to surface top 0.5m grouted with foam.

| | | |
|---|---|---|
| **Bore Completion:** | Lockable Steel Riser | |
| **Bore Construction:** | Cement | |
| | Bentonite/Cement Grout | |
| | Gravel Pack | Type: Washed gravel >5mm |
| | Filter Sock | |
| **Bore Casing:** | Solid | Type: 100mm UPV |
| **Bore Screen:** | Screen | Type: 100mm UPV |
| ▼ | Ground Water Level | |

| | |
|---|---|
| **Date:** | 13-April-2018 |
| **pH:** | 5.50 |
| **Temperature ($^{o}$C):** | 24.1 |
| **Electrical Conductivity (dS/cm):** | 2,950 |
| **Total Dissolved Solids (mg/L):** | 1,700 |
| **Salinity (ppt):** | - |
| **Dissolved Oxygen (%):** | - |
| **Dissolved Oxygen (mg/L)** | 7.50 |
| **Oxidation Reduction Potential (ORP, mV):** | - |

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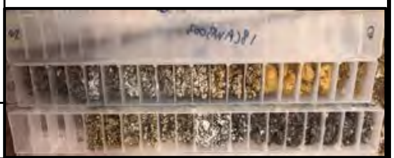
| | |
|---|---|
| Northing (mN): | 466,170.00 |
| Easting (mE): | 6,571,710.00 |
| Elevation (mAHD): | 245.00 |
| Zone: | 50J |

**Bore ID: 18CAWB003**

| | | | | | |
|---|---|---|---|---|---|
| Project: | Calingiri Project | Driller: | Orbit Drilling | Elevation (ToC, mAHD): | 245.00 |
| Reference: | PES18011 | Method: | RC/Mud Rotary | Top of Casing (ToC, agl): | - |
| Client: | Caravel Minerals | Date Started: | 15-March-2018 | Depth to Ground Water (GWL, mbToC): | - |
| | | Date Completed: | 18-March-2018 | Depth to Ground Water (GWL, mbgl): | 4.27 |
| | | Logged: | RL | Ground Water Level (GWL, mAHD): | 240.73 |

| Depth mbgl | Depth RL (m) | Well Construction | Moisture Content / Water Strike | Lithological Description | Observations and Remarks |
|---|---|---|---|---|---|
| 0.0 | 245.00 | | | | |
| 1.0 | 244.0 | | Dry to moist | sandy CLAY. | |
| 2.0 | 243.0 | | | | |
| 3.0 | 242.0 | | | | |
| 4.0 | 241.0 | ▼ | Moist to wet | | |
| 5.0 | 240.0 | | | Grey/cream GRAVEL. | Chips of rock. |
| 6.0 | 239.0 | | | | |
| 7.0 | 238.0 | | | | |
| 8.0 | 237.0 | | | | |
| 9.0 | 236.0 | | | | |
| 10.0 | 235.0 | | | | |
| 11.0 | 234.0 | | | | |
| 12.0 | 233.0 | | | | |
| 13.0 | 232.0 | | | | |
| 14.0 | 231.0 | | | | |
| 15.0 | 230.0 | | | | |
| 16.0 | 229.0 | | | | |
| 17.0 | 228.0 | | | GRAVEL. | Increasing presenc of quartz. |
| 18.0 | 227.0 | | | | |
| 19.0 | 226.0 | | | | |
| 20.0 | 225.0 | | | | |
| 21.0 | 224.0 | | | | |
| 22.0 | 223.0 | | | | |
| 23.0 | 222.0 | | | | |
| 24.0 | 221.0 | | | | |
| 25.0 | 220.0 | | | | |
| 26.0 | 219.0 | | | | |
| 27.0 | 218.0 | | | | |
| 28.0 | 217.0 | | | | |
| 29.0 | 216.0 | | | | |
| 30.0 | 215.0 | | | | |
| 31.0 | 214.0 | | | | |
| 32.0 | 213.0 | | | | |
| 33.0 | 212.0 | | | | |
| 34.0 | 211.0 | | | | |
| 35.0 | 210.0 | | | Weathered Bedrock. | |
| 36.0 | 209.0 | | | End of Hole. | |
| 37.0 | 208.0 | | | | |
| 38.0 | 207.0 | | | | |
| 39.0 | 206.0 | | | | |
| 40.0 | 205.0 | | | | |
| 41.0 | 204.0 | | | | |
| 42.0 | 203.0 | | | | |
| 43.0 | 202.0 | | | | |
| 44.0 | 201.0 | | | | |
| 45.0 | 200.0 | | | | |
| 46.0 | 199.0 | | | | |
| 47.0 | 198.0 | | | | |
| 48.0 | 197.0 | | | | |
| 49.0 | 196.0 | | | | |
| 50.0 | 195.0 | | | | |



**Bore Construction Notes:**

Pilot hole drilled using RC to final depth.

Pilot hole reamed to 203mmDIA fitted with 100mmDIA UPVC casings/screens.

Solid casing/screen: 100mm DIA uPVC Class 9, 9mm wall thickness.

Screens: 100mmDIA uPVC Class 12 with 8 rows around screen, 37 banks on each row and 22 0.51mm slots on each bank.

Filter/gravel (> 5mmDIA) packs to surface top 0.5m grouted with foam.

| | | | |
|---|---|---|---|
| Bore Completion: | | Lockable Steel Riser | |
| Bore Construction: | | Cement | |
| | | Bentonite/Cement Grout | |
| | | Gravel Pack | Type: Washed gravel >5mm |
| | | Filter Sock | |
| Bore Casing: | | Solid | Type: 100mm UPV |
| Bore Screen: | | Screen | Type: 100mm UPV |
| | ▼ | Ground Water Level | |

| | |
|---|---|
| Date: | 13-April-2018 |
| pH: | 5.50 |
| Temperature ($^{0}$C): | 24.1 |
| Electrical Conductivity (dS/cm): | 2,950 |
| Total Dissolved Solids (mg/L): | 1,700 |
| Salinity (ppt): | - |
| Dissolved Oxygen (%): | - |
| Dissolved Oxygen (mg/L) | 7.50 |
| Oxidation Reduction Potential (ORP, mV): | - |

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| | | | |
|---|---|---|---|
| Northing (mN): | 467,595.00 | **Bore ID:** | **18CAWB004** |
| Easting (mE): | 6,571,140.00 | | |
| Elevation (mAHD): | 256.00 | | |
| Zone: | 50J | | |

| | | | | | |
|---|---|---|---|---|---|
| Project: | Calingiri Project | Driller: | Orbit Drilling | Elevation (ToC, mAHD): | 256.00 |
| Reference: | PES18011 | Method: | RC/Mud Rotary | Top of Casing (ToC, agl): | - |
| Client: | Caravel Minerals | Date Started: | 18-March-2018 | Depth to Ground Water (GWL, mbToC): | - |
| | | Date Completed: | 19-March-2018 | Depth to Ground Water (GWL, mbgl): | 12.00 |
| | | Logged: | RL | Ground Water Level (GWL, mAHD): | 244.00 |

| Depth mbgl | RL (m) | Well Construction | Moisture Content Water Strike | Lithological Description | Observations and Remarks |
|---|---|---|---|---|---|
| 0.0 | 256.00 | | | | |
| 1.0 | 255.0 | | Dry to moist | | |
| 2.0 | 254.0 | | | Brown GRAVEL. | |
| 3.0 | 253.0 | | | | |
| 4.0 | 252.0 | | | | |
| 5.0 | 251.0 | | | Medium to large, grey/brown GRAVEL. | |
| 6.0 | 250.0 | | | | |
| 7.0 | 249.0 | | | | |
| 8.0 | 248.0 | | | Sandy GRAVEL. | |
| 9.0 | 247.0 | | | | |
| 10.0 | 246.0 | | | | |
| 11.0 | 245.0 | | | Weathered bedrock. | |
| 12.0 | 244.0 | ▼ | Moist to wet | | |
| 13.0 | 243.0 | | | | |
| 14.0 | 242.0 | | | | |
| 15.0 | 241.0 | | | | |
| 16.0 | 240.0 | | | | |
| 17.0 | 239.0 | | | | |
| 18.0 | 238.0 | | | | |
| 19.0 | 237.0 | | | | |
| 20.0 | 236.0 | | | End of Hole | |
| 21.0 | 235.0 | | | | |
| 22.0 | 234.0 | | | | |
| 23.0 | 233.0 | | | | |
| 24.0 | 232.0 | | | | |
| 25.0 | 231.0 | | | | |
| 26.0 | 230.0 | | | | |
| 27.0 | 229.0 | | | | |
| 28.0 | 228.0 | | | | |
| 29.0 | 227.0 | | | | |
| 30.0 | 226.0 | | | | |
| 31.0 | 225.0 | | | | |
| 32.0 | 224.0 | | | | |
| 33.0 | 223.0 | | | | |
| 34.0 | 222.0 | | | | |
| 35.0 | 221.0 | | | | |
| 36.0 | 220.0 | | | | |
| 37.0 | 219.0 | | | | |
| 38.0 | 218.0 | | | | |
| 39.0 | 217.0 | | | | |
| 40.0 | 216.0 | | | | |
| 41.0 | 215.0 | | | | |
| 42.0 | 214.0 | | | | |
| 43.0 | 213.0 | | | | |
| 44.0 | 212.0 | | | | |
| 45.0 | 211.0 | | | | |
| 46.0 | 210.0 | | | | |
| 47.0 | 209.0 | | | | |
| 48.0 | 208.0 | | | | |
| 49.0 | 207.0 | | | | |
| 50.0 | 206.0 | | | | |

**Bore Construction Notes:**

Pilot hole drilled using RC to final depth.

Pilot hole reamed to 203mmDIA fitted with 100mmDIA UPVC casings/screens.

Solid casing/screen: 100mm DIA uPVC Class 9, 9mm wall thickness.

Screens: 100mmDIA uPVC Class 12 with 8 rows around screen, 37 banks on each row and 22 0.51mm slots on each bank.

Filter/gravel (> 5mmDIA) packs to surface top 0.5m grouted with foam.

| | | |
|---|---|---|
| **Bore Completion:** | Lockable Steel Riser | |
| **Bore Construction:** | Cement | |
| | Bentonite/Cement Grout | |
| | Gravel Pack | Type: Washed gravel >5mm |
| | Filter Sock | |
| **Bore Casing:** | Solid | Type: 100mm UPV |
| **Bore Screen:** | Screen | Type: 100mm UPV |
| ▼ | Ground Water Level | |

| | |
|---|---|
| Date: | 13-April-2018 |
| pH: | - |
| Temperature (°C): | - |
| Electrical Conductivity (dS/cm): | - |
| Total Dissolved Solids (mg/L): | - |
| Salinity (ppt): | - |
| Dissolved Oxygen (%): | - |
| Dissolved Oxygen (mg/L) | - |
| Oxidation Reduction Potential (ORP, mV): | - |

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| | |
|---|---|
| Northing (mN): | 467,585.00 |
| Easting (mE): | 6,570,340.00 |
| Elevation (mAHD): | 235.00 |
| Zone: | 50J |

**Bore ID: 18CAWB005**

| | | | | | |
|---|---|---|---|---|---|
| Project: | Calingiri Project | Driller: | Orbit Drilling | Elevation (ToC, mAHD): | 235.00 |
| Reference: | PES18011 | Method: | RC/Mud Rotary | Top of Casing (ToC, agl): | - |
| Client: | Caravel Minerals | Date Started: | 19-March-2018 | Depth to Ground Water (GWL, mbToC): | - |
| | | Date Completed: | 19-March-2018 | Depth to Ground Water (GWL, mbgl): | 1.40 |
| | | Logged: | RL | Ground Water Level (GWL, mAHD): | 233.60 |

| Depth mbgl | Depth RL (m) | Well Construction | Moisture Content / Water Strike | Lithological Description | Observations and Remarks |
|---|---|---|---|---|---|
| 0.0 | 235.00 | | | | |
| 1.0 | 234.0 | ▼ | Dry to moist | Brown GRAVEL. | |
| 2.0 | 233.0 | | Moist to wet | | |
| 3.0 | 232.0 | | | | |
| 4.0 | 231.0 | | | Clayey GRAVEL. | |
| 5.0 | 230.0 | | | | |
| 6.0 | 229.0 | | | | |
| 7.0 | 228.0 | | | | |
| 8.0 | 227.0 | | | | |
| 9.0 | 226.0 | | | | |
| 10.0 | 225.0 | | | | |
| 11.0 | 224.0 | | | | |
| 12.0 | 223.0 | | | | |
| 13.0 | 222.0 | | | | Alternating layers of clay and gravel. |
| 14.0 | 221.0 | | | | |
| 15.0 | 220.0 | | | | |
| 16.0 | 219.0 | | | | |
| 17.0 | 218.0 | | | | |
| 18.0 | 217.0 | | | | |
| 19.0 | 216.0 | | | | |
| 20.0 | 215.0 | | | | |
| 21.0 | 214.0 | | | | |
| 22.0 | 213.0 | | | | |
| 23.0 | 212.0 | | | | |
| 24.0 | 211.0 | | | | |
| 25.0 | 210.0 | | | | Increasing clay content below. |
| 26.0 | 209.0 | | | | |
| 27.0 | 208.0 | | | | |
| 28.0 | 207.0 | | | | |
| 29.0 | 206.0 | | | | |
| 30.0 | 205.0 | | | | |
| 31.0 | 204.0 | | | | |
| 32.0 | 203.0 | | | | |
| 33.0 | 202.0 | | | | |
| 34.0 | 201.0 | | | | |
| 35.0 | 200.0 | | | | |
| 36.0 | 199.0 | | | | |
| 37.0 | 198.0 | | | | |
| 38.0 | 197.0 | | | Clayey weathered bedrock. | |
| 39.0 | 196.0 | | | Bedrock. | |
| 40.0 | 195.0 | | | | |
| 41.0 | 194.0 | | | | |
| 42.0 | 193.0 | | | | |
| 43.0 | 192.0 | | | | |
| 44.0 | 191.0 | | | | |
| 45.0 | 190.0 | | | | |
| 46.0 | 189.0 | | End of Hole. | | |
| 47.0 | 188.0 | | | | |
| 48.0 | 187.0 | | | | |
| 49.0 | 186.0 | | | | |
| 50.0 | 185.0 | | | | |

**Bore Construction Notes:**

Pilot hole drilled using RC to final depth.

Pilot hole reamed to 203mmDIA fitted with 100mmDIA UPVC casings/screens.

Solid casing/screen: 100mm DIA uPVC Class 9, 9mm wall thickness.

Screens: 100mmDIA uPVC Class 12 with 8 rows around screen, 37 banks on each row and 22 0.51mm slots on each bank.

Filter/gravel (> 5mmDIA) packs to surface top 0.5m grouted with foam.

| | | |
|---|---|---|
| **Bore Completion:** | Lockable Steel Riser | |
| **Bore Construction:** | Cement | |
| | Bentonite/Cement Grout | |
| | Gravel Pack | Type: Washed gravel >5mm |
| | Filter Sock | |
| **Bore Casing:** | Solid | Type: 100mm UPV |
| **Bore Screen:** | Screen | Type: 100mm UPV |
| ▼ | Ground Water Level | |

| | |
|---|---|
| Date: | 13-April-2018 |
| pH: | 5.72 |
| Temperature ($^{0}$C): | 23.5 |
| Electrical Conductivity (dS/cm): | 8,120 |
| Total Dissolved Solids (mg/L): | 4,600 |
| Salinity (ppt): | - |
| Dissolved Oxygen (%): | - |
| Dissolved Oxygen (mg/L) | 5.80 |
| Oxidation Reduction Potential (ORP, mV): | - |

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| | |
|---|---|
| Northing (mN): | 467,565.00 |
| Easting (mE): | 6,569,820.00 |
| Elevation (mAHD): | 231.00 |
| Zone: | 50J |

**Bore ID: 18CAWB006**

| | | | | | |
|---|---|---|---|---|---|
| Project: | Calingiri Project | Driller: | Orbit Drilling | Elevation (ToC, mAHD): | 231.00 |
| Reference: | PES18011 | Method: | RC/Mud Rotary | Top of Casing (ToC, agl): | - |
| Client: | Caravel Minerals | Date Started: | 20-March-2018 | Depth to Ground Water (GWL, mbToC): | - |
| | | Date Completed: | 20-March-2018 | Depth to Ground Water (GWL, mbgl): | 3.01 |
| | | Logged: | RL | Ground Water Level (GWL, mAHD): | 227.99 |

| Depth mbgl | RL (m) |
|---|---|
| 0.0 | 231.00 |
| 1.0 | 230.0 |
| 2.0 | 229.0 |
| 3.0 | 228.0 |
| 4.0 | 227.0 |
| 5.0 | 226.0 |
| 6.0 | 225.0 |
| 7.0 | 224.0 |
| 8.0 | 223.0 |
| 9.0 | 222.0 |
| 10.0 | 221.0 |
| 11.0 | 220.0 |
| 12.0 | 219.0 |
| 13.0 | 218.0 |
| 14.0 | 217.0 |
| 15.0 | 216.0 |
| 16.0 | 215.0 |
| 17.0 | 214.0 |
| 18.0 | 213.0 |
| 19.0 | 212.0 |
| 20.0 | 211.0 |
| 21.0 | 210.0 |
| 22.0 | 209.0 |
| 23.0 | 208.0 |
| 24.0 | 207.0 |
| 25.0 | 206.0 |
| 26.0 | 205.0 |
| 27.0 | 204.0 |
| 28.0 | 203.0 |
| 29.0 | 202.0 |
| 30.0 | 201.0 |
| 31.0 | 200.0 |
| 32.0 | 199.0 |
| 33.0 | 198.0 |
| 34.0 | 197.0 |
| 35.0 | 196.0 |
| 36.0 | 195.0 |
| 37.0 | 194.0 |
| 38.0 | 193.0 |
| 39.0 | 192.0 |
| 40.0 | 191.0 |
| 41.0 | 190.0 |
| 42.0 | 189.0 |
| 43.0 | 188.0 |
| 44.0 | 187.0 |
| 45.0 | 186.0 |
| 46.0 | 185.0 |
| 47.0 | 184.0 |
| 48.0 | 183.0 |
| 49.0 | 182.0 |
| 50.0 | 181.0 |

| Depth (mbgl) | Moisture Content / Water Strike | Lithological Description | Observations and Remarks |
|---|---|---|---|
| 0.0 – 4.0 | Dry to moist; Moist to wet | Brown GRAVEL. | Alternating layers of clay and gravel. |
| 4.0 – 24.0 | | Clayey GRAVEL. | Alternating layers of clay and gravel. |
| 24.0 – 34.0 | | Clayey GRAVEL. End of Hole. | Increasing clay content. |

**Bore Construction Notes:**

Pilot hole drilled using RC to final depth.

Pilot hole reamed to 203mmDIA fitted with 100mmDIA UPVC casings/screens.

Solid casing/screen: 100mm DIA uPVC Class 9, 9mm wall thickness.

Screens: 100mmDIA uPVC Class 12 with 8 rows around screen, 37 banks on each row and 22 0.51mm slots on each bank.

Filter/gravel (> 5mmDIA) packs to surface top 0.5m grouted with foam.

| | | |
|---|---|---|
| Bore Completion: | Lockable Steel Riser | |
| Bore Construction: | Cement | |
| | Bentonite/Cement Grout | |
| | Gravel Pack | Type: Washed gravel >5mm |
| | Filter Sock | |
| Bore Casing: | Solid | Type: 100mm UPV |
| Bore Screen: | Screen | Type: 100mm UPV |
| | Ground Water Level | |

| | |
|---|---|
| Date: | 13-April-2018 |
| pH: | 5.58 |
| Temperature ($^0$C): | 24.1 |
| Electrical Conductivity (dS/cm): | 8,560 |
| Total Dissolved Solids (mg/L): | 4,750 |
| Salinity (ppt): | - |
| Dissolved Oxygen (%): | - |
| Dissolved Oxygen (mg/L) | 4.90 |
| Oxidation Reduction Potential (ORP, mV): | - |

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Suite 2, Level 1, 464 Murray Street
Perth WA 6000
Tel No: (08) 9382-8286
email: info@pendragonenvironmental.com

| | |
|---|---|
| Northing (mN): | 467,734.00 |
| Easting (mE): | 6,560,805.00 |
| Elevation (mAHD): | 229.00 |
| Zone: | 50J |

**Bore ID: 18CARC27**

| | | | | | |
|---|---|---|---|---|---|
| Project: | Calingiri Project | Driller: | Orbit Drilling | Elevation (ToC, mAHD): | 229.00 |
| Reference: | PES18011 | Method: | RC/Mud Rotary | Top of Casing (ToC, agl): | - |
| Client: | Caravel Minerals | Date Started: | 12-March-2018 | Depth to Ground Water (GWL, mbToC): | - |
| | | Date Completed: | 13-March-2018 | Depth to Ground Water (GWL, mbgl): | 1.72 |
| | | Logged: | RL | Ground Water Level (GWL, mAHD): | 227.28 |

| Depth mbgl | Depth RL (m) | Well Construction | Moisture Content / Water Strike | Lithological Description | Observations and Remarks |
|---|---|---|---|---|---|
| 0.0 | 229.00 | | | | |
| 1.0 | 228.0 | | Dry to moist | | Dolerite present. |
| 2.0 | 227.0 | ▼ | Moist to wet | | |
| 3.0 | 226.0 | | | | |
| 4.0 | 225.0 | | | | |
| 5.0 | 224.0 | | | | |
| 6.0 | 223.0 | | | | |
| 7.0 | 222.0 | | | | |
| 8.0 | 221.0 | | | | |
| 9.0 | 220.0 | | | | |
| 10.0 | 219.0 | | | | |
| 11.0 | 218.0 | | | Dry to moist and wet, grey sandy CLAY. | |
| 12.0 | 217.0 | | | | |
| 13.0 | 216.0 | | | | |
| 14.0 | 215.0 | | | | |
| 15.0 | 214.0 | | | | |
| 16.0 | 213.0 | | | | |
| 17.0 | 212.0 | | | | |
| 18.0 | 211.0 | | | | |
| 19.0 | 210.0 | | | | |
| 20.0 | 209.0 | | | | |
| 21.0 | 208.0 | | | | |
| 22.0 | 207.0 | | | | |
| 23.0 | 206.0 | | | | |
| 24.0 | 205.0 | | | **End of Hole.** | |
| 25.0 | 204.0 | | | | |
| 26.0 | 203.0 | | | | |
| 27.0 | 202.0 | | | | |
| 28.0 | 201.0 | | | | |
| 29.0 | 200.0 | | | | |
| 30.0 | 199.0 | | | | |
| 31.0 | 198.0 | | | | |
| 32.0 | 197.0 | | | | |
| 33.0 | 196.0 | | | | |
| 34.0 | 195.0 | | | | |
| 35.0 | 194.0 | | | | |
| 36.0 | 193.0 | | | | |
| 37.0 | 192.0 | | | | |
| 38.0 | 191.0 | | | | |
| 39.0 | 190.0 | | | | |
| 40.0 | 189.0 | | | | |
| 41.0 | 188.0 | | | | |
| 42.0 | 187.0 | | | | |
| 43.0 | 186.0 | | | | |
| 44.0 | 185.0 | | | | |
| 45.0 | 184.0 | | | | |
| 46.0 | 183.0 | | | | |
| 47.0 | 182.0 | | | | |
| 48.0 | 181.0 | | | | |
| 49.0 | 180.0 | | | | |
| 50.0 | 179.0 | | | | |

**Bore Construction Notes:**

Pilot hole drilled using RC to final depth.

Pilot hole reamed to 203mmDIA fitted with 100mmDIA UPVC casings/screens.

Solid casing/screen: 100mm DIA uPVC Class 9, 9mm wall thickness.

Screens: 100mmDIA uPVC Class 12 with 8 rows around screen, 37 banks on each row and 22 0.51mm slots on each bank.

Filter/gravel (> 5mmDIA) packs to surface top 0.5m grouted with foam.

| | | |
|---|---|---|
| Bore Completion: | Lockable Steel Riser | |
| Bore Construction: | Cement | |
| | Bentonite/Cement Grout | |
| | Gravel Pack | Type: Washed gravel >5mm |
| | Filter Sock | |
| Bore Casing: | Solid | Type: 100mm UPV |
| Bore Screen: | Screen | Type: 100mm UPV |
| | ▼ Ground Water Level | |

| | |
|---|---|
| Date: | 13-April-2018 |
| pH: | 5.44 |
| Temperature ($^0$C): | 24.3 |
| Electrical Conductivity (dS/cm): | 6.7 |
| Total Dissolved Solids (mg/L): | 3,950 |
| Salinity (ppt): | - |
| Dissolved Oxygen (%): | - |
| Dissolved Oxygen (mg/L) | 6.70 |
| Oxidation Reduction Potential (ORP, mV): | - |

| | | | |
|---|---|---|---|
| pendragon environmental solutions<br>www.pendragonenvironmental.com | Suite 2, Level 1, 464 Murray Street<br>Perth WA 6000<br>Tel No: (08) 9382-8286<br>email: info@pendragonenvironmental.com | **Northing (mN):** 467,906.00<br>**Easting (mE):** 6,560,782.00<br>**Elevation (mAHD):** 246.00<br>**Zone:** 50J | **Bore ID:** **18CARC28** |

| | | | | | |
|---|---|---|---|---|---|
| **Project:** | **Calingiri Project** | **Driller:** | **Orbit Drilling** | **Elevation (ToC, mAHD):** | **246.00** |
| **Reference:** | **PES18011** | **Method:** | **RC/Mud Rotary** | **Top of Casing (ToC, agl):** | **-** |
| **Client:** | **Caravel Minerals** | **Date Started:** | **13-March-2018** | **Depth to Ground Water (GWL, mbToC):** | **-** |
| | | **Date Completed:** | **13-March-2018** | **Depth to Ground Water (GWL, mbgl):** | **0.00** |
| | | **Logged:** | **RL** | **Ground Water Level (GWL, mAHD):** | **246.00** |

| Depth mbgl | Depth RL (m) | Well Construction | Moisture Content / Water Strike | Lithological Description | Observations and Remarks |
|---|---|---|---|---|---|
| 0.0 | 246.00 | | | | |
| 1.0 | 245.0 | ▼ | Moist to wet | | Dolerite present. |
| 2.0 | 244.0 | | | | |
| 3.0 | 243.0 | | | | |
| 4.0 | 242.0 | | | | |
| 5.0 | 241.0 | | | | |
| 6.0 | 240.0 | | | Dry to moist and wet, brown sandy GRAVEL. | |
| 7.0 | 239.0 | | | | |
| 8.0 | 238.0 | | | | |
| 9.0 | 237.0 | | | | |
| 10.0 | 236.0 | | | | |
| 11.0 | 235.0 | | | | |
| 12.0 | 234.0 | | | | |
| 13.0 | 233.0 | | | | |
| 14.0 | 232.0 | | | | |
| 15.0 | 231.0 | | | | |
| 16.0 | 230.0 | | | Fine, yellow/orange SAND. | |
| 17.0 | 229.0 | | | | |
| 18.0 | 228.0 | | | | |
| 19.0 | 227.0 | | | | |
| 20.0 | 226.0 | | | | |
| 21.0 | 225.0 | | | | |
| 22.0 | 224.0 | | | | |
| 23.0 | 223.0 | | | | |
| 24.0 | 222.0 | | | | |
| 25.0 | 221.0 | | | | |
| 26.0 | 220.0 | | | | |
| 27.0 | 219.0 | | | | |
| 28.0 | 218.0 | | | Orange SAND, increasing grey clay content. | |
| 29.0 | 217.0 | | | | |
| 30.0 | 216.0 | | | | |
| 31.0 | 215.0 | | | | |
| 32.0 | 214.0 | | | | |
| 33.0 | 213.0 | | | | |
| 34.0 | 212.0 | | | | |
| 35.0 | 211.0 | | | | |
| 36.0 | 210.0 | | | | |
| 37.0 | 209.0 | | | | |
| 38.0 | 208.0 | | | | |
| 39.0 | 207.0 | | | Grey CLAY. | |
| 40.0 | 206.0 | | | | |
| 41.0 | 205.0 | | | | |
| 42.0 | 204.0 | | | End of Casing/Screen. | Bore drilled to bedrock at 66.0m. |
| 43.0 | 203.0 | | | | |
| 44.0 | 202.0 | | | | |
| 45.0 | 201.0 | | | | |
| 46.0 | 200.0 | | | | |
| 47.0 | 199.0 | | | | |
| 48.0 | 198.0 | | | | |
| 49.0 | 197.0 | | | | |
| 50.0 | 196.0 | | | | |

**Bore Construction Notes:**

Pilot hole drilled using RC to final depth.

Pilot hole reamed to 203mmDIA fitted with 100mmDIA UPVC casings/screens.

Solid casing/screen: 100mm DIA uPVC Class 9, 9mm wall thickness.

Screens: 100mmDIA uPVC Class 12 with 8 rows around screen, 37 banks on each row and 22 0.51mm slots on each bank.

Filter/gravel (> 5mmDIA) packs to surface top 0.5m grouted with foam.

| | | | |
|---|---|---|---|
| **Bore Completion:** | Lockable Steel Riser | | |
| **Bore Construction:** | Cement | | |
| | Bentonite/Cement Grout | | |
| | Gravel Pack | Type: Washed gravel >5mm | |
| | Filter Sock | | |
| **Bore Casing:** | Solid | Type: 100mm UPV | |
| **Bore Screen:** | Screen | Type: 100mm UPV | |
| ▼ | Ground Water Level | | |

| | |
|---|---|
| **Date:** | 13-April-2018 |
| **pH:** | 6.01 |
| **Temperature ($^{o}$C):** | 23.8 |
| **Electrical Conductivity (dS/cm):** | 7,650 |
| **Total Dissolved Solids (mg/L):** | 4,600 |
| **Salinity (ppt):** | - |
| **Dissolved Oxygen (%):** | - |
| **Dissolved Oxygen (mg/L)** | 6.30 |
| **Oxidation Reduction Potential (ORP, mV):** | - |

# CONTINUIOS PUMPING RATE

| NAME | | DATE | 26.3.18 |
|---|---|---|---|
| ADDRESS | | | |
| SUBURB | CALINGIRI | POST CODE | |

| STATIC WATER LEVEL: 2 metres | | | | PUMPING INLET: 40.00 metres | | | |
|---|---|---|---|---|---|---|---|
| PUMPING RATE: 4.8 Lt / sec OR 288 Lpm | | | | PUMPING RATE : 0.000 | | | |
| Time 7.00 am | Actual Pumping Level | Time | Actual Pumping Level | Time | Actual Pumping Level | Time | Actual Pumping Level |
| 1 Min | 3800 m | 4 ¼ Hr | 3800 m | Recovery Readings | | | |
| 2 Min | 3900 m | 4 ½ Hr | 3800 m | 1 Min | 2 m | | |
| 3 Min | 3900 m | 4 ¾ Hr | 3900 m | 2 Min | m | | |
| 4 Min | 3900 m | 5 Hr | 3900 m | 3 Min | m | | |
| 5 Min | 3900 m | 5 ¼ Hr | 3900 m | 4 Min | m | | |
| 6 Min | 3900 m | 5 ½ Hr | 3900 m | 5 Min | m | | |
| 7 Min | 3900 m | 5 ¾ Hr | 3900 m | 6 Min | m | | |
| 8 Min | 3900 m | 6 Hr | 3900 m | 7 Min | m | | |
| 9 Min | 3900 m | 6 ¼ Hr | 3900 m | 8 Min | m | | |
| 10 Min | 3900 m | 6 ½ Hr | 3900 m | 9 Min | m | | |
| 15 Min | 3900 m | 6 ¾ Hr | 3900 m | 10 Min | m | | |
| 20 Min | 3900 m | 7 Hr | 3900 m | 15 Min | m | | |
| 25 Min | 3900 m | 7 ¼ Hr | 3900 m | 20 Min | m | | |
| 30 Min | 3900 m | 7 ½ Hr | 3900 m | 25 Min | m | | |
| 35 Min | 3900 m | 7 ¾ Hr | 3900 m | 30 Min | m | | |
| 40 Min | 3900 m | 8 Hr | 3900 m | 35 Min | m | | |
| 50 Min | 3900 m | 9 | 3900 | 40 Min | m | | |
| 1 Hr | 3900 m | 10 | 3900 | 50 Min | m | | |
| 1 ¼ Hr | 3900 m | 11 | 3900 | 1 Hr | m | | |
| 1 ½ Hr | 3900 m | 12 | 3900 | | | | |
| 1 ¾ Hr | 3900 m | | | | | | |
| 2 Hr | 3800 m | | | | | | |
| 2 ¼ Hr | 3800 m | | | | | | |
| 2 ½ Hr | 3800 m | | | SALT LEVEL START | 2890 PPM | | |
| 2 ¾ Hr | 3800 m | | | SALT LEVEL FINISH | 3050 PPM | | |
| 3 Hr | 3800 m | | | | | | |
| 3 ¼ Hr | 3800 m | | | | | | |
| 3 ½ Hr | 3800 m | | | | | | |
| 3 ¾ Hr | 3800 m | | | SWL | 2.000 M | | |
| 4 Hr | 3900 m | | | | | | |
| | | | | TOP OF SCREEN | M | | |
| | | | | TOTAL DEPTH | 45.80 M | | |
| START TIME | 1300 PM | | | FINISH TIME | 1.00 AM | | |
| COMMENTS | Bore No 1 | | | | | | |

# CONTINUIOS PUMPING RATE

| | | | |
|---|---|---|---|
| NAME | | DATE | 27.3.18 |
| ADDRESS | | | |
| SUBURB | Calingiri | POST CODE | |

| STATIC WATER LEVEL: 5.200 metres | | | | PUMPING INLET: 36 000 metres | | | |
|---|---|---|---|---|---|---|---|
| PUMPING RATE: 4.5 Lt / sec OR 270 Lpm | | | | PUMPING RATE : 0.000 | | | |
| Time 7.00 am | Actual Pumping Level | Time | Actual Pumping Level | Time | Actual Pumping Level | Time | Actual Pumping Level |
| 1 Min | 9.600 m | 4 ¼ Hr | 10.800 m | Recovery Readings | | | |
| 2 Min | 9.000 m | 4 ½ Hr | 10.900 m | 1 Min | 5.600 m | | |
| 3 Min | 8.700 m | 4 ¾ Hr | 10.950 m | 2 Min | 5.200 m | | |
| 4 Min | 8.700 m | 5 Hr | 11.000 m | 3 Min | m | | |
| 5 Min | 8.900 m | 5 ¼ Hr | 11000 m | 4 Min | m | | |
| 6 Min | 8.900 m | 5 ½ Hr | 10900 m | 5 Min | m | | |
| 7 Min | 8.900 m | 5 ¾ Hr | 11000 m | 6 Min | m | | |
| 8 Min | 8.900 m | 6 Hr | 10950 m | 7 Min | m | | |
| 9 Min | 8.900 m | 6 ¼ Hr | 11050 m | 8 Min | m | | |
| 10 Min | 9.000 m | 6 ½ Hr | 11150 m | 9 Min | m | | |
| 15 Min | 9.100 m | 6 ¾ Hr | 11250 m | 10 Min | m | | |
| 20 Min | 9100 m | 7 Hr | 11000 m | 15 Min | m | | |
| 25 Min | 9300 m | 7 ¼ Hr | 11050 m | 20 Min | m | | |
| 30 Min | 9300 m | 7 ½ Hr | 11000 m | 25 Min | m | | |
| 35 Min | 9400 m | 7 ¾ Hr | 11050 m | 30 Min | m | | |
| 40 Min | 9500 m | 8 Hr | 11050 m | 35 Min | m | | |
| 50 Min | 9600 m | 8 1/4 Hr | 11000 | 40 Min | m | | |
| 1 Hr | 9700 m | 8 1/2 Hr | 11000 | 50 Min | m | | |
| 1 ¼ Hr | 10000 m | 8 3/4 Hr | 11000 | 1 Hr | m | | |
| 1 ½ Hr | 9900 m | 9 Hr | 11000 | | | | |
| 1 ¾ Hr | 10.000 m | 9 1/4 Hr | 11000 | | | | |
| 2 Hr | 10.160 m | 9 1/2 Hr | 11000 | | | | |
| 2 ¼ Hr | 1027 m | 9 3/4 Hr | 11000 | | | | |
| 2 ½ Hr | 1035 m | 10 Hr | 11000 | SALT LEVEL START | | 984 | PPM |
| 2 ¾ Hr | 1037 m | 10 1/4 Hr | 11000 | SALT LEVEL FINISH | | 1610 | PPM |
| 3 Hr | 10.42 m | 10 1/2 Hr | 10900 | | | | |
| 3 ¼ Hr | 10.61 m | 10 3/4 Hr | 10900 | | | | |
| 3 ½ Hr | 10.74 m | 11 Hr | 11000 | | | | |
| 3 ¾ Hr | 1070 m | 11 1/4 Hr | 11000 | SWL | | 5.200 | M |
| 4 Hr | 10.800 m | 11 1/2 Hr | 11000 | | | | |
| | | 11 3/4 Hr | 11000 | TOP OF SCREEN | | | M |
| | | 12 Hr | 11.000 | | | | |
| | | | | TOTAL DEPTH | | 40.00 | M |
| | | | | | | | |
| START TIME | | 7.30 | | FINISH TIME | | 19.30 | |
| | | | | | | | |
| COMMENTS | | | | | | | |

BORE NO. 2

# CONTINUIOS PUMPING RATE

| | | | |
|---|---|---|---|
| NAME | | DATE | 28.3.18 |
| ADDRESS | | | |
| SUBURB | CALINGIRI | POST CODE | |

BORE NO. 3.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| STATIC WATER LEVEL: 4.300 metres | | | | PUMPING INLET: 35 metres | | | |
| PUMPING RATE: 1.5 Lt / sec OR Lpm | | | | PUMPING RATE : 0.000 | | | |
| Time 7.00 am | Actual Pumping Level | Time | Actual Pumping Level | Time | Actual Pumping Level | Time | Actual Pumping Level |
| 1 Min | RUN OUT m | 4 ¼ Hr | m | Recovery Readings | | | |
| 2 Min | m | 4 ½ Hr | m | 1 Min | m | | |
| 3 Min | m | 4 ¾ Hr | m | 2 Min | m | | |
| 4 Min | m | 5 Hr | m | 3 Min | m | | |
| 5 Min | m | 5 ¼ Hr | m | 4 Min | m | | |
| 6 Min | m | 5 ½ Hr | m | 5 Min | m | | |
| 7 Min | m | 5 ¾ Hr | m | 6 Min | m | | |
| 8 Min | m | 6 Hr | m | 7 Min | m | | |
| 9 Min | m | 6 ¼ Hr | m | 8 Min | m | | |
| 10 Min | m | 6 ½ Hr | m | 9 Min | m | | |
| 15 Min | m | 6 ¾ Hr | m | 10 Min | m | | |
| 20 Min | m | 7 Hr | m | 15 Min | m | | |
| 25 Min | m | 7 ¼ Hr | m | 20 Min | m | | |
| 30 Min | m | 7 ½ Hr | m | 25 Min | m | | |
| 35 Min | m | 7 ¾ Hr | m | 30 Min | m | | |
| 40 Min | m | 8 Hr | m | 35 Min | m | | |
| 50 Min | m | | | 40 Min | m | | |
| 1 Hr | m | | | 50 Min | m | | |
| 1 ¼ Hr | m | | | 1 Hr | m | | |
| 1 ½ Hr | m | | | | | | |
| 1 ¾ Hr | m | | | | | | |
| 2 Hr | m | | | | | | |
| 2 ¼ Hr | m | | | | | | |
| 2 ½ Hr | m | | | SALT LEVEL START | | PPM | |
| 2 ¾ Hr | m | | | SALT LEVEL FINISH | | PPM | |
| 3 Hr | m | | | | | | |
| 3 ¼ Hr | m | | | | | | |
| 3 ½ Hr | m | | | | | | |
| 3 ¾ Hr | m | | | SWL | | 4.300 M | |
| 4 Hr | m | | | | | | |
| | | | | TOP OF SCREEN | | M | |
| | | | | | | | |
| | | | | TOTAL DEPTH | | 36.000 M | |
| | | | | | | | |
| START TIME | | | | FINISH TIME | | | |
| | | | | | | | |
| COMMENTS | | NO WATER | | | | | |

BORE 18CARC27

# CONTINUIOS PUMPING RATE

| NAME | | DATE | 4.4.18 |
|---|---|---|---|
| ADDRESS | | | |
| SUBURB | CALINGIRI | POST CODE | |

BORE NO 18 CARC 027

| STATIC WATER LEVEL: 1.430 metres | | | | PUMPING INLET: 26.000 metres | | | |
|---|---|---|---|---|---|---|---|
| PUMPING RATE: 1.8 Lt / sec OR 108 Lpm | | | | PUMPING RATE : 0.000 | | | |
| Time 7.00 am | Actual Pumping Level | Time | Actual Pumping Level | Time | Actual Pumping Level | Time | Actual Pumping Level |
| 1 Min | 6.200 m | 4 ¼ Hr | 20500 m | Recovery Readings | | | |
| 2 Min | 7.200 m | 4 ½ Hr | 21360 m | 1 Min | 22.000 m | | |
| 3 Min | 7.900 m | 4 ¾ Hr | 21500 m | 2 Min | 21.600 m | 7.AM 1.700 | |
| 4 Min | 8.800 m | 5 Hr | 21650 m | 3 Min | 21.400 m | | |
| 5 Min | 9.500 m | 5 ¼ Hr | 21500 m | 4 Min | 21.200 m | | |
| 6 Min | 10.400 m | 5 ½ Hr | 21600 m | 5 Min | 21.050 m | | |
| 7 Min | 10.700 m | 5 ¾ Hr | 21730 m | 6 Min | 20.900 m | | |
| 8 Min | 11.000 m | 6 Hr | 21900 m | 7 Min | 20.800 m | | |
| 9 Min | 11.100 m | 6 ¼ Hr | 22100 m | 8 Min | 20.200 m | | |
| 10 Min | 10.950 m | 6 ½ Hr | 22440 m | 9 Min | 19.500 m | | |
| 15 Min | 10.950 m | 6 ¾ Hr | 22430 m | 10 Min | 18.800 m | | |
| 20 Min | 10.950 m | 7 Hr | 22540 m | 15 (11) Min | 17.300 m | | |
| 25 Min | 10.900 m | 7 ¼ Hr | 22700 m | 20 (12) Min | 16.300 m | 12 | |
| 30 Min | 10.900 m | 7 ½ Hr | 22700 m | 25 (13) Min | 15.400 m | 13 | |
| 35 Min | 10.900 m | 7 ¾ Hr | 22700 m | 30 (14) Min | 14.900 m | 14 | |
| 40 Min | 10.900 m | 8 Hr | 22650 m | 35 (15) Min | 14.200 m | 15 | |
| 50 Min | 10.900 m | | | 40 Min | 12.900 m | 20M | |
| 1 Hr | 10.950 m | | | 50 Min | 12.600 m | 30M | |
| 1 ¼ Hr | 10.950 m | | | 1 Hr | 11.900 m | 40M | |
| 1 ½ Hr | 11.000 m | | | | 11.800 | 50M | |
| 1 ¾ Hr | 11.150 m | | | | 11.800 | 1Hr | |
| 2 Hr | 11.200 m | | | | 11.600 | 1.30 Hr | |
| 2 ¼ Hr | 11.450 m | | | 6.PM | 11.500 | 2 Hr | |
| 2 ½ Hr | 11.600 m | | | SALT LEVEL START | | | PPM |
| 2 ¾ Hr | 11.850 m | | | SALT LEVEL FINISH | | | PPM |
| 3 Hr | 11.950 m | | | | | | |
| 3 ¼ Hr | 12.200 m | | | | | | |
| 3 ½ Hr | 13.900 m | | | | | | |
| 3 ¾ Hr | 16.250 m | | | | SWL | 1.430 | M |
| 3.50 4 Hr | 17.560 m | | | | | | |
| 3.45 Hr | 17090 | 17920 | | | TOP OF SCREEN | | M |
| 4 Hr | 18570 | | | | | | |
| 4.05 Hr | 19510 | | | | TOTAL DEPTH | 27.600 | M |
| 4.10 Hr | 20100 | | | | | | |
| START TIME | | | | | FINISH TIME | | |
| | | | | | | | |
| COMMENTS | | | | | | | |

1.8 LT/sec. (beside 1–9 Min readings)

# CONTINUIOS PUMPING RATE

| | | | |
|---|---|---|---|
| NAME | | DATE | 4.4.18 |
| ADDRESS | | | |
| SUBURB | CALINGIRI | POST CODE | |

0430310085 BORE NO 18CARC028

| STATIC WATER LEVEL: 0.00 metres | | | | PUMPING INLET: 40 metres | | | |
|---|---|---|---|---|---|---|---|
| PUMPING RATE: 2 Lt / sec OR Lpm | | | | PUMPING RATE : 0.000 | | | |
| Time 7.00 am | Actual Pumping Level | Time | Actual Pumping Level | Time | Actual Pumping Level | Time | Actual Pumping Level |
| 1 Min | RUN AUT m | 4 ¼ Hr | m | Recovery Readings | | | |
| 2 Min | m | 4 ½ Hr | m | 1 Min | m | | |
| 3 Min | m | 4 ¾ Hr | m | 2 Min | m | | |
| 4 Min | m | 5 Hr | m | 3 Min | m | | |
| 5 Min | m | 5 ¼ Hr | m | 4 Min | m | | |
| 6 Min | m | 5 ½ Hr | m | 5 Min | m | | |
| 7 Min | m | 5 ¾ Hr | m | 6 Min | m | | |
| 8 Min | m | 6 Hr | m | 7 Min | m | | |
| 9 Min | m | 6 ¼ Hr | m | 8 Min | m | | |
| 10 Min | m | 6 ½ Hr | m | 9 Min | m | | |
| 15 Min | m | 6 ¾ Hr | m | 10 Min | m | | |
| 20 Min | m | 7 Hr | m | 15 Min | m | | |
| 25 Min | m | 7 ¼ Hr | m | 20 Min | m | | |
| 30 Min | m | 7 ½ Hr | m | 25 Min | m | | |
| 35 Min | m | 7 ¾ Hr | m | 30 Min | m | | |
| 40 Min | m | 8 Hr | m | 35 Min | m | | |
| 50 Min | m | | | 40 Min | m | | |
| 1 Hr | m | | | 50 Min | m | | |
| 1 ¼ Hr | m | | | 1 Hr | m | | |
| 1 ½ Hr | m | | | | | | |
| 1 ¾ Hr | m | | | | | | |
| 2 Hr | m | | | | | | |
| 2 ¼ Hr | m | | | | | | |
| 2 ½ Hr | m | | | SALT LEVEL START | | | PPM |
| 2 ¾ Hr | m | | | SALT LEVEL FINISH | | | PPM |
| 3 Hr | m | | | | | | |
| 3 ¼ Hr | m | | | | | | |
| 3 ½ Hr | m | | | | | | |
| 3 ¾ Hr | m | | | 0.00 SWL | | ~~0.00~~ | M |
| 4 Hr | m | | | | | | |
| | | | | TOP OF SCREEN | | | M |
| | | | | | | | |
| | | | 41.03 | TOTAL DEPTH | | 41.03 | M |
| | | | | | | | |
| START TIME | | | | FINISH TIME | | | |
| | | | | | | | |
| COMMENTS | | NO WATER | | | | | |

# CONTINUIOS PUMPING RATE

| NAME | | DATE | 6.4.18 |
|---|---|---|---|
| ADDRESS | | | |
| SUBURB | CALINGIRI | POST CODE | |

BORE NO: 6

| STATIC WATER LEVEL: 3.100 metres | | | | PUMPING INLET: 19.000 metres | | | |
|---|---|---|---|---|---|---|---|
| PUMPING RATE: 1 Lt / sec OR 60 Lpm | | | | PUMPING RATE : 0.000 | | | |
| Time 7.00 am | Actual Pumping Level | Time | Actual Pumping Level | Time | Actual Pumping Level | Time | Actual Pumping Level |
| 1 Min | 11.300 m | 4 ¼ Hr | m | Recovery Readings | | | |
| 2 Min | 17.700 m | 4 ½ Hr | m | 1 Min | 9.500 m | | |
| 3 Min | 18.000 m | 4 ¾ Hr | m | 2 Min | 8.600 m | | |
| 4 Min | 18.300 m | 5 Hr | m | 3 Min | 7500 m | | |
| 5 Min | 17.800 m | 5 ¼ Hr | m | 4 Min | 6.500 m | | |
| 6 Min | 17.800 m | 5 ½ Hr | m | 5 Min | 6.000 m | | |
| 7 Min | 17,800 m | 5 ¾ Hr | m | 6 Min | 5.700 m | | |
| 8 Min | 17.800 m | 6 Hr | m | 7 Min | 5.500 m | | |
| 9 Min | 17.805 m | 6 ¼ Hr | m | 8 Min | 5.300 m | | |
| 10 Min | 17805 m | 6 ½ Hr | m | 9 Min | 5.200 m | | |
| 15 Min | 17805 m | 6 ¾ Hr | m | 10 Min | 5100 m | | |
| 20 Min | 17805 m | 7 Hr | m | 15 Min | 4,800 m | | |
| 25 Min | 17905 m | 7 ¼ Hr | m | 20 Min | 4.700 m | | |
| 30 Min | 13.300 m | 7 ½ Hr | m | 25 Min | 4500 m | | |
| 35 Min | 13.000 m | 7 ¾ Hr | m | 30 Min | 4450 m | | |
| 40 Min | 12.800 m | 8 Hr | m | 35 Min | 4400 m | | |
| 50 Min | 12.750 m | | | 40 Min | 4300 m | | |
| 1 Hr | 12.750 m | | | 50 Min | 4200 m | | |
| 1 ¼ Hr | m | | | 1 Hr | 4.100 m | | |
| 1 ½ Hr | m | | | | | | |
| 1 ¾ Hr | m | | | | | | |
| 2 Hr | m | | | | | | |
| 2 ¼ Hr | m | | | | | | |
| 2 ½ Hr | m | | | SALT LEVEL START | | PPM | |
| 2 ¾ Hr | m | | | SALT LEVEL FINISH | | PPM | |
| 3 Hr | m | | | | | | |
| 3 ¼ Hr | m | | | | | | |
| 3 ½ Hr | m | | | | | | |
| 3 ¾ Hr | m | | | SWL | | 3.100 M | |
| 4 Hr | m | | | | | | |
| | | | | TOP OF SCREEN | | M | |
| | | | | TOTAL DEPTH | | 20.500 M | |
| START TIME | | | | FINISH TIME | | | |
| COMMENTS | | | | | | | |

1LT/sec

0.6 LT/sec

## CONTINUIOS PUMPING RATE

| NAME | | DATE | 6.4.18 |
|---|---|---|---|
| ADDRESS | | | |
| SUBURB | CALINGIRI | POST CODE | |

BORE NO. 5

| STATIC WATER LEVEL: 1.400 metres | PUMPING INLET: 31.5 metres |
|---|---|
| PUMPING RATE: 2 Lt / sec OR 120 Lpm | PUMPING RATE : 0.000 |

| Time 7.00 am | Actual Pumping Level | Time | Actual Pumping Level | Time | Actual Pumping Level | Time | Actual Pumping Level |
|---|---|---|---|---|---|---|---|
| 1 Min | 4.500 m | 4 ¼ Hr | 28.000 m | Recovery Readings | | | |
| 2 Min | 6.800 m | 4 ½ Hr | 28.100 m | 1 Min | 16.400 m | | |
| 3 Min | 7.700 m | 4 ¾ Hr | 28.200 m | 2 Min | 14.400 m | | |
| 4 Min | 9.600 m | 5 Hr | 28.250 m | 3 Min | 14.170 m | | |
| 5 Min | 11.400 m | 5 ¼ Hr | m | 4 Min | 13.950 m | | |
| 6 Min | 12.300 m | 5 ½ Hr | m | 5 Min | m | | |
| 7 Min | 13.200 m | 5 ¾ Hr | m | 6 Min | m | | |
| 8 Min | 13.400 m | 6 Hr | m | 7 Min | 13.600 m | | |
| 9 Min | 13.450 m | 6 ¼ Hr | m | 8 Min | 13.600 m | | |
| 10 Min | 13.550 m | 6 ½ Hr | m | 9 Min | 13.800 m | | |
| 15 Min | 13.700 m | 6 ¾ Hr | m | 10 Min | 13.100 m | | |
| 20 Min | 14.100 m | 7 Hr | m | 15 Min | 13.280 m | PO | |
| 25 Min | 19.500 m | 7 ¼ Hr | m | 20 Min | 9.35 m | | |
| 30 Min | 24.300 m | 7 ½ Hr | m | 25 Min | 7.11 m | | |
| 35 Min | 24.780 m | 7 ¾ Hr | m | 30 Min | 6.14 m | | |
| 40 Min | 25.040 m | 8 Hr | m | 35 Min | 5.36 m | | |
| 50 Min | 25.350 m | | | 40 Min | 4.90 m | | |
| 1 Hr | 25.600 m | | | 50 Min | 4.17 m | | |
| 1 ¼ Hr | 25.750 m | | | 1 Hr | 3.79 m | | |
| 1 ½ Hr | 25.600 m | | | 1 ¼ | 3.38 | | |
| 1 ¾ Hr | 25.900 m | | | 1 ½ | 3.10 | | |
| 2 Hr | 26.050 m | | | 1 ¾ | 2.91 | | |
| 2 ¼ Hr | 26.800 m | | | 2 | 2.71 | | |
| 2 ½ Hr | 26.900 m | | | SALT LEVEL START | | | PPM |
| 2 ¾ Hr | 26.950 m | | | SALT LEVEL FINISH | | | PPM |
| 3 Hr | 27.150 m | | | 2 ½ | 2.55 | | |
| 3 ¼ Hr | 27.350 m | | | | | | |
| 3 ½ Hr | 27.350 m | | | | | | |
| 3 ¾ Hr | 27.300 m | | | | SWL | 1.400 | M |
| 4 Hr | 27.300 m | | | | | | |
| | | | | | TOP OF SCREEN | | M |
| | | | | | | | |
| | | | | | TOTAL DEPTH | 32.2 | M |
| | | | | | | | |
| | START TIME | | | | FINISH TIME | | |
| | | | | | | | |
| | COMMENTS | | | | | | |

37.5
24.92
45 - 25.10
56 - 25.46
65 - 2

# Appendix C: Water Quality Data and Laboratory Certificates.

**Calingiri Copper Project**

**Caravel Minerals**

**Date: 13 April 2018**

| Analyte | Field Measurements | | | | | | General Chemistry | | | | | Major Cations and Anions | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Ground Water Level | Temperature (°C) | pH | Dissolved Oxygen | Electrical Conductivity | Total Dissolved Solids | pH | Electrical Conductivity | Sodium Adsorption Ratio | Total Hardness as CaCO3 | TDS | Calcium (Ca) | Magnesium (Mg) | Sodium (Na) | Potassium (K) | Chloride (Cl) | Sulphate (SO4) | Hydroxide Alkalinity as $CaCO_3$ | Carbonate Alkalinity as $CaCO_3$ | Bicarbonate Alkalinity as $CaCO_3$ | Total Alkalinity as $CaCO_3$ |
| **Unit** | (mbgl) | (°C) | pH Units | mg/L | (µS/cm) | (mg/L) | pH Units | (µS/cm) | - | mg/L | | mg/L | | | | | | | | | |
| **LoR** | - | - | - | - | - | - | - | 1 | 0.01 | 1 | 10 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **Assessment Levels ANZECC (2000)[1]** | | | | | | | | | | | | | | | | | | | | | |
| **Fresh Water[2]: 99% Species Protection Level** | - | - | 6.5 - 8.5 | - | - | - | 6.5 - 8.5 | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **Fresh Water[2]: 95% Species Protection Level** | - | - | 6.5 - 8.5 | - | - | - | 6.5 - 8.5 | - | | | - | - | - | - | - | - | - | - | - | - | - |
| **Fresh Water[2]: 90% Species Protection Level** | - | - | 6.5 - 8.5 | - | - | - | 6.5 - 8.5 | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **Fresh Water[2]: 80% Species Protection Level** | - | - | 6.5 - 8.5 | - | - | - | 6.5 - 8.5 | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **ADWG (2011)[3]** | | | | | | | | | | | | | | | | | | | | | |
| **Health Value (HV)** | - | - | - | - | - | - | - | - | | | - | - | - | - | - | - | 500 | - | - | - | - |
| **Aesthetic Value (AV)** | - | - | 6.5 - 8.5 | >5 | - | - | 6.5 - 8.5 | - | | | 600 | - | - | 180 | - | 250 | 250 | - | - | - | - |
| **Surface Water** | | | | | | | | | | | | | | | | | | | | | |
| Lake | - | - | - | - | - | - | 8.03 | 20,700 | 33.9 | 2,100 | 13,400 | 57 | 476 | 3,570 | 128 | 7,400 | 529 | <1 | <1 | 315 | 315 |
| **Ground Water** | | | | | | | | | | | | | | | | | | | | | |
| CAWB001 | 2.00 | 24.3 | 4.77 | 7.5 | 5,980 | 3,300 | 6.84 | 5,870 | 15.9 | 569 | 3,820 | 20 | 126 | 874 | 35 | 1,700 | 185 | <1 | <1 | 32 | 32 |
| CAWB002 | 5.30 | 24.1 | 5.15 | 7.5 | 2,950 | 1,700 | 6.88 | 2,820 | 10.2 | 270 | 1,830 | 9 | 60 | 385 | 14 | 795 | 104 | <1 | <1 | 17 | 17 |
| CAWB003 | 4.27 | 23.7 | 4.71 | 5.0 | 8,950 | 4,850 | 5.14 | 8,700 | 15.3 | 1,120 | 5,660 | 15 | 263 | 1,180 | 46 | 2,720 | 315 | <1 | <1 | 5 | 5 |
| CAWB005 | 1.40 | 23.5 | 5.72 | 5.8 | 8,120 | 4,600 | 5.65 | 7,920 | 16.4 | 985 | 5,150 | 12 | 232 | 1,180 | 41 | 2,460 | 282 | <1 | <1 | 5 | 5 |
| CAWB006 | 3.01 | 24.1 | 5.58 | 4.9 | 8,560 | 4,750 | 5.50 | 8,410 | 16.6 | 918 | 5,470 | 10 | 217 | 1,160 | 39 | 2,720 | 299 | <1 | <1 | 7 | 7 |
| CARC027 | 1.72 | 24.3 | 5.44 | 6.7 | 6,750 | 3,950 | 7.06 | 6,330 | 22.6 | 393 | 4,110 | 22 | 82 | 1,030 | 31 | 1,870 | 198 | <1 | <1 | 70 | 70 |
| CARC028 | 0.00 | 23.8 | 6.01 | 6.3 | 7,650 | 4,600 | 6.50 | 7,770 | 18.2 | 956 | 5,050 | 20 | 220 | 1,290 | 47 | 2,420 | 258 | <1 | <1 | 30 | 30 |
| **Minimum** | 0.00 | 23.50 | 4.71 | 4.9 | 2,950 | 1,700 | 5.14 | 2,820 | 10.2 | 270 | 1,830 | 9 | 60 | 385 | 14 | 795 | 104 | - | - | 5 | 5 |
| **Maximum** | 5.30 | 24.30 | 6.01 | 7.5 | 8,950 | 4,850 | 7.06 | 8,700 | 22.6 | 1,120 | 5,660 | 22 | 263 | 1,290 | 47 | 2,720 | 315 | - | - | 70 | 70 |
| **Average** | 2.53 | 23.97 | 5.34 | 6.2 | 6,994 | 3,964 | 6.22 | 6,831 | 16.5 | 744 | 4,441 | 15 | 171 | 1,014 | 36 | 2,098 | 234 | - | - | 24 | 24 |
| **Standard Deviation** | 1.80 | 0.31 | 0.49 | 1.1 | 2,058 | 1,139 | 0.78 | 2,054 | 3.7 | 330 | 1,337 | 5 | 81 | 308 | 11 | 697 | 76 | - | - | 23 | 23 |

**Notes:**

1. ANZECC and ARMCANZ (2000). Australian Water Quality Guidelines for Fresh and Marine Water Quality.
2. Values are 'triggers' for slightly-moderately disturbed ecosystems. Values applicable to high conservation/ecological value systems and highly disturbed ecosystems are available in ANZECC and ARMCANZ (
3. NHMRC and ARMCANZ (2011). Australian Drinking Water Guidelines.

22

970

**Calingiri Copper Project** — Water Quality

**Caravel Minerals** — EP1804748 - 23 April 2018

**Date: 13 April 2018**

| Analyte | Aluminium | Arsenic | Cadmium | Chromium | Copper | Lead | Nickel | Selenium | Iron | Mercury | Zinc | Ammonia as N | Fluoride | Nitrite as N | Nitrate as N | Nitrite + Nitrate as N | Total Kjeldahl Nitrogen as N | Total Nitrogen as N | Reactive Phosphorus as P | Total Phosphorus as P | Total Anions | Total Cations | Ionic Balance |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Dissolved Metals | | | | | | | | | | | Nutrients | | | | | | | | | Ionic Balance | | |
| Unit | mg/L | | | | | | | | | | | mg/L | | | | | | | | | meq/L | | % |
| LoR | 0.010 | 0.001 | 0.0001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.01 | 0.05 | 0.0001 | 0.005 | 0.01 | 0.1 | 0.01 | 0.01 | 0.01 | 0.1 | 0.1 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| **Assessment Levels ANZECC (2000)[1]** | | | | | | | | | | | | | | | | | | | | | | | |
| **Fresh Water[2]: 99% Species Protection Level** | 0.027 | 0.008(V) | 0.00006 | 0.00001(VI) | 0.0010 | 0.001 | 0.008 | 0.005 | - | 0.00006 | 0.0024 | 0.32 | - | - | 0.017 | - | - | - | - | - | - | - | - |
| **Fresh Water[2]: 95% Species Protection Level** | 0.055 | 0.013(V) | 0.0002 | 0.001(VI) | - | - | 0.011 | 0.011 | - | - | 0.008 | 0.9 | - | - | 0.7 | - | - | - | - | - | - | - | - |
| **Fresh Water[2]: 90% Species Protection Level** | 0.08 | 0.042(V) | 0.0004 | 0.006(VI) | 0.0018 | 0.0056 | 0.013 | 0.018 | - | 0.0019 | 0.015 | 1.43 | - | - | 3.4 | - | - | - | - | - | - | - | - |
| **Fresh Water[2]: 80% Species Protection Level** | 0.15 | 0.140(V) | 0.0008 | 0.040(VI) | 0.0025 | 0.0094 | 0.017 | 0.034 | - | 0.0054 | 0.031 | 2.3 | - | - | 170 | - | - | - | - | - | - | - | - |
| **ADWG (2011)[3]** | | | | | | | | | | | | | | | | | | | | | | | |
| **Health Value (HV)** | - | 0.01 | 0.002 | 0.05(VI) | - | - | 0.2 | 0.01 | - | - | - | - | - | 0.91 | 11.3 | - | - | - | - | - | - | - | - |
| **Aesthetic Value (AV)** | 0.2 | - | - | - | - | - | - | - | - | - | 3 | - | - | - | - | - | - | - | - | - | - | - | - |
| **Surface Water** | | | | | | | | | | | | | | | | | | | | | | | |
| Lake | <0.01 | <0.001 | <0.0001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.01 | <0.05 | <0.0001 | <0.005 | 0.36 | 0.2 | <0.01 | <0.01 | <0.01 | 3.9 | 3.9 | 0.0 | 0.1 | 226 | 200 | 6.0 |
| **Ground Water** | | | | | | | | | | | | | | | | | | | | | | | |
| CAWB001 | <0.01 | <0.001 | <0.0001 | <0.001 | 0.003 | <0.001 | 0.002 | <0.01 | <0.05 | <0.0001 | <0.005 | 0.06 | 0.3 | <0.01 | 4.07 | 4.07 | 0.70 | 4.80 | 0.06 | 0.14 | 52.4 | 50.3 | 2.1 |
| CAWB002 | <0.01 | <0.001 | <0.0001 | <0.001 | 0.002 | <0.001 | <0.001 | <0.01 | <0.05 | <0.0001 | <0.005 | 0.03 | 0.2 | <0.01 | 12.30 | 12.30 | 2.80 | 15.10 | 0.02 | <0.05 | 24.9 | 22.5 | 5.1 |
| CAWB003 | 1.17 | <0.001 | <0.0001 | 0.002 | 0.005 | <0.001 | 0.015 | <0.01 | 0.75 | <0.0001 | 0.065 | 0.04 | 0.4 | <0.01 | <0.01 | <0.01 | 2.10 | 2.10 | 12.50 | 18.60 | 83.4 | 74.9 | 5.4 |
| CAWB005 | 0.35 | <0.001 | <0.0001 | <0.001 | 0.026 | <0.001 | 0.007 | <0.01 | 0.21 | <0.0001 | 0.036 | 0.04 | 0.2 | <0.01 | 0.88 | 0.88 | 0.30 | 1.20 | 0.02 | 0.04 | 75.4 | 72.1 | 2.2 |
| CAWB006 | 0.02 | <0.001 | <0.0001 | <0.001 | 0.030 | <0.001 | 0.004 | <0.01 | <0.05 | <0.0001 | 0.029 | 0.04 | 0.3 | <0.01 | 1.53 | 1.53 | 0.40 | 1.90 | 1.74 | 6.68 | 83.1 | 69.8 | 8.7 |
| CARC027 | <0.01 | <0.001 | <0.0001 | <0.001 | 0.017 | <0.001 | 0.005 | <0.01 | <0.05 | <0.0001 | 0.008 | 0.03 | 0.7 | <0.01 | 0.80 | 0.80 | 0.20 | 1.00 | 0.13 | 0.13 | 58.3 | 53.4 | 4.3 |
| CARC028 | <0.01 | <0.001 | <0.0001 | 0.001 | 0.015 | <0.001 | 0.006 | <0.01 | <0.05 | <0.0001 | 0.011 | 0.03 | 0.6 | <0.01 | 1.62 | 1.62 | 0.20 | 1.80 | 1.72 | 12.50 | 74.2 | 76.4 | 1.5 |
| **Minimum** | 0.02 | - | - | 0.001 | 0.002 | - | 0.002 | - | 0.21 | - | 0.008 | 0.03 | 0.2 | - | 0.80 | 0.80 | 0.20 | 1.00 | 0.02 | 0.04 | - | - | - |
| **Maximum** | 1.17 | - | - | 0.002 | 0.030 | - | 0.015 | - | 0.75 | - | 0.065 | 0.06 | 0.7 | - | 12.30 | 12.30 | 2.80 | 15.10 | 12.50 | 18.60 | - | - | - |
| **Average** | 0.51 | - | - | 0.002 | 0.014 | - | 0.007 | - | 0.48 | - | 0.030 | 0.04 | 0.4 | - | 3.53 | 3.53 | 0.96 | 3.99 | 2.31 | 6.35 | - | - | - |
| **Standard Deviation** | 0.59 | - | - | 0.001 | 0.011 | - | 0.005 | - | 0.38 | - | 0.023 | 0.01 | 0.2 | - | 4.46 | 4.46 | 1.05 | 5.06 | 4.56 | 7.81 | - | - | - |

**Notes:**

(2000).

# Chain of Custody (CoC) Documentation

## Pendragon Environmental Solutions

**Project Manager (PM):** Carel van der Westhuizen
**Job Number:** PES18011
**Site:** Calingiri
**Results required by (date):** NA

**Sampler:** Carel van der Westhuizen (carel@pendragonenvironmental.com)
**Mobile:** Carel 0439-993-933
**Phone:**
**e-mail analysis/report to:** carel@pendragonenvironmental.com
**Copy Invoice to:** carel@pendragonenvironmental.com

**Environmental Scientists and Engineers**

**For Laboratory Use Only!**
Cooler Seal
Intact: (Yes) No N/A
**Sample Temperature**
Chilled (Yes) No N/A

**Comments/Special Handling/Storage or Disposal**
Quote: EP-014-14
See Notes. Please filter metals

**Sample Information (S = Soil, Sed = Sediment, R = Rock, W=Water)**

| Lab ID | Sample ID | Matrix | Time | Date | Container Information: Type / Code | Container Information: Total | NT-14 | Dissolved W-30 |
|---|---|---|---|---|---|---|---|---|
| 1 | • CAWB001 | Water | | 11-Apr-18 | | 3 | x | x |
| 2 | • CAWB002 | Water | | 11-Apr-18 | | 3 | x | x |
| 3 | • CAWB003 | Water | | 11-Apr-18 | | 3 | x | x |
| 4 | • CAWB005 | Water | | 11-Apr-18 | | 3 | x | x |
| 5 | • CAWB006 | Water | | 11-Apr-18 | | 3 | x | x |
| 6 | CARC027 | Water | | 11-Apr-18 | | 3 | x | x |
| 7 | CARC028 | Water | | 11-Apr-18 | | 3 | x | x |
| 8 | LAKE | " | | " | | 3 | • | • |

**ANALYSIS REQUIRED**

Notes: e.g. Highly contaminated samples, extra volume for QC or trace LORs etc.

**Instructions to ALS:**
Do not discard any sample without written instruction.
Additional instructions, if any, will follow on completion of these preliminary tests

Environmental Division
Perth
Work Order Reference
EP1804748

Telephone : + 61-8-9406 1301

**Relinquished By:**

| | | | |
|---|---|---|---|
| **Name:** | Carel van der Westhuizen | **Date:** | 11/04/2018 |
| **Of:** | Pendragon Environmental Solutions | **Time:** | |
| **Name:** | | **Date:** | |
| **Of:** | | **Time:** | |

**Received By**

| | | |
|---|---|---|
| **Name:** | Natalie | 13/4/18 |
| **Of:** | ALS | 11:30am |
| **Name:** | | |
| **Of:** | | |

**Method of Shipment**
Courier:
Other:
Drop off

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

**Note: Job Number must be reflected on all invoices and statements. Attach copy of CoC to invoice.**

Number of Eskys: 1 | 1 OF 1

# SAMPLE RECEIPT NOTIFICATION (SRN)

**Work Order** : **EP1804748**

| | | | |
|---|---|---|---|
| Client | : **PENDRAGON ENVIRONMENTAL SOLUTIONS** | Laboratory | : Environmental Division Perth |
| Contact | : MR CAREL VAN DER WESTHUIZEN | Contact | : Customer Services EP |
| Address | : 310 NEWCASTLE STREET NORTHBRIDGE WESTERN AUSTRALIA 6003 | Address | : 26 Rigali Way Wangara WA Australia 6065 |
| E-mail | : carel@pendragonenvironmental.com | E-mail | : ALSEnviro.Perth@alsglobal.com |
| Telephone | : +61 08 9382 8286 | Telephone | : +61-8-9406 1301 |
| Facsimile | : +61 08 9382 8693 | Facsimile | : +61-8-9406 1399 |
| Project | : PES18011 | Page | : 1 of 3 |
| Order number | : | Quote number | : EP2018PENENV0002 (EN/222/17) |
| C-O-C number | : ---- | QC Level | : NEPM 2013 B3 & ALS QC Standard |
| Site | : Calingiri | | |
| Sampler | : | | |

## Dates

| | | | |
|---|---|---|---|
| Date Samples Received | : 13-Apr-2018 11:30 | Issue Date | : 13-Apr-2018 |
| Client Requested Due Date | : 20-Apr-2018 | Scheduled Reporting Date | : **20-Apr-2018** |

## Delivery Details

| | | | |
|---|---|---|---|
| Mode of Delivery | : Carrier | Security Seal | : Intact. |
| No. of coolers/boxes | : 1 | Temperature | : 9.5 - Ice Bricks present |
| Receipt Detail | : | No. of samples received / analysed | : 8 / 8 |

## General Comments

- This report contains the following information:
  - Sample Container(s)/Preservation Non-Compliances
  - Summary of Sample(s) and Requested Analysis
  - Proactive Holding Time Report
  - Requested Deliverables
- Please see scanned COC for sample discrepencies: extra samples , samples not received etc.
- Please direct any queries related to sample condition / numbering / breakages to Sample Receipt (SamplesPerth@alsenviro.com)
- Analytical work for this work order will be conducted at ALS Environmental Perth.
- Please direct any turnaround / technical queries to the laboratory contact designated above.
- Sample Disposal - Aqueous (3 weeks), Solid (2 months) from receipt of samples.
- **pH analysis should be conducted within 6 hours of sampling.**

## Sample Container(s)/Preservation Non-Compliances

All comparisons are made against pretreatment/preservation AS, APHA, USEPA standards.

- **No sample container / preservation non-compliance exists.**

## Summary of Sample(s) and Requested Analysis

Some items described below may be part of a laboratory process necessary for the execution of client requested tasks. Packages may contain additional analyses, such as the determination of moisture content and preparation tasks, that are included in the package.

If no sampling time is provided, the sampling time will default 00:00 on the date of sampling. If no sampling date is provided, the sampling date will be assumed by the laboratory and displayed in brackets without a time component

Matrix: **WATER**

| Laboratory sample ID | Client sampling date / time | Client sample ID | WATER - NT-14 Extended Water Suite B | WATER - W-30 11 Metals |
|---|---|---|---|---|
| EP1804748-001 | 11-Apr-2018 00:00 | CAWB001 | ✓ | ✓ |
| EP1804748-002 | 11-Apr-2018 00:00 | CAWB002 | ✓ | ✓ |
| EP1804748-003 | 11-Apr-2018 00:00 | CAWB003 | ✓ | ✓ |
| EP1804748-004 | 11-Apr-2018 00:00 | CAWB005 | ✓ | ✓ |
| EP1804748-005 | 11-Apr-2018 00:00 | CAWB006 | ✓ | ✓ |
| EP1804748-006 | 11-Apr-2018 00:00 | CARC027 | ✓ | ✓ |
| EP1804748-007 | 11-Apr-2018 00:00 | CARC028 | ✓ | ✓ |
| EP1804748-008 | 11-Apr-2018 00:00 | LAKE | ✓ | ✓ |

## Proactive Holding Time Report

The following table summarises breaches of recommended holding times that have occurred prior to samples/instructions being received at the laboratory.

Matrix: **WATER**

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

| Method / Client Sample ID(s) | Container | Due for extraction | Due for analysis | Samples Received Date | Samples Received Evaluation | Instructions Received Date | Instructions Received Evaluation |
|---|---|---|---|---|---|---|---|
| **EA005-P: pH by PC Titrator** | | | | | | | |
| CARC027 | Clear Plastic Bottle - Natural | ---- | 11-Apr-2018 | 13-Apr-2018 | × | ---- | ---- |
| CARC028 | Clear Plastic Bottle - Natural | ---- | 11-Apr-2018 | 13-Apr-2018 | × | ---- | ---- |
| CAWB001 | Clear Plastic Bottle - Natural | ---- | 11-Apr-2018 | 13-Apr-2018 | × | ---- | ---- |
| CAWB002 | Clear Plastic Bottle - Natural | ---- | 11-Apr-2018 | 13-Apr-2018 | × | ---- | ---- |
| CAWB003 | Clear Plastic Bottle - Natural | ---- | 11-Apr-2018 | 13-Apr-2018 | × | ---- | ---- |
| CAWB005 | Clear Plastic Bottle - Natural | ---- | 11-Apr-2018 | 13-Apr-2018 | × | ---- | ---- |
| CAWB006 | Clear Plastic Bottle - Natural | ---- | 11-Apr-2018 | 13-Apr-2018 | × | ---- | ---- |
| LAKE | Clear Plastic Bottle - Natural | ---- | 11-Apr-2018 | 13-Apr-2018 | × | ---- | ---- |

## *Requested Deliverables*

**CAREL VAN DER WESTHUIZEN**

| | | |
|---|---|---|
| - *AU Certificate of Analysis - NATA (COA) | Email | carel@pendragonenvironmental.com |
| - *AU Interpretive QC Report - DEFAULT (Anon QCI Rep) (QCI) | Email | carel@pendragonenvironmental.com |
| - *AU QC Report - DEFAULT (Anon QC Rep) - NATA (QC) | Email | carel@pendragonenvironmental.com |
| - A4 - AU Sample Receipt Notification - Environmental HT (SRN) | Email | carel@pendragonenvironmental.com |
| - A4 - AU Tax Invoice (INV) | Email | carel@pendragonenvironmental.com |
| - Chain of Custody (CoC) (COC) | Email | carel@pendragonenvironmental.com |
| - EDI Format - ENMRG (ENMRG) | Email | carel@pendragonenvironmental.com |
| - EDI Format - ESDAT (ESDAT) | Email | carel@pendragonenvironmental.com |
| - EDI Format - XTab (XTAB) | Email | carel@pendragonenvironmental.com |

# CERTIFICATE OF ANALYSIS



| | | | |
|---|---|---|---|
| **Work Order** | : **EP1804748** | Page | : 1 of 6 |
| Client | : **PENDRAGON ENVIRONMENTAL SOLUTIONS** | Laboratory | : Environmental Division Perth |
| Contact | : MR CAREL VAN DER WESTHUIZEN | Contact | : Customer Services EP |
| Address | : 310 NEWCASTLE STREET<br>NORTHBRIDGE WESTERN AUSTRALIA 6003 | Address | : 26 Rigali Way Wangara WA Australia 6065 |
| Telephone | : +61 08 9382 8286 | Telephone | : +61-8-9406 1301 |
| Project | : PES18011 | Date Samples Received | : 13-Apr-2018 11:30 |
| Order number | : | Date Analysis Commenced | : 13-Apr-2018 |
| C-O-C number | : ---- | Issue Date | : 23-Apr-2018 17:15 |
| Sampler | : ---- | | |
| Site | : Calingiri | | |
| Quote number | : EN/222/17 | | |
| No. of samples received | : 8 | | |
| No. of samples analysed | : 8 | | |

Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

**Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.**

## *Signatories*

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

| *Signatories* | *Position* | *Accreditation Category* |
|---|---|---|
| Canhuang Ke | Inorganics Supervisor | Perth Inorganics, Wangara, WA |
| Efua Wilson | Metals Chemist | Perth Inorganics, Wangara, WA |
| Indra Astuty | Instrument Chemist | Perth Inorganics, Wangara, WA |
| Jeremy Truong | Laboratory Manager | Perth Inorganics, Wangara, WA |

## General Comments

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

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

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

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

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

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

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

- EA016: Calculated TDS is determined from Electrical conductivity using a conversion factor of 0.65.

## Analytical Results

| Sub-Matrix: WATER (Matrix: WATER) | | | Client sample ID | CAWB001 | CAWB002 | CAWB003 | CAWB005 | CAWB006 |
|---|---|---|---|---|---|---|---|---|
| | | | Client sampling date / time | 11-Apr-2018 00:00 | 11-Apr-2018 00:00 | 11-Apr-2018 00:00 | 11-Apr-2018 00:00 | 11-Apr-2018 00:00 |
| Compound | CAS Number | LOR | Unit | EP1804748-001 | EP1804748-002 | EP1804748-003 | EP1804748-004 | EP1804748-005 |
| | | | | Result | Result | Result | Result | Result |
| **EA005P: pH by PC Titrator** | | | | | | | | |
| pH Value | ---- | 0.01 | pH Unit | 6.84 | 6.88 | 5.14 | 5.65 | 5.50 |
| **EA006: Sodium Adsorption Ratio (SAR)** | | | | | | | | |
| ^ Sodium Adsorption Ratio | ---- | 0.01 | - | 15.9 | 10.2 | 15.3 | 16.4 | 16.6 |
| **EA010P: Conductivity by PC Titrator** | | | | | | | | |
| Electrical Conductivity @ 25°C | ---- | 1 | µS/cm | 5870 | 2820 | 8700 | 7920 | 8410 |
| **EA016: Calculated TDS (from Electrical Conductivity)** | | | | | | | | |
| Total Dissolved Solids (Calc.) | ---- | 1 | mg/L | 3820 | 1830 | 5660 | 5150 | 5470 |
| **EA065: Total Hardness as CaCO3** | | | | | | | | |
| Total Hardness as CaCO3 | ---- | 1 | mg/L | 569 | 270 | 1120 | 985 | 918 |
| **ED037P: Alkalinity by PC Titrator** | | | | | | | | |
| Hydroxide Alkalinity as CaCO3 | DMO-210-001 | 1 | mg/L | <1 | <1 | <1 | <1 | <1 |
| Carbonate Alkalinity as CaCO3 | 3812-32-6 | 1 | mg/L | <1 | <1 | <1 | <1 | <1 |
| Bicarbonate Alkalinity as CaCO3 | 71-52-3 | 1 | mg/L | 32 | 17 | 5 | 5 | 7 |
| Total Alkalinity as CaCO3 | ---- | 1 | mg/L | 32 | 17 | 5 | 5 | 7 |
| **ED041G: Sulfate (Turbidimetric) as SO4 2- by DA** | | | | | | | | |
| Sulfate as SO4 - Turbidimetric | 14808-79-8 | 1 | mg/L | 185 | 104 | 315 | 282 | 299 |
| **ED045G: Chloride by Discrete Analyser** | | | | | | | | |
| Chloride | 16887-00-6 | 1 | mg/L | 1700 | 795 | 2720 | 2460 | 2720 |
| **ED093F: Dissolved Major Cations** | | | | | | | | |
| Calcium | 7440-70-2 | 1 | mg/L | 20 | 9 | 15 | 12 | 10 |
| Magnesium | 7439-95-4 | 1 | mg/L | 126 | 60 | 263 | 232 | 217 |
| Sodium | 7440-23-5 | 1 | mg/L | 874 | 385 | 1180 | 1180 | 1160 |
| Potassium | 7440-09-7 | 1 | mg/L | 35 | 14 | 46 | 41 | 39 |
| **EG020F: Dissolved Metals by ICP-MS** | | | | | | | | |
| Aluminium | 7429-90-5 | 0.01 | mg/L | <0.01 | <0.01 | 1.17 | 0.35 | 0.02 |
| Arsenic | 7440-38-2 | 0.001 | mg/L | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Cadmium | 7440-43-9 | 0.0001 | mg/L | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 |
| Chromium | 7440-47-3 | 0.001 | mg/L | <0.001 | <0.001 | 0.002 | <0.001 | <0.001 |
| Copper | 7440-50-8 | 0.001 | mg/L | 0.003 | 0.002 | 0.005 | 0.026 | 0.030 |
| Nickel | 7440-02-0 | 0.001 | mg/L | 0.002 | <0.001 | 0.015 | 0.007 | 0.004 |
| Lead | 7439-92-1 | 0.001 | mg/L | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Selenium | 7782-49-2 | 0.01 | mg/L | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Zinc | 7440-66-6 | 0.005 | mg/L | <0.005 | <0.005 | 0.065 | 0.036 | 0.029 |
| Iron | 7439-89-6 | 0.05 | mg/L | <0.05 | <0.05 | 0.75 | 0.21 | <0.05 |

## Analytical Results

| Sub-Matrix: WATER (Matrix: WATER) | | | Client sample ID | CAWB001 | CAWB002 | CAWB003 | CAWB005 | CAWB006 |
|---|---|---|---|---|---|---|---|---|
| | | | Client sampling date / time | 11-Apr-2018 00:00 | 11-Apr-2018 00:00 | 11-Apr-2018 00:00 | 11-Apr-2018 00:00 | 11-Apr-2018 00:00 |
| Compound | CAS Number | LOR | Unit | EP1804748-001 | EP1804748-002 | EP1804748-003 | EP1804748-004 | EP1804748-005 |
| | | | | Result | Result | Result | Result | Result |
| **EG035F: Dissolved Mercury by FIMS** | | | | | | | | |
| Mercury | 7439-97-6 | 0.0001 | mg/L | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 |
| **EK040P: Fluoride by PC Titrator** | | | | | | | | |
| Fluoride | 16984-48-8 | 0.1 | mg/L | **0.3** | **0.2** | **0.4** | **0.2** | **0.3** |
| **EK055G: Ammonia as N by Discrete Analyser** | | | | | | | | |
| Ammonia as N | 7664-41-7 | 0.01 | mg/L | **0.06** | **0.03** | **0.04** | **0.04** | **0.04** |
| **EK057G: Nitrite as N by Discrete Analyser** | | | | | | | | |
| Nitrite as N | 14797-65-0 | 0.01 | mg/L | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| **EK058G: Nitrate as N by Discrete Analyser** | | | | | | | | |
| Nitrate as N | 14797-55-8 | 0.01 | mg/L | **4.07** | **12.3** | <0.01 | **0.88** | **1.53** |
| **EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser** | | | | | | | | |
| Nitrite + Nitrate as N | ---- | 0.01 | mg/L | **4.07** | **12.3** | <0.01 | **0.88** | **1.53** |
| **EK061G: Total Kjeldahl Nitrogen By Discrete Analyser** | | | | | | | | |
| Total Kjeldahl Nitrogen as N | ---- | 0.1 | mg/L | **0.7** | **2.8** | **2.1** | **0.3** | **0.4** |
| **EK062G: Total Nitrogen as N (TKN + NOx) by Discrete Analyser** | | | | | | | | |
| ^ Total Nitrogen as N | ---- | 0.1 | mg/L | **4.8** | **15.1** | **2.1** | **1.2** | **1.9** |
| **EK067G: Total Phosphorus as P by Discrete Analyser** | | | | | | | | |
| Total Phosphorus as P | ---- | 0.01 | mg/L | **0.14** | <0.05 | **18.6** | **0.04** | **6.68** |
| **EK071G: Reactive Phosphorus as P by discrete analyser** | | | | | | | | |
| Reactive Phosphorus as P | 14265-44-2 | 0.01 | mg/L | **0.06** | **0.02** | **12.5** | **0.02** | **1.74** |
| **EN055: Ionic Balance** | | | | | | | | |
| Total Anions | ---- | 0.01 | meq/L | **52.4** | **24.9** | **83.4** | **75.4** | **83.1** |
| Total Cations | ---- | 0.01 | meq/L | **50.3** | **22.5** | **74.9** | **72.1** | **69.8** |
| Ionic Balance | ---- | 0.01 | % | **2.11** | **5.14** | **5.36** | **2.24** | **8.68** |

## Analytical Results

| Sub-Matrix: WATER (Matrix: WATER) | | | Client sample ID | CARC027 | CARC028 | LAKE | ---- | ---- |
|---|---|---|---|---|---|---|---|---|
| | | | Client sampling date / time | 11-Apr-2018 00:00 | 11-Apr-2018 00:00 | 11-Apr-2018 00:00 | ---- | ---- |
| Compound | CAS Number | LOR | Unit | EP1804748-006 | EP1804748-007 | EP1804748-008 | -------- | -------- |
| | | | | Result | Result | Result | ---- | ---- |
| **EA005P: pH by PC Titrator** | | | | | | | | |
| pH Value | ---- | 0.01 | pH Unit | **7.06** | **6.50** | **8.03** | ---- | ---- |
| **EA006: Sodium Adsorption Ratio (SAR)** | | | | | | | | |
| ^ Sodium Adsorption Ratio | ---- | 0.01 | - | **22.6** | **18.2** | **33.9** | ---- | ---- |
| **EA010P: Conductivity by PC Titrator** | | | | | | | | |
| Electrical Conductivity @ 25°C | ---- | 1 | µS/cm | **6330** | **7770** | **20700** | ---- | ---- |
| **EA016: Calculated TDS (from Electrical Conductivity)** | | | | | | | | |
| Total Dissolved Solids (Calc.) | ---- | 1 | mg/L | **4110** | **5050** | **13400** | ---- | ---- |
| **EA065: Total Hardness as CaCO3** | | | | | | | | |
| Total Hardness as CaCO3 | ---- | 1 | mg/L | **393** | **956** | **2100** | ---- | ---- |
| **ED037P: Alkalinity by PC Titrator** | | | | | | | | |
| Hydroxide Alkalinity as CaCO3 | DMO-210-001 | 1 | mg/L | <1 | <1 | <1 | ---- | ---- |
| Carbonate Alkalinity as CaCO3 | 3812-32-6 | 1 | mg/L | <1 | <1 | <1 | ---- | ---- |
| Bicarbonate Alkalinity as CaCO3 | 71-52-3 | 1 | mg/L | **70** | **30** | **315** | ---- | ---- |
| Total Alkalinity as CaCO3 | ---- | 1 | mg/L | **70** | **30** | **315** | ---- | ---- |
| **ED041G: Sulfate (Turbidimetric) as SO4 2- by DA** | | | | | | | | |
| Sulfate as SO4 - Turbidimetric | 14808-79-8 | 1 | mg/L | **198** | **258** | **529** | ---- | ---- |
| **ED045G: Chloride by Discrete Analyser** | | | | | | | | |
| Chloride | 16887-00-6 | 1 | mg/L | **1870** | **2420** | **7400** | ---- | ---- |
| **ED093F: Dissolved Major Cations** | | | | | | | | |
| Calcium | 7440-70-2 | 1 | mg/L | **22** | **20** | **57** | ---- | ---- |
| Magnesium | 7439-95-4 | 1 | mg/L | **82** | **220** | **476** | ---- | ---- |
| Sodium | 7440-23-5 | 1 | mg/L | **1030** | **1290** | **3570** | ---- | ---- |
| Potassium | 7440-09-7 | 1 | mg/L | **31** | **47** | **128** | ---- | ---- |
| **EG020F: Dissolved Metals by ICP-MS** | | | | | | | | |
| Aluminium | 7429-90-5 | 0.01 | mg/L | <0.01 | <0.01 | <0.01 | ---- | ---- |
| Arsenic | 7440-38-2 | 0.001 | mg/L | <0.001 | <0.001 | <0.001 | ---- | ---- |
| Cadmium | 7440-43-9 | 0.0001 | mg/L | <0.0001 | <0.0001 | <0.0001 | ---- | ---- |
| Chromium | 7440-47-3 | 0.001 | mg/L | <0.001 | **0.001** | <0.001 | ---- | ---- |
| Copper | 7440-50-8 | 0.001 | mg/L | **0.017** | **0.015** | <0.001 | ---- | ---- |
| Nickel | 7440-02-0 | 0.001 | mg/L | **0.005** | **0.006** | <0.001 | ---- | ---- |
| Lead | 7439-92-1 | 0.001 | mg/L | <0.001 | <0.001 | <0.001 | ---- | ---- |
| Selenium | 7782-49-2 | 0.01 | mg/L | <0.01 | <0.01 | <0.01 | ---- | ---- |
| Zinc | 7440-66-6 | 0.005 | mg/L | **0.008** | **0.011** | <0.005 | ---- | ---- |
| Iron | 7439-89-6 | 0.05 | mg/L | <0.05 | <0.05 | <0.05 | ---- | ---- |

## Analytical Results

| Sub-Matrix: WATER (Matrix: WATER) | | | Client sample ID | CARC027 | CARC028 | LAKE | ---- | ---- |
|---|---|---|---|---|---|---|---|---|
| | | | Client sampling date / time | 11-Apr-2018 00:00 | 11-Apr-2018 00:00 | 11-Apr-2018 00:00 | ---- | ---- |
| Compound | CAS Number | LOR | Unit | EP1804748-006 | EP1804748-007 | EP1804748-008 | -------- | -------- |
| | | | | Result | Result | Result | ---- | ---- |
| **EG035F: Dissolved Mercury by FIMS** | | | | | | | | |
| Mercury | 7439-97-6 | 0.0001 | mg/L | <0.0001 | <0.0001 | <0.0001 | ---- | ---- |
| **EK040P: Fluoride by PC Titrator** | | | | | | | | |
| Fluoride | 16984-48-8 | 0.1 | mg/L | **0.7** | **0.6** | **0.2** | ---- | ---- |
| **EK055G: Ammonia as N by Discrete Analyser** | | | | | | | | |
| Ammonia as N | 7664-41-7 | 0.01 | mg/L | **0.03** | **0.03** | **0.36** | ---- | ---- |
| **EK057G: Nitrite as N by Discrete Analyser** | | | | | | | | |
| Nitrite as N | 14797-65-0 | 0.01 | mg/L | <0.01 | <0.01 | <0.01 | ---- | ---- |
| **EK058G: Nitrate as N by Discrete Analyser** | | | | | | | | |
| Nitrate as N | 14797-55-8 | 0.01 | mg/L | **0.80** | **1.62** | <0.01 | ---- | ---- |
| **EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser** | | | | | | | | |
| Nitrite + Nitrate as N | ---- | 0.01 | mg/L | **0.80** | **1.62** | <0.01 | ---- | ---- |
| **EK061G: Total Kjeldahl Nitrogen By Discrete Analyser** | | | | | | | | |
| Total Kjeldahl Nitrogen as N | ---- | 0.1 | mg/L | **0.2** | **0.2** | **3.9** | ---- | ---- |
| **EK062G: Total Nitrogen as N (TKN + NOx) by Discrete Analyser** | | | | | | | | |
| ^ Total Nitrogen as N | ---- | 0.1 | mg/L | **1.0** | **1.8** | **3.9** | ---- | ---- |
| **EK067G: Total Phosphorus as P by Discrete Analyser** | | | | | | | | |
| Total Phosphorus as P | ---- | 0.01 | mg/L | **0.13** | **12.5** | **0.13** | ---- | ---- |
| **EK071G: Reactive Phosphorus as P by discrete analyser** | | | | | | | | |
| Reactive Phosphorus as P | 14265-44-2 | 0.01 | mg/L | **0.13** | **1.72** | **0.01** | ---- | ---- |
| **EN055: Ionic Balance** | | | | | | | | |
| Total Anions | ---- | 0.01 | meq/L | **58.3** | **74.2** | **226** | ---- | ---- |
| Total Cations | ---- | 0.01 | meq/L | **53.4** | **76.4** | **200** | ---- | ---- |
| Ionic Balance | ---- | 0.01 | % | **4.32** | **1.45** | **5.97** | ---- | ---- |

# QUALITY CONTROL REPORT

| | | | |
|---|---|---|---|
| **Work Order** | : **EP1804748** | Page | : 1 of 7 |
| Client | : **PENDRAGON ENVIRONMENTAL SOLUTIONS** | Laboratory | : Environmental Division Perth |
| Contact | : MR CAREL VAN DER WESTHUIZEN | Contact | : Customer Services EP |
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| Project | : PES18011 | Date Samples Received | : 13-Apr-2018 |
| Order number | : | Date Analysis Commenced | : 13-Apr-2018 |
| C-O-C number | : ---- | Issue Date | : 23-Apr-2018 |
| Sampler | : ---- | | |
| Site | : Calingiri | | |
| Quote number | : EN/222/17 | | |
| No. of samples received | : 8 | | |
| No. of samples analysed | : 8 | | |

Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. This document shall not be reproduced, except in full.

This Quality Control Report contains the following information:

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

## *Signatories*

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

| *Signatories* | *Position* | *Accreditation Category* |
|---|---|---|
| Canhuang Ke | Inorganics Supervisor | Perth Inorganics, Wangara, WA |
| Efua Wilson | Metals Chemist | Perth Inorganics, Wangara, WA |
| Indra Astuty | Instrument Chemist | Perth Inorganics, Wangara, WA |
| Jeremy Truong | Laboratory Manager | Perth Inorganics, Wangara, WA |

## General Comments

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

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

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

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

## Laboratory Duplicate (DUP) Report

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

Sub-Matrix: **WATER**

| | | | | Laboratory Duplicate (DUP) Report | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Laboratory sample ID | Client sample ID | Method: Compound | CAS Number | LOR | Unit | Original Result | Duplicate Result | RPD (%) | Recovery Limits (%) |
| **EA005P: pH by PC Titrator (QC Lot: 1576562)** | | | | | | | | | |
| EP1804712-005 | Anonymous | EA005-P: pH Value | ---- | 0.01 | pH Unit | 7.64 | 7.65 | 0.131 | 0% - 20% |
| EP1804741-005 | Anonymous | EA005-P: pH Value | ---- | 0.01 | pH Unit | 6.66 | 6.66 | 0.00 | 0% - 20% |
| **EA005P: pH by PC Titrator (QC Lot: 1576565)** | | | | | | | | | |
| EP1804821-008 | Anonymous | EA005-P: pH Value | ---- | 0.01 | pH Unit | 6.57 | 6.55 | 0.305 | 0% - 20% |
| EP1804748-008 | LAKE | EA005-P: pH Value | ---- | 0.01 | pH Unit | 8.03 | 8.10 | 0.868 | 0% - 20% |
| **EA010P: Conductivity by PC Titrator (QC Lot: 1576564)** | | | | | | | | | |
| EP1804741-005 | Anonymous | EA010-P: Electrical Conductivity @ 25°C | ---- | 1 | µS/cm | 590 | 593 | 0.512 | 0% - 20% |
| EP1804748-008 | LAKE | EA010-P: Electrical Conductivity @ 25°C | ---- | 1 | µS/cm | 20700 | 20800 | 0.443 | 0% - 20% |
| **ED037P: Alkalinity by PC Titrator (QC Lot: 1576563)** | | | | | | | | | |
| EP1804741-005 | Anonymous | ED037-P: Hydroxide Alkalinity as CaCO3 | DMO-210-001 | 1 | mg/L | <1 | <1 | 0.00 | No Limit |
| | | ED037-P: Carbonate Alkalinity as CaCO3 | 3812-32-6 | 1 | mg/L | <1 | <1 | 0.00 | No Limit |
| | | ED037-P: Bicarbonate Alkalinity as CaCO3 | 71-52-3 | 1 | mg/L | 24 | 22 | 7.97 | 0% - 20% |
| | | ED037-P: Total Alkalinity as CaCO3 | ---- | 1 | mg/L | 24 | 22 | 7.97 | 0% - 20% |
| EP1804748-008 | LAKE | ED037-P: Hydroxide Alkalinity as CaCO3 | DMO-210-001 | 1 | mg/L | <1 | <1 | 0.00 | No Limit |
| | | ED037-P: Carbonate Alkalinity as CaCO3 | 3812-32-6 | 1 | mg/L | <1 | <1 | 0.00 | No Limit |
| | | ED037-P: Bicarbonate Alkalinity as CaCO3 | 71-52-3 | 1 | mg/L | 315 | 325 | 3.26 | 0% - 20% |
| | | ED037-P: Total Alkalinity as CaCO3 | ---- | 1 | mg/L | 315 | 325 | 3.26 | 0% - 20% |
| **ED041G: Sulfate (Turbidimetric) as SO4 2- by DA (QC Lot: 1566804)** | | | | | | | | | |
| EP1804748-007 | CARC028 | ED041G: Sulfate as SO4 - Turbidimetric | 14808-79-8 | 1 | mg/L | 258 | 260 | 0.881 | 0% - 20% |
| EP1804740-002 | Anonymous | ED041G: Sulfate as SO4 - Turbidimetric | 14808-79-8 | 1 | mg/L | 280 | 275 | 1.73 | 0% - 20% |
| **ED045G: Chloride by Discrete Analyser (QC Lot: 1566805)** | | | | | | | | | |
| EP1804748-007 | CARC028 | ED045G: Chloride | 16887-00-6 | 1 | mg/L | 2420 | 2460 | 1.49 | 0% - 20% |
| EP1804740-002 | Anonymous | ED045G: Chloride | 16887-00-6 | 1 | mg/L | 395 | 400 | 1.32 | 0% - 20% |
| **ED093F: Dissolved Major Cations (QC Lot: 1578634)** | | | | | | | | | |

Sub-Matrix: **WATER**

| Laboratory sample ID | Client sample ID | Method: Compound | CAS Number | LOR | Unit | Original Result | Duplicate Result | RPD (%) | Recovery Limits (%) |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Laboratory Duplicate (DUP) Report | | | | | |
| **ED093F: Dissolved Major Cations (QC Lot: 1578634) - continued** | | | | | | | | | |
| EP1804741-004 | Anonymous | ED093F: Calcium | 7440-70-2 | 1 | mg/L | 116 | 117 | 1.08 | 0% - 20% |
| | | ED093F: Magnesium | 7439-95-4 | 1 | mg/L | 95 | 95 | 0.00 | 0% - 20% |
| | | ED093F: Sodium | 7440-23-5 | 1 | mg/L | 590 | 597 | 1.28 | 0% - 20% |
| | | ED093F: Potassium | 7440-09-7 | 1 | mg/L | 6 | 6 | 0.00 | No Limit |
| EP1804748-004 | CAWB005 | ED093F: Calcium | 7440-70-2 | 1 | mg/L | 12 | 12 | 0.00 | 0% - 50% |
| | | ED093F: Magnesium | 7439-95-4 | 1 | mg/L | 232 | 232 | 0.00 | 0% - 20% |
| | | ED093F: Sodium | 7440-23-5 | 1 | mg/L | 1180 | 1200 | 1.09 | 0% - 20% |
| | | ED093F: Potassium | 7440-09-7 | 1 | mg/L | 41 | 41 | 0.00 | 0% - 20% |
| **EG020F: Dissolved Metals by ICP-MS (QC Lot: 1578633)** | | | | | | | | | |
| EP1804741-002 | Anonymous | EG020A-F: Cadmium | 7440-43-9 | 0.0001 | mg/L | <0.0001 | 0.0001 | 0.00 | No Limit |
| | | EG020A-F: Arsenic | 7440-38-2 | 0.001 | mg/L | <0.001 | <0.001 | 0.00 | No Limit |
| | | EG020A-F: Chromium | 7440-47-3 | 0.001 | mg/L | <0.001 | <0.001 | 0.00 | No Limit |
| | | EG020A-F: Copper | 7440-50-8 | 0.001 | mg/L | <0.001 | <0.001 | 0.00 | No Limit |
| | | EG020A-F: Lead | 7439-92-1 | 0.001 | mg/L | <0.001 | <0.001 | 0.00 | No Limit |
| | | EG020A-F: Nickel | 7440-02-0 | 0.001 | mg/L | 0.030 | 0.032 | 4.31 | 0% - 20% |
| | | EG020A-F: Zinc | 7440-66-6 | 0.005 | mg/L | 0.009 | 0.008 | 0.00 | No Limit |
| | | EG020A-F: Aluminium | 7429-90-5 | 0.01 | mg/L | <0.01 | <0.01 | 0.00 | No Limit |
| | | EG020A-F: Selenium | 7782-49-2 | 0.01 | mg/L | <0.01 | <0.01 | 0.00 | No Limit |
| | | EG020A-F: Iron | 7439-89-6 | 0.05 | mg/L | <0.05 | <0.05 | 0.00 | No Limit |
| EP1804752-005 | Anonymous | EG020A-F: Cadmium | 7440-43-9 | 0.0001 | mg/L | <0.0001 | <0.0001 | 0.00 | No Limit |
| | | EG020A-F: Arsenic | 7440-38-2 | 0.001 | mg/L | <0.001 | <0.001 | 0.00 | No Limit |
| | | EG020A-F: Chromium | 7440-47-3 | 0.001 | mg/L | <0.001 | <0.001 | 0.00 | No Limit |
| | | EG020A-F: Copper | 7440-50-8 | 0.001 | mg/L | 0.006 | 0.006 | 0.00 | No Limit |
| | | EG020A-F: Lead | 7439-92-1 | 0.001 | mg/L | <0.001 | <0.001 | 0.00 | No Limit |
| | | EG020A-F: Nickel | 7440-02-0 | 0.001 | mg/L | 0.002 | 0.002 | 0.00 | No Limit |
| | | EG020A-F: Zinc | 7440-66-6 | 0.005 | mg/L | 0.010 | 0.010 | 0.00 | No Limit |
| | | EG020A-F: Aluminium | 7429-90-5 | 0.01 | mg/L | 0.02 | 0.02 | 0.00 | No Limit |
| | | EG020A-F: Selenium | 7782-49-2 | 0.01 | mg/L | <0.01 | <0.01 | 0.00 | No Limit |
| | | EG020A-F: Iron | 7439-89-6 | 0.05 | mg/L | <0.05 | <0.05 | 0.00 | No Limit |
| **EG035F: Dissolved Mercury by FIMS (QC Lot: 1578635)** | | | | | | | | | |
| EP1804741-008 | Anonymous | EG035F: Mercury | 7439-97-6 | 0.0001 | mg/L | <0.0001 | <0.0001 | 0.00 | No Limit |
| EP1804748-006 | CARC027 | EG035F: Mercury | 7439-97-6 | 0.0001 | mg/L | <0.0001 | <0.0001 | 0.00 | No Limit |
| **EK040P: Fluoride by PC Titrator (QC Lot: 1576555)** | | | | | | | | | |
| EP1804690-009 | Anonymous | EK040P: Fluoride | 16984-48-8 | 0.1 | mg/L | 2.3 | 2.3 | 0.00 | No Limit |
| EP1804741-005 | Anonymous | EK040P: Fluoride | 16984-48-8 | 0.1 | mg/L | <0.1 | <0.1 | 0.00 | No Limit |
| **EK040P: Fluoride by PC Titrator (QC Lot: 1576566)** | | | | | | | | | |
| EP1804748-008 | LAKE | EK040P: Fluoride | 16984-48-8 | 0.1 | mg/L | 0.2 | 0.2 | 0.00 | No Limit |
| **EK055G: Ammonia as N by Discrete Analyser (QC Lot: 1567025)** | | | | | | | | | |
| EP1804745-002 | Anonymous | EK055G: Ammonia as N | 7664-41-7 | 0.01 | mg/L | 19.6 | 19.2 | 2.24 | 0% - 20% |

Sub-Matrix: **WATER**

| Laboratory sample ID | Client sample ID | Method: Compound | CAS Number | LOR | Unit | Original Result | Duplicate Result | RPD (%) | Recovery Limits (%) |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Laboratory Duplicate (DUP) Report | | | | | |
| **EK055G: Ammonia as N by Discrete Analyser (QC Lot: 1567025) - continued** | | | | | | | | | |
| EP1804748-006 | CARC027 | EK055G: Ammonia as N | 7664-41-7 | 0.01 | mg/L | 0.03 | 0.04 | 0.00 | No Limit |
| **EK057G: Nitrite as N by Discrete Analyser (QC Lot: 1566803)** | | | | | | | | | |
| EP1804748-007 | CARC028 | EK057G: Nitrite as N | 14797-65-0 | 0.01 | mg/L | <0.01 | <0.01 | 0.00 | No Limit |
| EP1804740-002 | Anonymous | EK057G: Nitrite as N | 14797-65-0 | 0.01 | mg/L | 0.16 | 0.16 | 0.00 | 0% - 50% |
| **EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser (QC Lot: 1567026)** | | | | | | | | | |
| EP1804745-002 | Anonymous | EK059G: Nitrite + Nitrate as N | ---- | 0.01 | mg/L | 24.6 | 25.2 | 2.84 | 0% - 20% |
| EP1804748-006 | CARC027 | EK059G: Nitrite + Nitrate as N | ---- | 0.01 | mg/L | 0.80 | 0.80 | 0.00 | 0% - 20% |
| **EK061G: Total Kjeldahl Nitrogen By Discrete Analyser (QC Lot: 1578735)** | | | | | | | | | |
| EP1804741-005 | Anonymous | EK061G: Total Kjeldahl Nitrogen as N | ---- | 0.1 | mg/L | 0.6 | 0.6 | 0.00 | No Limit |
| EP1804745-003 | Anonymous | EK061G: Total Kjeldahl Nitrogen as N | ---- | 0.1 | mg/L | 9.2 | 9.2 | 0.00 | 0% - 20% |
| **EK061G: Total Kjeldahl Nitrogen By Discrete Analyser (QC Lot: 1578737)** | | | | | | | | | |
| EP1804748-008 | LAKE | EK061G: Total Kjeldahl Nitrogen as N | ---- | 0.1 | mg/L | 3.9 | 4.0 | 2.84 | 0% - 20% |
| **EK067G: Total Phosphorus as P by Discrete Analyser (QC Lot: 1578734)** | | | | | | | | | |
| EP1804741-005 | Anonymous | EK067G: Total Phosphorus as P | ---- | 0.01 | mg/L | 0.03 | 0.02 | 51.1 | No Limit |
| EP1804745-003 | Anonymous | EK067G: Total Phosphorus as P | ---- | 0.01 | mg/L | 0.04 | 0.05 | 0.00 | No Limit |
| **EK067G: Total Phosphorus as P by Discrete Analyser (QC Lot: 1578736)** | | | | | | | | | |
| EP1804776-004 | Anonymous | EK067G: Total Phosphorus as P | ---- | 0.01 | mg/L | <0.01 | 0.02 | 0.00 | No Limit |
| EP1804748-008 | LAKE | EK067G: Total Phosphorus as P | ---- | 0.01 | mg/L | 0.13 | 0.12 | 0.00 | 0% - 50% |
| **EK071G: Reactive Phosphorus as P by discrete analyser (QC Lot: 1566802)** | | | | | | | | | |
| EP1804748-007 | CARC028 | EK071G: Reactive Phosphorus as P | 14265-44-2 | 0.01 | mg/L | 1.72 | 1.72 | 0.00 | 0% - 20% |
| EP1804740-002 | Anonymous | EK071G: Reactive Phosphorus as P | 14265-44-2 | 0.01 | mg/L | 0.31 | 0.31 | 0.00 | 0% - 20% |

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

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

Sub-Matrix: **WATER**

| | | | | Method Blank (MB) Report | Laboratory Control Spike (LCS) Report | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Spike | Spike Recovery (%) | Recovery Limits (%) | |
| Method: Compound | CAS Number | LOR | Unit | Result | Concentration | LCS | Low | High |
| **EA005P: pH by PC Titrator (QCLot: 1576562)** | | | | | | | | |
| EA005-P: pH Value | ---- | ---- | pH Unit | ---- | 4 pH Unit | 100 | 99 | 102 |
| | | | | ---- | 7 pH Unit | 99.8 | 99 | 102 |
| **EA005P: pH by PC Titrator (QCLot: 1576565)** | | | | | | | | |
| EA005-P: pH Value | ---- | ---- | pH Unit | ---- | 4 pH Unit | 100 | 99 | 102 |
| | | | | ---- | 7 pH Unit | 99.8 | 99 | 102 |
| **EA010P: Conductivity by PC Titrator (QCLot: 1576564)** | | | | | | | | |
| EA010-P: Electrical Conductivity @ 25°C | ---- | 1 | µS/cm | <1 | 24800 µS/cm | 95.3 | 95 | 105 |
| **ED037P: Alkalinity by PC Titrator (QCLot: 1576563)** | | | | | | | | |
| ED037-P: Hydroxide Alkalinity as CaCO3 | DMO-210-001 | 1 | mg/L | <1 | ---- | ---- | ---- | ---- |
| ED037-P: Carbonate Alkalinity as CaCO3 | 3812-32-6 | 1 | mg/L | <1 | ---- | ---- | ---- | ---- |
| ED037-P: Bicarbonate Alkalinity as CaCO3 | 71-52-3 | 1 | mg/L | <1 | ---- | ---- | ---- | ---- |
| ED037-P: Total Alkalinity as CaCO3 | ---- | 1 | mg/L | <1 | 20 mg/L | 102 | 76 | 126 |
| | | | | <1 | 200 mg/L | 96.4 | 90 | 106 |
| **ED041G: Sulfate (Turbidimetric) as SO4 2- by DA (QCLot: 1566804)** | | | | | | | | |
| ED041G: Sulfate as SO4 - Turbidimetric | 14808-79-8 | 1 | mg/L | <1 | 25 mg/L | 105 | 89 | 113 |
| | | | | <1 | 100 mg/L | 95.6 | 79 | 121 |
| **ED045G: Chloride by Discrete Analyser (QCLot: 1566805)** | | | | | | | | |
| ED045G: Chloride | 16887-00-6 | 1 | mg/L | <1 | 10 mg/L | 104 | 84 | 120 |
| | | | | <1 | 1000 mg/L | 98.8 | 84 | 110 |
| **ED093F: Dissolved Major Cations (QCLot: 1578634)** | | | | | | | | |
| ED093F: Calcium | 7440-70-2 | 1 | mg/L | <1 | 50 mg/L | 95.1 | 91 | 109 |
| ED093F: Magnesium | 7439-95-4 | 1 | mg/L | <1 | 50 mg/L | 95.3 | 90 | 108 |
| ED093F: Sodium | 7440-23-5 | 1 | mg/L | <1 | 50 mg/L | 105 | 87 | 111 |
| ED093F: Potassium | 7440-09-7 | 1 | mg/L | <1 | 50 mg/L | 94.5 | 90 | 110 |
| **EG020F: Dissolved Metals by ICP-MS (QCLot: 1578633)** | | | | | | | | |
| EG020A-F: Aluminium | 7429-90-5 | 0.01 | mg/L | <0.01 | 0.5 mg/L | 97.9 | 84 | 120 |
| EG020A-F: Arsenic | 7440-38-2 | 0.001 | mg/L | <0.001 | 0.1 mg/L | 97.3 | 84 | 120 |
| EG020A-F: Cadmium | 7440-43-9 | 0.0001 | mg/L | <0.0001 | 0.1 mg/L | 96.7 | 86 | 120 |
| EG020A-F: Chromium | 7440-47-3 | 0.001 | mg/L | <0.001 | 0.1 mg/L | 94.1 | 85 | 120 |
| EG020A-F: Copper | 7440-50-8 | 0.001 | mg/L | <0.001 | 0.1 mg/L | 91.7 | 84 | 120 |
| EG020A-F: Lead | 7439-92-1 | 0.001 | mg/L | <0.001 | 0.1 mg/L | 96.1 | 85 | 120 |
| EG020A-F: Nickel | 7440-02-0 | 0.001 | mg/L | <0.001 | 0.1 mg/L | 101 | 84 | 120 |
| EG020A-F: Selenium | 7782-49-2 | 0.01 | mg/L | <0.01 | 0.1 mg/L | 98.2 | 88 | 120 |

Sub-Matrix: **WATER**

| | | | | Method Blank (MB) Report | Laboratory Control Spike (LCS) Report | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Spike | Spike Recovery (%) | Recovery Limits (%) | |
| Method: Compound | CAS Number | LOR | Unit | Result | Concentration | LCS | Low | High |
| **EG020F: Dissolved Metals by ICP-MS (QCLot: 1578633) - continued** | | | | | | | | |
| EG020A-F: Zinc | 7440-66-6 | 0.005 | mg/L | <0.005 | 0.1 mg/L | 101 | 89 | 120 |
| EG020A-F: Iron | 7439-89-6 | 0.05 | mg/L | <0.05 | 0.5 mg/L | 114 | 84 | 120 |
| **EG035F: Dissolved Mercury by FIMS (QCLot: 1578635)** | | | | | | | | |
| EG035F: Mercury | 7439-97-6 | 0.0001 | mg/L | <0.0001 | 0.01 mg/L | 102 | 92 | 116 |
| **EK040P: Fluoride by PC Titrator (QCLot: 1576555)** | | | | | | | | |
| EK040P: Fluoride | 16984-48-8 | 0.1 | mg/L | <0.1 | 5 mg/L | 102 | 86 | 116 |
| **EK040P: Fluoride by PC Titrator (QCLot: 1576566)** | | | | | | | | |
| EK040P: Fluoride | 16984-48-8 | 0.1 | mg/L | <0.1 | 5 mg/L | 104 | 86 | 116 |
| **EK055G: Ammonia as N by Discrete Analyser (QCLot: 1567025)** | | | | | | | | |
| EK055G: Ammonia as N | 7664-41-7 | 0.01 | mg/L | <0.01 | 1 mg/L | 99.6 | 87 | 115 |
| **EK057G: Nitrite as N by Discrete Analyser (QCLot: 1566803)** | | | | | | | | |
| EK057G: Nitrite as N | 14797-65-0 | 0.01 | mg/L | <0.01 | 0.5 mg/L | 101 | 86 | 112 |
| **EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser (QCLot: 1567026)** | | | | | | | | |
| EK059G: Nitrite + Nitrate as N | ---- | 0.01 | mg/L | <0.01 | 0.5 mg/L | 101 | 92 | 112 |
| **EK061G: Total Kjeldahl Nitrogen By Discrete Analyser (QCLot: 1578735)** | | | | | | | | |
| EK061G: Total Kjeldahl Nitrogen as N | ---- | 0.1 | mg/L | <0.1 | 10 mg/L | 95.3 | 82 | 110 |
| **EK061G: Total Kjeldahl Nitrogen By Discrete Analyser (QCLot: 1578737)** | | | | | | | | |
| EK061G: Total Kjeldahl Nitrogen as N | ---- | 0.1 | mg/L | <0.1 | 10 mg/L | 89.0 | 82 | 110 |
| **EK067G: Total Phosphorus as P by Discrete Analyser (QCLot: 1578734)** | | | | | | | | |
| EK067G: Total Phosphorus as P | ---- | 0.01 | mg/L | <0.01 | 4.42 mg/L | 92.2 | 70 | 130 |
| **EK067G: Total Phosphorus as P by Discrete Analyser (QCLot: 1578736)** | | | | | | | | |
| EK067G: Total Phosphorus as P | ---- | 0.01 | mg/L | <0.01 | 4.42 mg/L | 92.6 | 70 | 130 |
| **EK071G: Reactive Phosphorus as P by discrete analyser (QCLot: 1566802)** | | | | | | | | |
| EK071G: Reactive Phosphorus as P | 14265-44-2 | 0.01 | mg/L | <0.01 | 0.5 mg/L | 104 | 87 | 115 |

## *Matrix Spike (MS) Report*

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

Sub-Matrix: **WATER**

| | | | | Matrix Spike (MS) Report | | | |
|---|---|---|---|---|---|---|---|
| | | | | Spike | SpikeRecovery(%) | Recovery Limits (%) | |
| Laboratory sample ID | Client sample ID | Method: Compound | CAS Number | Concentration | MS | Low | High |
| **ED041G: Sulfate (Turbidimetric) as SO4 2- by DA (QCLot: 1566804)** | | | | | | | |
| EP1804740-001 | Anonymous | ED041G: Sulfate as SO4 - Turbidimetric | 14808-79-8 | 100 mg/L | 70.5 | 70 | 130 |
| **ED045G: Chloride by Discrete Analyser (QCLot: 1566805)** | | | | | | | |
| EP1804740-001 | Anonymous | ED045G: Chloride | 16887-00-6 | 1000 mg/L | 92.8 | 70 | 130 |

Sub-Matrix: **WATER**

| Laboratory sample ID | Client sample ID | Method: Compound | CAS Number | Matrix Spike (MS) Report | | | |
|---|---|---|---|---|---|---|---|
| | | | | Spike | SpikeRecovery(%) | Recovery Limits (%) | |
| | | | | Concentration | MS | Low | High |
| **EG020F: Dissolved Metals by ICP-MS (QCLot: 1578633)** | | | | | | | |
| EP1804741-003 | Anonymous | EG020A-F: Arsenic | 7440-38-2 | 0.2 mg/L | 100 | 70 | 130 |
| | | EG020A-F: Cadmium | 7440-43-9 | 0.05 mg/L | 98.1 | 70 | 130 |
| | | EG020A-F: Chromium | 7440-47-3 | 0.2 mg/L | 97.6 | 70 | 130 |
| | | EG020A-F: Copper | 7440-50-8 | 0.2 mg/L | 94.8 | 70 | 130 |
| | | EG020A-F: Lead | 7439-92-1 | 0.2 mg/L | 95.0 | 70 | 130 |
| | | EG020A-F: Nickel | 7440-02-0 | 0.2 mg/L | 103 | 70 | 130 |
| | | EG020A-F: Zinc | 7440-66-6 | 0.2 mg/L | 101 | 70 | 130 |
| **EG035F: Dissolved Mercury by FIMS (QCLot: 1578635)** | | | | | | | |
| EP1804741-009 | Anonymous | EG035F: Mercury | 7439-97-6 | 0.01 mg/L | 88.3 | 70 | 130 |
| **EK040P: Fluoride by PC Titrator (QCLot: 1576555)** | | | | | | | |
| EP1804690-007 | Anonymous | EK040P: Fluoride | 16984-48-8 | 49 mg/L | 84.9 | 70 | 130 |
| **EK040P: Fluoride by PC Titrator (QCLot: 1576566)** | | | | | | | |
| EP1804779-001 | Anonymous | EK040P: Fluoride | 16984-48-8 | 4.9 mg/L | 121 | 70 | 130 |
| **EK055G: Ammonia as N by Discrete Analyser (QCLot: 1567025)** | | | | | | | |
| EP1804745-001 | Anonymous | EK055G: Ammonia as N | 7664-41-7 | 1 mg/L | # Not Determined | 70 | 130 |
| **EK057G: Nitrite as N by Discrete Analyser (QCLot: 1566803)** | | | | | | | |
| EP1804740-001 | Anonymous | EK057G: Nitrite as N | 14797-65-0 | 0.5 mg/L | 106 | 70 | 130 |
| **EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser (QCLot: 1567026)** | | | | | | | |
| EP1804745-001 | Anonymous | EK059G: Nitrite + Nitrate as N | ---- | 0.5 mg/L | # Not Determined | 70 | 130 |
| **EK061G: Total Kjeldahl Nitrogen By Discrete Analyser (QCLot: 1578735)** | | | | | | | |
| EP1804741-006 | Anonymous | EK061G: Total Kjeldahl Nitrogen as N | ---- | 5 mg/L | 99.8 | 70 | 130 |
| **EK061G: Total Kjeldahl Nitrogen By Discrete Analyser (QCLot: 1578737)** | | | | | | | |
| EP1804748-008 | LAKE | EK061G: Total Kjeldahl Nitrogen as N | ---- | 5 mg/L | 101 | 70 | 130 |
| **EK067G: Total Phosphorus as P by Discrete Analyser (QCLot: 1578734)** | | | | | | | |
| EP1804741-006 | Anonymous | EK067G: Total Phosphorus as P | ---- | 1 mg/L | 98.3 | 70 | 130 |
| **EK067G: Total Phosphorus as P by Discrete Analyser (QCLot: 1578736)** | | | | | | | |
| EP1804748-008 | LAKE | EK067G: Total Phosphorus as P | ---- | 1 mg/L | 101 | 70 | 130 |
| **EK071G: Reactive Phosphorus as P by discrete analyser (QCLot: 1566802)** | | | | | | | |
| EP1804740-001 | Anonymous | EK071G: Reactive Phosphorus as P | 14265-44-2 | 0.5 mg/L | 113 | 70 | 130 |

# QA/QC Compliance Assessment to assist with Quality Review

| | | | |
|---|---|---|---|
| **Work Order** | : **EP1804748** | Page | : 1 of 9 |
| Client | : **PENDRAGON ENVIRONMENTAL SOLUTIONS** | Laboratory | : Environmental Division Perth |
| Contact | : MR CAREL VAN DER WESTHUIZEN | Telephone | : +61-8-9406 1301 |
| Project | : PES18011 | Date Samples Received | : 13-Apr-2018 |
| Site | : Calingiri | Issue Date | : 23-Apr-2018 |
| Sampler | : ---- | No. of samples received | : 8 |
| Order number | : | No. of samples analysed | : 8 |

**This report is automatically generated by the ALS LIMS through interpretation of the ALS Quality Control Report and several Quality Assurance parameters measured by ALS. This automated reporting highlights any non-conformances, facilitates faster and more accurate data validation and is designed to assist internal expert and external Auditor review. Many components of this report contribute to the overall DQO assessment and reporting for guideline compliance.**

Brief method summaries and references are also provided to assist in traceability.

## *Summary of Outliers*

### *Outliers : Quality Control Samples*

This report highlights outliers flagged in the Quality Control (QC) Report.

- **NO Method Blank value outliers occur.**
- **NO Duplicate outliers occur.**
- **NO Laboratory Control outliers occur.**
- **Matrix Spike outliers exist - please see following pages for full details.**
- **For all regular sample matrices, NO surrogate recovery outliers occur.**

### *Outliers : Analysis Holding Time Compliance*

- **Analysis Holding Time Outliers exist - please see following pages for full details.**

### *Outliers : Frequency of Quality Control Samples*

- **NO Quality Control Sample Frequency Outliers exist.**

## *Outliers : Quality Control Samples*

*Duplicates, Method Blanks, Laboratory Control Samples and Matrix Spikes*

Matrix: **WATER**

| Compound Group Name | Laboratory Sample ID | Client Sample ID | Analyte | CAS Number | Data | Limits | Comment |
|---|---|---|---|---|---|---|---|
| **Matrix Spike (MS) Recoveries** | | | | | | | |
| EK055G: Ammonia as N by Discrete Analyser | EP1804745--001 | Anonymous | **Ammonia as N** | 7664-41-7 | Not Determined | ---- | **MS recovery not determined, background level greater than or equal to 4x spike level.** |
| EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Ar | EP1804745--001 | Anonymous | **Nitrite + Nitrate as N** | ---- | Not Determined | ---- | **MS recovery not determined, background level greater than or equal to 4x spike level.** |

## *Outliers : Analysis Holding Time Compliance*

Matrix: **WATER**

| *Method* | | Extraction / Preparation | | | Analysis | | |
|---|---|---|---|---|---|---|---|
| **Container** / Client Sample ID(s) | | Date extracted | Due for extraction | *Days overdue* | Date analysed | Due for analysis | *Days overdue* |
| **EA005P: pH by PC Titrator** | | | | | | | |
| **Clear Plastic Bottle - Natural** | | | | | | | |
| CAWB001, | CAWB002, | ---- | ---- | ---- | 18-Apr-2018 | 11-Apr-2018 | **7** |
| CAWB003, | CAWB005, | | | | | | |
| CAWB006, | CARC027, | | | | | | |
| CARC028, | LAKE | | | | | | |

# *Analysis Holding Time Compliance*

If samples are identified below as having been analysed or extracted outside of recommended holding times, this should be taken into consideration when interpreting results.

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

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

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

Matrix: **WATER**

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

| *Method* | | Sample Date | Extraction / Preparation | | | Analysis | | |
|---|---|---|---|---|---|---|---|---|
| *Container / Client Sample ID(s)* | | | Date extracted | Due for extraction | Evaluation | Date analysed | Due for analysis | Evaluation |
| **EA005P: pH by PC Titrator** | | | | | | | | |
| **Clear Plastic Bottle - Natural (EA005-P)** | | | | | | | | |
| CAWB001, | CAWB002, | **11-Apr-2018** | **----** | ---- | ---- | **18-Apr-2018** | 11-Apr-2018 | ✘ |
| CAWB003, | CAWB005, | | | | | | | |
| CAWB006, | CARC027, | | | | | | | |
| CARC028, | LAKE | | | | | | | |

Matrix: **WATER**

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

| Method / Container / Client Sample ID(s) | | Sample Date | Extraction / Preparation: Date extracted | Due for extraction | Evaluation | Analysis: Date analysed | Due for analysis | Evaluation |
|---|---|---|---|---|---|---|---|---|
| **EA006: Sodium Adsorption Ratio (SAR)** | | | | | | | | |
| **Clear HDPE (U-T ORC) - Filtered; Lab-acidified (ED093F)** | | | | | | | | |
| CAWB001, | CAWB002, | **11-Apr-2018** | **----** | ---- | ---- | **19-Apr-2018** | 09-May-2018 | ✓ |
| CAWB003, | CAWB005, | | | | | | | |
| CAWB006, | CARC027, | | | | | | | |
| CARC028, | LAKE | | | | | | | |
| **EA010P: Conductivity by PC Titrator** | | | | | | | | |
| **Clear Plastic Bottle - Natural (EA010-P)** | | | | | | | | |
| CAWB001, | CAWB002, | **11-Apr-2018** | **----** | ---- | ---- | **18-Apr-2018** | 09-May-2018 | ✓ |
| CAWB003, | CAWB005, | | | | | | | |
| CAWB006, | CARC027, | | | | | | | |
| CARC028, | LAKE | | | | | | | |
| **EA065: Total Hardness as CaCO3** | | | | | | | | |
| **Clear HDPE (U-T ORC) - Filtered; Lab-acidified (ED093F)** | | | | | | | | |
| CAWB001, | CAWB002, | **11-Apr-2018** | **----** | ---- | ---- | **19-Apr-2018** | 09-May-2018 | ✓ |
| CAWB003, | CAWB005, | | | | | | | |
| CAWB006, | CARC027, | | | | | | | |
| CARC028, | LAKE | | | | | | | |
| **ED037P: Alkalinity by PC Titrator** | | | | | | | | |
| **Clear Plastic Bottle - Natural (ED037-P)** | | | | | | | | |
| CAWB001, | CAWB002, | **11-Apr-2018** | **----** | ---- | ---- | **18-Apr-2018** | 25-Apr-2018 | ✓ |
| CAWB003, | CAWB005, | | | | | | | |
| CAWB006, | CARC027, | | | | | | | |
| CARC028, | LAKE | | | | | | | |
| **ED041G: Sulfate (Turbidimetric) as SO4 2- by DA** | | | | | | | | |
| **Clear Plastic Bottle - Natural (ED041G)** | | | | | | | | |
| CAWB001, | CAWB002, | **11-Apr-2018** | **----** | ---- | ---- | **13-Apr-2018** | 09-May-2018 | ✓ |
| CAWB003, | CAWB005, | | | | | | | |
| CAWB006, | CARC027, | | | | | | | |
| CARC028, | LAKE | | | | | | | |
| **ED045G: Chloride by Discrete Analyser** | | | | | | | | |
| **Clear Plastic Bottle - Natural (ED045G)** | | | | | | | | |
| CAWB001, | CAWB002, | **11-Apr-2018** | **----** | ---- | ---- | **13-Apr-2018** | 09-May-2018 | ✓ |
| CAWB003, | CAWB005, | | | | | | | |
| CAWB006, | CARC027, | | | | | | | |
| CARC028, | LAKE | | | | | | | |
| **ED093F: Dissolved Major Cations** | | | | | | | | |
| **Clear HDPE (U-T ORC) - Filtered; Lab-acidified (ED093F)** | | | | | | | | |
| CAWB001, | CAWB002, | **11-Apr-2018** | **----** | ---- | ---- | **19-Apr-2018** | 09-May-2018 | ✓ |
| CAWB003, | CAWB005, | | | | | | | |
| CAWB006, | CARC027, | | | | | | | |
| CARC028, | LAKE | | | | | | | |

Work Order : EP1804748

Client : PENDRAGON ENVIRONMENTAL SOLUTIONS

Project : PES18011

Matrix: **WATER**

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

| Method / Container / Client Sample ID(s) | | Sample Date | Extraction / Preparation | | | Analysis | | |
|---|---|---|---|---|---|---|---|---|
| | | | Date extracted | Due for extraction | Evaluation | Date analysed | Due for analysis | Evaluation |
| **EG020F: Dissolved Metals by ICP-MS** | | | | | | | | |
| **Clear HDPE (U-T ORC) - Filtered; Lab-acidified (EG020A-F)** | | | | | | | | |
| CAWB001, | CAWB002, | **11-Apr-2018** | **----** | ---- | ---- | **19-Apr-2018** | 08-Oct-2018 | ✓ |
| CAWB003, | CAWB005, | | | | | | | |
| CAWB006, | CARC027, | | | | | | | |
| CARC028, | LAKE | | | | | | | |
| **EG035F: Dissolved Mercury by FIMS** | | | | | | | | |
| **Clear HDPE (U-T ORC) - Filtered; Lab-acidified (EG035F)** | | | | | | | | |
| CAWB001, | CAWB002, | **11-Apr-2018** | **----** | ---- | ---- | **19-Apr-2018** | 09-May-2018 | ✓ |
| CAWB003, | CAWB005, | | | | | | | |
| CAWB006, | CARC027, | | | | | | | |
| CARC028, | LAKE | | | | | | | |
| **EK040P: Fluoride by PC Titrator** | | | | | | | | |
| **Clear Plastic Bottle - Natural (EK040P)** | | | | | | | | |
| CAWB001, | CAWB002, | **11-Apr-2018** | **----** | ---- | ---- | **18-Apr-2018** | 09-May-2018 | ✓ |
| CAWB003, | CAWB005, | | | | | | | |
| CAWB006, | CARC027, | | | | | | | |
| CARC028, | LAKE | | | | | | | |
| **EK055G: Ammonia as N by Discrete Analyser** | | | | | | | | |
| **Clear Plastic Bottle - Sulfuric Acid (EK055G)** | | | | | | | | |
| CAWB001, | CAWB002, | **11-Apr-2018** | **----** | ---- | ---- | **13-Apr-2018** | 09-May-2018 | ✓ |
| CAWB003, | CAWB005, | | | | | | | |
| CAWB006, | CARC027, | | | | | | | |
| CARC028, | LAKE | | | | | | | |
| **EK057G: Nitrite as N by Discrete Analyser** | | | | | | | | |
| **Clear Plastic Bottle - Natural (EK057G)** | | | | | | | | |
| CAWB001, | CAWB002, | **11-Apr-2018** | **----** | ---- | ---- | **13-Apr-2018** | 13-Apr-2018 | ✓ |
| CAWB003, | CAWB005, | | | | | | | |
| CAWB006, | CARC027, | | | | | | | |
| CARC028, | LAKE | | | | | | | |
| **EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser** | | | | | | | | |
| **Clear Plastic Bottle - Sulfuric Acid (EK059G)** | | | | | | | | |
| CAWB001, | CAWB002, | **11-Apr-2018** | **----** | ---- | ---- | **13-Apr-2018** | 09-May-2018 | ✓ |
| CAWB003, | CAWB005, | | | | | | | |
| CAWB006, | CARC027, | | | | | | | |
| CARC028, | LAKE | | | | | | | |
| **EK061G: Total Kjeldahl Nitrogen By Discrete Analyser** | | | | | | | | |
| **Clear Plastic Bottle - Sulfuric Acid (EK061G)** | | | | | | | | |
| CAWB001, | CAWB002, | **11-Apr-2018** | **19-Apr-2018** | 09-May-2018 | ✓ | **19-Apr-2018** | 09-May-2018 | ✓ |
| CAWB003, | CAWB005, | | | | | | | |
| CAWB006, | CARC027, | | | | | | | |
| CARC028, | LAKE | | | | | | | |

Matrix: **WATER**

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

| Method / Container / Client Sample ID(s) | | Sample Date | Extraction / Preparation | | | Analysis | | |
|---|---|---|---|---|---|---|---|---|
| | | | Date extracted | Due for extraction | Evaluation | Date analysed | Due for analysis | Evaluation |
| **EK067G: Total Phosphorus as P by Discrete Analyser** | | | | | | | | |
| **Clear Plastic Bottle - Sulfuric Acid (EK067G)** | | | | | | | | |
| CAWB001, | CAWB002, | **11-Apr-2018** | **19-Apr-2018** | 09-May-2018 | ✓ | **19-Apr-2018** | 09-May-2018 | ✓ |
| CAWB003, | CAWB005, | | | | | | | |
| CAWB006, | CARC027, | | | | | | | |
| CARC028, | LAKE | | | | | | | |
| **EK071G: Reactive Phosphorus as P by discrete analyser** | | | | | | | | |
| **Clear Plastic Bottle - Natural (EK071G)** | | | | | | | | |
| CAWB001, | CAWB002, | **11-Apr-2018** | **----** | ---- | ---- | **13-Apr-2018** | 13-Apr-2018 | ✓ |
| CAWB003, | CAWB005, | | | | | | | |
| CAWB006, | CARC027, | | | | | | | |
| CARC028, | LAKE | | | | | | | |

## Quality Control Parameter Frequency Compliance

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

Matrix: **WATER**

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

| Quality Control Sample Type / *Analytical Methods* | *Method* | Count *QC* | Count *Regular* | Rate (%) ***Actual*** | Rate (%) ***Expected*** | *Evaluation* | *Quality Control Specification* |
|---|---|---|---|---|---|---|---|
| **Laboratory Duplicates (DUP)** | | | | | | | |
| Alkalinity by PC Titrator | ED037-P | 2 | 20 | **10.00** | **10.00** | ✓ | NEPM 2013 B3 & ALS QC Standard |
| Ammonia as N by Discrete analyser | EK055G | 2 | 20 | **10.00** | **10.00** | ✓ | NEPM 2013 B3 & ALS QC Standard |
| Chloride by Discrete Analyser | ED045G | 2 | 17 | **11.76** | **10.00** | ✓ | NEPM 2013 B3 & ALS QC Standard |
| Conductivity by PC Titrator | EA010-P | 2 | 20 | **10.00** | **10.00** | ✓ | NEPM 2013 B3 & ALS QC Standard |
| Dissolved Mercury by FIMS | EG035F | 2 | 13 | **15.38** | **10.00** | ✓ | NEPM 2013 B3 & ALS QC Standard |
| Dissolved Metals by ICP-MS - Suite A | EG020A-F | 2 | 20 | **10.00** | **10.00** | ✓ | NEPM 2013 B3 & ALS QC Standard |
| Fluoride by PC Titrator | EK040P | 3 | 24 | **12.50** | **10.00** | ✓ | NEPM 2013 B3 & ALS QC Standard |
| Major Cations - Dissolved | ED093F | 2 | 15 | **13.33** | **10.00** | ✓ | NEPM 2013 B3 & ALS QC Standard |
| Nitrite and Nitrate as N (NOx) by Discrete Analyser | EK059G | 2 | 20 | **10.00** | **10.00** | ✓ | NEPM 2013 B3 & ALS QC Standard |
| Nitrite as N by Discrete Analyser | EK057G | 2 | 15 | **13.33** | **10.00** | ✓ | NEPM 2013 B3 & ALS QC Standard |
| pH by PC Titrator | EA005-P | 4 | 37 | **10.81** | **10.00** | ✓ | NEPM 2013 B3 & ALS QC Standard |
| Reactive Phosphorus as P-By Discrete Analyser | EK071G | 2 | 12 | **16.67** | **10.00** | ✓ | NEPM 2013 B3 & ALS QC Standard |
| Sulfate (Turbidimetric) as SO4 2- by Discrete Analyser | ED041G | 2 | 17 | **11.76** | **10.00** | ✓ | NEPM 2013 B3 & ALS QC Standard |
| Total Kjeldahl Nitrogen as N By Discrete Analyser | EK061G | 3 | 28 | **10.71** | **10.00** | ✓ | NEPM 2013 B3 & ALS QC Standard |
| Total Phosphorus as P By Discrete Analyser | EK067G | 4 | 33 | **12.12** | **10.00** | ✓ | NEPM 2013 B3 & ALS QC Standard |
| **Laboratory Control Samples (LCS)** | | | | | | | |
| Alkalinity by PC Titrator | ED037-P | 2 | 20 | **10.00** | **10.00** | ✓ | NEPM 2013 B3 & ALS QC Standard |
| Ammonia as N by Discrete analyser | EK055G | 1 | 20 | **5.00** | **5.00** | ✓ | NEPM 2013 B3 & ALS QC Standard |
| Chloride by Discrete Analyser | ED045G | 2 | 17 | **11.76** | **10.00** | ✓ | NEPM 2013 B3 & ALS QC Standard |
| Conductivity by PC Titrator | EA010-P | 1 | 20 | **5.00** | **5.00** | ✓ | NEPM 2013 B3 & ALS QC Standard |
| Dissolved Mercury by FIMS | EG035F | 1 | 13 | **7.69** | **5.00** | ✓ | NEPM 2013 B3 & ALS QC Standard |
| Dissolved Metals by ICP-MS - Suite A | EG020A-F | 1 | 20 | **5.00** | **5.00** | ✓ | NEPM 2013 B3 & ALS QC Standard |
| Fluoride by PC Titrator | EK040P | 2 | 24 | **8.33** | **5.00** | ✓ | NEPM 2013 B3 & ALS QC Standard |
| Major Cations - Dissolved | ED093F | 1 | 15 | **6.67** | **5.00** | ✓ | NEPM 2013 B3 & ALS QC Standard |
| Nitrite and Nitrate as N (NOx) by Discrete Analyser | EK059G | 1 | 20 | **5.00** | **5.00** | ✓ | NEPM 2013 B3 & ALS QC Standard |
| Nitrite as N by Discrete Analyser | EK057G | 1 | 15 | **6.67** | **5.00** | ✓ | NEPM 2013 B3 & ALS QC Standard |
| pH by PC Titrator | EA005-P | 4 | 37 | **10.81** | **10.00** | ✓ | NEPM 2013 B3 & ALS QC Standard |
| Reactive Phosphorus as P-By Discrete Analyser | EK071G | 1 | 12 | **8.33** | **5.00** | ✓ | NEPM 2013 B3 & ALS QC Standard |
| Sulfate (Turbidimetric) as SO4 2- by Discrete Analyser | ED041G | 2 | 17 | **11.76** | **10.00** | ✓ | NEPM 2013 B3 & ALS QC Standard |
| Total Kjeldahl Nitrogen as N By Discrete Analyser | EK061G | 2 | 28 | **7.14** | **5.00** | ✓ | NEPM 2013 B3 & ALS QC Standard |
| Total Phosphorus as P By Discrete Analyser | EK067G | 2 | 33 | **6.06** | **5.00** | ✓ | NEPM 2013 B3 & ALS QC Standard |
| **Method Blanks (MB)** | | | | | | | |
| Alkalinity by PC Titrator | ED037-P | 1 | 20 | **5.00** | **5.00** | ✓ | NEPM 2013 B3 & ALS QC Standard |
| Ammonia as N by Discrete analyser | EK055G | 1 | 20 | **5.00** | **5.00** | ✓ | NEPM 2013 B3 & ALS QC Standard |
| Chloride by Discrete Analyser | ED045G | 1 | 17 | **5.88** | **5.00** | ✓ | NEPM 2013 B3 & ALS QC Standard |
| Conductivity by PC Titrator | EA010-P | 1 | 20 | **5.00** | **5.00** | ✓ | NEPM 2013 B3 & ALS QC Standard |

Matrix: **WATER**

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

| Quality Control Sample Type | | Count | | Rate (%) | | | Quality Control Specification |
|---|---|---|---|---|---|---|---|
| *Analytical Methods* | *Method* | *QC* | *Regular* | ***Actual*** | ***Expected*** | *Evaluation* | |
| **Method Blanks (MB) - Continued** | | | | | | | |
| Dissolved Mercury by FIMS | EG035F | 1 | 13 | **7.69** | **5.00** | ✓ | NEPM 2013 B3 & ALS QC Standard |
| Dissolved Metals by ICP-MS - Suite A | EG020A-F | 1 | 20 | **5.00** | **5.00** | ✓ | NEPM 2013 B3 & ALS QC Standard |
| Fluoride by PC Titrator | EK040P | 2 | 24 | **8.33** | **5.00** | ✓ | NEPM 2013 B3 & ALS QC Standard |
| Major Cations - Dissolved | ED093F | 1 | 15 | **6.67** | **5.00** | ✓ | NEPM 2013 B3 & ALS QC Standard |
| Nitrite and Nitrate as N (NOx) by Discrete Analyser | EK059G | 1 | 20 | **5.00** | **5.00** | ✓ | NEPM 2013 B3 & ALS QC Standard |
| Nitrite as N by Discrete Analyser | EK057G | 1 | 15 | **6.67** | **5.00** | ✓ | NEPM 2013 B3 & ALS QC Standard |
| Reactive Phosphorus as P-By Discrete Analyser | EK071G | 1 | 12 | **8.33** | **5.00** | ✓ | NEPM 2013 B3 & ALS QC Standard |
| Sulfate (Turbidimetric) as SO4 2- by Discrete Analyser | ED041G | 1 | 17 | **5.88** | **5.00** | ✓ | NEPM 2013 B3 & ALS QC Standard |
| Total Kjeldahl Nitrogen as N By Discrete Analyser | EK061G | 2 | 28 | **7.14** | **5.00** | ✓ | NEPM 2013 B3 & ALS QC Standard |
| Total Phosphorus as P By Discrete Analyser | EK067G | 2 | 33 | **6.06** | **5.00** | ✓ | NEPM 2013 B3 & ALS QC Standard |
| **Matrix Spikes (MS)** | | | | | | | |
| Ammonia as N by Discrete analyser | EK055G | 1 | 20 | **5.00** | **5.00** | ✓ | NEPM 2013 B3 & ALS QC Standard |
| Chloride by Discrete Analyser | ED045G | 1 | 17 | **5.88** | **5.00** | ✓ | NEPM 2013 B3 & ALS QC Standard |
| Dissolved Mercury by FIMS | EG035F | 1 | 13 | **7.69** | **5.00** | ✓ | NEPM 2013 B3 & ALS QC Standard |
| Dissolved Metals by ICP-MS - Suite A | EG020A-F | 1 | 20 | **5.00** | **5.00** | ✓ | NEPM 2013 B3 & ALS QC Standard |
| Fluoride by PC Titrator | EK040P | 2 | 24 | **8.33** | **5.00** | ✓ | NEPM 2013 B3 & ALS QC Standard |
| Nitrite and Nitrate as N (NOx) by Discrete Analyser | EK059G | 1 | 20 | **5.00** | **5.00** | ✓ | NEPM 2013 B3 & ALS QC Standard |
| Nitrite as N by Discrete Analyser | EK057G | 1 | 15 | **6.67** | **5.00** | ✓ | NEPM 2013 B3 & ALS QC Standard |
| Reactive Phosphorus as P-By Discrete Analyser | EK071G | 1 | 12 | **8.33** | **5.00** | ✓ | NEPM 2013 B3 & ALS QC Standard |
| Sulfate (Turbidimetric) as SO4 2- by Discrete Analyser | ED041G | 1 | 17 | **5.88** | **5.00** | ✓ | NEPM 2013 B3 & ALS QC Standard |
| Total Kjeldahl Nitrogen as N By Discrete Analyser | EK061G | 2 | 28 | **7.14** | **5.00** | ✓ | NEPM 2013 B3 & ALS QC Standard |
| Total Phosphorus as P By Discrete Analyser | EK067G | 2 | 33 | **6.06** | **5.00** | ✓ | NEPM 2013 B3 & ALS QC Standard |

## Brief Method Summaries

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

| *Analytical Methods* | *Method* | *Matrix* | *Method Descriptions* |
|---|---|---|---|
| pH by PC Titrator | EA005-P | WATER | In house: Referenced to APHA 4500 H+ B. This procedure determines pH of water samples by automated ISE. This method is compliant with NEPM (2013) Schedule B(3) |
| Conductivity by PC Titrator | EA010-P | WATER | In house: Referenced to APHA 2510 B. This procedure determines conductivity by automated ISE. This method is compliant with NEPM (2013) Schedule B(3) |
| Calculated TDS (from Electrical Conductivity) | EA016 | WATER | In house: Calculation from Electrical Conductivity (APHA 2510 B) using a conversion factor specified in the analytical report. This method is compliant with NEPM (2013) Schedule B(3) |
| Alkalinity by PC Titrator | ED037-P | WATER | In house: Referenced to APHA 2320 B This procedure determines alkalinity by automated measurement (e.g. PC Titrate) using pH 4.5 for indicating the total alkalinity end-point. This method is compliant with NEPM (2013) Schedule B(3) |
| Sulfate (Turbidimetric) as SO4 2- by Discrete Analyser | ED041G | WATER | In house: Referenced to APHA 4500-SO4. Dissolved sulfate is determined in a 0.45um filtered sample. Sulfate ions are converted to a barium sulfate suspension in an acetic acid medium with barium chloride. Light absorbance of the BaSO4 suspension is measured by a photometer and the SO4-2 concentration is determined by comparison of the reading with a standard curve. This method is compliant with NEPM (2013) Schedule B(3) |
| Chloride by Discrete Analyser | ED045G | WATER | In house: Referenced to APHA 4500 Cl - G.The thiocyanate ion is liberated from mercuric thiocyanate through sequestration of mercury by the chloride ion to form non-ionised mercuric chloride.in the presence of ferric ions the librated thiocynate forms highly-coloured ferric thiocynate which is measured at 480 nm APHA 21st edition seal method 2 017-1-L april 2003 |
| Major Cations - Dissolved | ED093F | WATER | In house: Referenced to APHA 3120 and 3125; USEPA SW 846 - 6010 and 6020; Cations are determined by either ICP-AES or ICP-MS techniques. This method is compliant with NEPM (2013) Schedule B(3)<br><br>Sodium Adsorption Ratio is calculated from Ca, Mg and Na which determined by ALS in house method QWI-EN/ED093F. This method is compliant with NEPM (2013) Schedule B(3)<br><br>Hardness parameters are calculated based on APHA 2340 B. This method is compliant with NEPM (2013) Schedule B(3) |
| Dissolved Metals by ICP-MS - Suite A | EG020A-F | WATER | In house: Referenced to APHA 3125; USEPA SW846 - 6020, ALS QWI-EN/EG020. Samples are 0.45µm filtered prior to analysis. The ICPMS technique utilizes a highly efficient argon plasma to ionize selected elements. Ions are then passed into a high vacuum mass spectrometer, which separates the analytes based on their distinct mass to charge ratios prior to their measurement by a discrete dynode ion detector. |
| Dissolved Mercury by FIMS | EG035F | WATER | In house: Referenced to AS 3550, APHA 3112 Hg - B (Flow-injection (SnCl2)(Cold Vapour generation) AAS) Samples are 0.45µm filtered prior to analysis. FIM-AAS is an automated flameless atomic absorption technique. A bromate/bromide reagent is used to oxidise any organic mercury compounds in the filtered sample. The ionic mercury is reduced online to atomic mercury vapour by SnCl2 which is then purged into a heated quartz cell. Quantification is by comparing absorbance against a calibration curve. This method is compliant with NEPM (2013) Schedule B(3) |

| *Analytical Methods* | *Method* | *Matrix* | *Method Descriptions* |
|---|---|---|---|
| Fluoride by PC Titrator | EK040P | WATER | In house: Referenced to APHA 4500-F C: CDTA is added to the sample to provide a uniform ionic strength background, adjust pH, and break up complexes. Fluoride concentration is determined by either manual or automatic ISE measurement. This method is compliant with NEPM (2013) Schedule B(3) |
| Ammonia as N by Discrete analyser | EK055G | WATER | In house: Referenced to APHA 4500-NH3 G Ammonia is determined by direct colorimetry by Discrete Analyser. This method is compliant with NEPM (2013) Schedule B(3) |
| Nitrite as N by Discrete Analyser | EK057G | WATER | In house: Referenced to APHA 4500-NO2- B. Nitrite is determined by direct colourimetry by Discrete Analyser. This method is compliant with NEPM (2013) Schedule B(3) |
| Nitrate as N by Discrete Analyser | EK058G | WATER | In house: Referenced to APHA 4500-NO3- F. Nitrate is reduced to nitrite by way of a chemical reduction followed by quantification by Discrete Analyser. Nitrite is determined seperately by direct colourimetry and result for Nitrate calculated as the difference between the two results. This method is compliant with NEPM (2013) Schedule B(3) |
| Nitrite and Nitrate as N (NOx) by Discrete Analyser | EK059G | WATER | In house: Referenced to APHA 4500-NO3- F. Combined oxidised Nitrogen (NO2+NO3) is determined by Chemical Reduction and direct colourimetry by Discrete Analyser. This method is compliant with NEPM (2013) Schedule B(3) |
| Total Kjeldahl Nitrogen as N By Discrete Analyser | EK061G | WATER | In house: Referenced to APHA 4500-Norg D (In house). An aliquot of sample is digested using a high temperature Kjeldahl digestion to convert nitrogenous compounds to ammonia. Ammonia is determined colorimetrically by discrete analyser. This method is compliant with NEPM (2013) Schedule B(3) |
| Total Nitrogen as N (TKN + Nox) By Discrete Analyser | EK062G | WATER | In house: Referenced to APHA 4500-Norg / 4500-NO3-. This method is compliant with NEPM (2013) Schedule B(3) |
| Total Phosphorus as P By Discrete Analyser | EK067G | WATER | In house: Referenced to APHA 4500-P H, Jirka et al (1976), Zhang et al (2006). This procedure involves sulphuric acid digestion of a sample aliquot to break phosphorus down to orthophosphate. The orthophosphate reacts with ammonium molybdate and antimony potassium tartrate to form a complex which is then reduced and its concentration measured at 880nm using discrete analyser. This method is compliant with NEPM (2013) Schedule B(3) |
| Reactive Phosphorus as P-By Discrete Analyser | EK071G | WATER | In house: Referenced to APHA 4500-P F Ammonium molybdate and potassium antimonyl tartrate reacts in acid medium with othophosphate to form a heteropoly acid -phosphomolybdic acid - which is reduced to intensely coloured molybdenum blue by ascorbic acid. Quantification is by Discrete Analyser. This method is compliant with NEPM (2013) Schedule B(3) |
| Ionic Balance by PCT DA and Turbi SO4 DA | EN055 - PG | WATER | In house: Referenced to APHA 1030F. This method is compliant with NEPM (2013) Schedule B(3) |

| *Preparation Methods* | *Method* | *Matrix* | *Method Descriptions* |
|---|---|---|---|
| TKN/TP Digestion | EK061/EK067 | WATER | In house: Referenced to APHA 4500 Norg - D; APHA 4500 P - H. This method is compliant with NEPM (2013) Schedule B(3) |