Drilling and Completion Report

Stage 2

Prepared for Snowy Hydro Limited
June 2019

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Stage 2

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1 Introduction

1.1 Project overview

Snowy Hydro Limited (SHL) proposes to develop Snowy 2.0, a large-scale pumped hydro-electric storage and generation project which would increase hydro-electric capacity within the existing Snowy Mountains Hydro-electric Scheme (Snowy Scheme). This will be achieved by establishing a new underground hydro-electric power station that will increase the generation capacity of the Snowy Scheme by almost 50%, providing an additional 2,000 megawatts (MW) generating capacity, and providing approximately 350 gigawatts hours (GWh) of storage available to the National Electricity Market (NEM) at any one time, which is critical to ensuring system security as Australia transitions to a decarbonised NEM. Snowy 2.0 will link the existing Tantangara and Talbingo reservoirs within the Snowy Scheme through a series of underground tunnels and a hydro-electric power station.

Snowy 2.0 has been declared Critical State Significant Infrastructure (CSSI) by the NSW Minister for Planning under the provisions of the *NSW Environmental Planning and Assessment Act 1979* (EP&A Act) and is defined in Clause 9 of Schedule 5 of the State Environmental Planning Policy (State and Regional Development) 2011 (SRD SEPP). Separate applications and environmental impact statements (EIS) for different phases of Snowy 2.0 are being submitted under Part 5, Division 5.2 of the EP&A Act.

1.2 Program objectives

The collection of field data is important for accurate representation of hydrogeological conceptual and numerical groundwater flow models which will inform the Groundwater Assessment in support of the Snowy 2.0 EIS. This assessment covers all issues relating to site water management, groundwater and surface water and their related environmental and other uses.

A comprehensive groundwater monitoring network has been installed to collect hydrogeological data which will be used to characterise the groundwater regime in the vicinity of the project area. The Stage 2 project area is located in-between both Talbingo and Tantangara reservoirs, which are existing structures that form part of the Snowy Scheme. Talbingo Reservoir is located approximately 50 kilometres (km) north-west of Adaminaby. Tantangara Reservoir is located approximately 25 km north-west of Adaminaby. The two regions are separated by the Snowy Mountains Highway, which connects Adaminaby and Cooma in the south-east, to Talbingo and Tumut to the north-west of KNP. The ravine region is between Talbingo Reservoir to the north-west and the Snowy Mountains Highway to the east. The plateau region extends from the Snowy Mountains Highway in the east to Tantangara Reservoir in the west.

The Stage 1 groundwater monitoring network comprises 20 monitoring bores, including conventional standpipe piezometers and nested monitoring sites, at 11 locations, installed in order to monitor potential sensitive features, including alpine bogs, the Yarongobilly River, the Murrumbidgee River, Tantangara Creek, Gooandra Creek and potential groundwater dependent ecosystems. The Stage 2 network is an extension of the project's groundwater monitoring network and comprises seven monitoring bores (three pre-existing monitoring bores, and four monitoring bores drilled as part of this program), and four test production bores (one pre-existing production bore and three production bores drilled as part of this program) at four nested locations. The extension of the network is essential to further inform the characterisation of groundwater systems across the Ravine and Plateau region of the main project area, as well as satisfying baseline groundwater monitoring requirements. This report summarises the Stage 2 drilling program of the Snowy 2.0 groundwater monitoring network.

Monitoring and test bores were drilled and installed by Highland Drilling and supervised by EMM Consulting Pty Limited (EMM) in consultation with NSW Department of Industry Water (DoI Water) between May and June 2018.

2 Drilling program

2.1 Monitoring bore network

The Stage 2 drilling program includes conventional groundwater monitoring bores and test production bores located within the vicinity of the Snowy 2.0 project area. Monitoring bores and test production bores are positioned to provide spatial coverage, investigate major hydrogeological systems, and monitor potentially sensitive environmental features along the project alignment.

Specifically, the groundwater monitoring network is designed to:

- identify and characterise water bearing units in the project area, with a focus on characterising groundwater flow and quality;
- characterise hydraulic properties (horizontal and vertical flow) within the major groundwater bearing zones across the project area;
- provide a degree of spatial representation and flux of pressure heads across the plateau area to investigate potential vertical hydraulic gradients and connectivity between water bearing units;
- investigate the potential for surface water and groundwater interaction, specifically at Gooandra and Tantangara creeks, and groundwater dependant ecosystems; and
- investigate the potential impacts to the groundwater and surface environments from the construction and operation of the project.

The network is comprised of seven monitoring bores (three pre-existing monitoring bores, and four monitoring bores drilled as part of this program), and four test production bores (one pre-existing production bore and three production bores drilled as part of this program) at four nested locations illustrated in Figure 2.1 and detailed in Table 2.1.

Test production bores were completed with open sections/screens targeting the proposed tunnel depth. Test production bores were pump tested to simulate groundwater yields during tunnelling. Shallow and deep monitoring bores were installed at each location to observe vertical and horizontal hydraulic conductivity/connectivity (if any) between the shallow and deep groundwater systems during pump testing. The exception being the PB05 site where only one deep monitoring bore was installed. Vertical conductivity is of interest due to the potential impacts of drawdown (during tunnelling) on groundwater dependent ecosystems and groundwater fed surface water features on the plateau.

A schematic of a nested groundwater monitoring/test production site is shown in Figure 2.2.

KEY

- Stage 2 groundwater monitoring bore
- Snowy Mountains Highway
- Existing road infrastructure
- Watercourse
- Waterbody

Project access road/track/trail

- Existing road/track
- Proposed track

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Source: EMM (2018); Snowy Hydro (2018); SMEC (2018); DFSI (2017); GA (2015)

Monitoring and production bore locations

Snowy 2.0
Drilling and completion report

Figure 2.1

Table 2.1 Stage 2 groundwater monitoring bores

Site location	Bore ID	Type	Easting[1]	Northing[1]	Ground level (mAHD)[2]	Total depth (mBGL)[3]	Screen (mBGL)[3]	Monitored formation	Lithology
Tantangara intake	PB01	Test Production Bore	649253.9	6038163.8	1231.5	60	45 – 60 open hole	Kelly's Plain Volcanics	Dacite
	BH116*	Monitoring Bore	649431.3	6038166	1234.46	93	80.5 – 89.5	Kelly's Plain Volcanics	Dacite
	BH115*	Monitoring Bore	649225.4	6038173	1231.2	54	42 - 51	Kelly's Plain Volcanics	Dacite
Tantangara Creek	PB03	Test Production Bore	640645.2	6038345.8	1335.6	215	200 – 215 open hole	Boggy Plain Suite	Volcanic rock
	SMB02	Monitoring Bore	640640.7	6038339.9	1334.8	195	182 - 194	Boggy Plain Suite	Volcanic rock
	SMB03	Monitoring Bore	640645.9	6038334	1334.7	50	40 – 49	Boggy Plain Suite	Volcanic rock
Gooandra Creek	PB04	Test Production Bore	638887.2	6038527.3	1341.3	200	185 – 200	Gooandra Volcanics/ Boggy Plains Suite	Chloritic schist Metagranite
	SMB04	Monitoring Bore	638897.7	6038519.2	1341.6	180	170 – 179	Gooandra Volcanics	Chloritic schist
	SMB05	Monitoring Bore	638890.2	6038515.5	1341.8	50	40 – 49	Gooandra Volcanics	Chloritic schists
Talbingo intake	PB05*	Test Production Bore	624500.3	6040714.1	614.3	100	50 – 100 open hole	Ravine Beds	Siltstone, sandstone, limestone
	BH7106*	Monitoring Bore	624510	6040720	612.9	154.15	141 – 153	Ravine Beds	Siltstone, sandstone, limestone

Notes: 1. Coordinates in MGA 94 (Zone 55)
2. mAHD = metres Australian Height Datum
3. mBGL = metres Below Ground Level
* pre-existing boreholes not drilled by EMM as part of this program.

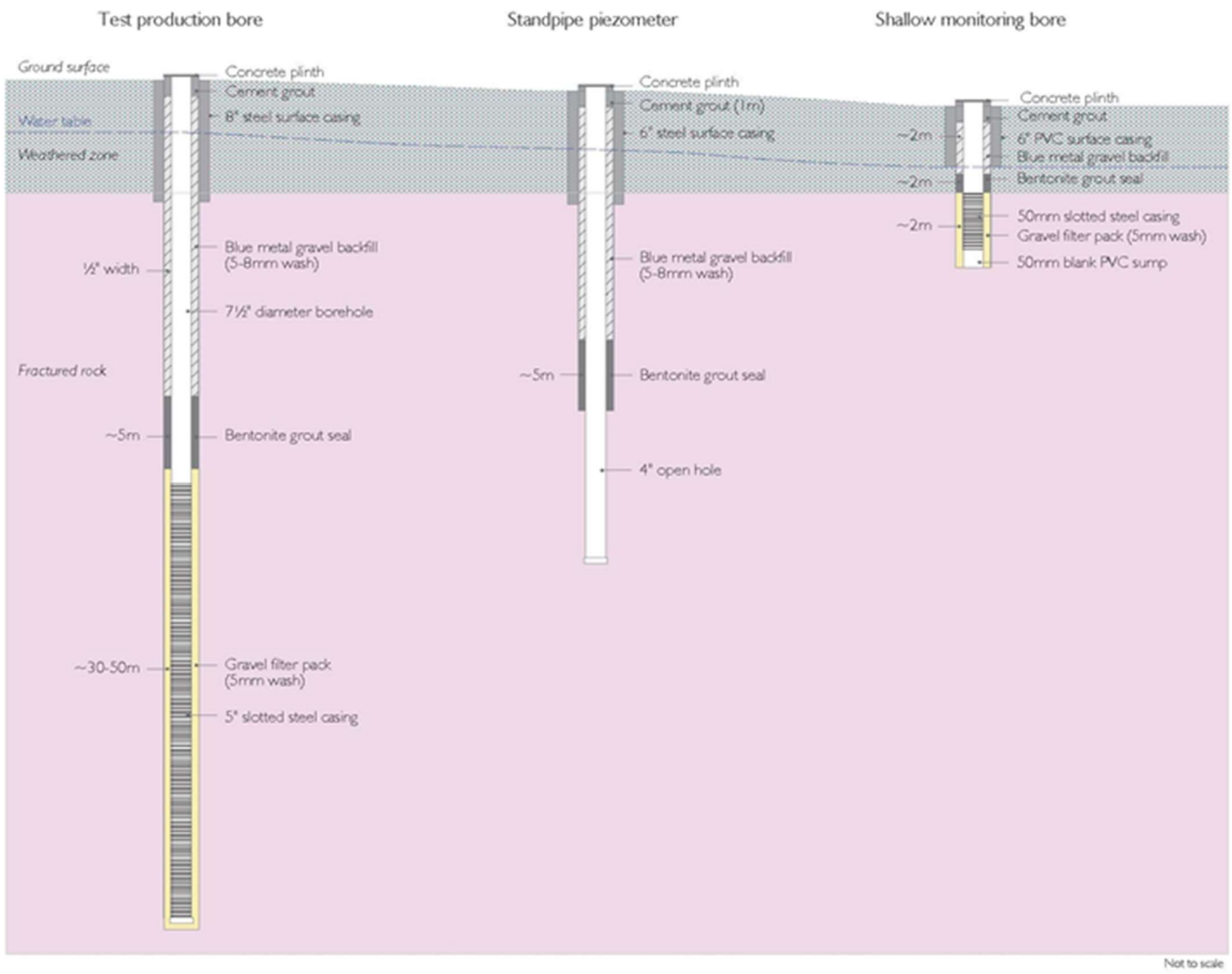


Figure 2.2 **Typical test production bore and associated nested monitoring bore schematic**

2.2 Monitoring bore licence

A test (monitoring bore) licence (40BL192701) under the *Water Act 1912* was obtained by SHL from DoI Water prior to the commencement of the drilling program (Appendix A). Form A: Particulars of Completed Works forms (drilling completion forms) were submitted to DoI Water following monitoring bore installation and are included in Appendix B.

2.3 Drilling and construction specifications

2.3.1 Overview

Highland Drilling was engaged by EMM to undertake borehole drilling and monitoring/test production bore construction and installation. EMM provided the design and specification and undertook project management and hydrogeological supervision during the drilling program.

All monitoring and test production bores were drilled and constructed in accordance with the Minimum Construction Requirements for Water Bores in Australia (NUDLC 2012). Drilling and construction is a minimal impact temporary activity with the final constructed bore presenting at the surface as a 100 millimetre (mm) high, 1 x 1 metre (m) concrete slab and flush galvanised steel gatic plate (see Figure 2.2).

2.3.2 Drilling

All monitoring and test production boreholes were drilled using an air rotary percussion technique (also known as air hammer) to evacuate cuttings from the annulus of the borehole during drilling. No drill muds or additives were used during the drilling. This method allows information on water strikes, quality, and yields to be collected while drilling.

All water produced from the bores during drilling was controlled in a series of above ground tanks and disposed of in accordance with the Snowy 2.0 Review of Environmental Factors (REF). Water used for drilling was sourced from a licensed supply in Adaminaby or recycled from settling tanks. Produced water was discharged only when it met the water quality criteria specified in the REF. All produced water that did not comply with REF criteria was contained in above-ground tanks and disposed of at a licensed waste facility.

Geology was logged at one metre intervals and groundwater yields recorded (if any) at the end of each drill rod (every 6 m). Water quality physico-chemical parameters were measured using a calibrated YSI™ water quality meter; parameters included temperature, Electrical Conductivity (EC), pH, Dissolved Oxygen (DO), Total Dissolved Solids (TDS) and Oxidation Reduction Potential (ORP). Physico-chemical parameters are shown on the geological bore logs in Appendix C.

All boreholes were developed at target depth until the discharge water was relatively free of sediment and the physico-chemical water quality parameters stabilised.

A washed and graded (3 to 5 mm) gravel filter pack was installed in the annulus around the screen (placed at the target depth) and extended a minimum of 3 m above the screened section. A bentonite pellet seal was installed 3 to 5 m above the gravel pack and the boreholes were backfilled with blue metal gravel to approximately 2 m below surface level. The bentonite seal ensures no vertical connection between target groundwater systems and those above the screened section. The annulus was completed with cement grout to surface.

Test production boreholes were drilled from surface at 7.5” diameter to the top of the open hole section. 5” steel casing was then welded and installed to depth. The annulus between the 5” steel casing was sealed with 3 m of bentonite pellets and then backfilled with blue metal gravel to surface. The “tail” open section of the borehole was

drilled at 5” diameter to target depth. The open hole sections of PB01, PB03 and PB05 and screened section of PB04 were designed to target the proposed tunnelling depth.

2.3.3 Survey

Following bore installation, the completed bores were surveyed by Peter W. Burns Pty Ltd, Cooma. Measurements collected during the survey process can be found in Table 2.2.

The survey included measurements of:

- MGA55 Easting and Northings of each bore,
- AHD71 level of the gatic lid and top of casing.

Table 2.2 Bore survey details

Bore ID	Easting (MGA 94)	Northing (MGA 94)	Gatic lid (mAHD)[1]	Top of casing (mAHD)[1]
PB01	649253.9	6038163.8	-	1231.5
PB03	640645.2	6038345.8	1335.5	1335.6
PB04	638887.2	6038527.3	-	1341.3
PB05	624500.3	6040714.1	614.3	614.3
SMB02	640640.7	6038339.9	1334.8	-
SMB03	640645.9	6038334.0	1334.7	-
SMB04	638897.7	6038519.2	1341.8	1341.6
SMB05	638890.2	6038515.5	1342.0	1341.8

Notes: 1. mAHD = metres Australian Height Datum

2.4 Geology encountered during drilling

The main geological formations encountered during drilling on the plateau in-between Tantangara Reservoir and Snowy Mountains Highway were the Gooandra Volcanics formation, Temperance Formation, and the Boggy Plain Suite. The predominant lithology encountered was a greenish-grey siliceous igneous volcanic rock, and a greenish-blue dacite. In the ravine region between Talbingo Reservoir and Lobs Hole Ravine road, in the Ravine Beds formation, the predominant geology was a fine-grained siltstone with sandstone, quartz and pyrite.

Table 2.3 provides a summary of geology encountered during drilling.

Table 2.3 Geology

Bore ID	Total depth (mBGL)[1]	Screened formation	Screened lithology
PB01	60	Kellys Plains Volcanics	Dacite; medium greenish blue grey
PB03	215	Boggy Plain Suite	Volcanic rock; medium greenish grey
PB04	200	Gooandra Volcanics	Volcanic rock; medium grey, siliceous
PB05	100	Ravine Beds	Siltstone; medium grey, fine grained
SMB02	195	Boggy Plain Suite	Dacite; medium greenish grey black
SMB03	50	Temperance Formation	Dacite; medium to dark grey
SMB04	180	Gooandra Volcanics	Volcanic rock; medium grey
SMB05	50	Gooandra Volcanics	Volcanic rock; medium grey

Note: 1. mBGL = metres below ground level

2.5 Groundwater flow

Except for SMB02 (2 L/s), all constructed bores had a yield of <0.2 L/s at first cut during drilling. PB04, SMB02, SMB03 and SMB04 had a yield of >2 L/s at screened depth during drilling, whilst the remaining bores had yields of <1 L/s. No readings were taken at SMB05 during drilling due to low flow.

A summary of groundwater flow for all bores drilled during the Stage 2 program is presented in Table 2.4. This table includes key information collected during drilling and at the end of airlift development when yield conditions had stabilised.

Table 2.4 Groundwater flow

Bore ID	First water cut (mBGL)[1]	Rate at first cut (L/s)	Screen depth (mBGL)	Rate at screen (L/s)	Final airlifting yield (L/s)
PB01	12.5	<0.1	open hole from 30 m	<0.1	0.1
PB03	24	0.1	open hole from 200 m	0.1	<0.1
PB04	66	0.2	185- 200	2	2
PB05	51.96	0.1	open hole from 55 m	0.1	0.1
SMB02	17	2	182-194	3	3
SMB03	12	0.1	40-49	3	3
SMB04	72	0.1	170-179	3	3

Table 2.4 Groundwater flow

Bore ID	First water cut (mBGL)[1]	Rate at first cut (L/s)	Screen depth (mBGL)	Rate at screen (L/s)	Final airlifting yield (L/s)
SMB05	19	-	40-49	-	-

Note: 1. mBGL = metres below ground level
2. No readings were taken at SMB05 due to low flow

2.6 Groundwater quality

A summary of groundwater quality is presented in Table 2.5. This table includes key information collected during drilling and at the end of airlift development when physico-chemical conditions had stabilised.

Electrical conductivity (EC) values at all constructed bores are considered 'fresh' as the highest recorded EC value at a screened interval was 177.4 µS/cm at PB05. All other bores recorded EC values of below 100 µS/cm at screened interval. pH measurements were consistently between 7.5 and 8.5 at the screened interval at all Stage 2 constructed bores.

PB01 and PB03 were airlift developed until dry, resulting in no stabilisation measurement being taken at the end of development. Similarly, due to low flow, no sample was obtained at stabilisation for PB05. No water quality readings were taken at SMB05 during drilling due to low flow.

Table 2.5 Groundwater quality

Bore ID	EC at screen (µS/cm)[1]	pH at screen	EC at stabilisation (µS/cm)	pH at stabilisation
PB01	59.7	7.58	dry	dry
PB03	62.8	7.92	dry	dry
PB04	36.6	8.25	117.3	7.65
PB05	177.4	7.98	-[2]	-[2]
SMB02	66.5	7.46	94.9	7.7
SMB03	69.7	8.2	51.2	7.59
SMB04	91.3	8.51	111.7	8.31
SMB05[2]	-	-	-	-

Note: 1. µS/cm = microsiemens per centimetre
2. No water quality readings were taken due to low flow

3 Field testing

3.1 Pumping tests

3.1.1 Pumping test methodology

Aquamann Irrigation was engaged by EMM to complete constant rate pumping tests at PB01, PB03, PB04, and PB05. Groundwater level was measured using automatic dataloggers and manual water level meters at regular intervals at both the production bores and respective shallow and deep monitoring bores. Field water quality parameters (pH, EC, DO%, temperature, and ORP) were also collected at regular intervals during each pumping test.

After analysis of slug test data from surrounding monitoring bores, it was determined that aquifer testing at each test production bore should consist of a 72-hour constant rate pumping test (CRT). Where possible, each test was preceded by a step rate test (SRT) (4 one-hour steps) to confirm pump selection and pumping rates for the CRT. Recovery of water levels were monitored, where possible, for up to 15 hours following the completion of the CRT. Target drawdown for the pump tests was over 40% of the available head to adequately stress the aquifer.

Due to the low yield and inflow rate at PB01, the pumping test was performed with intermittent pumping which kept the drawdown within 2.5 m of the base of the bore. The constant-drawdown test extended over a period of 38 hours and consisted of 156 drawdown and recovery cycles. In each cycle, the aquifer was pumped for approximately two minutes at a rate of 6.75 L/min on average, followed by a recovery period of 12-13 minutes.

All water extracted from the test production bores during pumping was disposed of in accordance with the Snowy 2.0 review of environmental factors (REF). There were no instances of uncontrolled release of water; water was discharged only when it met the water quality criteria specified in the REF.

A pumping test summary is provided in Table 3.1, and pumping test reports are presented in Appendix D.

Table 3.1 Pumping test summary table

Production bore	Date	Test duration	Pumping time	Recovery time	Constant discharge rate (L/s)[1]	Formation	Deep observation bore (distance from production bore)	Shallow observation bore (distance from production bore)
PB01	25/06/18 – 27/06/18	39 hours	-[2]	-[2]	0.1	Kelly's Plain Volcanics	BH116 (28.7m)	BH115 (180m)
PB03	02/07/18 – 03/07/18	11.5 hours	12 mins	11.25 hours	<0.1	Temperance Formation/ Boggy Plain Suite	SMB02 (7.4m)	SMB03 (11.8m)
PB04	28/03/18 – 01/04/18	95 hours	70 hours	15 hours	0.7	Gooandra Volcanics	SMB04 (10.8m)	SMB05 (10.8m)
PB05	06/08/18 – 08/08/18	71 hours	67 hours	4 hours	0.69 – 0.86	Ravine Beds	BH7106 (15m)	-

Note: 1. L/s = litres per second. 2.intermitant pumping and recovery cycled over 39 hour period to maintain drawdown due to low-flow.

3.1.2 Pumping test results

Water level data was collected throughout the pumping tests both manually, using electronic dip meters, and automatically via dataloggers. The data was evaluated using two different aquifer test analysis programs, AqteSolv and MLU, to estimate aquifer properties. AqteSolv is industry-leading software that allows for aquifer test interpretation using a range of solutions that are applicable to various aquifer types and test conditions. MLU is based on a single hybrid analytical solution that can handle a variety of test conditions and as such is useful for quickly estimating aquifer properties. Additionally, MLU can evaluate aquifer tests performed in multi-aquifer systems, allowing for layer-by-layer estimations of transmissivity and storativity.

Hydraulic conductivity (K) values for PB01, PB04 and PB05 were calculated by analysing drawdown data gathered throughout the duration of the pumping test. Due to low flow at PB03, there were not enough data points available for modelling the drawdown portion of the pumping test. Therefore, to model this test, AqteSolv was used to fit a curve to the late time recovery data up to 30 days after the cessation of pumping.

Table 3.2 details hydraulic conductivity and storativity results for bores drilled during the Stage 2 program.

Table 3.2 Aquifer properties

Bore ID	Kh[1] (m/d)[2]	Kv[3] (m/d)	S (-)
PB01	0.0046 – 0.013	0.010	1.9^{-7} - 2.6^{-5}
PB03	8.81e-8 - 9.07e-8	-	-
PB04	0.01 - 0.032	0.017	2.5^{-4} - 3.9^{-4}
PB05	7.70E-04	0.035	6.30E-05

Notes: 1.Kh = horizontal hydraulic conductivity
2.m/d = metres a day
3.Kv = vertical hydraulic conductivity

Pump test results are summarised as follows:

- **PB01** - the estimated horizontal hydraulic conductivity (Kh) ranged between 0.0046 and 0.013 metres per day (m/d). The vertical hydraulic conductivity was calculated at 0.01 m/d suggesting a slightly higher vertical connectivity. Storativity at PB01 ranged between 1.9^{-7} to 2.6^{-5} which is considered representative of the local geology of fractured dacite.

- **PB03** - the pumping test lasted 11.5 hours with just 12 minutes of pumping time due to lack of water and slow recharge. With this information the horizontal hydraulic conductivity was estimated to range between 8.81^{-8} and 9.07^{-8} m/d.

- **PB04** - the estimated horizontal hydraulic conductivity ranged between 0.01 and 0.032 m/d and a vertical hydraulic conductivity of 0.017 m/d suggesting a similar horizontal and vertical connectivity. Storativity at PB04 ranged between 2.5^{-4} to 3.9^{-4} which is considered representative of the local geology of fractured metabasalt.

- **PB05** – after five hours of constant rate discharge electrical conductivity (EC) values changed significantly and pumping rate and groundwater level stabilised indicating that the aquifer had reached a recharge boundary, meaning the recharge zone became dewatered and recharge flowed steadily from adjacent aquifers. Prior to dewatering the recharge zone (the first five hours of pump testing), horizontal hydraulic

conductivity was more prominent than vertical response whereas after dewatering, vertical hydraulic conductivity became more apparent. Horizontal hydraulic conductivity ranged between 3.7^{-3} and 3.3^{-4} m/d. Storativity ranged between 6.3^{-5} to 2.6^{-5} which is considered representative of the local geology of fractured siltstone and sandstone.

Groundwater levels continued to be monitored every six hours using automatic (Solinst™) dataloggers. The data from these loggers is retrieved monthly and analysed for seasonal variations against rainfall data or an event triggering a change. Hydrographs illustrating groundwater level changes can be found in Appendix E.

3.2 Groundwater quality monitoring

3.2.1 Groundwater sampling methodology

An initial round of groundwater quality monitoring was completed as part of the regular monitoring schedule for Snowy 2.0 monitoring bores, following the construction and aquifer testing of all Stage 2 bores.

A low flow sampling method was used to collect groundwater samples. During purging, physico-chemical parameters (pH, EC, ORP, DO% and temperature) were measured, and a representative groundwater sample collected when the parameters stabilised. Comprehensive analysis is completed by NATA-accredited laboratory ALS. Analytes are shown in Table 3.3.

Table 3.3 Groundwater sampling analytical suite

Suite	Analytes
Physico-chemical properties	Field parameters (pH, EC, redox potential, DO%, temperature), Total Dissolved Solids (TDS), Total Suspended Solids (TSS)
Major ions	Calcium, magnesium, sodium, potassium, sulphate, chloride, alkalinity
Dissolved metals	Arsenic, cadmium, chromium, copper, fluoride, lead, magnesium, nickel, zinc
Nutrients	Ammonia as N, nitrite as N, nitrate as N, reactive phosphorous, phosphorous, total phosphorous

3.2.2 QA/QC procedures

Quality Assurance and Quality Control (QA/QC) procedures were completed during sampling to ensure field and laboratory procedures are followed accurately and equipment is calibrated. The field sampling procedures conformed to EMM's quality assurance/quality control (QA/QC) protocols to prevent cross contamination and preserve sample integrity. Sampling and reporting were conducted in accordance with *Geoscience Australia's Groundwater Sampling and Analysis – A Field Guide* (Sundaram 2009) and EMM's water sampling Standard Operating Procedure document. The following QA/QC procedures were applied:

- calibration of equipment;
- unstable parameters were analysed in the field (physico-chemical parameters);
- samples were collected in clearly labelled bottles with appropriate preservation solutions;
- samples were delivered to the laboratories within the specified holding times;

- field duplicate samples (QA samples) were collected at a rate of one in ten samples; and
- samples were kept chilled and gloves were worn during sampling.

The laboratories conduct their own internal QA/QC program to assess the repeatability of the analytical procedures and instrument accuracy. These programs include analysis of laboratory sample duplicates, spike samples, certified reference standards, surrogate standards/spikes and laboratory blanks. In addition, a duplicate sample is collected in the field for every ten samples collected to assess sampling and laboratory analysis accuracy.

3.2.3 Groundwater sampling results

Groundwater quality results collected from July 2018 to March 2019 are summarised in Table 3.4 with ANZECC 2000 Freshwater 99% trigger values for reference.

Laboratory certificates are presented in Appendix F.

The groundwater quality results averaged in Table 3.4 are reasonably comparable between the different target formations across the Stage 2 boreholes:

- pH is slightly alkaline at all sites;
- DO% is relatively low at all sites except PB05 in the Ravine Beds where it averaged 74.06%;
- ORP at SMB03 and SMB05 indicates a reducing environment whereas results from all other sites indicate oxidising environments;
- alkalinity is highest at PB05 in the Ravine Beds formation which is typical of a limestone dominated location whereas the lowest average alkalinity is in the Gooandra Volcanics particularly at PB04;
- total organic carbon (TOC) is generally very low except at SMB03 in the Boggy Plains Suite formation where it averages 21.4 milligrams per litre (mg/L), almost three times the second highest result of 8.6 mg/L at SMB05 in the Gooandra Volcanics;
- the concentrations of major ions and dissolved metals are low for most samples collected from each groundwater system, with many measurements below detection limits. This is typical of groundwater with reasonably neutral pH;
- sulphate concentrations are generally low across the Stage 2 boreholes however, higher concentrations (averaging 34.7 mg/L) were found at SMB05. This could be caused by natural sulphate sources, specifically the dissolution/oxidation of pyrite which is common in the Gooandra Volcanics;
- iron concentrations are low except at SMB03 in the Boggy Plains Suite where average filtered iron concentrations are 1.2 mg/L; and
- nutrient concentrations are relatively low at all bores across all locations with the exception of nitrogen at SMB03, in the Boggy Plain Suite, which had a mean (total) nitrogen concentration of 0.82 mg/L during the reported period.

Table 3.4 Mean groundwater quality results (July 2018 – January 2019)

Parameters	Units	Site	PB01	PB04	PB05	SMB02	SMB03	SMB04	SMB05
Formation		ANZECC 99% protection guidelines	Kelly's Plain Volcanics	Gooandra Volcanics	Ravine Beds	Boggy Plain Suite	Boggy Plain Suite	Gooandra Volcanics	Gooandra Volcanics
Field Parameters									
Temp (Field)	°C		13.33	11.28	20.46	13.35	11.95	12.20	12.58
Dissolved Oxygen - % Saturation (Filtered)	%		15.96	17.72	74.06	47.97	21.75	14.12	15.18
Dissolved Oxygen (Field)	mg/L		1.24	1.87	6.35	4.91	2.36	1.49	1.61
Electrical Conductivity (field)	uS/cm		135.20	92.35	180.66	200.50	187.82	132.38	208.45
pH (Field)	pH_Units		9.08	8.67	7.91	7.74	7.15	8.10	7.74
Redox / oxidation reduction potential (Field)	mV		62.78	7.48	75.04	64.28	-23.22	17.38	-70.73
Total Dissolved Solids (Field)	mg/L		95.74	62.73	120.78	130.47	121.99	86.02	135.45
Analytical results - general									
Alkalinity (total) as CaCO3	mg/L		70.67	36.50	79.20	85.17	72.67	52.50	58.17
Hardness as CaCO3 (Filtered)	mg/L		55.00	33.25	74.75	75.50	67.75	44.25	67.25
Total Dissolved Solids	mg/L		93.50	64.67	114.80	140.00	145.33	92.00	153.17
Analytical results - nutrients									
Ammonia as N	mg/L	0.32	0.02	0.02	0.01	0.01	0.33	0.01	0.01
Nitrite + Nitrate as N	mg/L	0.017	0.02	0.01	0.28	0.15	0.03	0.02	0.07
Kjeldahl Nitrogen Total	mg/L		0.10	0.33	0.10	0.27	0.82	0.13	0.45
Nitrogen (Total)	mg/L		0.13	0.33	0.36	0.40	0.82	0.13	0.50
Reactive Phosphorus as P	mg/L		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01
Phosphorus	mg/L		0.078	0.016	0.067	0.036	0.102	0.027	0.480
Total Organic Carbon	mg/L		4.8	1.8	1.0	2.8	21.4	2.0	8.6

Table 3.4 Mean groundwater quality results (July 2018 – January 2019)

Parameters	Units	Site	PB01	PB04	PB05	SMB02	SMB03	SMB04	SMB05
Formation		ANZECC 99% protection guidelines	Kelly's Plain Volcanics	Gooandra Volcanics	Ravine Beds	Boggy Plain Suite	Boggy Plain Suite	Gooandra Volcanics	Gooandra Volcanics
Nitrate (as N)	mg/L		0.026	0.013	0.282	0.280	0.033	0.027	0.065
Nitrite (as N)	mg/L		<0.01	<0.01	<0.01	0.02	<0.01	<0.01	<0.01
Major ions									
Calcium (Filtered)	mg/L		10.5	12.2	17.6	25.5	20.2	17.7	26.7
Chloride	mg/L		2	<1	1	2.3	6.4	1.0	3.2
Magnesium (Filtered)	mg/L		6.5	1	7.6	2	2.8	<1	1
Sodium (Filtered)	mg/L		10.3	5.3	9.0	11.3	15.2	6.0	12.8
Potassium (Filtered)	mg/L		1	<1	1.6	1.8	<1	<1	1
Sulphate as SO4 - Turbidimetric (Filtered)	mg/L		8.4	11.0	16.2	9.3	16.2	13.7	34.7
Fluoride	mg/L		0.11	0.15	0.16	0.33	0.2	<0.01	0.13
Metals									
Aluminium (Filtered)	mg/L	0.027	<0.01	<0.01	0.02	0.06	0.03	0.01	0.02
Arsenic (Filtered)	mg/L		<0.001	<0.001	0.001	<0.001	<0.001	0.019	0.006
Barium (Filtered)	mg/L		0.037	0.092	0.059	0.018	0.030	0.009	0.019
Beryllium (Filtered)	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Boron (Filtered)	mg/L	0.09	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Cadmium (Filtered)	mg/L	0.00006	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Chromium (III+VI) (Filtered)	mg/L		<0.001	<0.001	0.001	0.001	<0.001	<0.001	<0.001
Cobalt (Filtered)	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Copper (Filtered)	mg/L	0.001	0.001	0.002	0.003	0.004	0.002	0.003	0.002

Table 3.4 Mean groundwater quality results (July 2018 – January 2019)

Parameters	Units	Site	PB01	PB04	PB05	SMB02	SMB03	SMB04	SMB05
Formation		ANZECC 99% protection guidelines	Kelly's Plain Volcanics	Gooandra Volcanics	Ravine Beds	Boggy Plain Suite	Boggy Plain Suite	Gooandra Volcanics	Gooandra Volcanics
Iron (Filtered)	mg/L		0.07	0.0925	<0.05	0.08	1.2	<0.05	<0.05
Lead (Filtered)	mg/L	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Manganese (Filtered)	mg/L	1.2	0.025	0.024	0.005	0.004	0.149	0.004	0.152
Mercury (Filtered)	mg/L	0.00006	<0.001	<0.0001	<0.0001	<0.0001	<0.0001	0.0001	<0.0001
Nickel (Filtered)	mg/L	0.008	0.001	<0.001	0.001	0.001	0.002	0.001	0.001
Selenium (Filtered)	mg/L	0.005	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Silver (Filtered)	mg/L	0.00002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Vanadium (Filtered)	mg/L		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc (Filtered)	mg/L	0.0024	<0.005	0.005	0.009	0.041	0.029	0.009	0.008
Alkalinity									
Alkalinity (Bicarbonate as CaCO3)	mg/L		60.83	36.17	79.20	85.17	72.67	52.50	58.17
Alkalinity (Carbonate as CaCO3)	mg/L		11.8	1	<1	<1	<1	<1	<1
Alkalinity (Hydroxide) as CaCO3	mg/L		<1	<1	<1	<1	<1	<1	<1
Inorganics									
Anions Total	meq/L		1.603	0.960	1.938	1.962	1.938	1.338	1.972
Cations Total	meq/L		1.512	0.855	1.936	1.962	1.900	1.143	1.933
Cyanide Total	mg/L	0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
Organics									
Methane	mg/L		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

References

Butler, J.J., Jr. 1988, *Pumping tests in nonuniform aquifers—the radially symmetric case*, Journal of Hydrology, vol. 101, pp. 15-30.

NUDLC 2012, *Minimum Construction Requirements for Water Bores in Australia National Third edition*, Australian Government National Water Commission, Uniform Drillers Licensing Committee

Sundaram B, Feitz A, de Caritat P, Plazinska A, Brodie R, Coram J and Ransley T 2009. *Groundwater Sampling and Analysis – a Field Guide*, Geoscience Australia

Wallis, L. Goode, J. EMM Consulting & Snowy Hydro Limited, Snowy 2.0 Feasability Study Submission L, *Review of Environmental Factors; groundwater monitoring bore drilling program*, November 2017

ANZECC 2000, *Australian and New Zealand guidelines for fresh and marine water quality,* National water quality management strategy, vol. 1. Australian Water Association.

Appendix A

Monitoring bore licence

NSW Office of Water

Murrumbidgee Region
Yanco Agricultural Institute Pri
2198 Irrigation Way East
Yanco NSW 2703
Phone: (02) 69512611

BORE LICENSE CERTIFICATE
UNDER SECTION 115 OF THE WATER ACT, 1912

40BL192701

Department of Primary Industries Office of Water

Snowy Hydro Limited
Po Box 332
Cooma NSW 2630

LICENSE NUMBER
40BL192701
DATE LICENSE VALID FROM
22-Dec-2017
DATE LICENSE VALID TO
PERPETUITY
FEE
$0.00

ABN 72189919072 GST NIL

LOCATION OF WORKS

Portion(s) or Lot/Section/DP	PARISH	COUNTY
R	Pinbeyan	Buccleuch
2//756723	Tantangara	Wallace

TYPE OF WORKS	PURPOSE(S) FOR WHICH WATER MAY BE USED
Bore - Monitoring	Monitoring Bore

CONDITIONS APPLYING TO THIS LICENSE ARE

As shown on the attached Condition Statement

COPY

NSW Office of Water

CONDITIONS STATEMENT REFERRED TO ON 40BL192701 ISSUED UNDER PART V OF THE WATER ACT, 1912 ON 22-Dec-2017

(1) THE LICENCE SHALL LAPSE IF THE WORK IS NOT COMMENCED AND COMPLETED WITHIN THREE YEARS OF THE DATE OF THE ISSUE OF THE LICENCE.

(2) THE LICENSEE SHALL WITHIN TWO MONTHS OF COMPLETION OR AFTER THE ISSUE OF THE LICENSE IF THE WORK IS EXISTING, FURNISH TO NSW OFFICE OF WATER:-

(A) DETAILS OF THE WORK SET OUT IN THE ATTACHED FORM "A" (MUST BE COMPLETED BY A DRILLER).

(B) A PLAN SHOWING ACCURATELY THE LOCATION OF THE WORK, IN RELATION TO PORTION AND PROPERTY BOUNDARIES.

(C) A ONE LITRE WATER SAMPLE FOR ALL LICENCES OTHER THAN THOSE FOR STOCK, DOMESTIC, TEST BORES AND FARMING PURPOSES.

(D) DETAILS OF ANY WATER ANALYSIS AND/OR PUMPING TESTS.

(3) THE LICENSEE SHALL ALLOW NSW OFFICE OF WATER OR ANY PERSON AUTHORISED BY IT, FULL AND FREE ACCESS TO THE WORKS, EITHER DURING OR AFTER CONSTRUCTION, FOR THE PURPOSE OF CARRYING OUT INSPECTION OR TEST OF THE WORKS AND ITS FITTINGS AND SHALL CARRY OUT ANY WORK OR ALTERATIONS DEEMED NECESSARY BY THE DEPARTMENT FOR THE PROTECTION AND PROPER MAINTENANCE OF THE WORKS, OR THE CONTROL OF THE WATER EXTRACTED AND FOR THE PROTECTION OF THE QUALITY AND THE PREVENTION FROM POLLUTION OR CONTAMINATION OF SUB-SURFACE WATER.

(4) IF A WORK IS ABANDONED AT ANY TIME THE LICENSEE SHALL NOTIFY NSW OFFICE OF WATER THAT THE WORK HAS BEEN ABANDONED AND SEAL OFF THE AQUIFER BY:-

(A) BACKFILLING THE WORK TO GROUND LEVEL WITH CLAY OR CEMENT AFTER WITHDRAWING THE CASING (LINING); OR

(B) SUCH METHODS AS AGREED TO OR DIRECTED BY NSW OFFICE OF WATER.

(5) IF THE BORE AUTHORISED BY THIS LICENSE IS LINED WITH STEEL OR PLASTIC CASING THE INSIDE DIAMETER OF THAT CASING SHALL NOT EXCEED 220 MM.

(6) WATER SHALL NOT BE PUMPED FROM THE BORE AUTHORISED BY THIS LICENSE FOR ANY PURPOSE OTHER THAN GROUNDWATER INVESTIGATION.

End Of Conditions

Appendix B

Form A’s

NSW GOVERNMENT Office of Water

Form A Particulars of completed work

Driller's Licence No:	DL1771	1
Class of Licence:	Class 4	
Driller's Name:	Brett Delamont	
Assistant Driller:	Ashley Wills	
Contractor:	Highland Drilling	

New bore	X	Replacement bore	
Deepened		Enlarged	
Reconditioned		Other (specify)	

Final Depth: 60 m

Work Licence No:	PB01	2
Name of Licensee:		
Intended Use:	Monitoring Bore	
Completion Date:	31-05-18	

DRILLING DETAILS (3)

From (m)	To (m)	Hole Diameter (mm)	Drilling Method (See Code 3)
0	30	190.5	9
30	60	99	9

WATER BEARING ZONES (4)

From (m)	To (m)	Thickness (m)	S W L (m)	Estimated Yield (L/s) Individual Aquifer	Estimated Yield (L/s) Cumulative	Test method (See Code 4)		D D L at end of test (m)	Duration Hrs	Duration min	Salinity (Conductivity or TDS) Cond (µS/cm)	Salinity (Conductivity or TDS) TDS (mg/L)
51	52	1		<0.1	<0.1	1	A				59.7	39

CASING / LINER DETAILS (5)

Material Code 5	OD (mm)	Wall Thickness (mm)	From (m)	To (m)	Method Fixing Code 5
9	130	4.2	0	30	2

Casing support method (See Code 5): 6

Type of casing bottom (See Code 5): 1

Centralisers installed {Yes/No}: (indicate on sketch)

Sump installed {Yes/No}: From m To m

Pressure cemented {Yes/No}: From m To m

Casing Protector cemented in place

WATER ENTRY DESIGN (6)

General Material Code 5	OD (mm)	Wall Thickness (mm)	From (m)	To (m)	Opening type (See Code 6)	Fixing (See Code 5)	Screen Aperture (mm)	Slot Details Length (mm)	Width (mm)	Alignment (See Code 6)
		open hole	30	60			Open hole	no casing		

GRAVEL PACK (7)

Type	Grade	Grain size (mm) From	Grain size (mm) To	Depth (m) From	Depth (m) To	Quantity Litres	Quantity m^3
Rounded	Graded	No	Gravel Pack	Open hole			
Crushed	Ungraded						
Bentonite/Grout seal (Yes/No): Yes				1	30		

Method of placement of Gravel Pack (See Code 7): 1

For Departmental use only: G W

NSW GOVERNMENT Office of Water

Form A Particulars of completed work

Work Licence No: PB01

BORE DEVELOPMENT 8

Chemical used for breaking down drilling mud (Yes/No) No Name:

Method	Bailing/Surging		Jetting		Airlifting	X	Backwashing		Pumping		Other:	
Duration		hrs		hrs	0.5	hrs		hrs		hrs		hrs

DISINFECTION ON COMPLETION 9

Chemical(s) used	Quantity applied (Litres)	Method of application

PUMPING TESTS ON COMPLETION 10

Test type		Date	Pump intake depth (m)	Initial Water Level (SWL) (m)	Pumping rate (L/s)	Water Level at end of pumping (DDL) (m)	Duration of Test (hrs)	Recovery: Water level (m)	Recovery: Time taken (hrs)	Recovery: Time taken (mins)
Multi stage (stepped drawdown)	Stage 1									
	Stage 2									
	Stage 3									
	Stage 4									
Single stage (constant rate)										

Height of measuring point above ground level m Test Method See Code 4

WORK PARTLY BACKFILLED OR ABANDONED 11

Original depth of work: m Is work partly backfilled: (Yes/No)

Is work abandoned: (Yes/No) Method of abandonment: Backfilled Plugged Capped

Has any casing been left in the work (Yes/No) From m To m

Sealing / fill type (See Code 11)	From depth (m)	To depth (m)	Sealing / fill type (See Code 11)	From depth (m)	To depth (m)

Site chosen by: Hydrogeologist X Geologist Driller Diviner Client Other 12

Lot No DP No 13

Work Location Co ordinates Easting 649253.9 Northing 6038163.8 Zone 55

GPS: (Yes/No) Yes >> AMG/AGD or MGA/GDA X (See explanation)

Please mark the work site with "X" on the CLID provided map.

Indicate also the distances in metres from two (2) adjacent boundaries, and attach the map to this Form A package.

Signatures:

Driller: ----------

Date: 03/09/2018 ----------

Licensee: ----------

Date: ----------

Work Licence No: PB01

DRILLER'S ROCK/STRATA DESCRIPTION (LITHOLOGY) — 15

Depth From (m)	Depth To (m)	Description (See Code 15)
0	1	SOIL medium reddish brown, extremely weathered, High clay content
1	7	GRAVEL medium brownish orange, extremely weathered, abundant, quartz, Coarse grained
7	60	DACITE medium greenish blue grey, chlorite, altered; minor, quartz

WORK CONSTRUCTION SKETCH

WORK NOT CONSTRUCTED BY DRILLING RIG — 16

Method of excavation: Hand dug ☐ Back hoe ☐ Dragline ☐ Dozer ☐ Other

Depth (m)	Length (m)	Width (m)	Diameter (m)	Lining material	Dimentions of liner (m)	From Depth (m)	To Depth (m)

Please attach copies of the following if available — 17

Geologist log	(Yes/No) Yes	Laboratory analysis of water Sample	(Yes/No)	Pumping test(s)	(Yes/No)
Geophysical log	(Yes/No)	Sieve analysis of aquifer material	(Yes/No)	Installed Pump details	(Yes/No)

NSW GOVERNMENT Office of Water

Form A Particulars of completed work

Driller's Licence No:	DL1913	1
Class of Licence:	Class 4	
Driller's Name:	Ian Palk	
Assistant Driller:	Scott Fieldsend	
Contractor:	Highland Drilling	

New bore	X	Replacement bore	
Deepened		Enlarged	
Reconditioned		Other (specify)	

Final Depth: 60 m

Work Licence No:	PB03	2
Name of Licensee:		
Intended Use:	Monitoring bore	
Completion Date:	20-06-18	

DRILLING DETAILS 3

From (m)	To (m)	Hole Diameter (mm)	Drilling Method See Code 3
0	21	200	9
21	200	190.5	9
200	215	99	9

WATER BEARING ZONES 4

From (m)	To (m)	Thickness (m)	S W L (m)	Estimated Yield (L/s) Individual Aquifer	Estimated Yield (L/s) Cumulative	Test method See Code 4		D D L at end of test (m)	Duration Hrs	Duration min	Salinity (Conductivity or TDS) Cond (µS/cm)	Salinity (Conductivity or TDS) TDS (mg/L)
			157.72									
				See	Attached							

CASING / LINER DETAILS 5

Material Code 5	OD (mm)	Wall Thickness (mm)	From (m)	To (m)	Method Fixing Code 5
9	219.1		0	21	6
9	130		0	200	6

Casing support method — See Code 5: 2

Type of casing bottom — See Code 5: 1

Centralisers installed {Yes/No}: (indicate on sketch)

Sump installed {Yes/No}: No — From m To m

Pressure cemented {Yes/No}: No — From m To m

Casing Protector cemented in place

WATER ENTRY DESIGN 6

General Material Code 5	OD (mm)	Wall Thickness (mm)	From (m)	To (m)	Opening type See Code 6	Fixing See Code 5	Screen Aperture (mm)	Slot Details Length (mm)	Width (mm)	Alignment See Code 6
	Open	Hole	200	215			Open	hole		

GRAVEL PACK 7

Type	Grade	Grain size (mm) From	Grain size (mm) To	Depth (m) From	Depth (m) To	Quantity Litres	Quantity m^3
Rounded	Graded	Open hole	No gravel				
Crushed	Ungraded						
Bentonite/Grout seal (Yes/No) Yes				1	200		

Method of placement of Gravel Pack — See Code 7

For Departmental use only: G W

NSW GOVERNMENT Office of Water

Form A Particulars of completed work

Work Licence No: PB03

BORE DEVELOPMENT 8

Chemical used for breaking down drilling mud (Yes/No)	No	Name:									
Method	Bailing/Surging		Jetting		Airlifting		Backwashing		Pumping		Other:
Duration		hrs		hrs		hrs		hrs		hrs		hrs

DISINFECTION ON COMPLETION 9

Chemical(s) used	Quantity applied (Litres)	Method of application

PUMPING TESTS ON COMPLETION 10

Test type		Date	Pump intake depth (m)	Initial Water Level (SWL) (m)	Pumping rate (L/s)	Water Level at end of pumping (DDL) (m)	Duration of Test (hrs)	Recovery		
								Water level (m)	Time taken (hrs)	(mins)
Multi stage (stepped drawdown)	Stage 1									
	Stage 2									
	Stage 3									
	Stage 4									
Single stage (constant rate)										

Height of measuring point above ground level ____ m Test Method ____ See Code 4

WORK PARTLY BACKFILLED OR ABANDONED 11

Original depth of work: ____ m Is work partly backfilled: (Yes/No) ____

Is work abandoned: (Yes/No) ____ Method of abandonment: Backfilled ____ Plugged ____ Capped ____

Has any casing been left in the work (Yes/No) ____ From ____ m To ____ m

Sealing / fill type See Code 11	From depth (m)	To depth (m)	Sealing / fill type See Code 11	From depth (m)	To depth (m)

Site chosen by: Hydrogeologist ____ Geologist ____ Driller ____ Diviner ____ Client ____ Other ____ 12

Lot No ____ DP No ____ 13

Work Location Co ordinates Easting 640645.2 Northing 6038345.8 Zone 55

GPS: (Yes/No) Yes >> AMG/AGD ____ or MGA/GDA X (See explanation)

Please mark the work site with "X" on the CLID provided map.

Indicate also the distances in metres from two (2) adjacent boundaries, and attach the map to this Form A package.

Signatures:

Driller: ---------- **Licensee:** ----------

Date: 03/09/2018 **Date:** ----------

Work Licence No: PB03

DRILLER'S ROCK/STRATA DESCRIPTION (LITHOLOGY) — 15

Depth From (m)	Depth To (m)	Description (See Code 15)
0	1	SOIL dark brown, Organic matter
1	4	CLAY medium brownish orange, highly weathered
4	215	VOLCANIC ROCK light greenish grey, moderately oxidised, platy

WORK CONSTRUCTION SKETCH

WORK NOT CONSTRUCTED BY DRILLING RIG — 16

Method of excavation: Hand dug ☐ Back hoe ☐ Dragline ☐ Dozer ☐ Other

Depth (m)	Length (m)	Width (m)	Diameter (m)	Lining material	Dimentions of liner (m)	From Depth (m)	To Depth (m)

Please attach copies of the following if available — 17

Geologist log	(Yes/No) ☐	Laboratory analysis of water Sample	(Yes/No) ☐	Pumping test(s)	(Yes/No) ☐
Geophysical log	(Yes/No) ☐	Sieve analysis of aquifer material	(Yes/No) ☐	Installed Pump details	(Yes/No) ☐

WATER BEARING ZONES 4

From (m)	To (m)	Thickness (m)	S W L (m)	Estimated Yield (L/s)		Test method		D D L at end of test (m)	Duration		Salinity (Conductivity or TDS)	
				Individual Aquifer	Cumulative	See Code 4			Hrs	min	Cond (µS/cm)	TDS (mg/L)
23	24		157.72			1	A				70.1	
24	30					1	A				70.6	
30	36					1	A				62.6	
36	42					1	A				71.9	
42	48					1	A				78.1	
48	84					1	A				80	
84	88					1	A				56	
88	120					1	A				104	
120	126					1	A				110	
126	132					1	A				105	
132	138					1	A				111	
138	144					1	A				100	
144	150					1	A				84.5	
150	156					1	A				86.3	
156	162					1	A				82.3	
162	186					1	A				100.1	
186	192					1	A				98.6	
192	198					1	A				92.4	
198	200					1	A				62.8	
200	210			<0.1		1	A				92	

NSW GOVERNMENT Office of Water

Form A Particulars of completed work

Driller's Licence No:	DL1913	1
Class of Licence:	Class 4	
Driller's Name:	Ian Palk	
Assistant Driller:	Scott Fieldsend	
Contractor:	Highland Drilling	

New bore	X	Replacement bore	
Deepened		Enlarged	
Reconditioned		Other (specify)	

Final Depth: 200 m

Work Licence No:	PB04	2
Name of Licensee:		
Intended Use:	Monitoring bore	
Completion Date:	23-05-18	

DRILLING DETAILS 3

From (m)	To (m)	Hole Diameter (mm)	Drilling Method (See Code 3)
0	17	254	9
17	200	190.5	9

WATER BEARING ZONES 4

From (m)	To (m)	Thickness (m)	S W L (m)	Estimated Yield (L/s) Individual Aquifer	Estimated Yield (L/s) Cumulative	Test method (See Code 4)		D D L at end of test (m)	Duration Hrs	Duration min	Salinity (Conductivity or TDS) Cond (µS/cm)	Salinity (Conductivity or TDS) TDS (mg/L)
				See	Attached							

CASING / LINER DETAILS 5

Material Code 5	OD (mm)	Wall Thickness (mm)	From (m)	To (m)	Method Fixing Code 5
9	274		0	17	6
9	130		0	185	6

Casing support method (See Code 5): 2

Type of casing bottom (See Code 5): 1

Centralisers installed {Yes/No}: No (indicate on sketch)

Sump installed {Yes/No}: No From m To m

Pressure cemented {Yes/No}: No From m To m

Casing Protector cemented in place

WATER ENTRY DESIGN 6

General Material Code 5	OD (mm)	Wall Thickness (mm)	From (m)	To (m)	Opening type (See Code 6)	Fixing (See Code 5)	Screen Aperture (mm)	Slot Details Length (mm)	Width (mm)	Alignment (See Code 6)
9	130	4.2	185	200	7	6	2	100	120	D

GRAVEL PACK 7

Type		Grade		Grain size (mm) From	Grain size (mm) To	Depth (m) From	Depth (m) To	Quantity Litres	Quantity m^3
Rounded	X	Graded	X	5	8	171	200		
Crushed		Ungraded							
Bentonite/Grout seal (Yes/No)		Yes				161	171		

Method of placement of Gravel Pack (See Code 7): 1

For Departmental use only: G W

NSW GOVERNMENT Office of Water

Form A Particulars of completed work

Work Licence No: PB04

BORE DEVELOPMENT 8

Chemical used for breaking down drilling mud (Yes/No) No Name:

Method	Bailing/Surging		Jetting		Airlifting		Backwashing		Pumping		Other:	
Duration		hrs		hrs	1	hrs		hrs		hrs		hrs

DISINFECTION ON COMPLETION 9

Chemical(s) used	Quantity applied (Litres)	Method of application

PUMPING TESTS ON COMPLETION 10

Test type		Date	Pump intake depth (m)	Initial Water Level (SWL) (m)	Pumping rate (L/s)	Water Level at end of pumping (DDL) (m)	Duration of Test (hrs)	Recovery: Water level (m)	Recovery: Time taken (hrs)	Recovery: Time taken (mins)
Multi stage (stepped drawdown)	Stage 1									
	Stage 2									
	Stage 3									
	Stage 4									
Single stage (constant rate)										

Height of measuring point above ground level m Test Method See Code 4

WORK PARTLY BACKFILLED OR ABANDONED 11

Original depth of work: m Is work partly backfilled: (Yes/No)

Is work abandoned: (Yes/No) Method of abandonment: Backfilled Plugged Capped

Has any casing been left in the work (Yes/No) From m To m

Sealing / fill type (See Code 11)	From depth (m)	To depth (m)	Sealing / fill type (See Code 11)	From depth (m)	To depth (m)

Site chosen by: Hydrogeologist Geologist Driller Diviner Client Other 12

Lot No DP No 13

Work Location Co ordinates Easting 638887 Northing 6038528 Zone 55

GPS: (Yes/No) Yes >> AMG/AGD or MGA/GDA X (See explanation)

Please mark the work site with "X" on the CLID provided map.

Indicate also the distances in metres from two (2) adjacent boundaries, and attach the map to this Form A package.

Signatures:

Driller: ---------- **Licensee:** ----------

Date: 03/09/2018 **Date:** ----------

Work Licence No: PB04

DRILLER'S ROCK/STRATA DESCRIPTION (LITHOLOGY) — 15

Depth From (m)	Depth To (m)	Description (See Code 15)
0	1	CLAY light brown, highly weathered
1	5	CLAY light brown, highly weathered, VOLCANIC ROCK, 5% medium grey, highly oxidised
5	6	CLAY light brown, highly weathered, VOLCANIC ROCK, 50% medium grey, highly oxidised
6	14	VOLCANIC ROCK, medium greyish blue, slightly oxidised, platy
14	200	VOLCANIC ROCK, medium grey

WORK CONSTRUCTION SKETCH

WORK NOT CONSTRUCTED BY DRILLING RIG — 16

Method of excavation: Hand dug ☐ Back hoe ☐ Dragline ☐ Dozer ☐ Other

Depth (m)	Length (m)	Width (m)	Diameter (m)	Lining material	Dimentions of liner (m)	From Depth (m)	To Depth (m)

Please attach copies of the following if available — 17

Geologist log	(Yes/No) Yes	Laboratory analysis of water Sample	(Yes/No)	Pumping test(s)	(Yes/No)
Geophysical log	(Yes/No)	Sieve analysis of aquifer material	(Yes/No)	Installed Pump details	(Yes/No)

WATER BEARING ZONES												4
From (m)	To (m)	Thickness (m)	S W L (m)	Estimated Yield (L/s)		Test method		D D L at end of test (m)	Duration		Salinity (Conductivity or TDS)	
				Individual Aquifer	Cumulative	See Code 4			Hrs	min	Cond (µS/cm)	TDS (mg/L)
65	66	1	12.77	0.2	0.2	1	A				105.4	
125	126	1		0.1	0.3	1	A				44.7	
131	132	1		0.1	0.4	1	A				45.3	
173	174	1		0.1	0.5	1	A				39.2	
173	174	1		0.5	1	1	A				35.4	
179	180	1		1	1	1	A				36.2	

NSW GOVERNMENT Office of Water

Form A Particulars of completed work

Driller's Licence No:	DL1913	1
Class of Licence:	Class 4	
Driller's Name:	Ian Palk	
Assistant Driller:	Scott Fieldsend	
Contractor:	Highland Drilling	

New bore	X	Replacement bore	
Deepened		Enlarged	
Reconditioned		Other (specify)	

Final Depth: 195 m

Work Licence No:	SMB02	2
Name of Licensee:		
Intended Use:	Monitoring Bore	
Completion Date:	31-05-18	

DRILLING DETAILS (3)

From (m)	To (m)	Hole Diameter (mm)	Drilling Method (See Code 3)
0	17	168	9
17	195	140	9

WATER BEARING ZONES (4)

From (m)	To (m)	Thickness (m)	S W L (m)	Estimated Yield (L/s) Individual Aquifer	Estimated Yield (L/s) Cumulative	Test method (See Code 4)		D D L at end of test (m)	Duration Hrs	Duration min	Salinity (Conductivity or TDS) Cond (µS/cm)	Salinity (Conductivity or TDS) TDS (mg/L)
16	17	1	2.12	2	2	1	A				95.9	
22	23	1		0.5	2.5	1	A				77.8	
29	30	1		0.5	3	1	A				77	

CASING / LINER DETAILS (5)

Material Code 5	OD (mm)	Wall Thickness (mm)	From (m)	To (m)	Method Fixing Code 5
9	168	4.2	0	17	6
8	60.2	5	0	186	5

Casing support method (See Code 5): 2

Type of casing bottom (See Code 5): 2

Centralisers installed {Yes/No}	No	(indicate on sketch)					
Sump installed {Yes/No}	No	From		m	To		m
Pressure cemented {Yes/No}	No	From		m	To		m
Casing Protector cemented in place							

WATER ENTRY DESIGN (6)

General Material Code 5	OD (mm)	Wall Thickness (mm)	From (m)	To (m)	Opening type (See Code 6)	Fixing (See Code 5)	Screen Aperture (mm)	Slot Details Length (mm)	Width (mm)	Alignment (See Code 6)
8	60.2	5	186	195	5	5	0.4	20	10	H

GRAVEL PACK (7)

Type		Grade		Grain size (mm) From	Grain size (mm) To	Depth (m) From	Depth (m) To	Quantity Litres	Quantity m^3
Rounded	X	Graded	X	3	5	0	183		
Crushed		Ungraded							
Bentonite/Grout seal (Yes/No)	Yes					178	183		

Method of placement of Gravel Pack (See Code 7): 1

For Departmental use only: G W

NSW GOVERNMENT Office of Water

Form A Particulars of completed work

Work Licence No: SMB02

BORE DEVELOPMENT 8

Chemical used for breaking down drilling mud (Yes/No) No Name:

Method	Bailing/Surging		Jetting		Airlifting	X	Backwashing		Pumping		Other:	
Duration		hrs		hrs	0.5	hrs		hrs		hrs		hrs

DISINFECTION ON COMPLETION 9

Chemical(s) used	Quantity applied (Litres)	Method of application

PUMPING TESTS ON COMPLETION 10

Test type		Date	Pump intake depth (m)	Initial Water Level (SWL) (m)	Pumping rate (L/s)	Water Level at end of pumping (DDL) (m)	Duration of Test (hrs)	Recovery: Water level (m)	Recovery: Time taken (hrs)	Recovery: Time taken (mins)
Multi stage (stepped drawdown)	Stage 1									
	Stage 2									
	Stage 3									
	Stage 4									
Single stage (constant rate)										

Height of measuring point above ground level m Test Method See Code 4

WORK PARTLY BACKFILLED OR ABANDONED 11

Original depth of work: m Is work partly backfilled: (Yes/No)

Is work abandoned: (Yes/No) Method of abandonment: Backfilled Plugged Capped

Has any casing been left in the work (Yes/No) From m To m

Sealing / fill type (See Code 11)	From depth (m)	To depth (m)	Sealing / fill type (See Code 11)	From depth (m)	To depth (m)

Site chosen by: Hydrogeologist Geologist Driller Diviner Client Other 12

Lot No DP No 13

Work Location Co ordinates Easting 640640.7 Northing 6038339.9 Zone 55

GPS: (Yes/No) Yes >> AMG/AGD or MGA/GDA X (See explanation)

Please mark the work site with "X" on the CLID provided map.

Indicate also the distances in metres from two (2) adjacent boundaries, and attach the map to this Form A package.

Signatures:

Driller: ---------- **Licensee:** ----------

Date: 03/09/2018 **Date:** ----------

Work Licence No: SMB02

DRILLER'S ROCK/STRATA DESCRIPTION (LITHOLOGY) — 15

Depth From (m)	Depth To (m)	Description (See Code 15)
0	1	SOIL dark brown, organic matter present
1	2	CLAY medium brownish orange, extremely weathered, small rock fragments present
2	10	VOLCANIC ROCK medium orangey brown, extremely weathered, highly oxidised
10	12	DACITE medium greyish green, slightly weathered, indistinct foliation in larger rock frgments
12	52	VOLCANIC ROCK medium grey, fresh, minor quartz, veining
52	195	DACITE fine grained, medium to dark grey, fresh, rare quartz

WORK CONSTRUCTION SKETCH

WORK NOT CONSTRUCTED BY DRILLING RIG — 16

Method of excavation: Hand dug ☐ Back hoe ☐ Dragline ☐ Dozer ☐ Other

Depth (m)	Length (m)	Width (m)	Diameter (m)	Lining material	Dimentions of liner (m)	From Depth (m)	To Depth (m)

Please attach copies of the following if available — 17

Geologist log	(Yes/No) Yes	Laboratory analysis of water Sample	(Yes/No)	Pumping test(s)	(Yes/No)
Geophysical log	(Yes/No)	Sieve analysis of aquifer material	(Yes/No)	Installed Pump details	(Yes/No)

Form A Particulars of completed work

NSW GOVERNMENT Office of Water

Driller's Licence No:	DL1913	1
Class of Licence:	Class 4	
Driller's Name:	Ian Palk	
Assistant Driller:	Scott Fieldsend	
Contractor:	Highland Drilling	

New bore	X	Replacement bore	
Deepened		Enlarged	
Reconditioned		Other (specify)	

Final Depth: 50 m

Work Licence No:	SMB03	2
Name of Licensee:		
Intended Use:	Monitoring Bore	
Completion Date:	30-05-18	

DRILLING DETAILS (3)

From (m)	To (m)	Hole Diameter (mm)	Drilling Method See Code 3
0	16	168	9

WATER BEARING ZONES (4)

From (m)	To (m)	Thickness (m)	S W L (m)	Estimated Yield (L/s) Individual Aquifer	Estimated Yield (L/s) Cumulative	Test method See Code 4		D D L at end of test (m)	Duration Hrs	Duration min	Salinity (Conductivity or TDS) Cond (µS/cm)	Salinity (Conductivity or TDS) TDS (mg/L)
29	30	1	2.26	3	3	1	A				58.1	

CASING / LINER DETAILS (5)

Material Code 5	OD (mm)	Wall Thickness (mm)	From (m)	To (m)	Method Fixing Code 5
9	168	4.8	0	16	6
8	60.2	5	0	40	5
8	60.2	5	49	50	5

Casing support method (See Code 5): 2

Type of casing bottom (See Code 5): 2

Centralisers installed {Yes/No}	No	(indicate on sketch)					
Sump installed {Yes/No}	No	From		m	To		m
Pressure cemented {Yes/No}	No	From		m	To		m
Casing Protector cemented in place							

WATER ENTRY DESIGN (6)

General Material Code 5	OD (mm)	Wall Thickness (mm)	From (m)	To (m)	Opening type See Code 6	Fixing See Code 5	Screen Aperture (mm)	Slot Details Length (mm)	Width (mm)	Alignment See Code 6
8	60.2	5	40	49	5	5	0.4	20	10	H

GRAVEL PACK (7)

Type		Grade		Grain size (mm) From	Grain size (mm) To	Depth (m) From	Depth (m) To	Quantity Litres	Quantity m^3
Rounded	X	Graded	X	3	5	38	50		
Crushed		Ungraded							
Bentonite/Grout seal (Yes/No)	Yes					33	38		

Method of placement of Gravel Pack (See Code 7): 1

For Departmental use only: G W

NSW GOVERNMENT Office of Water

Form A Particulars of completed work

Work Licence No: SMB03

BORE DEVELOPMENT 8

Chemical used for breaking down drilling mud (Yes/No) No Name:

Method	Bailing/Surging	Jetting	Airlifting	Backwashing	Pumping	Other:
			X			
Duration	hrs	hrs	0.5 hrs	hrs	hrs	hrs

DISINFECTION ON COMPLETION 9

Chemical(s) used	Quantity applied (Litres)	Method of application

PUMPING TESTS ON COMPLETION 10

Test type		Date	Pump intake depth (m)	Initial Water Level (SWL) (m)	Pumping rate (L/s)	Water Level at end of pumping (DDL) (m)	Duration of Test (hrs)	Recovery: Water level (m)	Recovery: Time taken (hrs)	Recovery: Time taken (mins)
Multi stage (stepped drawdown)	Stage 1									
	Stage 2									
	Stage 3									
	Stage 4									
Single stage (constant rate)										

Height of measuring point above ground level m Test Method See Code 4

WORK PARTLY BACKFILLED OR ABANDONED 11

Original depth of work: m Is work partly backfilled: (Yes/No)

Is work abandoned: (Yes/No) Method of abandonment: Backfilled Plugged Capped

Has any casing been left in the work (Yes/No) From m To m

Sealing / fill type (See Code 11)	From depth (m)	To depth (m)	Sealing / fill type (See Code 11)	From depth (m)	To depth (m)

Site chosen by: Hydrogeologist Geologist Driller Diviner Client Other 12

Lot No DP No 13

Work Location Co ordinates Easting 640645.9 Northing 6038334 Zone 55

GPS: (Yes/No) Yes >> AMG/AGD or MGA/GDA X (See explanation)

Please mark the work site with "X" on the CLID provided map.

Indicate also the distances in metres from two (2) adjacent boundaries, and attach the map to this Form A package.

Signatures:

Driller: ---------- **Licensee:** ----------

Date: 03/09/2018 **Date:** ----------

NSW GOVERNMENT Office of Water

Form A Particulars of completed work

Work Licence No: SMB03

DRILLER'S ROCK/STRATA DESCRIPTION (LITHOLOGY) — 15

Depth From (m)	Depth To (m)	Description (See Code 15)
0	1	SOIL medium to dark brown, contains organic matter
1	2	CLAY orange, extremely weathered
2	18	DACITE medium to dark orange brown, extremely weathered, fractured
18	31	DACITE medium to dark grey, fresh, small fractures evident
31	32	DACITE medium to dark grey, DACITE, 5% medium orange brown, oxidised
32	48	DACITE medium to dark grey, fresh
48	50	DACITE light to medium grey, fresh

WORK CONSTRUCTION SKETCH

WORK NOT CONSTRUCTED BY DRILLING RIG — 16

Method of excavation: Hand dug ☐ Back hoe ☐ Dragline ☐ Dozer ☐ Other

Depth (m)	Length (m)	Width (m)	Diameter (m)	Lining material	Dimentions of liner (m)	From Depth (m)	To Depth (m)

Please attach copies of the following if available — 17

Geologist log	(Yes/No) ☐	Laboratory analysis of water Sample	(Yes/No) ☐	Pumping test(s)	(Yes/No) ☐
Geophysical log	(Yes/No) ☐	Sieve analysis of aquifer material	(Yes/No) ☐	Installed Pump details	(Yes/No) ☐

NSW GOVERNMENT Office of Water

Form A Particulars of completed work

Driller's Licence No:	DL1913	1
Class of Licence:	Class 4	
Driller's Name:	Ian Palk	
Assistant Driller:	Scott Fieldsend	
Contractor:		

New bore	X	Replacement bore	
Deepened		Enlarged	
Reconditioned		Other (specify)	

Final Depth: 180 m

Work Licence No:	SMB04	2
Name of Licensee:		
Intended Use:	Monitoring bore	
Completion Date:	10-05-18	

DRILLING DETAILS (3)

From (m)	To (m)	Hole Diameter (mm)	Drilling Method (See Code 3)
0	16	203	9
16	180	140	9

WATER BEARING ZONES (4)

From (m)	To (m)	Thickness (m)	S W L (m)	Estimated Yield (L/s) Individual Aquifer	Estimated Yield (L/s) Cumulative	Test method (See Code 4)		D D L at end of test (m)	Duration Hrs	Duration min	Salinity (Conductivity or TDS) Cond (µS/cm)	Salinity (Conductivity or TDS) TDS (mg/L)
			SEE	ATTACHED								

CASING / LINER DETAILS (5)

Material Code 5	OD (mm)	Wall Thickness (mm)	From (m)	To (m)	Method Fixing Code 5
5	160.25	2.8	0	16	1
8	60.2	5	0	170	5
8	60.2	5	179	180	5

Casing support method (See Code 5): 2

Type of casing bottom (See Code 5): 2

Centralisers installed {Yes/No}: No (indicate on sketch)

Sump installed {Yes/No}: Yes From 179 m To 180 m

Pressure cemented {Yes/No}: No From m To m

Casing Protector cemented in place

WATER ENTRY DESIGN (6)

General Material Code 5	OD (mm)	Wall Thickness (mm)	From (m)	To (m)	Opening type (See Code 6)	Fixing (See Code 5)	Screen Aperture (mm)	Slot Details Length (mm)	Width (mm)	Alignment (See Code 6)
8	60.2	5	170	179	5	5	0.4	20	10	H

GRAVEL PACK (7)

Type		Grade		Grain size (mm) From	Grain size (mm) To	Depth (m) From	Depth (m) To	Quantity Litres	Quantity m^3
Rounded	X	Graded	X	3	5	168	180		
Crushed		Ungraded							
Bentonite/Grout seal (Yes/No)	Yes					163	168		

Method of placement of Gravel Pack (See Code 7): 1

For Departmental use only: G W

NSW GOVERNMENT Office of Water

Form A Particulars of completed work

Work Licence No: SMB04

BORE DEVELOPMENT 8

Chemical used for breaking down drilling mud (Yes/No) No Name:

Method	Bailing/Surging		Jetting		Airlifting		Backwashing		Pumping		Other:	
Duration		hrs		hrs	1	hrs		hrs		hrs		hrs

DISINFECTION ON COMPLETION 9

Chemical(s) used	Quantity applied (Litres)	Method of application

PUMPING TESTS ON COMPLETION 10

Test type		Date	Pump intake depth (m)	Initial Water Level (SWL) (m)	Pumping rate (L/s)	Water Level at end of pumping (DDL) (m)	Duration of Test (hrs)	Recovery: Water level (m)	Recovery: Time taken (hrs)	Recovery: Time taken (mins)
Multi stage (stepped drawdown)	Stage 1									
	Stage 2									
	Stage 3									
	Stage 4									
Single stage (constant rate)										

Height of measuring point above ground level m Test Method See Code 4

WORK PARTLY BACKFILLED OR ABANDONED 11

Original depth of work: m Is work partly backfilled: (Yes/No)

Is work abandoned: (Yes/No) Method of abandonment: Backfilled Plugged Capped

Has any casing been left in the work (Yes/No) From m To m

Sealing / fill type (See Code 11)	From depth (m)	To depth (m)	Sealing / fill type (See Code 11)	From depth (m)	To depth (m)

Site chosen by: Hydrogeologist X Geologist Driller Diviner Client Other 12

Lot No DP No 13

Work Location Co ordinates Easting 638897.7 Northing 6038519.2 Zone 55

GPS: (Yes/No) Yes >> AMG/AGD or MGA/GDA X (See explanation)

Please mark the work site with "X" on the CLID provided map.

Indicate also the distances in metres from two (2) adjacent boundaries, and attach the map to this Form A package.

Signatures:

Driller: _____ **Licensee:** _____

Date: 03/09/2018 **Date:** _____

Work Licence No: SMB04

DRILLER'S ROCK/STRATA DESCRIPTION (LITHOLOGY) — 15

Depth From (m)	Depth To (m)	Description (See Code 15)
0	0.5	SOIL dark brown, extremely weathered, Contains organic matter
0.5	1	CLAY medium yellowish brown, extremely weathered
1	3	CLAY medium yellowish grey, highly weathered
3	4	CLAY medium yellowish grey, moderately weathered, small rock fragments present
4	14	VOLCANIC ROCK medium brown, slightly weathered
14	180	VOLCANIC ROCK medium grey, fresh

WORK CONSTRUCTION SKETCH

WORK NOT CONSTRUCTED BY DRILLING RIG — 16

Method of excavation: Hand dug ☐ Back hoe ☐ Dragline ☐ Dozer ☐ Other

Depth (m)	Length (m)	Width (m)	Diameter (m)	Lining material	Dimentions of liner (m)	From Depth (m)	To Depth (m)

Please attach copies of the following if available — 17

Geologist log	(Yes/No) Yes	Laboratory analysis of water Sample	(Yes/No)	Pumping test(s)	(Yes/No)
Geophysical log	(Yes/No)	Sieve analysis of aquifer material	(Yes/No)	Installed Pump details	(Yes/No)

WATER BEARING ZONES												4
From (m)	To (m)	Thickness (m)	S W L (m)	Estimated Yield (L/s)		Test method		D D L at end of test (m)	Duration		Salinity (Conductivity or TDS)	
				ndividua Aquifer	Cumulative	See Code 4			Hrs	min	Cond (µS/cm)	TDS (mg/L)
83	84	1	12.27	0.1	0.1	1	A				85.4	
101	102	1		0.1	0.2	1	A				68.9	
119	120	1		0.1	0.3	1	A				74.1	
125	126	1		0.2	0.5	1	A				68.4	
155	156	1		0.2	0.7	1	A				65.9	
173	174	1		2.3	3	1	A				91.3	

NSW GOVERNMENT Office of Water

Form A Particulars of completed work

Driller's Licence No:	DL1913	1
Class of Licence:	Class 4	
Driller's Name:	Ian Palk	
Assistant Driller:	Scott Fieldsend	
Contractor:	Highland Drilling	

New bore	X	Replacement bore	
Deepened		Enlarged	
Reconditioned		Other (specify)	

Final Depth: 50 m

Work Licence No:	SMB05	2
Name of Licensee:		
Intended Use:	Monitoring bore	
Completion Date:	14-05-18	

DRILLING DETAILS (3)

From (m)	To (m)	Hole Diameter (mm)	Drilling Method (See Code 3)
0	16	203	9
16	50	140	9

WATER BEARING ZONES (4)

From (m)	To (m)	Thickness (m)	S W L (m)	Estimated Yield (L/s) Individual Aquifer	Estimated Yield (L/s) Cumulative	Test method (See Code 4)		D D L at end of test (m)	Duration Hrs	Duration min	Salinity (Conductivity or TDS) Cond (µS/cm)	Salinity (Conductivity or TDS) TDS (mg/L)
		Drilled	18.83									
		Dry										

CASING / LINER DETAILS (5)

Material Code 5	OD (mm)	Wall Thickness (mm)	From (m)	To (m)	Method Fixing Code 5
5	160.25	2.8	0	16	1
8	60.2	5	0	40	5
8	60.2	5	49	50	5

Casing support method (See Code 5): 2

Type of casing bottom (See Code 5): 2

Centralisers installed {Yes/No}	No	(indicate on sketch)					
Sump installed {Yes/No}	Yes	From	49	m	To	50	m
Pressure cemented {Yes/No}	No	From		m	To		m
Casing Protector cemented in place							

WATER ENTRY DESIGN (6)

General Material Code 5	OD (mm)	Wall Thickness (mm)	From (m)	To (m)	Opening type (See Code 6)	Fixing (See Code 5)	Screen Aperture (mm)	Slot Details Length (mm)	Width (mm)	Alignment (See Code 6)
8	60.2	5	40	49	5	5	0.4	20	10	H

GRAVEL PACK (7)

Type		Grade		Grain size (mm) From	Grain size (mm) To	Depth (m) From	Depth (m) To	Quantity Litres	Quantity m^3
Rounded	X	Graded	X	3	5	38	50		
Crushed		Ungraded							
Bentonite/Grout seal (Yes/No)	Yes					33	38		

Method of placement of Gravel Pack (See Code 7): 1

For Departmental use only: G W

NSW GOVERNMENT Office of Water

Form A Particulars of completed work

Work Licence No: SMB05

BORE DEVELOPMENT 8

Chemical used for breaking down drilling mud (Yes/No)	No	Name:									
Method	Bailing/Surging		Jetting		Airlifting	X	Backwashing		Pumping		Other:	
Duration		hrs		hrs	1	hrs		hrs		hrs		hrs

DISINFECTION ON COMPLETION 9

Chemical(s) used	Quantity applied (Litres)	Method of application

PUMPING TESTS ON COMPLETION 10

Test type		Date	Pump intake depth (m)	Initial Water Level (SWL) (m)	Pumping rate (L/s)	Water Level at end of pumping (DDL) (m)	Duration of Test (hrs)	Recovery: Water level (m)	Recovery: Time taken (hrs)	Recovery: Time taken (mins)
Multi stage (stepped drawdown)	Stage 1									
	Stage 2									
	Stage 3									
	Stage 4									
Single stage (constant rate)										

Height of measuring point above ground level ____ m Test Method ____ See Code 4

WORK PARTLY BACKFILLED OR ABANDONED 11

Original depth of work: ____ m Is work partly backfilled: (Yes/No) ____

Is work abandoned: (Yes/No) ____ Method of abandonment: Backfilled ____ Plugged ____ Capped ____

Has any casing been left in the work (Yes/No) ____ From ____ m To ____ m

Sealing / fill type (See Code 11)	From depth (m)	To depth (m)	Sealing / fill type (See Code 11)	From depth (m)	To depth (m)

Site chosen by: Hydrogeologist X Geologist ____ Driller ____ Diviner ____ Client ____ Other ____ 12

Lot No ____ DP No ____ 13

Work Location Co ordinates Easting 638890.2 Northing 6038515.5 Zone 55

GPS: (Yes/No) Yes >> AMG/AGD ____ or MGA/GDA X (See explanation)

Please mark the work site with "X" on the CLID provided map.

Indicate also the distances in metres from two (2) adjacent boundaries, and attach the map to this Form A package.

Signatures:

Driller: _____ **Licensee:** _____

Date: 03/09/2018 **Date:** _____

Work Licence No: SMB05

DRILLER'S ROCK/STRATA DESCRIPTION (LITHOLOGY) — 15

Depth From (m)	Depth To (m)	Description (See Code 15)
0	4	No sample
4	7	VOLCANIC ROCK medium grey, moderately oxidised
7	8	VOLCANIC ROCK medium grey
8	14	VOLCANIC ROCK medium grey, moderately oxidised
14	50	VOLCANIC ROCK medium grey

WORK CONSTRUCTION SKETCH

WORK NOT CONSTRUCTED BY DRILLING RIG — 16

Method of excavation: Hand dug ☐ Back hoe ☐ Dragline ☐ Dozer ☐ Other

Depth (m)	Length (m)	Width (m)	Diameter (m)	Lining material	Dimentions of liner (m)	From Depth (m)	To Depth (m)

Please attach copies of the following if available — 17

Geologist log	(Yes/No) Yes	Laboratory analysis of water Sample	(Yes/No)	Pumping test(s)	(Yes/No)
Geophysical log	(Yes/No)	Sieve analysis of aquifer material	(Yes/No)	Installed Pump details	(Yes/No)

Appendix C

Geological and bore construction logs

www.emmconsulting.com.au
Suite 01, 20 Chandos Street
St Leonards NSW 2065
T: 02 9493 9500
F: 02 9493 9599

WATER MONITORING BORE LOG

Bore ID: PB01

Client: Snowy Hydro
Project: Snowy Hydro 2.0

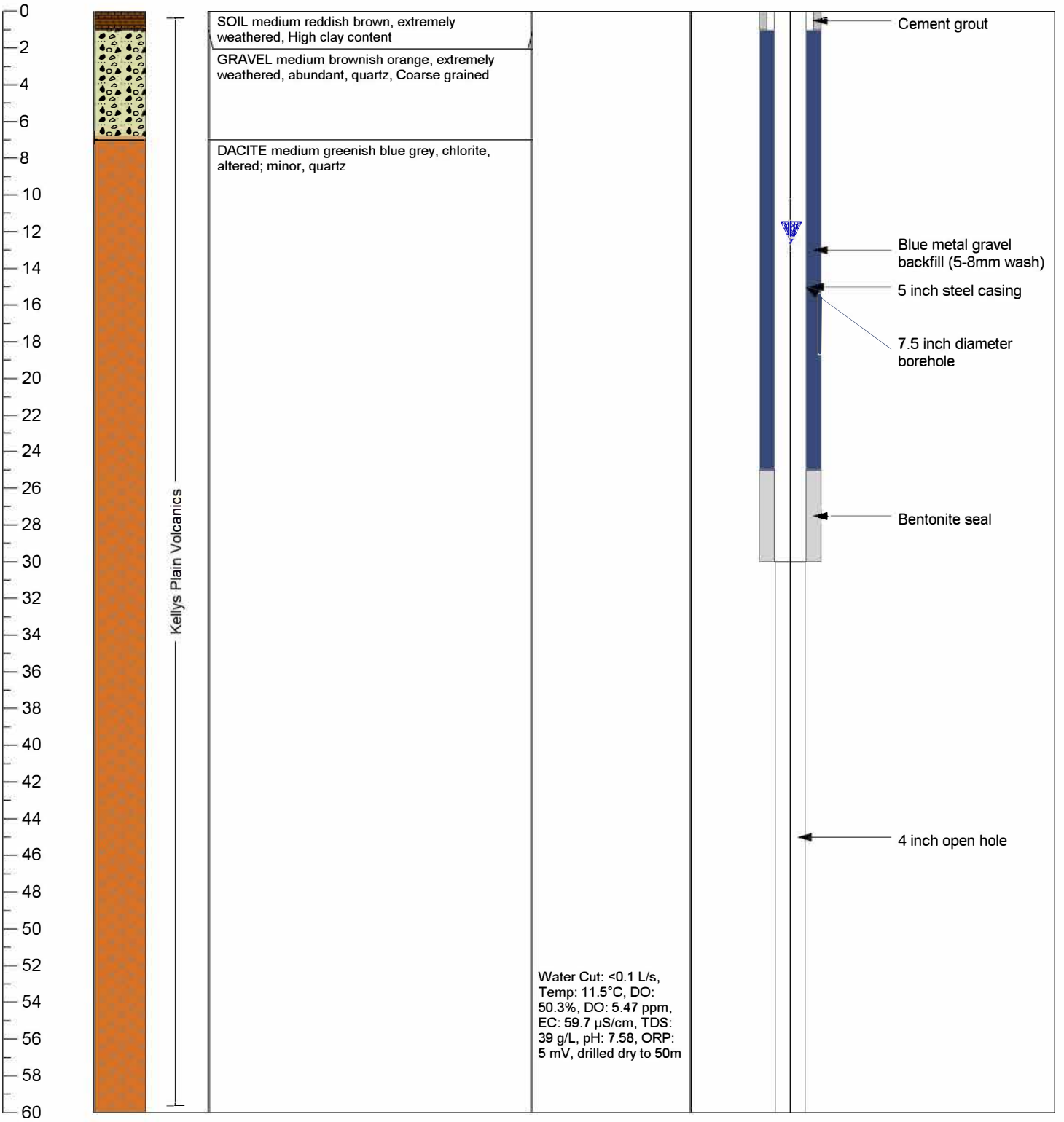
Date completed: 19/06/2018
Drilling contractor: Highland Drilling
Drilling method: Air rotary
Hydrogeologist: K Maher

Project number: J17188
Elevation: 1231.5
Easting: 649253.9
Northing: 6038163.8

Static Water Level: 12.04 mbgl
Screened Formation: Kellys Plain Volcanics
Date: 19/06/2018

Total depth: 60 m
Screened depth: 30 - 60 mbgl
Casing: 5 inch steel

Depth (mbgl)	Lithology Graphic	Description	Water Quality	Bore Completion Diagram	
				Diagram	Design notes



SOIL medium reddish brown, extremely weathered, High clay content

GRAVEL medium brownish orange, extremely weathered, abundant, quartz, Coarse grained

DACITE medium greenish blue grey, chlorite, altered; minor, quartz

Water Cut: <0.1 L/s, Temp: 11.5°C, DO: 50.3%, DO: 5.47 ppm, EC: 59.7 µS/cm, TDS: 39 g/L, pH: 7.58, ORP: 5 mV, drilled dry to 50m

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WATER MONITORING BORE LOG

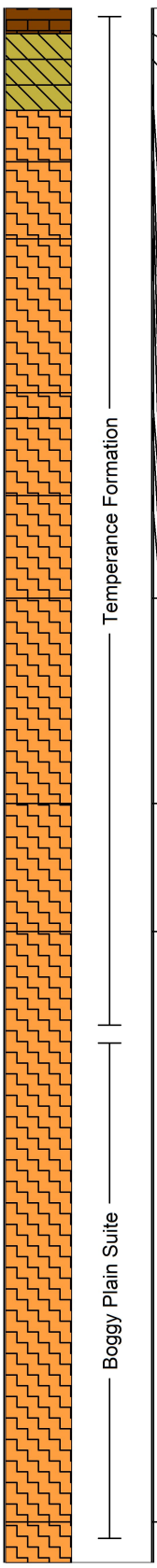
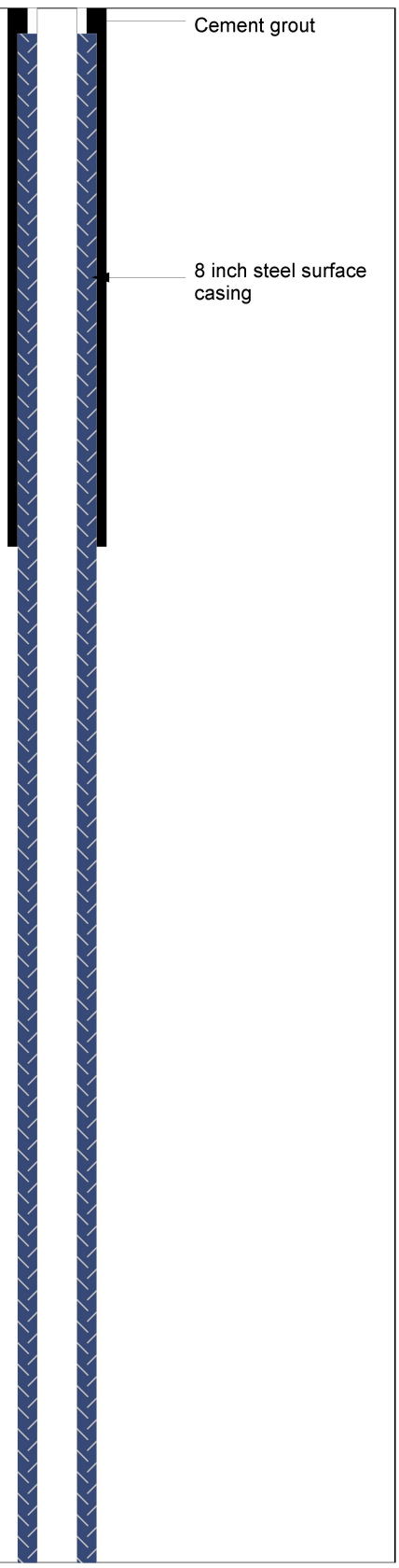
Bore ID: PB03

Client: Snowy Hydro **Project:** Snowy Hydro 2.0

Date completed:	20/06/2018	**Project number:**	J17188
Drilling contractor:	Highland Drilling	**Elevation:**	1335.6
Drilling method:	Air rotary	**Easting:**	640645.2
Hydrogeologist:	K Maher	**Northing:**	6038345.8

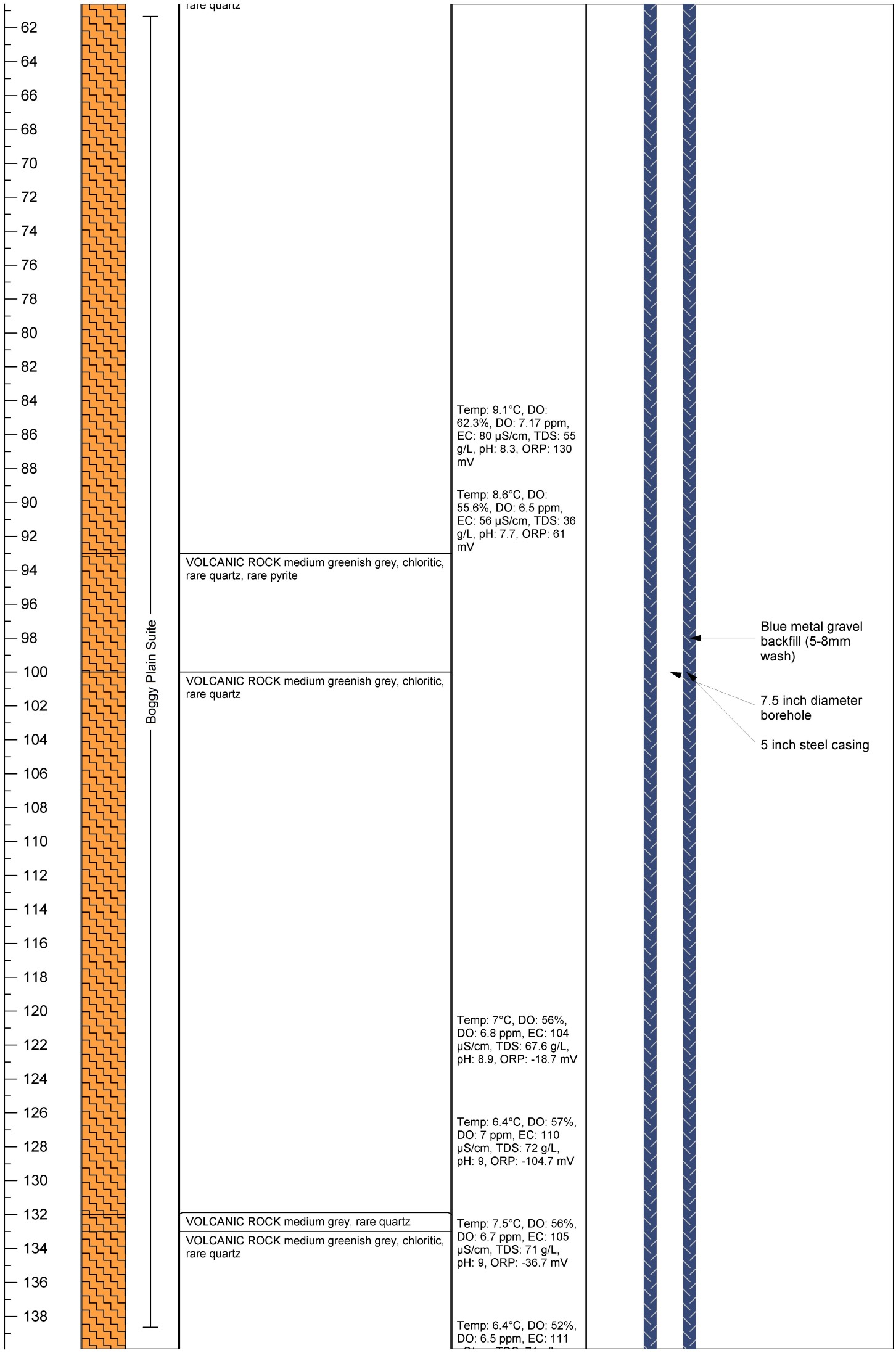
Static Water Level: 157.72 mbgl **Screened Formation:** Boggy Plain Suite **Date:** 20/06/2018

Total depth: 215 m **Screened depth:** open hole 200-215 mbgl **Casing:** 5 inch steel

Depth (mbgl)	Lithology Graphic	Description	Water Quality	Bore Completion Diagram: Diagram	Bore Completion Diagram: Design notes
0–60		SOIL dark brown, Organic matter			Cement grout
		CLAY medium brownish orange, highly weathered			
		CLAY medium brownish orange, highly weathered, VOLCANIC ROCK, 5% light greenish grey, moderately weathered, SOIL, 5% dark brownish black, highly weathered, Highly compacted soil nodules			
		CLAY medium brownish orange, highly weathered, VOLCANIC ROCK, 40% light greenish grey, moderately weathered, SOIL, 5% dark brownish black, highly weathered, Highly compacted soil nodules			8 inch steel surface casing
		VOLCANIC ROCK light greenish grey, moderately weathered, CLAY, 40% medium brownish orange, highly weathered			
		VOLCANIC ROCK light greenish grey, moderately weathered, CLAY, 10% medium brownish orange, highly weathered			
		VOLCANIC ROCK light greenish grey, moderately oxidised			
		VOLCANIC ROCK light greenish grey, moderately oxidised, platy			
		VOLCANIC ROCK medium greenish grey, moderately oxidised, chloritic, rare quatrz veins			
		VOLCANIC ROCK dark grey, slightly oxidised			
		VOLCANIC ROCK medium greenish grey, slightly oxidised, rare quartz	Temp: 9.7°C, DO: 78.8%, DO: 8.81 ppm, EC: 70.1 µS/cm, TDS: 45.5 g/L, pH: 7.39, ORP: 88.2 mV		
		VOLCANIC ROCK medium greenish grey, slightly oxidised, rare quartz	Temp: 10.7°C, DO: 64.2%, DO: 7.13 ppm, EC: 70.6 µS/cm, TDS: 46.15 g/L, pH: 8.37, ORP: 90.7 mV		
		VOLCANIC ROCK medium greenish grey, rare quartz	Temp: 11.4°C, DO: 57.9%, DO: 6.32 ppm, EC: 62.6 µS/cm, TDS: 40.9 g/L, pH: 8.12, ORP: 80.7 mV		
			Temp: 11.1°C, DO: 53.2%, DO: 5.85 ppm, EC: 71.9 µS/cm, TDS: 46.8 g/L, pH: 8.59, ORP: 71.8 mV		
			Temp: 11.1°C, DO: 50.3%, DO: 5.52 ppm, EC: 78.1 µS/cm, TDS: 50.7 g/L, pH: 8.79, ORP: 60.1 mV		
		VOLCANIC ROCK medium greenish grey, chloritic, rare quartz			

Temperance Formation

Boggy Plain Suite


rare quartz
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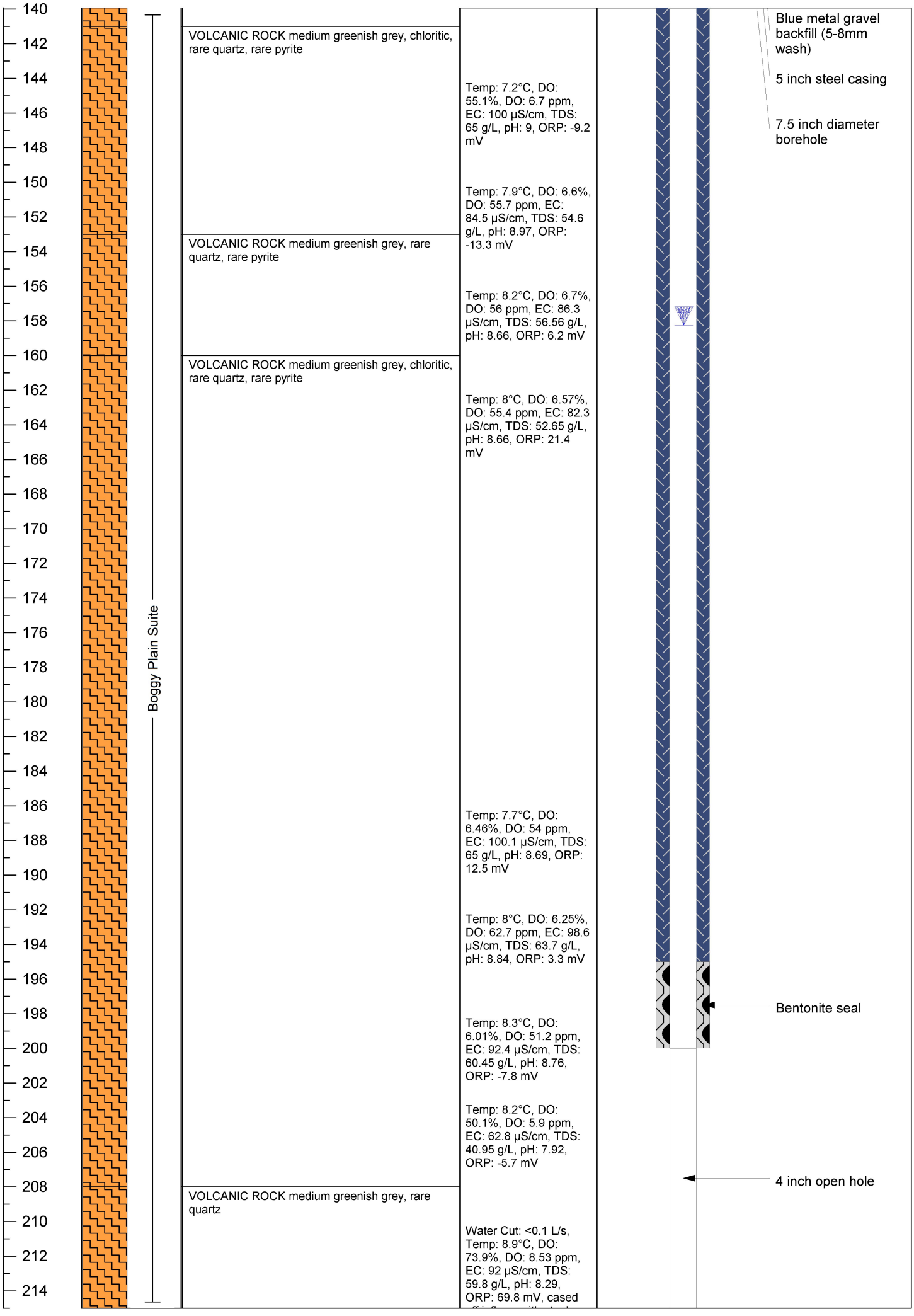
Boggy Plain Suite
VOLCANIC ROCK medium greenish grey, chloritic, rare quartz, rare pyrite
VOLCANIC ROCK medium greenish grey, chloritic, rare quartz
VOLCANIC ROCK medium grey, rare quartz
VOLCANIC ROCK medium greenish grey, chloritic, rare quartz
Temp: 9.1°C, DO: 62.3%, DO: 7.17 ppm, EC: 80 µS/cm, TDS: 55 g/L, pH: 8.3, ORP: 130 mV
Temp: 8.6°C, DO: 55.6%, DO: 6.5 ppm, EC: 56 µS/cm, TDS: 36 g/L, pH: 7.7, ORP: 61 mV
Temp: 7°C, DO: 56%, DO: 6.8 ppm, EC: 104 µS/cm, TDS: 67.6 g/L, pH: 8.9, ORP: -18.7 mV
Temp: 6.4°C, DO: 57%, DO: 7 ppm, EC: 110 µS/cm, TDS: 72 g/L, pH: 9, ORP: -104.7 mV
Temp: 7.5°C, DO: 56%, DO: 6.7 ppm, EC: 105 µS/cm, TDS: 71 g/L, pH: 9, ORP: -36.7 mV
Temp: 6.4°C, DO: 52%, DO: 6.5 ppm, EC: 111
Blue metal gravel backfill (5-8mm wash)
7.5 inch diameter borehole
5 inch steel casing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Boggy Plain Suite
VOLCANIC ROCK medium greenish grey, chloritic, rare quartz, rare pyrite
VOLCANIC ROCK medium greenish grey, rare quartz, rare pyrite
VOLCANIC ROCK medium greenish grey, chloritic, rare quartz, rare pyrite
VOLCANIC ROCK medium greenish grey, rare quartz
Temp: 7.2°C, DO: 55.1%, DO: 6.7 ppm, EC: 100 µS/cm, TDS: 65 g/L, pH: 9, ORP: -9.2 mV
Temp: 7.9°C, DO: 6.6%, DO: 55.7 ppm, EC: 84.5 µS/cm, TDS: 54.6 g/L, pH: 8.97, ORP: -13.3 mV
Temp: 8.2°C, DO: 6.7%, DO: 56 ppm, EC: 86.3 µS/cm, TDS: 56.56 g/L, pH: 8.66, ORP: 6.2 mV
Temp: 8°C, DO: 6.57%, DO: 55.4 ppm, EC: 82.3 µS/cm, TDS: 52.65 g/L, pH: 8.66, ORP: 21.4 mV
Temp: 7.7°C, DO: 6.46%, DO: 54 ppm, EC: 100.1 µS/cm, TDS: 65 g/L, pH: 8.69, ORP: 12.5 mV
Temp: 8°C, DO: 6.25%, DO: 62.7 ppm, EC: 98.6 µS/cm, TDS: 63.7 g/L, pH: 8.84, ORP: 3.3 mV
Temp: 8.3°C, DO: 6.01%, DO: 51.2 ppm, EC: 92.4 µS/cm, TDS: 60.45 g/L, pH: 8.76, ORP: -7.8 mV
Temp: 8.2°C, DO: 50.1%, DO: 5.9 ppm, EC: 62.8 µS/cm, TDS: 40.95 g/L, pH: 7.92, ORP: -5.7 mV
Water Cut: <0.1 L/s, Temp: 8.9°C, DO: 73.9%, DO: 8.53 ppm, EC: 92 µS/cm, TDS: 59.8 g/L, pH: 8.29, ORP: 69.8 mV, cased
Blue metal gravel backfill (5-8mm wash)
5 inch steel casing
7.5 inch diameter borehole
Bentonite seal
4 inch open hole

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WATER MONITORING BORE LOG

Bore ID: SMB02

Client: Snowy Hydro **Project:** Snowy Hydro 2.0

Date completed:	31/05/2018	**Project number:**	J17188
Drilling contractor:	Highland Drilling	**Elevation:**	1334.8
Drilling method:	Air rotary	**Easting:**	640640.7
Hydrogeologist:	S Cassidy	**Northing:**	6038339.9

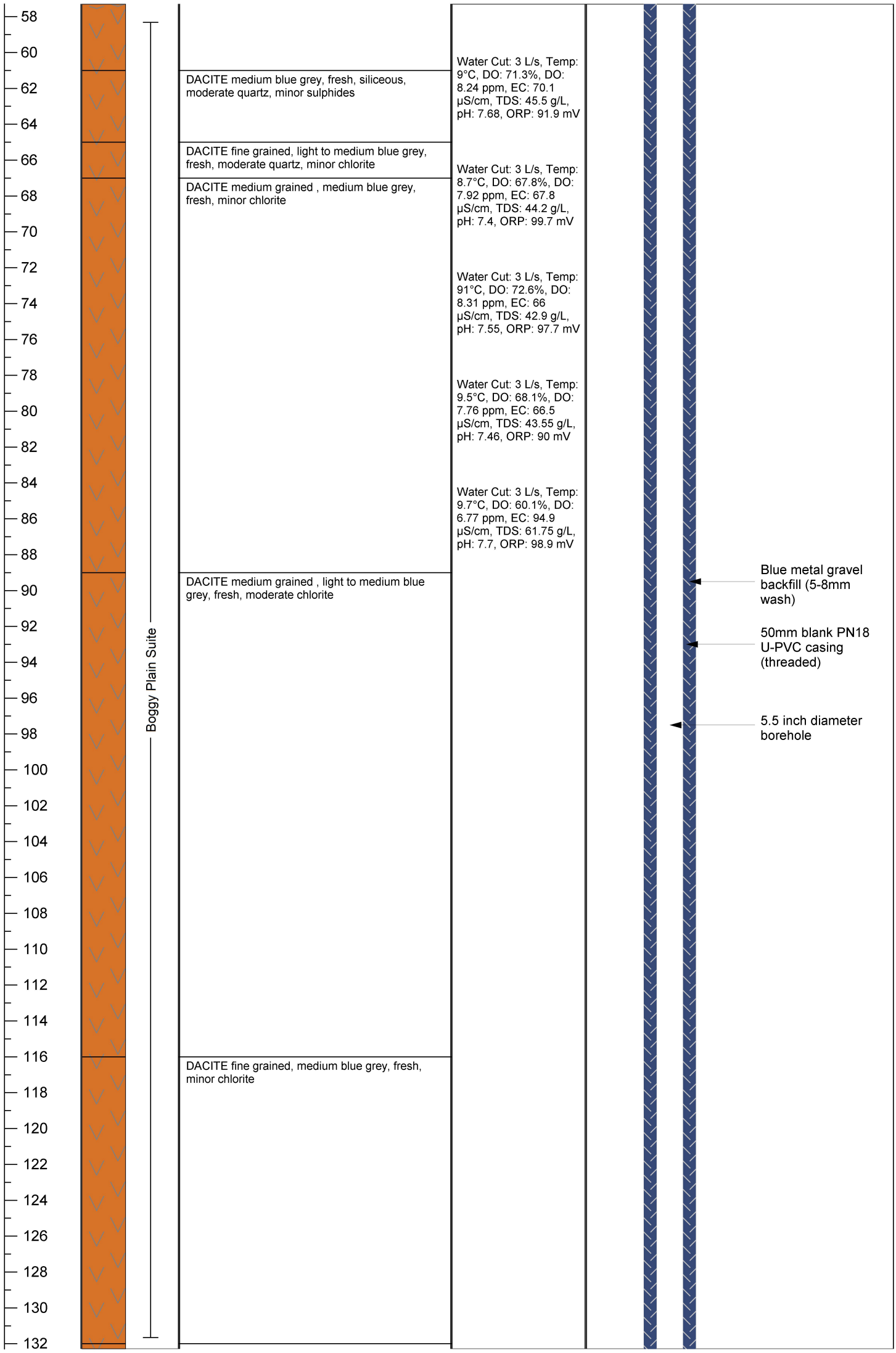
Static Water Level: 2.12 mbgl **Screened Formation:** Boggy Plain Suite **Date:** 31/05/2018

Total depth: 195 m **Screened depth:** 182 - 194 mbgl **Casing:** 50 mm PVC

Depth (mbgl)	Lithology Graphic	Description	Water Quality	Bore Completion Diagram: Diagram	Bore Completion Diagram: Design notes
0–2		SOIL dark brown, organic matter present		Cement grout	
2–10		CLAY medium brownish orange, extremely weathered, small rock fragments present			
4–10		VOLCANIC ROCK medium orangey brown, extremely weathered, highly oxidised		6 inch steel surface casing	
10–12		DACITE medium greyish green, slightly weathered, indistinct foliation in larger rock frgments			
12–22		VOLCANIC ROCK medium to dark grey, fresh, minor quartz, minor chlorite, veining	no samples during odex install Water Cut: 2 L/s, Temp: 7.8°C, DO: 61.6%, DO: 7.27 ppm, EC: 95.9 µS/cm, TDS: 62.4 g/L, pH: 6.07, ORP: 44 mV		
22–24		VOLCANIC ROCK medium to dark grey, slightly oxidised, orange brown oxidatiion stains on broken surfaces and large frgments indicate presence of fracture	Water Cut: 2.5 L/s, fracture 23-24 m , fracture 24-25 m		
24–36		VOLCANIC ROCK medium grey, fresh, minor quartz, veining	Water Cut: 2.5 L/s, Temp: 8.9°C, DO: 72.2%, DO: 8.42 ppm, EC: 77.8 µS/cmTDS: 50.7 g/LpH: 6.82ORP: 77.8 mV Water Cut: 3 L/s, Temp: 8.9°C, DO: 73.5%, DO: 8.5 ppm, EC: 77 µS/cm, TDS: 50.05 g/L, pH: 7.49, ORP: 76.2 mV		
36–38		VOLCANIC ROCK medium grey, slightly oxidised, siliceous, hard; brown oxidation staining on broken surfaces	Water Cut: 3 L/s, Temp: 9.3°C, DO: 72.3%, DO: 8.29 ppm, EC: 73 µS/cm, TDS: 47.45 g/L, pH: 7.33, ORP: 86.6 mV		
38–52		VOLCANIC ROCK medium grey, fresh, hard, minor quartz	Water Cut: 3 L/s, Temp: 9.1°C, DO: 75.2%, DO: 8.66 ppm, EC: 82.3 µS/cm, TDS: 53.3 g/L, pH: 8.35, ORP: 74.9 mV Water Cut: 3 L/s, Temp: 9.3°C, DO: 72.7%, DO: 8.35 ppm, EC: 78.7 µS/cm, TDS: 51.35 g/L, pH: 8.14, ORP: 80.1 mV		
52–56		DACITE medium greenish blue grey, fresh, minor chlorite	Water Cut: 3 L/s, Temp: 9.7°C, DO: 72.6%, DO: 8.25 ppm, EC: 71.4 µS/cm, TDS: 46.15 g/L,		

Temperance Formation

BPS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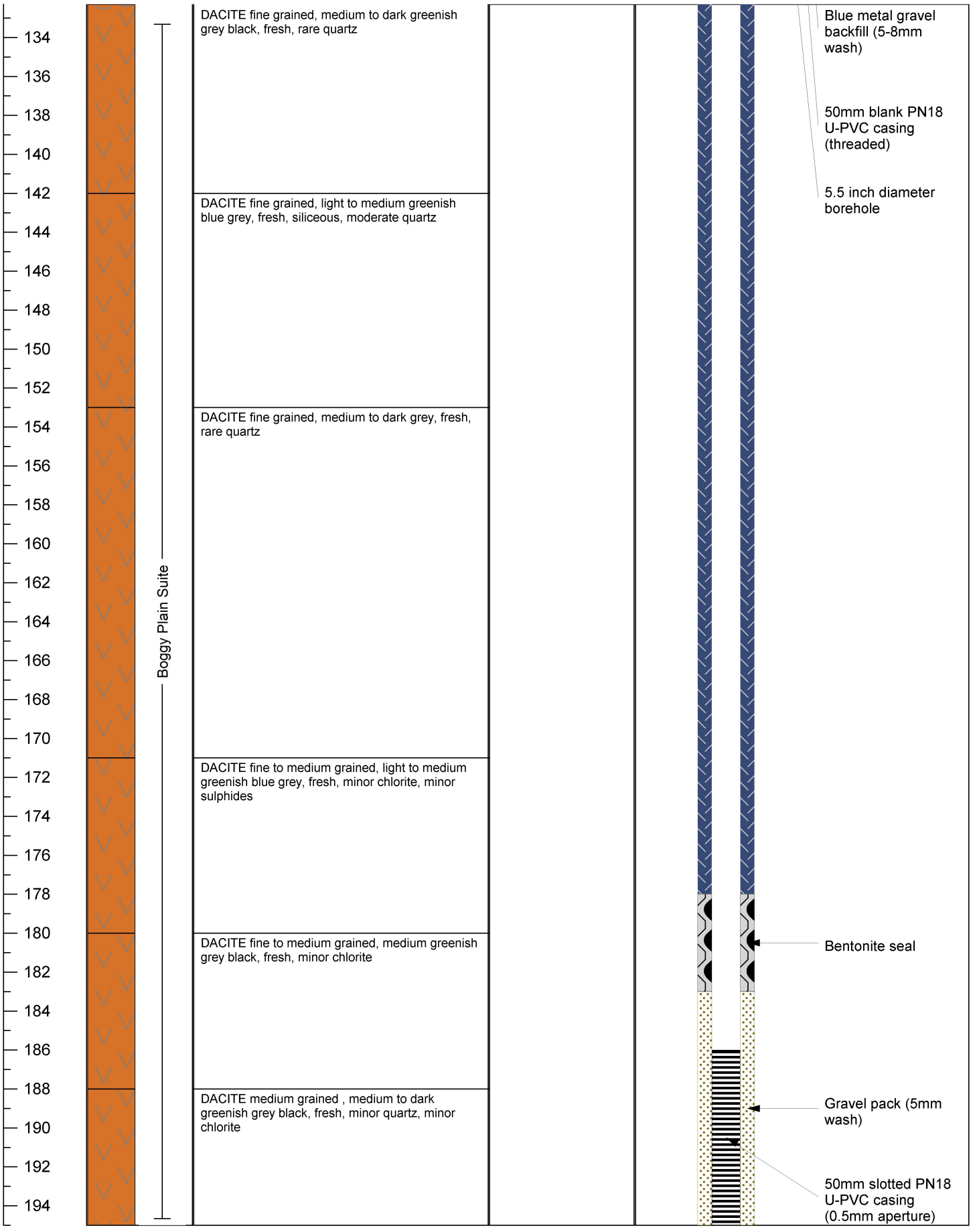
Boggy Plain Suite
DACITE medium blue grey, fresh, siliceous, moderate quartz, minor sulphides
DACITE fine grained, light to medium blue grey, fresh, moderate quartz, minor chlorite
DACITE medium grained , medium blue grey, fresh, minor chlorite
DACITE medium grained , light to medium blue grey, fresh, moderate chlorite
DACITE fine grained, medium blue grey, fresh, minor chlorite
Water Cut: 3 L/s, Temp: 9°C, DO: 71.3%, DO: 8.24 ppm, EC: 70.1 µS/cm, TDS: 45.5 g/L, pH: 7.68, ORP: 91.9 mV
Water Cut: 3 L/s, Temp: 8.7°C, DO: 67.8%, DO: 7.92 ppm, EC: 67.8 µS/cm, TDS: 44.2 g/L, pH: 7.4, ORP: 99.7 mV
Water Cut: 3 L/s, Temp: 91°C, DO: 72.6%, DO: 8.31 ppm, EC: 66 µS/cm, TDS: 42.9 g/L, pH: 7.55, ORP: 97.7 mV
Water Cut: 3 L/s, Temp: 9.5°C, DO: 68.1%, DO: 7.76 ppm, EC: 66.5 µS/cm, TDS: 43.55 g/L, pH: 7.46, ORP: 90 mV
Water Cut: 3 L/s, Temp: 9.7°C, DO: 60.1%, DO: 6.77 ppm, EC: 94.9 µS/cm, TDS: 61.75 g/L, pH: 7.7, ORP: 98.9 mV
Blue metal gravel backfill (5-8mm wash)
50mm blank PN18 U-PVC casing (threaded)
5.5 inch diameter borehole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Boggy Plain Suite
DACITE fine grained, medium to dark greenish grey black, fresh, rare quartz
DACITE fine grained, light to medium greenish blue grey, fresh, siliceous, moderate quartz
DACITE fine grained, medium to dark grey, fresh, rare quartz
DACITE fine to medium grained, light to medium greenish blue grey, fresh, minor chlorite, minor sulphides
DACITE fine to medium grained, medium greenish grey black, fresh, minor chlorite
DACITE medium grained , medium to dark greenish grey black, fresh, minor quartz, minor chlorite
Blue metal gravel backfill (5-8mm wash)
50mm blank PN18 U-PVC casing (threaded)
5.5 inch diameter borehole
Bentonite seal
Gravel pack (5mm wash)
50mm slotted PN18 U-PVC casing (0.5mm aperture)

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WATER MONITORING BORE LOG

Bore ID: SMB03

Client: Snowy Hydro **Project:** Snowy Hydro 2.0

Date completed:	30/05/2018	**Project number:**	J17188
Drilling contractor:	Highland Drilling	**Elevation:**	1334.7
Drilling method:	Air rotary	**Easting:**	640645.9
Hydrogeologist:	K Maher	**Northing:**	6038334

Static Water Level: 2.26 mbgl **Screened Formation:** Temperance Formation **Date:** 30/05/2018

Total depth: 50 m **Screened depth:** 40 - 49 mbgl **Casing:** 50 mm PVC

Depth (mbgl)	Lithology Graphic	Description	Water Quality	Bore Completion Diagram: Diagram	Bore Completion Diagram: Design notes
0–2		SOIL medium to dark brown, contains organic matter			Cement grout
2–4		CLAY orange, extremely weathered			
4–18		DACITE medium to dark orange brown, extremely weathered, fractured	Temp: 9.3°C, DO: 53.9%, DO: 6.18 ppm, EC: 87 µS/cm, TDS: 56.55 g/L, pH: 7.35, ORP: 130.3 mV		6 inch steel surface casing
18–30		DACITE medium to dark grey, fresh, small fractures evident	Temp: 8.7°C, DO: 57.2%, DO: 6.66 ppm, EC: 73.5 µS/cm, TDS: 48.1 g/L, pH: 6.91, ORP: 109.3 mV		Blue metal gravel backfill (5-8mm wash) 50mm blank PN18 U-PVC casing (threaded) 5 1/2 inch diameter borehole
30–32		DACITE medium to dark grey, DACITE, 5% medium orange brown, oxidised, evidence of water bearing fractures	Water Cut: 3 L/s, Temp: 9.1°C, DO: 53.8%, DO: 6.21 ppm, EC: 58.1 µS/cm, TDS: 37.7 g/L, pH: 7.35, ORP: 78.5 mV		
32–48		DACITE medium to dark grey, fresh	Water Cut: 3 L/s, Temp: 9.3°C, DO: 52.7%, DO: 6.05 ppm, EC: 69.7 µS/cm, TDS: 45.5 g/L, pH: 8.2, ORP: 65.1 mV		Bentonite seal Gravel pack (5mm wash) 50mm slotted PN18 U-PVC casing (0.5mm aperture)
48–50		DACITE light to medium grey, fresh	Water Cut: 3 L/s, Temp: 9.3°C, DO: 51.5%, DO: 5.91 ppm, EC: 57.7		50mm blank PN18 U-PVC sump (threaded)

Temperance Formation

BPS

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WATER MONITORING BORE LOG

Bore ID: PB04

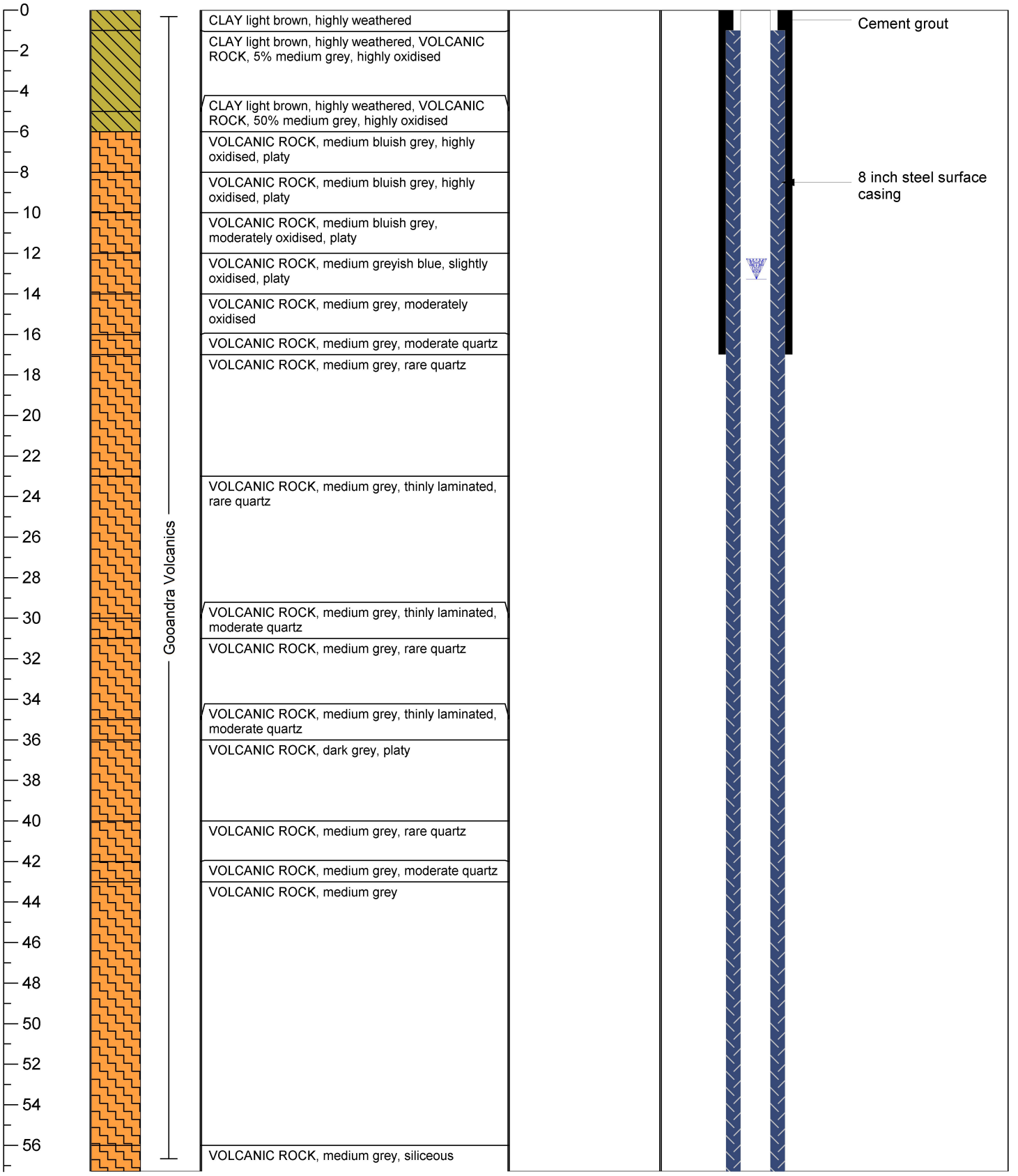
Client: Snowy Hydro **Project:** Snowy Hydro 2.0

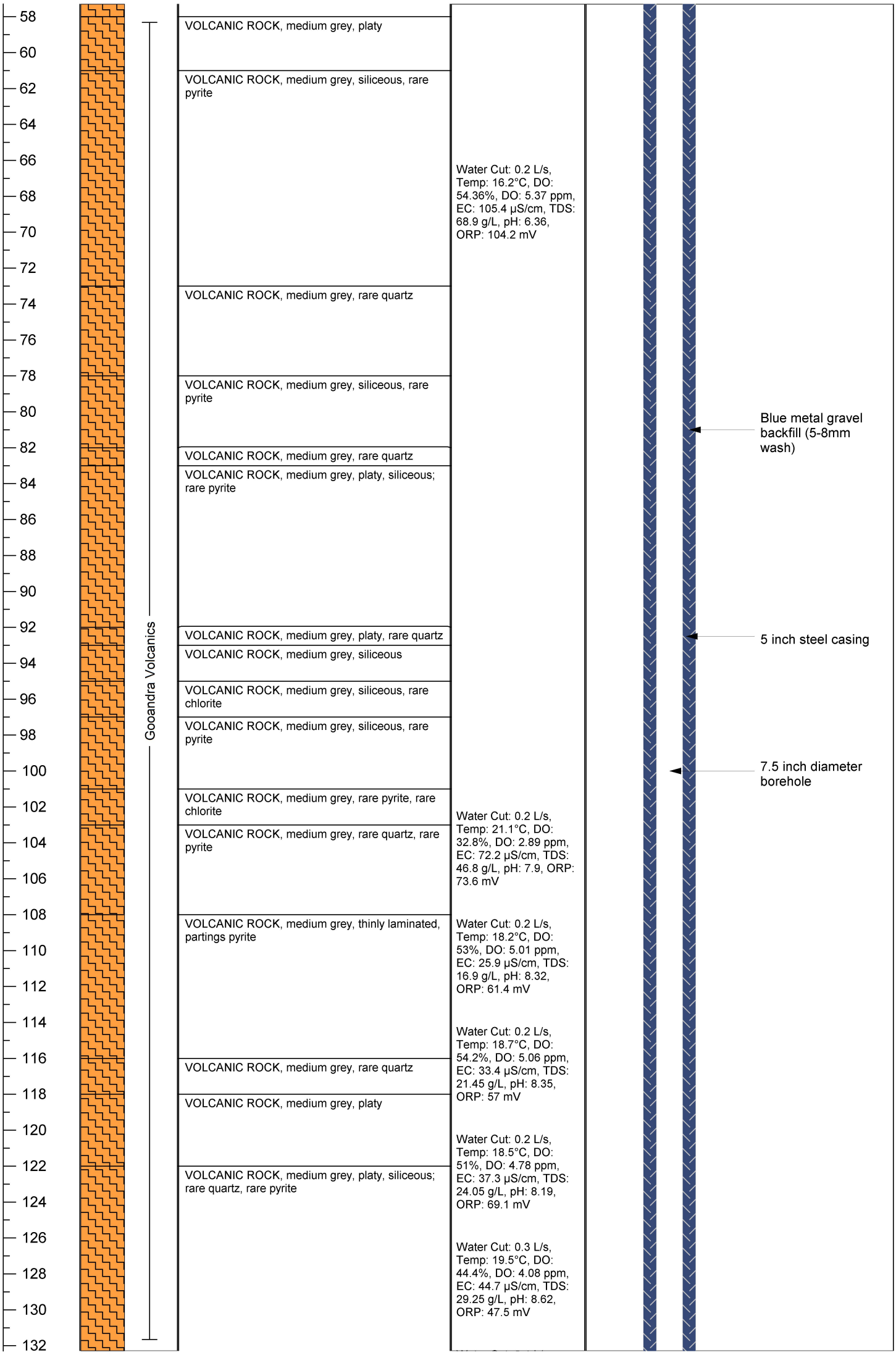
Date completed:	23/05/2018	**Project number:**	J17188
Drilling contractor:	Highland Drilling	**Elevation:**	1341.3
Drilling method:	Air rotary	**Easting:**	638887.2
Hydrogeologist:	I Cywinski-Jan	**Northing:**	6038527.3

Static Water Level: 12.77 mbgl **Screened Formation:** Gooandra Volcanics **Date:** 23/05/2018

Total depth: 200 m **Screened depth:** 185 - 200 mbgl **Casing:** 5 inch steel

Depth (mbgl)	Lithology Graphic	Description	Water Quality	Bore Completion Diagram	
				Diagram	Design notes

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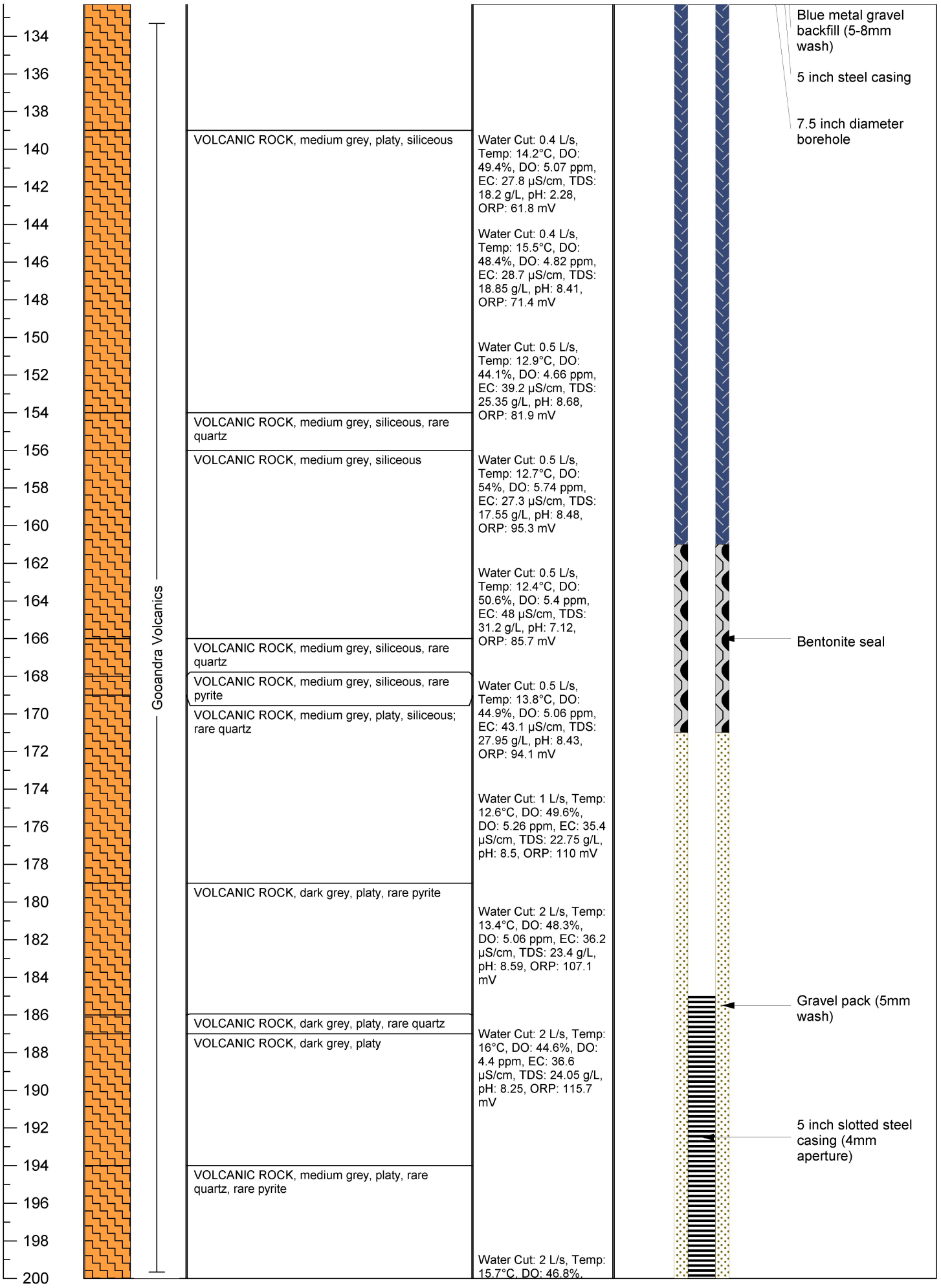
Gooandra Volcanics
VOLCANIC ROCK, medium grey, platy
VOLCANIC ROCK, medium grey, siliceous, rare pyrite
VOLCANIC ROCK, medium grey, rare quartz
VOLCANIC ROCK, medium grey, siliceous, rare pyrite
VOLCANIC ROCK, medium grey, rare quartz
VOLCANIC ROCK, medium grey, platy, siliceous; rare pyrite
VOLCANIC ROCK, medium grey, platy, rare quartz
VOLCANIC ROCK, medium grey, siliceous
VOLCANIC ROCK, medium grey, siliceous, rare chlorite
VOLCANIC ROCK, medium grey, siliceous, rare pyrite
VOLCANIC ROCK, medium grey, rare pyrite, rare chlorite
VOLCANIC ROCK, medium grey, rare quartz, rare pyrite
VOLCANIC ROCK, medium grey, thinly laminated, partings pyrite
VOLCANIC ROCK, medium grey, rare quartz
VOLCANIC ROCK, medium grey, platy
VOLCANIC ROCK, medium grey, platy, siliceous; rare quartz, rare pyrite
Water Cut: 0.2 L/s, Temp: 16.2°C, DO: 54.36%, DO: 5.37 ppm, EC: 105.4 µS/cm, TDS: 68.9 g/L, pH: 6.36, ORP: 104.2 mV
Water Cut: 0.2 L/s, Temp: 21.1°C, DO: 32.8%, DO: 2.89 ppm, EC: 72.2 µS/cm, TDS: 46.8 g/L, pH: 7.9, ORP: 73.6 mV
Water Cut: 0.2 L/s, Temp: 18.2°C, DO: 53%, DO: 5.01 ppm, EC: 25.9 µS/cm, TDS: 16.9 g/L, pH: 8.32, ORP: 61.4 mV
Water Cut: 0.2 L/s, Temp: 18.7°C, DO: 54.2%, DO: 5.06 ppm, EC: 33.4 µS/cm, TDS: 21.45 g/L, pH: 8.35, ORP: 57 mV
Water Cut: 0.2 L/s, Temp: 18.5°C, DO: 51%, DO: 4.78 ppm, EC: 37.3 µS/cm, TDS: 24.05 g/L, pH: 8.19, ORP: 69.1 mV
Water Cut: 0.3 L/s, Temp: 19.5°C, DO: 44.4%, DO: 4.08 ppm, EC: 44.7 µS/cm, TDS: 29.25 g/L, pH: 8.62, ORP: 47.5 mV
Blue metal gravel backfill (5-8mm wash)
5 inch steel casing
7.5 inch diameter borehole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Gooandra Volcanics
VOLCANIC ROCK, medium grey, platy, siliceous
VOLCANIC ROCK, medium grey, siliceous, rare quartz
VOLCANIC ROCK, medium grey, siliceous
VOLCANIC ROCK, medium grey, siliceous, rare quartz
VOLCANIC ROCK, medium grey, siliceous, rare pyrite
VOLCANIC ROCK, medium grey, platy, siliceous; rare quartz
VOLCANIC ROCK, dark grey, platy, rare pyrite
VOLCANIC ROCK, dark grey, platy, rare quartz
VOLCANIC ROCK, dark grey, platy
VOLCANIC ROCK, medium grey, platy, rare quartz, rare pyrite
Water Cut: 0.4 L/s, Temp: 14.2°C, DO: 49.4%, DO: 5.07 ppm, EC: 27.8 µS/cm, TDS: 18.2 g/L, pH: 2.28, ORP: 61.8 mV
Water Cut: 0.4 L/s, Temp: 15.5°C, DO: 48.4%, DO: 4.82 ppm, EC: 28.7 µS/cm, TDS: 18.85 g/L, pH: 8.41, ORP: 71.4 mV
Water Cut: 0.5 L/s, Temp: 12.9°C, DO: 44.1%, DO: 4.66 ppm, EC: 39.2 µS/cm, TDS: 25.35 g/L, pH: 8.68, ORP: 81.9 mV
Water Cut: 0.5 L/s, Temp: 12.7°C, DO: 54%, DO: 5.74 ppm, EC: 27.3 µS/cm, TDS: 17.55 g/L, pH: 8.48, ORP: 95.3 mV
Water Cut: 0.5 L/s, Temp: 12.4°C, DO: 50.6%, DO: 5.4 ppm, EC: 48 µS/cm, TDS: 31.2 g/L, pH: 7.12, ORP: 85.7 mV
Water Cut: 0.5 L/s, Temp: 13.8°C, DO: 44.9%, DO: 5.06 ppm, EC: 43.1 µS/cm, TDS: 27.95 g/L, pH: 8.43, ORP: 94.1 mV
Water Cut: 1 L/s, Temp: 12.6°C, DO: 49.6%, DO: 5.26 ppm, EC: 35.4 µS/cm, TDS: 22.75 g/L, pH: 8.5, ORP: 110 mV
Water Cut: 2 L/s, Temp: 13.4°C, DO: 48.3%, DO: 5.06 ppm, EC: 36.2 µS/cm, TDS: 23.4 g/L, pH: 8.59, ORP: 107.1 mV
Water Cut: 2 L/s, Temp: 16°C, DO: 44.6%, DO: 4.4 ppm, EC: 36.6 µS/cm, TDS: 24.05 g/L, pH: 8.25, ORP: 115.7 mV
Water Cut: 2 L/s, Temp: 15.7°C, DO: 46.8%,
Blue metal gravel backfill (5-8mm wash)
5 inch steel casing
7.5 inch diameter borehole
Bentonite seal
Gravel pack (5mm wash)
5 inch slotted steel casing (4mm aperture)

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WATER MONITORING BORE LOG

Bore ID: SMB04

Client: Snowy Hydro **Project:** Snowy Hydro 2.0

Date completed:	10/05/2018	**Project number:**	J17188
Drilling contractor:	Highland Drilling	**Elevation:**	1341.6
Drilling method:	Air rotary	**Easting:**	638897.7
Hydrogeologist:	K Maher	**Northing:**	6038519.2

Static Water Level: 12.27 mbgl **Screened Formation:** Gooandra Volcanics **Date:** 10/05/2018

Total depth: 180 m **Screened depth:** 170 - 179 mbgl **Casing:** 50 mm PVC

Depth (mbgl)	Lithology Graphic	Description	Water Quality	Bore Completion Diagram: Diagram	Bore Completion Diagram: Design notes
0		SOIL dark brown, extremely weathered, Contains organic matter			
2		CLAY medium yellowish brown, extremely weathered			
		CLAY medium yellowish grey, highly weathered			
4		CLAY medium yellowish grey, moderately weathered, small rock fragments present			
		VOLCANIC ROCK medium yellowish brown, moderately weathered, VOLCANIC ROCK, 50% medium bluish grey, moderately weathered			
6					
		VOLCANIC ROCK medium brown, slightly weathered			
8		VOLCANIC ROCK medium yellowish brown, slightly oxidised, VOLCANIC ROCK, 50% medium bluish grey, slightly oxidised, platy			
		VOLCANIC ROCK dark greyish brown, fresh, easily broken by hand			
10		VOLCANIC ROCK medium yellowish brown, slightly oxidised			
		VOLCANIC ROCK medium yellowish grey, slightly oxidised			
12		VOLCANIC ROCK medium yellowish brown, slightly oxidised			
		VOLCANIC ROCK medium bluish grey, fresh, VOLCANIC ROCK, 20% medium brown, slightly oxidised			
14		VOLCANIC ROCK medium brown, slightly oxidised, VOLCANIC ROCK, 40% medium bluish grey, fresh			
		VOLCANIC ROCK dark bluish grey, fresh, platy, hard	Started injecting water at 18m due to dust. No noticable fractures intercepted. Insufficient volumes to sample at end of rods 18-66m		
16					
		VOLCANIC ROCK medium grey, fresh			
18		VOLCANIC ROCK dark bluish grey, fresh, rare quartz			
20					
		VOLCANIC ROCK medium bluish grey, fresh			
22		VOLCANIC ROCK light grey, fresh, siliceous, hard; rare quartz			
24					
		VOLCANIC ROCK medium grey, fresh			
26		VOLCANIC ROCK medium grey, fresh, rare quartz			
28					
		VOLCANIC ROCK medium grey, fresh			
30		VOLCANIC ROCK medium grey, fresh			
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34					
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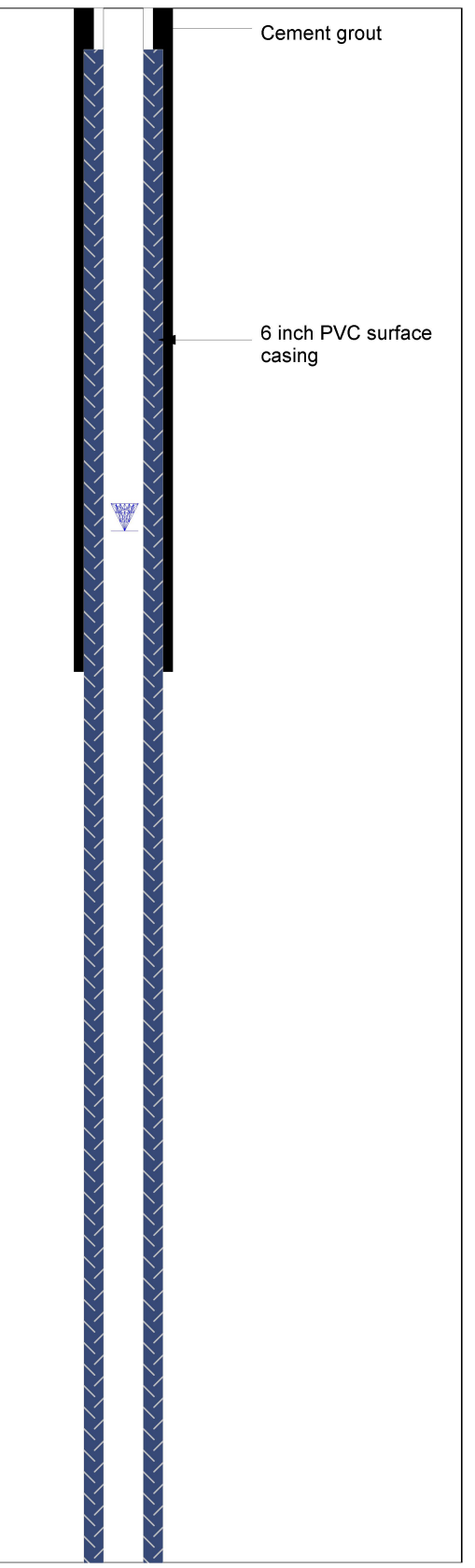
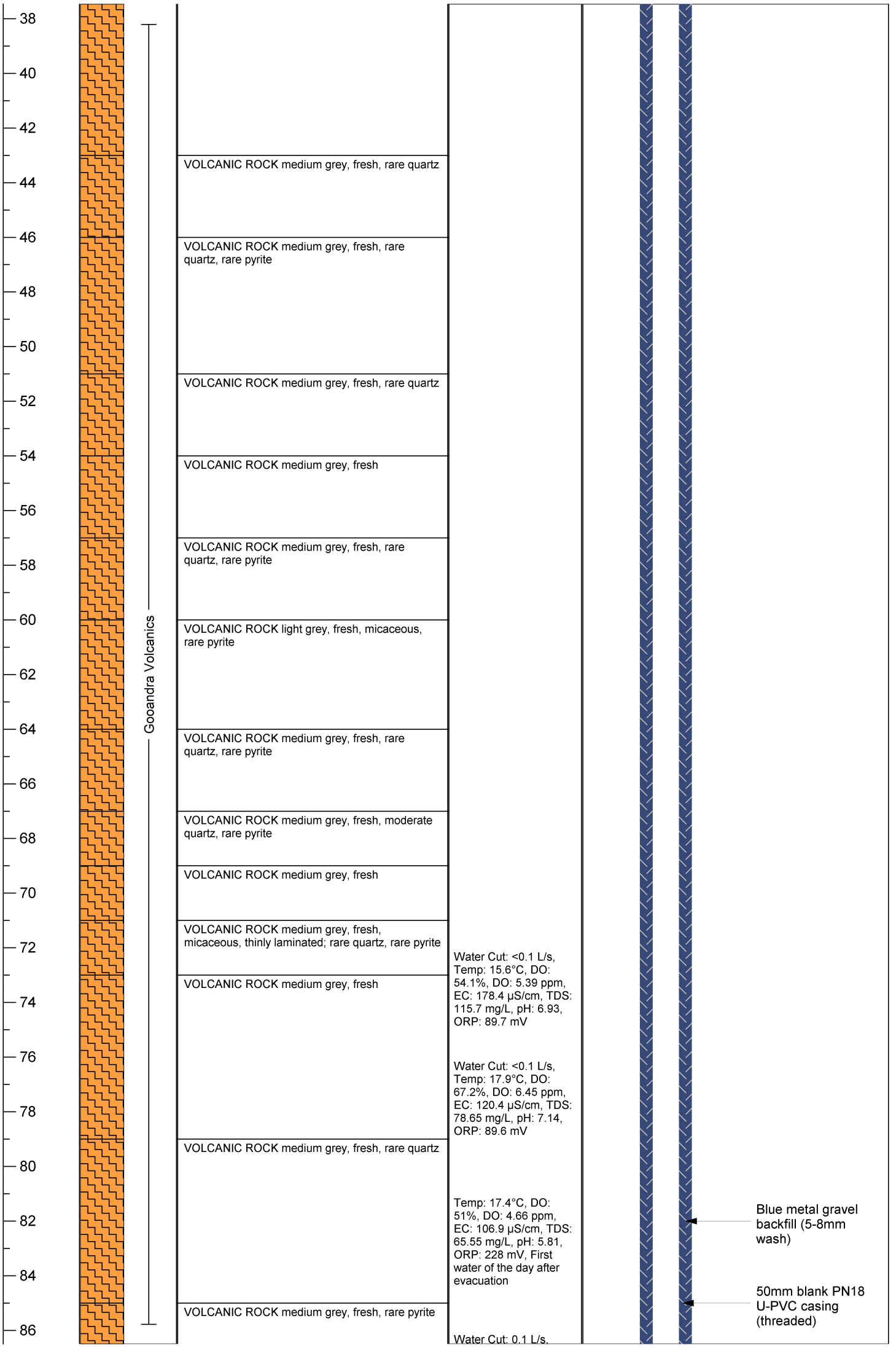
Gooandra Volcanics

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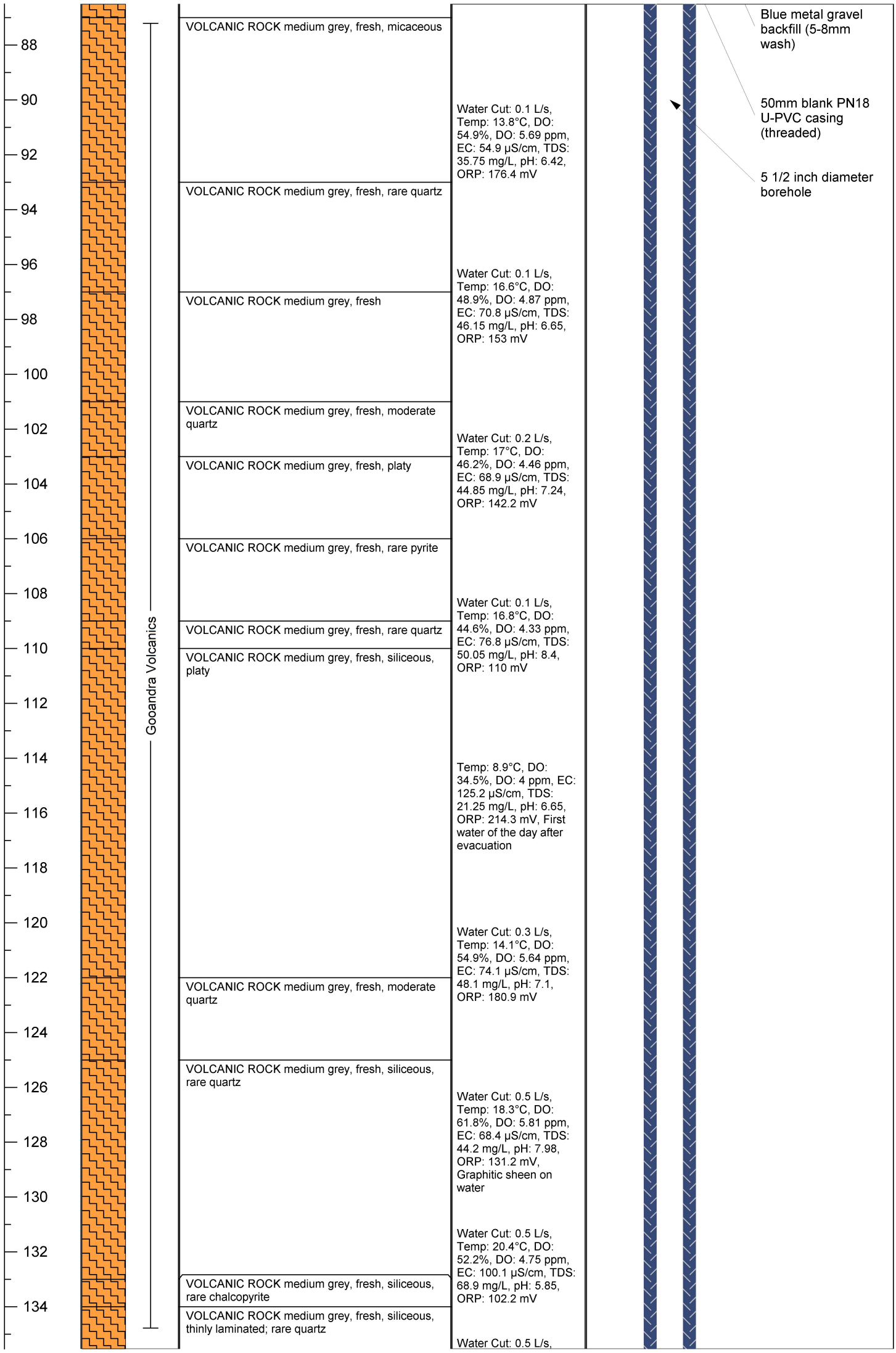
Gooandra Volcanics
VOLCANIC ROCK medium grey, fresh, rare quartz
VOLCANIC ROCK medium grey, fresh, rare quartz, rare pyrite
VOLCANIC ROCK medium grey, fresh, rare quartz
VOLCANIC ROCK medium grey, fresh
VOLCANIC ROCK medium grey, fresh, rare quartz, rare pyrite
VOLCANIC ROCK light grey, fresh, micaceous, rare pyrite
VOLCANIC ROCK medium grey, fresh, rare quartz, rare pyrite
VOLCANIC ROCK medium grey, fresh, moderate quartz, rare pyrite
VOLCANIC ROCK medium grey, fresh
VOLCANIC ROCK medium grey, fresh, micaceous, thinly laminated; rare quartz, rare pyrite
VOLCANIC ROCK medium grey, fresh
VOLCANIC ROCK medium grey, fresh, rare quartz
VOLCANIC ROCK medium grey, fresh, rare pyrite
Water Cut: <0.1 L/s, Temp: 15.6°C, DO: 54.1%, DO: 5.39 ppm, EC: 178.4 µS/cm, TDS: 115.7 mg/L, pH: 6.93, ORP: 89.7 mV
Water Cut: <0.1 L/s, Temp: 17.9°C, DO: 67.2%, DO: 6.45 ppm, EC: 120.4 µS/cm, TDS: 78.65 mg/L, pH: 7.14, ORP: 89.6 mV
Temp: 17.4°C, DO: 51%, DO: 4.66 ppm, EC: 106.9 µS/cm, TDS: 65.55 mg/L, pH: 5.81, ORP: 228 mV, First water of the day after evacuation
Water Cut: 0.1 L/s,
Blue metal gravel backfill (5-8mm wash)
50mm blank PN18 U-PVC casing (threaded)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Gooandra Volcanics
VOLCANIC ROCK medium grey, fresh, micaceous
VOLCANIC ROCK medium grey, fresh, rare quartz
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VOLCANIC ROCK medium grey, fresh, moderate quartz
VOLCANIC ROCK medium grey, fresh, platy
VOLCANIC ROCK medium grey, fresh, rare pyrite
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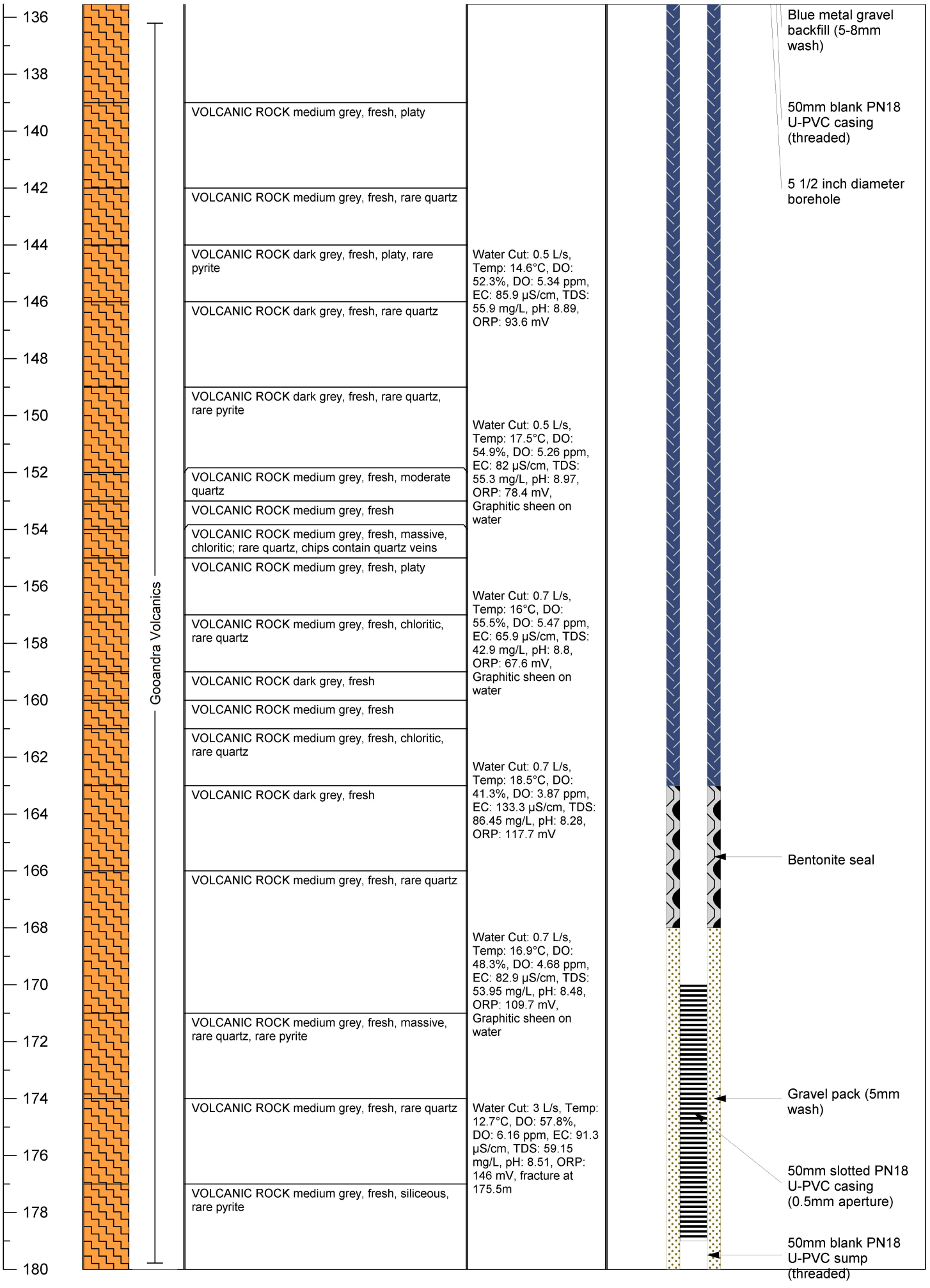
VOLCANIC ROCK medium grey, fresh, siliceous, platy
VOLCANIC ROCK medium grey, fresh, moderate quartz
VOLCANIC ROCK medium grey, fresh, siliceous, rare quartz
VOLCANIC ROCK medium grey, fresh, siliceous, rare chalcopyrite
VOLCANIC ROCK medium grey, fresh, siliceous, thinly laminated; rare quartz
Water Cut: 0.1 L/s, Temp: 13.8°C, DO: 54.9%, DO: 5.69 ppm, EC: 54.9 µS/cm, TDS: 35.75 mg/L, pH: 6.42, ORP: 176.4 mV
Water Cut: 0.1 L/s, Temp: 16.6°C, DO: 48.9%, DO: 4.87 ppm, EC: 70.8 µS/cm, TDS: 46.15 mg/L, pH: 6.65, ORP: 153 mV
Water Cut: 0.2 L/s, Temp: 17°C, DO: 46.2%, DO: 4.46 ppm, EC: 68.9 µS/cm, TDS: 44.85 mg/L, pH: 7.24, ORP: 142.2 mV
Water Cut: 0.1 L/s, Temp: 16.8°C, DO: 44.6%, DO: 4.33 ppm, EC: 76.8 µS/cm, TDS: 50.05 mg/L, pH: 8.4, ORP: 110 mV
Temp: 8.9°C, DO: 34.5%, DO: 4 ppm, EC: 125.2 µS/cm, TDS: 21.25 mg/L, pH: 6.65, ORP: 214.3 mV, First water of the day after evacuation
Water Cut: 0.3 L/s, Temp: 14.1°C, DO: 54.9%, DO: 5.64 ppm, EC: 74.1 µS/cm, TDS: 48.1 mg/L, pH: 7.1, ORP: 180.9 mV
Water Cut: 0.5 L/s, Temp: 18.3°C, DO: 61.8%, DO: 5.81 ppm, EC: 68.4 µS/cm, TDS: 44.2 mg/L, pH: 7.98, ORP: 131.2 mV, Graphitic sheen on water
Water Cut: 0.5 L/s, Temp: 20.4°C, DO: 52.2%, DO: 4.75 ppm, EC: 100.1 µS/cm, TDS: 68.9 mg/L, pH: 5.85, ORP: 102.2 mV
Water Cut: 0.5 L/s,
Blue metal gravel backfill (5-8mm wash)
50mm blank PN18 U-PVC casing (threaded)
5 1/2 inch diameter borehole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Gooandra Volcanics
VOLCANIC ROCK medium grey, fresh, platy
VOLCANIC ROCK medium grey, fresh, rare quartz
VOLCANIC ROCK dark grey, fresh, platy, rare pyrite
VOLCANIC ROCK dark grey, fresh, rare quartz
VOLCANIC ROCK dark grey, fresh, rare quartz, rare pyrite
VOLCANIC ROCK medium grey, fresh, moderate quartz
VOLCANIC ROCK medium grey, fresh
VOLCANIC ROCK medium grey, fresh, massive, chloritic; rare quartz, chips contain quartz veins
VOLCANIC ROCK medium grey, fresh, platy
VOLCANIC ROCK medium grey, fresh, chloritic, rare quartz
VOLCANIC ROCK dark grey, fresh
VOLCANIC ROCK medium grey, fresh
VOLCANIC ROCK medium grey, fresh, chloritic, rare quartz
VOLCANIC ROCK dark grey, fresh
VOLCANIC ROCK medium grey, fresh, rare quartz
VOLCANIC ROCK medium grey, fresh, massive, rare quartz, rare pyrite
VOLCANIC ROCK medium grey, fresh, rare quartz
VOLCANIC ROCK medium grey, fresh, siliceous, rare pyrite
Water Cut: 0.5 L/s, Temp: 14.6°C, DO: 52.3%, DO: 5.34 ppm, EC: 85.9 µS/cm, TDS: 55.9 mg/L, pH: 8.89, ORP: 93.6 mV
Water Cut: 0.5 L/s, Temp: 17.5°C, DO: 54.9%, DO: 5.26 ppm, EC: 82 µS/cm, TDS: 55.3 mg/L, pH: 8.97, ORP: 78.4 mV, Graphitic sheen on water
Water Cut: 0.7 L/s, Temp: 16°C, DO: 55.5%, DO: 5.47 ppm, EC: 65.9 µS/cm, TDS: 42.9 mg/L, pH: 8.8, ORP: 67.6 mV, Graphitic sheen on water
Water Cut: 0.7 L/s, Temp: 18.5°C, DO: 41.3%, DO: 3.87 ppm, EC: 133.3 µS/cm, TDS: 86.45 mg/L, pH: 8.28, ORP: 117.7 mV
Water Cut: 0.7 L/s, Temp: 16.9°C, DO: 48.3%, DO: 4.68 ppm, EC: 82.9 µS/cm, TDS: 53.95 mg/L, pH: 8.48, ORP: 109.7 mV, Graphitic sheen on water
Water Cut: 3 L/s, Temp: 12.7°C, DO: 57.8%, DO: 6.16 ppm, EC: 91.3 µS/cm, TDS: 59.15 mg/L, pH: 8.51, ORP: 146 mV, fracture at 175.5m
Blue metal gravel backfill (5-8mm wash)
50mm blank PN18 U-PVC casing (threaded)
5 1/2 inch diameter borehole
Bentonite seal
Gravel pack (5mm wash)
50mm slotted PN18 U-PVC casing (0.5mm aperture)
50mm blank PN18 U-PVC sump (threaded)

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WATER MONITORING BORE LOG

Bore ID: SMB05

Client: Snowy Hydro **Project:** Snowy Hydro 2.0

Date completed:	14/05/2018	**Project number:**	J17188
Drilling contractor:	Highland Drilling	**Elevation:**	1341.8
Drilling method:	Air rotary	**Easting:**	638890.2
Hydrogeologist:	S Cassidy	**Northing:**	6038515.5

Static Water Level: 18.83 mbgl **Screened Formation:** Gooandra Volcanics **Date:** 14/05/2018

Total depth: 50 m **Screened depth:** 40 - 49 mbgl **Casing:** 50 mm PVC

Depth (mbgl)	Lithology Graphic	Description	Water Quality	Bore Completion Diagram: Diagram	Bore Completion Diagram: Design notes
0–2		NO SAMPLE		Cement grout	
2–4		VOLCANIC ROCK medium grey, moderately oxidised			
4–6		VOLCANIC ROCK medium grey			
6–8		VOLCANIC ROCK medium grey, moderately oxidised			
8–10		VOLCANIC ROCK medium grey, moderately oxidised, rare quartz			
10–12		VOLCANIC ROCK medium grey, moderately oxidised, chloritic, massive			
12–14		VOLCANIC ROCK medium grey, moderately oxidised, rare quartz			
14–16		VOLCANIC ROCK medium grey, slightly oxidised, rare quartz		Blue metal gravel backfill (5-8mm wash)	
16–18				50mm blank PN18 U-PVC casing (threaded)	
18–20					
20–22					
22–24				5 1/2 inch diameter borehole	
24–26		VOLCANIC ROCK medium grey, moderate quartz			
26–28		VOLCANIC ROCK medium grey, rare quartz			
28–30		VOLCANIC ROCK medium grey			
30–32		VOLCANIC ROCK dark grey			
32–34					
34–36				Bentonite seal	
36–38		VOLCANIC ROCK medium grey			
38–40					
40–42					
42–44				Gravel pack (5mm wash)	
44–46					
46–48				50mm slotted PN18 U-PVC casing (0.5mm aperture)	
48–50					
				50mm blank PN18 U-PVC sump (threaded)	

Gooandra Volcanics

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WATER MONITORING BORE LOG

Bore ID: PB05

Client: Snowy Hydro Limited **Project:** Snowy Hydro 2.0

Date completed: 18/06/2018
Drilling contractor: Mulligans Geotechnical
Drilling method: Mud rotary
Hydrogeologist: GHD

Project number: J17188
Elevation: 614.3 mAHD
Easting: 624500.3
Northing: 6040714.1

Static Water Level: 51.96 mBGL **Open Formation:** Ravine Beds **Date:** 19/01/2019
Total depth: 100 mBGL **Open Depth:** Open hole 55 - 100 **Casing:** Class 9 PVC

Depth (mbgl)	Lithology Graphic	Description	Drilling Notes	Bore Completion: Diagram	Bore Completion: Design notes
0		SILTSTONE fine grained, dark brown, slightly oxidised, interbedded, SANDSTONE, 20% fine grained, light brown, slightly oxidised, minor quartz, minor calcite			Cement grout
5		CONGLOMERATE fine to coarse grained, light brown, sub-angular, SAND, 40% fine grained, light greenish brown			
10		SILTSTONE fine grained, medium brownish grey, minor quartz			126 mm diameter borehole
15					
20		SILTSTONE fine grained, medium brownish grey, 20% quartz			50 mm class 9 PVC casing
25		SILTSTONE fine grained, medium grey, minor quartz, minor calcite, occasional interbedded sandstone layers			
30		SILTSTONE fine grained, medium grey, minor quartz, minor calcite, rare pyrite			
35		SILTSTONE fine grained, medium grey, slightly oxidised, 20% quartz, rare pyrite			Blue metal gravel backfill (5-8mm wash)
40		SILTSTONE fine grained, medium grey, SANDSTONE, 30% fine grained, medium grey			
45		SILTSTONE fine grained, medium grey, SANDSTONE, 30% fine to coarse grained, medium grey, 20% quartz			
50					Bentonite seal
55			Temp: 27.2°C, DO: 99.8%, DO: 7.91 ppm, EC: 177.4 µS/cm, TDS: 115.05 g/L, pH: 7.98, ORP: 112.3 mV		
60		SANDSTONE fine to coarse grained, medium grey			
65		SILTSTONE fine grained, medium grey			
70		SANDSTONE fine to coarse grained, medium grey, ?rounded pebbles			
75		SILTSTONE fine grained, medium grey, SANDSTONE, 30% fine to coarse grained, medium grey			
80					
85		SILTSTONE fine grained, medium grey, SANDSTONE, 30% fine to coarse grained, medium grey, 20% quartz			
90		SILTSTONE fine grained, medium grey, SANDSTONE, 30% fine to coarse grained, medium grey			
95					
100					

Ravine Beds

Appendix D

Pumping test reports

Memorandum

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11 July 2018

To Snowy Hydro Limited
From EMM Consulting Pty Limited

Subject Pumping test analysis report - Tantangara Reservoir (PB01 site).

Dear Chris,

Please find below a brief technical report summarising the pumping test analysis undertaken at the PB01 site, located at Tantangara Reservoir, Snowy Mountains, NSW (Figure 1).

1 Summary

The PB01 pumping test was undertaken by AquaMann Irrigation and supervised by EMM Consulting Pty Limited (EMM).

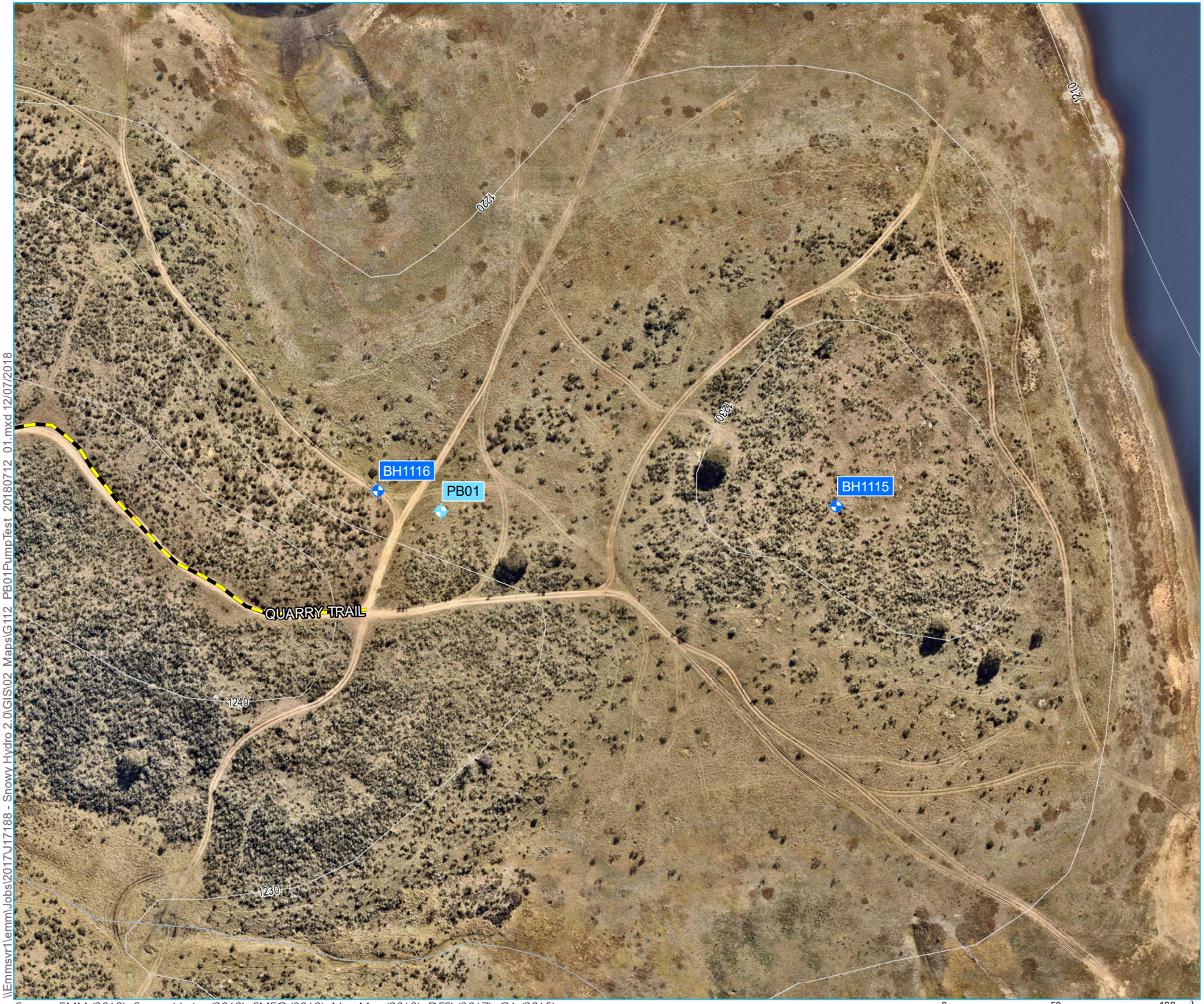
A constant-drawdown test (pumping test) was performed over a period of three days between 25 and 27 June 2018.

Due to the low aquifer volume and inflow rate, the pumping test was performed with intermittent pumping which kept the drawdown of PB01 within 0.5 m of 58.3 mBGL. The constant-drawdown test extended over a period of 38 hours and consisted of 156 drawdown and recovery cycles. In each cycle, the aquifer was pumped for approximately two minutes at a rate of 6.75 L/min on average, followed by a recovery period of 12-13 minutes. A summary of the test is provided in Table 1.

Table 1 PB01 Constant-drawdown test summary table

Description	Detail
Test type	Constant-drawdown test
Date	25 Jun - 27 Jun 2018
Discharge rate	0.11 L/s[1] while pumping (6.75 L/min[2] overall)
Site location	Tantangara Reservoir
Duration	38 hours
Production bore	PB01 - open hole from 30-60 mBGL[3]
Observation bore (deep)	BH1116 - distance of 28.7 m from PB01, screened from 78.5 – 92.8 mBGL
Observation bore (shallow)	BH1115 - distance of 180 m from PB01, screened from 39 - 54 mBGL
Initial water level	PB01 - 12.04 mbTOC[4] measured on 25 June 2018
	BH1116 - 9.44 mBGL measured on 25 June 2018
	BH1115 - 11.64 mBGL measured on 25 June 2018

Notes: *1. L/s = litres per second;*
2. L/min = litres per minute;
3. mBGL = metres below ground level; and
4. mbTOC = metres below top of casing.



KEY

Name

- Monitoring bore
- Production bore
- Project access road/track/trail
- Watercourse / drainage line
- Contour (10 m)

\\Emmsvr1\emm\Jobs\2017\J177188 - Snowy Hydro 2.0\GIS\02 Maps\G112 PB01PumpTest 20180712 01.mxd 12/07/2018

Source: EMM (2018); Snowy Hydro (2018); SMEC (2018); NearMap (2018); DFSI (2017); GA (2015)

0 50 100 m

GDA 1994 MGA Zone 55

N

Tantangara Reservoir site

Snowy 2.0
Tantangara Reservoir pumping test
Figure 1

EMM

snowy 2.0

2 Conceptualisation and assumptions

A 2-dimenional cross-sectional model of the pumping test is shown in Figure 2, with the following highlighted:

- The groundwater pumping/monitoring set-up at Tantangara Reservoir consisted of one production bore (PB01) and two monitoring bores (BH1115 and BH1116).
- The bores were arranged such that BH1115 and BH1116 were 180 and 28.7 m away from the production bore respectively.
- The shallow monitoring bore, BH1115 was screened from 42 – 51 mBGL, with a gravel pack installed from 39 - 54 mBGL;
- The deep monitoring bore, BH1116 was screened from 80.5 – 89.5 mBGL, with a gravel pack installed from 78.5 – 92.8 mBGL;
- The PB01 production bore consisted of an open hole between 30 - 60 mBGL with no gravel pack.

Two analytical methods were used to estimate aquifer properties including:

1. AqteSolv: industry leading software for analysing aquifer tests using a variety of aquifer types and solutions.
2. MLU: a multi-layered model used to analyse aquifer test data and design wellfields based on the Stehfest's numerical method, superposition principles, and the Levenberg-Marquardt algorithm for parameter optimisation.

The following additional assumptions were used to facilitate analysis:

- aquifers and aquitards are infinite in extent;
- aquifers are homogeneous and uniform in thickness;
- aquitards have a uniform vertical hydraulic conductivity;
- flow in aquitards are vertical;
- flow to the well is horizontal;
- for the AqteSolv solutions, the aquifer is conceptualised as one thick aquifer only;
- the initial water table was approximately measured at 12 mBGL;
- the shallower aquifer system was assumed to be 48 m thick for the MLU model (ie the water table height minus the base of the PB01 open hole);
- the sediment pile between the two monitoring bores, conceptualised to be an aquitard for the MLU model, was set to a thickness of 18.5 m (ie the base of the PB01 open hole minus the top of the gravel pack for BH1116);
- the deeper aquifer was assumed to be 14.3 m thick for the MLU model (ie the top of the BH1116 gravel pack minus the base of the BH1116 gravel pack); and
- the aquifer thickness of the AqteSolv model was assumed to be 80.8 m (ie the water table minus the base of the gravel pack of BH1116).

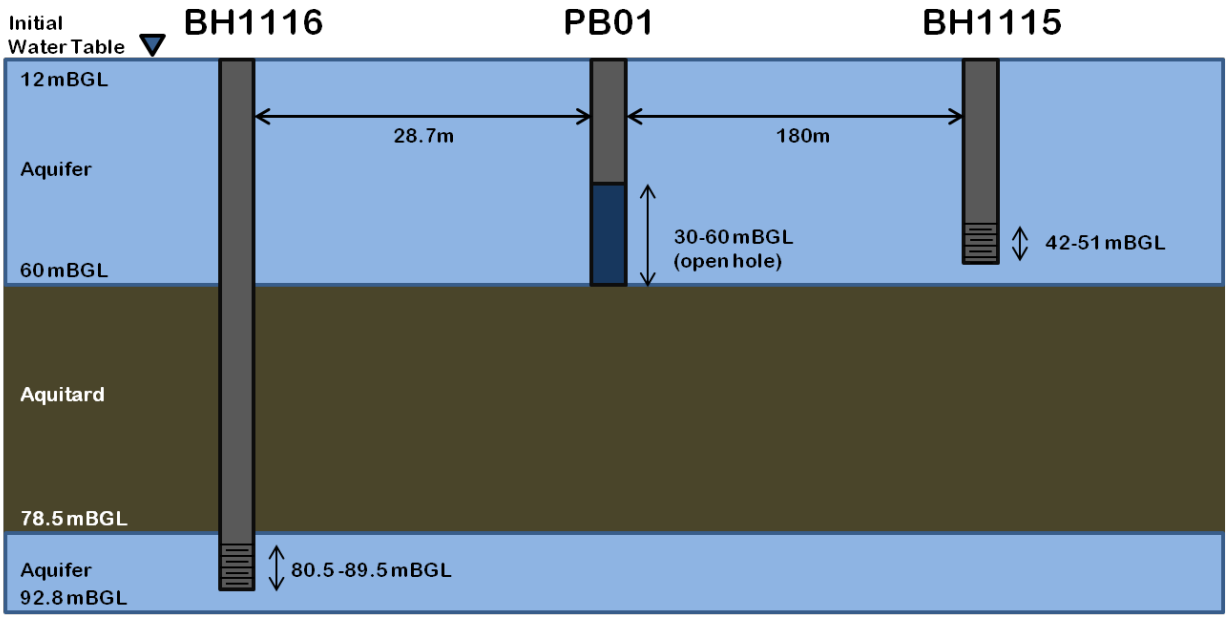


Figure 2: Cross-section of the PB01 pumping test setup at Tantangara Reservoir.

3 Analysis

Summaries of the results from MLU and AqteSolv are provided in Table 2, Table 3 and Table 4. A brief discussion of the results is provided in Section 4.

Table 2 PB01 MLU analysis - aquifers

Aquifer	Distance from Production bore PB01 (m)	Aquifer thickness (m)	T (m^2/d)[1]	Kh (m/d)[2]	S [-]
Shallow Aquifer	0	48	0.22	0.0046	1.9e-7
Deep Aquifer	28.7	14.3	0.18	0.013	2.6e-5

Notes: 1. m^2/d = Metres squared per day; and
2. m/d = metres per day.

Table 3 PB01 MLU analysis - aquitards

Data Sets	Aquitard Thickness (m)	c (d)	Kv (m/d)
BH1115 and PB01	18.5	1885	0.010

Table 4 PB01 AqteSolv analysis

Solution Type	Aquifer Type	Aquifer Thickness (m)	Partial Penetration	K (m^2/d)	K'(m/d)
Barker (Double Porosity)	Fractured	80.8	Yes	6.5e-3	5.3e-3

4 Discussion

The results of the pumping test analyses show estimates of horizontal hydraulic conductivity (Kh) within an order of magnitude, ranging between 0.0046 and 0.013 m/d. The MLU analysis shows a vertical hydraulic conductivity of 0.010 m/d for the aquitard between the deep and shallow systems, suggesting an aquifer anisotropy value close to 1.

Storativity values ranging between 1.9^{-7} and 2.6^{-5} have been estimated using MLU, the lower value of which is seen in sound rocks, while the higher value can be found in fractured rocks (Batu 1998). This result is reasonable as the aquifers monitored in the PB01 pumping test were composed of fractured dacite.

In terms of flow conditions, the AqteSolv solution can estimate the derivative of drawdown, which provides some insight into flow conditions. The blue curve, shown on Figure 3 represents the type curve matched to the drawdown data within PB01, and the red curve shows the derivative. When plotted on semi-log axes, the type curve obtains a constant positive linear slope later in the pumping test (after approximately 0.4 days). This implies that the production bore is being fed by infinite acting radial flow.

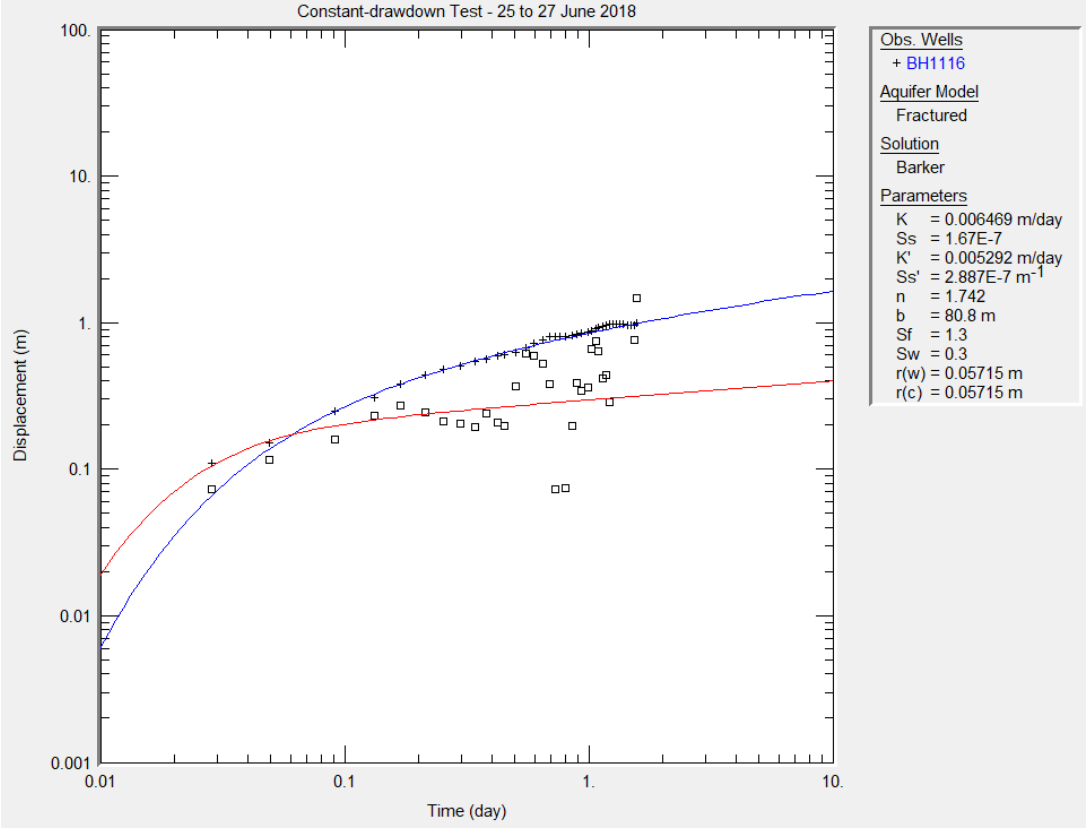


Figure 3: Pumping test analysis for the BH1116 monitoring well using the Barker double porosity method. (blue = type curve, red = derivative)

5 Closing

We trust that this document addresses your requirements. Please let us know if you have any questions.

Yours Sincerely,

Bill Bull

Environmental Engineer

bbull@emmconsulting.com.au

6 References

Batu, V 1998, *Aquifer Hydraulics: A Comprehensive Guide to Hydrogeologic Data Analysis*, John Wiley & Sons, New York, 727p.

Memorandum

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11 July 2018

To Snowy Hydro Limited
From EMM Consulting Pty Limited

Subject Pumping test analysis report - Tantangara Creek (PB03 site).

Dear Chris,

Please find below a brief technical report summarising the pumping test analysis undertaken at the PB03 site, located near Tantangara Creek, Snowy Mountains, NSW (Figure 1).

1 Summary

The PB03 pumping test was undertaken by AquaMann Irrigation and supervised by EMM Consulting Pty Limited (EMM).

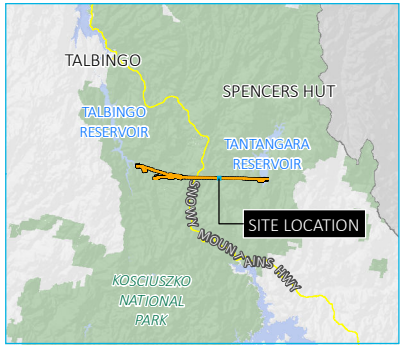
A constant-rate test (pumping test) was performed over a period of two days: 2 and 3 July 2018.

The constant-rate test extended over a period of 11.5 hours and consisted of 12 minutes of continuous pumping and 11.25 hours of recovery. During the drawdown period, the aquifer was pumped at a rate of 100 mL/min. Due to the low aquifer volume and water inflow rate, the pump was only operated for a short time to prevent excessive heating and potential damage. A summary of the test is provided in Table 1.

Table 1 PB03 Constant-rate test summary table

Description	Detail
Test type	Constant-rate test
Date	2 Jul – 3 Jul 2018
Discharge rate	100 mL/min[1]
Site location	Tantangara Creek
Duration	11.5 hours
Production bore	PB03 - open hole from 200 - 215 mBGL[2]
Observation bore (deep)	SMB02 - distance of 7.4 m from PB03, screened from 183 – 195 mBGL
Observation bore (shallow)	SMB03 - distance of 11.8 m from PB03, screened from 41 - 50 mBGL
Initial water level	PB03 - 157.6 mbTOC[3] (after dewatering) measured on 2 July 2018
	SMB02 - 2.215 mBGL measured on 2 July 2018
	SMB03 - 2.045 mBGL measured on 2 July 2018

Notes: *1. mL/min = millilitres per minute;*
2. mBGL = metres below ground level; and
3. mbTOC = metres below top of casing.



KEY

- Production bore (PB03)
- Monitoring bore (SMB02; SMB03)
- Watercourse / drainage line
- Contour (10 m)

PB03 pumping test

Source: EMM (2018); Snowy Hydro (2018); PhotoMapping (2018); SMEC (2018); DFSI (2017)

0 50 100 m

GDA 1994 MGA Zone 55

N

Snowy 2.0
Tantangara Creek pumping test
Figure 1

snowy 2.0

EMM creating opportunities

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2 Conceptualisation and assumptions

A 2-dimenional cross-sectional model of the pumping test is shown in Figure 2, with the following highlighted:

- The groundwater pumping/monitoring set-up near Tantangara Creek consisted of one production bore (PB03) and two monitoring bores (SMB02, SMB03).
- The bores were arranged such that SMB02 and SMB03 were 7.4 and 11.8 m away from the production bore respectively.
- The shallow monitoring bore, SMB03 was screened from 41 – 50 mBGL, with a gravel pack installed from 38 - 50 mBGL;
- The deep monitoring bore, SMB02 was screened from 183 – 195 mBGL, with a gravel pack installed from 180 – 195 mBGL;
- The PB03 production bore consisted of an open hole between 200 – 215 mBGL with no gravel pack.

AqteSolv was the analytical method used to estimate aquifer properties. AqteSolv is industry leading software for analysing aquifer tests using a variety of aquifer types and solutions.

The following additional assumptions were used to facilitate analysis:

- aquifers and aquitards are infinite in extent;
- aquifers are homogeneous and uniform in thickness;
- aquitards have a uniform vertical hydraulic conductivity;
- flow in aquitards are vertical;
- flow to the well is horizontal;
- for the AqteSolv solutions, the aquifer is conceptualised as one thick aquifer only;
- the initial water table was approximately measured at 2.1 mBGL;
- the aquifer thickness of the AqteSolv model was assumed to be 55 m (ie the initial water level in PB03 to the base of the PB03 open hole).

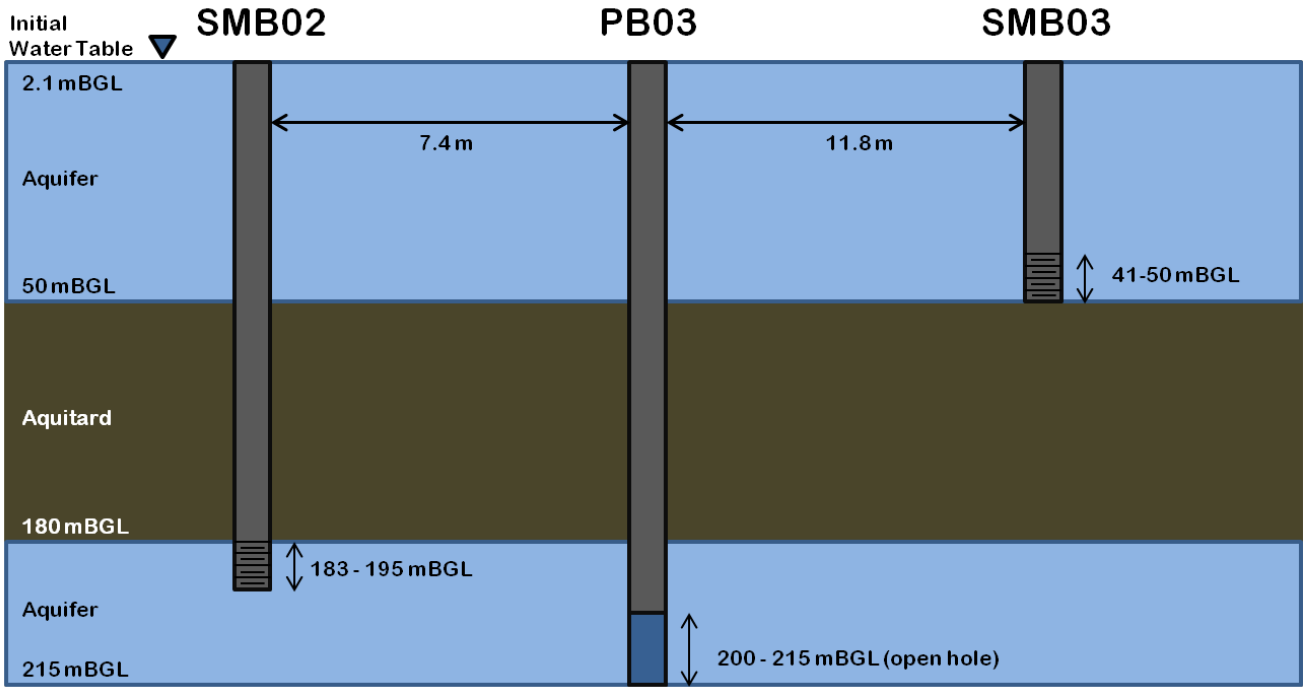

Figure 2: Cross-section of the PB03 pumping test setup near Tantangara Creek.

3 Analysis

Summaries of the results from AqteSolv are provided in Table 2. A brief discussion of the results is provided in Section 4.

Table 2 PB03 AqteSolv analysis

Solution Type	Aquifer Type	Aquifer Thickness (m)	Partial Penetration	K (m/d)[1,2]	K' (m/d)[3]
Moench (Double Porosity)	Fractured	55	Yes	8.81 e-8	5.97 e-9
Barker	Confined	55	Yes	9.07 e-8	-

Notes: *1. K = overall hydraulic conductivity (confined solution) or hydraulic conductivity of fractures (fractured solution);*

2. m/d = meters per day; and

3. K' = hydraulic conductivity of the rock matrix (fractured solution).

4 Discussion

Due to low volumes of water in the aquifer and small inflow rates, the pump was only operated for 12 minutes at a flow rate of 100 mL/min before no further water could be extracted. Due to this, there were not many data points available for modelling the drawdown portion of the pumping test. Additionally, only 5 cm of recovery was noted over an 11.5 period after the pump was removed. Therefore, to model this pumping test, AqteSolv was used to fit a curve to the late time recovery data up to 30 days after the cessation of pumping. This analysis is shown in Figure 3.

The results of both pumping test models (double-porosity fractured aquifer and confined aquifer) produce similar values for horizontal hydraulic conductivity (K), ranging between 8.81e-8 and 9.07e-8 m/d. These values are typical for unfractured volcanic rocks, which usually show hydraulic conductivities of 2.59e-9 to 1.73e-5 (Batu 1998). This result fits with the low water volumes and inflow rates observed in PB03 during the pumping test, as well as the aquifer composition of volcanic rock noted on the drill logs.

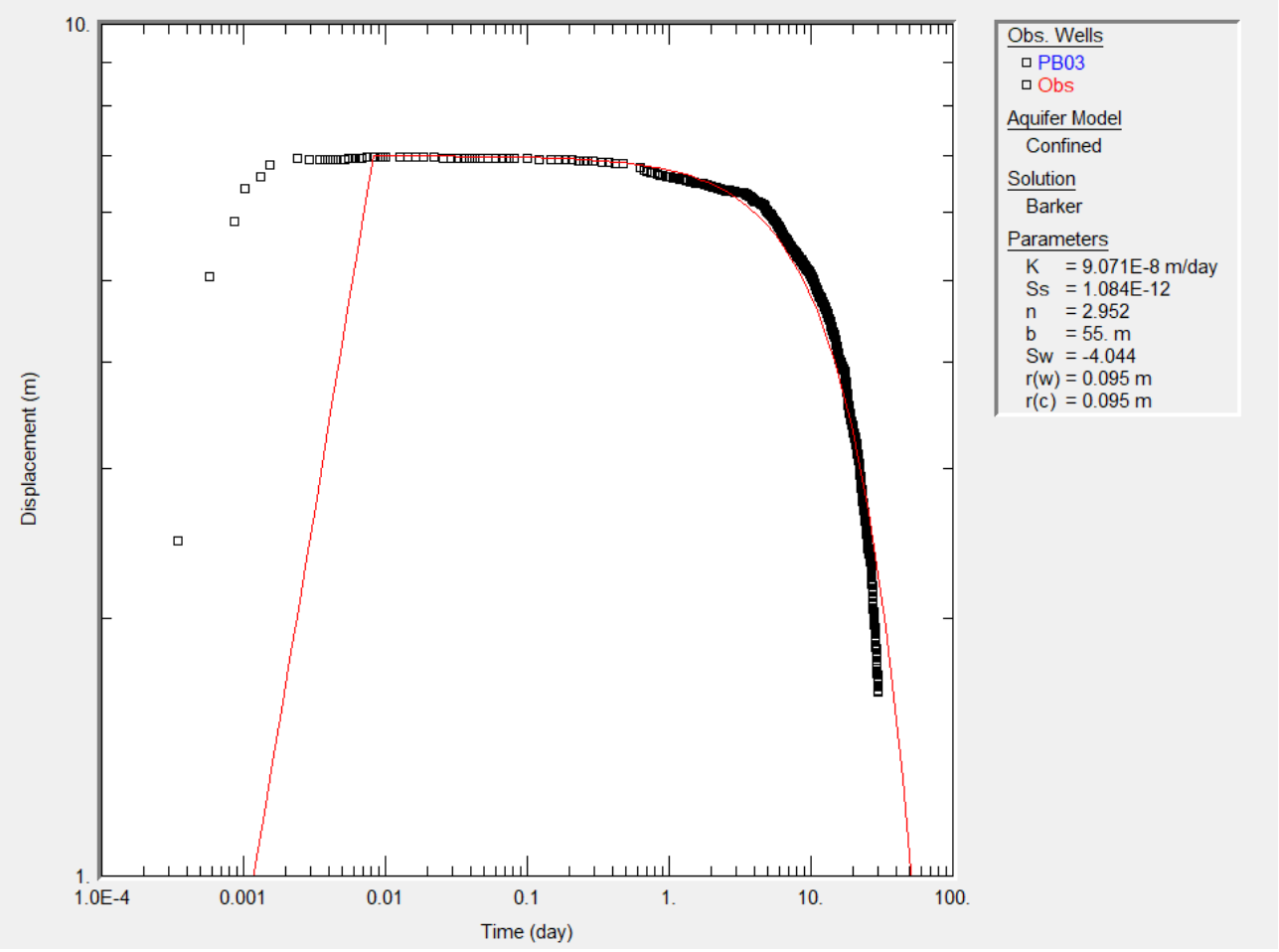

Figure 3: Pumping test analysis for PB03 using the Barker confined aquifer model fit to late time data.

5 Closing

We trust that this document addresses your requirements. Please let us know if you have any questions.

Yours Sincerely,

Bill Bull

Environmental Engineer

bbull@emmconsulting.com.au

6 References

Batu, V 1998, *Aquifer Hydraulics: A Comprehensive Guide to Hydrogeologic Data Analysis*, John Wiley & Sons, New York, 727p.

Memorandum

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2 July 2018

To Richard Clarke
From EMM Consulting Pty Limited

Subject Pumping Test Analysis Report- Gooandra Creek (PB04 site).

Dear Richard,

Please find below a brief technical report summarising the pumping test analysis undertaken at the PB04 site, located at Goondra Creek, Snowy Mountains, NSW (Figure 1).

1 Summary

The PB04 pumping test was undertaken by AquaMann Irrigation and supervised by EMM Consulting Pty Limited (EMM).

A constant rate test (pumping test) was performed over a period of five days between 28 May and 1 Jun 2018. The constant rate test extended over a period of 85 hours, including 70 hours of constant pumping and 15 hours of recovery. Details of the test summary are provided in Table 1.

Table 1 PB04 Constant rate test summary table

Description	Detail
Test type	Constant rate test
Date	28 May - 1 Jun 2018
Discharge rate	0.69 L/s[1]
Site location	Gooandra Creek
Duration	85 hours
Production bore	PB04 screened from 185 - 200 mBGL[2]
Observation bore (deep)	SMB04 - distance of 10.8 m from PB04, screened from 170 - 179 mBGL
Observation bore (shallow)	SMB05 - distance of 10.8 m from PB04, screened from 40 - 49 Mbgl
Initial water level	PB04 - 12.32 mbTOC[3] measured on 24 May 18
	SMB04 - 14.96 mBGL measured on 24 May 18
	SMB05 - 19.51 mBGL measured on 24 May 18

Notes: *1. L/s = litres per second;*
2. mBGL = metres below ground level; and
3. mbTOC = metres below top of casing.

KEY

- Proposed bore - indicative location
- Proposed drill pad (indicative location)
- Project access track/trail
- Watercourse / drainage line
- Contour (10 m)
- NPWS reserve

Ravine alignment option

- Exploration tunnel and portal
- Tunnel and access alignment

Source: EMM (2018); Snowy Hydro (2018); SMEC (2018); NearMap (2018); DFSI (2017); GA (2015)

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Gooandra Creek

Snowy 2.0
Construction environmental management plan
Figure 6

2 Conceptualisation and assumptions

A 2-dimenional cross-sectional model of the pumping test is shown in Figure 2, with the following highlighted:

- The groundwater pumping/monitoring set-up at Gooandra Creek consisted of one production bore (PB04) and two monitoring bores (SMB04 and SMB05).
- The bores were arranged in a triangle configuration with each monitoring bore located 10.8 m from the production bore and approximately 8 m away from each other;
- The shallow monitoring bore, SMB05 was screened from 40 – 49 mBGL, with a gravel pack installed from 38 - 50 mBGL;
- The deep monitoring bore, SMB04 was screened from 170 - 179 mBGL, with a gravel pack installed from 168 – 180 mBGL.
- The PB04 production bore was screened from 185 - 200 mBGL, with a gravel pack installed from 171 - 200 mBGL.

Two analytical methods were used to estimate aquifer properties including:

1. AqteSolv- industry leading software for analysing aquifer tests using a variety of aquifer types and solutions.
2. MLU: a multi-layered model used to analyse aquifer test data and design wellfields based on the Stehfest's numerical method, superposition principles, and the Levenberg-Marquardt algorithm for parameter optimisation.

The following additional assumptions were used to facilitate analysis:

- aquifers and aquitards are infinite in extent;
- aquifers are homogeneous and uniform in thickness;
- aquitards have a uniform vertical hydraulic conductivity;
- flow in aquitards are vertical;
- flow to the well is horizontal;
- for the AqteSolv solutions, the aquifer is conceptualised as one thick aquifer only;
- the initial water table was approximately measured at 13.5 mBGL;
- the shallower aquifer system was assumed to be 36.5 m thick for the MLU model (ie the water table height minus the base of the SMB05 gravel pack);
- the sediment pile between the two monitoring bores, conceptualised to be an aquitard for the MLU model, was set to a thickness of 118 m (ie the base of the SMB05 gravel pack minus the top of the gravel pack for SMB04);
- the deeper aquifer was assumed to be 32 m thick for the MLU model (ie the top of the SMB05 gravel pack minus the base of the PB04 gravel pack); and
- the aquifer thickness of the AqteSolv model was assumed to be 186.5 m (ie the water table minus the base of the gravel pack of production bore PB04).

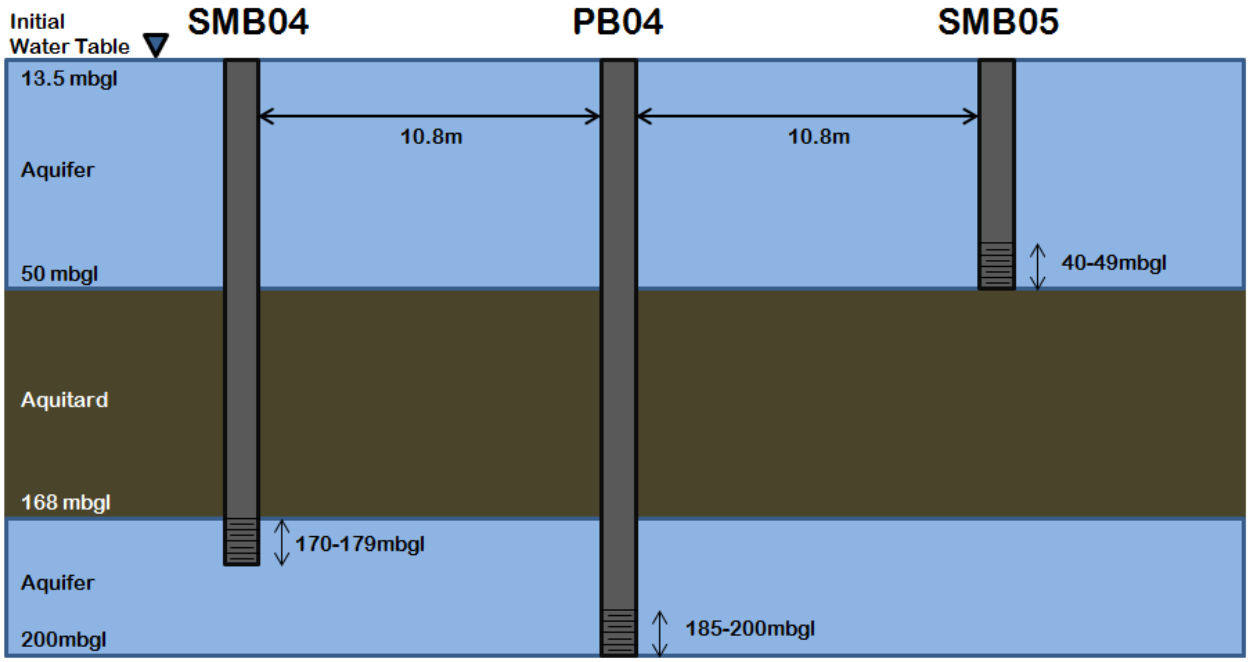

Figure 2: Cross-section of the PB04 pumping test setup at Gooandra Creek.

3 Analysis

A summary of the results are provided in Tables 2, Table 3 and Table 4. A brief discussion of the results is provided in Section 4.

Table 2 PB04 MLU analysis - aquifers

Monitoring well	Distance from Production bore PB04 (m)	Aquifer thickness (m)	T (m^2/d)[1]	Kh (m/d)[2]	S [-]
PB04	0	32	0.58	0.018	
SMB04	10.8	32	0.92	0.032	2.5e-4
SMB05	10.8	36.5	0.46	0.013	3.9e-4

Notes: 1. m^2/d = Metres squared per day; and
2. m/d = metres per day.

Table 3 PB04 MLU analysis - aquitards

Data Sets	Aquitard Thickness (m)	c (d)	Kv (m/d)
SMB04 and SMB05	118	7031	0.017

Table 4 PB04 AqteSolv analysis

Solution Type	Aquifer Type	Aquifer Thickness (m)	Partial Penetration	T (m^2/d)	Kh (m/d)
Tartakovsky-Neuman	Unconfined	186.5	Yes	2.80	0.015
Hantush-Jacob	Leaky confined	186.5	Yes	1.9	0.01

4 Discussion

The results of the pumping test analysis show consistent estimates of horizontal hydraulic conductivity (Kh), ranging between 0.01 and 0.032 m/d. The MLU analysis show a vertical hydraulic conductivity of 0.017 m/d for the sediment pile between the deep and shallow systems, suggesting an aquifer anisotropy value close to 1.

Storativity values, ranging between 2.5^{-4} and 3.9^{-4} have been estimated using MLU and are typical values for hard rock.

In terms of flow conditions, the AqteSolv solution can estimate the derivative of drawdown, which provides some insight into flow conditions. The blue curve, shown on Figure 4 represents the type curve matched to the drawdown data within PB04, and the red curve shows the derivative. The derivative approached a constant value during the early period of the pumping test (<3 minutes), and suggests radial flow conditions were established in an infinite-acting aquifer. During later time (~ 5 hours into the test), the derivative dramatically reduces suggesting the system is starting to reaching a steady state equilibrium. No boundary conditions were observed.

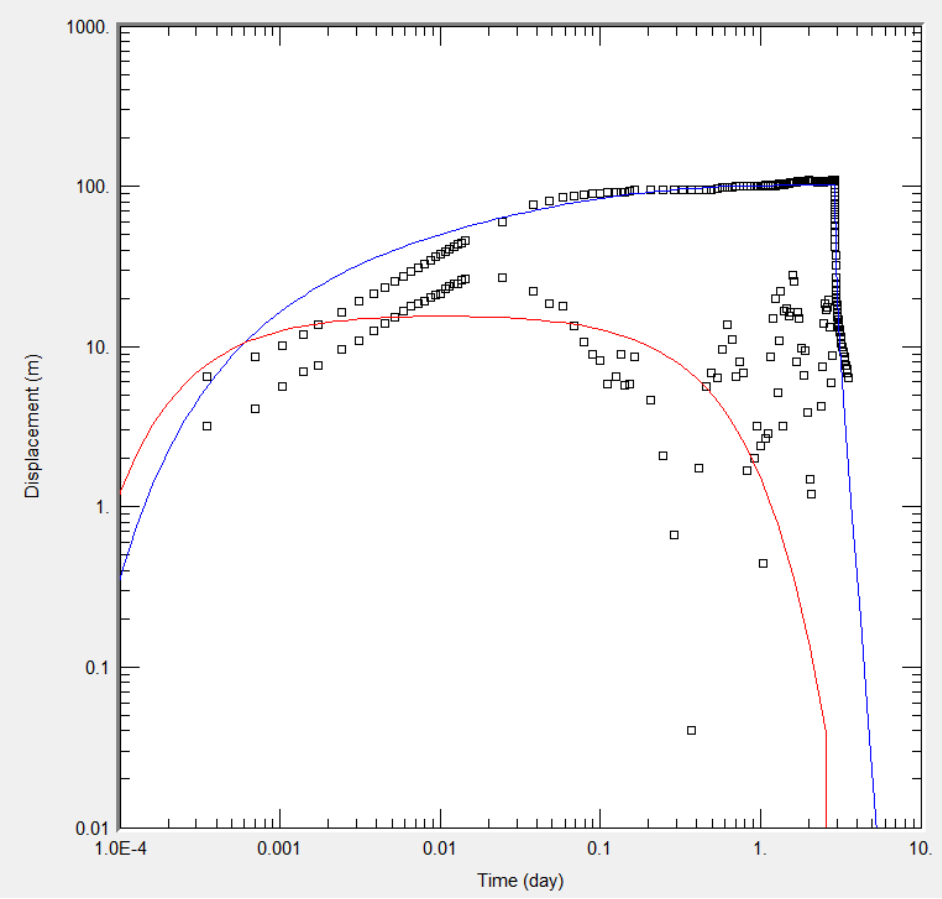

Figure 3: Pumping test analysis for PB04 usng the Hantush-Jacobs method. (blue = type curve, red = derivative)

5 Closing

We trust that this document addresses your requirements. Please let us know if you have any questions.

Yours Sincerely,

Sean Cassidy

Senior Hydrogeologist

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Memorandum

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12 September 2018

To Richard Clarke
From EMM Consulting Pty Limited

Subject Pumping test analysis report – Lobs Hole (PB05 site)

Dear Richard,

Please find below a brief technical report summarising the pumping test analysis undertaken at the PB05 site, located at Lobs Hole, Snowy Mountains, NSW (Figure 1).

1 Summary

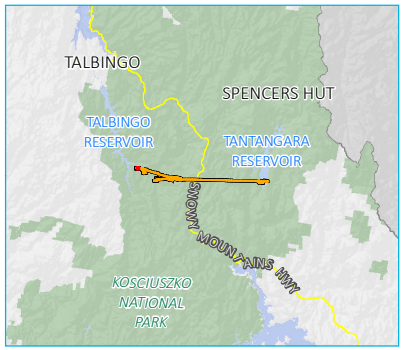
The pumping test was undertaken by AquaMann Irrigation and supervised by EMM Consulting Pty Limited (EMM).

A constant rate test (pumping test) was performed over a period of four days between 6 and 9 August 2018. The pumping test took place over a period of 71 hours, including 67 hours of constant pumping and 4 hours of recovery. Details of the test summary are provided in Table 1.

Table 1 PB05 constant rate test summary table

Description	Detail
Test type	Constant rate and recovery test
Date	6 August to 9 August 2018
Discharge rate	0.79 L/min
Site location	Lobs Hole
Duration	71 hours
Production bore	PB05 open hole from 50 – 100 mBGL[2]
Observation bore	BH7106 – distance of 15 m from PB05, screened from 130 – 153 mBGL
Initial water level	PB05 – 51.96 mBGL measured on 6 August 2018
	BH7106 – 51.66 mBGL measured on 6 August 2018

Notes: 1. L/s = litres per second; and
2. mBGL = metres below ground level.



KEY

- Production bore
- Monitoring bore
- Watercourse / drainage line
- Contour (10 m)

PB05 pumping test

Source: EMM (2018); Snowy Hydro (2018); SMEC (2018); DFSI (2017)

0 50 100 m

GDA 1994 MGA Zone 55

N

Snowy 2.0
PB05 pumping test
Figure 1

snowy 2.0

EMM creating opportunities

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2 Conceptualisation and assumptions

A 2-dimensional conceptualised cross-section model for the PB05 site is shown in Figure 2 with the following details:

- The groundwater pumping/monitoring set-up at Lobs Hole consisted of one production bore (PB05) and one monitoring bore (BH7106).
- The bores were located approximately 15 m away from each other.
- The production bore, PB05 had an open hole from 50 - 100 mBGL;
- The monitoring bore, BH7106 was screened from 130 – 153 mBGL, with a gravel pack installed from 125 – 153 mBGL;

Two analytical methods were used to estimate aquifer properties including:

1. AqteSolv: industry leading software for analysing aquifer tests using a variety of aquifer types and solutions.

2. MLU: a multi-layered model used to analyse aquifer test data and design wellfields based on the Stehfest's numerical method, superposition principles, and the Levenberg-Marquardt algorithm for parameter optimisation.

The following additional assumptions were used to facilitate analysis:

- aquifers and aquitards are infinite in extent;
- aquifers are homogeneous and uniform in thickness;
- aquitards have a uniform vertical hydraulic conductivity;
- flow in aquitards are vertical;
- flow to the well is horizontal;
- for the AqteSolv and MLU solutions, the aquifer is conceptualised as one thick aquifer only;
- the initial water table was approximately measured at 51.8 mBGL; and
- the aquifer thickness assumed when modelling was 101 m (ie the water table minus the base of the gravel pack of BH7106).

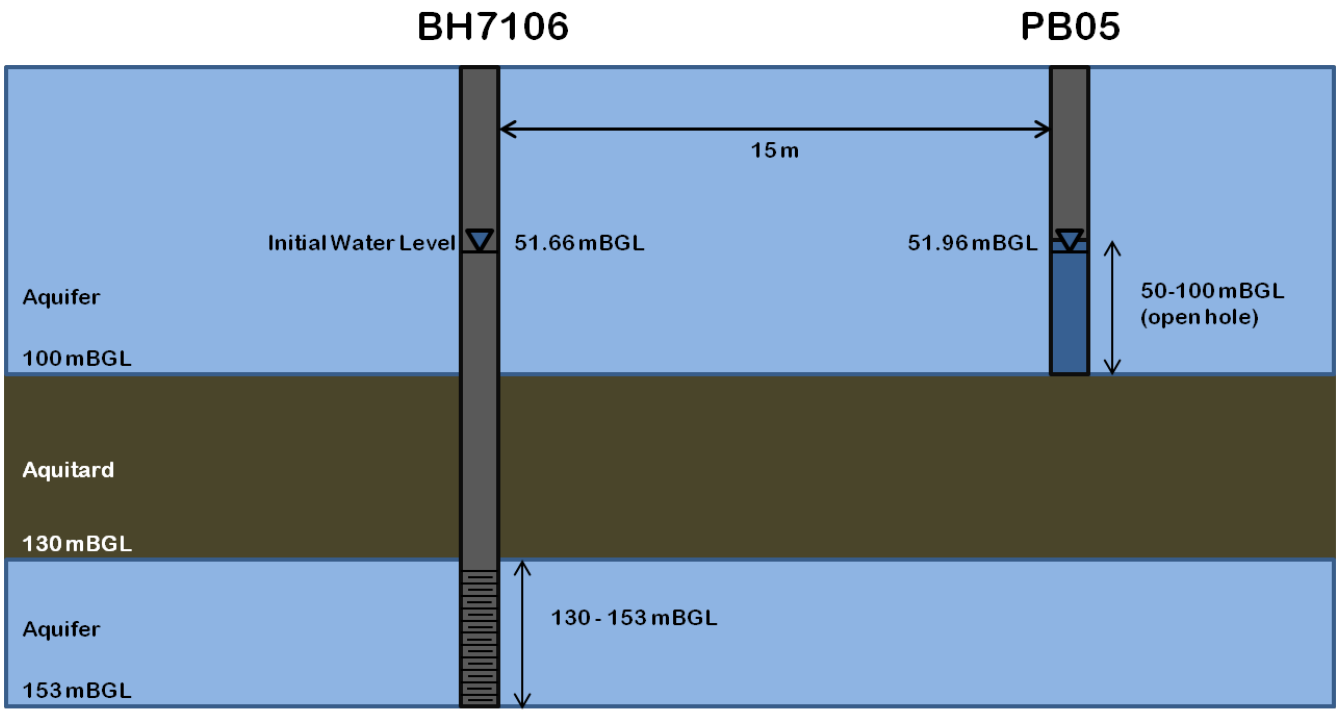


Figure 2: Cross-section of the PB05 pumping test setup at Lobs Hole.

3 Analysis

A summary of the results are provided in Table 2 and Table 3. A brief discussion of the results is provided in Section 4. The data was analysed in two parts: early-time data and late-time data. The early-time data is characterised by the influence of a recharge boundary which holds the drawdown in PB05 relatively constant. After the recharge zone had been completely dewatered, the data was considered as late-time data.

Table 2 PB05 pumping test MLU analysis

Data Set	Modelled aquifer thickness (m)	T (m^2/d)[1]	Kh (m/d)[2]	S [-]
Late-time	101	0.077	7.7e-4	2.5e-12

Notes: *1. m^2/d = metres squared per day; and*
2. m/d = metres per day.

Table 3 PB05 pumping test AqteSolv analysis

Data Set	Solution Type	Aquifer Type	Aquifer Thickness (m)	Kh (m/d)	S [-]	Kv/Kh [-]
Early-time	Gringarten-Witherspoon	Single vertical fracture	101	3.7e-3	6.3e-5	0.035
Late-time	Gringarten-Witherspoon	Single vertical fracture	101	3.3e-4	2.6e-5	0.24

Notes: *1. K_v/K_h= ratio of vertical hydraulic conductivity to horizontal hydraulic conductivity.*

4 Discussion

To characterise the groundwater flow for the PB05 and BH7106 bores, linear and bilinear diagnostic plots were used. Figure 2 shows that both bores have unit slopes on a linear flow plot at late times. This suggests that linear flow is taking place in a channel aquifer.

Figure 3 is a bilinear flow plot of the data, which shows that PB05 exhibits bilinear flow conditions earlier in the pumping test. This is indicative of bilinear flow to a single fracture with finite conductivity.

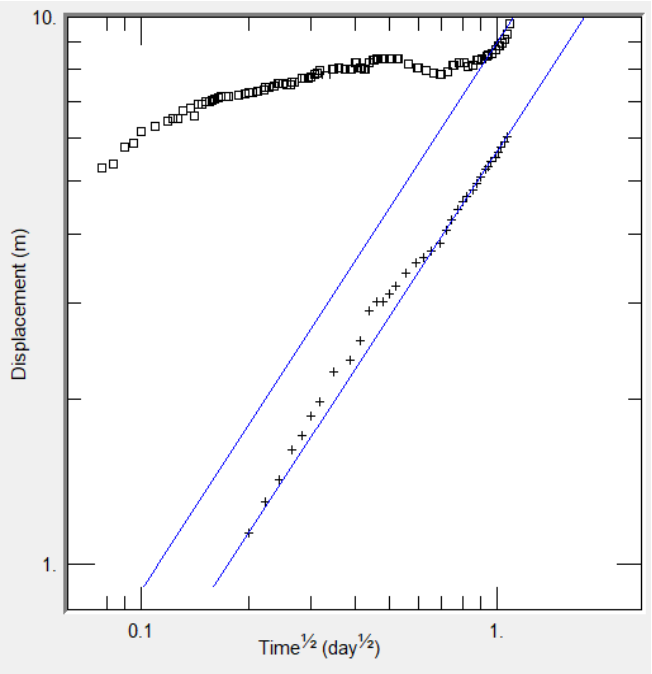


Figure 2: Linear flow plot of the PB05 (squares) and BH7106 (crosses) data showing that linear flow condition are reached in both bores for the late-time data.

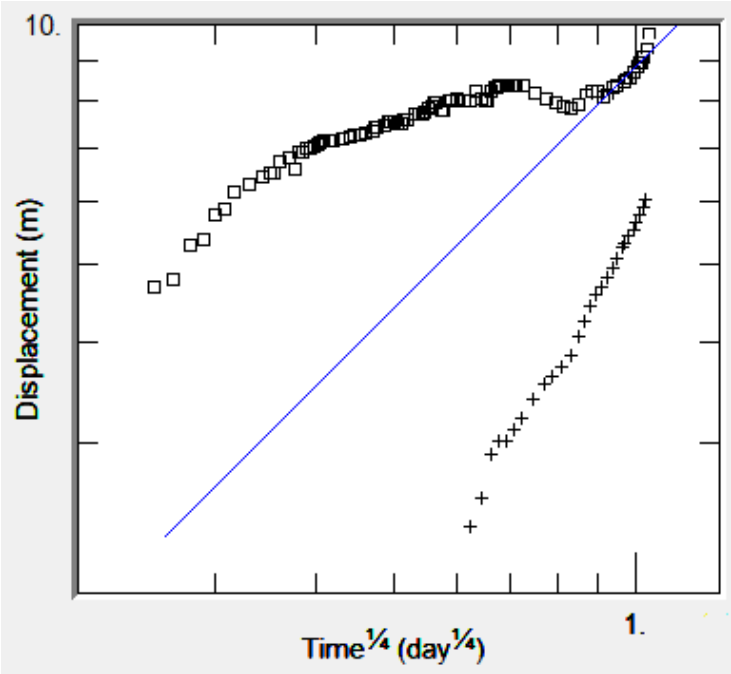


Figure 3: Bilinear flow plot of the PB05 (squares) and BH7106 (crosses) data showing that bilinear flow conditions are seen in the early data for PB05.

The pumping test data also shows the influence of a recharge boundary. Figure 4 shows that from approximately 5 to 24 hours (0.2 to 1 days) after beginning the test, the drawdown of PB05 is held relatively constant. This is likely due to the cone of depression reaching a recharge boundary, which stabilizes the drawdown in the well. Following 24 hours of continuous pumping, the recharge zone becomes dewatered, as seen in the rapid increase in drawdown in PB05. This is also supported by the water quality data collected, which shows the total dissolved solids and electrical conductivity measurements of the water decreasing until the recharge zone is dewatered, after which they remain constant (see Figure 5).

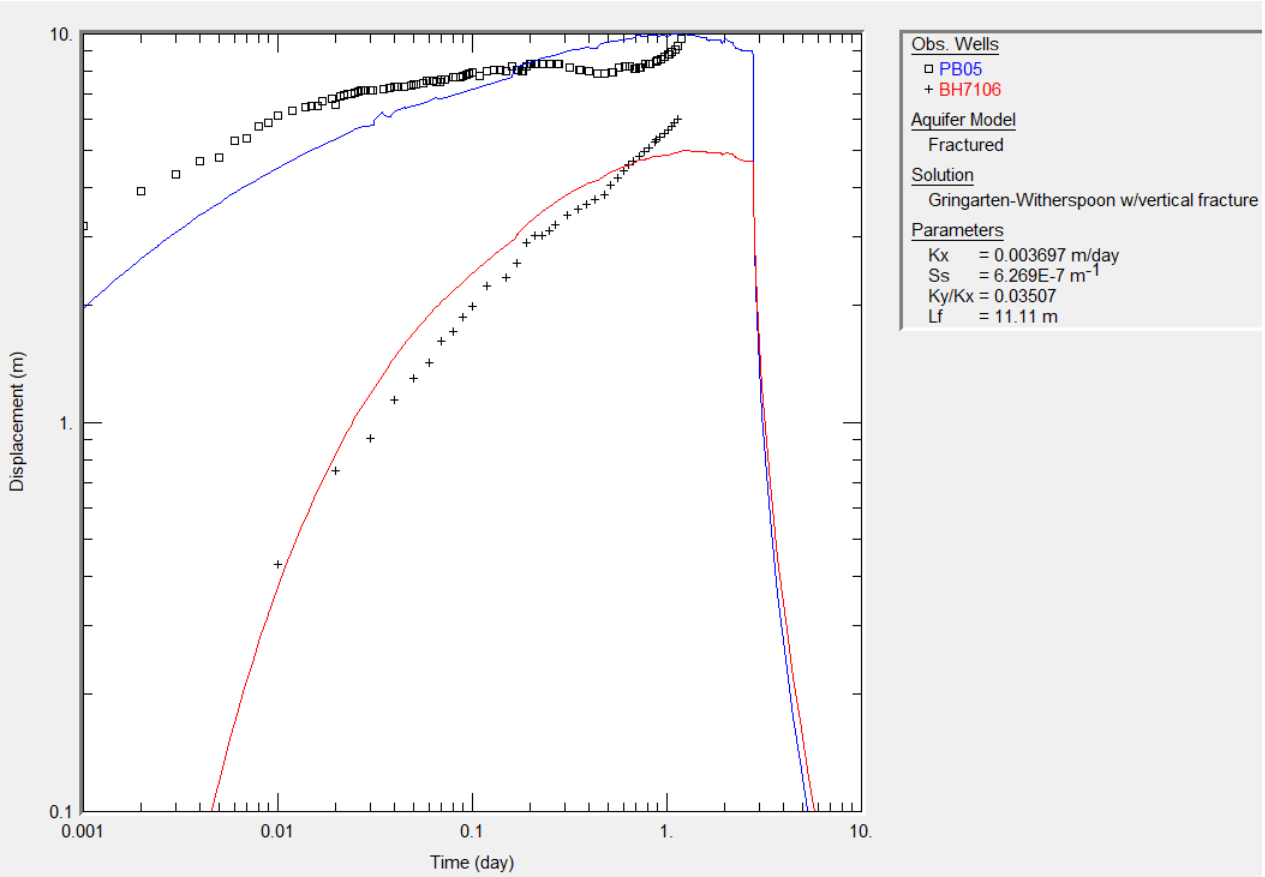


Figure 4: Pumping test analysis of PB05 and BH7106 early data using the Gringarten-Witherspoon vertical fracture model.

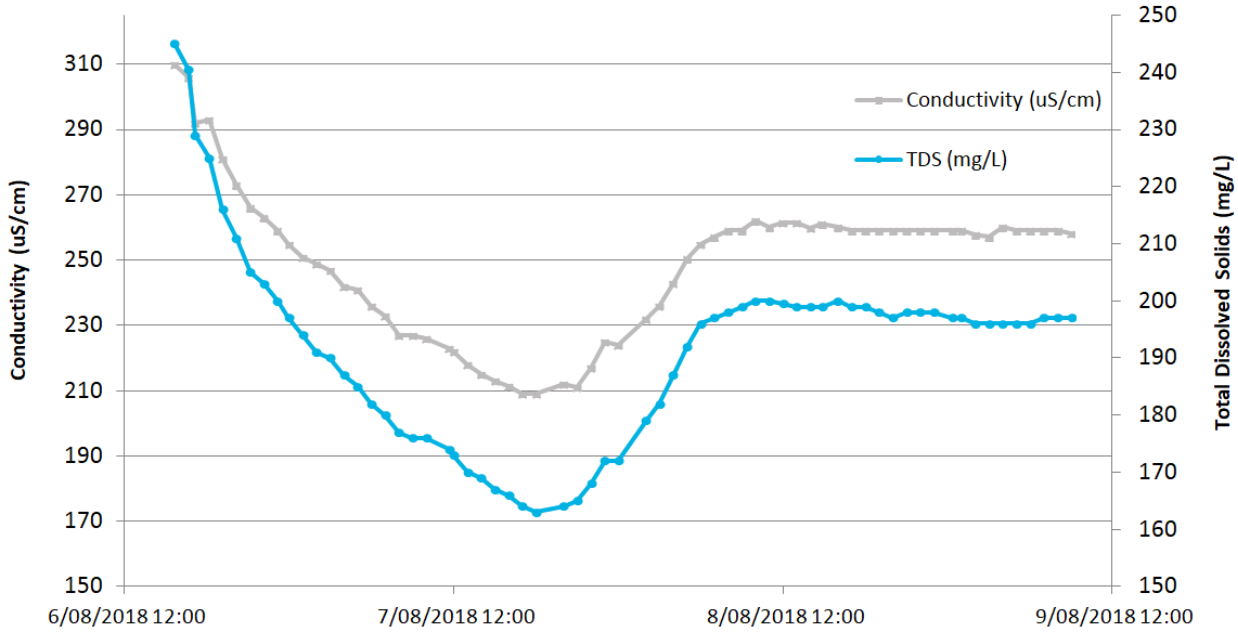


Figure 5: PB05 water quality data showing decreasing conductivity and TDS meaurements until the recharge zone is dewatered.

Based on this interpretation, data collected for both PB05 and BH7106 was able to be approximately modelled in AqteSolv using the Gringarten-Witherspoon vertical fracture model. The early-time data model is shown in Figure 4, while the late-time model is shown in Figure 6. The horizontal hydraulic conductivity was found to be similar for both the early-time and late-time cases, with values of 3.7e-3 and 3.3e-4 m/d modelled respectively. The reduction in hydraulic conductivity in the late-time data could be due to the dewatering of high conductivity fractures in the recharge zone.

MLU analysis of the late-time data agrees with the AqteSolv results, with a Kh of 7.7e-4 being calculated. The MLU model is shown in Figure 7.

The modelled ratios of Kv/Kh for each dataset were different, with a ratio of 0.035 being found for the early-time data, and 0.24 for the late-time data. Vertical movement of groundwater becoming more significant after dewatering the recharge zone could suggest the recharge zone is made up of high-conductivity horizontal fractures.

Storativity values estimated from both AqteSolv models were in agreement. A storativity of 6.3e-5 was found when modelling the early-time data, and 2.6e-5 was found with the late-time data.

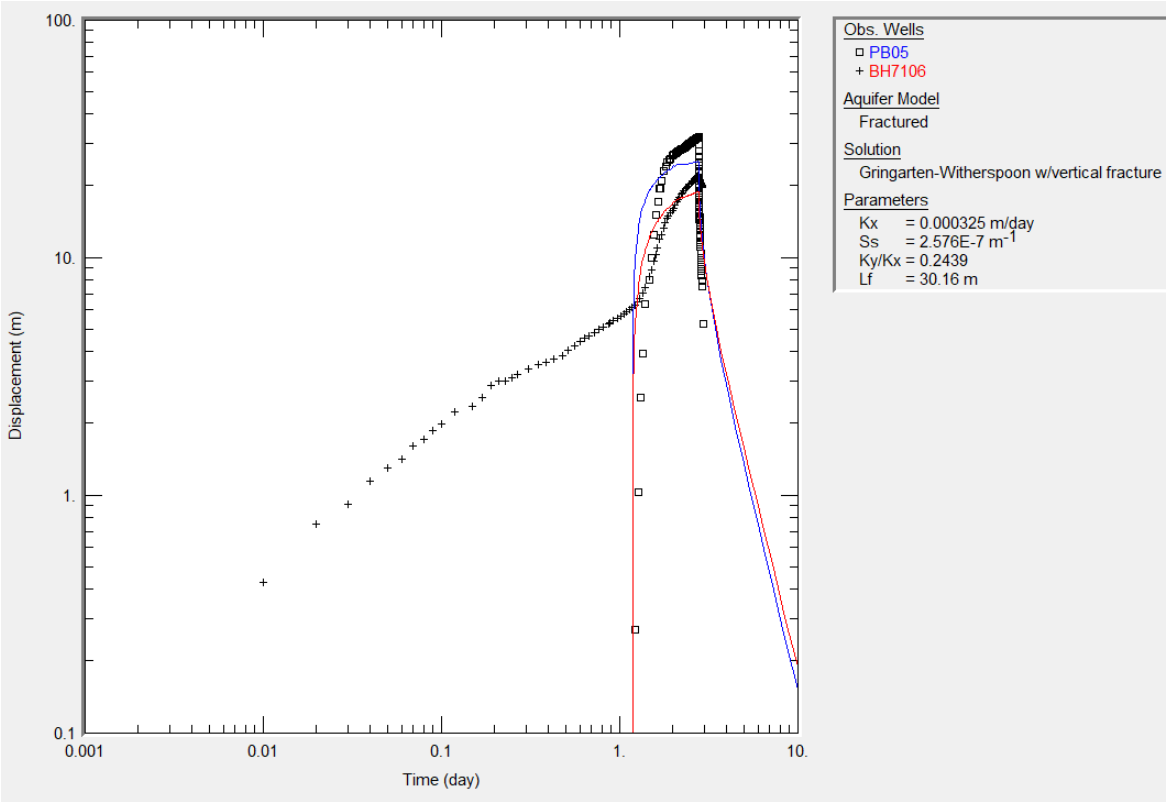


Figure 6: Pumping test analysis of PB05 and BH7106 late data using the Gringarten-Witherspoon vertical fracture model.

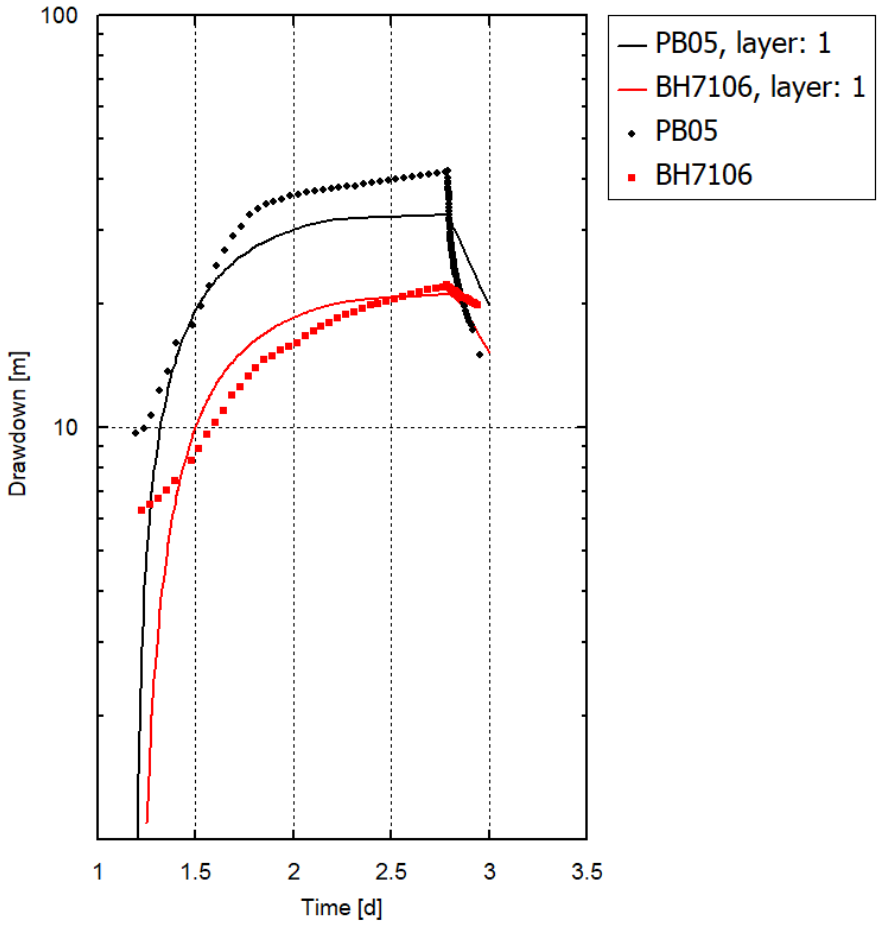


Figure 7: Pumping test analysis of PB05 and BH7106 late data using MLU.

5 Closing

We trust that this document addresses your requirements. Please let us know if you have any questions.

Yours Sincerely,

Bill Bull

Environmental Engineer

bbull@emmconsulting.com.au

Sean Cassidy

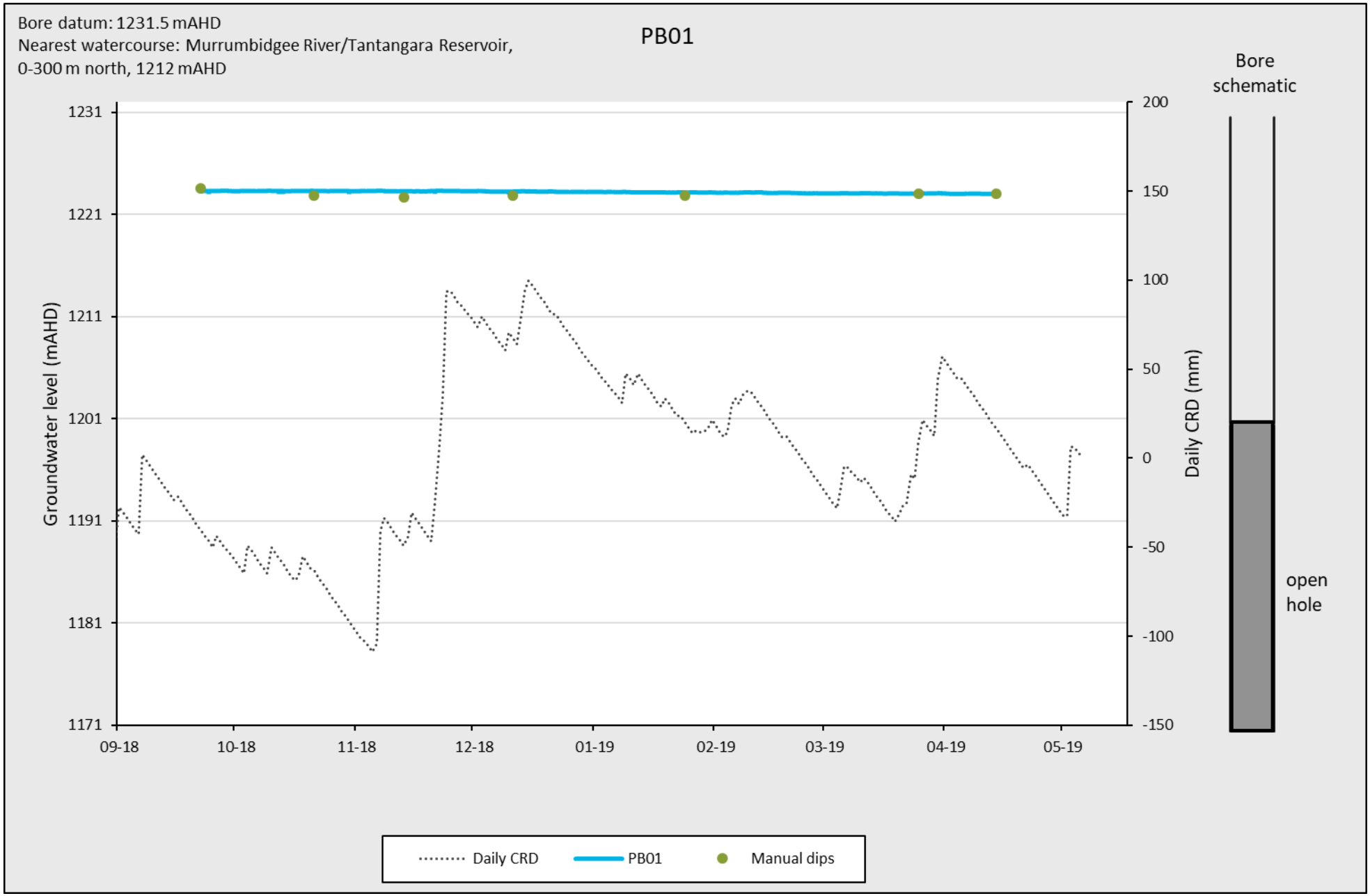
Associate Hydrogeologist

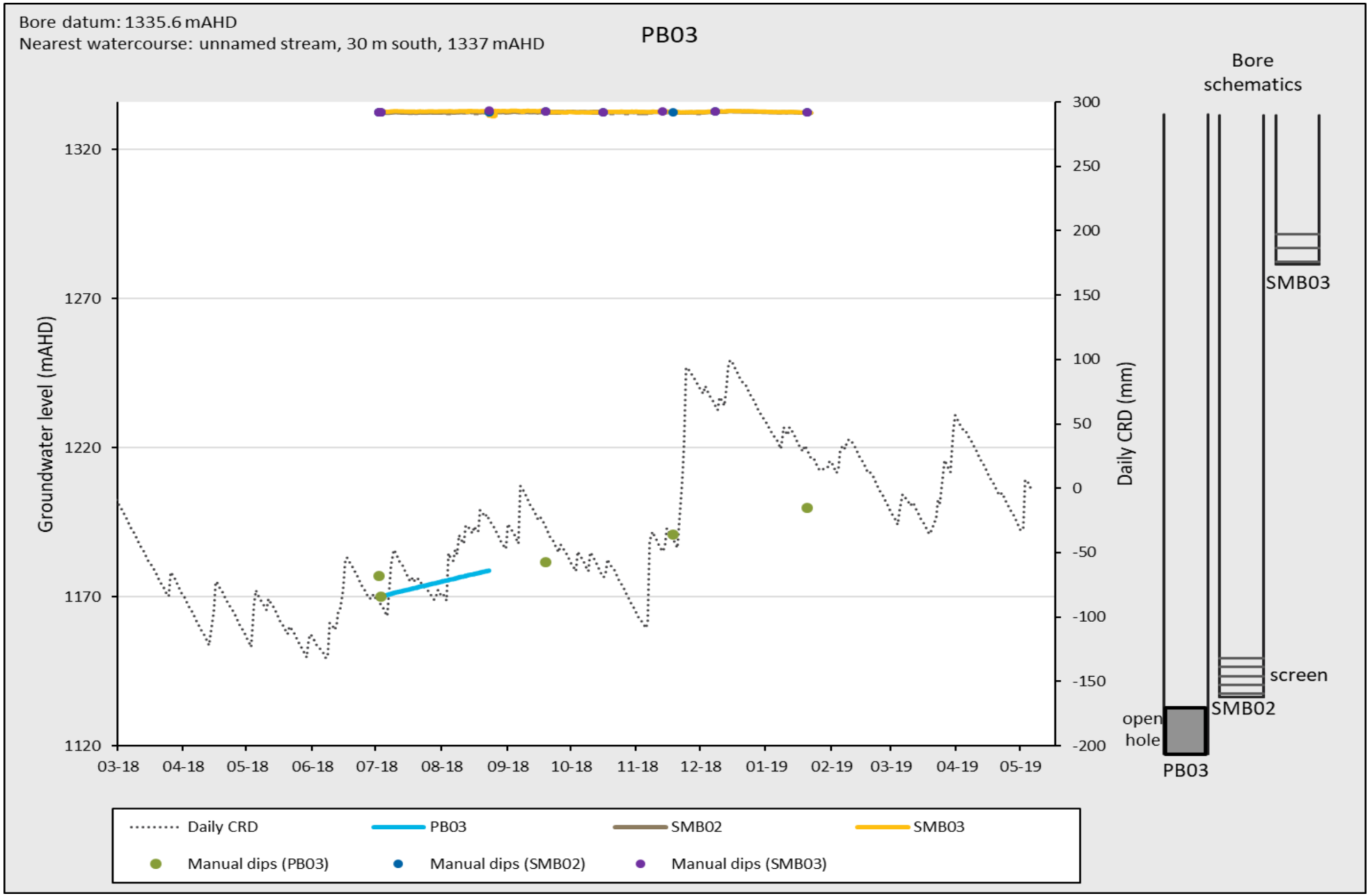
scassidy@emmconsulting.com.au

Appendix E

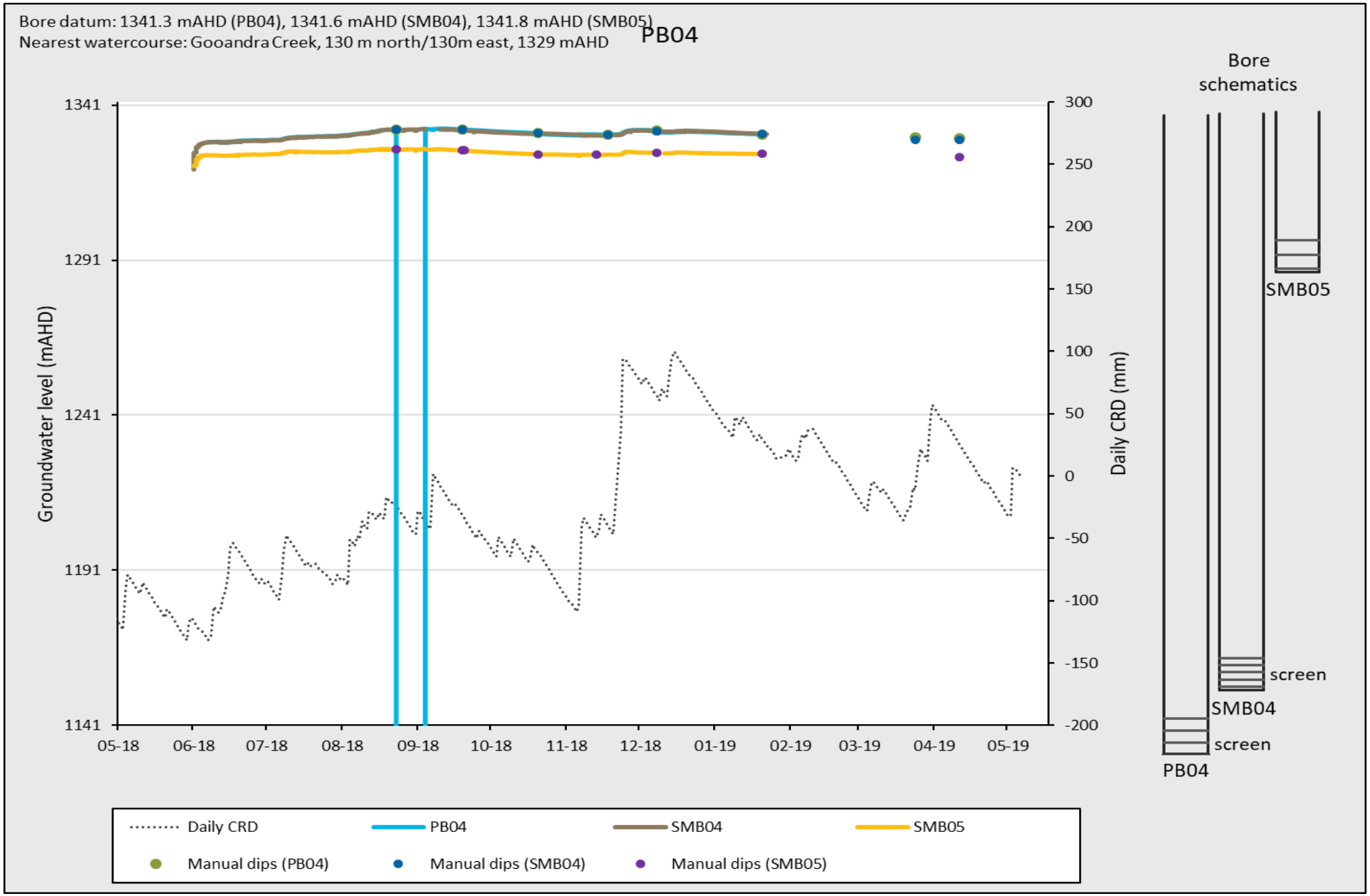
Hydrographs

Bore datum: 1231.5 mAHD
Nearest watercourse: Murrumbidgee River/Tantangara Reservoir, 0-300 m north, 1212 mAHD

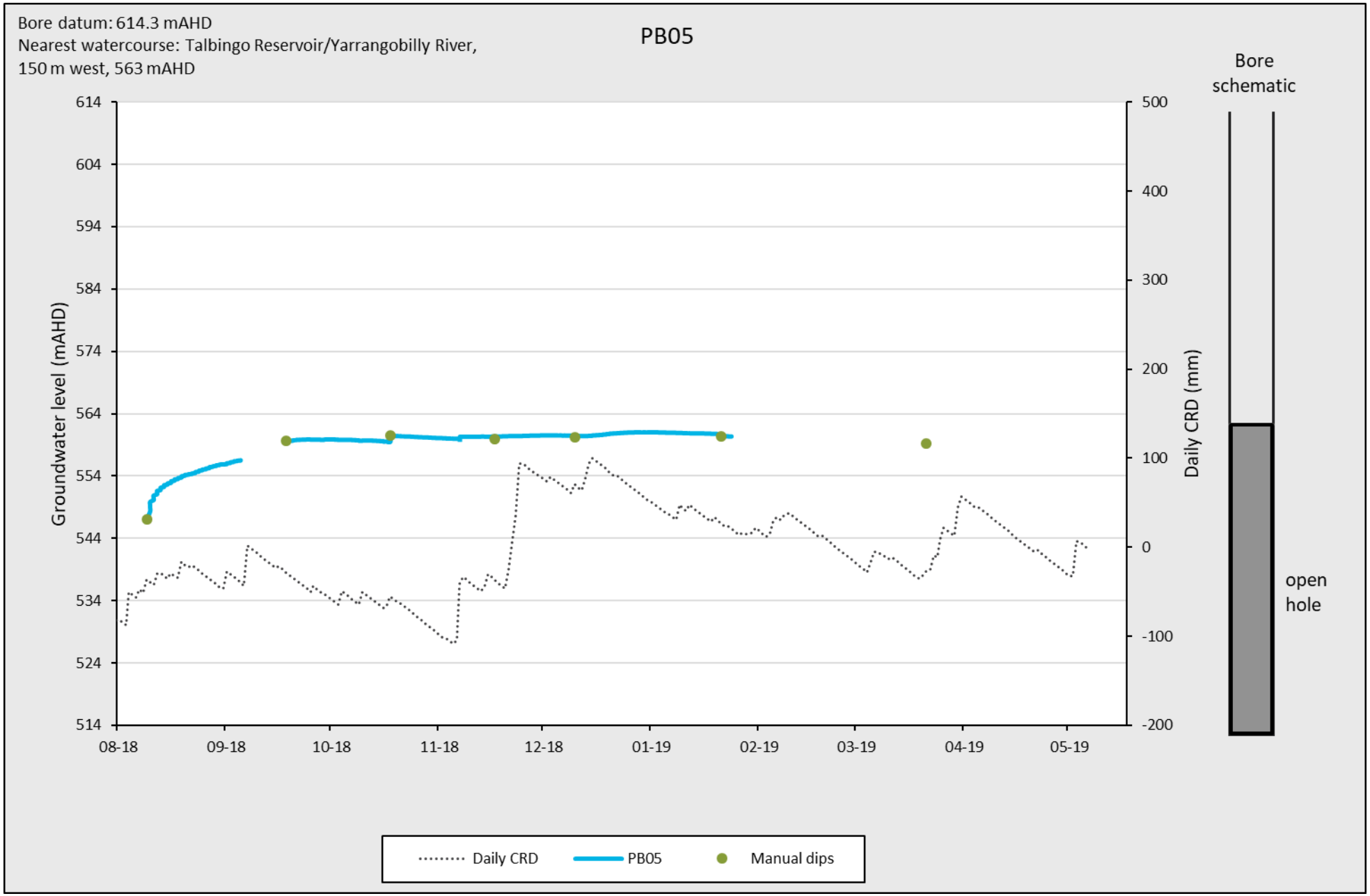



Bore datum: 1335.6 mAHD
Nearest watercourse: unnamed stream, 30 m south, 1337 mAHD
PB03
Groundwater level (mAHD)
Daily CRD (mm)
1320
1270
1220
1170
1120
300
250
200
150
100
50
0
-50
-100
-150
-200
03-18
04-18
05-18
06-18
07-18
08-18
09-18
10-18
11-18
12-18
01-19
02-19
03-19
04-19
05-19
Bore schematics
SMB03
screen
SMB02
open hole
PB03
Daily CRD
PB03
SMB02
SMB03
Manual dips (PB03)
Manual dips (SMB02)
Manual dips (SMB03)

Bore datum: 1341.3 mAHD (PB04), 1341.6 mAHD (SMB04), 1341.8 mAHD (SMB05)
Nearest watercourse: Gooandra Creek, 130 m north/130m east, 1329 mAHD



Bore datum: 614.3 mAHD
Nearest watercourse: Talbingo Reservoir/Yarrangobilly River, 150 m west, 563 mAHD



Appendix F

Groundwater sampling laboratory certificates

ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order	: **ES1820721**	Page	: 1 of 6
Client	: **EMM CONSULTING PTY LTD**	Laboratory	: Environmental Division Sydney
Contact	: MR SEAN CASSIDY	Contact	: Customer Services ES
Address	: Ground Floor Suite 1 20 Chandos Street St Leonards NSW NSW 2065	Address	: 277-289 Woodpark Road Smithfield NSW Australia 2164
Telephone	: +61 02 9493 9500	Telephone	: +61-2-8784 8555
Project	: J17188	Date Samples Received	: 13-Jul-2018 08:30
Order number	: ----	Date Analysis Commenced	: 13-Jul-2018
C-O-C number	: ----	Issue Date	: 18-Jul-2018 16:45
Sampler	: JAKE TURI, KAITLYN BRODIE		
Site	: ----		
Quote number	: SY/068/18 V2		
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*
Ankit Joshi	Inorganic Chemist	Sydney Inorganics, Smithfield, NSW
Celine Conceicao	Senior Spectroscopist	Sydney Inorganics, Smithfield, NSW

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.

- TDS by method EA-015 may bias high for various samples due to the presence of fine particulate matter, which may pass through the prescribed GF/C paper.
- EN055: Ionic Balance out of acceptable limits for sample 2 due to analytes not quantified in this report.
- Sodium Adsorption Ratio (where reported): Where results for Na, Ca or Mg are <LOR, a concentration at half the reported LOR is incorporated into the SAR calculation. This represents a conservative approach for Na relative to the assumption that <LOR = zero concentration and a conservative approach for Ca & Mg relative to the assumption that <LOR is equivalent to the LOR concentration.

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)				Client sample ID	PB01	MB04B	MB04A	MB06A	MB06B
				Client sampling date / time	12-Jul-2018 08:10	11-Jul-2018 16:10	11-Jul-2018 15:00	10-Jul-2018 13:45	10-Jul-2018 14:55
Compound	CAS Number	LOR	Unit		ES1820721-001	ES1820721-002	ES1820721-003	ES1820721-004	ES1820721-005
					Result	Result	Result	Result	Result
EA015: Total Dissolved Solids dried at 180 ± 5 °C									
Total Dissolved Solids @180°C	----	10	mg/L		81	644	271	90	208
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		16	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L		39	135	86	65	92
Total Alkalinity as CaCO3	----	1	mg/L		55	135	86	65	92
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA									
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L		6	80	82	<1	43
ED045G: Chloride by Discrete Analyser									
Chloride	16887-00-6	1	mg/L		5	56	8	2	8
ED093F: Dissolved Major Cations									
Calcium	7440-70-2	1	mg/L		8	10	45	15	29
Magnesium	7439-95-4	1	mg/L		4	1	3	4	8
Sodium	7440-23-5	1	mg/L		11	104	18	3	15
Potassium	7440-09-7	1	mg/L		<1	1	2	1	2
EG020F: Dissolved Metals by ICP-MS									
Arsenic	7440-38-2	0.001	mg/L		<0.001	0.002	<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	0.001	0.002	<0.001
Copper	7440-50-8	0.001	mg/L		0.001	0.002	0.014	0.007	<0.001
Nickel	7440-02-0	0.001	mg/L		0.001	0.009	0.004	0.025	0.004
Lead	7439-92-1	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
Zinc	7440-66-6	0.005	mg/L		<0.005	0.008	0.047	0.027	<0.005
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		<0.1	0.6	0.4	<0.1	0.2
EK055G: Ammonia as N by Discrete Analyser									
Ammonia as N	7664-41-7	0.01	mg/L		0.02	<0.01	0.04	<0.01	<0.01
EK057G: Nitrite as N by Discrete Analyser									
Nitrite as N	14797-65-0	0.01	mg/L		<0.01	<0.01	0.04	<0.01	<0.01
EK058G: Nitrate as N by Discrete Analyser									
Nitrate as N	14797-55-8	0.01	mg/L		0.02	0.01	0.48	0.03	0.04

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)				Client sample ID	PB01	MB04B	MB04A	MB06A	MB06B
				Client sampling date / time	12-Jul-2018 08:10	11-Jul-2018 16:10	11-Jul-2018 15:00	10-Jul-2018 13:45	10-Jul-2018 14:55
Compound	CAS Number	LOR	Unit		ES1820721-001	ES1820721-002	ES1820721-003	ES1820721-004	ES1820721-005
					Result	Result	Result	Result	Result
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser									
Nitrite + Nitrate as N	----	0.01	mg/L		**0.02**	**0.01**	**0.52**	**0.03**	**0.04**
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser									
Total Kjeldahl Nitrogen as N	----	0.1	mg/L		**0.1**	**0.2**	**0.1**	<0.1	<0.1
EK062G: Total Nitrogen as N (TKN + NOx) by Discrete Analyser									
^ Total Nitrogen as N	----	0.1	mg/L		**0.1**	**0.2**	**0.6**	<0.1	<0.1
EK067G: Total Phosphorus as P by Discrete Analyser									
Total Phosphorus as P	----	0.01	mg/L		**0.02**	**0.11**	**0.02**	<0.01	**0.02**
EN055: Ionic Balance									
Total Anions	----	0.01	meq/L		**1.36**	**5.94**	**3.65**	**1.36**	**2.96**
Total Cations	----	0.01	meq/L		**1.21**	**5.13**	**3.33**	**1.23**	**2.81**
Ionic Balance	----	0.01	%		**----**	**7.33**	**4.65**	**----**	**----**

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)				Client sample ID	MB01B	MB01C	MB03	----	----
				Client sampling date / time	10-Jul-2018 16:45	10-Jul-2018 16:00	10-Jul-2018 09:30	----	----
Compound	CAS Number	LOR	Unit		ES1820721-006	ES1820721-007	ES1820721-008	--------	--------
					Result	Result	Result	----	----
EA015: Total Dissolved Solids dried at 180 ± 5 °C									
Total Dissolved Solids @180°C	----	10	mg/L		49	133	77	----	----
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		24	83	49	----	----
Total Alkalinity as CaCO3	----	1	mg/L		24	83	49	----	----
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA									
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L		<1	10	1	----	----
ED045G: Chloride by Discrete Analyser									
Chloride	16887-00-6	1	mg/L		<1	<1	3	----	----
ED093F: Dissolved Major Cations									
Calcium	7440-70-2	1	mg/L		5	16	8	----	----
Magnesium	7439-95-4	1	mg/L		1	6	4	----	----
Sodium	7440-23-5	1	mg/L		1	9	4	----	----
Potassium	7440-09-7	1	mg/L		<1	1	<1	----	----
EG020F: Dissolved Metals by ICP-MS									
Arsenic	7440-38-2	0.001	mg/L		<0.001	0.006	<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		0.004	0.005	0.002	----	----
Nickel	7440-02-0	0.001	mg/L		0.002	0.002	<0.001	----	----
Lead	7439-92-1	0.001	mg/L		<0.001	<0.001	<0.001	----	----
Zinc	7440-66-6	0.005	mg/L		0.010	0.012	0.006	----	----
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		<0.1	<0.1	<0.1	----	----
EK055G: Ammonia as N by Discrete Analyser									
Ammonia as N	7664-41-7	0.01	mg/L		<0.01	<0.01	<0.01	----	----
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		0.04	0.02	0.25	----	----

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)				Client sample ID	MB01B	MB01C	MB03	----	----
				Client sampling date / time	10-Jul-2018 16:45	10-Jul-2018 16:00	10-Jul-2018 09:30	----	----
Compound	CAS Number	LOR	Unit		ES1820721-006	ES1820721-007	ES1820721-008	--------	--------
					Result	Result	Result	----	----
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser									
Nitrite + Nitrate as N	----	0.01	mg/L		**0.04**	**0.02**	**0.25**	**----**	**----**
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser									
Total Kjeldahl Nitrogen as N	----	0.1	mg/L		<0.1	<0.1	<0.1	**----**	**----**
EK062G: Total Nitrogen as N (TKN + NOx) by Discrete Analyser									
^ Total Nitrogen as N	----	0.1	mg/L		<0.1	<0.1	**0.2**	**----**	**----**
EK067G: Total Phosphorus as P by Discrete Analyser									
Total Phosphorus as P	----	0.01	mg/L		**0.38**	**0.02**	**0.02**	**----**	**----**
EN055: Ionic Balance									
Total Anions	----	0.01	meq/L		**0.48**	**1.87**	**1.08**	**----**	**----**
Total Cations	----	0.01	meq/L		**0.38**	**1.71**	**0.90**	**----**	**----**

ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order	: **ES1825251**	Page	: 1 of 12
Client	: **EMM CONSULTING PTY LTD**	Laboratory	: Environmental Division Sydney
Contact	: MR SEAN CASSIDY	Contact	: Customer Services ES
Address	: Ground Floor Suite 1 20 Chandos Street St Leonards NSW NSW 2065	Address	: 277-289 Woodpark Road Smithfield NSW Australia 2164
Telephone	: +61 02 9493 9500	Telephone	: +61-2-8784 8555
Project	: J17188	Date Samples Received	: 27-Aug-2018 15:00
Order number	:	Date Analysis Commenced	: 28-Aug-2018
C-O-C number	: ----	Issue Date	: 31-Aug-2018 14:41
Sampler	: JAKE TURI/KAITLYN BRODIE		
Site	: ----		
Quote number	: SY/068/18 V2		
No. of samples received	: 23		
No. of samples analysed	: 23		

ilac-MRA NATA
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*
Ankit Joshi	Inorganic Chemist	Sydney Inorganics, Smithfield, NSW
Dian Dao		Sydney Inorganics, Smithfield, NSW
Ivan Taylor	Analyst	Sydney Inorganics, Smithfield, NSW
Wisam Marassa	Inorganics Coordinator	Sydney Inorganics, Smithfield, NSW

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.

- Sodium Adsorption Ratio (where reported): Where results for Na, Ca or Mg are <LOR, a concentration at half the reported LOR is incorporated into the SAR calculation. This represents a conservative approach for Na relative to the assumption that <LOR = zero concentration and a conservative approach for Ca & Mg relative to the assumption that <LOR is equivalent to the LOR concentration.

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)				Client sample ID	TMB02A	TMB02B	TMB03A	TMB03B	TMB03C
				Client sampling date / time	21-Aug-2018 10:40	21-Aug-2018 10:20	22-Aug-2018 14:30	22-Aug-2018 14:45	22-Aug-2018 16:00
Compound	CAS Number	LOR	Unit		ES1825251-001	ES1825251-002	ES1825251-003	ES1825251-004	ES1825251-005
					Result	Result	Result	Result	Result
EA015: Total Dissolved Solids dried at 180 ± 5 °C									
Total Dissolved Solids @180°C	----	10	mg/L		21	69	64	96	75
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		11	72	36	86	65
Total Alkalinity as CaCO3	----	1	mg/L		11	72	36	86	65
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA									
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L		1	1	5	3	<1
ED045G: Chloride by Discrete Analyser									
Chloride	16887-00-6	1	mg/L		<1	<1	<1	<1	<1
ED093F: Dissolved Major Cations									
Calcium	7440-70-2	1	mg/L		4	15	4	20	8
Magnesium	7439-95-4	1	mg/L		<1	2	3	2	4
Sodium	7440-23-5	1	mg/L		2	7	5	6	8
Potassium	7440-09-7	1	mg/L		<1	<1	<1	5	2
EG020F: Dissolved Metals by ICP-MS									
Arsenic	7440-38-2	0.001	mg/L		<0.001	0.002	0.002	0.002	<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	<0.001	<0.001	<0.001
Copper	7440-50-8	0.001	mg/L		0.010	<0.001	<0.001	<0.001	<0.001
Nickel	7440-02-0	0.001	mg/L		<0.001	0.001	0.003	<0.001	<0.001
Lead	7439-92-1	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
Zinc	7440-66-6	0.005	mg/L		<0.005	<0.005	0.011	0.007	<0.005
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		<0.1	0.2	<0.1	0.8	0.1
EK055G: Ammonia as N by Discrete Analyser									
Ammonia as N	7664-41-7	0.01	mg/L		<0.01	<0.01	<0.01	<0.01	0.02
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		<0.01	0.02	9.92	0.02	0.04

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)				Client sample ID	TMB02A	TMB02B	TMB03A	TMB03B	TMB03C
				Client sampling date / time	21-Aug-2018 10:40	21-Aug-2018 10:20	22-Aug-2018 14:30	22-Aug-2018 14:45	22-Aug-2018 16:00
Compound	CAS Number	LOR	Unit		ES1825251-001	ES1825251-002	ES1825251-003	ES1825251-004	ES1825251-005
					Result	Result	Result	Result	Result
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser									
Nitrite + Nitrate as N	----	0.01	mg/L		<0.01	**0.02**	**9.92**	**0.02**	**0.04**
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser									
Total Kjeldahl Nitrogen as N	----	0.1	mg/L		<0.1	<0.1	**1.0**	<0.1	<0.1
EK062G: Total Nitrogen as N (TKN + NOx) by Discrete Analyser									
^ Total Nitrogen as N	----	0.1	mg/L		<0.1	<0.1	**10.9**	<0.1	<0.1
EK067G: Total Phosphorus as P by Discrete Analyser									
Total Phosphorus as P	----	0.01	mg/L		<0.01	<0.01	**0.13**	**0.02**	**0.03**
EN055: Ionic Balance									
Total Anions	----	0.01	meq/L		**0.24**	**1.46**	**0.82**	**1.78**	**1.30**
Total Cations	----	0.01	meq/L		**0.29**	**1.22**	**0.66**	**1.55**	**1.13**

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)				Client sample ID	MB04A	MB04B	MB07A	MB07B	MB01B
				Client sampling date / time	22-Aug-2018 12:45	22-Aug-2018 12:45	23-Aug-2018 11:15	23-Aug-2018 11:15	23-Aug-2018 09:10
Compound	CAS Number	LOR	Unit		ES1825251-006	ES1825251-007	ES1825251-008	ES1825251-009	ES1825251-010
					Result	Result	Result	Result	Result
EA015: Total Dissolved Solids dried at 180 ± 5 °C									
Total Dissolved Solids @180°C	----	10	mg/L		272	458	113	320	51
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		77	124	14	40	45
Total Alkalinity as CaCO3	----	1	mg/L		77	124	14	40	45
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA									
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L		142	79	48	221	<1
ED045G: Chloride by Discrete Analyser									
Chloride	16887-00-6	1	mg/L		4	40	<1	5	<1
ED093F: Dissolved Major Cations									
Calcium	7440-70-2	1	mg/L		59	11	13	60	13
Magnesium	7439-95-4	1	mg/L		4	2	6	7	2
Sodium	7440-23-5	1	mg/L		22	107	4	30	1
Potassium	7440-09-7	1	mg/L		3	1	<1	4	<1
EG020F: Dissolved Metals by ICP-MS									
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	<0.001	<0.001	<0.001
Copper	7440-50-8	0.001	mg/L		0.003	0.001	0.005	<0.001	0.020
Nickel	7440-02-0	0.001	mg/L		0.001	0.003	<0.001	0.001	<0.001
Lead	7439-92-1	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
Zinc	7440-66-6	0.005	mg/L		0.014	0.008	0.006	0.036	0.005
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		0.5	0.6	<0.1	0.8	<0.1
EK055G: Ammonia as N by Discrete Analyser									
Ammonia as N	7664-41-7	0.01	mg/L		0.03	0.01	<0.01	<0.01	0.06
EK057G: Nitrite as N by Discrete Analyser									
Nitrite as N	14797-65-0	0.01	mg/L		0.06	<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		0.27	0.16	0.12	<0.01	0.04

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)				Client sample ID	MB04A	MB04B	MB07A	MB07B	MB01B
				Client sampling date / time	22-Aug-2018 12:45	22-Aug-2018 12:45	23-Aug-2018 11:15	23-Aug-2018 11:15	23-Aug-2018 09:10
Compound	CAS Number	LOR	Unit		ES1825251-006	ES1825251-007	ES1825251-008	ES1825251-009	ES1825251-010
					Result	Result	Result	Result	Result
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser									
Nitrite + Nitrate as N	----	0.01	mg/L		**0.33**	**0.16**	**0.12**	<0.01	**0.04**
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser									
Total Kjeldahl Nitrogen as N	----	0.1	mg/L		<0.1	<0.1	<0.1	<0.1	<0.1
EK062G: Total Nitrogen as N (TKN + NOx) by Discrete Analyser									
^ Total Nitrogen as N	----	0.1	mg/L		**0.3**	**0.2**	**0.1**	<0.1	<0.1
EK067G: Total Phosphorus as P by Discrete Analyser									
Total Phosphorus as P	----	0.01	mg/L		**0.02**	**0.10**	**0.01**	**0.02**	**1.03**
EN055: Ionic Balance									
Total Anions	----	0.01	meq/L		**4.61**	**5.25**	**1.28**	**5.54**	**0.90**
Total Cations	----	0.01	meq/L		**4.31**	**5.39**	**1.32**	**4.98**	**0.86**
Ionic Balance	----	0.01	%		**3.37**	**1.34**	**----**	**5.36**	**----**

Analytical Results

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

Compound	CAS Number	LOR	Unit	Client sample ID	MB01C	TMB04	SMB02	SMB03	SMB04
				Client sampling date / time	23-Aug-2018 10:00	23-Aug-2018 14:10	23-Aug-2018 13:40	23-Aug-2018 13:45	23-Aug-2018 15:05
					ES1825251-011	ES1825251-012	ES1825251-013	ES1825251-014	ES1825251-015
					Result	Result	Result	Result	Result
EA015: Total Dissolved Solids dried at 180 ± 5 °C									
Total Dissolved Solids @180°C	----	10	mg/L		**92**	**48**	**95**	**73**	**85**
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		**77**	**32**	**76**	**48**	**46**
Total Alkalinity as CaCO3	----	1	mg/L		**77**	**32**	**76**	**48**	**46**
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA									
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L		**8**	**3**	**6**	**2**	**13**
ED045G: Chloride by Discrete Analyser									
Chloride	16887-00-6	1	mg/L		<1	<1	**1**	<1	<1
ED093F: Dissolved Major Cations									
Calcium	7440-70-2	1	mg/L		**16**	**9**	**21**	**12**	**17**
Magnesium	7439-95-4	1	mg/L		**6**	<1	**2**	**2**	<1
Sodium	7440-23-5	1	mg/L		**8**	**2**	**10**	**4**	**5**
Potassium	7440-09-7	1	mg/L		**1**	<1	<1	<1	<1
EG020F: Dissolved Metals by ICP-MS									
Arsenic	7440-38-2	0.001	mg/L		**0.006**	<0.001	<0.001	<0.001	**0.016**
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	**0.001**	<0.001	<0.001
Copper	7440-50-8	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
Nickel	7440-02-0	0.001	mg/L		<0.001	<0.001	<0.001	**0.004**	<0.001
Lead	7439-92-1	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
Zinc	7440-66-6	0.005	mg/L		**0.007**	**0.006**	**0.037**	**0.037**	**0.007**
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		<0.1	<0.1	**0.3**	<0.1	<0.1
EK055G: Ammonia as N by Discrete Analyser									
Ammonia as N	7664-41-7	0.01	mg/L		**0.02**	<0.01	**0.01**	**0.08**	<0.01
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		<0.01	**0.02**	<0.01	**0.06**	**0.01**

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)				Client sample ID	MB01C	TMB04	SMB02	SMB03	SMB04
				Client sampling date / time	23-Aug-2018 10:00	23-Aug-2018 14:10	23-Aug-2018 13:40	23-Aug-2018 13:45	23-Aug-2018 15:05
Compound	CAS Number	LOR	Unit		ES1825251-011	ES1825251-012	ES1825251-013	ES1825251-014	ES1825251-015
					Result	Result	Result	Result	Result
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser									
Nitrite + Nitrate as N	----	0.01	mg/L		<0.01	**0.02**	<0.01	**0.06**	**0.01**
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser									
Total Kjeldahl Nitrogen as N	----	0.1	mg/L		<0.1	<0.1	<0.1	<0.1	<0.1
EK062G: Total Nitrogen as N (TKN + NOx) by Discrete Analyser									
^ **Total Nitrogen as N**	----	0.1	mg/L		<0.1	<0.1	<0.1	<0.1	<0.1
EK067G: Total Phosphorus as P by Discrete Analyser									
Total Phosphorus as P	----	0.01	mg/L		**0.05**	**0.02**	**0.02**	<0.01	**0.03**
EN055: Ionic Balance									
Total Anions	----	0.01	meq/L		**1.70**	**0.70**	**1.67**	**1.00**	**1.19**
Total Cations	----	0.01	meq/L		**1.66**	**0.54**	**1.65**	**0.94**	**1.06**

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)				Client sample ID	SMB05	PB04	MB02	MB03	MB06A
				Client sampling date / time	23-Aug-2018 15:00	23-Aug-2018 14:45	24-Aug-2018 09:15	24-Aug-2018 10:10	25-Aug-2018 10:00
Compound	CAS Number	LOR	Unit		ES1825251-016	ES1825251-017	ES1825251-018	ES1825251-019	ES1825251-020
					Result	Result	Result	Result	Result
EA015: Total Dissolved Solids dried at 180 ± 5 °C									
Total Dissolved Solids @180°C	----	10	mg/L		144	57	64	51	85
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		51	45	42	44	49
Total Alkalinity as CaCO3	----	1	mg/L		51	45	42	44	49
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA									
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L		39	11	2	1	10
ED045G: Chloride by Discrete Analyser									
Chloride	16887-00-6	1	mg/L		4	<1	<1	<1	2
ED093F: Dissolved Major Cations									
Calcium	7440-70-2	1	mg/L		29	10	13	8	12
Magnesium	7439-95-4	1	mg/L		1	<1	1	4	3
Sodium	7440-23-5	1	mg/L		13	5	1	4	12
Potassium	7440-09-7	1	mg/L		<1	<1	<1	<1	<1
EG020F: Dissolved Metals by ICP-MS									
Arsenic	7440-38-2	0.001	mg/L		0.004	<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	<0.001	<0.001	0.002
Copper	7440-50-8	0.001	mg/L		<0.001	<0.001	0.004	0.002	0.002
Nickel	7440-02-0	0.001	mg/L		<0.001	<0.001	0.001	<0.001	0.016
Lead	7439-92-1	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
Zinc	7440-66-6	0.005	mg/L		0.008	<0.005	0.006	0.007	0.013
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		0.2	0.2	<0.1	<0.1	<0.1
EK055G: Ammonia as N by Discrete Analyser									
Ammonia as N	7664-41-7	0.01	mg/L		0.01	<0.01	0.01	<0.01	0.02
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		0.02	<0.01	0.01	0.21	<0.01

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)				Client sample ID	SMB05	PB04	MB02	MB03	MB06A
				Client sampling date / time	23-Aug-2018 15:00	23-Aug-2018 14:45	24-Aug-2018 09:15	24-Aug-2018 10:10	25-Aug-2018 10:00
Compound	CAS Number	LOR	Unit		ES1825251-016	ES1825251-017	ES1825251-018	ES1825251-019	ES1825251-020
					Result	Result	Result	Result	Result
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser									
Nitrite + Nitrate as N	----	0.01	mg/L		**0.02**	<0.01	**0.01**	**0.21**	<0.01
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser									
Total Kjeldahl Nitrogen as N	----	0.1	mg/L		<0.1	<0.1	<0.1	<0.1	<0.1
EK062G: Total Nitrogen as N (TKN + NOx) by Discrete Analyser									
^ Total Nitrogen as N	----	0.1	mg/L		<0.1	<0.1	<0.1	**0.2**	<0.1
EK067G: Total Phosphorus as P by Discrete Analyser									
Total Phosphorus as P	----	0.01	mg/L		**0.05**	**0.03**	**0.04**	**0.07**	**0.12**
EN055: Ionic Balance									
Total Anions	----	0.01	meq/L		**1.94**	**1.13**	**0.88**	**0.90**	**1.24**
Total Cations	----	0.01	meq/L		**2.09**	**0.72**	**0.77**	**0.90**	**1.37**

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)				Client sample ID	MB06B	QA2	QA3	----	----
				Client sampling date / time	25-Aug-2018 10:10	22-Aug-2018 00:00	25-Aug-2018 00:00	----	----
Compound	CAS Number	LOR	Unit		ES1825251-021	ES1825251-022	ES1825251-023	--------	--------
					Result	Result	Result	----	----
EA015: Total Dissolved Solids dried at 180 ± 5 °C									
Total Dissolved Solids @180°C	----	10	mg/L		220	238	82	----	----
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		95	71	49	----	----
Total Alkalinity as CaCO3	----	1	mg/L		95	71	49	----	----
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA									
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L		57	155	11	----	----
ED045G: Chloride by Discrete Analyser									
Chloride	16887-00-6	1	mg/L		7	5	2	----	----
ED093F: Dissolved Major Cations									
Calcium	7440-70-2	1	mg/L		26	60	12	----	----
Magnesium	7439-95-4	1	mg/L		7	4	3	----	----
Sodium	7440-23-5	1	mg/L		30	22	12	----	----
Potassium	7440-09-7	1	mg/L		1	3	1	----	----
EG020F: Dissolved Metals by ICP-MS									
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	0.002	----	----
Copper	7440-50-8	0.001	mg/L		<0.001	0.001	0.002	----	----
Nickel	7440-02-0	0.001	mg/L		0.005	0.001	0.016	----	----
Lead	7439-92-1	0.001	mg/L		<0.001	<0.001	<0.001	----	----
Zinc	7440-66-6	0.005	mg/L		<0.005	0.009	0.015	----	----
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		0.2	0.5	<0.1	----	----
EK055G: Ammonia as N by Discrete Analyser									
Ammonia as N	7664-41-7	0.01	mg/L		<0.01	0.05	<0.01	----	----
EK057G: Nitrite as N by Discrete Analyser									
Nitrite as N	14797-65-0	0.01	mg/L		<0.01	0.06	<0.01	----	----
EK058G: Nitrate as N by Discrete Analyser									
Nitrate as N	14797-55-8	0.01	mg/L		<0.01	0.27	<0.01	----	----

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)				Client sample ID	MB06B	QA2	QA3	----	----
				Client sampling date / time	25-Aug-2018 10:10	22-Aug-2018 00:00	25-Aug-2018 00:00	----	----
Compound	CAS Number	LOR	Unit		ES1825251-021	ES1825251-022	ES1825251-023	--------	--------
					Result	Result	Result	----	----
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser									
Nitrite + Nitrate as N	----	0.01	mg/L		<0.01	**0.33**	<0.01	----	----
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser									
Total Kjeldahl Nitrogen as N	----	0.1	mg/L		<0.1	<0.1	<0.1	----	----
EK062G: Total Nitrogen as N (TKN + NOx) by Discrete Analyser									
^ Total Nitrogen as N	----	0.1	mg/L		<0.1	**0.3**	<0.1	----	----
EK067G: Total Phosphorus as P by Discrete Analyser									
Total Phosphorus as P	----	0.01	mg/L		**0.03**	**0.02**	**0.06**	----	----
EN055: Ionic Balance									
Total Anions	----	0.01	meq/L		**3.28**	**4.79**	**1.26**	----	----
Total Cations	----	0.01	meq/L		**3.20**	**4.36**	**1.39**	----	----
Ionic Balance	----	0.01	%		**1.21**	**4.70**	----	----	----

ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order	: **ES1828283**	Page	: 1 of 26
Client	: **EMM CONSULTING PTY LTD**	Laboratory	: Environmental Division Sydney
Contact	: MR SEAN CASSIDY	Contact	: Customer Services ES
Address	: Ground Floor Suite 1 20 Chandos Street St Leonards NSW NSW 2065	Address	: 277-289 Woodpark Road Smithfield NSW Australia 2164
Telephone	: +61 02 9493 9500	Telephone	: +61-2-8784 8555
Project	: J17188	Date Samples Received	: 25-Sep-2018 08:30
Order number	:	Date Analysis Commenced	: 25-Sep-2018
C-O-C number	: ----	Issue Date	: 03-Oct-2018 17:55
Sampler	: Imogen Frawley, Kaitlyn Brodie		
Site	: ----		
Quote number	: SY/068/18 V2		
No. of samples received	: 59		
No. of samples analysed	: 59		

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*
Ankit Joshi	Inorganic Chemist	Sydney Inorganics, Smithfield, NSW
Ivan Taylor	Analyst	Sydney Inorganics, Smithfield, NSW

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.

- EK061G/EK062G: : LOR raised for TKN & TN on sample No 15 & 52 due to sample matrix.
- TDS by method EA-015 may bias high for various samples due to the presence of fine particulate matter, which may pass through the prescribed GF/C paper.TDS confirmed by reanalysis for sample no 45
- TDS by method EA-015 may bias high for various samples due to the presence of fine particulate matter, which may pass through the prescribed GF/C paper.
- EP002 : It has been noted that DOC is greater than TOC for various samples, however this difference is within the limits of experimental variation.
- Sodium Adsorption Ratio (where reported): Where results for Na, Ca or Mg are <LOR, a concentration at half the reported LOR is incorporated into the SAR calculation. This represents a conservative approach for Na relative to the assumption that <LOR = zero concentration and a conservative approach for Ca & Mg relative to the assumption that <LOR is equivalent to the LOR concentration.

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)				Client sample ID	TMB01A	TMB01B	LH_SW_004	LH_SW_003	LH_SW_007
				Client sampling date / time	23-Sep-2018 08:45	23-Sep-2018 09:20	23-Sep-2018 10:30	23-Sep-2018 09:45	23-Sep-2018 11:40
Compound	CAS Number	LOR	Unit		ES1828283-001	ES1828283-002	ES1828283-003	ES1828283-004	ES1828283-005
					Result	Result	Result	Result	Result
EA015: Total Dissolved Solids dried at 180 ± 5 °C									
Total Dissolved Solids @180°C	----	10	mg/L		195	955	50	38	54
EA025: Total Suspended Solids dried at 104 ± 2°C									
Suspended Solids (SS)	----	5	mg/L		----	----	<5	<5	<5
ED037P: Alkalinity by PC Titrator									
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L		<1	<1	----	----	----
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L		<1	<1	----	----	----
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L		83	648	----	----	----
Total Alkalinity as CaCO3	----	1	mg/L		83	648	----	----	----
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA									
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L		11	14	----	----	----
ED045G: Chloride by Discrete Analyser									
Chloride	16887-00-6	1	mg/L		5	113	----	----	----
ED093F: Dissolved Major Cations									
Calcium	7440-70-2	1	mg/L		6	13	----	----	----
Magnesium	7439-95-4	1	mg/L		2	10	----	----	----
Sodium	7440-23-5	1	mg/L		36	341	----	----	----
Potassium	7440-09-7	1	mg/L		1	9	----	----	----
ED093F: SAR and Hardness Calculations									
Total Hardness as CaCO3	----	1	mg/L		----	----	26	17	29
EG020F: Dissolved Metals by ICP-MS									
Aluminium	7429-90-5	0.01	mg/L		----	----	0.03	0.01	0.03
Arsenic	7440-38-2	0.001	mg/L		0.003	0.026	<0.001	<0.001	<0.001
Boron	7440-42-8	0.05	mg/L		----	----	<0.05	<0.05	<0.05
Barium	7440-39-3	0.001	mg/L		----	----	0.013	0.038	0.016
Beryllium	7440-41-7	0.001	mg/L		----	----	<0.001	<0.001	<0.001
Cadmium	7440-43-9	0.0001	mg/L		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Cobalt	7440-48-4	0.001	mg/L		----	----	<0.001	<0.001	<0.001
Chromium	7440-47-3	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
Copper	7440-50-8	0.001	mg/L		0.001	<0.001	<0.001	0.001	<0.001
Manganese	7439-96-5	0.001	mg/L		----	----	<0.001	<0.001	<0.001
Nickel	7440-02-0	0.001	mg/L		<0.001	0.008	0.001	<0.001	<0.001
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
Vanadium	7440-62-2	0.01	mg/L		----	----	<0.01	<0.01	<0.01

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)				Client sample ID	TMB01A	TMB01B	LH_SW_004	LH_SW_003	LH_SW_007
				Client sampling date / time	23-Sep-2018 08:45	23-Sep-2018 09:20	23-Sep-2018 10:30	23-Sep-2018 09:45	23-Sep-2018 11:40
Compound	CAS Number	LOR	Unit		ES1828283-001	ES1828283-002	ES1828283-003	ES1828283-004	ES1828283-005
					Result	Result	Result	Result	Result
EG020F: Dissolved Metals by ICP-MS - Continued									
Zinc	7440-66-6	0.005	mg/L		**0.006**	<0.005	<0.005	**0.006**	<0.005
Silver	7440-22-4	0.001	mg/L		**----**	**----**	<0.001	<0.001	<0.001
Iron	7439-89-6	0.05	mg/L		**----**	**----**	<0.05	<0.05	<0.05
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		**0.8**	**3.8**	**----**	**----**	**----**
EK055G: Ammonia as N by Discrete Analyser									
Ammonia as N	7664-41-7	0.01	mg/L		**0.05**	**0.10**	<0.01	<0.01	<0.01
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		<0.01	<0.01	**0.02**	<0.01	<0.01
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser									
Nitrite + Nitrate as N	----	0.01	mg/L		<0.01	<0.01	**0.02**	<0.01	<0.01
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser									
Total Kjeldahl Nitrogen as N	----	0.1	mg/L		**0.4**	**0.1**	<0.1	<0.1	<0.1
EK062G: Total Nitrogen as N (TKN + NOx) by Discrete Analyser									
^ Total Nitrogen as N	----	0.1	mg/L		**0.4**	**0.1**	<0.1	<0.1	<0.1
EK067G: Total Phosphorus as P by Discrete Analyser									
Total Phosphorus as P	----	0.01	mg/L		**0.27**	<0.01	<0.01	<0.01	<0.01
EK071G: Reactive Phosphorus as P by discrete analyser									
Reactive Phosphorus as P	14265-44-2	0.01	mg/L		**----**	**----**	<0.01	<0.01	<0.01
EN055: Ionic Balance									
Total Anions	----	0.01	meq/L		**2.03**	**16.4**	**----**	**----**	**----**
Total Cations	----	0.01	meq/L		**2.06**	**16.5**	**----**	**----**	**----**
Ionic Balance	----	0.01	%		**----**	**0.33**	**----**	**----**	**----**
EP002: Dissolved Organic Carbon (DOC)									
Dissolved Organic Carbon	----	1	mg/L		**----**	**----**	**5**	**2**	**1**
EP005: Total Organic Carbon (TOC)									
Total Organic Carbon	----	1	mg/L		**3**	**2**	**2**	**1**	**1**

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)				Client sample ID	QA5	LH_SW_006	TanN_SW_001	QA4	TanS_SW_003
				Client sampling date / time	23-Sep-2018 00:00	23-Sep-2018 12:30	22-Sep-2018 08:30	22-Sep-2018 00:00	22-Sep-2018 10:40
Compound	CAS Number	LOR	Unit		ES1828283-007	ES1828283-008	ES1828283-009	ES1828283-010	ES1828283-011
					Result	Result	Result	Result	Result
EA015: Total Dissolved Solids dried at 180 ± 5 °C									
Total Dissolved Solids @180°C	----	10	mg/L		**41**	**47**	**15**	**25**	**37**
EA025: Total Suspended Solids dried at 104 ± 2°C									
Suspended Solids (SS)	----	5	mg/L		<5	<5	<5	<5	**36**
ED093F: SAR and Hardness Calculations									
Total Hardness as CaCO3	----	1	mg/L		**29**	**29**	**2**	**2**	**14**
EG020F: Dissolved Metals by ICP-MS									
Aluminium	7429-90-5	0.01	mg/L		**0.01**	**0.02**	**0.10**	**0.09**	**0.16**
Arsenic	7440-38-2	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
Boron	7440-42-8	0.05	mg/L		<0.05	<0.05	<0.05	<0.05	<0.05
Barium	7440-39-3	0.001	mg/L		**0.026**	**0.027**	**0.019**	**0.009**	**0.025**
Beryllium	7440-41-7	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
Cobalt	7440-48-4	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
Chromium	7440-47-3	0.001	mg/L		<0.001	**0.001**	<0.001	<0.001	<0.001
Copper	7440-50-8	0.001	mg/L		**0.001**	**0.001**	**0.001**	<0.001	**0.001**
Manganese	7439-96-5	0.001	mg/L		<0.001	<0.001	**0.012**	**0.010**	**0.012**
Nickel	7440-02-0	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
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
Vanadium	7440-62-2	0.01	mg/L		<0.01	<0.01	<0.01	<0.01	<0.01
Zinc	7440-66-6	0.005	mg/L		**0.007**	**0.005**	**0.007**	<0.005	**0.007**
Silver	7440-22-4	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
Iron	7439-89-6	0.05	mg/L		<0.05	<0.05	**0.18**	**0.16**	**0.22**
EG035F: Dissolved Mercury by FIMS									
Mercury	7439-97-6	0.0001	mg/L		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
EK055G: Ammonia as N by Discrete Analyser									
Ammonia as N	7664-41-7	0.01	mg/L		<0.01	<0.01	<0.01	<0.01	<0.01
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		<0.01	<0.01	<0.01	<0.01	**0.09**
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser									
Nitrite + Nitrate as N	----	0.01	mg/L		<0.01	<0.01	<0.01	<0.01	**0.09**
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser									

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)				Client sample ID	QA5	LH_SW_006	TanN_SW_001	QA4	TanS_SW_003
				Client sampling date / time	23-Sep-2018 00:00	23-Sep-2018 12:30	22-Sep-2018 08:30	22-Sep-2018 00:00	22-Sep-2018 10:40
Compound	CAS Number	LOR	Unit		ES1828283-007	ES1828283-008	ES1828283-009	ES1828283-010	ES1828283-011
					Result	Result	Result	Result	Result
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser - Continued									
Total Kjeldahl Nitrogen as N	----	0.1	mg/L		<0.1	<0.1	**0.2**	**0.1**	**0.9**
EK062G: Total Nitrogen as N (TKN + NOx) by Discrete Analyser									
^ Total Nitrogen as N	----	0.1	mg/L		<0.1	<0.1	**0.2**	**0.1**	**1.0**
EK067G: Total Phosphorus as P by Discrete Analyser									
Total Phosphorus as P	----	0.01	mg/L		<0.01	<0.01	<0.01	<0.01	**0.11**
EK071G: Reactive Phosphorus as P by discrete analyser									
Reactive Phosphorus as P	14265-44-2	0.01	mg/L		<0.01	<0.01	<0.01	<0.01	<0.01
EP002: Dissolved Organic Carbon (DOC)									
Dissolved Organic Carbon	----	1	mg/L		**1**	**2**	**3**	**3**	**3**
EP005: Total Organic Carbon (TOC)									
Total Organic Carbon	----	1	mg/L		<1	**1**	**3**	**3**	**5**

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)				Client sample ID	TanS_SW_005	TanS_SW_001	TanR_SW_001	PB01	TanS_SW_002
				Client sampling date / time	22-Sep-2018 10:10	22-Sep-2018 09:55	22-Sep-2018 13:20	22-Sep-2018 11:10	22-Sep-2018 09:30
Compound	CAS Number	LOR	Unit		ES1828283-012	ES1828283-013	ES1828283-014	ES1828283-015	ES1828283-016
					Result	Result	Result	Result	Result
EA015: Total Dissolved Solids dried at 180 ± 5 °C									
Total Dissolved Solids @180°C	----	10	mg/L		26	32	16	115	27
EA025: Total Suspended Solids dried at 104 ± 2°C									
Suspended Solids (SS)	----	5	mg/L		<5	24	<5	----	<5
ED037P: Alkalinity by PC Titrator									
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L		----	----	----	<1	----
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L		----	----	----	6	----
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L		----	----	----	77	----
Total Alkalinity as CaCO3	----	1	mg/L		----	----	----	83	----
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA									
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L		----	----	----	9	----
ED045G: Chloride by Discrete Analyser									
Chloride	16887-00-6	1	mg/L		----	----	----	1	----
ED093F: Dissolved Major Cations									
Calcium	7440-70-2	1	mg/L		----	----	----	13	----
Magnesium	7439-95-4	1	mg/L		----	----	----	7	----
Sodium	7440-23-5	1	mg/L		----	----	----	11	----
Potassium	7440-09-7	1	mg/L		----	----	----	1	----
ED093F: SAR and Hardness Calculations									
Total Hardness as CaCO3	----	1	mg/L		<1	<1	<1	----	2
EG020F: Dissolved Metals by ICP-MS									
Aluminium	7429-90-5	0.01	mg/L		0.03	0.02	0.01	----	0.06
Arsenic	7440-38-2	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
Boron	7440-42-8	0.05	mg/L		<0.05	<0.05	<0.05	----	<0.05
Barium	7440-39-3	0.001	mg/L		0.012	0.026	0.030	----	0.017
Beryllium	7440-41-7	0.001	mg/L		<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
Cobalt	7440-48-4	0.001	mg/L		<0.001	<0.001	<0.001	----	<0.001
Chromium	7440-47-3	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
Copper	7440-50-8	0.001	mg/L		0.001	0.001	<0.001	<0.001	0.001
Manganese	7439-96-5	0.001	mg/L		0.002	0.002	0.003	----	0.005
Nickel	7440-02-0	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
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
Vanadium	7440-62-2	0.01	mg/L		<0.01	<0.01	<0.01	----	<0.01

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)				Client sample ID	TanS_SW_005	TanS_SW_001	TanR_SW_001	PB01	TanS_SW_002
				Client sampling date / time	22-Sep-2018 10:10	22-Sep-2018 09:55	22-Sep-2018 13:20	22-Sep-2018 11:10	22-Sep-2018 09:30
Compound	CAS Number	LOR	Unit		ES1828283-012	ES1828283-013	ES1828283-014	ES1828283-015	ES1828283-016
					Result	Result	Result	Result	Result
EG020F: Dissolved Metals by ICP-MS - Continued									
Zinc	7440-66-6	0.005	mg/L		**0.007**	**0.007**	<0.005	<0.005	**0.006**
Silver	7440-22-4	0.001	mg/L		<0.001	<0.001	<0.001	----	<0.001
Iron	7439-89-6	0.05	mg/L		<0.05	<0.05	<0.05	----	**0.18**
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		----	----	----	**0.2**	----
EK055G: Ammonia as N by Discrete Analyser									
Ammonia as N	7664-41-7	0.01	mg/L		<0.01	<0.01	<0.01	<0.01	<0.01
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		<0.01	**0.06**	<0.01	<0.01	<0.01
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser									
Nitrite + Nitrate as N	----	0.01	mg/L		<0.01	**0.06**	<0.01	<0.01	<0.01
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser									
Total Kjeldahl Nitrogen as N	----	0.1	mg/L		<0.1	**0.1**	**0.4**	<0.2	**0.2**
EK062G: Total Nitrogen as N (TKN + NOx) by Discrete Analyser									
^ Total Nitrogen as N	----	0.1	mg/L		<0.1	**0.2**	**0.4**	<0.2	**0.2**
EK067G: Total Phosphorus as P by Discrete Analyser									
Total Phosphorus as P	----	0.01	mg/L		<0.01	<0.01	<0.01	**0.25**	<0.01
EK071G: Reactive Phosphorus as P by discrete analyser									
Reactive Phosphorus as P	14265-44-2	0.01	mg/L		<0.01	<0.01	<0.01	----	<0.01
EN055: Ionic Balance									
Total Anions	----	0.01	meq/L		----	----	----	**1.87**	----
Total Cations	----	0.01	meq/L		----	----	----	**1.73**	----
EP002: Dissolved Organic Carbon (DOC)									
Dissolved Organic Carbon	----	1	mg/L		**1**	**2**	**2**	----	**3**
EP005: Total Organic Carbon (TOC)									
Total Organic Carbon	----	1	mg/L		**1**	**2**	**1**	**4**	**2**

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Client sample ID	TanS_SW004	YC04	YC03	YC05	YC02
			Client sampling date / time	22-Sep-2018 12:20	21-Sep-2018 08:00	21-Sep-2018 08:20	21-Sep-2018 09:40	21-Sep-2018 10:45
Compound	CAS Number	LOR	Unit	ES1828283-017	ES1828283-018	ES1828283-019	ES1828283-020	ES1828283-021
				Result	Result	Result	Result	Result
EA015: Total Dissolved Solids dried at 180 ± 5 °C								
Total Dissolved Solids @180°C	----	10	mg/L	**43**	**24**	**27**	**94**	**115**
EA025: Total Suspended Solids dried at 104 ± 2°C								
Suspended Solids (SS)	----	5	mg/L	**25**	<5	<5	**9**	**60**
ED093F: SAR and Hardness Calculations								
Total Hardness as CaCO3	----	1	mg/L	**14**	<1	**2**	**36**	**82**
EG020F: Dissolved Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	**0.07**	**0.03**	**0.07**	**0.02**	<0.01
Arsenic	7440-38-2	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	**0.001**
Boron	7440-42-8	0.05	mg/L	<0.05	<0.05	<0.05	<0.05	<0.05
Barium	7440-39-3	0.001	mg/L	**0.030**	**0.019**	**0.021**	**0.011**	**0.022**
Beryllium	7440-41-7	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
Cobalt	7440-48-4	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Chromium	7440-47-3	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Copper	7440-50-8	0.001	mg/L	<0.001	<0.001	**0.001**	<0.001	<0.001
Manganese	7439-96-5	0.001	mg/L	**0.006**	<0.001	**0.002**	<0.001	<0.001
Nickel	7440-02-0	0.001	mg/L	<0.001	<0.001	<0.001	**0.001**	<0.001
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
Vanadium	7440-62-2	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc	7440-66-6	0.005	mg/L	**0.009**	<0.005	**0.006**	<0.005	**0.005**
Silver	7440-22-4	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Iron	7439-89-6	0.05	mg/L	<0.05	<0.05	**0.06**	<0.05	<0.05
EG035F: Dissolved Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
EK055G: Ammonia as N by Discrete Analyser								
Ammonia as N	7664-41-7	0.01	mg/L	**0.01**	<0.01	<0.01	<0.01	<0.01
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	**0.04**	<0.01	<0.01	**0.04**	**0.06**
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								
Nitrite + Nitrate as N	----	0.01	mg/L	**0.04**	<0.01	<0.01	**0.04**	**0.06**
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)				Client sample ID	TanS_SW004	YC04	YC03	YC05	YC02
				Client sampling date / time	22-Sep-2018 12:20	21-Sep-2018 08:00	21-Sep-2018 08:20	21-Sep-2018 09:40	21-Sep-2018 10:45
Compound	CAS Number	LOR	Unit		ES1828283-017	ES1828283-018	ES1828283-019	ES1828283-020	ES1828283-021
					Result	Result	Result	Result	Result
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser - Continued									
Total Kjeldahl Nitrogen as N	----	0.1	mg/L		**0.4**	<0.1	<0.1	**0.2**	<0.1
EK062G: Total Nitrogen as N (TKN + NOx) by Discrete Analyser									
^ **Total Nitrogen as N**	----	0.1	mg/L		**0.4**	<0.1	<0.1	**0.2**	<0.1
EK067G: Total Phosphorus as P by Discrete Analyser									
Total Phosphorus as P	----	0.01	mg/L		**0.34**	<0.01	<0.01	**0.02**	<0.01
EK071G: Reactive Phosphorus as P by discrete analyser									
Reactive Phosphorus as P	14265-44-2	0.01	mg/L		<0.01	<0.01	<0.01	<0.01	<0.01
EP002: Dissolved Organic Carbon (DOC)									
Dissolved Organic Carbon	----	1	mg/L		**2**	**2**	**2**	**4**	**2**
EP005: Total Organic Carbon (TOC)									
Total Organic Carbon	----	1	mg/L		**2**	**2**	**2**	<1	<1

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)				Client sample ID	YC01	TMB02B	TMB02A	TalS_SW_001	SMB03
				Client sampling date / time	21-Sep-2018 11:20	21-Sep-2018 13:45	21-Sep-2018 14:10	20-Sep-2018 08:30	20-Sep-2018 10:25
Compound	CAS Number	LOR	Unit		ES1828283-022	ES1828283-023	ES1828283-024	ES1828283-025	ES1828283-026
					Result	Result	Result	Result	Result
EA015: Total Dissolved Solids dried at 180 ± 5 °C									
Total Dissolved Solids @180°C	----	10	mg/L		119	93	19	26	149
EA025: Total Suspended Solids dried at 104 ± 2°C									
Suspended Solids (SS)	----	5	mg/L		9	----	----	<5	----
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		----	64	9	----	67
Total Alkalinity as CaCO3	----	1	mg/L		----	64	9	----	67
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA									
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L		----	1	<1	----	22
ED045G: Chloride by Discrete Analyser									
Chloride	16887-00-6	1	mg/L		----	<1	<1	----	7
ED093F: Dissolved Major Cations									
Calcium	7440-70-2	1	mg/L		----	16	2	----	20
Magnesium	7439-95-4	1	mg/L		----	2	<1	----	3
Sodium	7440-23-5	1	mg/L		----	7	1	----	18
Potassium	7440-09-7	1	mg/L		----	<1	<1	----	<1
ED093F: SAR and Hardness Calculations									
Total Hardness as CaCO3	----	1	mg/L		93	----	----	18	----
EG020F: Dissolved Metals by ICP-MS									
Aluminium	7429-90-5	0.01	mg/L		<0.01	----	----	0.03	----
Arsenic	7440-38-2	0.001	mg/L		0.002	0.003	<0.001	<0.001	<0.001
Boron	7440-42-8	0.05	mg/L		<0.05	----	----	<0.05	----
Barium	7440-39-3	0.001	mg/L		0.014	----	----	0.016	----
Beryllium	7440-41-7	0.001	mg/L		<0.001	----	----	<0.001	----
Cadmium	7440-43-9	0.0001	mg/L		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Cobalt	7440-48-4	0.001	mg/L		<0.001	----	----	<0.001	----
Chromium	7440-47-3	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
Copper	7440-50-8	0.001	mg/L		<0.001	0.001	0.002	<0.001	0.001
Manganese	7439-96-5	0.001	mg/L		<0.001	----	----	0.002	----
Nickel	7440-02-0	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
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	----
Vanadium	7440-62-2	0.01	mg/L		<0.01	----	----	<0.01	----

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)				Client sample ID	YC01	TMB02B	TMB02A	TalS_SW_001	SMB03
				Client sampling date / time	21-Sep-2018 11:20	21-Sep-2018 13:45	21-Sep-2018 14:10	20-Sep-2018 08:30	20-Sep-2018 10:25
Compound	CAS Number	LOR	Unit		ES1828283-022	ES1828283-023	ES1828283-024	ES1828283-025	ES1828283-026
					Result	Result	Result	Result	Result
EG020F: Dissolved Metals by ICP-MS - Continued									
Zinc	7440-66-6	0.005	mg/L		<0.005	**0.006**	**0.008**	**0.007**	**0.044**
Silver	7440-22-4	0.001	mg/L		<0.001	----	----	<0.001	----
Iron	7439-89-6	0.05	mg/L		<0.05	----	----	<0.05	----
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		----	**0.1**	<0.1	----	**0.2**
EK055G: Ammonia as N by Discrete Analyser									
Ammonia as N	7664-41-7	0.01	mg/L		<0.01	<0.01	<0.01	<0.01	<0.01
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		**0.07**	**0.37**	<0.01	<0.01	<0.01
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser									
Nitrite + Nitrate as N	----	0.01	mg/L		**0.07**	**0.37**	<0.01	<0.01	<0.01
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser									
Total Kjeldahl Nitrogen as N	----	0.1	mg/L		<0.1	<0.1	<0.1	<0.1	**0.1**
EK062G: Total Nitrogen as N (TKN + NOx) by Discrete Analyser									
^ Total Nitrogen as N	----	0.1	mg/L		<0.1	**0.4**	<0.1	<0.1	**0.1**
EK067G: Total Phosphorus as P by Discrete Analyser									
Total Phosphorus as P	----	0.01	mg/L		<0.01	<0.01	<0.01	<0.01	<0.01
EK071G: Reactive Phosphorus as P by discrete analyser									
Reactive Phosphorus as P	14265-44-2	0.01	mg/L		<0.01	----	----	<0.01	----
EN055: Ionic Balance									
Total Anions	----	0.01	meq/L		----	**1.30**	**0.18**	----	**1.99**
Total Cations	----	0.01	meq/L		----	**1.27**	**0.14**	----	**2.03**
EP002: Dissolved Organic Carbon (DOC)									
Dissolved Organic Carbon	----	1	mg/L		**1**	----	----	**2**	----
EP005: Total Organic Carbon (TOC)									
Total Organic Carbon	----	1	mg/L		<1	<1	<1	**1**	**4**

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)				Client sample ID	SMB02	SMB04	SMB05	PL_SW_007	MB02
				Client sampling date / time	20-Sep-2018 10:30	20-Sep-2018 11:20	20-Sep-2018 11:10	20-Sep-2018 11:45	20-Sep-2018 14:00
Compound	CAS Number	LOR	Unit		ES1828283-027	ES1828283-028	ES1828283-029	ES1828283-030	ES1828283-031
					Result	Result	Result	Result	Result
EA015: Total Dissolved Solids dried at 180 ± 5 °C									
Total Dissolved Solids @180°C	----	10	mg/L		120	84	150	27	77
EA025: Total Suspended Solids dried at 104 ± 2°C									
Suspended Solids (SS)	----	5	mg/L		----	----	----	<5	----
ED037P: Alkalinity by PC Titrator									
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L		<1	<1	<1	----	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L		<1	<1	<1	----	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L		77	48	72	----	44
Total Alkalinity as CaCO3	----	1	mg/L		77	48	72	----	44
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA									
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L		7	16	40	----	1
ED045G: Chloride by Discrete Analyser									
Chloride	16887-00-6	1	mg/L		2	<1	5	----	<1
ED093F: Dissolved Major Cations									
Calcium	7440-70-2	1	mg/L		24	18	25	----	13
Magnesium	7439-95-4	1	mg/L		2	<1	1	----	1
Sodium	7440-23-5	1	mg/L		10	8	15	----	2
Potassium	7440-09-7	1	mg/L		<1	<1	1	----	<1
ED093F: SAR and Hardness Calculations									
Total Hardness as CaCO3	----	1	mg/L		----	----	----	5	----
EG020F: Dissolved Metals by ICP-MS									
Aluminium	7429-90-5	0.01	mg/L		----	----	----	0.01	----
Arsenic	7440-38-2	0.001	mg/L		<0.001	0.020	0.006	<0.001	<0.001
Boron	7440-42-8	0.05	mg/L		----	----	----	<0.05	----
Barium	7440-39-3	0.001	mg/L		----	----	----	0.009	----
Beryllium	7440-41-7	0.001	mg/L		----	----	----	<0.001	----
Cadmium	7440-43-9	0.0001	mg/L		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Cobalt	7440-48-4	0.001	mg/L		----	----	----	<0.001	----
Chromium	7440-47-3	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
Copper	7440-50-8	0.001	mg/L		0.002	0.001	<0.001	0.001	0.002
Manganese	7439-96-5	0.001	mg/L		----	----	----	0.002	----
Nickel	7440-02-0	0.001	mg/L		0.001	<0.001	0.001	<0.001	0.002
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	----
Vanadium	7440-62-2	0.01	mg/L		----	----	----	<0.01	----

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)				Client sample ID	SMB02	SMB04	SMB05	PL_SW_007	MB02
				Client sampling date / time	20-Sep-2018 10:30	20-Sep-2018 11:20	20-Sep-2018 11:10	20-Sep-2018 11:45	20-Sep-2018 14:00
Compound	CAS Number	LOR	Unit		ES1828283-027	ES1828283-028	ES1828283-029	ES1828283-030	ES1828283-031
					Result	Result	Result	Result	Result
EG020F: Dissolved Metals by ICP-MS - Continued									
Zinc	7440-66-6	0.005	mg/L		**0.050**	**0.015**	<0.005	**0.006**	<0.005
Silver	7440-22-4	0.001	mg/L		----	----	----	<0.001	----
Iron	7439-89-6	0.05	mg/L		----	----	----	<0.05	----
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**	<0.1	**0.1**	----	<0.1
EK055G: Ammonia as N by Discrete Analyser									
Ammonia as N	7664-41-7	0.01	mg/L		<0.01	<0.01	**0.02**	<0.01	<0.01
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		<0.01	<0.01	<0.01	<0.01	<0.01
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser									
Nitrite + Nitrate as N	----	0.01	mg/L		<0.01	<0.01	<0.01	<0.01	<0.01
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser									
Total Kjeldahl Nitrogen as N	----	0.1	mg/L		**0.3**	**0.2**	**1.1**	**0.1**	<0.1
EK062G: Total Nitrogen as N (TKN + NOx) by Discrete Analyser									
^ Total Nitrogen as N	----	0.1	mg/L		**0.3**	**0.2**	**1.1**	**0.1**	<0.1
EK067G: Total Phosphorus as P by Discrete Analyser									
Total Phosphorus as P	----	0.01	mg/L		**0.03**	**0.03**	**1.87**	<0.01	**0.06**
EK071G: Reactive Phosphorus as P by discrete analyser									
Reactive Phosphorus as P	14265-44-2	0.01	mg/L		----	----	----	<0.01	----
EN055: Ionic Balance									
Total Anions	----	0.01	meq/L		**1.74**	**1.29**	**2.41**	----	**0.90**
Total Cations	----	0.01	meq/L		**1.80**	**1.25**	**2.01**	----	**0.82**
EP002: Dissolved Organic Carbon (DOC)									
Dissolved Organic Carbon	----	1	mg/L		----	----	----	**2**	----
EP005: Total Organic Carbon (TOC)									
Total Organic Carbon	----	1	mg/L		**3**	**4**	**22**	**1**	<1

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)				Client sample ID	MB01B	MB01C	TMB03B	QA3	TMB03A
				Client sampling date / time	20-Sep-2018 14:40	20-Sep-2018 15:00	20-Sep-2018 00:00	20-Sep-2018 00:00	20-Sep-2018 16:15
Compound	CAS Number	LOR	Unit		ES1828283-032	ES1828283-033	ES1828283-034	ES1828283-035	ES1828283-036
					Result	Result	Result	Result	Result
EA015: Total Dissolved Solids dried at 180 ± 5 °C									
Total Dissolved Solids @180°C	----	10	mg/L		29	115	104	109	82
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		20	72	76	76	37
Total Alkalinity as CaCO3	----	1	mg/L		20	72	76	76	37
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA									
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L		<1	7	2	1	3
ED045G: Chloride by Discrete Analyser									
Chloride	16887-00-6	1	mg/L		<1	<1	1	1	1
ED093F: Dissolved Major Cations									
Calcium	7440-70-2	1	mg/L		4	15	21	20	5
Magnesium	7439-95-4	1	mg/L		1	5	2	2	3
Sodium	7440-23-5	1	mg/L		<1	7	6	6	5
Potassium	7440-09-7	1	mg/L		<1	2	5	5	<1
EG020F: Dissolved Metals by ICP-MS									
Arsenic	7440-38-2	0.001	mg/L		<0.001	0.009	0.002	0.002	0.002
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	<0.001	<0.001	<0.001
Copper	7440-50-8	0.001	mg/L		0.010	<0.001	<0.001	<0.001	<0.001
Nickel	7440-02-0	0.001	mg/L		0.002	0.005	<0.001	0.001	0.014
Lead	7439-92-1	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
Zinc	7440-66-6	0.005	mg/L		0.007	<0.005	<0.005	<0.005	0.011
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		<0.1	<0.1	0.7	0.7	<0.1
EK055G: Ammonia as N by Discrete Analyser									
Ammonia as N	7664-41-7	0.01	mg/L		<0.01	0.03	0.01	<0.01	0.06
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		<0.01	<0.01	0.02	<0.01	<0.01

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)				Client sample ID	MB01B	MB01C	TMB03B	QA3	TMB03A
				Client sampling date / time	20-Sep-2018 14:40	20-Sep-2018 15:00	20-Sep-2018 00:00	20-Sep-2018 00:00	20-Sep-2018 16:15
Compound	CAS Number	LOR	Unit		ES1828283-032	ES1828283-033	ES1828283-034	ES1828283-035	ES1828283-036
					Result	Result	Result	Result	Result
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser									
Nitrite + Nitrate as N	----	0.01	mg/L		<0.01	<0.01	**0.02**	<0.01	<0.01
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser									
Total Kjeldahl Nitrogen as N	----	0.1	mg/L		<0.1	<0.1	**0.1**	<0.1	<0.1
EK062G: Total Nitrogen as N (TKN + NOx) by Discrete Analyser									
^ Total Nitrogen as N	----	0.1	mg/L		<0.1	<0.1	**0.1**	<0.1	<0.1
EK067G: Total Phosphorus as P by Discrete Analyser									
Total Phosphorus as P	----	0.01	mg/L		**0.07**	<0.01	<0.01	**0.01**	**0.20**
EN055: Ionic Balance									
Total Anions	----	0.01	meq/L		**0.40**	**1.58**	**1.59**	**1.57**	**0.83**
Total Cations	----	0.01	meq/L		**0.28**	**1.52**	**1.60**	**1.55**	**0.71**
EP005: Total Organic Carbon (TOC)									
Total Organic Carbon	----	1	mg/L		<1	<1	<1	<1	<1

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Client sample ID	TMB03C	MB07A	MB07B	PL_SW_005	QA2
			Client sampling date / time	20-Sep-2018 16:45	19-Sep-2018 09:45	19-Sep-2018 09:20	19-Sep-2018 11:15	19-Sep-2018 00:00
Compound	CAS Number	LOR	Unit	ES1828283-037	ES1828283-038	ES1828283-039	ES1828283-040	ES1828283-041
				Result	Result	Result	Result	Result
EA015: Total Dissolved Solids dried at 180 ± 5 °C								
Total Dissolved Solids @180°C	----	10	mg/L	70	88	365	20	13
EA025: Total Suspended Solids dried at 104 ± 2°C								
Suspended Solids (SS)	----	5	mg/L	----	----	----	<5	<5
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	56	12	43	----	----
Total Alkalinity as CaCO3	----	1	mg/L	56	12	43	----	----
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA								
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	<1	45	220	----	----
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	1	mg/L	2	1	4	----	----
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	8	12	78	----	----
Magnesium	7439-95-4	1	mg/L	3	5	6	----	----
Sodium	7440-23-5	1	mg/L	8	4	23	----	----
Potassium	7440-09-7	1	mg/L	2	<1	5	----	----
ED093F: SAR and Hardness Calculations								
Total Hardness as CaCO3	----	1	mg/L	----	----	----	2	2
EG020F: Dissolved Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	----	----	----	0.03	0.02
Arsenic	7440-38-2	0.001	mg/L	<0.001	<0.001	0.001	<0.001	<0.001
Boron	7440-42-8	0.05	mg/L	----	----	----	<0.05	<0.05
Barium	7440-39-3	0.001	mg/L	----	----	----	0.006	0.018
Beryllium	7440-41-7	0.001	mg/L	----	----	----	<0.001	<0.001
Cadmium	7440-43-9	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Cobalt	7440-48-4	0.001	mg/L	----	----	----	<0.001	<0.001
Chromium	7440-47-3	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Copper	7440-50-8	0.001	mg/L	<0.001	0.006	<0.001	<0.001	0.002
Manganese	7439-96-5	0.001	mg/L	----	----	----	0.002	0.002
Nickel	7440-02-0	0.001	mg/L	0.001	<0.001	0.003	<0.001	<0.001
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
Vanadium	7440-62-2	0.01	mg/L	----	----	----	<0.01	<0.01

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)				Client sample ID	TMB03C	MB07A	MB07B	PL_SW_005	QA2
				Client sampling date / time	20-Sep-2018 16:45	19-Sep-2018 09:45	19-Sep-2018 09:20	19-Sep-2018 11:15	19-Sep-2018 00:00
Compound	CAS Number	LOR	Unit		ES1828283-037	ES1828283-038	ES1828283-039	ES1828283-040	ES1828283-041
					Result	Result	Result	Result	Result
EG020F: Dissolved Metals by ICP-MS - Continued									
Zinc	7440-66-6	0.005	mg/L		<0.005	**0.008**	**0.065**	<0.005	**0.007**
Silver	7440-22-4	0.001	mg/L		----	----	----	<0.001	<0.001
Iron	7439-89-6	0.05	mg/L		----	----	----	<0.05	<0.05
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		**0.1**	<0.1	**0.6**	----	----
EK055G: Ammonia as N by Discrete Analyser									
Ammonia as N	7664-41-7	0.01	mg/L		**0.02**	<0.01	<0.01	<0.01	<0.01
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		<0.01	**0.10**	<0.01	<0.01	<0.01
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser									
Nitrite + Nitrate as N	----	0.01	mg/L		<0.01	**0.10**	<0.01	<0.01	<0.01
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser									
Total Kjeldahl Nitrogen as N	----	0.1	mg/L		<0.1	<0.1	<0.1	<0.1	**0.4**
EK062G: Total Nitrogen as N (TKN + NOx) by Discrete Analyser									
^ Total Nitrogen as N	----	0.1	mg/L		<0.1	**0.1**	<0.1	<0.1	**0.4**
EK067G: Total Phosphorus as P by Discrete Analyser									
Total Phosphorus as P	----	0.01	mg/L		**0.02**	<0.01	<0.01	<0.01	**0.05**
EK071G: Reactive Phosphorus as P by discrete analyser									
Reactive Phosphorus as P	14265-44-2	0.01	mg/L		----	----	----	<0.01	<0.01
EN055: Ionic Balance									
Total Anions	----	0.01	meq/L		**1.18**	**1.20**	**5.55**	----	----
Total Cations	----	0.01	meq/L		**1.04**	**1.18**	**5.51**	----	----
Ionic Balance	----	0.01	%		----	----	**0.34**	----	----
EP002: Dissolved Organic Carbon (DOC)									
Dissolved Organic Carbon	----	1	mg/L		----	----	----	**2**	**2**
EP005: Total Organic Carbon (TOC)									
Total Organic Carbon	----	1	mg/L		**2**	<1	**3**	**2**	**3**

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)				Client sample ID	PL_SW_009	PL_SW_002	PL_SW_008	TMB04	PB04
				Client sampling date / time	19-Sep-2018 12:20	19-Sep-2018 14:30	19-Sep-2018 14:45	19-Sep-2018 15:45	19-Sep-2018 16:30
Compound	CAS Number	LOR	Unit		ES1828283-042	ES1828283-043	ES1828283-044	ES1828283-045	ES1828283-046
					Result	Result	Result	Result	Result
EA015: Total Dissolved Solids dried at 180 ± 5 °C									
Total Dissolved Solids @180°C	----	10	mg/L		12	21	16	103	54
EA025: Total Suspended Solids dried at 104 ± 2°C									
Suspended Solids (SS)	----	5	mg/L		<5	<5	<5	----	----
ED037P: Alkalinity by PC Titrator									
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L		----	----	----	<1	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L		----	----	----	<1	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L		----	----	----	29	28
Total Alkalinity as CaCO3	----	1	mg/L		----	----	----	29	28
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA									
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L		----	----	----	2	11
ED045G: Chloride by Discrete Analyser									
Chloride	16887-00-6	1	mg/L		----	----	----	<1	<1
ED093F: Dissolved Major Cations									
Calcium	7440-70-2	1	mg/L		----	----	----	10	11
Magnesium	7439-95-4	1	mg/L		----	----	----	<1	<1
Sodium	7440-23-5	1	mg/L		----	----	----	2	5
Potassium	7440-09-7	1	mg/L		----	----	----	<1	<1
ED093F: SAR and Hardness Calculations									
Total Hardness as CaCO3	----	1	mg/L		5	2	2	----	----
EG020F: Dissolved Metals by ICP-MS									
Aluminium	7429-90-5	0.01	mg/L		0.02	0.04	0.02	----	----
Arsenic	7440-38-2	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
Boron	7440-42-8	0.05	mg/L		<0.05	<0.05	<0.05	----	----
Barium	7440-39-3	0.001	mg/L		0.014	0.010	0.015	----	----
Beryllium	7440-41-7	0.001	mg/L		<0.001	<0.001	<0.001	----	----
Cadmium	7440-43-9	0.0001	mg/L		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Cobalt	7440-48-4	0.001	mg/L		<0.001	<0.001	<0.001	----	----
Chromium	7440-47-3	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
Copper	7440-50-8	0.001	mg/L		0.001	0.002	0.002	0.002	0.001
Manganese	7439-96-5	0.001	mg/L		0.002	0.003	0.002	----	----
Nickel	7440-02-0	0.001	mg/L		<0.001	<0.001	<0.001	0.001	<0.001
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	----	----
Vanadium	7440-62-2	0.01	mg/L		<0.01	<0.01	<0.01	----	----

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)				Client sample ID	PL_SW_009	PL_SW_002	PL_SW_008	TMB04	PB04
				Client sampling date / time	19-Sep-2018 12:20	19-Sep-2018 14:30	19-Sep-2018 14:45	19-Sep-2018 15:45	19-Sep-2018 16:30
Compound	CAS Number	LOR	Unit		ES1828283-042	ES1828283-043	ES1828283-044	ES1828283-045	ES1828283-046
					Result	Result	Result	Result	Result
EG020F: Dissolved Metals by ICP-MS - Continued									
Zinc	7440-66-6	0.005	mg/L		**0.005**	**0.018**	**0.006**	**0.009**	**0.007**
Silver	7440-22-4	0.001	mg/L		<0.001	<0.001	<0.001	----	----
Iron	7439-89-6	0.05	mg/L		<0.05	**0.05**	<0.05	----	----
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		----	----	----	<0.1	**0.2**
EK055G: Ammonia as N by Discrete Analyser									
Ammonia as N	7664-41-7	0.01	mg/L		**0.02**	<0.01	<0.01	<0.01	**0.02**
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		<0.01	<0.01	<0.01	**0.01**	<0.01
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser									
Nitrite + Nitrate as N	----	0.01	mg/L		<0.01	<0.01	<0.01	**0.01**	<0.01
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser									
Total Kjeldahl Nitrogen as N	----	0.1	mg/L		<0.1	<0.1	**0.2**	**0.7**	**1.5**
EK062G: Total Nitrogen as N (TKN + NOx) by Discrete Analyser									
^ Total Nitrogen as N	----	0.1	mg/L		<0.1	<0.1	**0.2**	**0.7**	**1.5**
EK067G: Total Phosphorus as P by Discrete Analyser									
Total Phosphorus as P	----	0.01	mg/L		<0.01	<0.01	<0.01	**0.19**	<0.01
EK071G: Reactive Phosphorus as P by discrete analyser									
Reactive Phosphorus as P	14265-44-2	0.01	mg/L		<0.01	<0.01	<0.01	----	----
EN055: Ionic Balance									
Total Anions	----	0.01	meq/L		----	----	----	**0.62**	**0.79**
Total Cations	----	0.01	meq/L		----	----	----	**0.58**	**0.77**
EP002: Dissolved Organic Carbon (DOC)									
Dissolved Organic Carbon	----	1	mg/L		**2**	**2**	**2**	----	----
EP005: Total Organic Carbon (TOC)									
Total Organic Carbon	----	1	mg/L		**1**	**2**	**2**	**1**	**3**

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Client sample ID	PL_SW_001	PL_SW_003	LH_SW_009	LH_SW_008	PB05
			Client sampling date / time	19-Sep-2018 16:45	19-Sep-2018 17:25	18-Sep-2018 10:20	18-Sep-2018 10:55	18-Sep-2018 11:50
Compound	CAS Number	LOR	Unit	ES1828283-047	ES1828283-048	ES1828283-049	ES1828283-050	ES1828283-051
				Result	Result	Result	Result	Result
EA015: Total Dissolved Solids dried at 180 ± 5 °C								
Total Dissolved Solids @180°C	----	10	mg/L	----	----	----	----	129
Total Dissolved Solids @180°C	----	10	mg/L	26	23	50	42	----
EA025: Total Suspended Solids dried at 104 ± 2°C								
Suspended Solids (SS)	----	5	mg/L	<5	<5	<5	<5	----
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	----	----	----	----	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	----	----	----	----	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	----	----	----	----	73
Total Alkalinity as CaCO3	----	1	mg/L	----	----	----	----	73
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA								
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	----	----	----	----	19
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	1	mg/L	----	----	----	----	<1
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	----	----	----	----	18
Magnesium	7439-95-4	1	mg/L	----	----	----	----	8
Sodium	7440-23-5	1	mg/L	----	----	----	----	10
Potassium	7440-09-7	1	mg/L	----	----	----	----	2
ED093F: SAR and Hardness Calculations								
Total Hardness as CaCO3	----	1	mg/L	5	5	21	24	----
EG020F: Dissolved Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	0.01	0.02	0.02	0.10	----
Arsenic	7440-38-2	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Boron	7440-42-8	0.05	mg/L	<0.05	<0.05	<0.05	<0.05	----
Barium	7440-39-3	0.001	mg/L	0.014	0.004	0.010	0.013	----
Beryllium	7440-41-7	0.001	mg/L	<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
Cobalt	7440-48-4	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	----
Chromium	7440-47-3	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	0.001
Copper	7440-50-8	0.001	mg/L	0.002	<0.001	0.001	<0.001	<0.001
Manganese	7439-96-5	0.001	mg/L	0.002	0.001	<0.001	<0.001	----
Nickel	7440-02-0	0.001	mg/L	<0.001	<0.001	0.002	<0.001	0.001
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	----

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)				Client sample ID	PL_SW_001	PL_SW_003	LH_SW_009	LH_SW_008	PB05
				Client sampling date / time	19-Sep-2018 16:45	19-Sep-2018 17:25	18-Sep-2018 10:20	18-Sep-2018 10:55	18-Sep-2018 11:50
Compound	CAS Number	LOR	Unit		ES1828283-047	ES1828283-048	ES1828283-049	ES1828283-050	ES1828283-051
					Result	Result	Result	Result	Result
EG020F: Dissolved Metals by ICP-MS - Continued									
Vanadium	7440-62-2	0.01	mg/L		<0.01	<0.01	<0.01	<0.01	----
Zinc	7440-66-6	0.005	mg/L		**0.007**	<0.005	<0.005	<0.005	<0.005
Silver	7440-22-4	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	----
Iron	7439-89-6	0.05	mg/L		<0.05	<0.05	<0.05	**0.06**	----
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		----	----	----	----	**0.2**
EK055G: Ammonia as N by Discrete Analyser									
Ammonia as N	7664-41-7	0.01	mg/L		<0.01	<0.01	**0.01**	<0.01	**0.02**
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		<0.01	<0.01	<0.01	<0.01	**0.36**
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser									
Nitrite + Nitrate as N	----	0.01	mg/L		<0.01	<0.01	<0.01	<0.01	**0.36**
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser									
Total Kjeldahl Nitrogen as N	----	0.1	mg/L		<0.1	<0.1	<0.1	<0.1	**0.1**
EK062G: Total Nitrogen as N (TKN + NOx) by Discrete Analyser									
^ Total Nitrogen as N	----	0.1	mg/L		<0.1	<0.1	<0.1	<0.1	**0.5**
EK067G: Total Phosphorus as P by Discrete Analyser									
Total Phosphorus as P	----	0.01	mg/L		<0.01	<0.01	<0.01	<0.01	<0.01
EK071G: Reactive Phosphorus as P by discrete analyser									
Reactive Phosphorus as P	14265-44-2	0.01	mg/L		<0.01	<0.01	<0.01	<0.01	----
EN055: Ionic Balance									
Total Anions	----	0.01	meq/L		----	----	----	----	**1.85**
Total Cations	----	0.01	meq/L		----	----	----	----	**2.04**
EP002: Dissolved Organic Carbon (DOC)									
Dissolved Organic Carbon	----	1	mg/L		**2**	**1**	**5**	**2**	----
EP005: Total Organic Carbon (TOC)									
Total Organic Carbon	----	1	mg/L		**1**	**1**	**1**	**2**	----

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)				Client sample ID	MB06A	MB06B	PN_SW_001	PN_SW_002	QA1
				Client sampling date / time	18-Sep-2018 13:25	18-Sep-2018 14:00	18-Sep-2018 14:30	18-Sep-2018 15:00	18-Sep-2018 00:00
Compound	CAS Number	LOR	Unit		ES1828283-052	ES1828283-053	ES1828283-054	ES1828283-055	ES1828283-056
					Result	Result	Result	Result	Result
EA015: Total Dissolved Solids dried at 180 ± 5 °C									
Total Dissolved Solids @180°C	----	10	mg/L		68	246	----	----	----
Total Dissolved Solids @180°C	----	10	mg/L		----	----	34	14	12
EA025: Total Suspended Solids dried at 104 ± 2°C									
Suspended Solids (SS)	----	5	mg/L		----	----	<5	<5	<5
ED037P: Alkalinity by PC Titrator									
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L		<1	<1	----	----	----
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L		<1	<1	----	----	----
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L		44	89	----	----	----
Total Alkalinity as CaCO3	----	1	mg/L		44	89	----	----	----
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA									
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L		2	54	----	----	----
ED045G: Chloride by Discrete Analyser									
Chloride	16887-00-6	1	mg/L		2	9	----	----	----
ED093F: Dissolved Major Cations									
Calcium	7440-70-2	1	mg/L		12	29	----	----	----
Magnesium	7439-95-4	1	mg/L		2	7	----	----	----
Sodium	7440-23-5	1	mg/L		5	29	----	----	----
Potassium	7440-09-7	1	mg/L		1	1	----	----	----
ED093F: SAR and Hardness Calculations									
Total Hardness as CaCO3	----	1	mg/L		----	----	7	2	<1
EG020F: Dissolved Metals by ICP-MS									
Aluminium	7429-90-5	0.01	mg/L		----	----	0.08	0.06	0.06
Arsenic	7440-38-2	0.001	mg/L		0.001	0.003	<0.001	<0.001	<0.001
Boron	7440-42-8	0.05	mg/L		----	----	<0.05	<0.05	<0.05
Barium	7440-39-3	0.001	mg/L		----	----	0.011	0.008	0.006
Beryllium	7440-41-7	0.001	mg/L		----	----	<0.001	<0.001	<0.001
Cadmium	7440-43-9	0.0001	mg/L		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Cobalt	7440-48-4	0.001	mg/L		----	----	<0.001	<0.001	<0.001
Chromium	7440-47-3	0.001	mg/L		0.002	<0.001	<0.001	<0.001	<0.001
Copper	7440-50-8	0.001	mg/L		0.002	<0.001	<0.001	<0.001	<0.001
Manganese	7439-96-5	0.001	mg/L		----	----	0.002	0.004	0.002
Nickel	7440-02-0	0.001	mg/L		0.016	0.016	<0.001	<0.001	<0.001
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

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)				Client sample ID	MB06A	MB06B	PN_SW_001	PN_SW_002	QA1
				Client sampling date / time	18-Sep-2018 13:25	18-Sep-2018 14:00	18-Sep-2018 14:30	18-Sep-2018 15:00	18-Sep-2018 00:00
Compound	CAS Number	LOR	Unit		ES1828283-052	ES1828283-053	ES1828283-054	ES1828283-055	ES1828283-056
					Result	Result	Result	Result	Result
EG020F: Dissolved Metals by ICP-MS - Continued									
Vanadium	7440-62-2	0.01	mg/L		----	----	<0.01	<0.01	<0.01
Zinc	7440-66-6	0.005	mg/L		**0.011**	<0.005	<0.005	<0.005	<0.005
Silver	7440-22-4	0.001	mg/L		----	----	<0.001	<0.001	<0.001
Iron	7439-89-6	0.05	mg/L		----	----	<0.05	**0.06**	**0.06**
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		<0.1	**0.1**	----	----	----
EK055G: Ammonia as N by Discrete Analyser									
Ammonia as N	7664-41-7	0.01	mg/L		<0.01	<0.01	<0.01	<0.01	<0.01
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		<0.01	<0.01	<0.01	<0.01	<0.01
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser									
Nitrite + Nitrate as N	----	0.01	mg/L		<0.01	<0.01	<0.01	<0.01	<0.01
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser									
Total Kjeldahl Nitrogen as N	----	0.1	mg/L		<0.2	<0.1	<0.1	<0.1	<0.1
EK062G: Total Nitrogen as N (TKN + NOx) by Discrete Analyser									
^ Total Nitrogen as N	----	0.1	mg/L		<0.2	<0.1	<0.1	<0.1	<0.1
EK067G: Total Phosphorus as P by Discrete Analyser									
Total Phosphorus as P	----	0.01	mg/L		**0.12**	<0.01	<0.01	<0.01	<0.01
EK071G: Reactive Phosphorus as P by discrete analyser									
Reactive Phosphorus as P	14265-44-2	0.01	mg/L		----	----	<0.01	<0.01	<0.01
EN055: Ionic Balance									
Total Anions	----	0.01	meq/L		**0.98**	**3.16**	----	----	----
Total Cations	----	0.01	meq/L		**1.01**	**3.31**	----	----	----
Ionic Balance	----	0.01	%		----	**2.38**	----	----	----
EP002: Dissolved Organic Carbon (DOC)									
Dissolved Organic Carbon	----	1	mg/L		----	----	**4**	**5**	**2**
EP005: Total Organic Carbon (TOC)									
Total Organic Carbon	----	1	mg/L		----	----	**2**	**2**	**3**

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)				Client sample ID	MB04A	MB04B	MB03	LH_SW_005	----
				Client sampling date / time	18-Sep-2018 15:45	18-Sep-2018 16:20	18-Sep-2018 17:05	23-Sep-2018 12:10	----
Compound	CAS Number	LOR	Unit		ES1828283-057	ES1828283-058	ES1828283-059	ES1828283-060	--------
					Result	Result	Result	Result	----
EA015: Total Dissolved Solids dried at 180 ± 5 °C									
Total Dissolved Solids @180°C	----	10	mg/L		347	441	74	----	----
Total Dissolved Solids @180°C	----	10	mg/L		----	----	----	372	----
EA025: Total Suspended Solids dried at 104 ± 2°C									
Suspended Solids (SS)	----	5	mg/L		----	----	----	12	----
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		62	120	49	----	----
Total Alkalinity as CaCO3	----	1	mg/L		62	120	49	----	----
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA									
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L		186	76	<1	----	----
ED045G: Chloride by Discrete Analyser									
Chloride	16887-00-6	1	mg/L		6	43	<1	----	----
ED093F: Dissolved Major Cations									
Calcium	7440-70-2	1	mg/L		78	13	8	----	----
Magnesium	7439-95-4	1	mg/L		5	2	4	----	----
Sodium	7440-23-5	1	mg/L		22	99	5	----	----
Potassium	7440-09-7	1	mg/L		4	<1	<1	----	----
ED093F: SAR and Hardness Calculations									
Total Hardness as CaCO3	----	1	mg/L		----	----	----	308	----
EG020F: Dissolved Metals by ICP-MS									
Aluminium	7429-90-5	0.01	mg/L		----	----	----	<0.01	----
Arsenic	7440-38-2	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	----
Boron	7440-42-8	0.05	mg/L		----	----	----	<0.05	----
Barium	7440-39-3	0.001	mg/L		----	----	----	0.114	----
Beryllium	7440-41-7	0.001	mg/L		----	----	----	<0.001	----
Cadmium	7440-43-9	0.0001	mg/L		<0.0001	<0.0001	<0.0001	<0.0001	----
Cobalt	7440-48-4	0.001	mg/L		----	----	----	<0.001	----
Chromium	7440-47-3	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	----
Copper	7440-50-8	0.001	mg/L		0.002	<0.001	<0.001	0.003	----
Manganese	7439-96-5	0.001	mg/L		----	----	----	0.002	----
Nickel	7440-02-0	0.001	mg/L		0.002	0.002	<0.001	0.001	----
Lead	7439-92-1	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	----
Selenium	7782-49-2	0.01	mg/L		----	----	----	<0.01	----

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)				Client sample ID	MB04A	MB04B	MB03	LH_SW_005	----
				Client sampling date / time	18-Sep-2018 15:45	18-Sep-2018 16:20	18-Sep-2018 17:05	23-Sep-2018 12:10	----
Compound	CAS Number	LOR	Unit		ES1828283-057	ES1828283-058	ES1828283-059	ES1828283-060	--------
					Result	Result	Result	Result	----
EG020F: Dissolved Metals by ICP-MS - Continued									
Vanadium	7440-62-2	0.01	mg/L		----	----	----	<0.01	----
Zinc	7440-66-6	0.005	mg/L		**0.007**	<0.005	<0.005	<0.005	----
Silver	7440-22-4	0.001	mg/L		----	----	----	<0.001	----
Iron	7439-89-6	0.05	mg/L		----	----	----	<0.05	----
EG035F: Dissolved Mercury by FIMS									
Mercury	7439-97-6	0.0001	mg/L		<0.0001	<0.0001	<0.0001	<0.0001	----
EK040P: Fluoride by PC Titrator									
Fluoride	16984-48-8	0.1	mg/L		**0.4**	**0.4**	<0.1	----	----
EK055G: Ammonia as N by Discrete Analyser									
Ammonia as N	7664-41-7	0.01	mg/L		**0.04**	**0.02**	**0.04**	<0.01	----
EK057G: Nitrite as N by Discrete Analyser									
Nitrite as N	14797-65-0	0.01	mg/L		**0.12**	<0.01	<0.01	<0.01	----
EK058G: Nitrate as N by Discrete Analyser									
Nitrate as N	14797-55-8	0.01	mg/L		**15.2**	<0.01	**0.21**	<0.01	----
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser									
Nitrite + Nitrate as N	----	0.01	mg/L		**15.3**	<0.01	**0.21**	<0.01	----
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser									
Total Kjeldahl Nitrogen as N	----	0.1	mg/L		**0.3**	**0.2**	<0.1	<0.1	----
EK062G: Total Nitrogen as N (TKN + NOx) by Discrete Analyser									
^ Total Nitrogen as N	----	0.1	mg/L		**15.6**	**0.2**	**0.2**	<0.1	----
EK067G: Total Phosphorus as P by Discrete Analyser									
Total Phosphorus as P	----	0.01	mg/L		<0.01	**0.05**	<0.01	<0.01	----
EK071G: Reactive Phosphorus as P by discrete analyser									
Reactive Phosphorus as P	14265-44-2	0.01	mg/L		----	----	----	<0.01	----
EN055: Ionic Balance									
Total Anions	----	0.01	meq/L		**5.28**	**5.19**	**0.98**	----	----
Total Cations	----	0.01	meq/L		**5.36**	**5.12**	**0.94**	----	----
Ionic Balance	----	0.01	%		**0.77**	**0.71**	----	----	----
EP002: Dissolved Organic Carbon (DOC)									
Dissolved Organic Carbon	----	1	mg/L		----	----	----	**4**	----
EP005: Total Organic Carbon (TOC)									
Total Organic Carbon	----	1	mg/L		----	----	----	**2**	----

Drilling and completion report

Stage 3

Prepared for Snowy Hydro Limited
July 2019

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Drilling and completion report

Stage 3

Report Number

J17188 RP#52

Client

Snowy Hydro Limited

Date

31 July 2019

Version

v2 Final

Prepared by	**Approved by**
	
Kaitlyn Brodie Hydrogeologist 31 July 2019	**Jonathon Tait** Senior Hydrogeologist 31 July 2019

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1 Introduction

1.1 Project overview

Snowy Hydro Limited (SHL) proposes to develop Snowy 2.0, a large-scale pumped hydro-electric storage and generation project which would increase hydro-electric capacity within the existing Snowy Mountains Hydro-electric Scheme (Snowy Scheme). This would be achieved by establishing a new underground hydro-electric power station that would increase the generation capacity of the Snowy Scheme by almost 50%, providing an additional 2,000 megawatts (MW) generating capacity, and providing approximately 350 gigawatts hours (GWh) of storage available to the National Electricity Market (NEM) at any one time, which is critical to ensuring system security as Australia transitions to a decarbonised NEM. Snowy 2.0 would link the existing Tantangara and Talbingo reservoirs within the Snowy Scheme through a series of underground tunnels and hydro-electric power station.

Snowy 2.0 has been declared Critical State Significant Infrastructure (CSSI) by the NSW Minister for Planning under the provisions of the *NSW Environmental Planning and Assessment Act 1979* (EP&A Act) and is defined in Clause 9 of Schedule 5 of the State Environmental Planning Policy (State and Regional Development) 2011 (SRD SEPP).

1.2 Program objectives

The collection of field data is important for accurate representation of hydrogeological conceptual and numerical groundwater flow models which will inform the Groundwater Assessment in support of the Snowy 2.0 EIS. This assessment covers all issues relating to site water management, groundwater and surface water and their related environmental and other uses.

A comprehensive groundwater monitoring network has been installed to collect hydrogeological data which will be used to characterise the groundwater regime in the vicinity of project area. The Stage 3 project area is located in-between the Talbingo and Tantangara reservoirs, which are existing structures that form part of the Snowy Scheme. Talbingo Reservoir is located approximately 50 kilometres (km) north-west of Adaminaby. Tantangara Reservoir is located approximately 25 km north-west of Adaminaby. The two regions are separated by the Snowy Mountains Highway, which connects Adaminaby and Cooma in the south-east, to Talbingo and Tumut to the north-west of KNP. The ravine region is between Talbingo Reservoir to the north-west and the Snowy Mountains Highway to the east. The plateau region extends from the Snowy Mountains Highway in the east to Tantangara Reservoir in the west.

The Stage 1 groundwater monitoring network comprises 20 monitoring bores, including conventional standpipe piezometers and nested monitoring sites, at 11 locations. The Stage 2 groundwater monitoring network comprises 7 monitoring bores (3 pre-existing monitoring bores, and 4 monitoring bores drilled as part of the program), and 4 test production bores (1 pre-existing production bore, and 3 production bores drilled as part of the program) at 4 nested locations.

The Stage 3 network is comprised of 7 monitoring bores and 3 test production bores at 4 locations. This program expands the monitoring network and allows further monitoring of potentially sensitive features, including; alpine bogs, the Yarangobilly River, Murrumbidgee River, Tantangara Creek, Gooandra Creek and potential groundwater dependent ecosystems. This report summarises the Stage 3 drilling program of the Snowy 2.0 groundwater monitoring network.

Monitoring and test bores were drilled and installed by Highland Drilling and Watson Drilling supervised by EMM Consulting Pty Limited (EMM) in consultation with NSW Department of Industry Water (DoI Water) between October 2018 and February 2019.

2 Drilling program

2.1 Monitoring bore network

The Stage 3 drilling program includes conventional groundwater monitoring bores and test production bores located within the vicinity of the Snowy 2.0 project area. Monitoring bores and test production bores are positioned to provide spatial coverage, investigate major hydrogeological systems, and monitor potentially sensitive environmental features along the project alignment.

Specifically, the groundwater monitoring network is designed to:

- identify and characterise water bearing units in the project area, focusing on characterising groundwater flow and quality;
- characterise hydraulic properties (horizontal and vertical flow) within the major groundwater bearing zones across the project area;
- provide a greater degree of spatial representation and flux of pressure heads across the plateau area to investigate potential vertical hydraulic gradients and connectivity between water bearing units; and
- investigate the potential for surface water–groundwater interaction, specifically at Gooandra, Zinc Ridge, and Marica.

The network is comprised of seven monitoring bores and three test production bores at four locations illustrated in Figure 2.1 and detailed in Table 2.1. Nested monitoring bores are present at three monitoring locations allowing multiple hydrogeological systems to be monitored. Nested sites have two monitoring bores with screened sections targeting the shallow unconfined groundwater system and deep fractured rock groundwater system. MB11A is a solitary bore targeting the shallow unconfined water bearing zone. MB11A was intended to be used as an observation bore for PB08 which was cancelled prior to the start of the drilling program. Existing monitoring bores BH3104, BH4103, BH5102 and BH3102 that were drilled by GHD were used to monitor drawdown and recovery levels during pumping tests.

Test production bores were completed with open section across the proposed tunnel depth. Shallow and deep nested monitoring bores were used to observe responses in their respective groundwater systems during pump testing.

Test production bores were pump tested to simulate groundwater yields during tunnelling and estimate vertical and horizontal hydraulic conductivity and connectivity between the shallow and deep groundwater systems. Vertical conductivity is of interest due to the potential of groundwater drawdown (during tunnelling) to impact groundwater dependent ecosystems and surface water features on the plateau.

A schematic of a nested groundwater monitoring/test production sites is shown in Figure 2.2.

KEY

- Stage 3 groundwater monitoring bore
- Snowy Mountains Highway
- Existing road infrastructure
- Watercourse
- Waterbody

Project access road/track/trail

- Existing road/track
- Proposed track

\\emmsvr1\EMMJobs\2017\J177188 - Snowy Hydro 2.0\GIS\02 Maps\G195 Stage3Network 20190516 01.mxd 16/05/2019

Source: EMM (2018); Snowy Hydro (2018); SMEC (2018); DFSI (2017); GA (2015)

0 2.5 5 km

GDA 1994 MGA Zone 55

N

Monitoring and production bore locations

Snowy 2.0

Drilling and completion report

Figure 2.1

EMM

snowy 2.0

Table 2.1 Stage 3 groundwater monitoring and test production bore summary

Site location	Bore ID	Easting[1]	Northing[1]	Ground level (mAHD)[2]	Total depth (mBGL)[3]	Screen (mBGL)[3]	Targeted formation	Lithology
Zinc Ridge (East) BH3104	PB06	643796.8	6038289.1	1435.5	318	Open Hole (298 - 318)	Adaminaby Group	Siltstone and Shale
	MB08A	643789.6	6038268.2	1435.2	30	19 - 29		Sandstone and Shale
	MB08B	643789.6	6038276.7	1435.6	298	277 - 297		Siltstone and Shale
Marica Track (East) BH4103	PB08	Drilling cancelled						
	MB11A	634500.2	6038677.8	1485	24	17 - 23	Gooandra Volcanics	Chloritic schist
Marica Track (West) BH5102	PB09	632503.2	6038542.1	1330	300	Open Hole (200 - 300)	Ravine Beds	Siltstone
	MB12A	632508.0	6038549.3	1329.9	36	26 - 35		
	MB12B	632514.8	6038541.6	1330.5	180	149 - 179		
Zinc Ridge (West) BH3102	PB10	641299.1	6038399.5	1382	230	Open Hole (210 - 230)	Temperance Formation	Siltstone
	MB13A	641298.6	6038411.3	1382.2	60	50 - 59		
	MB13B	641310.2	6038405.7	1381.5	190	180 - 189		

Notes:

1. Coordinates in MGA 94 (Zone 55)
2. mAHD = metres Australian Height Datum
3. mBGL = metres Below Ground Level

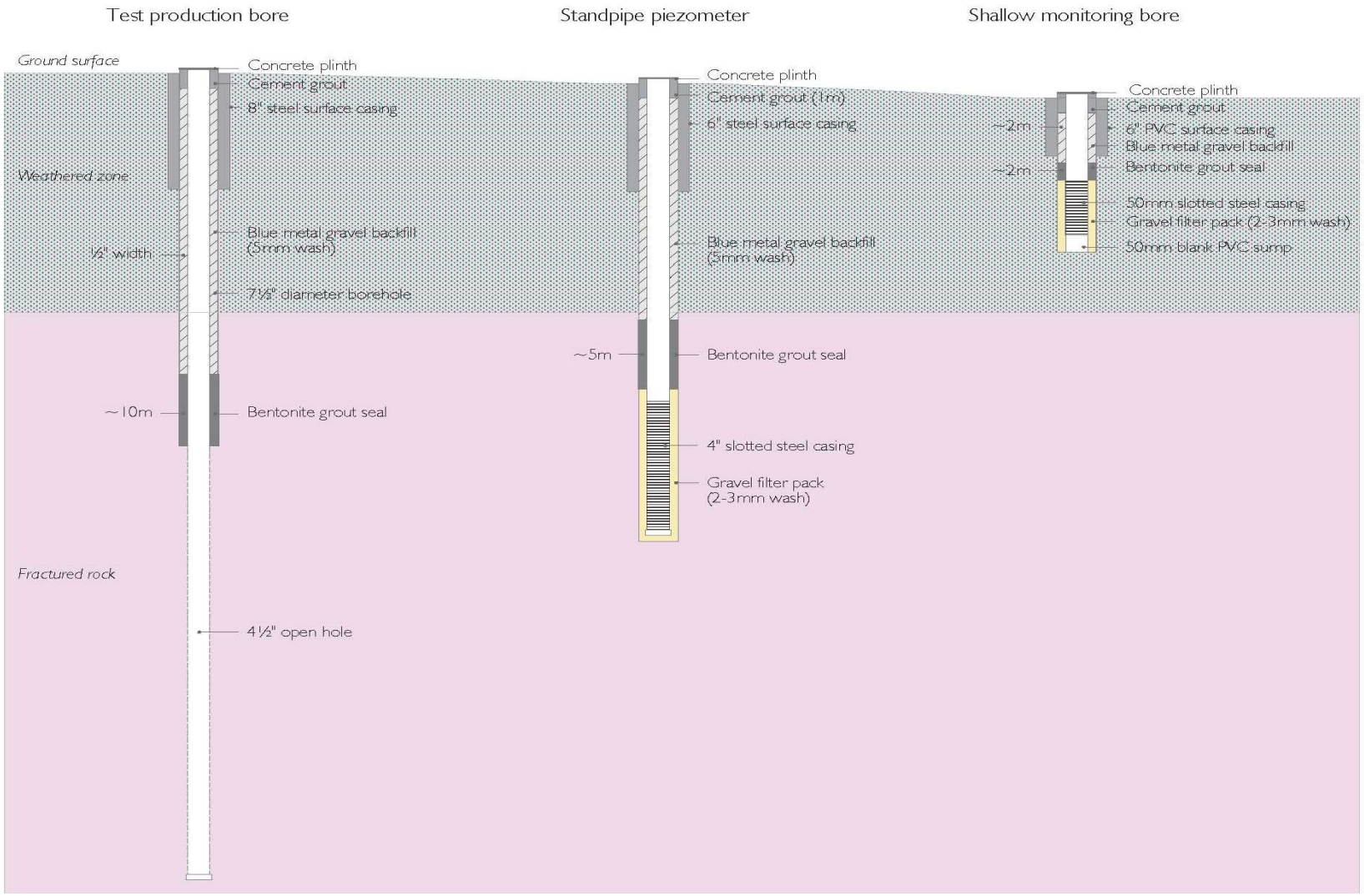

Figure 2.2 Typical test production bore and associated nested monitoring bores

2.2 Monitoring and test production bore licences

Test production bore and monitoring bore licences were obtained by EMM, on behalf of SHL, under the *Water Act 1912* from DoI Water prior to the commencement of the drilling program (Appendix A). Form A Particulars of Completed Works forms (drilling completion forms) were submitted to DoI Water following monitoring bore installation and are included in Appendix B.

The following licenses apply to test and monitoring bores:

- Test production license 40BL192723 - PB06, PB09, and PB10; and
- Monitoring bore licence 40BL192733 - MB08A, MB08B, M11A, MB12A, MB12B, MB13A and MB13B.

2.3 Drilling construction specifications

2.3.1 Overview

Highland Drilling and Watson Drilling were engaged by EMM to complete the drilling and installation of monitoring and test production bores. EMM provided the design and specifications for the monitoring/test production bores and supervision of the drilling and installations.

All monitoring and test production bores were drilled and constructed in accordance with the Minimum Construction Requirements for Water Bores in Australia (NUDLC 2012). Drilling and construction is a minimal impact and temporary activity with the final constructed bore presenting at the surface as a 100 millimetre (mm) high, 1 x 1 metre (m) concrete slab and flush galvanised steel gatic plate.

2.3.2 Drilling

All monitoring and test production boreholes were drilled using an air rotary percussion technique (also known as air hammer) to evacuate cuttings from the annulus of the borehole during drilling. No drill muds or additives were used during the drilling. This This method allows information on water strikes, quality, and yields to be collected while drilling.

All water produced from the bores during drilling was controlled in a series of above ground tanks and disposed of in accordance with the Snowy 2.0 Review of Environmental Factors (REF) (SHL 2018). Water used for drilling was sourced from a licensed supply in Adaminaby or recycled from settling tanks. Produced water was discharged only when it met the water quality criteria specified in the REF. All produced water that did not comply with REF criteria was contained in above-ground tanks and disposed of at a licensed waste facility.

Geology was logged at one metre intervals and groundwater yields recorded (if any) at the end of each drill rod (every 6 m). Water quality physico-chemical parameters were measured using a calibrated YSI™ water quality meter; parameters included temperature, Electrical Conductivity (EC), pH, Dissolved Oxygen (DO), Total Dissolved Solids (TDS) and Oxidation Reduction Potential (ORP). Physico-chemical parameters are shown on the geological bore logs in Appendix C.

All boreholes were developed at target depth until the discharge water was relatively free of sediment and the physico-chemical water quality parameters stabilised.

A washed and graded (3 to 5 mm) gravel filter pack was installed in the annulus around the screen and extended a minimum of 3 m above the screened section (placed at the target depth). A bentonite pellet seal was installed 3 to 5 m above the gravel pack and the boreholes were backfilled with blue metal gravel to approximately 2 m below surface level. The bentonite seal ensures no vertical connection between target groundwater systems to those above the screened section. The annulus was completed with a cement grout to surface.

Test production boreholes were drilled from surface at 7.5” to the top of the open hole section. 5” steel casing was then welded and installed to depth. The annulus between the 5” steel casing was sealed with 3 m of bentonite pellets and then backfilled with blue metal gravel to surface. The “tail” open section of the borehole was drilled at 5” to target depth. The open hole sections of PB06, PB09 and PB10 were designed to target the proposed tunnelling depth.

2.3.3 Survey

Following bore installation, the completed bores were surveyed by Peter W. Burns Pty Ltd, Cooma. Measurements collected during the survey process can be found in Table 2.1.

The survey included measurements of:

- MGA55 Easting and Northings of each bore,
- AHD71 level of the gatic lid and top of casing.

Table 2.2 Bore survey details

Bore ID	Easting (MGA 94)	Northing (MGA 94)	Gatic lid (mAHD) [1]	Top of casing (mAHD) [1]
PB06	643796.8	6038289.1	1435.5	1435.4
MB08A	643789.6	6038268.2	1435.2	1435.1
MB08B	643789.6	6038276.7	1435.6	1435.5
MB11A	634500.2	6038677.8	1485.0	1485.1
PB09	632503.2	6038542.1	-	1330.7
MB12A	632508.0	6038549.3	1329.9	1329.8
MB12B	632514.8	6038541.6	1330.5	1330.3
PB10	641299.1	6038399.5	1382.0	1382.0
MB13A	641298.6	6038411.3	1382.2	1382.1
MB13B	641310.2	6038405.7	1381.5	1381.4

Notes:

1. mAHD = metres Australian Height Datum

2.4 Geology encountered during drilling

The main geological formations encountered during drilling on the plateau were the Adaminaby Group, Temperance Formation and the Gooandra Volcanics. In the ravine region, on the western portion of the project area, the geological formation encountered was the Ravine Beds. The predominant geology encountered at screen depth, in both the ravine and plateau regions, during drilling was a very fine-grained meta-siltstone ranging from black to bluish-grey with poorly consolidated/fractured and weathered sandstone. The only exception was a dark grey greenschist was encountered within the Gooandra Volcanics formation at MB11A.

Table 2.3 provides a comprehensive breakdown of geology encountered during drilling.

Table 2.3 Geology

Bore ID	Total depth (mBGL)[1]	Screened formation	Screened lithology
PB06	318	Adaminaby Group	Siltstone; very fine grained, medium grey
MB08A	30	Adaminaby Group	Sandstone / slate
MB08B	298	Adaminaby Group	Siltstone; fine grained, medium grey
MB11A	24	Gooandra Volcanics	Greenschist; fine grained, light brown
PB09	300	Ravine Beds	Siltstone; fine grained, black
MB12A	36	Adaminaby Group	Siltstone; very fine grained, brownish grey
MB12B	180	Ravine Beds	Siltstone; very fine grained, dark bluish grey
PB10	230	Temperance Formation	Siltstone; dark grey
MB13A	60	Temperance Formation	Siltstone; dark grey
MB13B	190	Temperance Formation	Siltstone; dark grey, weathered

Notes:

1. mBGL = metres below ground level

2.5 Groundwater flow

Except for MB13A, all constructed bores had a yield of < 1 L/s during drilling. Bores MB08B, MB12B, MB13A and MB13B had a final airlift yield value of > 1 L/s during development, whilst all other bores produced less than 1 L/s during development. A summary of groundwater flow for all bores drilled during the Stage 3 program is presented in Table 2.4.

Table 2.4 Groundwater flow

Bore ID	First water cut (mbgl)	Rate at first cut (L/s)	Screen depth (mBGL)	Rate at screen (L/s)	Final airlift yield (L/s)
PB06	60	0.07	open hole from 298	0.5	0.5
MB08A	dry	dry	19-29	dry	dry
MB08B	30	0.1	278	1.5	1.5
MB11A	18	-	17-23	-	-
PB09	36	0.3	open hole from 200 m	0.3	0.3
MB12A	30	-	26-35	-	-

Table 2.4 Groundwater flow

Bore ID	First water cut (mbgl)	Rate at first cut (L/s)	Screen depth (mBGL)	Rate at screen (L/s)	Final airlift yield (L/s)
MB12B	36	0.4	149-179	1	1
PB10	6	0.14	open hole from 200 m	0.77	0.31
MB13A	12	1	50-59	1	1
MB13B	6	0.5	180-189	1	1

2.6 Groundwater quality

A summary of groundwater quality is presented in Table 2.5. This table includes key information collected during drilling and at the end of airlift development when physico-chemical conditions had stabilised.

Electrical conductivity (EC) at all bores throughout the project is considered 'fresh' with the highest EC value recorded at a screened interval being ~156.3 µS/cm at MB08B. All other bores had EC values ranged between 63.0 to 156.3 µS/cm. pH at most sites where neutral to slightly alkaline besides MB11A which demonstrated a pH of 5.70.

Table 2.5 Groundwater quality

Bore ID	EC at screened interval (µS/cm)	pH at screened interval
PB06	101	8.42
MB08A	DRY	DRY
MB08B	156.3	8.33
MB11A	103.3	5.7
PB09	114	8.54
MB12A	157	6.55
MB12B	63	8.46
PB10	101	9.81
MB13A	107	9.66
MB13B	77	9.08

3 Field testing

3.1 Test pumping

3.1.1 Test pumping methodology

Aquamann Irrigation was engaged by EMM to complete test pumping at test bores PB09 and PB10. The groundwater level at PB06 was too low to complete a pumping test. However, the slowly recovering groundwater level at PB06 was analysed (as a slug test) to provide an approximate horizontal hydraulic conductivity. During test pumping, groundwater level loggers were installed in the test bores and observation bores, and manual water level measurements completed at regular intervals. Phyisco-chemical water quality parameters (pH, EC, DO%, temperature and ORP) were also collected at the test bore discharge point during testing.

After analysis of slug test data from surrounding monitoring bores, it was determined that aquifer testing at each test production bore should consist of a 72-hour constant rate pumping test (CRT). Recovery of water levels were monitored, where possible, for up to 15 hours following the completion of the CRT. Target drawdown for the pump tests is over 40% of the available head to adequately stress the aquifer.

All water extracted from the test production bores during pumping was disposed of in accordance with the Snowy 2.0 REF (SHL 2018). There were no instances of uncontrolled release of water. Water was discharged only when it met the water quality criteria specified in the REF.

A pumping test summary is provided in Table 3.1 and Table 3.2, and pumping test reports are presented in Appendix D.

Table 3.1 Stage 3 pumping test summary data

Production bore	Date	Test duration	Pumping time	Recovery time	Constant discharge rate (L/s)[1]	Formation	Deep observation bore (distance from production bore)	Shallow observation bore (distance from production bore)
PB06*	20/11/2018	NA	NA	NA	NA	Adaminaby Group	MB08B	MB08A
PB09	08/01/2019 - 11/01/2019	74 hours	71 hours	3 hours	0.15 - 0.185	Ravine Beds	MB12B (11.65 m)	MB12A (8.86 m)
PB10	10/12/2018 - 13/12/2018	65 hours	44 hours	21 hours	0.073	Temperance Formation	MB13B (12.5 m) BH3102 (18 m)	MB13A (11.8 m)

Notes: 1. L/s = litres per second

* Groundwater level too low to complete the test

3.1.2 Test pumping results

Water level data was collected manually, using electronic dip meters, and automatically via dataloggers. The data was evaluated using two different aquifer test analysis programs, AqteSolv and MLU, to estimate aquifer properties. AqteSolv is industry-leading software that allows for aquifer test interpretation using a range of solutions that are applicable to various aquifer types and test conditions. MLU is based on a single hybrid analytical solution that can handle a variety of test conditions and as such is useful for quickly estimating aquifer properties. Additionally, MLU can evaluate aquifer tests performed in multi-aquifer systems, allowing for layer-by-layer estimations of transmissivity and storativity.

After analysis of slug test data from surrounding monitoring bores, it was determined that aquifer testing at each test production bore should consist of a 72-hour constant rate pumping test (CRT). Where possible, each test was preceded by a step rate test (SRT) (4 one-hour steps) to confirm pump selection and pumping rates for the CRT. Recovery of water levels were monitored, where possible, for up to 15 hours following the completion of the CRT. Target drawdown for the pump tests was over 40% of the available head to adequately stress the aquifer. A pump test was not completed at PB06 because the water level was too low. The initial water level recovery after the completion of PB06 was recorded by a water level datalogger. The recovery data was used to estimate a hydraulic conductivity of 3.90×10^{-6} and 6.40×10^{-7} metres per day (m/d).

The water level data obtained from PB09 was analysed using AqteSolv. The data was analysed in two components: the manually measured drawdown and recovery data that was collected over the 74-hour test period, and the logger data which recorded an additional 72 hours of recovery from each bore. These two datasets were analysed separately because the well continued to develop throughout the test; although the pump was working at a constant speed, the flow rate increased from 0.15 to 0.185 L/sec over the 72-hour period.

Slug tests were completed at MB08A/B. The MB08A slug test showed relatively high hydraulic conductivity values averaging 0.8 m/d which is typical of a poorly consolidated/fractured and weathered siltstone/sandstone. MB08B, which is much deeper and in a more consolidated siltstone, displayed a lower hydraulic conductivity averaging 4.00×10^{-4} m/d.

At PB09, the hydraulic conductivity of the fractured rock ranged between 6.07×10^{-4} and 6.96×10^{-4} m/d. The matrix hydraulic conductivity values ranged between 1.44×10^{-7} and 3.51×10^{-6} m/d. Both calculated hydraulic properties are consistent with the textbook ranges (Domenico and Schwartz 1990). The fracture specific storage values ranged between 1.0×10^{-9} and 1.23×10^{-8} m^{-1}. The matrix storativities differed significantly between those calculated using the manually measured drawdown and recovery data, finding a storativity of 2.94×10^{-10} and the 72 hours of recovery data recorded by the dataloggers finding 6.31×10^{-5}. Typical fractured siltstone specific storativity ranges from 3.28×10^{-6} to 6.9×10^{-5} (Domenico and Mifflin 1965) hence the storativity value derived from logger recovery data is more representative.

Throughout the pumping test at PB10, the water level in PB10 (200 m) and MB13B (0.7 m) decreased while the water level in MB13A (0.18 m) and BH3102 (0.28 m) increased. It is possible that MB13A and BH3102 where responding to prior rainfall events. Weather stations in Cabramurra and Adaminaby show 10 to 20 mm of rainfall on most days throughout the pumping test. As no previous data is available to allow these results to be adjusted, only data collected for PB10 and MB13B was considered in the analysis. Furthermore, the increasing water levels observed at MB13A and BH3102 while the pump test was being completed demonstrates the lack of vertical connectivity during the 65-hour test.

The horizontal hydraulic conductivity at PB10 and MB13B (derived from slug test data) was found to be similar in both the MLU and AqteSolv analyses, with values of 8×10^{-6} and 6.4×10^{-6} m/d modelled respectively. This falls within the hydraulic conductivity range suggested by Domenico & Schwartz (1990) for siltstone: 8.64×10^{-7} to 0.0012 m/d. The storativity values estimated from both models were quite different. A storativity of 5.0×10^{-5} was found using the MLU model, while the AqteSolv model found a value of 1.1×10^{-6}.

A summary of these results is presented below in Table 3.2 and attached in Appendix D.

Table 3.2 Pumping test results

Site location	Bore ID	Formation	Kh[1] (m/d)[2] (solution type)[3]	Kh[1] (m/d)[2] (solution type)[3]	S[4] (m^{-1})[5]	S [-][6]
BH3104	MB08A	Adaminaby Group	0.8 (overall average)			
	MB08B		4.0×10^{-4} (overall average)			
	PB06		3.90×10^{-6} (Hvorslev)	6.40×10^{-7} (Theis using recovery data)		
BH5102	MB12A	Ravine Beds East	No impact observed during pump testing.			
	MB12B		6.07×10^{-4} (Manual data, Moench double porosity parameters)	6.96×10^{-4} (logger data, Moench double porosity parameters)	1.0×10^{-9} (manual data) 1.23×10^{-8} (logger data) (Moench double porosity parameters)	
	PB09		6.07×10^{-4} (Manual data, Moench double porosity)	6.96×10^{-4} (logger data, Moench double porosity)	1.0×10^{-9} (manual recovery data) 1.23×10^{-8} (logger drawdown/recovery data) (Moench double porosity)	
BH3102	MB13A	Temperance Formation	No impact observed during pump testing.			
	MB13B		8.0×10^{-6} (MLU Hybrid parameters)	6.4×10^{-6} (Barker)		5.0×10^{-5} (MLU hybrid)/1.1×10^{-6} (Barker)
	PB10		8.0×10^{-6} (MLU Hybrid parameters)	6.4×10^{-6} (Barker)		5.0×10^{-5} (MLU hybrid)/1.1×10^{-6} (Barker)

Notes:

1. Kh = average horizontal hydraulic conductivity
2. m/d = metres per day
3. solution type = analytical solutions for interpreting different conditions encountered in the field (eg Moench, Barker, Theis, etc). solution types are used in programs including MLU - a software program used for drawdown calculations and inverse modelling of transient well flow (pumping tests analysis) in layered aquifer systems and stratified aquifers; and AqteSolv, a software program used for design and interpretation of aquifer tests (pumping tests, slug tests, constant-head tests) in confined, leaky, unconfined and fractured aquifers.
4. S = fracture specific storage (the volume of water released from storage per unit decline in hydraulic head in the aquifer per unit area in the aquifer)
5. m^{-1} = unit measurement for fracture specific storage
6. S [-] = storativity the volume of water released from storage per unit decline in hydraulic head in the aquifer per unit area in the aquifer

3.2 Groundwater level monitoring

Groundwater levels in all Stage 3 monitoring and test production bores are monitored using groundwater level dataloggers which record every six hours. The data from these loggers is retrieved monthly and analysed for seasonal variations against rainfall data or an event triggering a change. Hydrographs illustrating groundwater level changes can be found in Appendix E.

3.3 Groundwater quality monitoring

3.3.1 Groundwater sampling methodology

Following the construction and aquifer testing of Stage 3 bores, an initial round of groundwater quality monitoring was completed as part of the regular monitoring schedule for Snowy 2.0 using low flow sampling methods. During purging, physico-chemical parameters (pH, EC, ORP, DO% and temperature) were measured and a representative groundwater sample collected when the parameters stabilised. Comprehensive analysis was completed by NATA-accredited laboratory ALS Environmental Pty Ltd. Analytes are shown in Table 3.3.

Table 3.3 Groundwater sampling analytical suite

Suite	Analytes
Physico-chemical properties	Field parameters (pH, EC, ORP, DO%, temperature), Total Dissolved Solids (TDS), Total Suspended Solids (TSS)
Major ions	Calcium, magnesium, sodium, potassium, sulphate, chloride, alkalinity
Dissolved metals	Arsenic, cadmium, chromium, copper, fluoride, lead, magnesium, nickel, zinc
Nutrients	Ammonia as N, nitrite as N, nitrate as N, reactive phosphorous, phosphorous, total phosphorous

3.3.2 QA/QC procedures

Quality Assurance and Quality Control (QA/QC) procedures were completed during sampling to ensure field and laboratory procedures are followed accurately and equipment is calibrated. The field sampling procedures conformed to EMM's quality assurance/quality control (QA/QC) protocols to prevent cross contamination and preserve sample integrity. Sampling and reporting were conducted in accordance with *Geoscience Australia's Groundwater Sampling and Analysis – A Field Guide* (Sundaram 2009) and EMM's water sampling Standard Operating Procedure document. The following QA/QC procedures were applied:

- calibration of equipment;
- unstable parameters were analysed in the field (physico-chemical parameters);
- samples were collected in clearly labelled bottles with appropriate preservation solutions;
- samples were delivered to the laboratories within the specified holding times;
- field duplicate samples (QA samples) were collected at a rate of one in ten samples; and
- samples were kept chilled and gloves were worn during sampling.

The laboratories conduct their own internal QA/QC program to assess the repeatability of the analytical procedures and instrument accuracy. These programs include analysis of laboratory sample duplicates, spike samples, certified reference standards, surrogate standards/spikes and laboratory blanks. In addition, a duplicate sample is collected in the field for every ten samples collected to assess sampling and laboratory analysis accuracy.

3.3.3 Groundwater sampling results

Groundwater quality results collected between December 2018 and February 2019 are presented as an average for each monitoring site in Table 3.4 with ANZECC 2000 Freshwater 99% trigger values for reference

No water quality results exist for PB06 because water levels were too low to sample at the time. Laboratory certificates are presented in Appendix F. The groundwater quality results in Table 3.4 highlight regional differences between the different target formations across the Stage 3 boreholes:

- DO% is relatively low across all sites which is typical of groundwater. The highest average DO was 45.05% at MB13B in the Temperance Formation.

- Upon sampling, electrical conductivity (EC) was found to be higher than observed during drilling. MB12B, the deep monitoring bore in the Ravine Beds, and MB13B and PB10, the deep monitoring and test bore in the Temperance Formation, were found to be slightly to moderately saline with values ranging between 662 to 3,051 µS/cm. Remaining sites were less than 237 µS/cm.

- PB10 in the Temperance Formation was highly alkaline with a pH of 12.63. MB11A and MB12A, the shallow monitoring bores in the Gooandra Volcanics and Ravine Beds, have more acidic pH of 4.63 and 5.00 respectively. Remaining sites pH slightly acidic to neutral.

- Redox was reducing in all deep boreholes and oxidising in all shallow boreholes. MB11A in the Gooandra Volcanics recording highest average value of 230.5 mV and MB12B in the Ravine Beds formation had the lowest average redox value of -193.0 mV.

- Average Total Dissolved Solids (TDS) was highest at MB13B in the Temperance Formation with 629 milligrams per litre (mg/L). The lowest TDS recorded was in the Gooandra Volcanics at MB11A with 66 mg/L.

- Nutrient levels are generally low across the Stage 3 sites except for nitrogen and phosphorous levels at MB08A, which recorded values of 6.40 mg/L, and 13.8 mg/L respectively. These values are six, and seventy-two times higher than the second highest value. However, MB08A data presented in Table 3.4 is based on one sampling event.

- Total Organic Carbon (TOC) was low at four sites with average values equal to or less than 2 mg/L. Three sites had moderate average TOC values ranging between 2.1 mg/L and 10.1 mg/L. PB10 and MB13B recorded high concentrations of TOC averaging 77.0 mg/L and 43.0 mg/L respectively.

- For the major ions across the Stage 3 sites, calcium averaged less than 50 mg/L across all sites except PB10 where it reached 199 mg/L. Average chloride levels were equal to or less than 2 mg/L for six sites, MB13B recorded the highest average chloride levels of 34.0 mg/L. Magnesium was relatively stable across all Stage 3 sites with average results ranging between 1 and 8 mg/L. Sodium varied significantly across sites from 2.5 mg/L at MB12A in the Ravine Beds formation, to 230.0 mg/L at MB13B in the Temperance Formation. The average potassium value was also low across all Stage 3 sites except for PB10 which recorded an average value of 26.0 mg/L. Sulphates had a wide range of averages from as low as 1 mg/L at MB12A to 443.3 mg/L at MB13B. Fluoride was low across the sites with values ranging between 0.1 and 0.5 mg/L.

- The average results for metals indicate a few locations that exceeded the ANZECC 99% guidelines for water quality (ANZECC 2000). Minor aluminium exceedances were recorded at MB08A in the Adaminaby Group and at MB11A, PB10, MB13A and MB13B in the Gooandra Volcanics. Minor copper exceedances occurred at all Stage 3 locations except PB09 in the Ravine Beds. Average iron results were relatively low except at PB09 where the value reached 4.14 mg/L. However, high concentrations of iron could be due to the oxidation of the steel casing in which the bore was constructed. Average concentrations for nickel exceeded the ANZECC

99% guidelines at MB08B and MB12A. The zinc analysis shows all locations are below detection limits, which is higher than the ANZECC 99% guidelines exceedance values.

- Alkalinity as a carbonate and hydroxide was very high at PB10 but averaged values of less than 1 mg/L at all other Stage 3 sites. However, as a bicarbonate, PB10 was below detection limits while MB12B recorded the highest average value of 187.5 mg/L.

Table 3.4 Mean groundwater quality results (November 2018 – February 2019)

Parameters	Units	Site	MB08A	MB08B	MB11A	PB09	MB12A	MB12B	PB10	MB13A	MB13B
Formation		**ANZECC 2000 FW 99%**	**Tantangara Formation**	**Tantangara Formation**	**Gooandra Volcanics**	**Ravine Beds**	**Ravine Beds**	**Ravine Beds**	**Temperance Formation**	**Temperance Formation**	**Temperance Formation**
Field Parameters											
Temperature (Field)	oC		12.0	12.50	10.35	19.80	12.20	13.10	14.3	11.53	12.60
Dissolved Oxygen - % Saturation (Filtered)	%		55.20	5.75	21.80	13.80	8.70	2.60	10.4	7.77	45.05
Dissolved Oxygen (Field)	mg/L		5.91	0.82	1.26	1.25	2.44	0.50	1.05	0.86	3.68
Electrical Conductivity (field)	µS/cm		146.00	209.63	108.45	180.60	99.05	662.75	3051	237.90	1279.20
pH (Field)	pH_Units		6.69	8.10	4.63	7.14	5.00	7.36	12.63	7.95	7.79
Redox (Field)	mV		73.90	-49.77	230.55	-46.50	138.70	-193.85	-161.7	-130.53	-72.47
Total Dissolved Solids (Field)	mg/L		94.90	136.20	66.95	117.70	87.75	410.80	198.2	154.43	629.20
Analytical Results											
Alkalinity (total) as CaCO3	mg/L		52.0	92.7	27.5	88.0	49.0	187.5	573.0	101.7	104.3
Hardness as CaCO3 (Filtered)	mg/L		41.0	72.0	15.5	75.0	47.5	154.5	497.0	72.7	116.3
Total Dissolved Solids	mg/L		1500.0	178.7	85.0	109.0	81.0	473.0	825.0	183.0	900.7
Analytical results - nutrients											
Ammonia as N	mg/L		<0.01	<0.01	0.02	<0.01	0.03	<0.01	0.08	0.02	0.06
Nitrite + Nitrate as N	mg/L		<0.01	0.01	0.04	<0.01	0.01	<0.01	0.01	0.09	0.05
Kjeldahl Nitrogen Total	mg/L		6.40	<0.01	0.02	<0.1	1.40	0.30	0.50	0.30	0.17
Nitrogen (Total)	mg/L		6.40	<0.01	0.02	<0.1	1.40	0.30	0.50	0.40	0.20
Reactive Phosphorus as P	mg/L		<0.01	0.02	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01

Table 3.4 Mean groundwater quality results (November 2018 – February 2019)

Parameters	Units	Site	MB08A	MB08B	MB11A	PB09	MB12A	MB12B	PB10	MB13A	MB13B
Formation		**ANZECC 2000 FW 99%**	**Tantangara Formation**	**Tantangara Formation**	**Gooandra Volcanics**	**Ravine Beds**	**Ravine Beds**	**Ravine Beds**	**Temperance Formation**	**Temperance Formation**	**Temperance Formation**
Phosphorus	mg/L		13.800	0.025	0.070	0.020	0.520	0.025	0.080	0.190	0.060
Total Organic Carbon	mg/L		<10	2.0	1.5	2.0	1.5	9.0	77.0	10.0	43.0
Nitrate (as N)	mg/L		<0.01	0.01	0.03	<0.01	0.02	<0.01	<0.01	0.09	0.05
Nitrite (as N)	mg/L		<0.01	<0.01	0.02	<0.01	<0.01	<0.01	0.03	<0.01	<0.01
Major ions											
Calcium (Filtered)	mg/L		10	16	3	17	10	48	199	22	41
Chloride	mg/L		<1	2.0	<1	1.0	<1	15.5	2.0	5.7	34.0
Magnesium (Filtered)	mg/L		4.0	8.0	2.0	8.0	5.5	8.5	<1	4.3	3.7
Sodium (Filtered)	mg/L		8.0	23.0	15.0	9.0	2.5	95.5	104.0	16.7	230.0
Potassium (Filtered)	mg/L		3.0	5.5	<1	2.0	<1	1	26.0	9.7	2.7
Sulfate as SO4 - Turbidimetric (Filtered)	mg/L		5.0	26.0	20.0	2.0	1.0	138.5	43.0	24.5	443.3
Fluoride	mg/L		0.1	0.40	<0.1	<0.1	<0.1	0.15	0.50	0.40	0.45
Metals											
Aluminium (Filtered)	mg/L	0.027	0.04	<0.01	0.03	<0.01	0.01	<0.01	0.3	0.08	0.09
Arsenic (Filtered)	mg/L		0.001		<0.001	<0.001	<0.001	0.007	0.001	0.016	0.041
Barium (Filtered)	mg/L		0.147		0.009	0.033	0.032	0.060	0.615	0.057	0.019
Beryllium (Filtered)	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Boron (Filtered)	mg/L	0.09	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.10	<0.05	0.06

Table 3.4 Mean groundwater quality results (November 2018 – February 2019)

Parameters	Units	Site	MB08A	MB08B	MB11A	PB09	MB12A	MB12B	PB10	MB13A	MB13B
Formation		**ANZECC 2000 FW 99%**	**Tantangara Formation**	**Tantangara Formation**	**Gooandra Volcanics**	**Ravine Beds**	**Ravine Beds**	**Ravine Beds**	**Temperance Formation**	**Temperance Formation**	**Temperance Formation**
Cadmium (Filtered)	mg/L	0.00006	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Chromium (III+VI) (Filtered)	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cobalt (Filtered)	mg/L		<0.001	<0.001	<0.001	<0.001	0.0025	<0.001	<0.001	<0.001	<0.001
Copper (Filtered)	mg/L	0.001	0.004	0.002	0.003	<0.001	0.003	<0.001	0.002	0.004	0.003
Iron (Filtered)	mg/L		<0.05	0.09	<0.05	4.14	0.06	0.06	0.22	0.09	2.27
Lead (Filtered)	mg/L	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Manganese (Filtered)	mg/L	1.2	0.372	0.07	0.24	0.38	0.47	0.15	<0.001	0.03	0.14
Mercury (Filtered)	mg/L	0.00006	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Nickel (Filtered)	mg/L	0.008	0.001	0.010	0.005	<0.001	0.020	0.003	0.001	0.006	0.002
Selenium (Filtered)	mg/L	0.005	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Silver (Filtered)	mg/L	0.00002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Vanadium (Filtered)	mg/L		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc (Filtered)	mg/L	0.0024	0.006		0.011	<0.005	0.024	<0.005	<0.005	0.0126	0.009
Alkalinity											
Alkalinity (Bicarbonate as CaCO3)	mg/L		52.0	92.7	27.5	88.0	49.0	187.5	<1	101.7	104.3
Alkalinity (Carbonate as CaCO3)	mg/L		<1	<1	<1	<1	<1	<1	92	<1	<1
Alkalinity (Hydroxide) as CaCO3	mg/L		<1	<1	<1	<1	<1	<1	481	<1	<1

Table 3.4 Mean groundwater quality results (November 2018 – February 2019)

Parameters	Units	Site	MB08A	MB08B	MB11A	PB09	MB12A	MB12B	PB10	MB13A	MB13B
Formation		**ANZECC 2000 FW 99%**	**Tantangara Formation**	**Tantangara Formation**	**Gooandra Volcanics**	**Ravine Beds**	**Ravine Beds**	**Ravine Beds**	**Temperance Formation**	**Temperance Formation**	**Temperance Formation**
Inorganics											
Anions Total	meq/L		1.14	2.45	0.97	1.83	0.99	7.07	12.40	2.53	12.26
Cations Total	meq/L		1.25	2.53	0.97	1.95	1.06	7.26	15.10	2.43	12.41
Cyanide Total	mg/L	0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
Ionic Balance	%		-	0.92	-	-	-	4.04	9.88	-	0.72
Inorganics											
Methane	mg/L		-	<0.01	<0.01	0.08	<0.01	<0.01	-	<0.01	<0.01

Notes: 1: MB08B, MB13A, and MB13B have results averaged over 3 months between December 2018, and February 2019
2: MB11A, MB12A, and MB12B have results averaged over 2 months (January and February)
3: MB08A, PB09, and PB10 have only one round of sampling results (undertaken in February) therefore these results are not averaged

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