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CAIRNS SHIPPING DEVELOPMENT PROJECT

Revised Draft Environmental Impact Statement

APPENDIX L: Groundwater Values Assessment Northern Sands Report (2016)

23 January 2017

BASELINE HYDROGEOLOGICAL ASSESSMENT NORTHERN SANDS

Cairns Shipping Development Project

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REPORT

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Golder Associates

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GLOSSARY, ACRONYMS, ABBREVIATIONS

Term	Meaning
AHD	Australian Height Datum
bgl	below ground level
BOM	Bureau of Meteorology
COD	chemical oxygen demand
CSD	Cairns Shipping Development
ºC	Degrees Celsius
DEHP	Department of Environment and Heritage Protection
DNRM	Department of Natural Resources and Mines
EC	electrical conductivity
EIS	Environmental Impact Statement
FCG	Flanagan Consulting Group
Golder	Golder Associates Pty Ltd
km	kilometre
m	metre
mm	millimetre
bwl	below water level
m/s	metres per second
mm/day	millimetre per day
m^2/day	square metres per day
m^3	cubic metres
m^3/day	cubic metres per day
µS/cm	micro-Siemens per centimeter
PASS	Potential Acid Sulphate Soils

1.0 INTRODUCTION

Flanagan Consulting Group (FCG) commissioned Golder Associates Pty Ltd (Golder) to provide advice and assessment of groundwater issues as part of the Revised Draft Environmental Impact Statement (EIS) for the Cairns Shipping Development (CSD) project.

The recalibrated CSD project involves the following:

- Reduced channel widening and deepening plus dredging of the swing basin and berth pockets in the inner port area (capital dredging). This will result in a total capital dredging volume of ~800 000 m^3. This is an in-situ material volume calculated as occurring between current maintenance dredging depths and the enlarged channel target depths including insurance depth and appropriate minimal over-dredging allowances.
- Land placement of capital dredged material at the following sites (i.e. with both being the subject of the Revised Draft EIS):
  - Northern Sands (an existing void in the Barron River delta created by past sand extraction and now used for burial of 'inert' construction and demolition fill and a limited quantity of Potential Acid Sulphate Soils (PASS).
  - East Trinity (a new bunded site or sites within the general East Trinity area).

This report is addresses the placement of capital dredged material at the Northern Sands site – an existing void in the Barron Delta as shown on Figure 1. Conceptual placement of dredged materials at Northern Sands would have the following requirements:

- A pumping delivery line along one of the route options shown on Figure 1 including:
  - A floating pump-out facility.
  - The conceptual design for the pipeline includes 1 m diameter welded steel pipe on the seabed and creek bed where appropriate, and flanged steel section above ground on temporary earth pads. Booster stations will be positioned along the pipeline at various locations (possible locations are shown on Figure 1).
- Dredged material will be pumped into the sand pit (which may be enlarged prior to dredging operations) with identified PASS material placed in the deeper portion of the pit and covered by self-neutralising material. PASS will be placed to achieve a final surface at least 1 m below the permanent water table. Other self-neutralising material will also be placed below the permanent water table (subject to final design and approvals).
- Provision for tailwater treatment – subject to preliminary concept design.

This report is based on additional studies and is an update of Golder 1546223-012-R-Rev1 Stage1B-Groundwater Report Northern Sands dated 22 November 2016, which was largely based on desktop studies.

The aims of the overall studies were to describe the existing groundwater conditions associated with the Northern Sands site and to identify:

- Key groundwater related constraints (and opportunities) to design and construction of the facilities required for placement of the dredged material.
- Potential groundwater related environmental impacts and mitigation/management measures.

It should be noted that where relevant this report supersedes the previous report.

2.0 SITE SETTING

2.1 Site Background Information

The Northern Sands site covers an area of about 84 hectares and is located on the Barron River floodplain. The site contains an operating sand pit and is licenced to receive 'inert wastes' and PASS, both of which are placed into the excavated pit below the water table. The current sand pit covers an area of about 25 hectares and is known as "Narelle Lake." It should be noted that the existing pit may be enlarged by either deepening the eastern section or by extension into an area located to the north of the pit (see Figure 1).

2.2 Climate

The climate of the Cairns region and that of the Study Area is tropical with weather patterns consisting of very wet summers and drier winters. Key climatological and weather data was obtained from the nearest weather station, located at the Cairns Airport (Bureau of Meteorology (BOM) Station Number 031011) and is summarised below:

- Mean annual monthly maximum temperature is 29.0º Celsius (ºC); with highest temperatures in December and January.
- Mean annual monthly minimum temperature is 20.8ºC; with lowest temperatures in July.
- Mean annual rainfall is 1999.7 millimetres (mm) with highest rainfall in January through March.
- Mean number of days of rain greater than or equal to 1 mm is 119.6 days per year.
- Mean annual 9 am humidity is 72%; with February, March, and April having the highest humidity.
- Mean annual 3 pm humidity is 62% with February having the highest humidity.

Mean monthly rainfall and evaporation are presented in Table 1 and the annual rainfall from 2005 to 2015 is presented in Table 2.

Table 1: Mean rainfall and calculated evaporation data at the Cairns Airport (Weather Station Number 031011). Source: Bureau of Meteorology (2016).

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Mean rainfall 1942 to 2016 (mm)	390	448	419	195	92	48	30	27	33	46	94	178
Mean evaporation 1965 to 2016 (mm)	198	164	180	162	152	141	155	174	201	233	225	223.

Note: data is rounded to the nearest millimetre

Table 2: Annual total rainfall data between 2005 and 2015 at the Cairns Airport (Weather Station Number 031011). Source: Bureau of Meteorology (2016).

Year	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015*
Rainfall (mm)	1471	2289	1813	2215	2199	2660	2623	2003	1269	1826	1897

Note: data is rounded to the nearest millimetre

*Not quality controlled by BOM (2016)

The Cairns region experiences cyclonic storms on a regular basis with extreme rainfall events every two to eight years. Runoff intensity and storm surges from the sea would be expected. Significant rainfalls of 100 mm/day or greater can occur at any time during most of the year. Due to the proximity of the site area to tidally influenced streams and the nature of the local hydrologic conditions, episodic extreme weather events would also be expected. The topography consists of low lying coastal plains which may be influenced by storm surge impacts and large storm run-off or flood events.

2.3 Drainage and Topography

The topography of the Northern Sands site is characterised by alluvial terraces near the Barron River and flat coastal plains extending from the west of the site and east toward the ocean. Ground surface levels across the site typically range from about 5.5 m to 2 m Australia Height Datum (m AHD). Recent hydrographic survey (July 2016 by Ports North) of the pit indicates excavation levels typically in the range of -1.5 m to -2.5 m AHD across the majority of the pit, apart from the southern and eastern sections of the pit where excavation levels range from -6.5 m to -14.5 m AHD. Contours of the elevation of the base of the lake from the recent hydrographic survey are shown on Figure 2.

The Barron River, Thomatis Creek and Narelle Lake are the dominant drainage features in the site area. The Barron River lies to the immediate south and west of the site, and averages about 150 m in width with an assumed bed level of around -2 m AHD. Narelle Lake is the main surface water feature on the site with a water level around 0.5 m AHD indicated in the July 2016 hydrographic survey.

2.4 Regional Geology and Hydrogeology

The Northern Sands site is located on the alluvial fan and delta of the Barron River. Unconsolidated sediments reach thicknesses of up to around 90 m, in the area to the immediate north-east of the site, as shown below in Plate 1 (reproduced from QLD Water Resources Commission, 1982). Surface geology in the area of the site is shown on Figure 3.

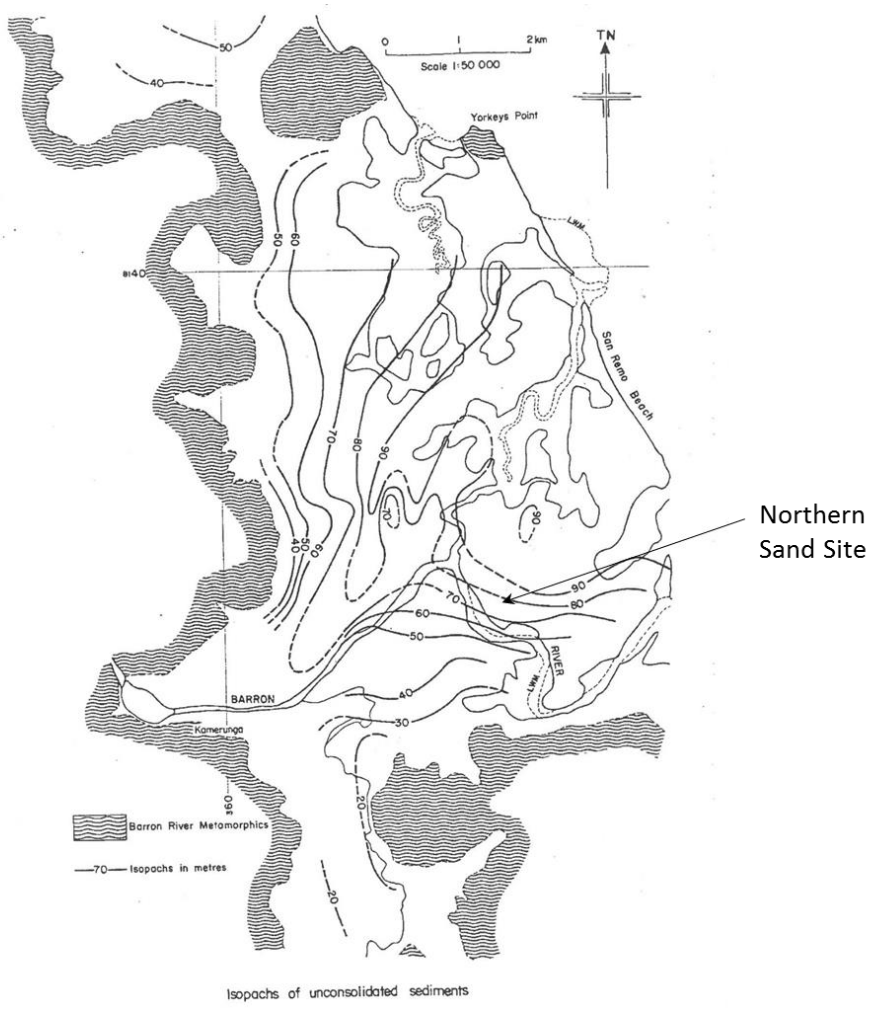


Plate 1 – Thickness of Unconsolidated Alluvium

Bedrock which underlies the unconsolidated sediments is exposed in the Macalister Ranges which outcrop to the west of the delta. Bedrock comprises Silurian/Devonian age metasediments (sedimentary rocks that have undergone some degree of metamorphism) comprising inter-bedded phyllite, schist, quartzite and chert beds which generally strike north to south.

Erosion of the bedrock has resulted in the formation of the Barron River floodplain that stretches from Trinity Beach to the north of the site to south of the Cairns Airport. The floodplain is underlain by unconsolidated Quaternary age alluvial deposits of sands, gravels, silts and clays.

Stratigraphic information available from the Queensland Registered Groundwater database (GWDB) (DNRM, 2016) within 2 km of the site indicates that the Quaternary age sediments are comprised of the following:

- Younger (Holocene age) alluvial deposits that generally range from surface to depths of 90 m. This sequence is associated with channel systems and consists of sand, silt and mud deposits, as well as minor gravel beds.
- Coastal (Holocene age) deposits in tidal mangrove and supratidal flats. These are located to the west and to the east of the site and consist of silt, sand and mud. This sequence is deposited in a marine environment with tidal influences from the Coral Sea. During transgressional and regressional periods, changes in sea levels, beach type sand, or silt and clay deposits would inter-tongue with terrestrial deposits.

There are two major aquifers in the Barron River delta within the unconsolidated sediments (QLD Water Resources Commission, 1982):

- An upper, unconfined aquifer varying in thickness from about 2 m to 11 m, which is overlain by up to 5 m of beach ridge deposits or clayey strata.
- A lower, confined or semi-confined aquifer, separated from the upper aquifer by a clay layer of varying thickness from around 3 m to around 25 m. The lower aquifer includes numerous inter-fingering clay layers.

Bore yields of up to 1500 m^3/day are reported for these aquifers; however, the potential for use of this water for various beneficial uses is impacted by the salinity of the groundwater. Poor water quality is observed up to 3 km from the coast (QLD Water Resources Commission, 1982).

Twenty-four registered bores are located within 2 km of the Northern Sands site as shown on Figure 4. Summary details of the registered bores are provided in Appendix A. The range of measured groundwater levels in these registered bores over the period from 1976 to 2016 are also shown on Figure 4. Hydrographs showing the variation in groundwater level over time for the registered groundwater bores are presented on Figure 5.

Figures 4 and 5 indicate that groundwater levels are generally lower in the vicinity of Thomatis Creek. QLD Water Resources (1982) states that “it seems likely that for most of the year, Thomatis/Richter Creek and a major part of the Barron River are effluent streams, acting as a line sink draining water from the aquifer system”. This is illustrated in Plate 2 below, reproduced from that report. It is also noted that relatively low groundwater levels have been recorded in registered bores 11000025 and 11000031, which are located in the vicinity of low-lying mangrove areas. It is also noted that relatively low groundwater levels have been recorded in registered bores 11000032 and 11000049 which are located within 300 m of Narelle Lake, towards the east. These lower groundwater levels were recorded between 1977 and 2005. It is not known whether the lower groundwater levels at these bores is associated with the lake, or groundwater extraction.

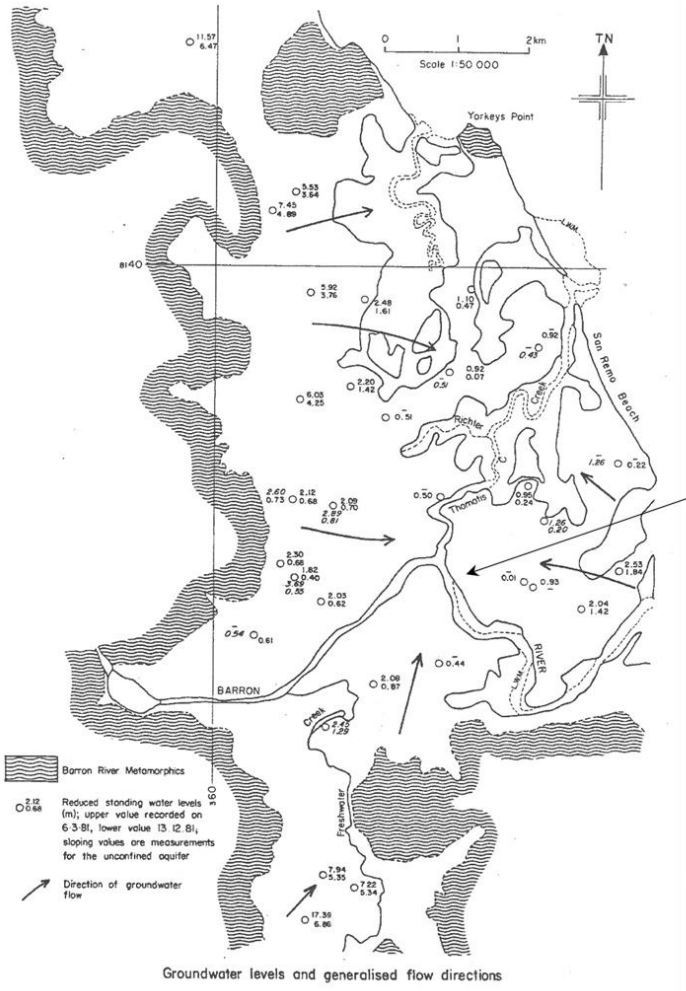


Plate 2 – Groundwater Flow across the Barron Delta

Water quality parameters from the registered bores are shown on Figure 6, and further information on groundwater quality parameters for the registered bores is provided in Appendix B.

Pumping tests carried out for the QLD Water Resources Commission 1982 study indicate transmissivities in the range of around 1500 to 6800 square metres per day (m^2/day) for the upper unconfined aquifer (corresponding to values of hydraulic conductivity in the range of $2x10^{-3}$ to $4x10^{-3}$ m/s), and around 550 to 3900 m^2/day for the lower confined aquifer.

2.5 Groundwater Dependant Ecosystems

Groundwater Dependent Ecosystems (GDE) are defined as ecosystems whose ecological processes and biodiversity are wholly, or partially, reliant on groundwater. Examples of GDEs include wetlands, vegetation, mound springs, river base flows, plus saline discharges, springs, mangroves. GDEs may include aquatic ecosystems in rivers and streams that receive groundwater baseflow.

Information on potential groundwater dependent ecosystems is available from the National Atlas of Groundwater Dependent Ecosystems. Based on information from this atlas, the potential for groundwater dependent ecosystems in surface water bodies and for vegetation in the vicinity of the site is shown in Figure 7. Further information on groundwater dependent ecosystems is presented in the Terrestrial Ecology report - Northern Sands (Biotropica, August 2016).

Figure 7 indicates the presence of vegetation with a high potential for groundwater interaction between Narelle Lake and the Barron River along the western and southern boundaries of the lake. The reaches of Thomatis Creek and Barron River in the vicinity of the Northern Sands site are indicated to have moderate potential for groundwater interaction.

3.0 GROUNDWATER CONDITIONS ON SITE

3.1 Stratigraphy

Previous subsurface investigations carried out on and adjacent to the Northern Sands site include the following:

- Borehole investigation carried out by Probin Pty Ltd in 2007. This work comprised 21 No. boreholes to depths ranging between approximately 15 m to 24 m below ground level (m bgl) on the subject site.
- Borehole investigation carried out by GEO Investigate in 2013. This work comprised 10 No. boreholes within the existing lake to depths ranging from 18 m to 30 m below water level (m bwl).
- Cone Penetrometer Testing (CPT) carried out by GEO Investigate in July 2016. This work comprised 30 No. CPT's to depths ranging from approximately 8 m to 24 m bgl on the subject site.
- Borehole investigation carried out by Golder in 1995. This work comprised 10 No. boreholes to depths ranging approximately 6 m bgl to the north of the subject site.
- Cone Penetrometer Testing (CPT) carried out by GEO Investigate in July 2016. This work comprised 14 No. CPT's to depths ranging from approximately 11.6 m to 14.7 m bgl to the north of the subject site.

Additional subsurface investigations carried out for these studies on and adjacent to the Northern Sands site include the following:

- Groundwater monitoring borehole installation, sampling and testing by Golder in September 2016 and November 2016. This work comprised 5 No. boreholes to depths ranging from approximately 1.4 m to 12 m bgl on the subject site. Borehole reports are presented in Appendix D.
- Cone Penetrometer Testing (CPT) carried out by Golder in November 2016. This work comprised 7 No. CPT's to depths ranging from approximately 9.8 m to 18.5 m bgl to the east of the subject site. CPT reports are presented in Appendix D.

The investigation locations are shown on Figure 8. Inferred subsurface cross-sections (utilising information from registered groundwater bores as well as the investigations outlined above) are presented in Figures 9 and 10.

The inferred subsurface conditions in the site area are broadly consistent with the published geology and generally comprises the following sequence.

- Sandy silty clay typically above -1 m AHD.
- Sand/gravelly sand broadly between 3 m to -7 m AHD.
- Silty clay broadly between 0 m to -16 m AHD and ranging in thickness from around 3 m to around 6 m. This layer may not be continuous although it is shown to be so in Figures 9 and 10.
- Sand/gravelly sand broadly between -6 m AHD to a maximum depth below -25 m AHD.
- Silty clay broadly between – 14 m AHD to a maximum depth below -36 m AHD, and with a maximum measured thickness of 12 m.
- Gravelly sand/sandy gravel below -20 m to -22 m AHD, to a maximum depth of -37 m AHD in registered monitoring bores RN139211 and RN11000053.

The upper two sand/gravelly sand units (and the 3 m to 6 m thick clayey interbed in the site area) are interpreted to represent the upper unconfined regional aquifer. The lower gravelly sand/sandy gravel unit encountered below -20 m to -22m AHD is interpreted to represent the lower semi-confined/confined regional aquifer.

3.2 Groundwater Levels

Six shallow groundwater monitoring bores (UG1, UG2, BH2, BH3, BH4a and BH5a) have been installed by others at the locations shown on Figure 11. The depth of the monitoring bores ranges between 3.9 m and 8.5 m bgl, however further information regarding the construction of these bores is not available. Hydrographs of groundwater levels and the water levels in the lake between mid-2009 and mid-2016 (information provided by Landline Consulting – environmental consultants to Northern Sands operations) are shown on Figure 12. It was suspected that the recorded lake levels may be approximately 0.5 m above the actual water levels (i.e. actual lake water levels may be approximately 0.5 m below those illustrated in Figure 12). Recent survey of groundwater and lake water levels by Golder confirmed these suspicions in the historical data, however, the data in Figure 12 has not been adjusted from that provided by Landline Consulting.

Notwithstanding the potential error in the lake water levels, the pattern of variation of groundwater levels matches the pattern of variation in the lake level. Measured groundwater levels generally vary between -0.3 m and 1.0 m AHD. It is likely that the groundwater levels in the monitoring bores closest to the Barron River are impacted by tidal fluctuations in the Barron River, and that in particular, measured groundwater levels lower than 0 m AHD are likely to reflect low tide conditions at or close to the time of measurement.

Four shallow groundwater monitoring bores (BH01, BH02, BH03 and GA04) were installed by Golder at the locations shown on Figure 11. The depth of these monitoring bores ranges between 5.5 m and 12 m bgl. Construction information for these monitoring bores are presented on the borehole reports in Appendix D and summarised in Table 4. These boreholes were developed after their installation by purging at least 5 well volumes to remove drilling influences in the bores and to assist groundwater representative of the aquifer to flow into the monitoring bore. Along with purging 5 well volumes from each bore, water quality parameters were monitored until parameters stabilised.

Data logging pressure transducers were installed in BH01 and BH03 in September 2016 to record groundwater levels at 1 hour intervals. Hydrographs of groundwater levels at BH01 and BH03 from 29 September to 22 November 2016 are presented in Figure 14. Groundwater level ranges are summarised in Table 4. The hydrographs for BH01 and BH03 show a response to rainfall and tidal influence of approximately 0.10 m.

Table 3: Monitoring bore location and level

Borehole ID	Easting*	Northing*	Elevation (m AHD)	Standpipe Stick up (m)
BH01	363627.63	8136178.11	2.64	0.67
BH02	364376.67	8135447.11	2.13	0.63
BH03	364301.50	8135126.42	1.97	0.67
GA04	364331.65	8135689.89	3.58	0.90

*Coordinates system: GDA 94 zone 55

Table 4: Monitoring bore construction information and water levels

Borehole ID	Bore depth (m bgl)	Screened interval (m bgl)	Soil description	Aquifer type	Water Level Range	
					*(m bgl)	*(m AHD)
BH01	6.0	3.0 to 6.0	Sand	Unconfined	2.18 to 2.64	0.17 to 0.46
BH02	6.0	3.0 to 6.0	Clayey sand	Unconfined	1.93	0.2
BH03	12.0	6.0 to 12.0	Clayey sand and clay	Unconfined	1.47 to 1.76	0.18 to 0.51
GA04	5.5	3.5 to 5.5	Sand	Unconfined	3.29	0.29

**Where data is not presented in a range, only a single data point exists.*

The nearest measurement of river levels in the Barron River is at Cairns Airport, approximately 2 km downstream of the site. Records from this station indicate a long-term average river level of 0.5 m AHD. Comparison with the groundwater levels illustrated in Figure 12 indicates that the long term average groundwater levels close to the river, and the lake level, are similar to the average river level.

Given the above information, 0 m AHD has been adopted as the lowest permanent water level in the lake.

3.3 Groundwater Quality

Monitoring bores BH2, BH3, BH4a and BH5a have been sampled and tested monthly by others (Landline Consulting) from September 2014 to April 2016 for the following parameters:

- Aluminum
- Arsenic
- Cadmium
- Chloride
- Chromium
- COD (Chemical oxygen demand)
- Copper
- EC
- Lead
- Iron
- Mercury
- pH
- Sulphate
- Total Nitrogen
- Total Phosphorus
- Zinc

Copies of plots showing the results of water quality testing are presented in Appendix C.

Ranges of EC and pH at monitoring bores and regional groundwater bores in the area of Narelle Lake are shown in Figure 13. The EC in Narelle Lake between September 2011 and March 2016 varied between 200 S/cm and 1000 μS/cm. It is noted that registered groundwater bores 11000049 and 11000033 to the immediate east of Narelle Lake have high recorded EC ranging from 19 000 μS/cm to 38 000 μS/cm. The measured EC at these two registered groundwater bores is higher than at all other registered groundwater bores within a 2 km radius where water quality measurements are available.

Golder monitoring bores BH01, BH02, BH03 were sampled on 29 September and 22 November 2016, and GA04 was sampled on 24 November 2016. Groundwater samples from BH01, BH02, BH3 and GA04 were forwarded under chain of custody to SGS (a NATA accredited laboratory) for testing. Samples were analysed for the following parameters. It should be noted that only aluminium, iron and total iron were tested during the 29 September 2016 sampling event.

- Alkalinity
- Aluminium
- Anions
- Calcium
- Cation
- Chloride
- EC
- Iron
- Magnesium
- pH
- Potassium
- Sodium
- Sulphate
- TDS
- Total hardness
- Total Iron
- Total Nitrogen

The field data and laboratory results are presented in Appendix E and summarized in Table 5.

Table 5: Field and laboratory pH and salinity results

Monitoring bore	pH range lab results	pH range field results	EC range (μS/cm) lab results	EC range (μS/cm) field results	Salinity
BH01	6.8 to 7.0	6.5 to 7.2	230 to 250	300 to 373	Fresh water
BH02	7.7 to 7.9	6.7 to 8.0	9,300 to 11,000	8,000 to 10,000	Brackish water
BH03	7.9	7.2 to 10.2	24,000	25,500 to 26,540	Brackish water
GA04	6.5	5.74	160	148	Fresh water

3.4 Hydraulic Conductivity

Slug tests were carried out at BH01, BH02, BH03 and GA04 during field investigations in November 2016. Two falling and two rising head test were conducted at each bore location. Data was recorded by a pressure transducer recording water level every second in conjunction with manual water level measurement during the test. Hydraulic conductivities estimated from the falling and rising head tests conducted at each bore are presented in Figures 15 to 18 and summarised in

Table 6.

Talsma tests were carried out within the upper clay layer at the location of GA04 and GA05. Laboratory plasticity and grading tests were carried out to confirm soil classifications at the locations of the Talsma tests. The results of the laboratory testing on the soils are presented in Appendix F. The results of the Talsma tests are presented in Appendix G and are summarised in Table 6.

Table 6: Field hydraulic conductivity testing results

Test Location	Test depth range (m)	Soil description	Method used	Hydraulic conductivity K (m/s)
BH01	3.0 to 6.0	Sand	Hvorslev	2×10^{-4}
BH02	3.0 to 6.0	Clayey sand	Hvorslev	9×10^{-7}
BH03	6.0 to 12.0	Clayey sand	Hvorslev	3×10^{-4}
GA04	3.5 to 5.5	Sand	Hvorslev	2×10^{-3}
GA04	0.3 to1.4	Sandy clay	Talsma equation	7×10^{-7}
GA05	0.3 to 1.5	Sandy clay	Talsma equation	1×10^{-7}

3.5 Porosity

Samples of the upper sands from GA04 and at GA05 were forwarded for laboratory testing to assess their maximum/minimum densities. Relative density of the sands was inferred from the results of Cone Penetrometer Testing at nearby test locations. The in situ density of the sands was then assessed by comparing the inferred relative density with the maximum/minimum densities achieved in the laboratory testing. Void ratios and porosities for the upper sand formation were calculated based on the interpreted insitu dry densities. Results of the laboratory testing are presented in Appendix F and the assessed porosity results are presented in Table 7.

Table 7: Assessed porosity for upper sand formation.

Sample	Inferred Density Ratio (%) from CPT	Inferred *in situ* Density (t/m^3)	Inferred Dry Density (t/m^3)	Moisture Content (%)	Void Ratio (e)	Porosity (n)
GA04 (Brown Sand)	45	1.62	1.27	27.5	1.08	0.52
GA04 (Brown Sand)	96	1.86	1.46	27.5	0.82	0.45
GA05 (Yellow Sand)	45	1.67	1.46	14.0	0.81	0.45
GA05 (Yellow Sand)	96	1.87	1.64	14.0	0.61	0.38

A porosity of 0.38 was adopted for the groundwater modelling.

3.6 Conceptual Hydrogeological Model

A conceptual hydrogeological model for the Northern Sands site is illustrated in Figure 19. The following points are noted regarding this conceptual model:

- The Northern Sands site is underlain by an upper unconfined aquifer and a lower confined or semi-confined aquifer. Both of these aquifers extend broadly across the Barron River delta.
- In the area of the Northern Sands site, the upper unconfined aquifer includes a 3 m to 5 m thick clayey interbed, which may or may not be laterally continuous. The upper aquifer is recharged directly by rainfall.
- The overall direction of groundwater flow in the upper unconfined aquifer is towards the Barron River and Thomatis Creek, as discussed in QLD Water Resources Commission (1982). Close to these streams, groundwater exchange will occur as a result of tidal fluctuations in the streams.
- Groundwater in the deep confined aquifer is towards the coast. Recharge to this aquifer occurs further to the west where the confining unit is absent in some areas.

In the current condition, the groundwater level in the lake is similar to the groundwater level in the upper unconfined aquifer. When the lake level is raised during the period of placement of dredged material along with large volumes of seawater, a hydraulic gradient away from the lake will be created, and saline water will flow away from the lake. In the early stages of placement, saline water from the lake will also flow downwards through areas where the clayey interbed has been removed by sand extraction operations in the lake. It is likely, however, that this flow will diminish significantly over time as a result of the low permeability of dredged material which will fill the base of the lake.

4.0 CONSTRAINTS AND OPPORTUNITIES

Dredged material will be placed in the sand pit along with large volumes of seawater, within an area on the eastern side of the existing lake. The lake will be deepened prior to dredging and bunded where required to contain the dredged material and tailwater. Water levels in the lake could be raised to between 3 m to 5 m AHD during placement of the dredged material. As a consequence, the lake level in this area will be at a level above the groundwater level in the surrounding aquifer and above the level in the Barron River for this period. The seepage rate out of the lake during this period will be significantly lower than the flow rate delivered to the lake with the dredged material, and thus the majority of the delivered water will need to be managed through tailwater ponds. The proposed concepts for tailwater management have been developed by BMT JFA and are outlined in their Dredged Material Placement Assessment, 2016.

As noted above, saline water will flow radially away from the lake during the period that the lake level is artificially raised. Along the southern boundary of the lake, this water will flow through the upper sandy layer towards the Barron River, with the potential to impact on the salinity of the river. Along the remainder of the perimeter of the lake, water will flow out into the upper unconfined aquifer both horizontally through the sandy materials exposed around the edges of the lake and through the area where the clayey interbed has been removed by sand extraction operations in the lake, with the potential to impact on water quality in this aquifer.

The potential for unacceptable impacts on water quality in the Barron River and in the upper unconfined aquifer may constrain the approach to placement of dredged material at the Northern Sands site, and require management measures to mitigate impacts.

5.0 ASSESSMENT OF IMPACTS

5.1 Groundwater modelling

As discussed in Section 3.6, a conceptual hydrogeological model for the Northern Sands site was prepared as shown in Figure 19. The conceptual model is based on the inferred subsurface cross-section shown in Figure 9.

Prior to groundwater modelling all of the additional information on ground conditions from the current studies and from historical investigations in the vicinity was collated, and the ground model for the site area was updated. In order to provide an assessment of saline water flow away from the lake during the period of increased lake water level, two simplified cross-sectional numerical models were developed, based on the inferred subsurface conditions along the SW to NE and NW to SE oriented cross-sections as shown in Figure 20. The simplified cross-sectional models are shown in Figure 21, noting that the profile of the lake is based on the assumption that the eastern end of the existing pit will be expanded prior to disposal operations.

The finite element software SEEP/W was used to develop a variably saturated, density dependent solute transport model. Parameters for the modelling were based on the results of the fieldwork and laboratory testing as appropriate. The adopted boundary conditions are shown in Figure 22.

During the placement of dredged material, the water level in the lake will be raised and the lake filled with saline water. Modelling has been carried out for lake levels at RL 3 m AHD, RL 4 m AHD and RL 5 m AHD. Placement of the dredged material has been modelled in 4 sequential steps (0 to15 days, 15 to 30 days, 30 to 60 days and 60 to 90 days), with placement of the dredged material in a series of horizontal lifts to raise the dredged material level to -1 m AHD over a period of approximately 90 days. It has been assumed that the dredged material will have a hydraulic conductivity of 1 x 10^{-7} m/s.

5.2 Impacts on the upper unconfined aquifer and shallow soils to the north and east of Narelle Lake

Results from the groundwater models for Sections 1 and 2 are presented in Figures 23 to 26. Figures 25 and 26 show contours of the salinity concentration under increased lake levels during the period of disposal. Figures 23 and 24 show profiles of the **increase** in salinity concentration above the existing concentration (i.e. prior to disposal) with distance away from the lake. The profiles are based on salinity concentrations in the upper sand layer immediately below the near surface clay layer. The results show that in the sand layer, the area impacted by an increase in salinity increases with increased lake levels during the period of disposal. A summary of the approximate distance from the lake impacted by an increase in salinity is provided in Table 8. These distances are also shown on Figure 27.

Table 8: Extent of increase in salinity in upper sand layer

Section	Level of water in disposal area	Approximate maximum distance to which increased concentration extends
Section 1	RL 3m AHD	50 m
	RL 4 m AHD	65 m
	RL 5 m AHD	80 m
Section 2	RL 3m AHD	90 m
	RL 4 m AHD	110 m
	RL 5 m AHD	130 m

The results of the modelling indicate that the hydraulic gradient remains downwards throughout the period considered in the modelling (i.e. up to 2 years after the start of placement of dredged material). This downward hydraulic gradient will limit the extent to which salt can migrate upwards into the near surface clay layer and it is assessed that negligible changes in the salinity of the near surface clay will occur.

5.3 Impacts on the Barron River

The potential flow rate and solute transport rate between the lake and the Barron River during the period of increased lake water level was preliminarily assessed during previous studies, noting that at that stage a lower lake level was adopted and that a different lake configuration was proposed. The previous estimate of the total seepage volume into the Barron River was based on an assumption that the lake level would be raised across the entire area of the existing lake. The length of river adjacent to the lake will be reduced for the currently proposed approach, which will offset the effect of the higher lake levels within the disposal area.

The previous studies indicated that the steady state groundwater seepage from the lake to the river was estimated to be 4800 m^3/day as a result of the increase in lake level. The estimated time for breakthrough of the saline water plume from the lake to the river was estimated to be 40 to 80 days after raising the level in the lake. After the breakthrough the salinity of the seepage water would be equal to the concentration in the lake. The previous studies did not account for a progressive diminishing in the rate of seepage as dredged material was placed in the lake.

The results of the current modelling indicate that the groundwater seepage from the lake to the river during the period of the raised water level in the lake will reach a rate of 3100 m^3/day with a salt flux of 450 g/s for a lake level in the disposal area of RL 5 m AHD.

Potential impacts of the seepage on water quality in the Barron River have been addressed by BMT WBM in their Marine Water Quality report, 2016.

6.0 REFERENCES

- Biotropica, August 2016.
- Bureau of Meteorology (BOM), 2016, Climate Data, access 16 December 2016 <http://www.bom.gov.au/>
- Department of Natural Resources and Mines (DNRM), *Groundwater Database*, QLD Globe, 2016, State of Queensland <accessed 09 August 2016>.
- Landline Consulting, 2016, *Northern Sands Lake and Bore Stats,* Prepared for Flanagan Consulting Group, Queensland, Australia, 20 July 2016.
- Probin Pty Ltd (2007), *Sand Resource Evaluation*, Prepared for Northern Sands Pty Ltd, Queensland Australia, 27 April 2007.
- QLD Water Resources Commission (1982). *Barron River Groundwater Investigations – Groundwater Resources of the Barron River Coastal Plan*. Record 1982/23, Ref: E158, December 1982.
- Golder Associates Pty Ltd (Golder), 2016, *Stage1B-Groundwater Report Northern Sands*, Prepared for Flanagan Consulting Group, Cairns shipping development project.

7.0 IMPORTANT INFORMATION

Your attention is drawn to the document - “Important Information relating to this report”, which is included as Appendix H. The statements presented in this document are intended to advise you of what your realistic expectations of this report should be. The document is not intended to reduce the level of responsibility accepted by Golder Associates, but rather to ensure that all parties who may rely on this report are aware of the responsibilities each assumes in so doing.

Report Signature Page

GOLDER ASSOCIATES PTY LTD

Jennifer Lallier
Hydrogeologist

Scott Fidler
Principal

JL/DB/SRF/MSC/ow

A.B.N. 64 006 107 857

j:\geo\2015\1546223 - fcg - eis stage 1 - port development\corr out\stage 1b hydrogeology assessment\northern sands\report 012 rev4\1546223-012-r-rev4 baseline hydrogeological assessment northern sands.docx

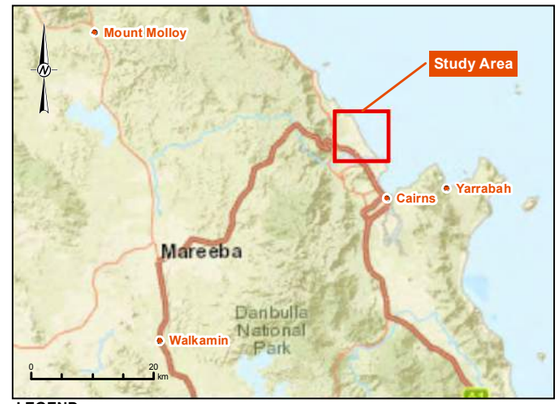
FIGURES

362,000
364,000
366,000
368,000
8,142,000
8,140,000
8,138,000
8,136,000

Yorkeys Knob
VARLEY STREET
YORKEY'S KNOB ROAD
CAPTAIN COOK HIGHWAY
WISTARIA STREET
HOLLOWAY BEACH ROAD
MACHANS STREET
MACHANS BEACH ROAD
Barr Creek
Machans Beach

Booster #1
Booster #2
Booster #3

LOCATION MAP



LEGEND

- Localities
- Roads and Tracks
- Drainage (25k)

Pipeline Route Options

Inbound Aquis
- Booster Locations (with Marine Booster)
- Booster Locations (no Marine Booster)
- Inbound Pipeline

Inbound Yorkeys
- Booster Locations
- Inbound Pipeline

Inbound Machans Beach
- Booster Locations
- Inbound Pipeline

- Dredge Pumpout and Marine Booster Areas
- Storage and Laydown Areas
- Northern Sands Placement Area
- Pit Expansion Area

0 1 2
Kilometres
1:30,000 at A3
PROJECTION: GDA 1994 MGA Zone 55

CLIENT
FLANAGAN CONSULTING GROUP

PROJECT
CAIRNS SHIPPING DEVELOPMENT EIS:

TITLE
LOCALITY: NORTHERN SANDS

CONSULTANT
Golder Associates

YYYY-MM-DD	2016-09-29
PREPARED	DP
DESIGNED	DP
REVIEWED	DS
APPROVED	DS

PROJECT NO.	CONTROL	REV.	FIGURE
1546223	012	4	1

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: A3
25mm
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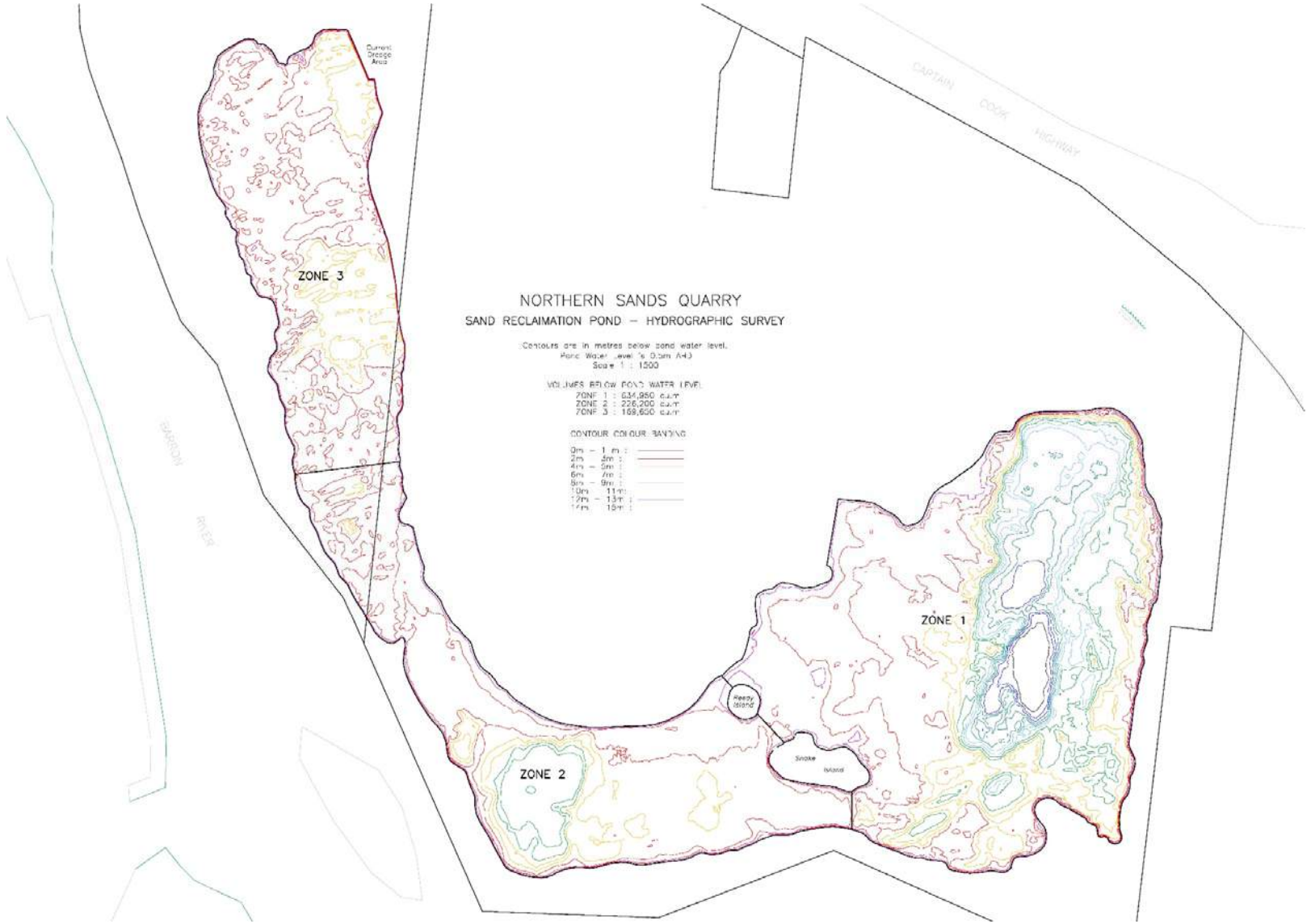
Path: \\golder.gds\GAP\Cairns\Jobs\Geo\2015\1546223 - FCG - EIS Stage 1 - Port Development\GIS\MXD\Soils_Geology_Figures\Northern_Sands\1546223-001-R-Rev0_F001_Nth_Sands_Locality.mxd



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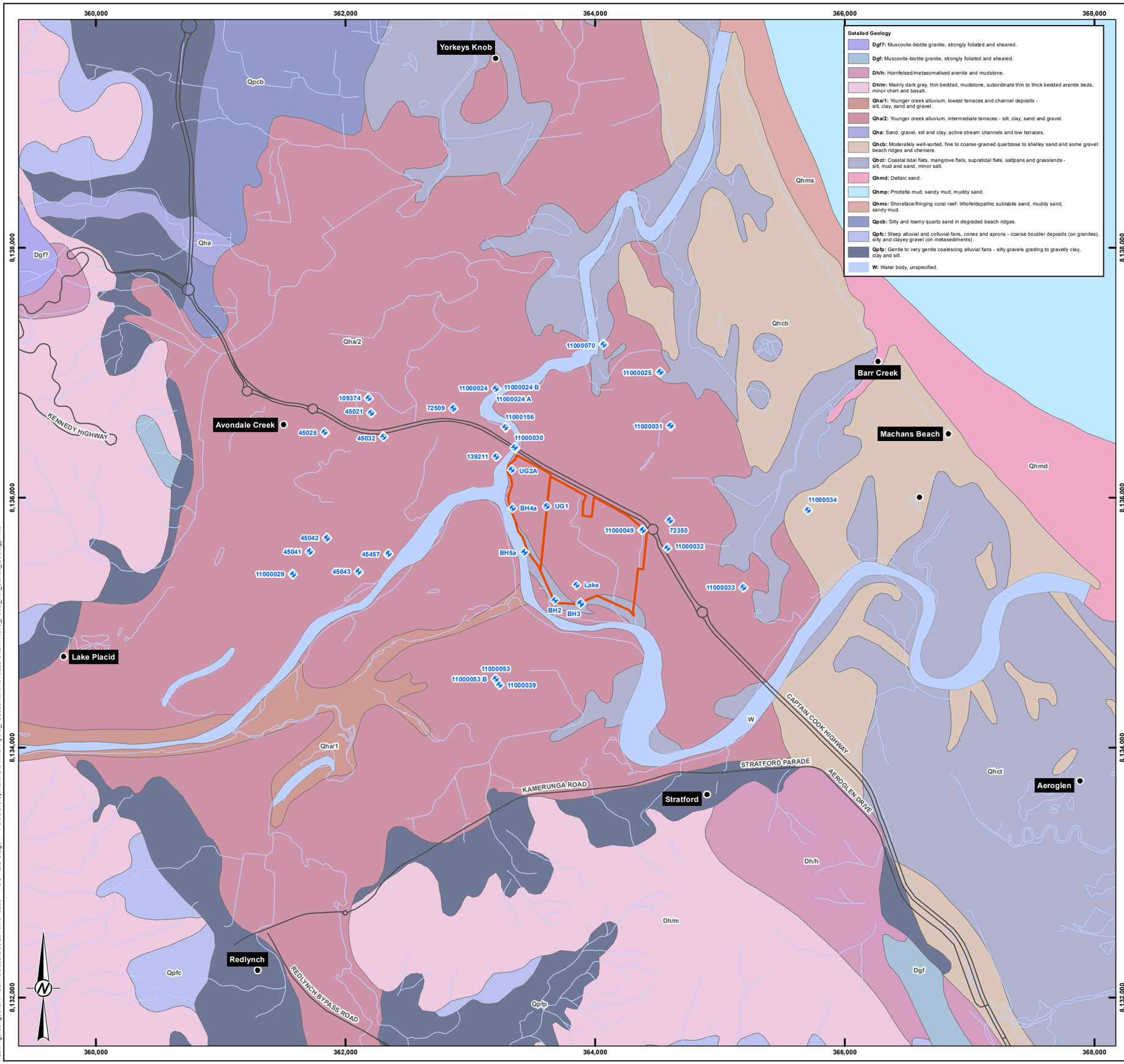
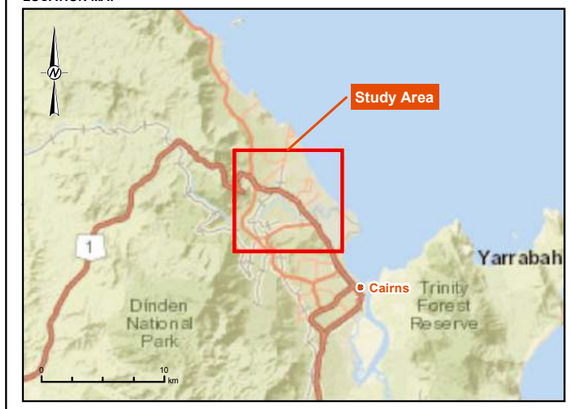
	CHECKED: SRF	DATE: 19/9/16			
	SCALE:	SHEET SIZE: A4		PROJECT No: 1546223-012	REVISION: 4	FIGURE No: FIGURE 2



LOCATION MAP



LEGEND

- Localities
- Monitoring Borehole Locations
- Roads and Tracks
- Drainage (25k)
- Northern Sands Site

0 1 2
Kilometres

1:30,000 at A3
PROJECTION: GDA 1994 MGA Zone 55

CLIENT
FLANAGAN CONSULTING GROUP

PROJECT
CAIRNS SHIPPING DEVELOPMENT EIS

TITLE
DETAILED GEOLOGY: NORTHERN SANDS SITE

CONSULTANT
Golder Associates

YYYY-MM-DD	2017-01-20
PREPARED	DP
DESIGNED	DP
REVIEWED	DS
APPROVED	DS

PROJECT NO.	CONTROL	REV.	FIGURE
1546223	012	4	3

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM A3
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361,000 362,000 363,000 364,000 365,000 366,000

8,138,000 8,137,000 8,136,000 8,135,000 8,134,000

Holloways Beach
Thomatis Creek
Barr Creek
Avondale Creek
Barron
Freshwater Creek
Stratford

CAPTAIN COOK HIGHWAY
KAMERUNGA ROAD
STRATFORD PARADE
AEROGLEN DRIVE

ID: 109374
Screen Interval: No data
WL mAHD: No data

ID: 45021
Screen Interval: 0.0 to 5.5
WL mAHD: No data

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Screen Interval: 23.0 to 35.0
WL mAHD: no data

ID: 11000025
Screen Interval: 24.0 to 36.0
WL mAHD: 0.2 to 1.0

ID: 72509
Screen Interval: 4.5 to 5.5 and 8.5 to 10.0
WL mAHD: No data

ID: 11000031
Screen Interval: 4.0 to 13.0
WL mAHD: -0.2 to 2.2

ID: 45028
Screen Interval: 0.0 to 6.1
WL mAHD: No data

ID: 11000030
Screen Interval: No data
WL mAHD: -0.8 to 1.4

ID: 11000156
Screen Interval: 14.0 to 26.0
WL mAHD: 0.01 to 0.8

ID: 45032
Screen Interval: 1.8 to 6.1
WL mAHD: No data

ID: 139211
Screen Interval: no data
WL mAHD: No data

ID: 11000034
Screen Interval: 38.0 to 56.0
WL mAHD: 1.7 to 2.5

ID: 45042
Screen Interval: 0.0 to 7.6
WL mAHD: No data

ID: 72350
Screen Interval: 6.1 to12.2
WL mAHD: No data

ID: BH4
Screen Interval:
WL mAHD: -0.44 to 2.35

ID: 45041
Screen Interval: 0.0 to 7.6
WL mAHD: No data

ID: 45457
Screen Interval: 5.5 to 6.5
WL mAHD: No data

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Screen Interval: 28.0 to 34.0
WL mAHD: 0.1 to 1.7

ID: 11000029
Screen Interval: 24.0 to 30.0
WL mAHD: 0.4 to 2.5

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WL mAHD: 0.0 to 1.1

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Screen Interval: 0.0 to 7.6
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Screen Interval: 30.1 to 32.1
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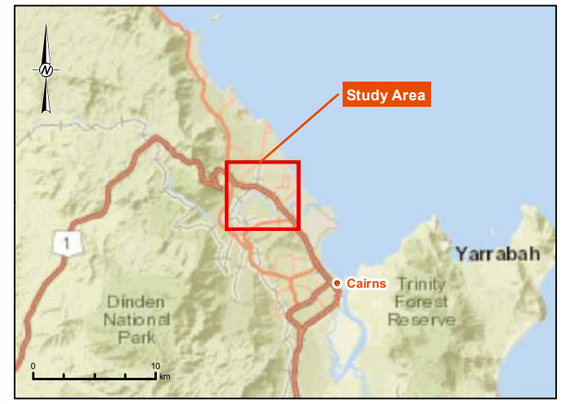
LOCATION MAP



LEGEND

- Localities
- Registered Groundwater Bores
- Roads and Tracks
- Drainage (25k)
- Northern Sands Site

0 0.5 1
Kilometres
1:20,000 at A3
PROJECTION: GDA 1994 MGA Zone 55

CLIENT
FLANAGAN CONSULTING GROUP

PROJECT
CAIRNS SHIPPING DEVELOPMENT EIS

TITLE
GROUNDWATER LEVELS AT REGISTERED BORES

CONSULTANT
Golder Associates

YYYY-MM-DD	2016-09-19
PREPARED	DP
DESIGNED	DP
REVIEWED	DS
APPROVED	DS

PROJECT NO.	CONTROL	REV.	FIGURE
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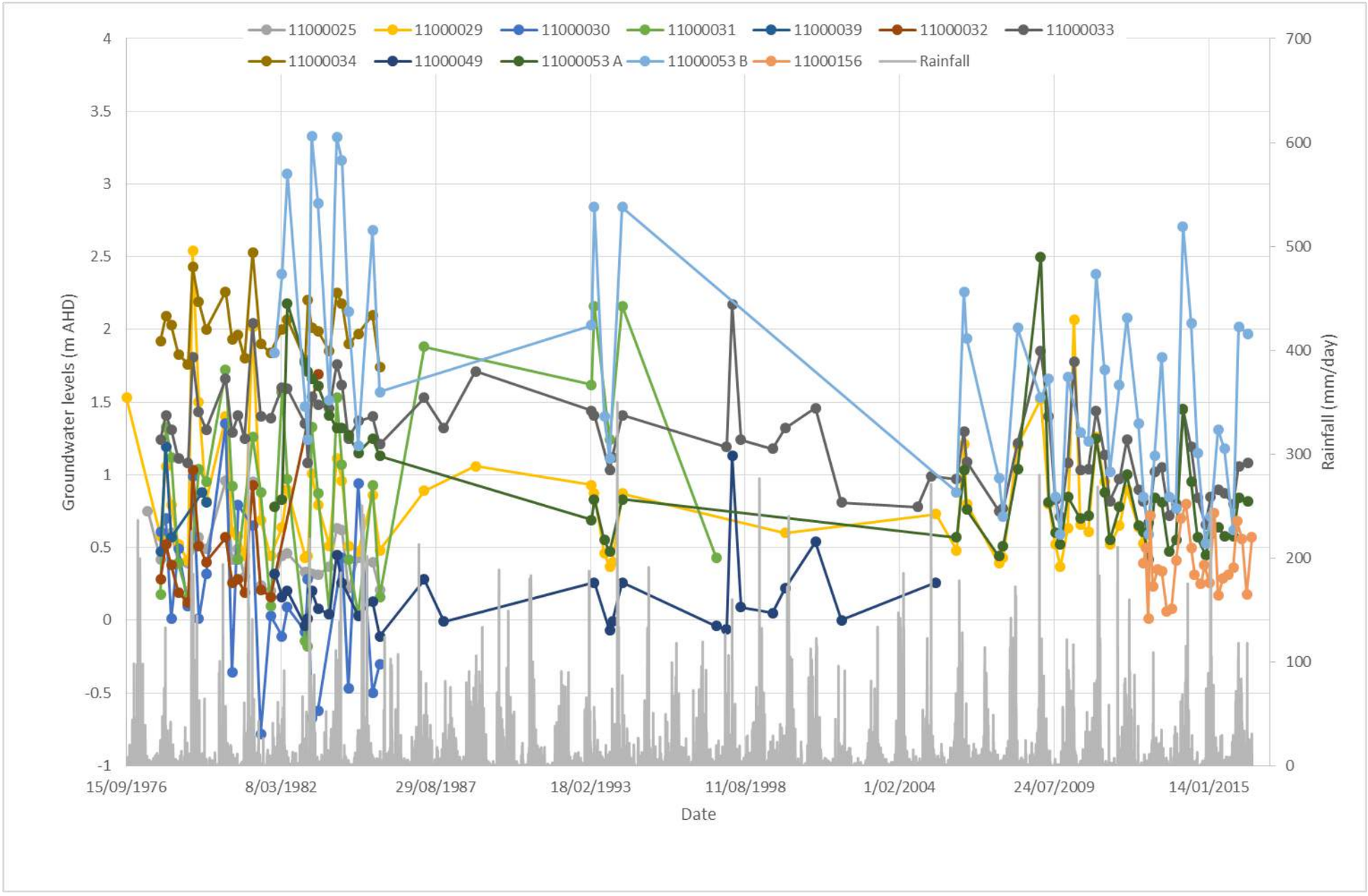

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	DRAWN: JL	DATE: 19/9/16	TITLE: Hydrographs for Registered Groundwater Bores	
	CHECKED: SRF	DATE: 19/9/16		
	SCALE	SHEET SIZE: A4	PROJECT No: 1546223-012	REVISION: 4 / FIGURE No: FIGURE 5

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8,138,000 8,137,000 8,136,000 8,135,000 8,134,000

Holloways Beach
Thomatis Creek
Barr Creek
Avondale Creek
Barron
Freshwater Creek
Stratford
CAPTAIN COOK HIGHWAY
STRATFORD PARADE
KAMERUNGA ROAD
AEROGLEN DRIVE

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EC: No data

ID: 45021
pH: No data
EC: No data

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pH: No data
EC: 313 (µS/cm)

ID: 11000070
pH: No data
EC: No data

ID: 11000025
pH: 7.8
EC: 26500 (µS/cm)

ID: 11000156
pH: 7.1
EC: 9650 (µS/cm)

ID: 11000031
pH: 6.7
EC: 17500 (µS/cm)

ID: 139211
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EC: 6000 to 7500 (µS/cm)

ID: 11000030
pH: No Data
EC: No Data

ID: 45028
pH: No data
EC: No data

ID: 45032
pH: 7.2
EC: 295 (µS/cm)

ID: BH4
pH: 6.3 to 6.9
EC: 100 to 300 (µS/cm)

ID: 72350
pH: No Data
EC: No Data

ID: 11000034
pH: 7.1
EC: 700 (µS/cm)

ID: 45042
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EC: No data

ID: 45041
pH: No data
EC: No data

ID: 45457
pH: No data
EC: No data

ID: 11000032
pH: 6.7
EC: 3800 (µS/cm)

ID: 11000029
pH: 6.3 to 7.6
EC: 128 to 1251 (µS/cm)

ID: 11000049
pH: 6.6 to 7.9
EC: 29700 to 31000 (µS/cm)

ID: 11000033
pH: 6.7 to 7.8
EC: 19360 to 37700 (µS/cm)

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EC: No data

ID: 11000053 B
pH: No Data
EC: No Data

ID: 11000053 A
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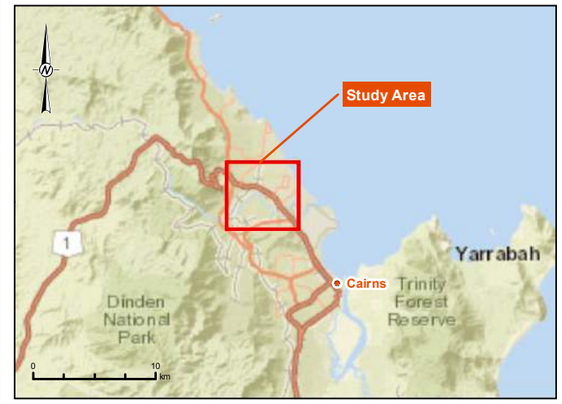
pH: 6.4 to 7.6
EC: 700 to 17500 (µS/cm)

LOCATION MAP



LEGEND

- Localities
- Registered Groundwater Bores
- Roads and Tracks
- Drainage (25k)
- Northern Sands Site

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Kilometres

1:20,000 at A3
PROJECTION: GDA 1994 MGA Zone 55

CLIENT
FLANAGAN CONSULTING GROUP

PROJECT
CAIRNS SHIPPING DEVELOPMENT EIS

TITLE
GROUNDWATER QUALITY AT REGISTERED BORES

CONSULTANT
Golder Associates

YYYY-MM-DD	2016-09-19
PREPARED	DP
DESIGNED	DP
REVIEWED	SF
APPROVED	SF

PROJECT NO.	CONTROL	REV.	FIGURE
1546223	012	4	6

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: A3

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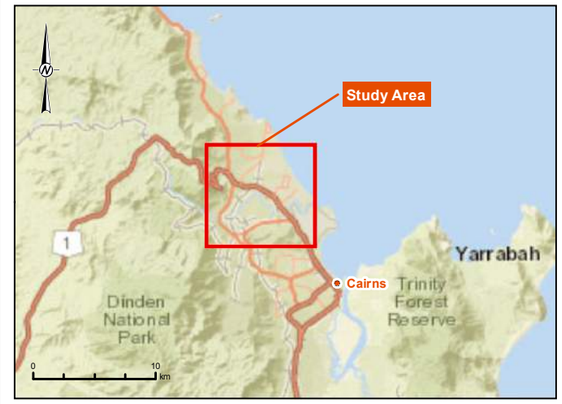
360,000
362,000
364,000
366,000
8,138,000
8,136,000
8,134,000
8,132,000

Yorkeys Knob
Barr Creek
Avondale Creek
Machans Beach
Lake Placid
Stratford
Redlynch
KENNEDY HIGHWAY
KAMERUNGA ROAD
STRATFORD PARADE
AEROGLEN DRIVE
CAPTAIN COOK HIGHWAY
REDLYNCH BYPASS ROAD

LOCATION MAP



LEGEND

- Localities
- Roads and Tracks
- Drainage (25k)
- Northern Sands Site

Groundwater Dependent Ecosystems (GDE)

GDE Reliant on Surface Expression of Groundwater (rivers, springs, wetlands)

- High potential for GW interaction
- Moderate potential for GW interaction
- Low potential for GW interaction

GDE Reliant on Subsurface Groundwater Vegetation

- High potential for GW interaction
- Moderate potential for GW interaction
- Low potential for GW interaction

0 1 2
Kilometres
1:30,000 at A3
PROJECTION: GDA 1994 MGA Zone 55

CLIENT
FLANAGAN CONSULTING GROUP

PROJECT
CAIRNS SHIPPING DEVELOPMENT EIS

TITLE
GROUNDWATER DEPENDENT ECOSYSTEMS: NORTHERN SANDS

CONSULTANT
Golder Associates

YYYY-MM-DD	2016-09-19
PREPARED	DP
DESIGNED	DP
REVIEWED	DS
APPROVED	DS

PROJECT NO.	CONTROL	REV.	FIGURE
1546223	012	4	7

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: A3
25mm
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11000156
11000030
139211
11000025
11000031
Booster #3 Booster #3
AH1 AH2 AH3 AH4 AH5 AH6 AH7 AH8 AH9 AH10
GeoNorth_CPT11 GeoNorth_CPT10 GeoNorth_CPT12 GeoNorth_CPT13 GeoNorth_CPT14
GeoNorth_CPT8 GeoNorth_CPT9 GeoNorth_CPT7 GeoNorth_CPT6 GeoNorth_CPT5 GeoNorth_CPT4 GeoNorth_CPT3 GeoNorth_CPT2 GeoNorth_CPT1
CAPTAIN COOK HIGHWAY
WISTARIA STREET
HOLLOWAY BEACH ROAD
UG2A UG2 UG2A
BH10 CPT21 BH01 BH01 BH09 CPT20 BH04 CPT7 CPT8 CPT23 CPT10 CPT9 BH11 CPT22 BH02 CPT14 BH4a BH05 CPT15 BH08 CPT28 CPT5 UG1 CPT6 CPT16 BH4 BH06 CPT19 CPT3 CPT18 CPT13 BH12 BH07 BH03 CPT2 CPT17 CPT24 CPT1 CPT4 CPT12 BH16 CPT25
BH18 11000049 GA04 BH19 BH17 BH15 CPT11 BH13 NS9 CPT29 BH21 BH20 BH5 NS10 BH14 BH5a NS7 NS3 NS1 CPT30 BH02 NS5 NS6 NS4 NS2 NS8 GA05 Lake
11000032 CPT1 Booster #3 CPT2
11000033 MACHANS BEACH ROAD CPT3 CPT4 CPT5 CPT6
BH2 BH3 BH03 CPT26 CPT27
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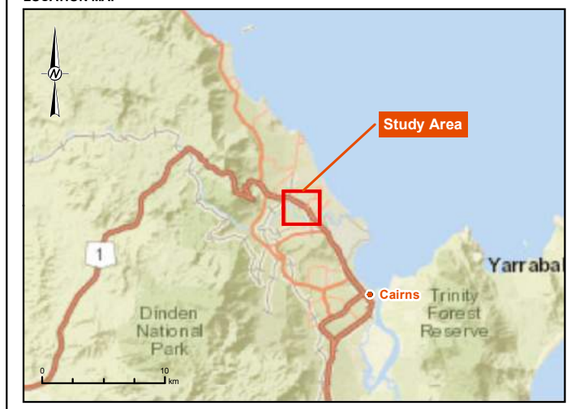
72350
Barron River River



LEGEND

- Localities
- Sections
- Roads and Tracks
- Watercourses (25k)

Investigation Locations

- GW Monitoring Bore
- Probin Boreholes
- GEO Investigate
- Well Locations

Pipeline Route Options

Inbound Yorkeys

- Booster Locations

Inbound Aquis

- Booster Locations

Inbound Machans Beach

- Booster Locations

Inbound Aquis - No Marine Booster

- Inbound Pipeline
- Inbound Pipeline
- Inbound Pipeline
- Inbound Pipeline

- Northern Sands Placement Area
- Pit Expansion Area

0 0.25 0.5
Kilometres
1:10,000 at A3
PROJECTION: GDA 1994 MGA Zone 55

CLIENT
FLANAGAN CONSULTING GROUP

PROJECT
CAIRNS SHIPPING DEVELOPMENT EIS

TITLE
INVESTIGATION AND WELL LOCATIONS

CONSULTANT
Golder Associates

YYYY-MM-DD	2017-01-23
PREPARED	DP
DESIGNED	DP
REVIEWED	DS
APPROVED	DS

PROJECT NO.	CONTROL	REV.	FIGURE
1546223	012	4	8

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0 25mm

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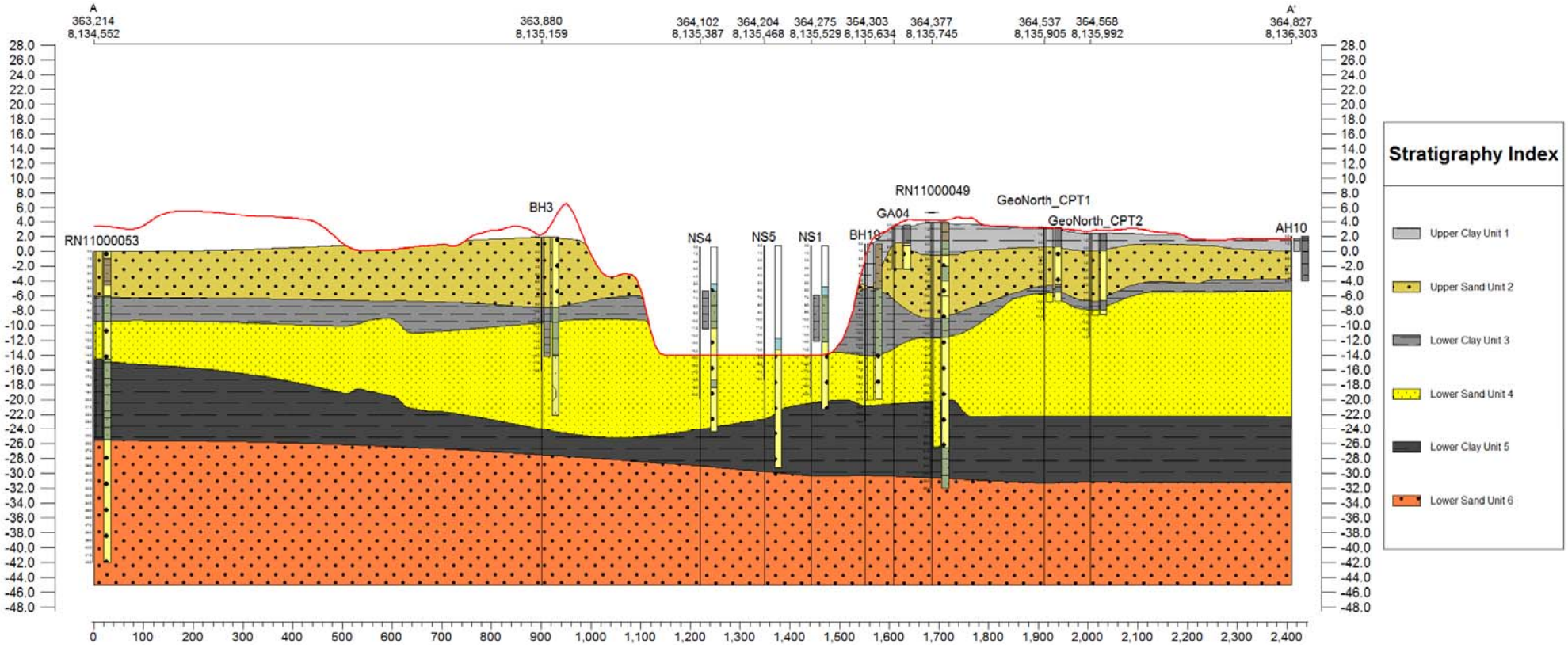
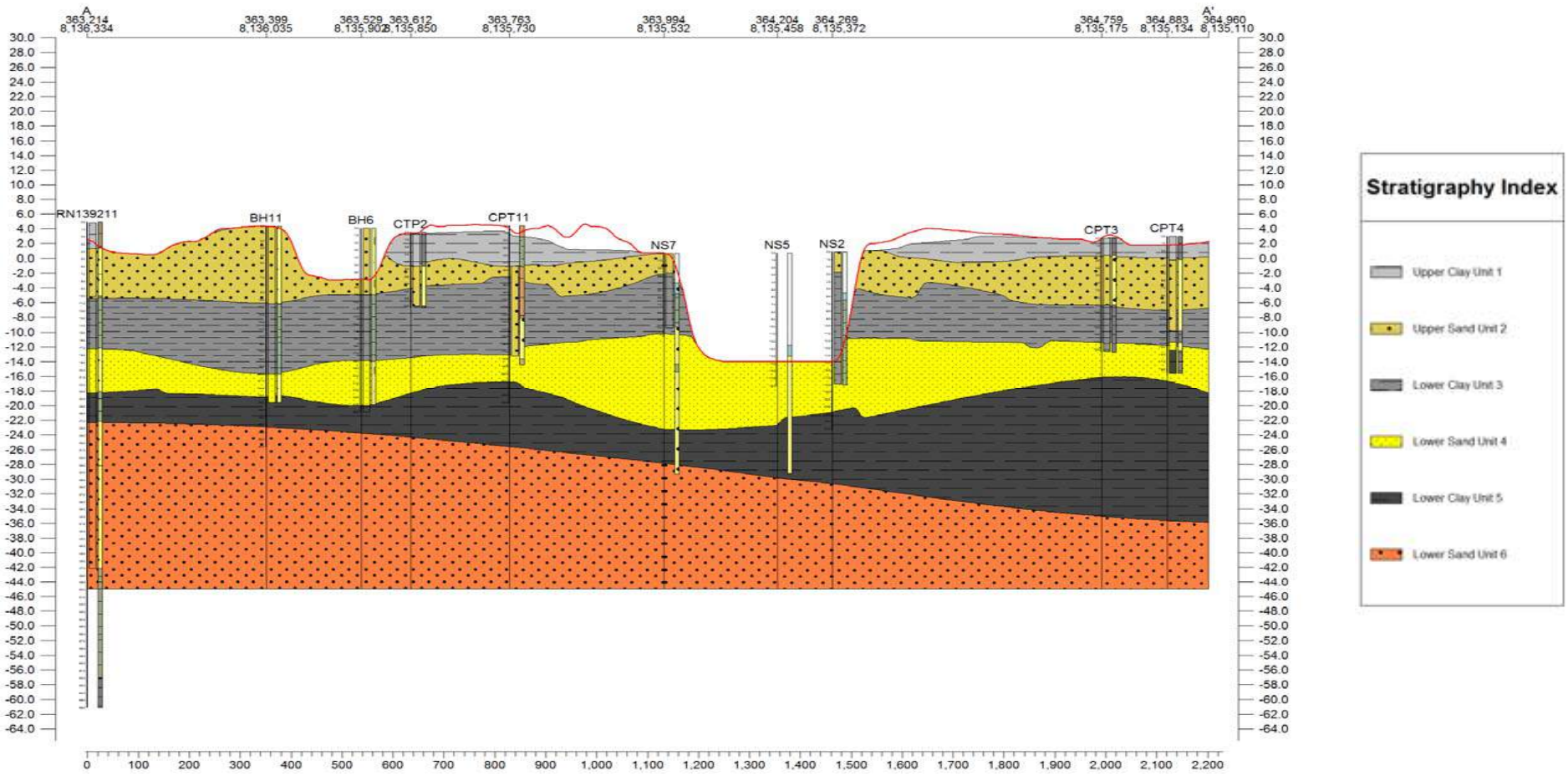


CLIENT: Flanagan Consulting Group		PROJECT: Cairns Shipping Development EIS	
DRAWN: JL	DATE: 1512/2016	SW-NE Inferred Geological Section 1	
CHECKED: MSC	DATE: 15/12/2016		
SCALE: A4		PROJECT No. 1546223-013	FIGURE No. 9

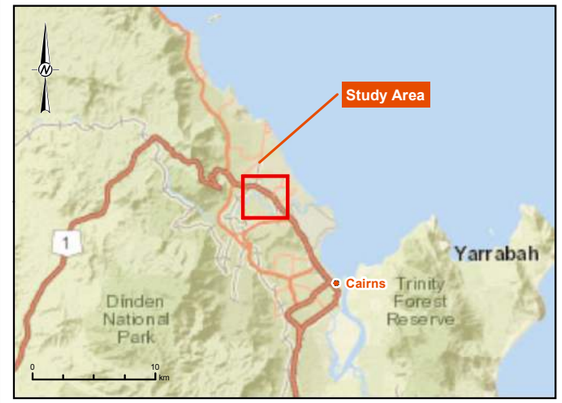
\\golder.gds\GAP\Cairns\Jobs\Geo\2015\1546223 - FCG - EIS Stage 1 - Port Development\CORR OUT\Stage 1B Hydrogeology Assessment\Northern Sands\Report012 Rev3\Figures\Figures\Figure 9\.FIG 9.xlsx.Landscape



Golder Associates	CLIENT: Flanagan Consulting Group		PROJECT: Cairns Shipping Development EIS	
	DRAWN: JL	DATE: 1512/2016	NW-SE Inferred Geological section	
	CHECKED: MSC	DATE: 15/12/2016	Section 2	
	SCALE: A4		PROJECT No.: 1546223-013	FIGURE No.: 10

\\golder.gds\GAP\Cairns\Jobs\Geo\2015\1546223 - FCG - EIS Stage 1 - Port Development\CORR OUT\Stage 1B Hydrogeology Assessment\Northern Sands\Report012 Rev3\Figures\Figures\Figure 10\FIG 10.xlsx Landscape

LOCATION MAP



LEGEND

- Localities
- Registered Groundwater Bores
- Roads and Tracks
- Drainage (25k)
- Northern Sands Site

0 0.25 0.5
Kilometres

1:12,500 at A3
PROJECTION: GDA 1994 MGA Zone 55

CLIENT
FLANAGAN CONSULTING GROUP

PROJECT
CAIRNS SHIPPING DEVELOPMENT EIS

TITLE
MONITORING BORES IN THE VICINITY OF NORTHERN SANDS SITE

CONSULTANT
Golder Associates

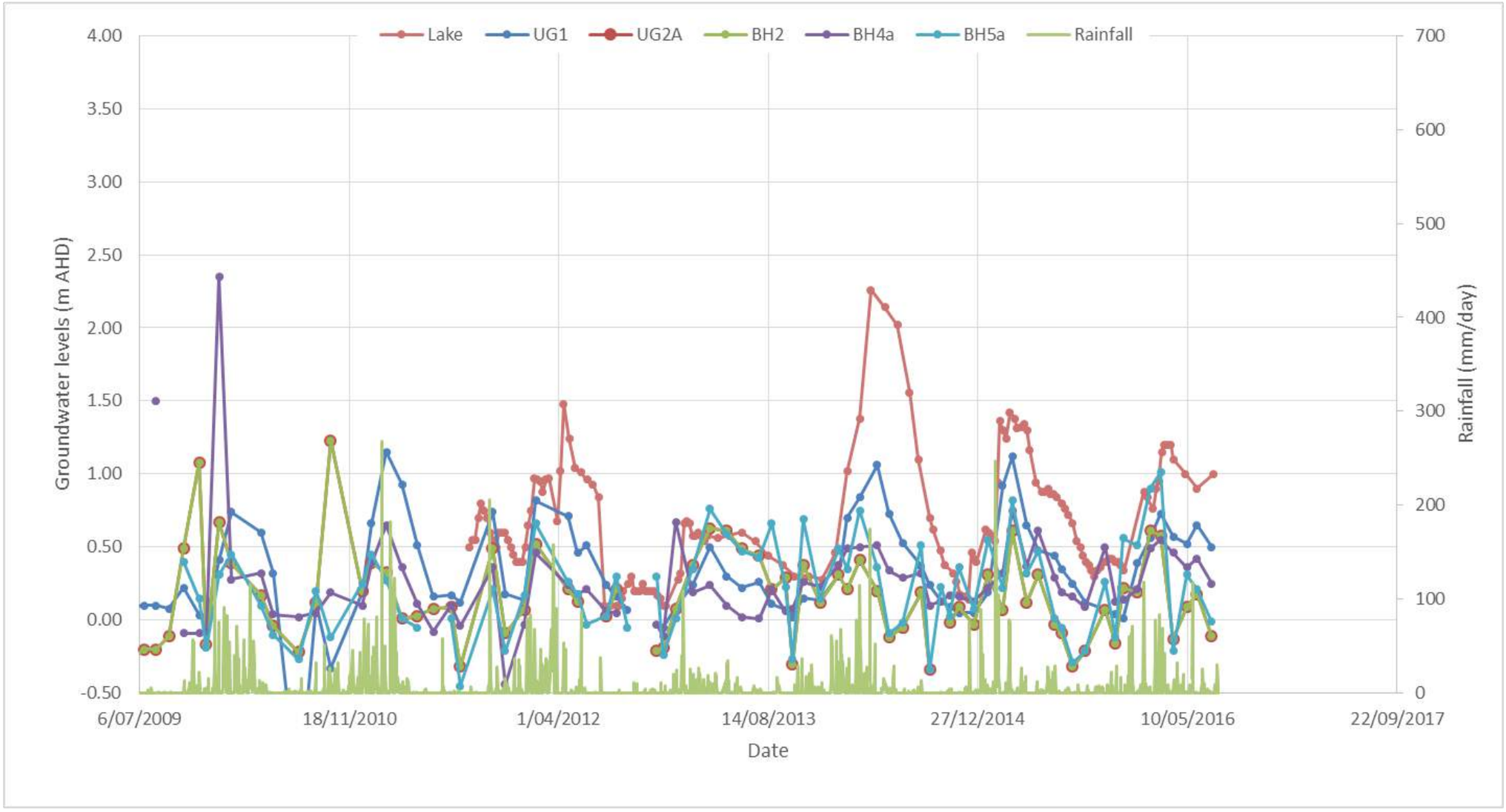
YYYY-MM-DD	2017-01-20
PREPARED	DP
DESIGNED	DP
REVIEWED	DS
APPROVED	DS

PROJECT NO.	CONTROL	REV.	FIGURE
1546223	012	4	11

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: A3

25mm

Path: \\golder.gds\GAP\Cairns\Jobs\Geo\2015\1546223 - FCG - EIS Stage 1 - Port Development\GIS\MXD\Hydro_Assessment\1546223-012-R-Rev1_F011_Nth_Sands_Vicinity_WLAHD.mxd



Golder Associates	CLIENT: Flanagan Consulting Group		PROJECT: Cairns Shipping Development EIS	
	DRAWN: JL	DATE: 19/9/16	TITLE: Hydrographs for Monitoring Bores at the Northern Sands Site	
	CHECKED: SRF	DATE: 19/9/16		
	SCALE	SHEET SIZE: A4	PROJECT No: 1546223-012	REVISION: 4 / FIGURE No: FIGURE 12

362,000 362,500 363,000 363,500 364,000 364,500 365,000 365,500

8,137,000 8,136,500 8,136,000 8,135,500 8,135,000 8,134,500

ID: 11000070
pH: No data
EC: No data

ID: 11000025
pH: 7.8
EC: 26500 (µS/cm)

ID: 109374
pH: No data
EC: No data

ID: 11000156
pH: 7.1
EC: 9650 (µS/cm)

ID: 11000031
pH: 6.7
EC: 17500 (µS/cm)

CAPTAIN COOK HIGHWAY

ID: 11000030
pH: No Data
EC: No Data

ID: 45032
pH: 7.2
EC: 295 (µS/cm)

ID: UG2A
pH: No Data
EC: No Data

ID: BH01
pH: 6.8 to 7.0
EC: 230 to 250 (µS/cm)

ID: GA04
pH: 6.5
EC: 160 (µS/cm)

ID: 11000049
pH: 6.6 to 7.9
EC: 29700 to 31000 (µS/cm)

ID: BH4a
pH: 6.3 to 6.9
EC: 100 to 300 (µS/cm)

ID: UG1
pH: No Data
EC: No Data

Barron River

ID: 11000032
pH: 6.7
EC: 3800 (µS/cm)

ID: 45043
pH: No data
EC: No data

ID: BH5a
pH: 6.5 to 2.4
EC: 1000 to 5500 (µS/cm)

ID: 11000033
pH: 6.7 to 7.8
EC: 19360 to 37700 (µS/cm)

ID: BH02
pH: 7.7 to 7.9
EC: 9300 to 11000 (µS/cm)

ID: BH2
pH: 6.6 to 7.6
EC: 100 to 1900 (µS/cm)

ID: BH3
pH: 5.9 to 7.5
EC: 500 to 19000 (µS/cm)

ID: BH03
pH: 7.9
EC: 24000 (µS/cm)

Barron

ID: 11000053 A
pH: 6.3 to 7.5
EC: 360 to 4190 (µS/cm)

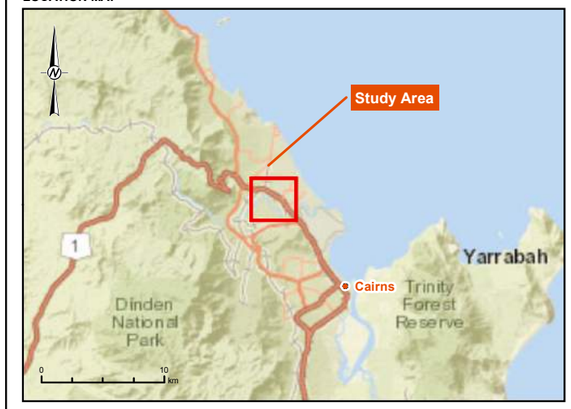
ID: 11000053 B
pH: No Data
EC: No Data

ID: 11000039
pH: 6.4 to 7.6
EC: 700 to 17500 (µS/cm)

362,000 362,500 363,000 363,500 364,000 364,500 365,000 365,500

Path: \\golder.gds\GAP\Cairns\Jobs\Geo\2015\1546223 - FCG - EIS Stage 1 - Port Development\GIS\MXD\Hydro_Assessment\1546223-012-R-Rev1_F013_Nth_Sands_Vicinity_Conductivity.mxd

LOCATION MAP



LEGEND

- Localities
- Registered Groundwater Bores
- Roads and Tracks
- Drainage (25k)
- Northern Sands Site

0 0.25 0.5
Kilometres
1:12,500 at A3
PROJECTION: GDA 1994 MGA Zone 55

CLIENT
FLANAGAN CONSULTING GROUP

PROJECT
CAIRNS SHIPPING DEVELOPMENT EIS

TITLE
GROUNDWATER QUALITY IN VICINITY OF NORTHERN SANDS SITE

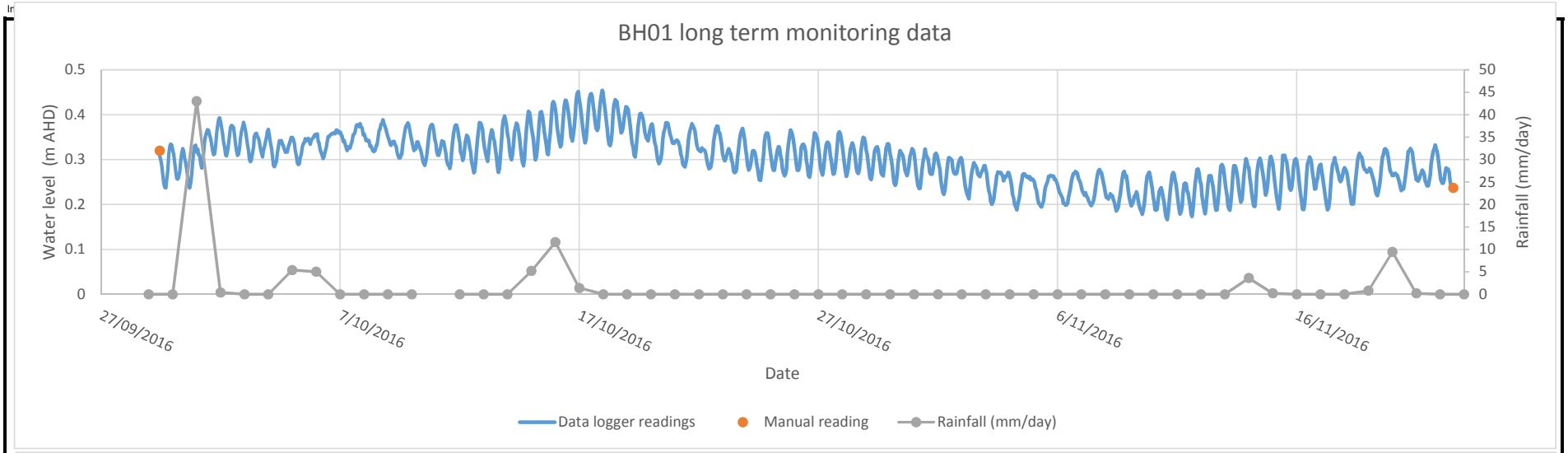
CONSULTANT
Golder Associates

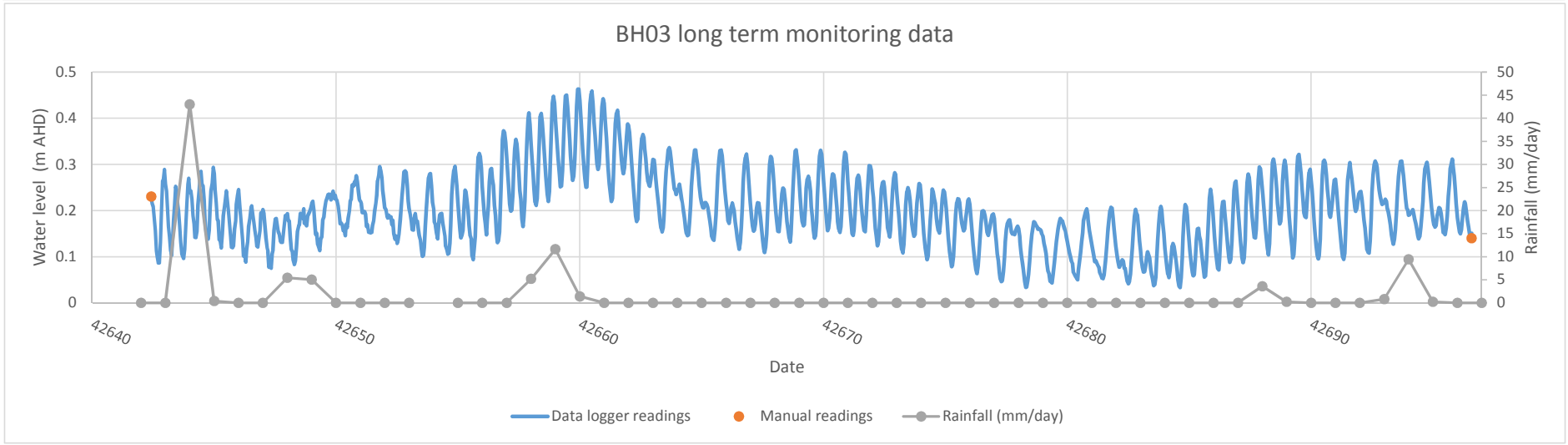
YYYY-MM-DD	2017-01-20
PREPARED	DP
DESIGNED	DP
REVIEWED	SF
APPROVED	SF

PROJECT NO.	CONTROL	REV.	FIGURE
1546223	012	4	13

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: A3

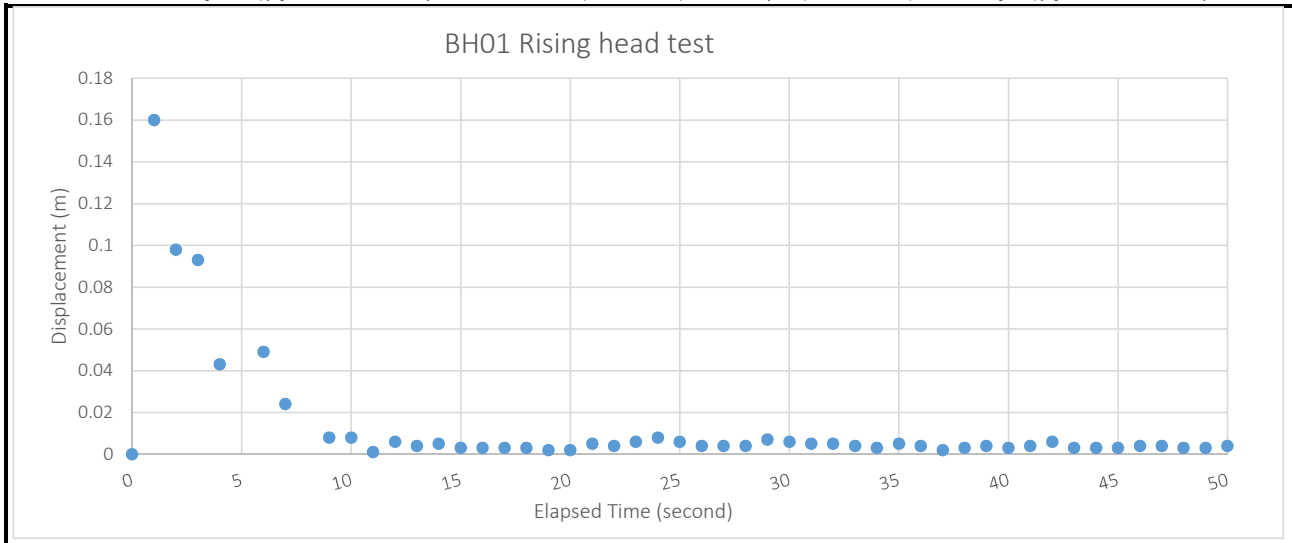
0 25mm



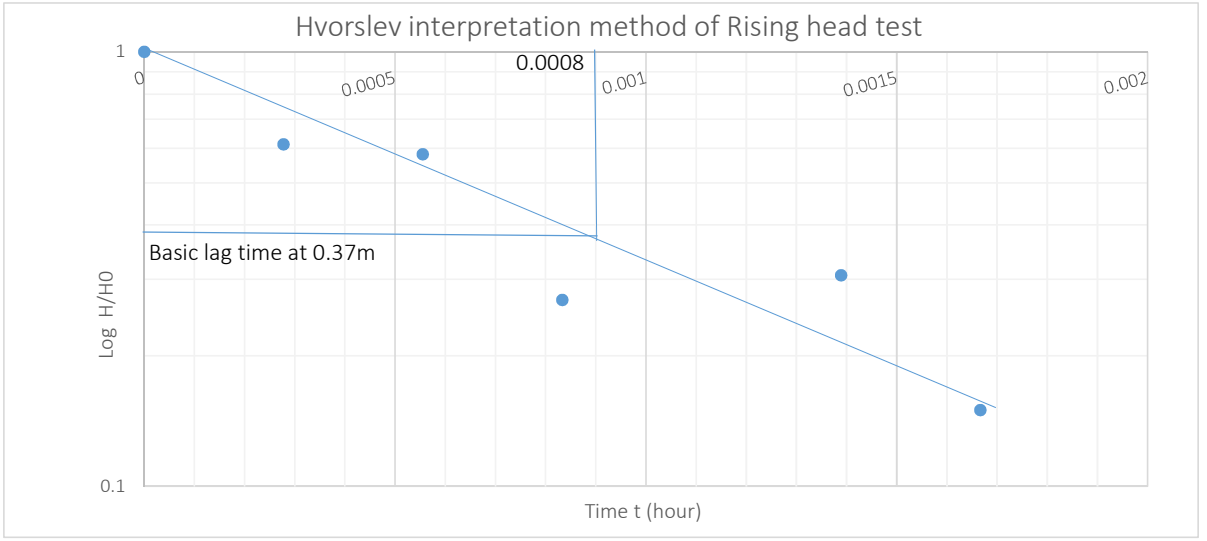


Golder Associates	CLIENT: Flanagan Consulting Group	PROJECT: **Cairns Shipping Development EIS**	
	DRAWN: JL DATE: 15/12/2016	**BH01 and BH02 long term Water level monitoring**	
	CHECKED: MSC DATE: 15/12/2016		
	SCALE:	PROJECT No.: 1546223-014	FIGURE No.: **14** A4

C:\Users\mcook\Documents\AA PN Dredge Spoil Disposal\Groundwater Report\Figures\F015 SWL BH02.xlsx Landscape

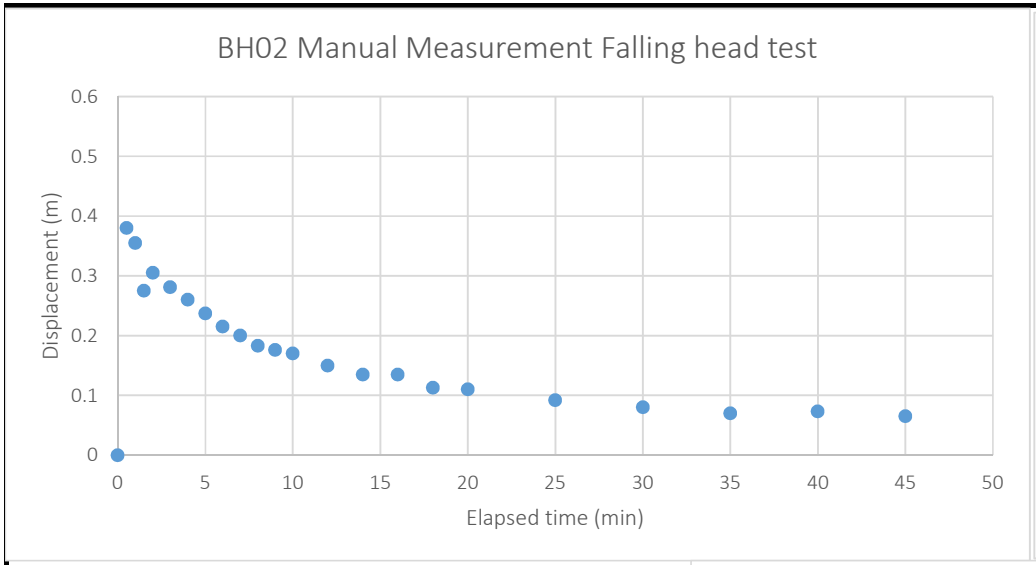


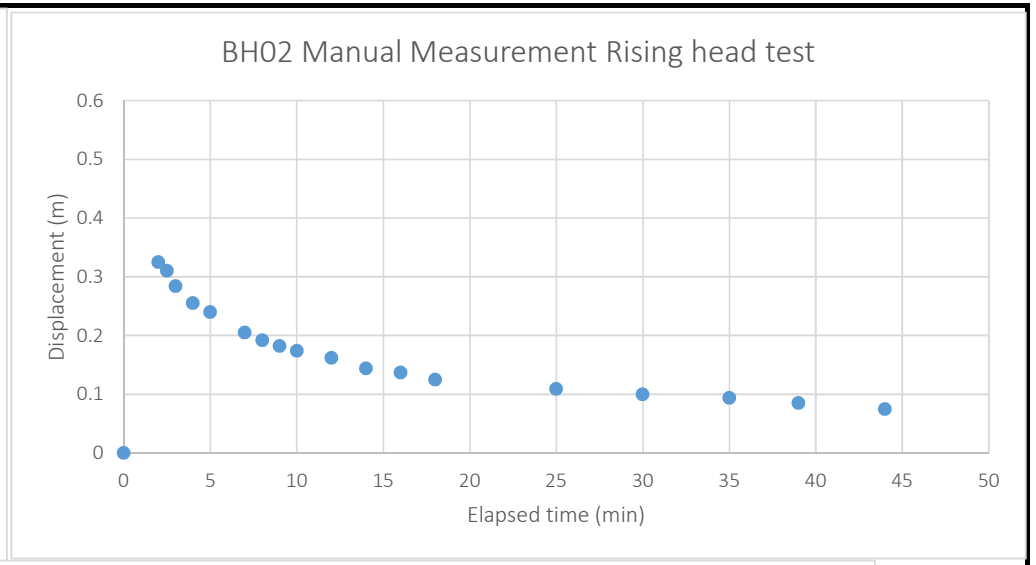
r^2 (m)	0.000625
A (m^2)	0.0019625
T (hour)	0.0008
F (Shape factor)	3.935254829
k (m/hour)	0.623371321
k (m/s)	**1.73E-04**



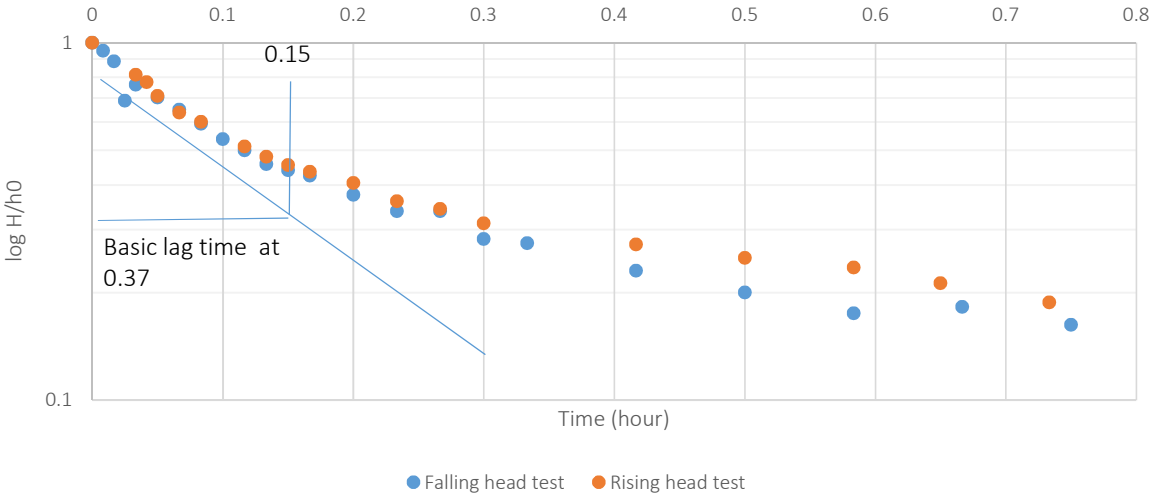
CLIENT	Flanagan Consulting Group	PROJECT	**Cairns Shipping Development EIS**
DRAWN	JL	DATE: 1512/2016	**BH01 Slug test analysis using Hvorslev method**
CHECKED	SRF	DATE: 15/12/2016	
SCALE:	A4	PROJECT No. 1546223-013	FIGURE No. **15**

\\golder.gds\GAP\Cairns\Jobs\Geo\2015\1546223 - FCG - EIS Stage 1 - Port Development\CORR OUT\Stage 1B Hydrogeology Assessment\Northern Sands\Report012 Rev3\Figures\Figures\.Figure 20 location of 2 crossections.xlsx.Landscape

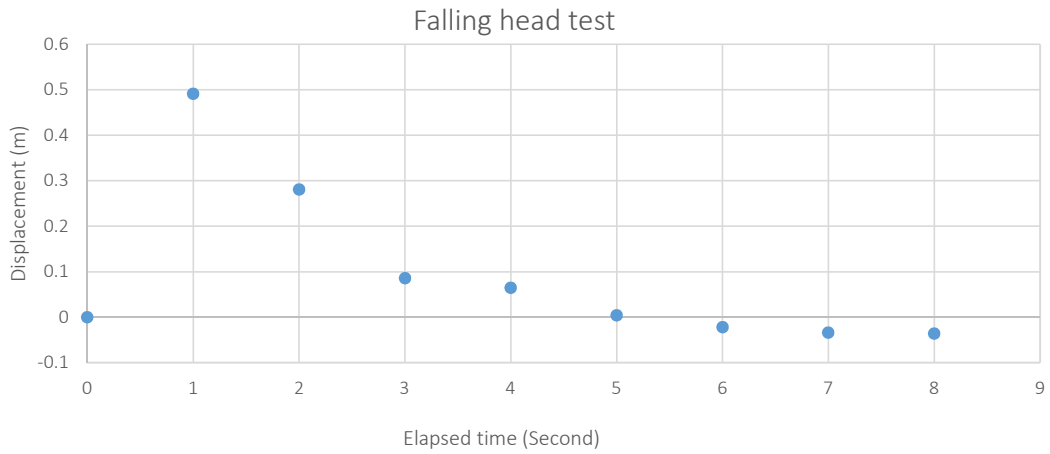




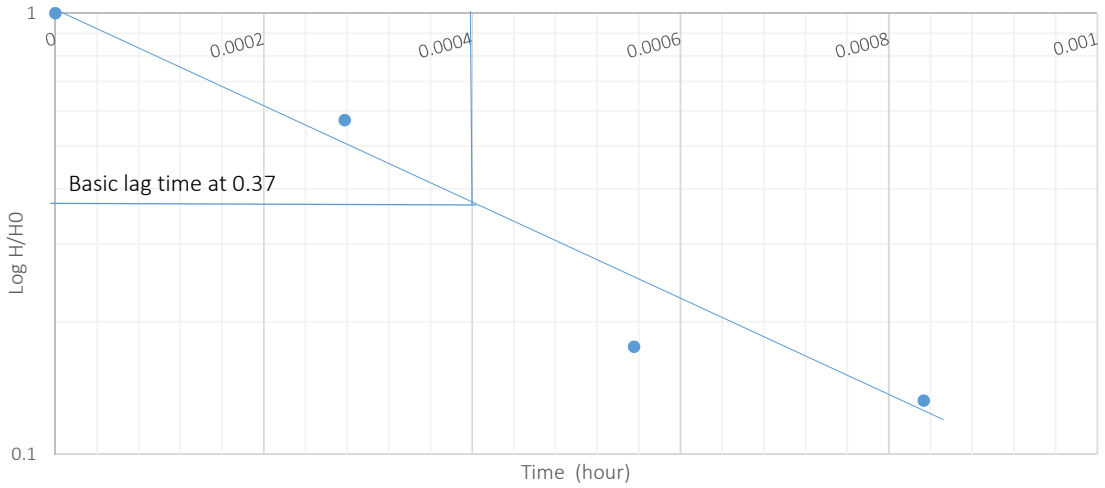
r^2 (m)	0.000625
A (m^2)	0.0019625
T (Hours)	0.15
F (shape factor)	3.9352548
k (m/hour)	0.0033246
k (m/s)	**9.235E-07**



CLIENT	Flanagan Consulting Group	PROJECT	**Cairns Shipping Development EIS**
DRAWN	JL	DATE: 1512/2016	**BH02 Slug test analysis using Hvorslev method**
CHECKED	SRF	DATE: 15/12/2016	
SCALE:	A4	PROJECT No. 1546223-013	FIGURE No. 16

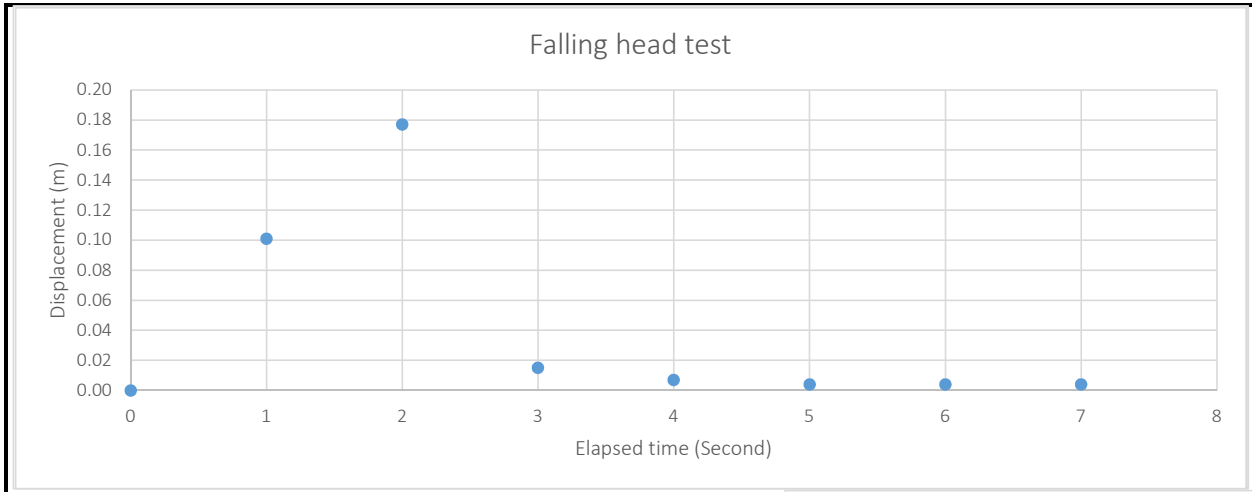


r^2 (m)	0.000625
A (m^2)	0.0019625
T (Hours)	0.0004
F (shape factor)	4.447913896
k (m/hour)	1.103045184
k (m/s)	**3.06E-04**

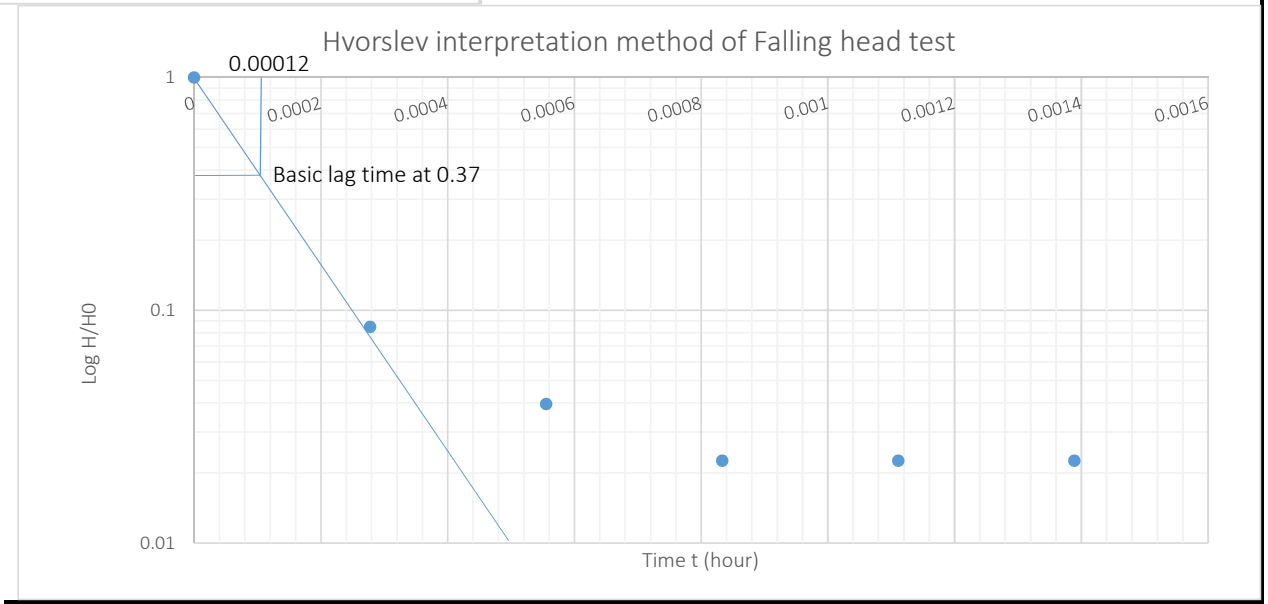


CLIENT	Flanagan Consulting Group	PROJECT	Cairns Shipping Development EIS
DRAWN	JL	DATE: 1512/2016	BH03 Slug test analysis using Hvorslev method
CHECKED	SRF	DATE: 15/12/2016	
SCALE:	A4	PROJECT No. 1546223-013	FIGURE No. 17

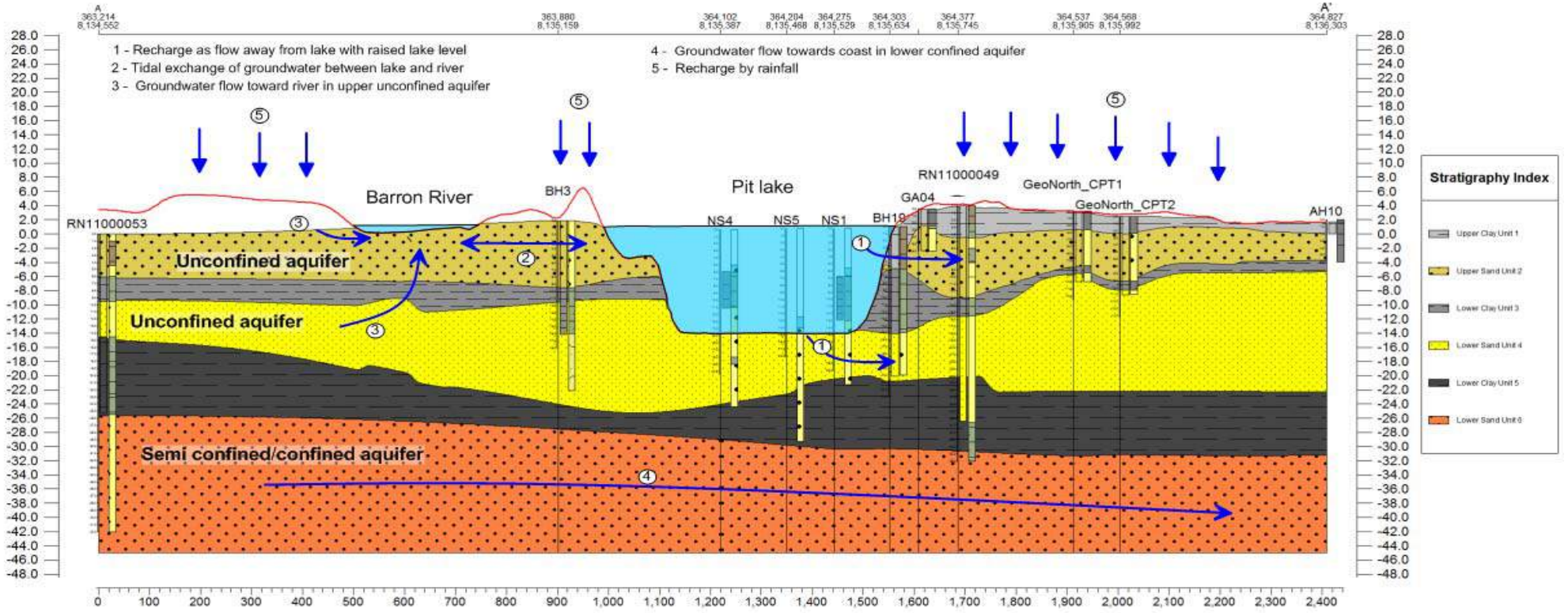
\\golder.gds\GAP\Cairns\Jobs\Geo\2015\1546223 - FCG - EIS Stage 1 - Port Development\CORR OUT\Stage 1B Hydrogeology Assessment\Northern Sands\Report012 Rev3\Figures\Figures\.Figure 20 location of 2 crossections.xlsx.Landscape



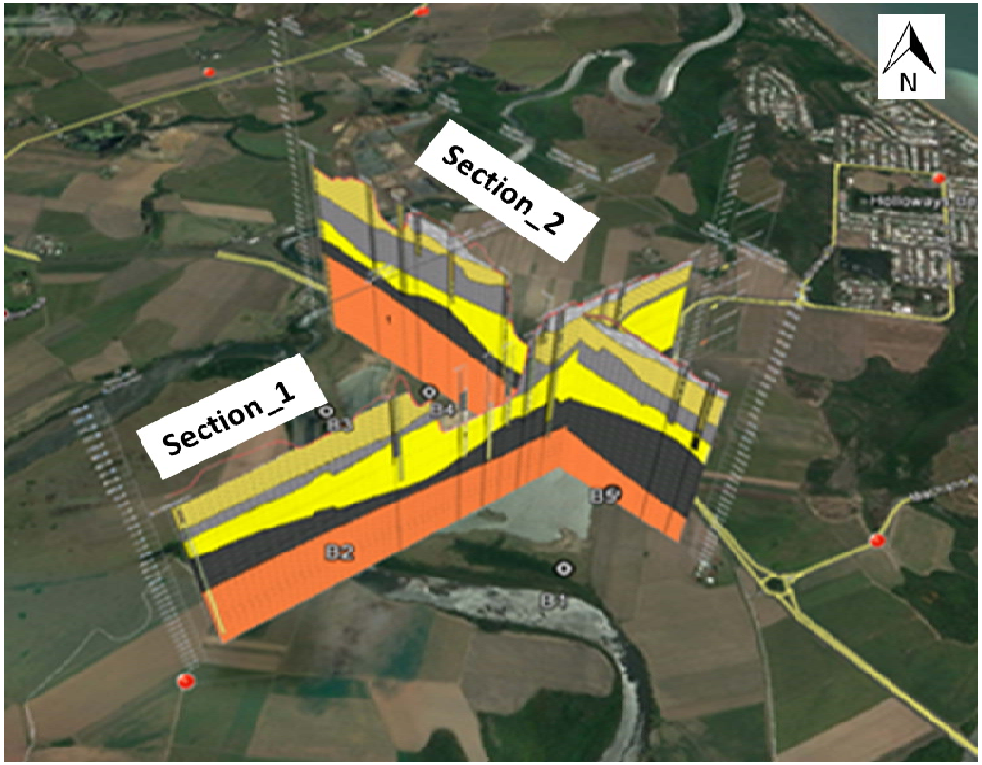
r^2 (m)	0.000625
A (m^2)	0.0019625
T (Hours)	0.00012
F (Shape factor)	2.866253687
k (m/hour)	5.705763847
k (m/s)	**1.58E-03**



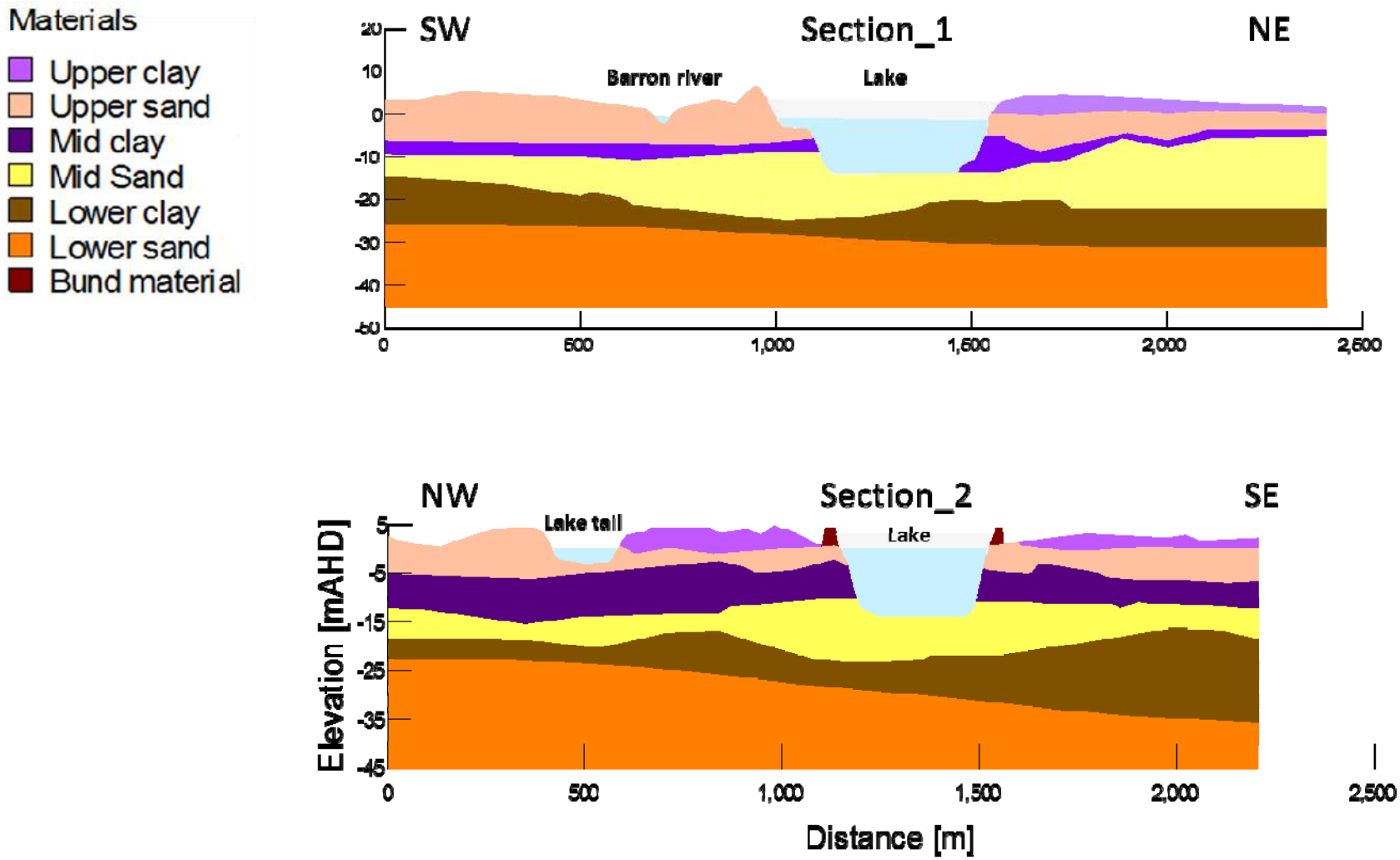
CLIENT	Flanagan Consulting Group	PROJECT	**Cairns Shipping Development EIS**
DRAWN	JL	DATE: 1512/2016	**GA04 Slug test analysis using Hvorslev method**
CHECKED	SRF	DATE: 15/12/2016	
SCALE:	A4	PROJECT No. 1546223-013	FIGURE No. **18**



CLIENT: Flanagan Consulting Group		PROJECT: **Cairns Shipping Development EIS**	
DRAWN: JL	DATE: 18/01/2017	**Conceptual Hydrogeological model**	
CHECKED: SF	DATE: 18/01/2017	**Northern Sands Site**	
SCALE: A4		PROJECT No. 1546223-013	FIGURE No. **19**

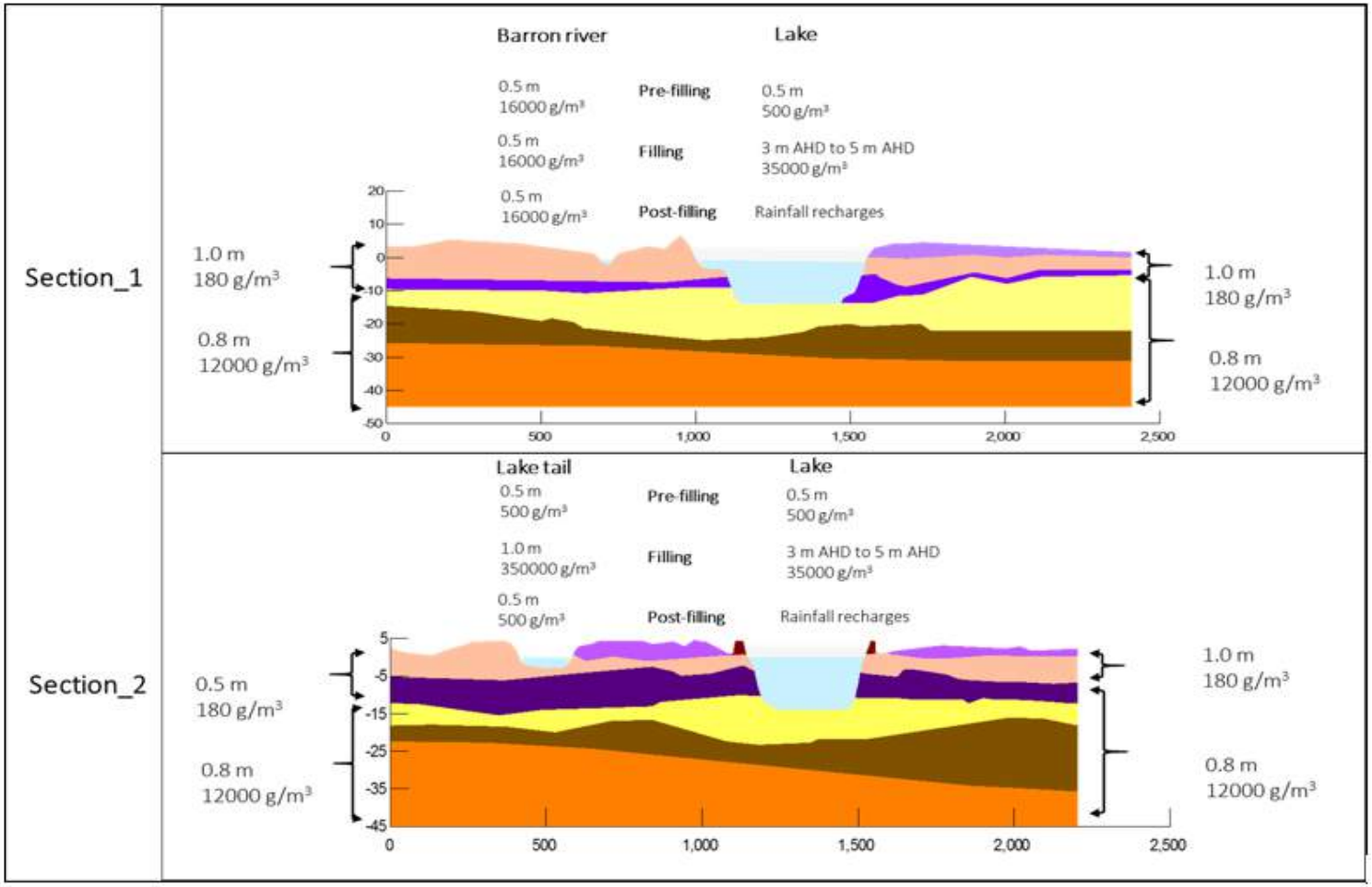


Golder Associates	CLIENT: Flanagan Consulting Group		PROJECT: **Cairns Shipping Development EIS**
	DRAWN: YM	DATE: 1512/2016	**Location of two cross-sectional models**
	CHECKED: DB	DATE: 15/12/2016	
	SCALE: A4		PROJECT No. 1546223-012 / FIGURE No. **FIGURE 20**

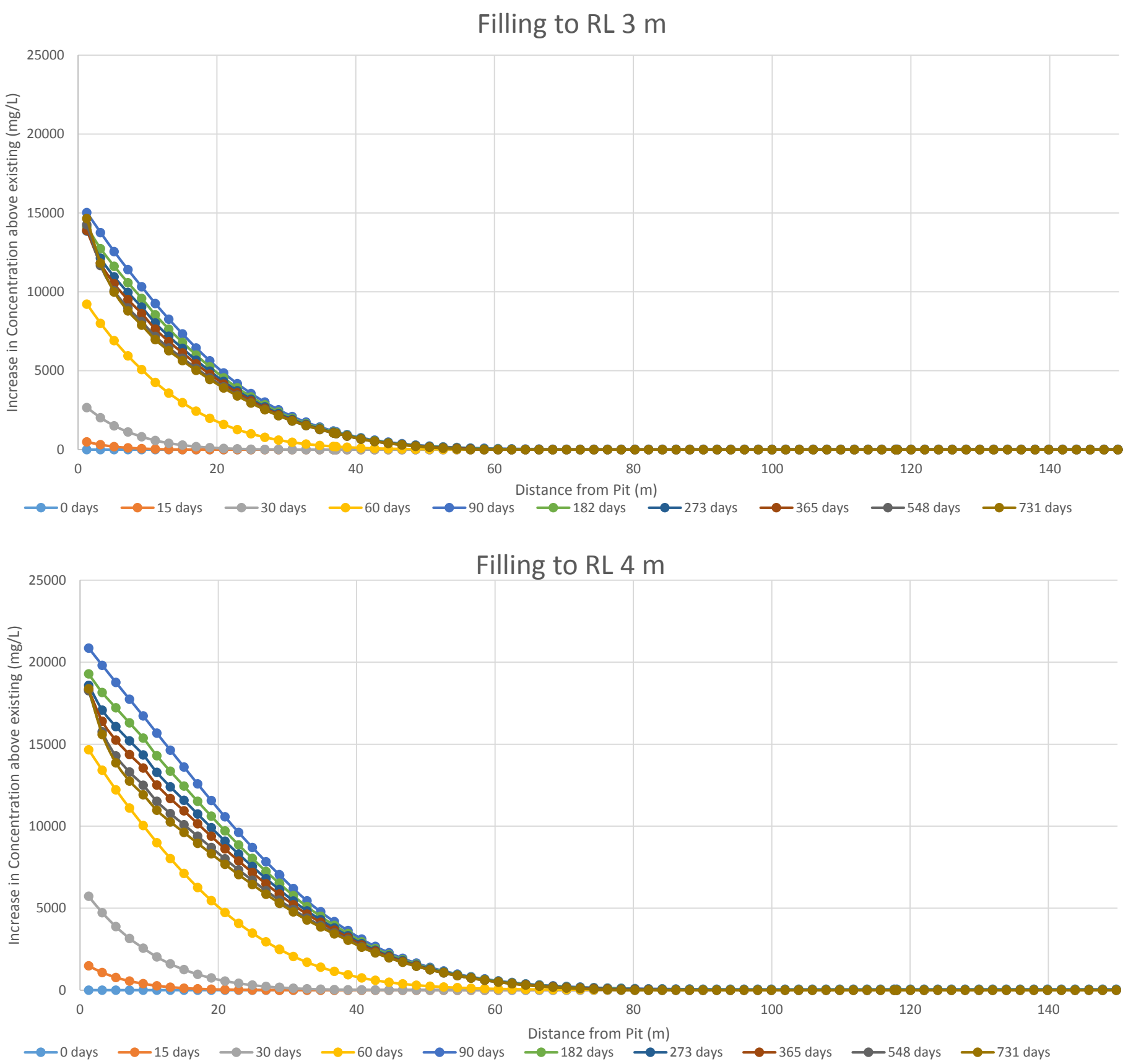


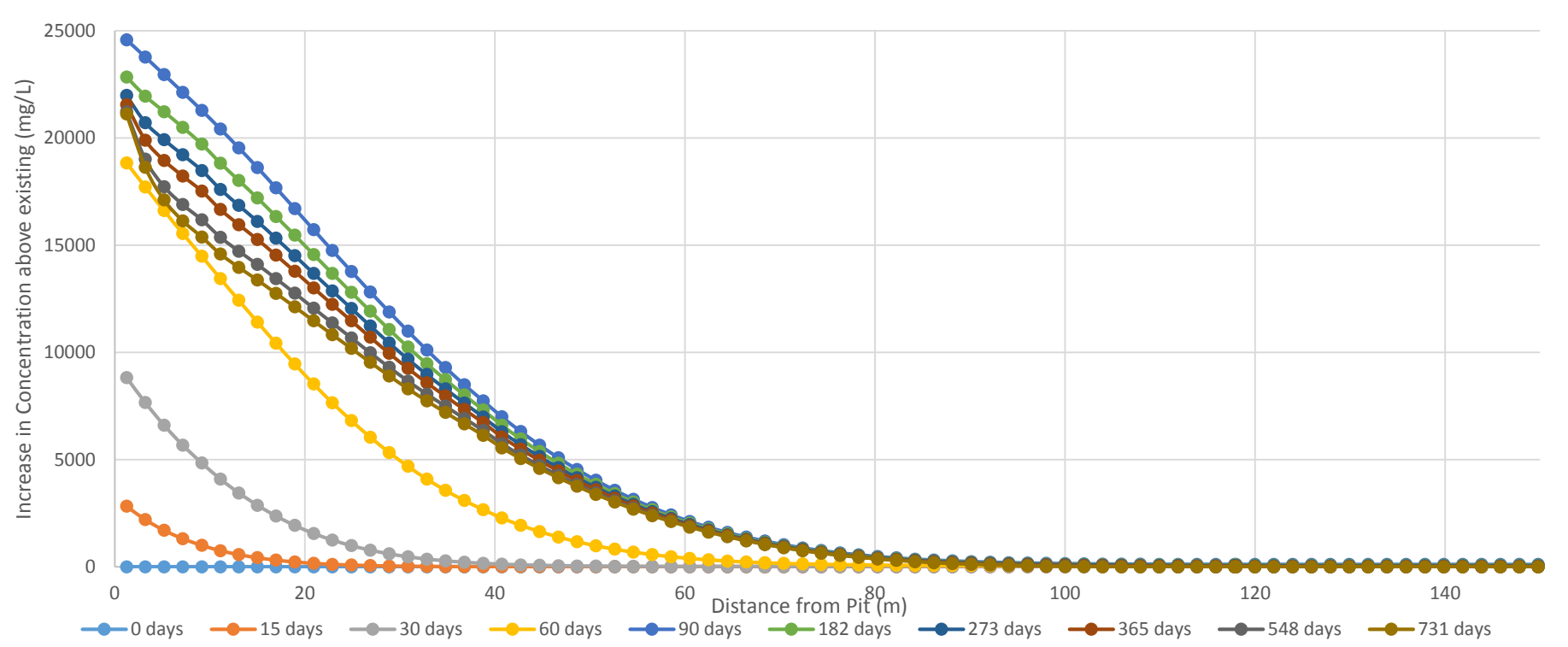
Golder Associates	CLIENT: Flanagan Consulting Group	PROJECT: Cairns Shipping Development EIS	
	DRAWN: YM DATE: 1512/2016	Seep/W cross-sectional models	
	CHECKED: DB DATE: 15/12/2016		
	SCALE: A4	PROJECT No. 1546223-012	FIGURE No. FIGURE 21

\\golder.gds\GAP\Cairns\Jobs\Geo\2015\1546223 - FCG - EIS Stage 1 - Port Development\CORR OUT\Stage 1B Hydrogeology Assessment\Northern Sands\Report012 Rev3\Figures\Figures\Figure 21 seep_W crossection.xlsx:Landscape



Golder Associates	CLIENT: Flanagan Consulting Group	PROJECT: **Cairns Shipping Development EIS**	
	DRAWN: YM DATE: 1512/2016	**Boundary condition of models**	
	CHECKED: DB DATE: 15/12/2016		
	SCALE: A4	PROJECT No. 1546223-012	FIGURE No. **FIGURE 22**

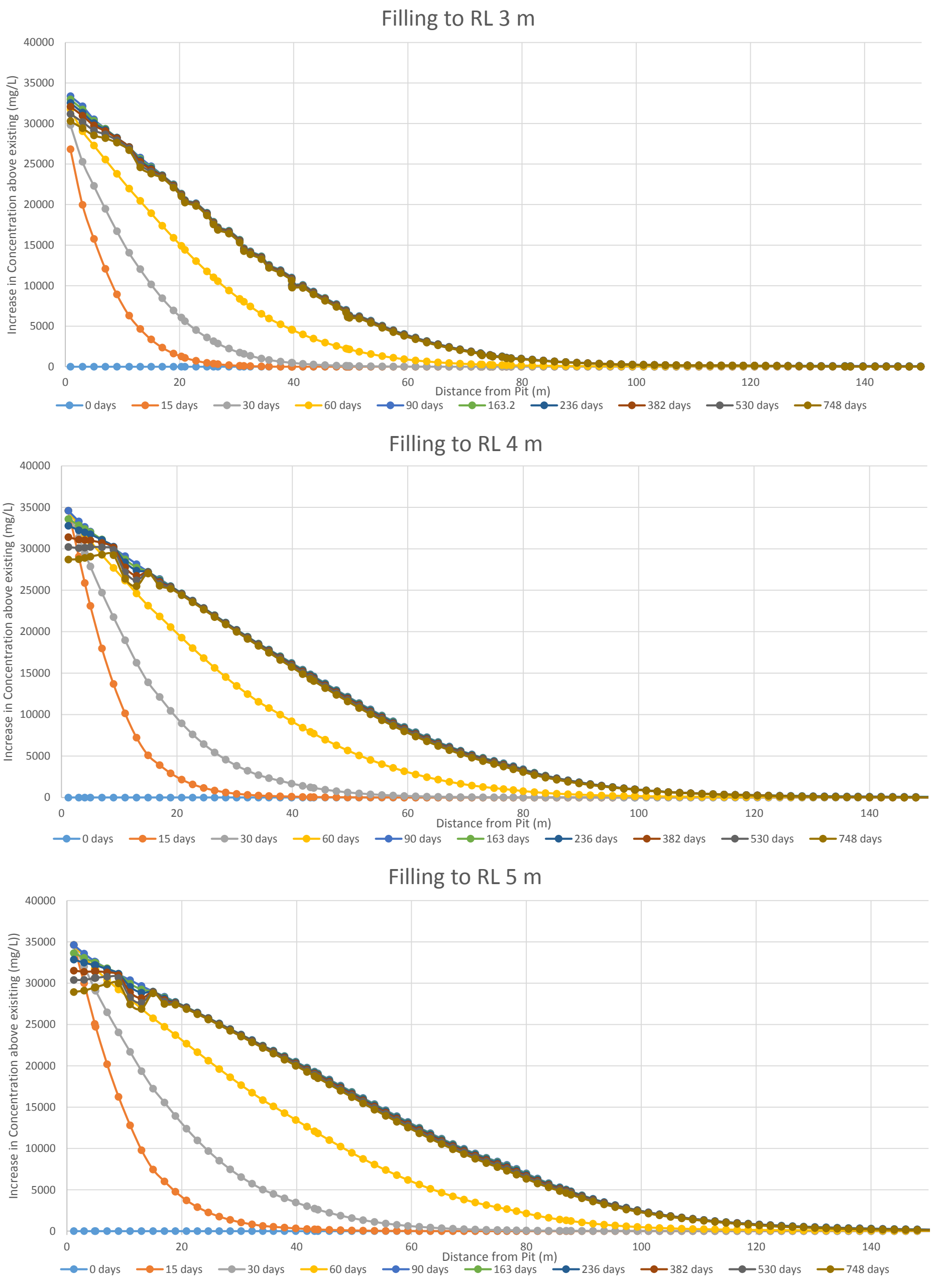




Profiles based on concentrations in the upper sand layer immediately below the upper clay layer

Golder Associates

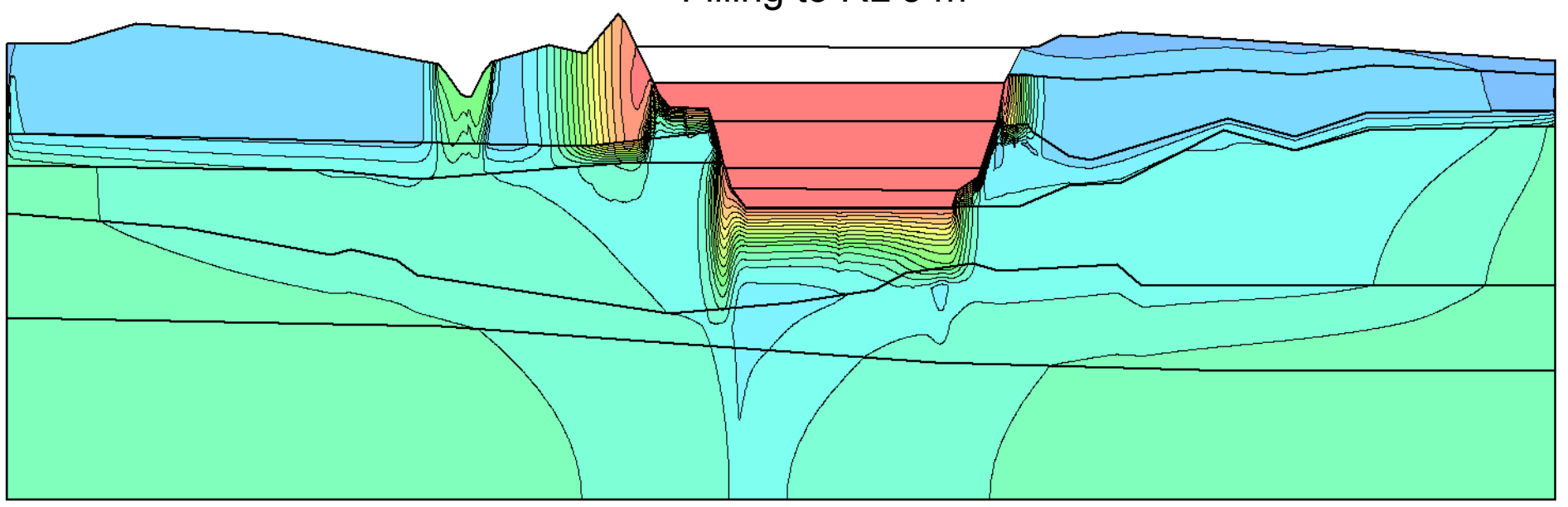
CLIENT	Flanagan Consulting Group	PROJECT	Cairns Shipping Development EIS
DRAWN	SRF	DATE	23/01/17
CHECKED	SRF	DATE	23/01/17
TITLE	**Profiles of increase in concentration with distance from lake – Section 1**		
SCALE	Not to Scale	PROJECT No	1546223-012
FIGURE No	**23**	REV No	**4**
			A3



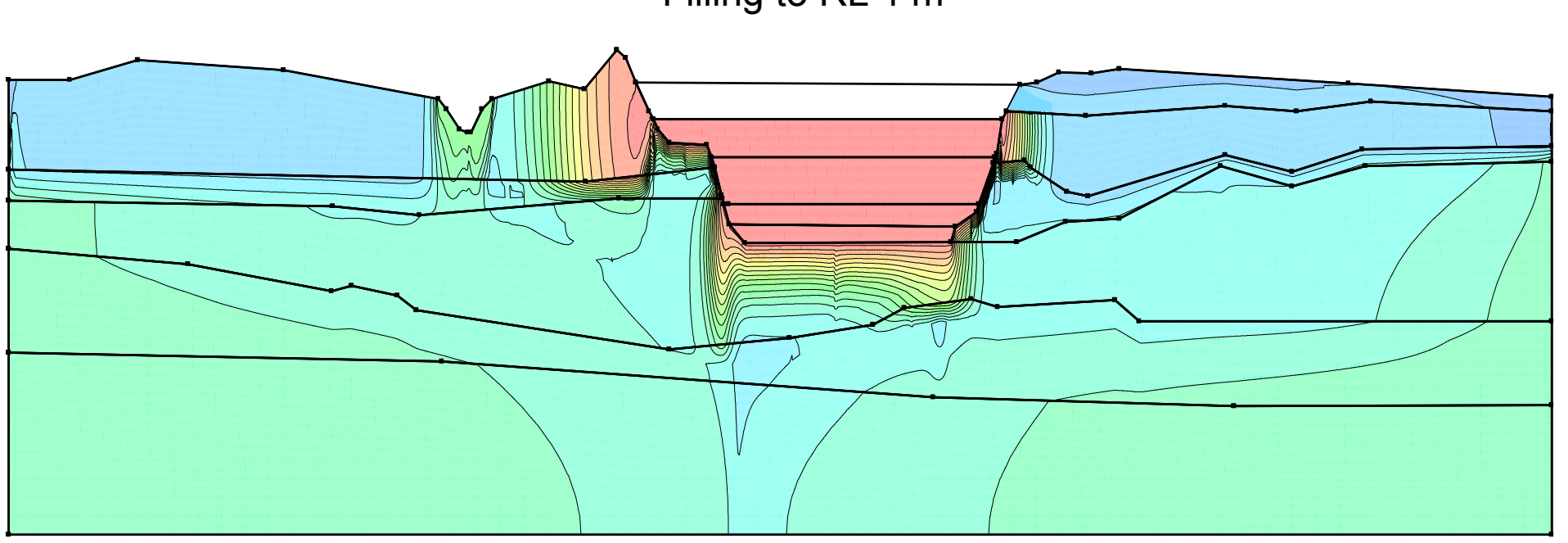
Profiles based on concentrations in the upper sand layer immediately below the upper clay layer

Golder Associates	CLIENT: Flanagan Consulting Group		PROJECT: Cairns Shipping Development EIS
	DRAWN: SRF	DATE: 23/01/17	TITLE: **Profiles of increase in concentration with distance from lake – Section 2**
	CHECKED: SRF	DATE: 23/01/17	
	SCALE: Not to Scale	PROJECT No: 1546223-012	FIGURE No: **23** REV No: **4** **A3**

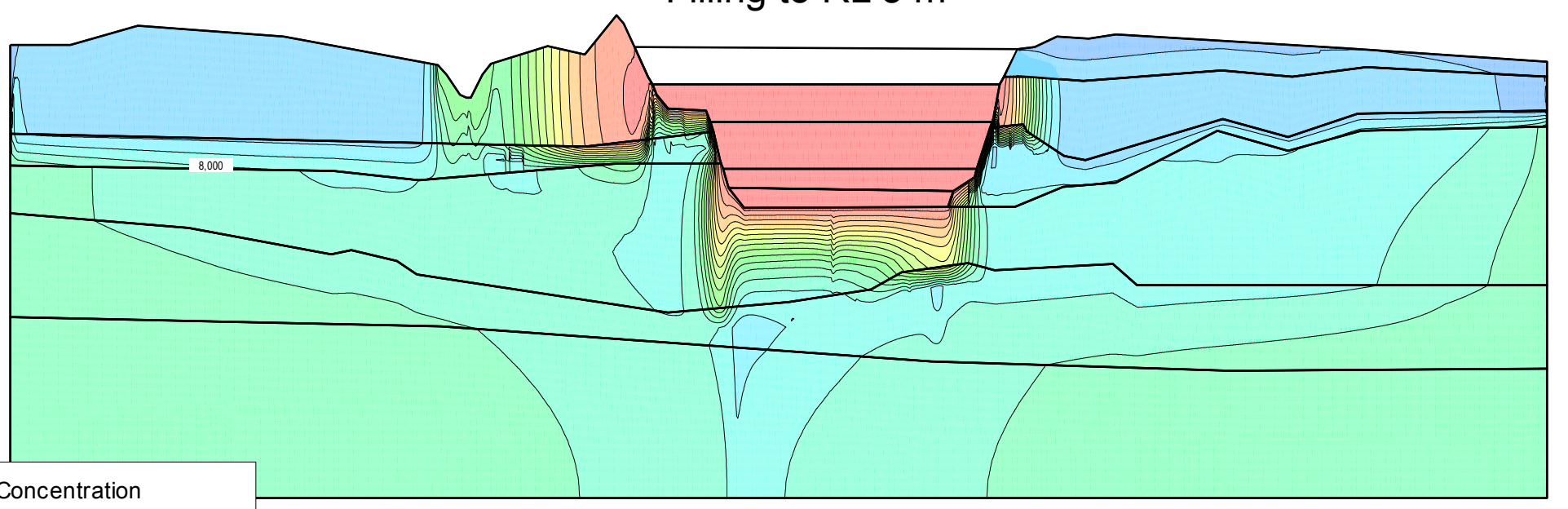
Filling to RL 3 m



Filling to RL 4 m



Filling to RL 5 m



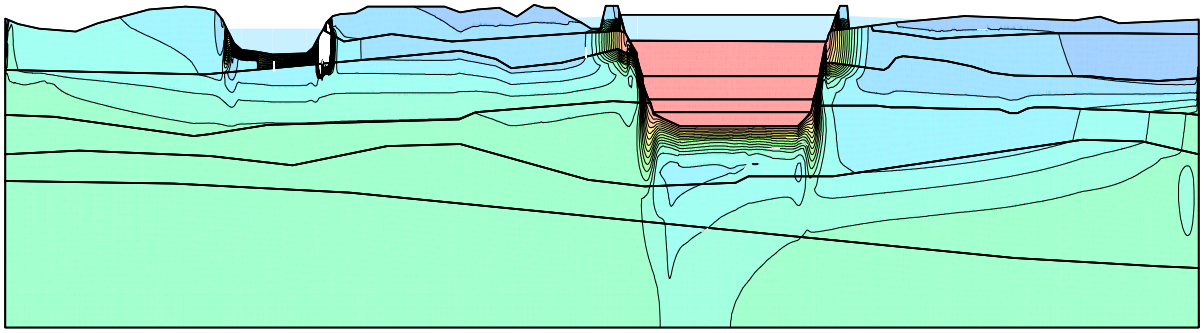
Concentration

- 0 - 2,000 g/m³
- 2,000 - 4,000 g/m³
- 4,000 - 6,000 g/m³
- 6,000 - 8,000 g/m³
- 8,000 - 10,000 g/m³
- 10,000 - 12,000 g/m³
- 12,000 - 14,000 g/m³
- 14,000 - 16,000 g/m³
- 16,000 - 18,000 g/m³
- 18,000 - 20,000 g/m³
- 20,000 - 22,000 g/m³
- 22,000 - 24,000 g/m³
- 24,000 - 26,000 g/m³
- 26,000 - 28,000 g/m³
- 28,000 - 30,000 g/m³
- 30,000 - 32,000 g/m³
- 32,000 - 34,000 g/m³
- 34,000 - 36,000 g/m³

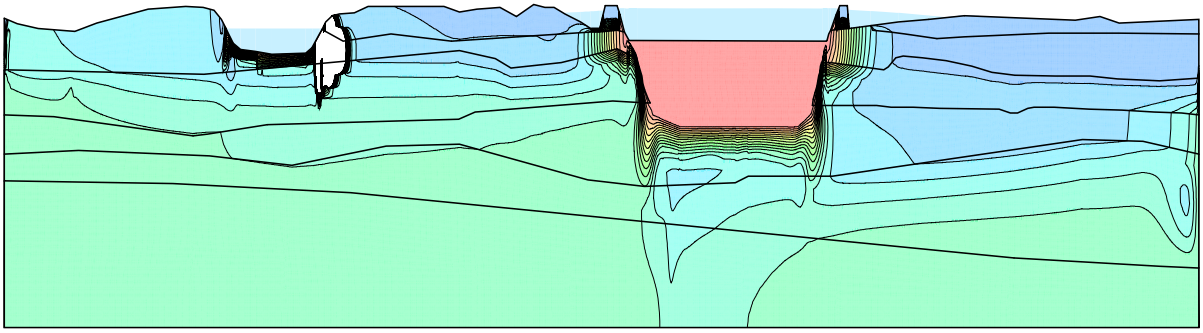
Golder Associates

CLIENT: Flanagan Consulting Group		PROJECT: Cairns Shipping Development EIS	
DRAWN: SRF	DATE: 23/01/17	TITLE: **Concentration contours at completion of filling – Section 1**	
CHECKED: MSC	DATE: 23/01/17		
SCALE: Not to Scale		PROJECT No: 1546223-012	FIGURE No: 25 / REV No: 3 / A3

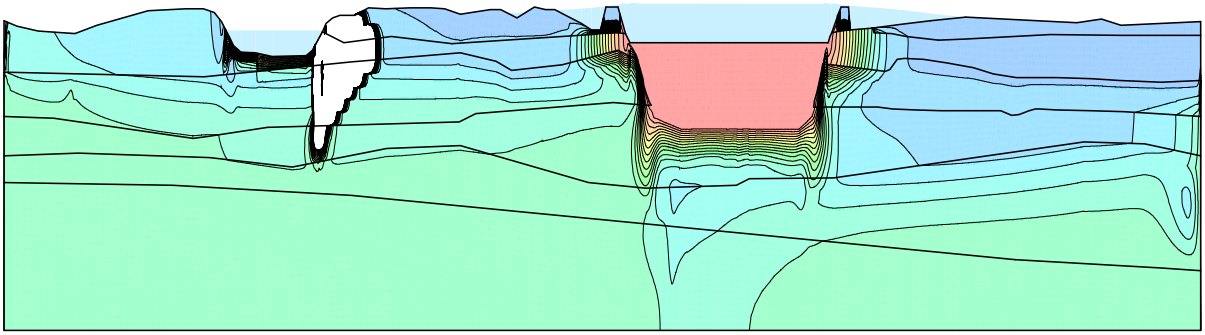
Filling to RL 3 m



Filling to RL 4 m



Filling to RL 5 m



Concentration

- 0 - 2,000 g/m³
- 2,000 - 4,000 g/m³
- 4,000 - 6,000 g/m³
- 6,000 - 8,000 g/m³
- 8,000 - 10,000 g/m³
- 10,000 - 12,000 g/m³
- 12,000 - 14,000 g/m³
- 14,000 - 16,000 g/m³
- 16,000 - 18,000 g/m³
- 18,000 - 20,000 g/m³
- 20,000 - 22,000 g/m³
- 22,000 - 24,000 g/m³
- 24,000 - 26,000 g/m³
- 26,000 - 28,000 g/m³
- 28,000 - 30,000 g/m³
- 30,000 - 32,000 g/m³
- 32,000 - 34,000 g/m³
- 34,000 - 36,000 g/m³

Golder Associates

CLIENT: Flanagan Consulting Group		PROJECT: Cairns Shipping Development EIS	
DRAWN: SRF	DATE: 23/01/17	TITLE: **Concentration contours at completion of filling – Section 2**	
CHECKED: MSC	DATE: 23/01/17		
SCALE: Not to Scale		PROJECT No: 1546223-012	FIGURE No: 26 REV No: 3 A3

363,000 363,500 364,000 364,500 365,000 365,500

8,137,000 8,136,500 8,136,000 8,135,500 8,135,000 8,134,500

11000024 11000024 B 11000024 A
72509 72509 RN72551
11000156 11000156
11000030 11000030
139211 139211
UG2A UG2 BH10 CPT21
Bore1 BH1 BH9 CPT20 BH4 CPT7 CPT8 CPT9 BH11 CPT23 CPT22 BH4A BH4 BH2 CPT10 CPT14 BH5 CPT28 CPT5 UG1 CPT15 CPT6 CPT16 BH8 BH6 CPT19 CPT3 CPT18 CPT13 BH12 BH7 BH3 CPT2 CPT17 CPT24 CPT1 CPT4 CPT12 CPT25 BH16
11000025 11000025
AH3 AH1 AH6 AH4 AH2 AH8 AH9 AH10 AH5 AH7
Booster #3 Booster #3
GeoNorth_CPT11 GeoNorth_CPT10 GeoNorth_CPT8 GeoNorth_CPT9 GeoNorth_CPT12 GeoNorth_CPT5 GeoNorth_CPT7 GeoNorth_CPT6 GeoNorth_CPT4 GeoNorth_CPT13 GeoNorth_CPT14 GeoNorth_CPT3 GeoNorth_CPT2 GeoNorth_CPT1
11000031 11000031
72350 72350
11000049 11000049
BH18 CPT11 BH15 BH19 BH17 BH21 BH20 NS3 NS7 NS1 Bore2 NS5 NS6 NS4 NS2 NS8 Lake GA05 CPT26 CPT27 BH2 BH3 BH3a Bore3
11000032 11000032
CPT1 CPT2 Booster #3 CPT3
11000033 11000033
CPT4 CPT5 CPT6
11000053 A 11000053 B 11000053 11000039 11000039
BH13 NS9 CPT29 BH14 NS10 BH5a CPT30 CPT30

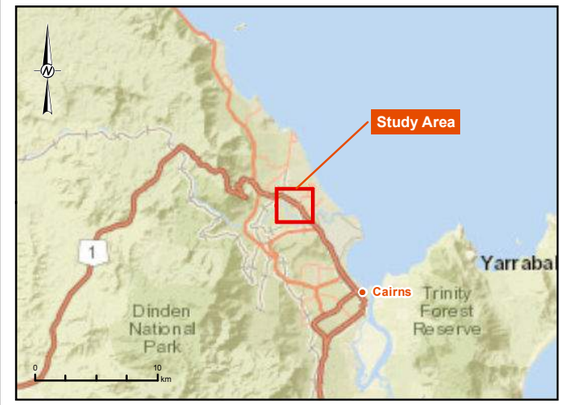
WISTARIA STREET
WISTARIA STREET
CAPTAIN COOK HIGHWAY
HOLLOWAY BEACH ROAD
MACHANS BEACH ROAD
Barron River
Barron River

RL 5
RL 3

N

Path: \\golder.gds\GAP\Cairns\Jobs\Geo\2015\1546223 - FCG - EIS Stage 1 - Port Development\GIS\MXD\Hydro_Assessment\1546223-012-R-Rev1_F008_Nth_Sands_Investigations.mxd

LOCATION MAP



LEGEND

- Localities
- Sections
- Roads and Tracks
- Watercourses (25k)

Investigation Locations

- GW Monitoring Bore
- Probin Boreholes
- GEO Investigate
- Well Locations

Pipeline Route Options

Inbound Yorkeys

- Booster Locations

Inbound Aquis

- Booster Locations

Inbound Machans Beach

- Booster Locations

Inbound Aquis - No Marine Booster

- Inbound Pipeline
- Inbound Pipeline
- Inbound Pipeline
- Inbound Pipeline

- Northern Sands Placement Area
- Pit Expansion Area

0 0.25 0.5
1:10,000 at A3 Kilometres
PROJECTION: GDA 1994 MGA Zone 55

CLIENT
FLANAGAN CONSULTING GROUP

CAIRNS SHIPPING DEVELOPMENT EIS

APPROXIMATE EXTENT OF INCREASE IN SALINITY IN UPPER SAND LAYER

CONSULTANT
Golder Associates

YYYY-MM-DD	2017-01-23
PREPARED	DP
DESIGNED	DP
REVIEWED	DS
APPROVED	DS

PROJECT NO.	CONTROL	REV.	FIGURE
1546223	012	4	27

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM A3
25mm
0

APPENDIX A

Summary details of registered groundwater bores

Table A1: Registered bore details.

Registered Borehole ID	Latitude	Longitude	Purpose	Year of installation or drilling	Status
45021	-16.8492	145.7066	Water supply	1974	Existing
45028	-16.8506	145.7031	Water supply	1974	Existing
45032	-16.8509	145.7075	Water supply	1974	Abandoned and destroyed
45041	-16.8592	145.7019	Water supply	1975	Existing
45042	-16.8582	145.7032	Water supply	1975	Existing
45043	-16.8607	145.7056	Water supply	1975	Existing
45457	-16.8594	145.7078	Water supply	1983	Existing
72350	-16.8571	145.729	Water supply	1986	Existing
72509	-16.8489	145.7128	Water supply	1991	Existing
109374	-16.8481	145.7064	Water supply	no data	Existing
139211	-16.8524	145.716	Water supply	2007	Abandoned and destroyed
11000024	-16.8475	145.716	Water resources investigation	1977	Abandoned but still useable
11000025	-16.8464	145.7283	Sub-Artesian monitoring	1977	Abandoned but still useable
11000029	-16.8608	145.7006	Water resources investigation	1976	Existing
11000030	-16.8518	145.7174	Water resources investigation	no data	Abandoned and destroyed
11000031	-16.8503	145.7291	Water resources investigation	1976	Abandoned but still useable
11000032	-16.8591	145.7288	Water resources investigation	1976	Abandoned but still useable
11000033	-16.862	145.7345	Water resources investigation	1976	Existing
11000034	-16.8564	145.7394	Water resources investigation	1977	Abandoned but still useable
11000039	-16.8689	145.7161	Water resources investigation	1977	Abandoned and destroyed
11000049	-16.8578	145.7269	Water resources investigation	1981	Existing
11000053	-16.8685	145.7158	Water resources investigation	1981	Existing
11000070	-16.8443	145.7241	Water resources investigation	1977	Abandoned and destroyed
11000156	-16.8503	145.7167	No data	2010	Existing

Historical groundwater depth information for existing groundwater wells located within 2 km in the surroundings and adjacent to the Northern Sand Site that was available from the DNRM groundwater database is summarised in Table A2.

Table A2: Bore construction details and groundwater levels

Borehole ID	Bore depth (m bgl)	Screened Interval (m bgl)	Screened formation (m bgl)	Stratigraphy	Aquifer type	Standing Water Level Range	
						*(m bgl)	*(m AHD)
45021	5.5	0.0 to 5.5	No data	No data	Shallow	2.4	No data
45028	6.0	0.0 to 6.1	Gravel and sand	Barron river alluvium	Shallow	3.0	No data
45032	6.1	1.8 to 6.1	Gravel and sand	Barron river alluvium	Shallow	3.4	No data
45041	7.6	0.0 to 7.6	No data	No data	Shallow	No data	No data
45042	7.6	0.0 to 7.6	No data	No data	Shallow	No data	No data
45043	7.6	0.0 to 7.6	No data	No data	Shallow	No data	No data
45457	6.5	5.5 to 6.5	Coarse sand	Barron river alluvium	Shallow	2.2	No data
72350	12.2	6.1 to12.2	Coarse sand	Barron river alluvium	Shallow	3.7	No data
72509	11.0	4.5 to 5.5 and 8.5 to 10.0	Mud/coarse sand	Barron river alluvium	Shallow	1.5	No data
109374	No data	No data	No data	No data	NA	No data	No data
139211	66.0	no data	Mud, sand and gravel	Barron river alluvium	Deep	No data	No data
11000024 A	74.0	62.0 to 74.0	Gravel	Quaternary sediment	Deep	1.2 to 4.3	1.0 to 4.1
11000024 B	No data	No data	No data	Quaternary sediment	NA	1.8 to 3.9	1.3 to 3.4
11000025	No data	24.0 to 36.0	Gravel	Quaternary sediment	Deep	1.0 to 1.8	0.2 to 1.0
11000029	30.0	24.0 to 30.0	Gravel	Quaternary sediment	Deep	4.0 to 6.2	0.4 to 2.5
11000030	No data	No data	No data	No data	NA	1.9 to 4.02	-0.8 to 1.4
11000031	85.5	4.0 to 13.0	Gravel	Quaternary sediment	Deep	0.5 to 2.9	-0.2 to 2.2
11000032	88.0	28.0 to 34.0	Gravel	Quaternary sediment	Deep	3.6 to 5.2	0.1 to 1.7
11000033	90.0	24.0 to 36.0	Gravel	Quaternary sediment	Deep	1.3 to 2.5	0.7 to 2.2
11000034	90.0	38.0 to 56.0	Gravel sand and clay	Quaternary sediment	Deep	1.7 to 2.5	1.7 to 2.5
11000039	72.0	30.0 to 42.0	Gravel	Quaternary sediment	Deep	3.0 to 4.2	0.5 to 1.2

Borehole ID	Bore depth (m bgl)	Screened Interval (m bgl)	Screened formation (m bgl)	Stratigraphy	Aquifer type	Standing Water Level Range	
						*(m bgl)	*(m AHD)
11000049	36.0	25.9 to 27.9	Gravel	Quaternary sediment	Deep	3.2 to 4.4	0.0 to 1.1
11000053 A	42.0	30.1 to 32.1	Gravel	Quaternary sediment	Deep	2.4 to 4.4	0.4 to 2.5
11000053 B	42.0	8.2 to 10.2	Sandy clay and fine to coarse sand	Quaternary sediment	Shallow	1.5 to 4.3	0.5 to 3.3
11000070	73.0	23.0 to 35.0	Sand, gravel and clay	Quaternary sediment	Deep	1.4	no data
11000156	26.0	14.0 to 26.0	Sand, gravel and clay	Barron river alluvium	Deep	2.4 to 4.0	0.01 to 0.8

** Where data is not presented in a range, only a single data point exists.*

APPENDIX B

Water quality data for registered groundwater bores

Water quality parameters for registered bores in the vicinity of the site are available from the Queensland Groundwater Database (GWDB). Bore reports in the database include field parameter measurements for pH and Electrical conductivity (EC), while other analytes are available in some instances where samples have been collected.

Cation and anion concentrations for each groundwater sample were converted to milliequivalents per litre (meq/L) and plotted as percentages of their respective totals in two triangles of the Piper diagram reported in Figure B1 which differentiates groundwater types based on the relative major ion composition.

Table B1 presents the pH, EC and water classification of the registered bores where information is available. Most of the registered bores are classified as a dominant sodium and chloride water types with a mix with sulphate.

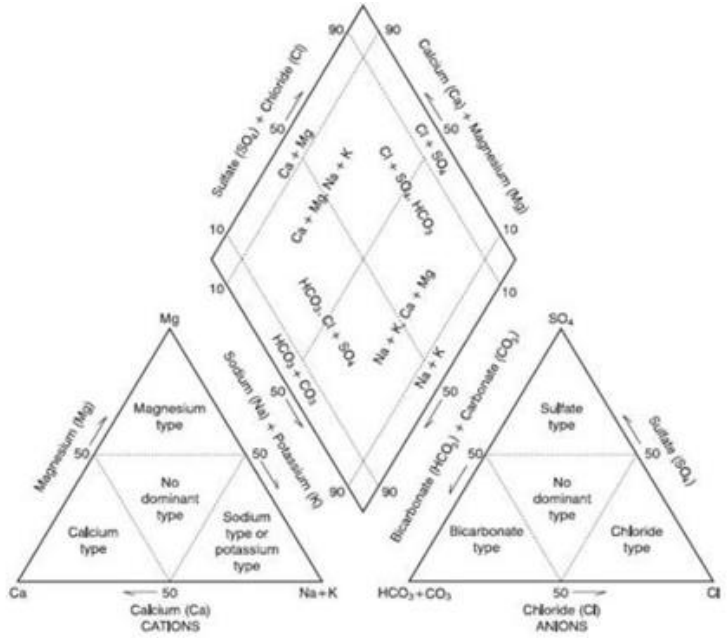
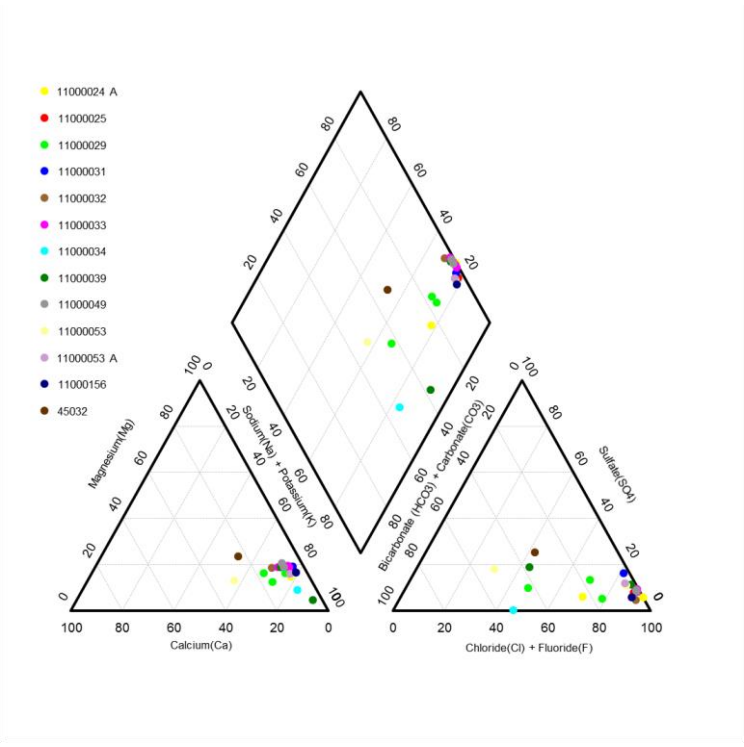
Classification of hydrochemical facies using Piper Diagrams	
Water types of groundwater samples from monitoring bores within 2 km of the Northern Sand site.	

Figure B1: Piper diagram for samples from the Queensland GWDB (DNRM, 2016) within 2 km of the Northern Sand site.

Table B1: pH, EC and water type classification at registered bores

Registered Bore	pH range*	EC range (µS/cm)*	Salinity	Water type from piper diagram
45021	No data	No data	NA	
45028	No data	No data	Potable water	NA
45032	7.2	295	Neutral and freshwater	$Cl+S0_4^{2-}+HC0_3^-$
45041	No data	No data	NA	NA
45042	No data	No data	NA	NA
45043	No data	No data	NA	NA
45457	No data	No data	Potable water	NA
72350	No data	No data	NA	NA
72509	No data	313	Freshwater	NA
109374	No data	No data	NA	NA
139211	No data	6 000 to 7 500	Slightly brackish	NA
11000024A	6.7 to 7.5	656 to 34 000	Slightly acidic/neutral and freshwater to highly brackish	$Cl+S0_4^{2-}+HC03^-$
11000024B	No data	No data	NA	NA
11000025	7.8	26 500	Neutral, highly brackish	$Cl+ Na+ S0_4^2$
11000029	6.3 to 7.6	128 to 1 251	Slightly acidic to neutral, freshwater	$Cl+S0_4^{2-}+HC0_3^-$and Na+K, Ca+Mg
11000030			Slightly acidic to neutral, freshwater	
11000031	6.7	17 500	Slightly acidic and brackish	Na+K, Ca+Mg
11000032	6.7	3 800	Slightly acidic and slightly brackish	$Cl+ Na+ S0_4^2$
11000033	6.7 to 7.8	19 360 to 37 700	Slightly acidic to slightly alkaline and brackish to highly brackish	$Cl+ Na+ S0_4^2$
11000034	7.1	700	Neutral and freshwater	Na+K, Ca+Mg
11000039	6.4 to 7.6	700 to 17 500	Slightly acidic to slightly alkaline and freshwater to brackish	$Cl+S0_4^{2-}+HC0_3^-$and Na+K, Ca+Mg
11000049	6.6 to 7.9	29 700 to 31 000	Slightly acidic to slightly alkaline and brackish to highly brackish	$Cl+S0_4^{2-}+HC0_3^-$
11000053 A	6.3 to 7.5	360 to 4 190	Slightly acidic to neutral and freshwater to slightly brackish	$Cl+S0_4^{2-}+HC0_3^-$
11000070	No data	No data	NA	NA
11000156	7.1	9 650	Neutral and slightly brackish	$Cl+S0_4^{2-}+HC0_3^-$

APPENDIX C

Onsite Groundwater Quality Information

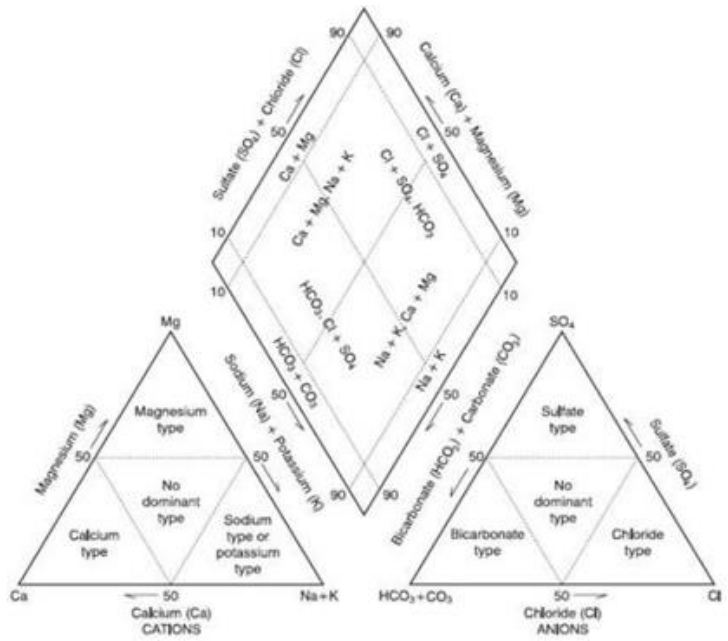
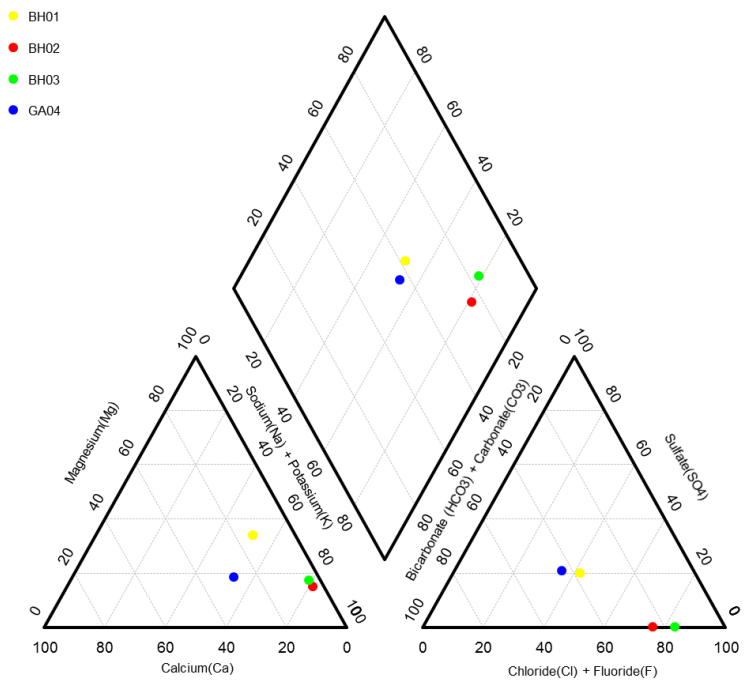
Classification of hydrochemical facies using Piper Diagrams	
Water types of groundwater samples from monitoring bores present on site during the November sampling event.	

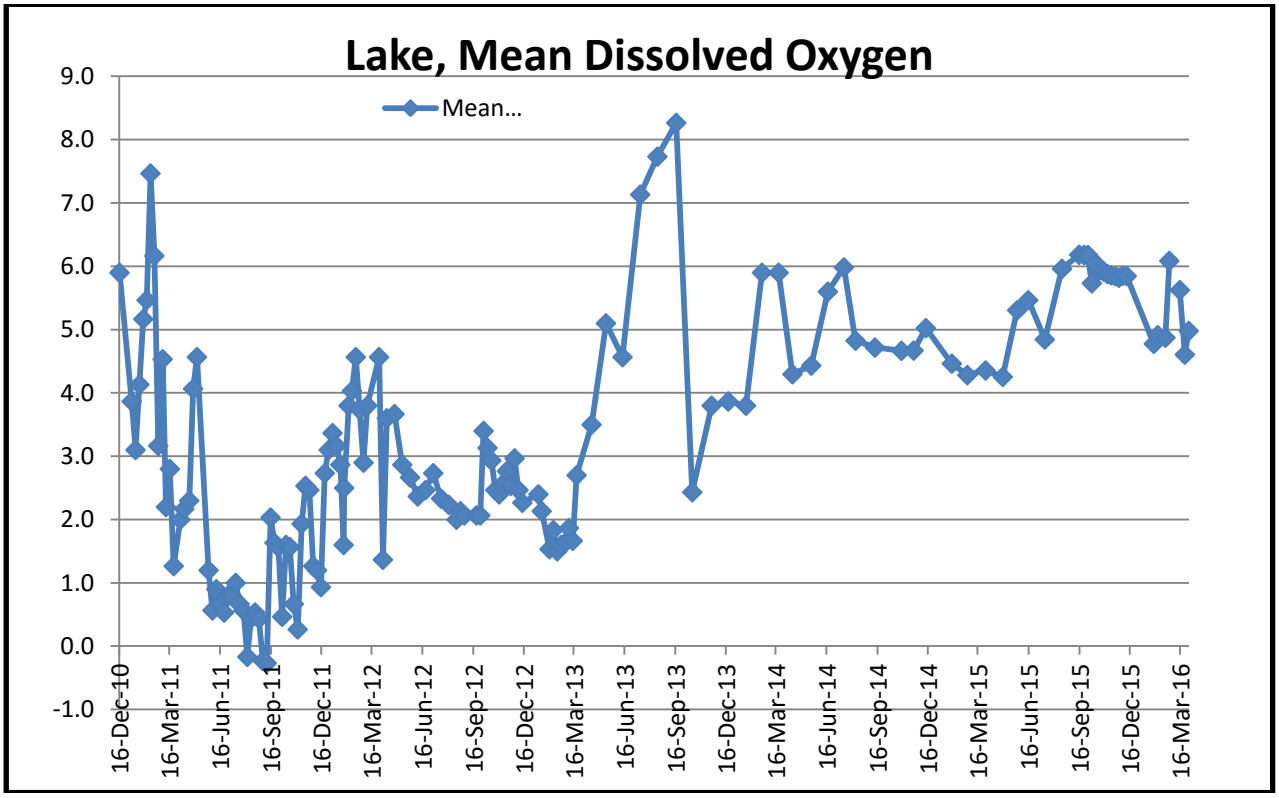
Figure B2: Piper diagram for samples from BH01, BH02, BH03 and GA04.

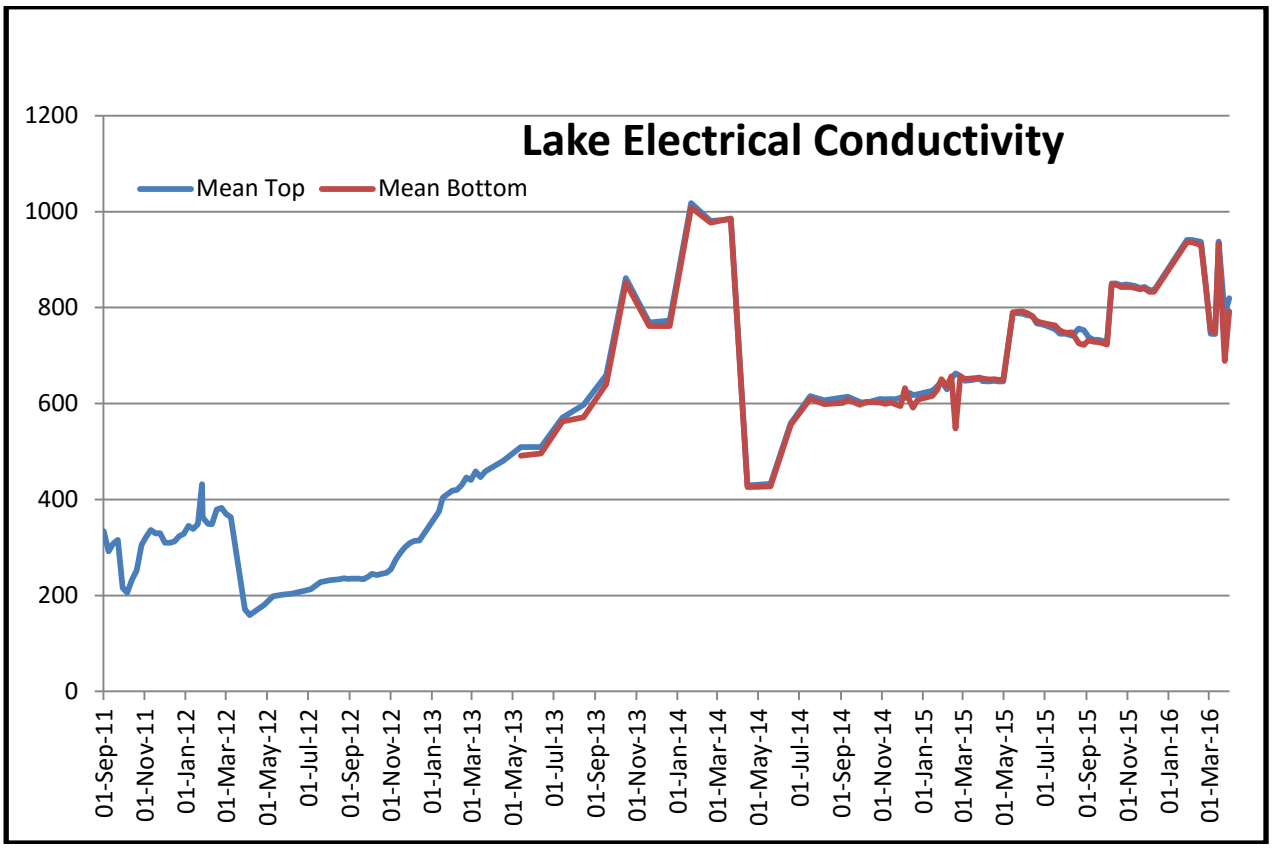
20 July 2016

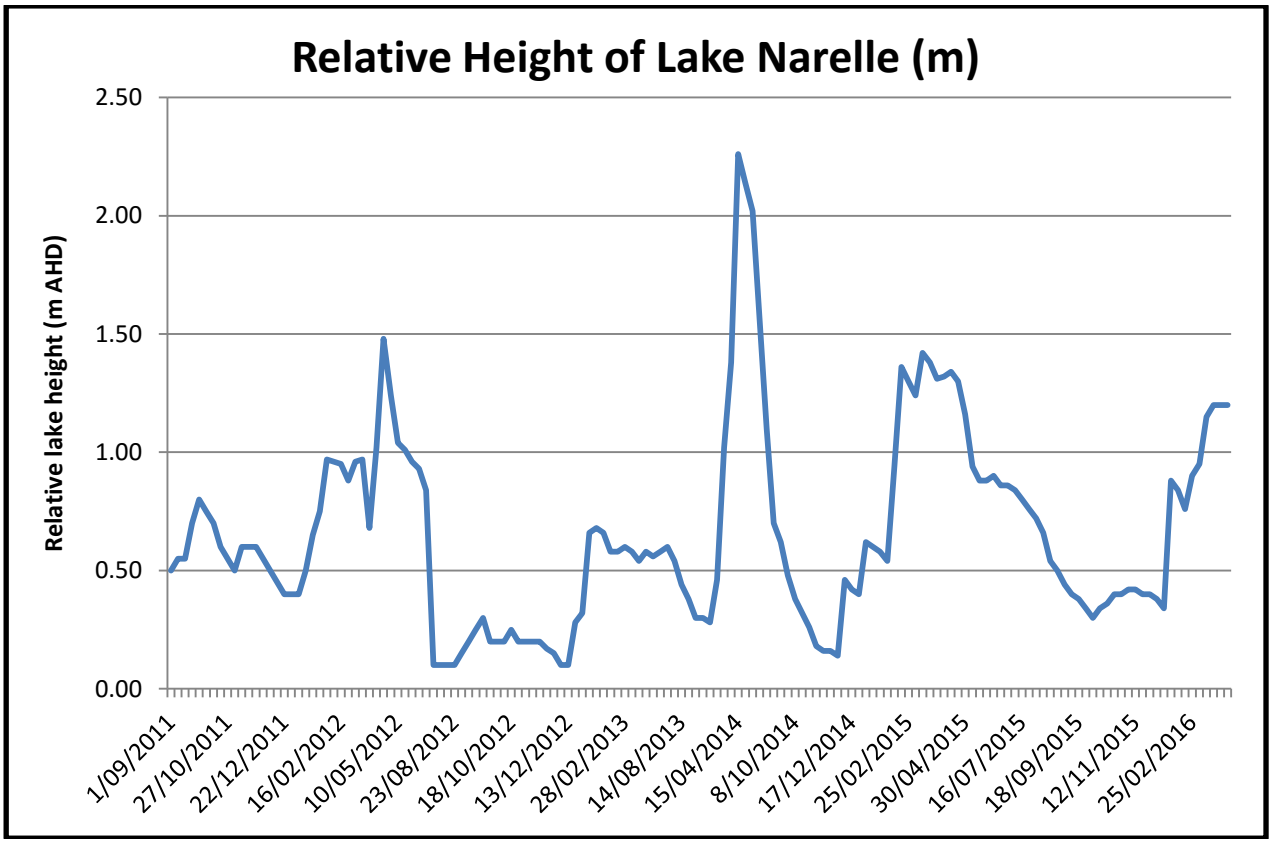
Compiled by Dean Jones of Landline Consulting on request of Tom Hedley for Flanagan Consulting Group representing Ports North.

Northern Sands Lake and Bore Stats.

The first three charts are derived from regular monitoring of the Lake undertaken by Northern Sands using handheld multiparametric water quality metre calibrated by Landline Consulting.

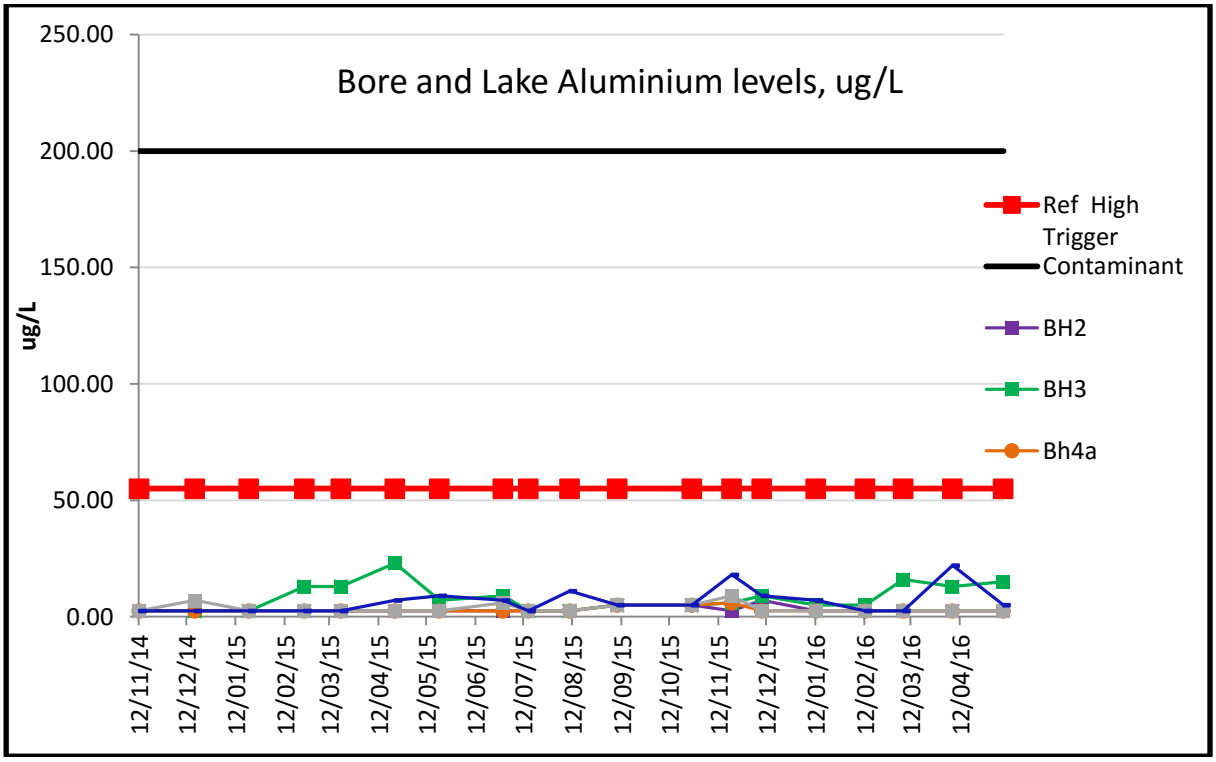


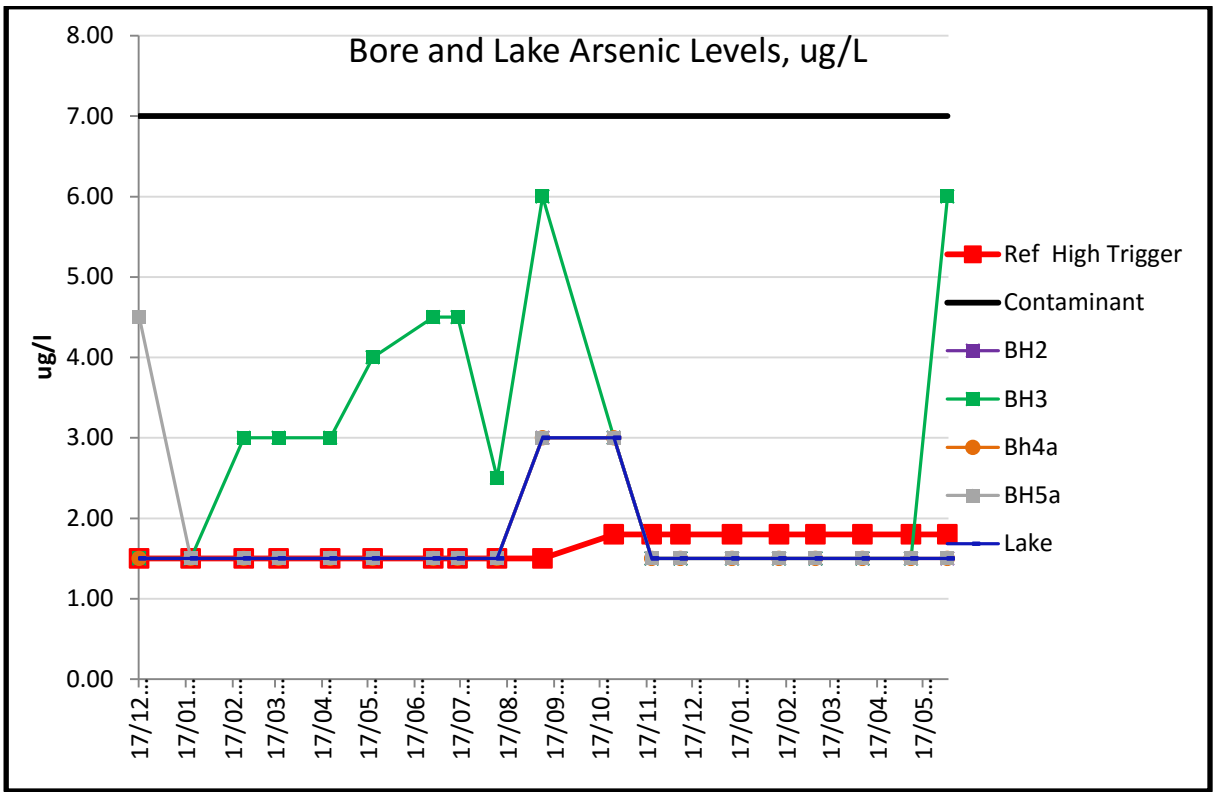

Lake Electrical Conductivity
Mean Top
Mean Bottom
1200
1000
800
600
400
200
0
01-Sep-11
01-Nov-11
01-Jan-12
01-Mar-12
01-May-12
01-Jul-12
01-Sep-12
01-Nov-12
01-Jan-13
01-Mar-13
01-May-13
01-Jul-13
01-Sep-13
01-Nov-13
01-Jan-14
01-Mar-14
01-May-14
01-Jul-14
01-Sep-14
01-Nov-14
01-Jan-15
01-Mar-15
01-May-15
01-Jul-15
01-Sep-15
01-Nov-15
01-Jan-16
01-Mar-16

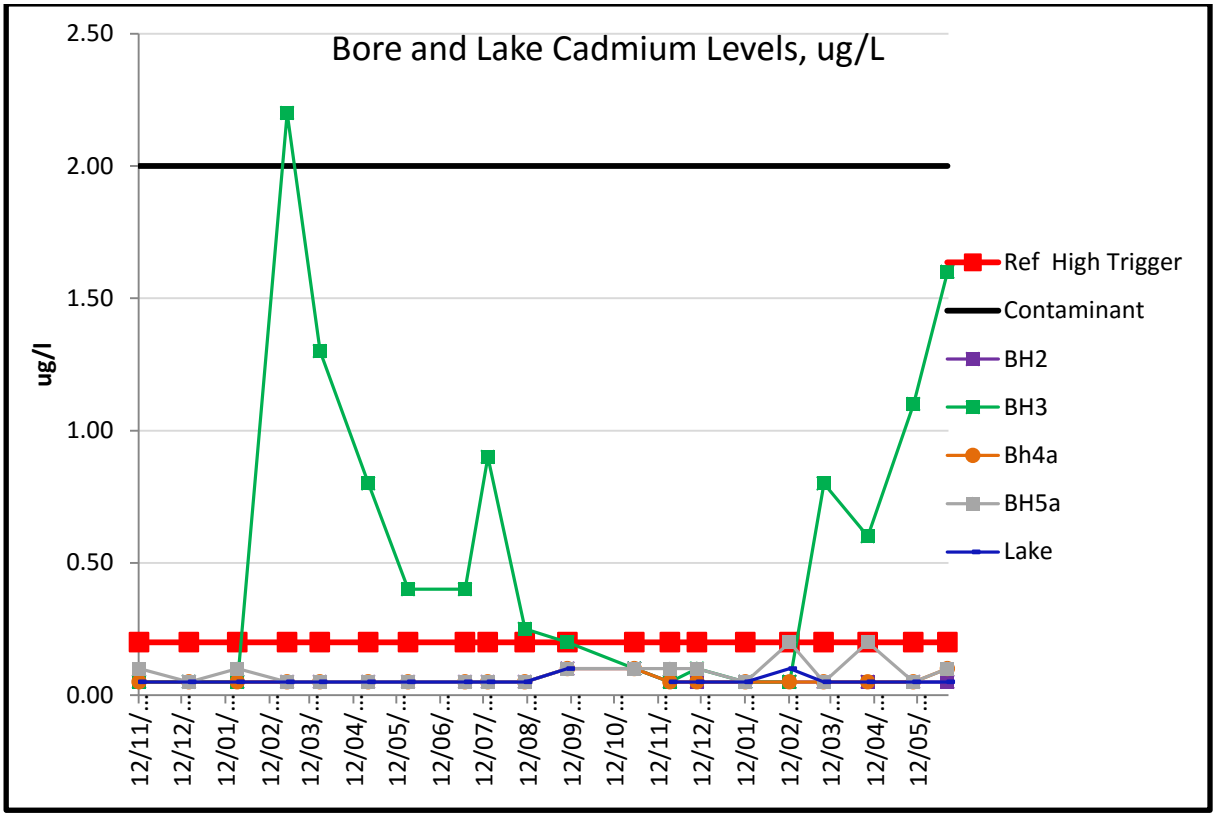

Relative Height of Lake Narelle (m)
Relative lake height (m AHD)
2.50
2.00
1.50
1.00
0.50
0.00
1/09/2011
27/10/2011
22/12/2011
16/02/2012
10/05/2012
23/08/2012
18/10/2012
13/12/2012
28/02/2013
14/08/2013
15/04/2014
8/10/2014
17/12/2014
25/02/2015
30/04/2015
16/07/2015
18/09/2015
12/11/2015
25/02/2016

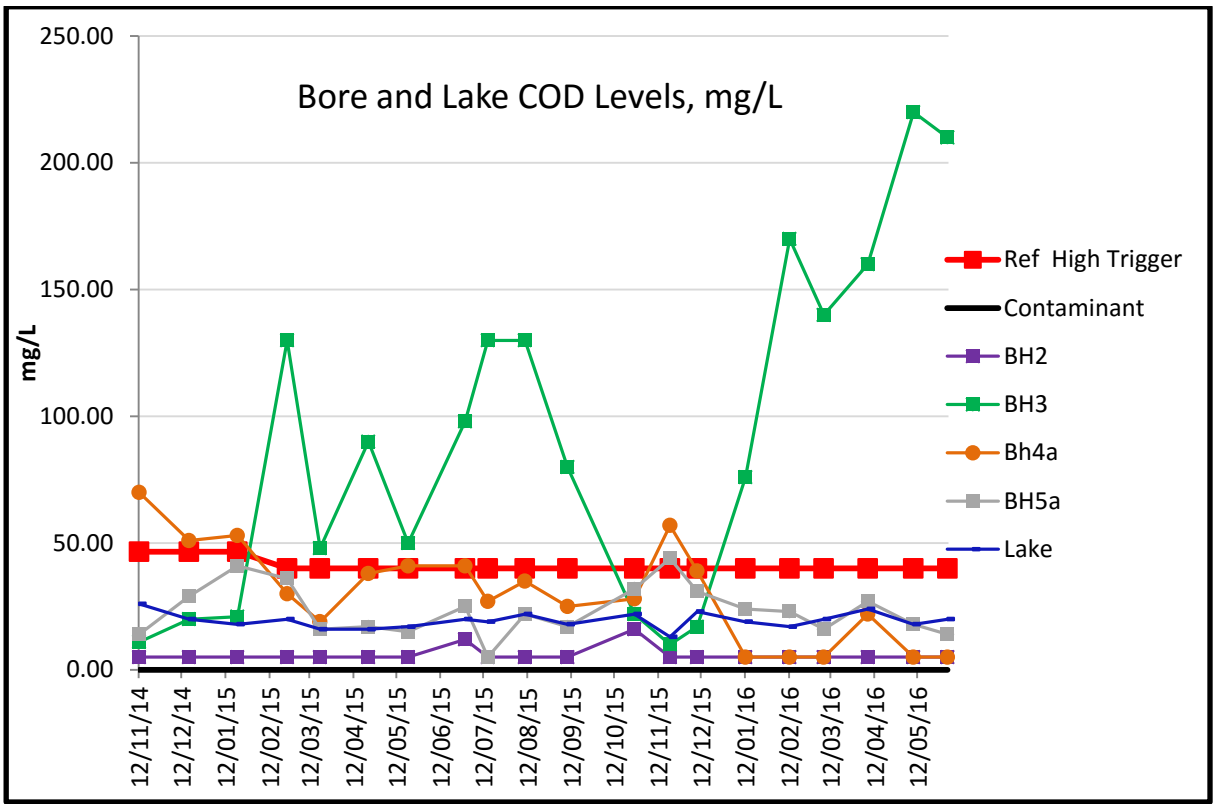
The next group of charts represent samples collected from Northern Sand site bores and lake. Samples are collected monthly and analysed by NATA approved facility. Most charts represent data collected over the last 24 months which is used for examination and interpretation for regular report. Additional historical data, dating back in most cases to 2005, can be provided upon request. However due to the changes in bore numbers over this period it may take some time to collate data.

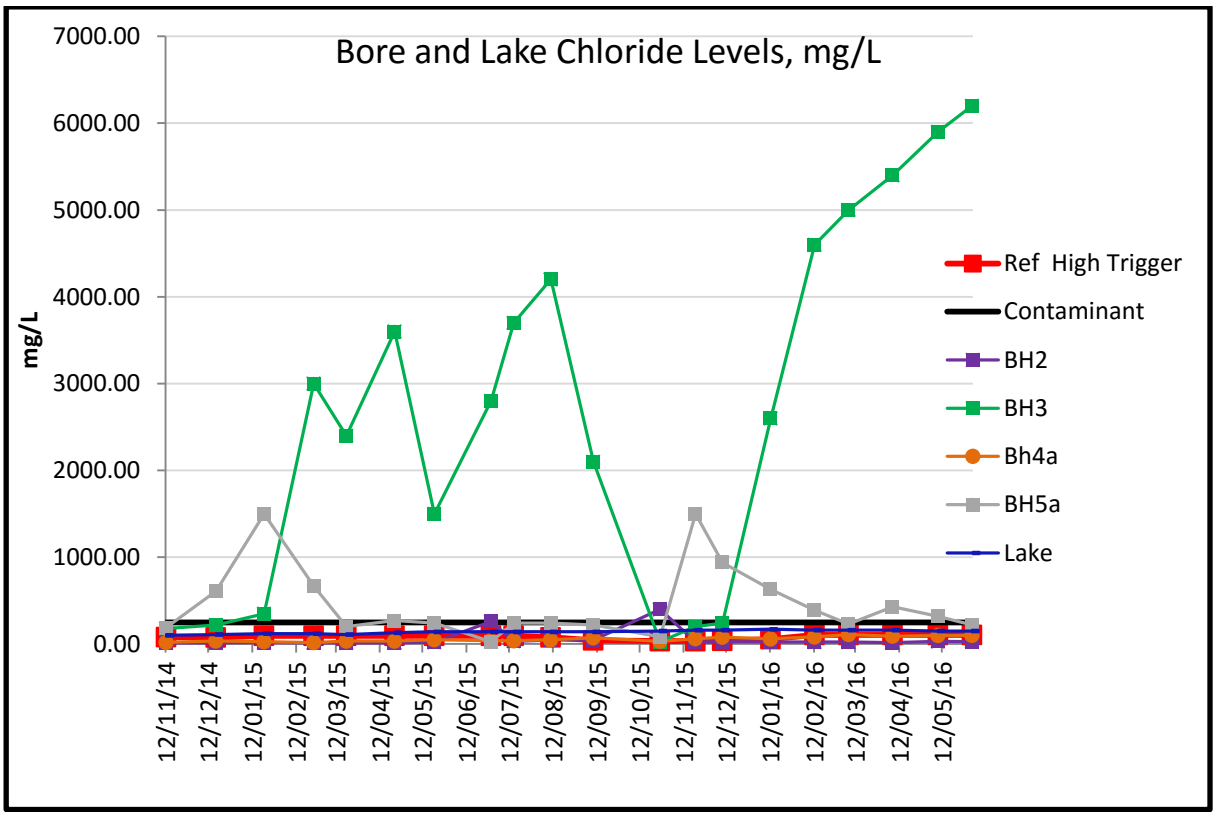
Please note that Bore 3 (BH3) experiences regular exceedences across many parameters. However it's close proximity to the Barron is believed to be responsible for these irregularities and not related to the Lake.

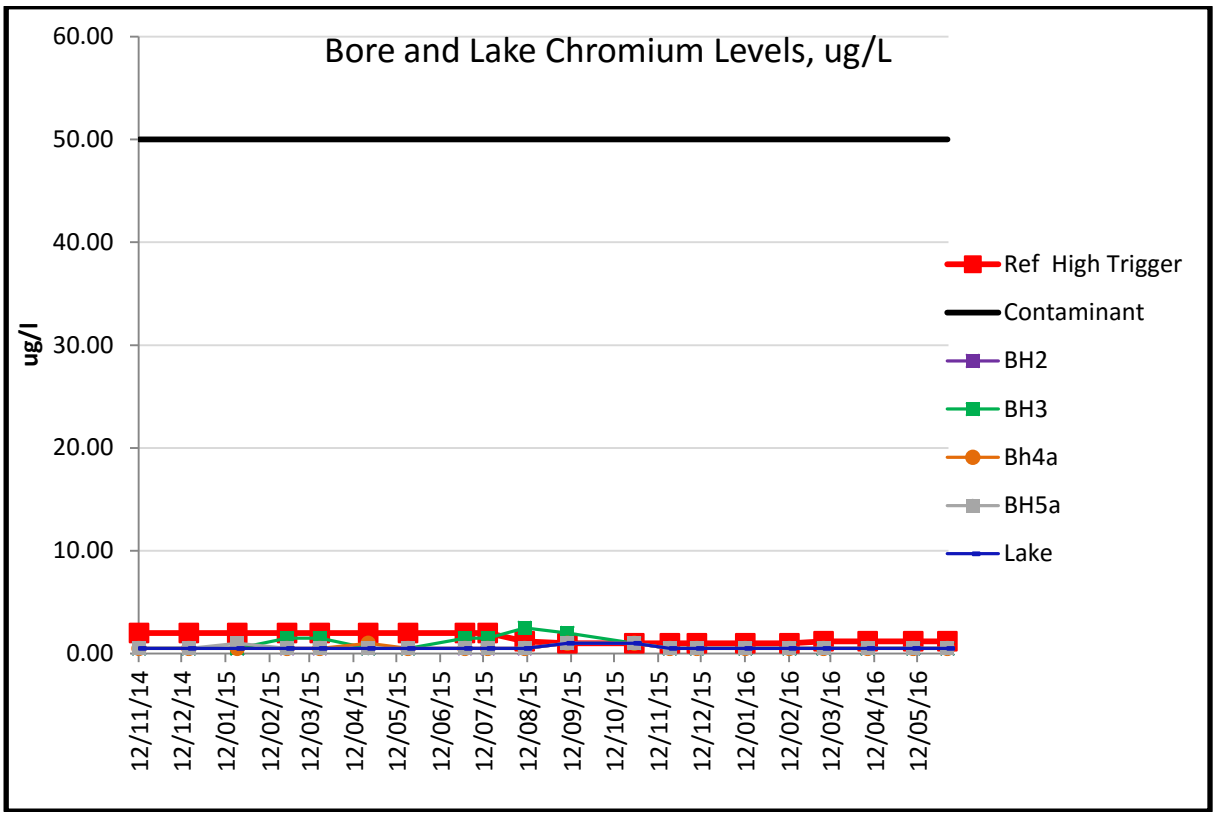


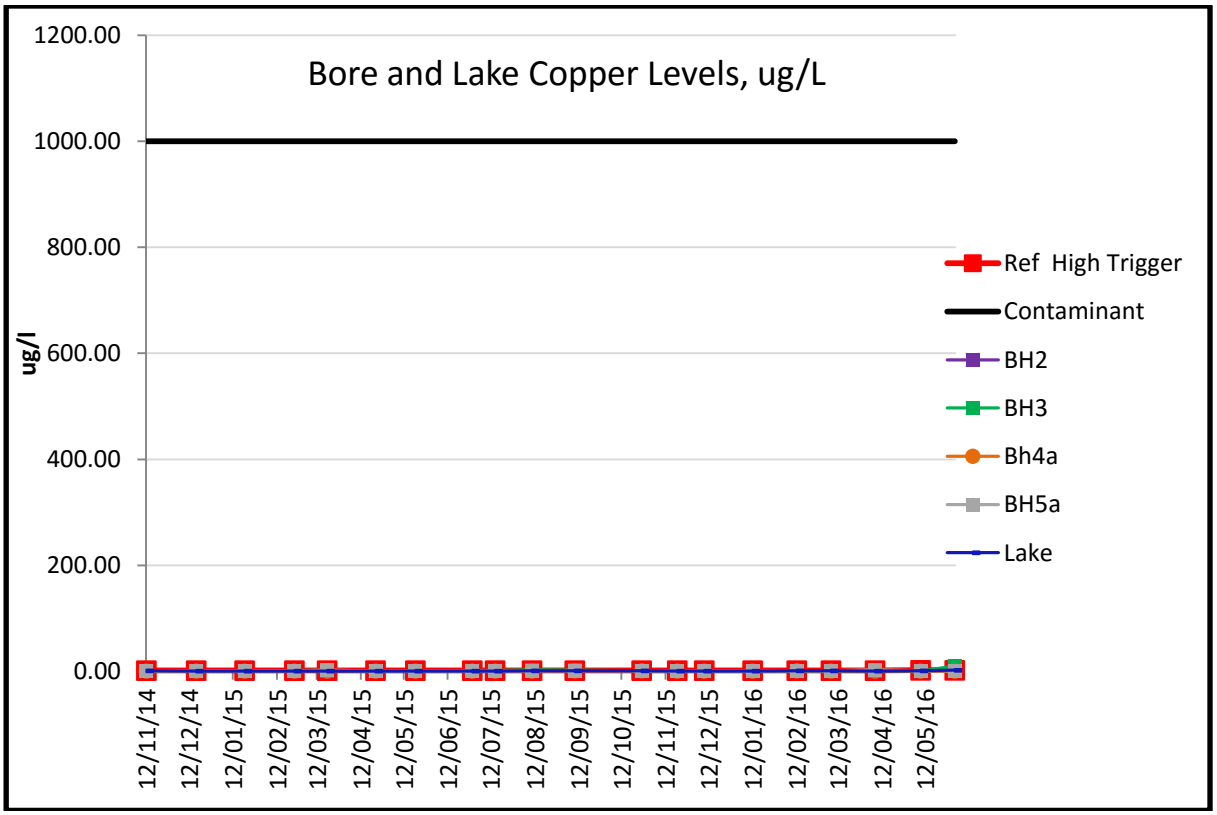

Bore and Lake Arsenic Levels, ug/L
ug/l
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
17/12...
17/01...
17/02...
17/03...
17/04...
17/05...
17/06...
17/07...
17/08...
17/09...
17/10...
17/11...
17/12...
17/01...
17/02...
17/03...
17/04...
17/05...
Ref High Trigger
Contaminant
BH2
BH3
Bh4a
BH5a
Lake

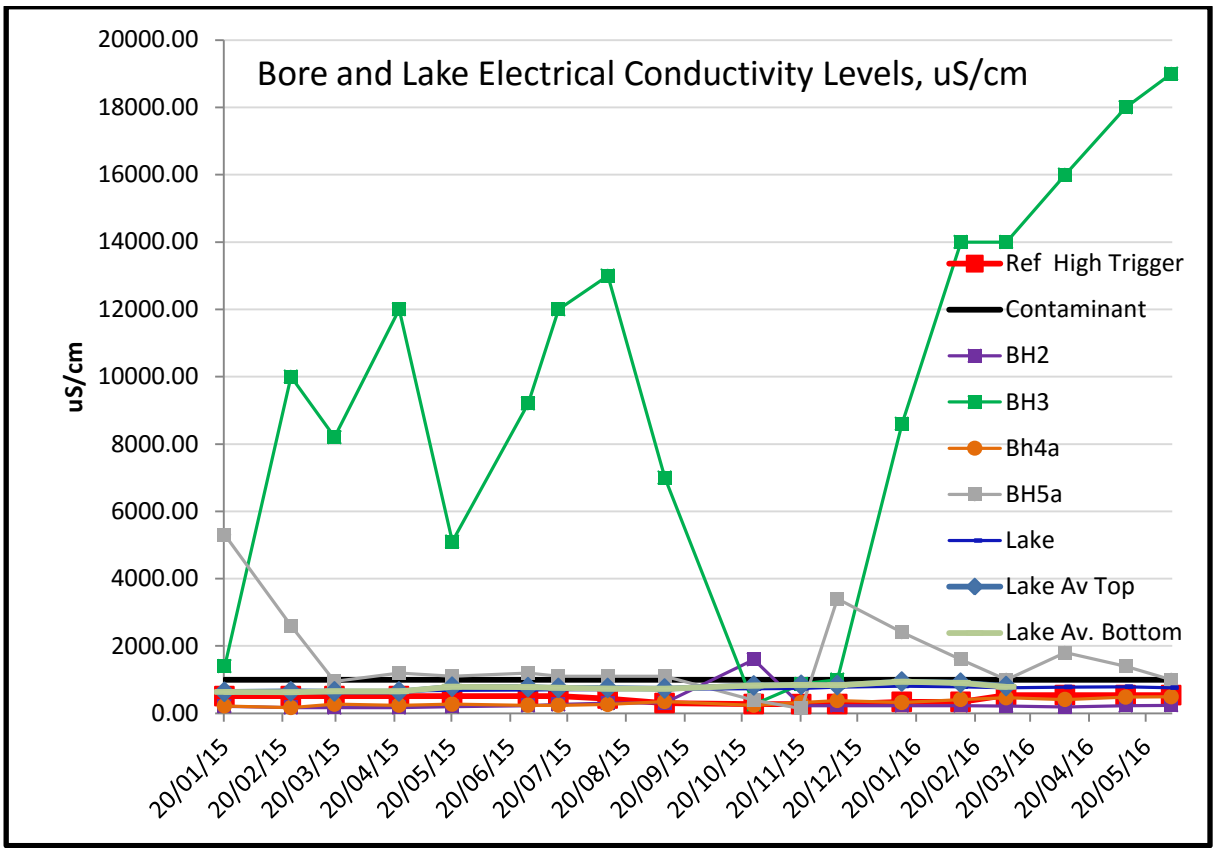

Bore and Lake Cadmium Levels, ug/L
ug/l
2.50
2.00
1.50
1.00
0.50
0.00
12/11/...
12/12/...
12/01/...
12/02/...
12/03/...
12/04/...
12/05/...
12/06/...
12/07/...
12/08/...
12/09/...
12/10/...
12/11/...
12/12/...
12/01/...
12/02/...
12/03/...
12/04/...
12/05/...
Ref High Trigger
Contaminant
BH2
BH3
Bh4a
BH5a
Lake

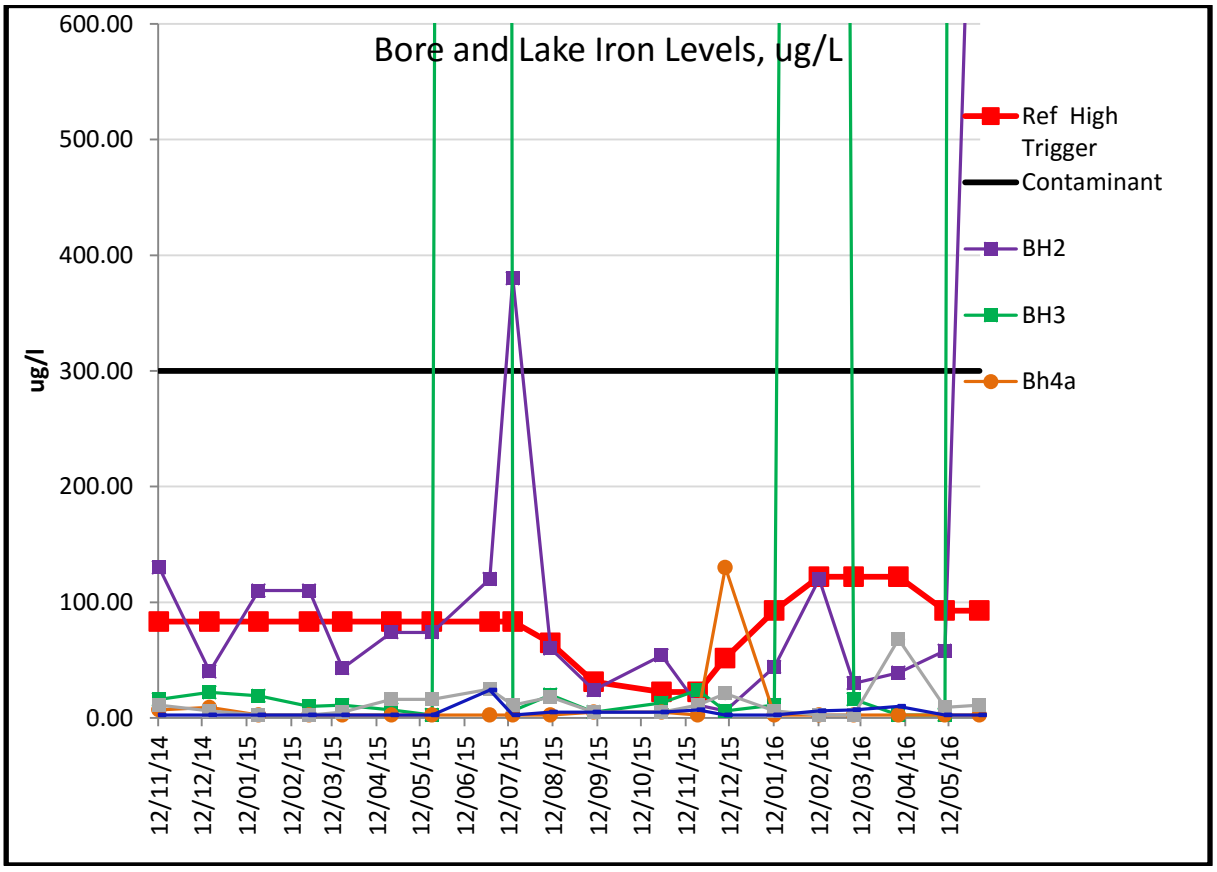

Bore and Lake COD Levels, mg/L
mg/L
250.00
200.00
150.00
100.00
50.00
0.00
12/11/14
12/12/14
12/01/15
12/02/15
12/03/15
12/04/15
12/05/15
12/06/15
12/07/15
12/08/15
12/09/15
12/10/15
12/11/15
12/12/15
12/01/16
12/02/16
12/03/16
12/04/16
12/05/16
Ref High Trigger
Contaminant
BH2
BH3
Bh4a
BH5a
Lake

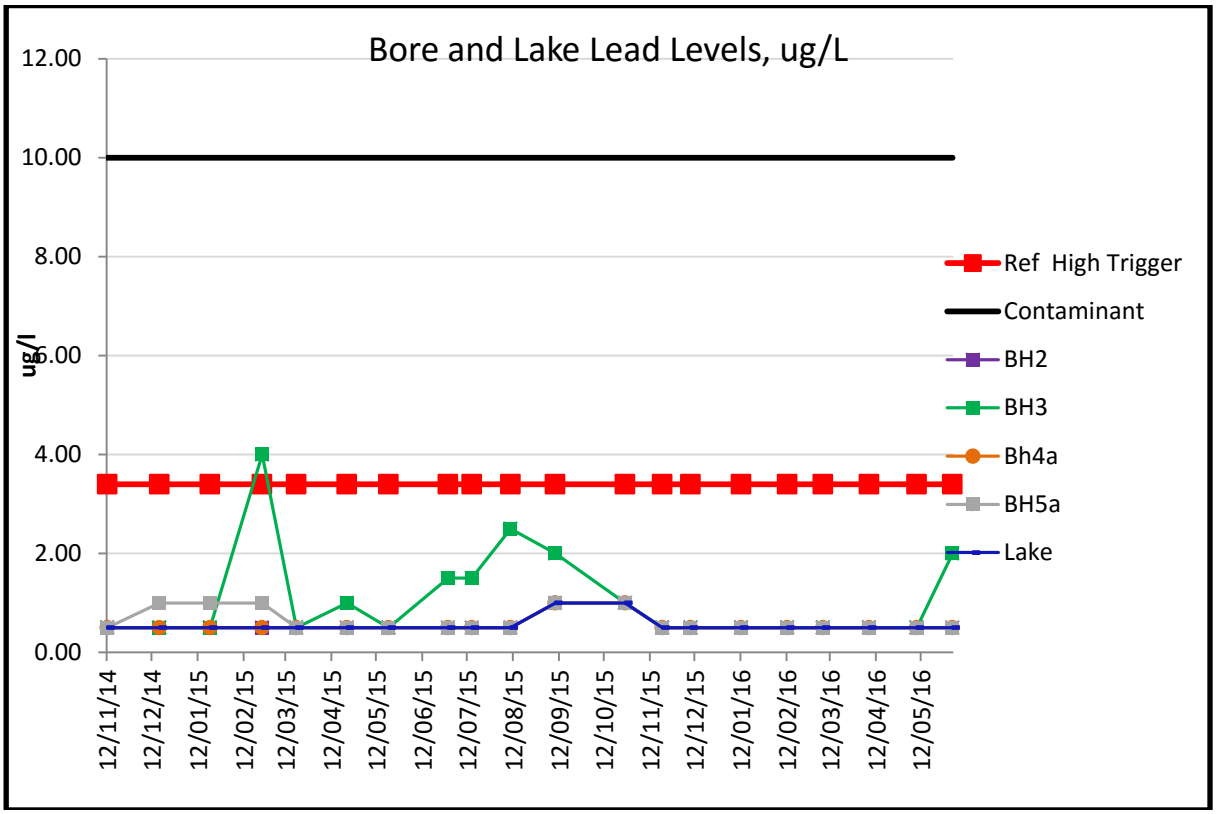

Bore and Lake Chloride Levels, mg/L
mg/L
7000.00
6000.00
5000.00
4000.00
3000.00
2000.00
1000.00
0.00
12/11/14
12/12/14
12/01/15
12/02/15
12/03/15
12/04/15
12/05/15
12/06/15
12/07/15
12/08/15
12/09/15
12/10/15
12/11/15
12/12/15
12/01/16
12/02/16
12/03/16
12/04/16
12/05/16
Ref High Trigger
Contaminant
BH2
BH3
Bh4a
BH5a
Lake

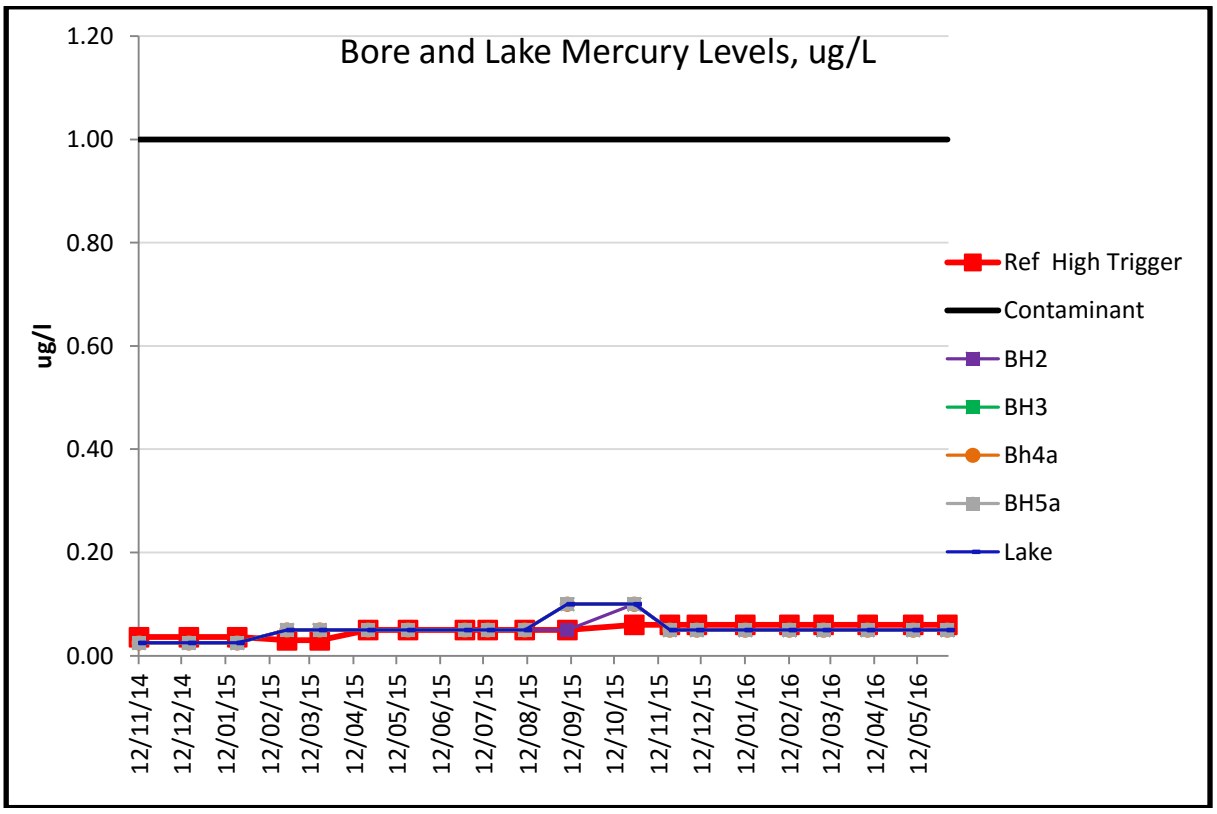

Bore and Lake Chromium Levels, ug/L
60.00
50.00
40.00
30.00
20.00
10.00
0.00
ug/l
12/11/14
12/12/14
12/01/15
12/02/15
12/03/15
12/04/15
12/05/15
12/06/15
12/07/15
12/08/15
12/09/15
12/10/15
12/11/15
12/12/15
12/01/16
12/02/16
12/03/16
12/04/16
12/05/16
Ref High Trigger
Contaminant
BH2
BH3
Bh4a
BH5a
Lake

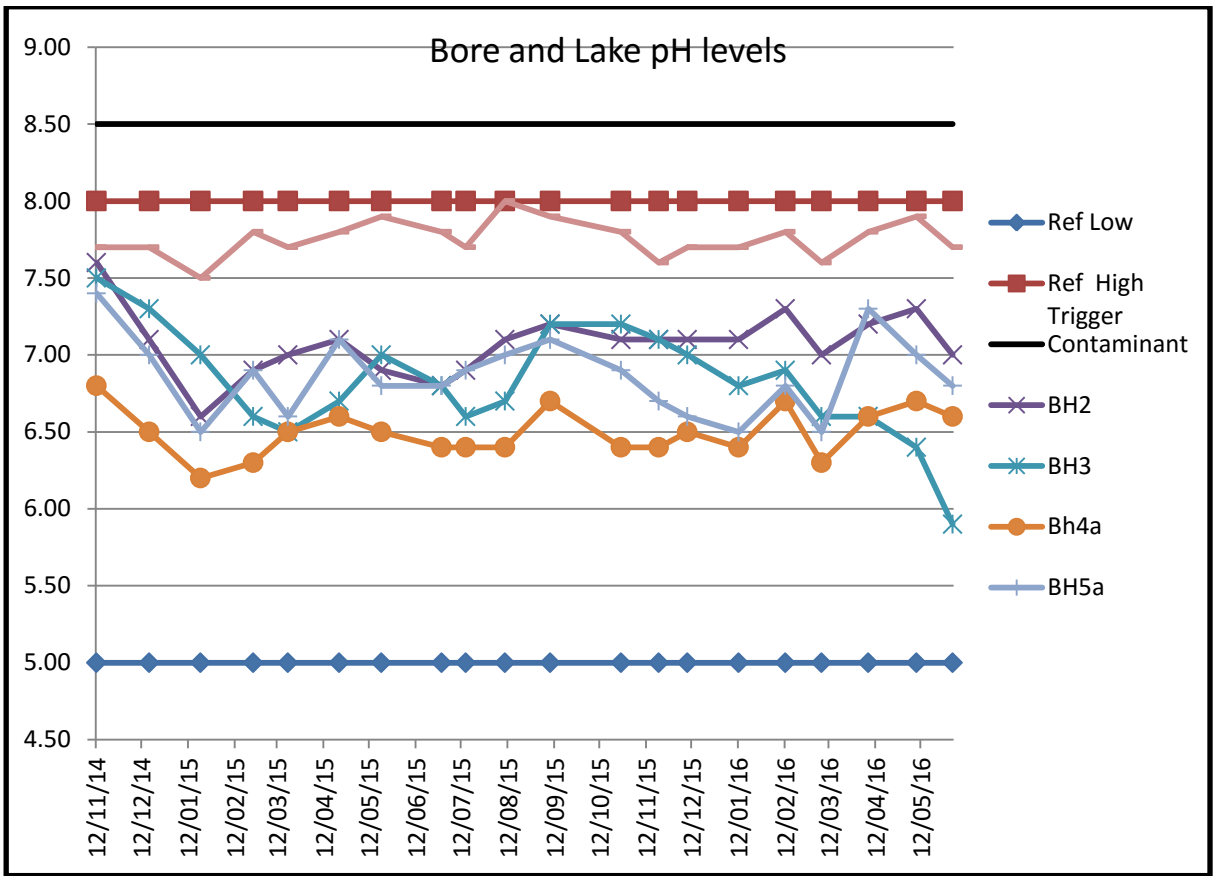

Bore and Lake Copper Levels, ug/L
1200.00
1000.00
800.00
600.00
400.00
200.00
0.00
ug/l
12/11/14
12/12/14
12/01/15
12/02/15
12/03/15
12/04/15
12/05/15
12/06/15
12/07/15
12/08/15
12/09/15
12/10/15
12/11/15
12/12/15
12/01/16
12/02/16
12/03/16
12/04/16
12/05/16
Ref High Trigger
Contaminant
BH2
BH3
Bh4a
BH5a
Lake

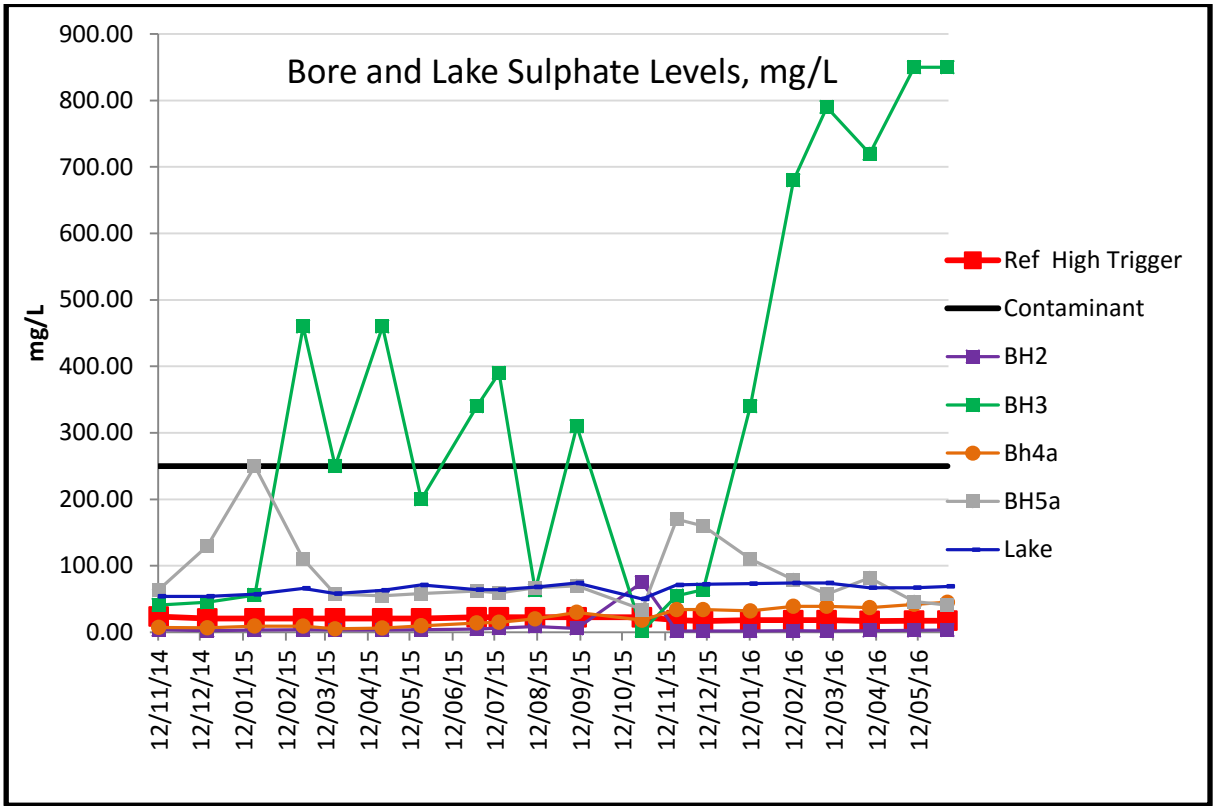

Bore and Lake Electrical Conductivity Levels, uS/cm
uS/cm
20000.00
18000.00
16000.00
14000.00
12000.00
10000.00
8000.00
6000.00
4000.00
2000.00
0.00
20/01/15
20/02/15
20/03/15
20/04/15
20/05/15
20/06/15
20/07/15
20/08/15
20/09/15
20/10/15
20/11/15
20/12/15
20/01/16
20/02/16
20/03/16
20/04/16
20/05/16
Ref High Trigger
Contaminant
BH2
BH3
Bh4a
BH5a
Lake
Lake Av Top
Lake Av. Bottom

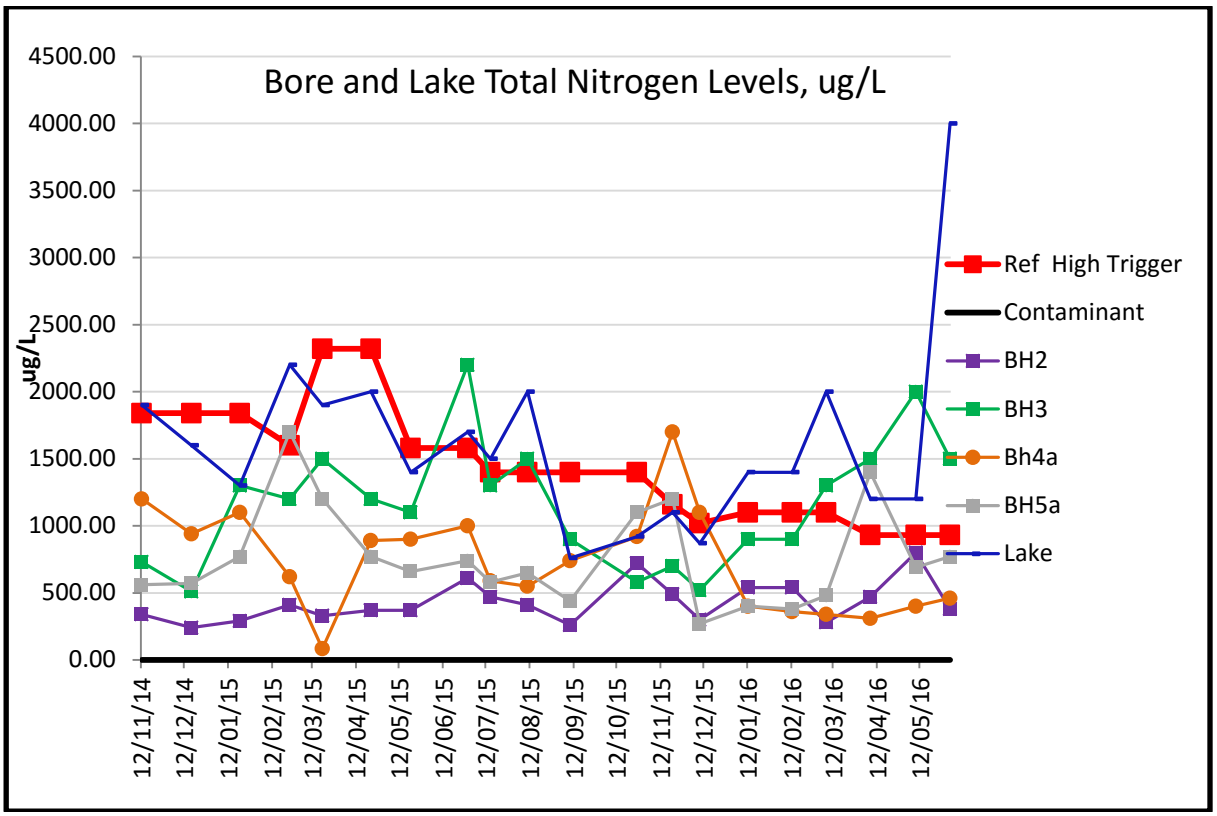

Bore and Lake Iron Levels, ug/L
ug/l
600.00
500.00
400.00
300.00
200.00
100.00
0.00
12/11/14
12/12/14
12/01/15
12/02/15
12/03/15
12/04/15
12/05/15
12/06/15
12/07/15
12/08/15
12/09/15
12/10/15
12/11/15
12/12/15
12/01/16
12/02/16
12/03/16
12/04/16
12/05/16
Ref High Trigger
Contaminant
BH2
BH3
Bh4a

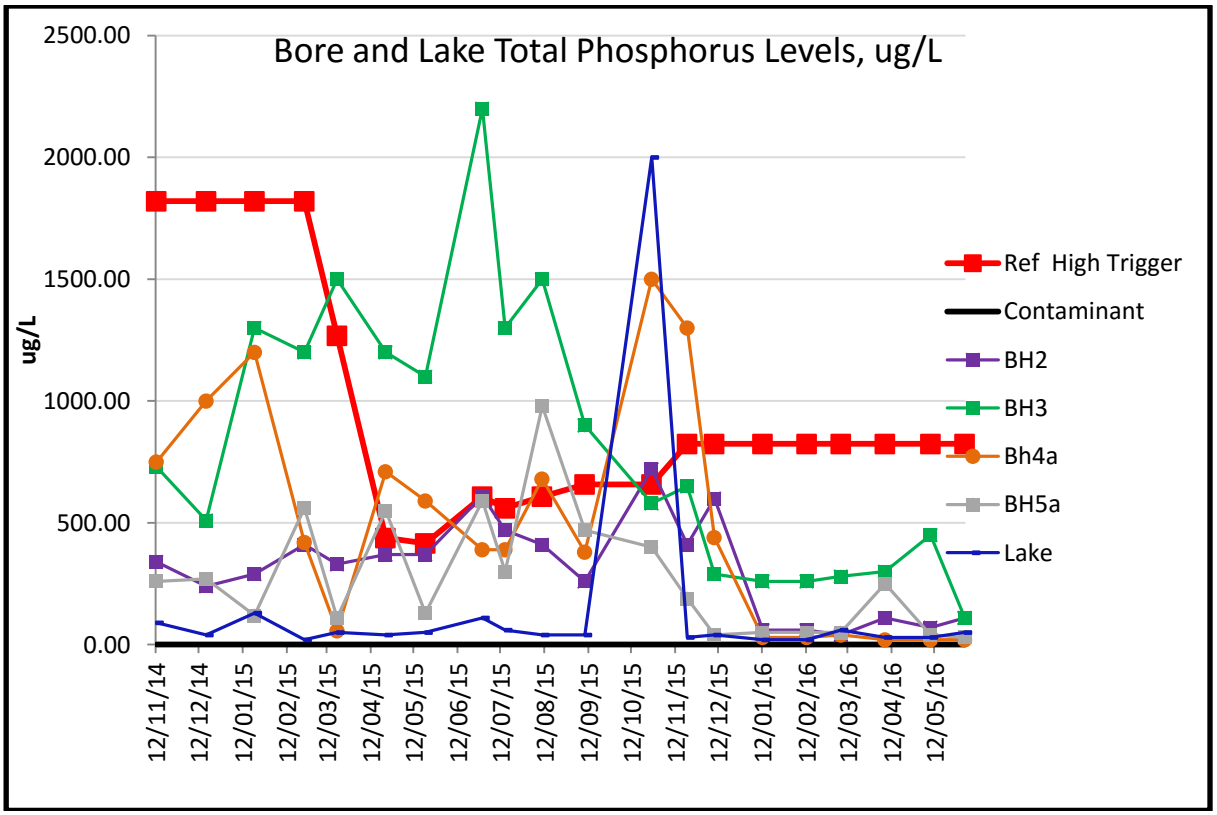

Bore and Lake Lead Levels, ug/L
12.00
10.00
8.00
6.00
4.00
2.00
0.00
ug/l
12/11/14
12/12/14
12/01/15
12/02/15
12/03/15
12/04/15
12/05/15
12/06/15
12/07/15
12/08/15
12/09/15
12/10/15
12/11/15
12/12/15
12/01/16
12/02/16
12/03/16
12/04/16
12/05/16
Ref High Trigger
Contaminant
BH2
BH3
Bh4a
BH5a
Lake

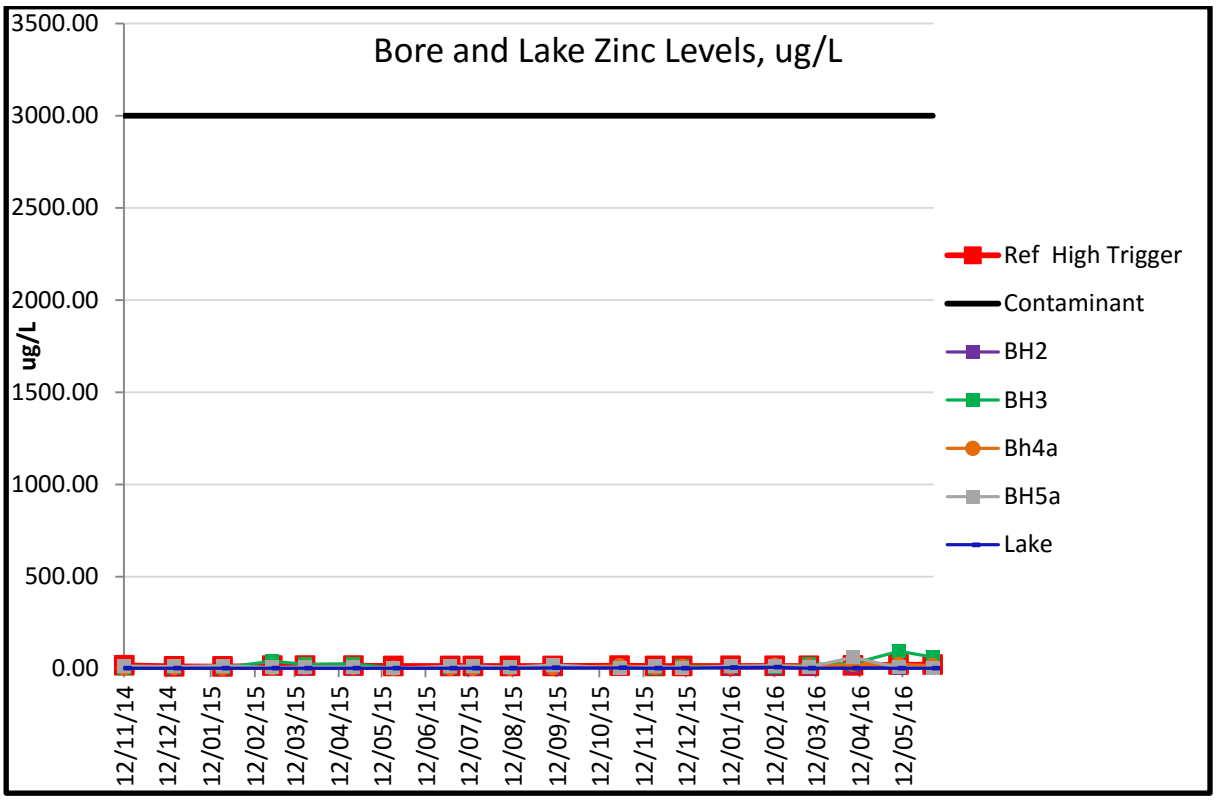

Bore and Lake Mercury Levels, ug/L
1.20
1.00
0.80
0.60
0.40
0.20
0.00
ug/l
12/11/14
12/12/14
12/01/15
12/02/15
12/03/15
12/04/15
12/05/15
12/06/15
12/07/15
12/08/15
12/09/15
12/10/15
12/11/15
12/12/15
12/01/16
12/02/16
12/03/16
12/04/16
12/05/16
Ref High Trigger
Contaminant
BH2
BH3
Bh4a
BH5a
Lake

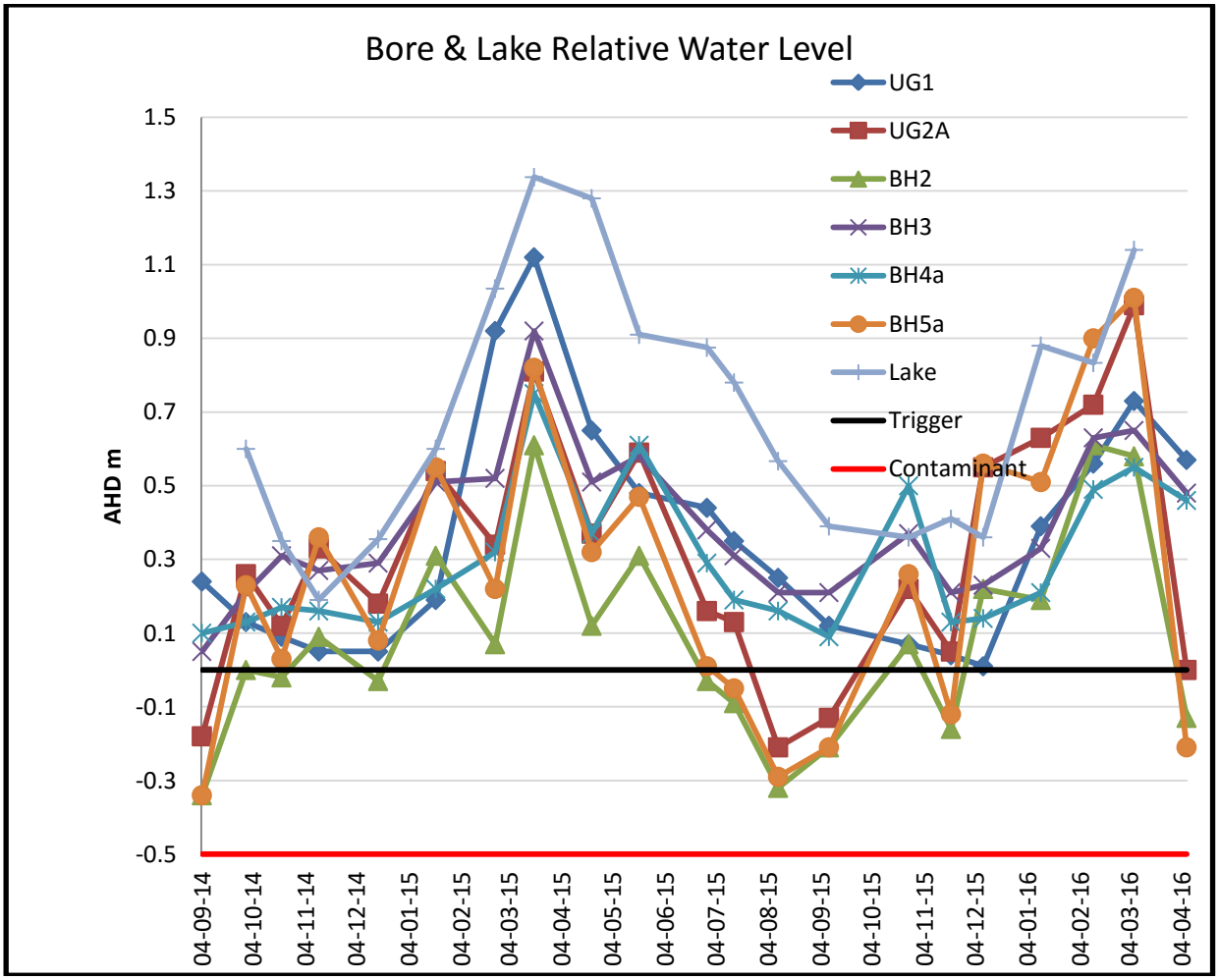

Bore and Lake pH levels
9.00
8.50
8.00
7.50
7.00
6.50
6.00
5.50
5.00
4.50
12/11/14
12/12/14
12/01/15
12/02/15
12/03/15
12/04/15
12/05/15
12/06/15
12/07/15
12/08/15
12/09/15
12/10/15
12/11/15
12/12/15
12/01/16
12/02/16
12/03/16
12/04/16
12/05/16
Ref Low
Ref High Trigger
Contaminant
BH2
BH3
Bh4a
BH5a

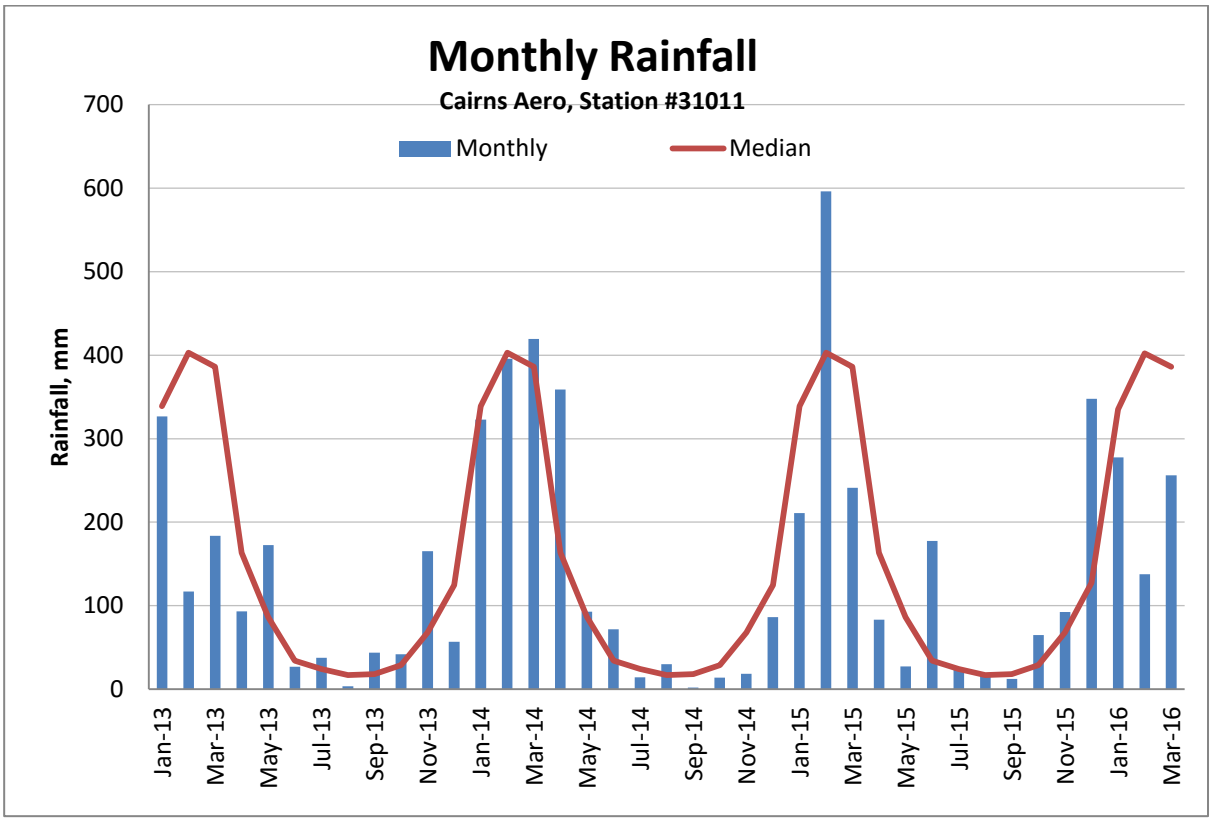

Bore and Lake Sulphate Levels, mg/L
mg/L
900.00
800.00
700.00
600.00
500.00
400.00
300.00
200.00
100.00
0.00
12/11/14
12/12/14
12/01/15
12/02/15
12/03/15
12/04/15
12/05/15
12/06/15
12/07/15
12/08/15
12/09/15
12/10/15
12/11/15
12/12/15
12/01/16
12/02/16
12/03/16
12/04/16
12/05/16
Ref High Trigger
Contaminant
BH2
BH3
Bh4a
BH5a
Lake


Bore and Lake Total Nitrogen Levels, ug/L
ug/L
4500.00
4000.00
3500.00
3000.00
2500.00
2000.00
1500.00
1000.00
500.00
0.00
12/11/14
12/12/14
12/01/15
12/02/15
12/03/15
12/04/15
12/05/15
12/06/15
12/07/15
12/08/15
12/09/15
12/10/15
12/11/15
12/12/15
12/01/16
12/02/16
12/03/16
12/04/16
12/05/16
Ref High Trigger
Contaminant
BH2
BH3
Bh4a
BH5a
Lake


Bore and Lake Total Phosphorus Levels, ug/L
ug/L
2500.00
2000.00
1500.00
1000.00
500.00
0.00
12/11/14
12/12/14
12/01/15
12/02/15
12/03/15
12/04/15
12/05/15
12/06/15
12/07/15
12/08/15
12/09/15
12/10/15
12/11/15
12/12/15
12/01/16
12/02/16
12/03/16
12/04/16
12/05/16
Ref High Trigger
Contaminant
BH2
BH3
Bh4a
BH5a
Lake


Bore and Lake Zinc Levels, ug/L
ug/L
3500.00
3000.00
2500.00
2000.00
1500.00
1000.00
500.00
0.00
12/11/14
12/12/14
12/01/15
12/02/15
12/03/15
12/04/15
12/05/15
12/06/15
12/07/15
12/08/15
12/09/15
12/10/15
12/11/15
12/12/15
12/01/16
12/02/16
12/03/16
12/04/16
12/05/16
Ref High Trigger
Contaminant
BH2
BH3
Bh4a
BH5a
Lake


Bore & Lake Relative Water Level
AHD m
1.5
1.3
1.1
0.9
0.7
0.5
0.3
0.1
-0.1
-0.3
-0.5
04-09-14
04-10-14
04-11-14
04-12-14
04-01-15
04-02-15
04-03-15
04-04-15
04-05-15
04-06-15
04-07-15
04-08-15
04-09-15
04-10-15
04-11-15
04-12-15
04-01-16
04-02-16
04-03-16
04-04-16
UG1
UG2A
BH2
BH3
BH4a
BH5a
Lake
Trigger
Contaminant


Monthly Rainfall
Cairns Aero, Station #31011
Monthly
Median
Rainfall, mm
700
600
500
400
300
200
100
0
Jan-13
Mar-13
May-13
Jul-13
Sep-13
Nov-13
Jan-14
Mar-14
May-14
Jul-14
Sep-14
Nov-14
Jan-15
Mar-15
May-15
Jul-15
Sep-15
Nov-15
Jan-16
Mar-16

APPENDIX D

2016 Borehole and CPT Reports

REPORT OF BOREHOLE: BH1

SHEET: 1 OF 1

CLIENT: FCG
PROJECT: Revised EIA
LOCATION: Northern Sands
JOB NO: 1546223

COORDS: 363630.0 m E 8136179.0 m N MGA94 56
SURFACE RL: DATUM: AHD
INCLINATION: -90°
HOLE DEPTH: 6.00 m

DRILL RIG: HV1
CONTRACTOR:
LOGGED: DSS DATE: 20/9/16
CHECKED: MSC DATE: 19/12/16

Drilling					Sampling		Field Material Description					
METHOD	PENETRATION RESISTANCE	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	USCS SYMBOL	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	PIEZOMETER DETAILS
ADH	L		0	0.20					TOPSOIL	M	VS	Stick up
									Clayey SAND grey			Cement
			1	1.00					Sandy CLAY grey	D	S	50mm PVC casing Bentonite
			2							W	VS	Sand
			3	3.00					SAND coarse grained, grey		S	Factory Slotted 500 mm PVC Screen
			4									
			5									
			6						END OF BOREHOLE @ 6.00 m GROUNDWATER NOT ENCOUNTERED			

REPORT OF BOREHOLE: BH2

SHEET: 1 OF 1

CLIENT: FCG
PROJECT: Revised EIA
LOCATION: Northern Sands
JOB NO: 1546223

COORDS: 364376.0 m E 8135443.0 m N MGA94 56
SURFACE RL: DATUM: AHD
INCLINATION: -90°
HOLE DEPTH: 6.00 m

DRILL RIG: HV1
CONTRACTOR:
LOGGED: DSS DATE: 20/9/16
CHECKED: MSC DATE: 19/12/16

Drilling					Sampling		Field Material Description					
METHOD	PENETRATION RESISTANCE	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	USCS SYMBOL	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	PIEZOMETER DETAILS
ADH	L	2m	0	0.20					TOPSOIL	M	VS	Stick up
			1						Clayey SAND medium grained, grey			Cement 50mm PVC casing Bentonite
			2	2.00					Clayey SAND fine grained, grey	W		Sand
			3							M	S	Factory Slotted 500 mm PVC Screen
			4									
			5									
			6						END OF BOREHOLE @ 6.00 m GROUNDWATER ENCOUNTERED @ 2.00 m DEPTH			

This report of borehole must be read in conjunction with accompanying notes and abbreviations. It has been prepared for environmental purposes only, without attempt to consider geotechnical properties or the geotechnical significance of the materials encountered. As such it should not be relied upon for geotechnical purposes.

GAP gINT FN. F01d RL3

REPORT OF BOREHOLE: BH3

SHEET: 1 OF 1

CLIENT: FCG
PROJECT: Revised EIA
LOCATION: Northern Sands
JOB NO: 1546223

COORDS: 364302.0 m E 8135127.0 m N MGA94 56
SURFACE RL: DATUM: AHD
INCLINATION: -90°
HOLE DEPTH: 12.00 m

DRILL RIG: HV1
CONTRACTOR:
LOGGED: DSS DATE: 20/9/16
CHECKED: MSC DATE: 19/12/16

Drilling					Sampling		Field Material Description					
METHOD	PENETRATION RESISTANCE	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	USCS SYMBOL	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	PIEZOMETER DETAILS
ADH	L	2m ▽	0	0.20					TOPSOIL	M	VS	Stick up
									Clayey SAND grey			
				1.00					Sandy CLAY medium plasticity, grey			Cement
			2									50mm PVC casing
												Bentonite
			4							W		
												Sand
				6.00					Clayey SAND grey		S	
			6							M		
			8									Factory Slotted 500 mm PVC Screen
				9.50					CLAY			
	M			10.00					Sandy CLAY red	D	St	
			10									
			12						END OF BOREHOLE @ 12.00 m GROUNDWATER ENCOUNTERED @ 2.00 m DEPTH			
			14									

REPORT OF BOREHOLE: GA04

SHEET: 1 OF 1

CLIENT: Flanagan Consulting Group
PROJECT: EIS Stage 1- Port Development
LOCATION: Northern Sands
JOB NO: 1546223

COORDS: 364331.6 m E 8135689.9 m N MGA94 56
SURFACE RL: 3.58 m DATUM: AHD
INCLINATION: -90°
HOLE DEPTH: 6.00 m

DRILL RIG: Ezi Probe
CONTRACTOR:
LOGGED: JL DATE: 23/11/16
CHECKED: MSC DATE: 19/12/16

Drilling					Sampling		Field Material Description					
METHOD	PENETRATION RESISTANCE	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	USCS SYMBOL	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	PIEZOMETER DETAILS
												0.9mm Stick up
PT			0	3.58					TOPSOIL: Sandy Silty CLAY high plasticity, brown, fine sand, with some roots <2mm	D		
				0.37 3.21					Sandy Silty CLAY high plasticity, brown			
			1	1.00 2.58					Sandy Silty CLAY high plasticity, pale brown, orange, fine to coarse grained sand, trace fine quartz gravel	D - M	F	50mm UPVC class 18 Blank casing Cement/grout
			2	2.46 1.12 2.70					Silty SAND fine to coarse grained, brown, orange brown, with some fine grained, subangular gravel			
				0.78					Sandy Silty CLAY high plasticity, brown, grey, fine to coarse grained sand			
			3	3.50					Silty SAND fine to coarse grained, grey, brown, orange brown, with some fine quartz gravel			Bentonite
				0.08					SAND medium to coarse grained, orange brown, with some fine to medium quartz gravel			
			4									50mm UPVC class 18, Screen, 1mm aparture size Gravel pack
			5	5.00 -1.42					SAND medium to coarse grained, grey, orange brown, with some silt, trace dark grey, fine to medium grained, shale gravel	W	L	
			6	-2.42					END OF BOREHOLE @ 6.00 m			
			7									
			8									
			9									

REPORT OF BOREHOLE: GA05

SHEET: 1 OF 1

CLIENT: Flanagan Consulting Group
PROJECT: Port Development ETS S1
LOCATION: Northern Sands
JOB NO: 1546223

COORDS: MGA94 56
SURFACE RL: DATUM: AHD
INCLINATION: -90°
HOLE DEPTH: 1.50 m

DRILL RIG: Eziprobe
CONTRACTOR: Golder
LOGGED: JJP DATE: 28/1/16
CHECKED: MSC DATE: 19/12/16

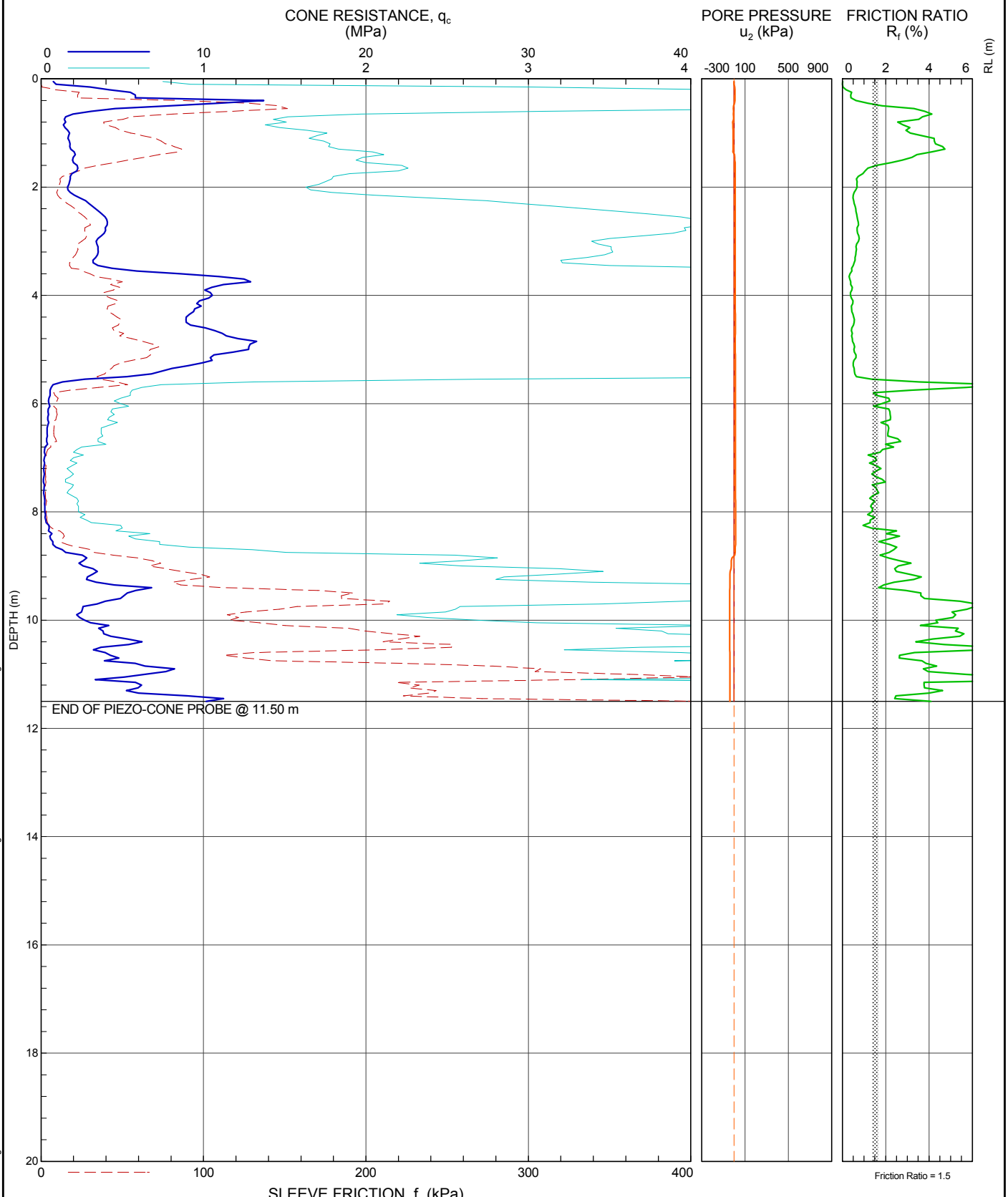
Drilling					Sampling		Field Material Description					
METHOD	PENETRATION RESISTANCE	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	USCS SYMBOL	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
PT	L	GWNE	0.0					ML	TOPSOIL: Sandy SILT fine to medium, grey brown, with some rootlets and clay	D - M	St	
				0.45								
			0.5		GA05-DS1 0.60-0.90 m			SM	Silty SAND fine grained, grey brown and grey, with some clay, (approx. 40% fines content)	M	MD	
			1.0									
				1.20								
					GA05-DS2 1.20-1.50 m			CI	Silty CLAY grey, with trace red brown pockets, with some fine grained sand and organics		F	
			1.5						END OF BOREHOLE @ 1.50 m TARGET DEPTH GROUNDWATER ENCOUNTERED @ m DEPTH			
			2.0									
			2.5									
			3.0									
			3.5									
			4.0									
			4.5									
			5.0									

REPORT OF PIEZO-CONE PROBE: CPT1

SHEET: 1 OF 1
CONE No.:
RIG:
CONTRACTOR: Geo Investigate
RECORDED: GZL DATE: 31/10/16
CHECKED: MSC DATE: 31/10/16

CLIENT: Flanagan Consulting Group
PROJECT: Cairns Shipping Development
LOCATION: Northern Sands
JOB NO: 1546223

COORDS: MGA94 56
SURFACE RL: DATUM: AHD
INCLINATION: -90°
HOLE DEPTH: 11.50 m



COMMENT:
Dissipation Test

This report of piezo-cone probe must be read in conjunction with accompanying notes and abbreviations. It has been prepared for geotechnical purposes only, without attempt to assess possible contamination. Any references to potential contamination are for information only and do not necessarily indicate the presence or absence of soil or groundwater contamination.

GAP gINT FN. F10
RL3

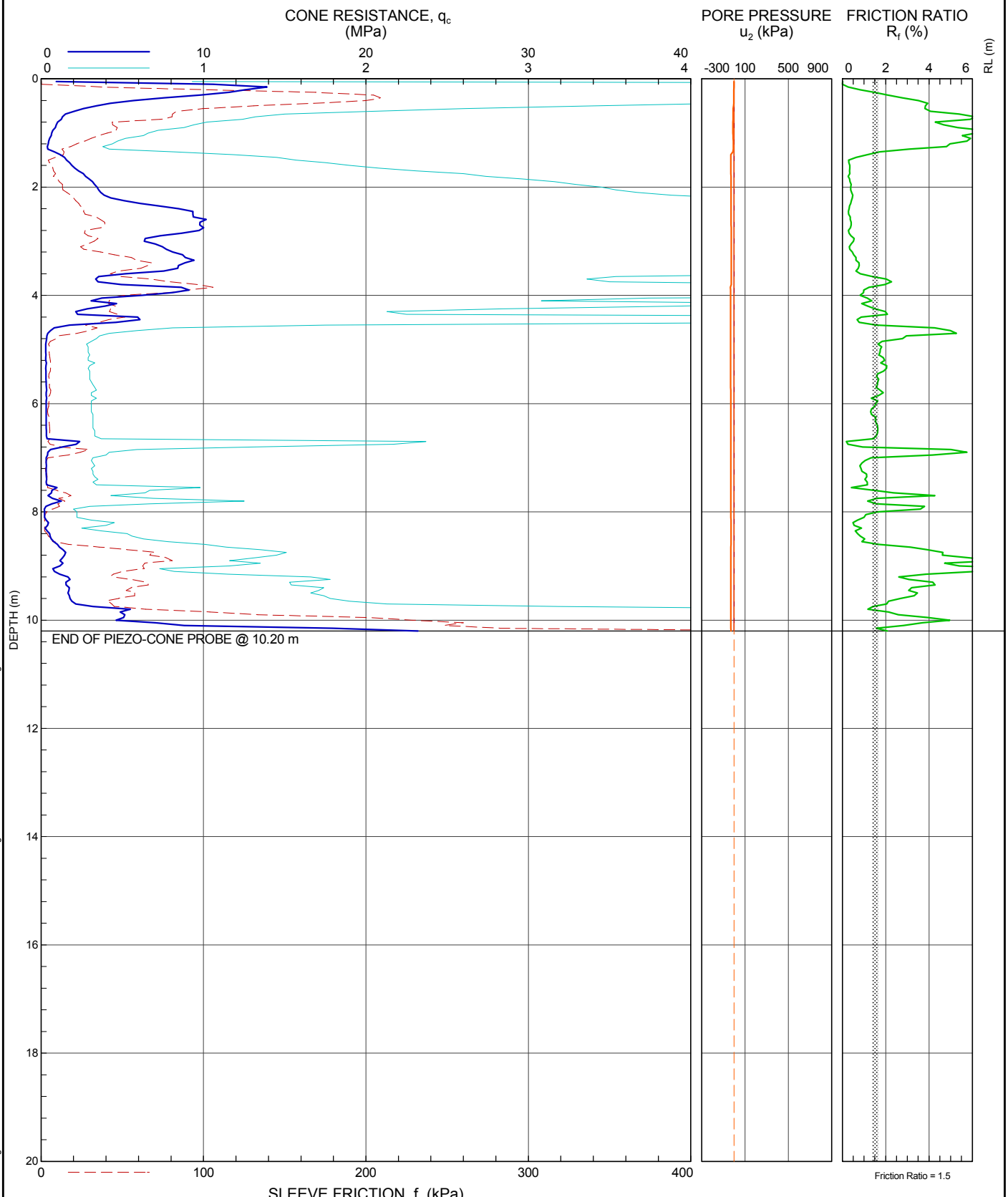
GAP 8_10.0 LIB.GLB Log GAP CPTU PIEZO CONE 2 1546223 CPT DATA ONLY.GPJ <<DrawingFile>> 23/01/2017 14:19 8.30.004 Datgel Tools

REPORT OF PIEZO-CONE PROBE: CPT2

SHEET: 1 OF 1
CONE No.:
RIG:
CONTRACTOR: Geo Investigate
RECORDED: GZL DATE: 31/10/16
CHECKED: MSC DATE: 31/10/16

CLIENT: Flanagan Consulting Group
PROJECT: Cairns Shipping Development
LOCATION: Northern Sands
JOB NO: 1546223

COORDS: MGA94 56
SURFACE RL: DATUM: AHD
INCLINATION: -90°
HOLE DEPTH: 10.20 m



COMMENT:
Dissipation Test

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GAP gINT FN. F10 RL3

GAP 8_10.0 LIB.GLB Log GAP CPTU PIEZO CONE 2 1546223 CPT DATA ONLY.GPJ <<DrawingFile>> 23/01/2017 14:19 8.30.004 Datgel Tools

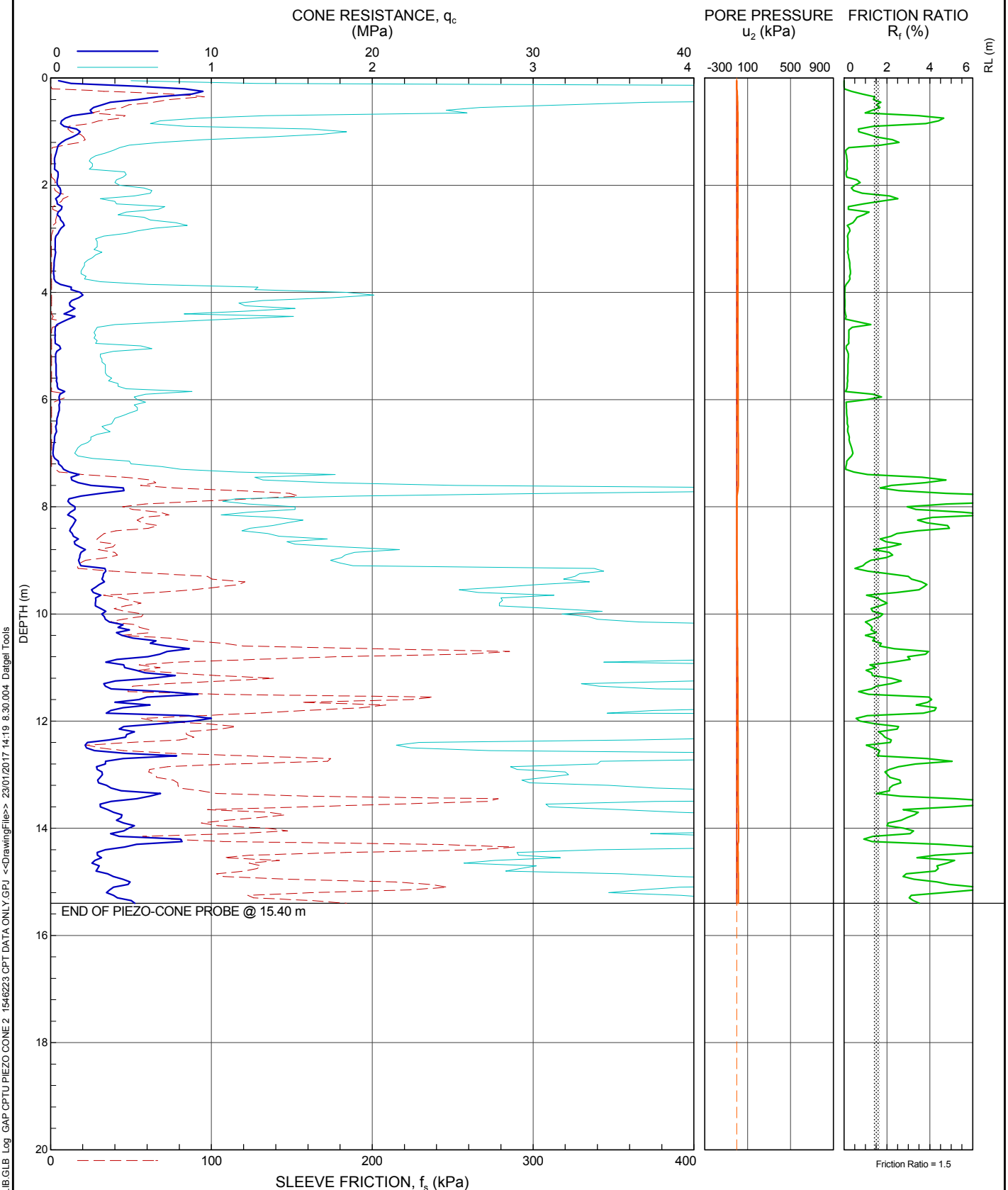
REPORT OF PIEZO-CONE PROBE: CPT3

Golder Associates

SHEET: 1 OF 1
CONE No.:
RIG:
CONTRACTOR: Geo Investigate
RECORDED: GZL DATE: 31/10/16
CHECKED: MSC DATE: 31/10/16

CLIENT: Flanagan Consulting Group
PROJECT: Cairns Shipping Development
LOCATION: Northern Sands
JOB NO: 1546223

COORDS: MGA94 56
SURFACE RL: DATUM: AHD
INCLINATION: -90°
HOLE DEPTH: 15.40 m



COMMENT:
Dissipation Test

This report of piezo-cone probe must be read in conjunction with accompanying notes and abbreviations. It has been prepared for geotechnical purposes only, without attempt to assess possible contamination. Any references to potential contamination are for information only and do not necessarily indicate the presence or absence of soil or groundwater contamination.

GAP gINT FN. F10 RL3

GAP 8_10.0 LIB.GLB Log GAP CPTU PIEZO CONE 2 1546223 CPT DATA ONLY.GPJ <<DrawingFile>> 23/01/2017 14:19 8.30.004 Datgel Tools

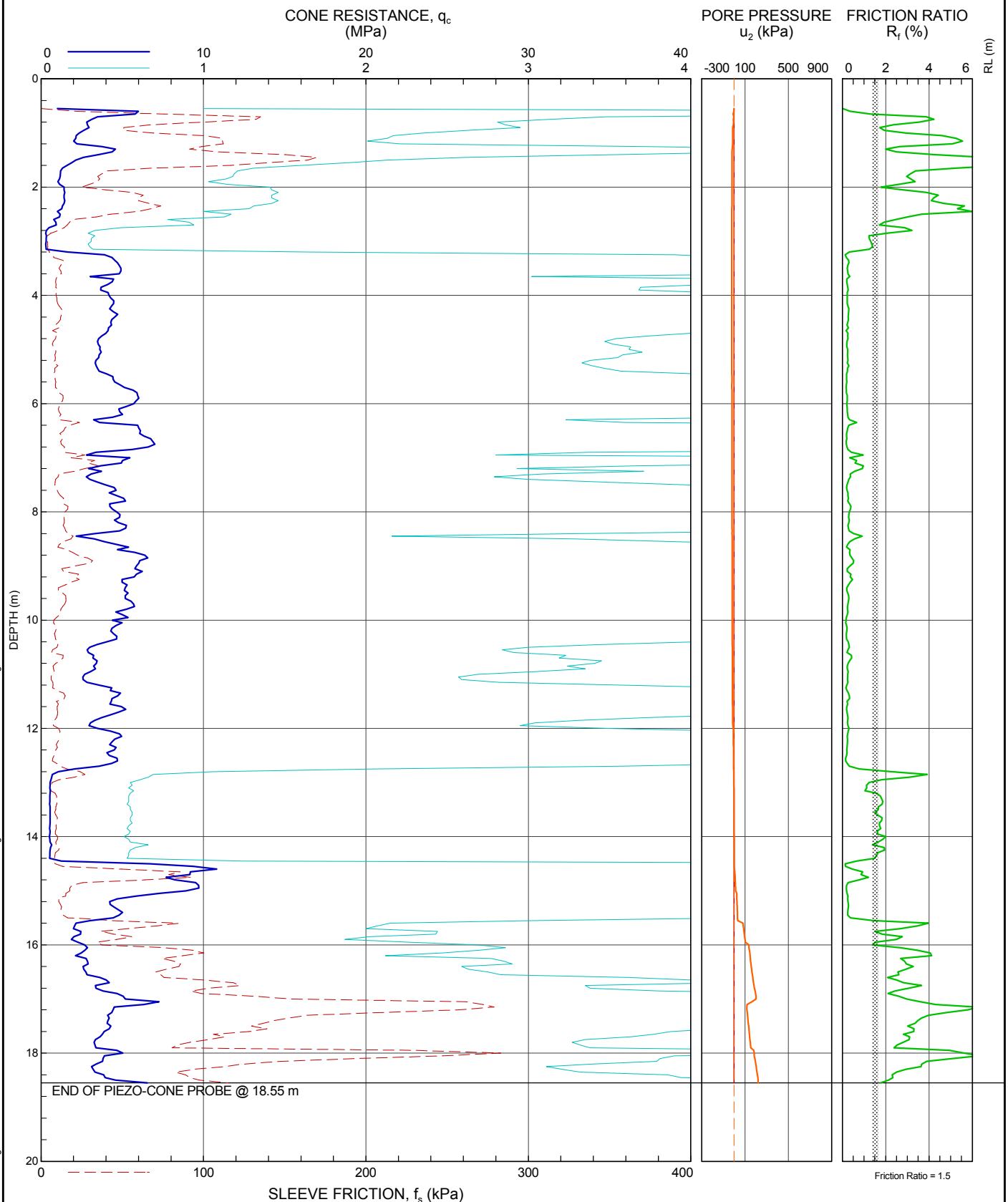
REPORT OF PIEZO-CONE PROBE: CPT4

Golder Associates

SHEET: 1 OF 1
CONE No.:
RIG:
CONTRACTOR: Geo Investigate
RECORDED: GZL DATE: 28/10/16
CHECKED: MSC DATE: 28/10/16

CLIENT: Flanagan Consulting Group
PROJECT: Cairns Shipping Development
LOCATION: Northern Sands
JOB NO: 1546223

COORDS: MGA94 56
SURFACE RL: DATUM: AHD
INCLINATION: -90°
HOLE DEPTH: 18.55 m



COMMENT:
Dissipation Test

This report of piezo-cone probe must be read in conjunction with accompanying notes and abbreviations. It has been prepared for geotechnical purposes only, without attempt to assess possible contamination. Any references to potential contamination are for information only and do not necessarily indicate the presence or absence of soil or groundwater contamination.

GAP gINT FN. F10
RL3

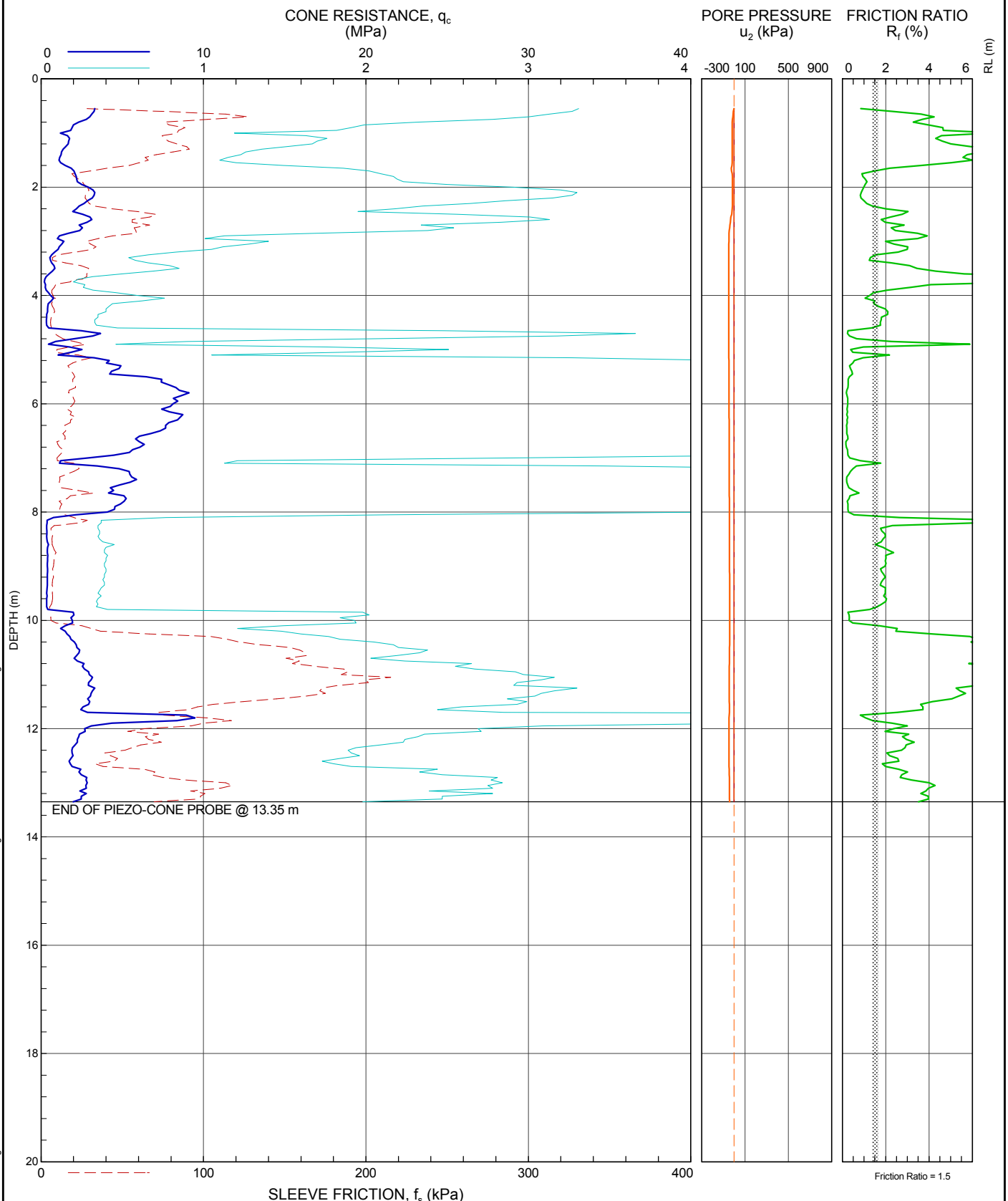
GAP 8_10.0 LIB.GLB Log GAP CPTU PIEZO CONE 2 1546223 CPT DATA ONLY.GPJ <<DrawingFile>> 23/01/2017 14:19 8.30.004 Datgel Tools

REPORT OF PIEZO-CONE PROBE: CPT5

SHEET: 1 OF 1
CONE No.:
RIG:
CONTRACTOR: Geo Investigate
RECORDED: GZL DATE: 28/10/16
CHECKED: MSC DATE: 28/10/16

CLIENT: Flanagan Consulting Group
PROJECT: Cairns Shipping Development
LOCATION: Northern Sands
JOB NO: 1546223

COORDS: MGA94 56
SURFACE RL: DATUM: AHD
INCLINATION: -90°
HOLE DEPTH: 13.35 m



COMMENT:
Dissipation Test

This report of piezo-cone probe must be read in conjunction with accompanying notes and abbreviations. It has been prepared for geotechnical purposes only, without attempt to assess possible contamination. Any references to potential contamination are for information only and do not necessarily indicate the presence or absence of soil or groundwater contamination.

GAP gINT FN. F10
RL3

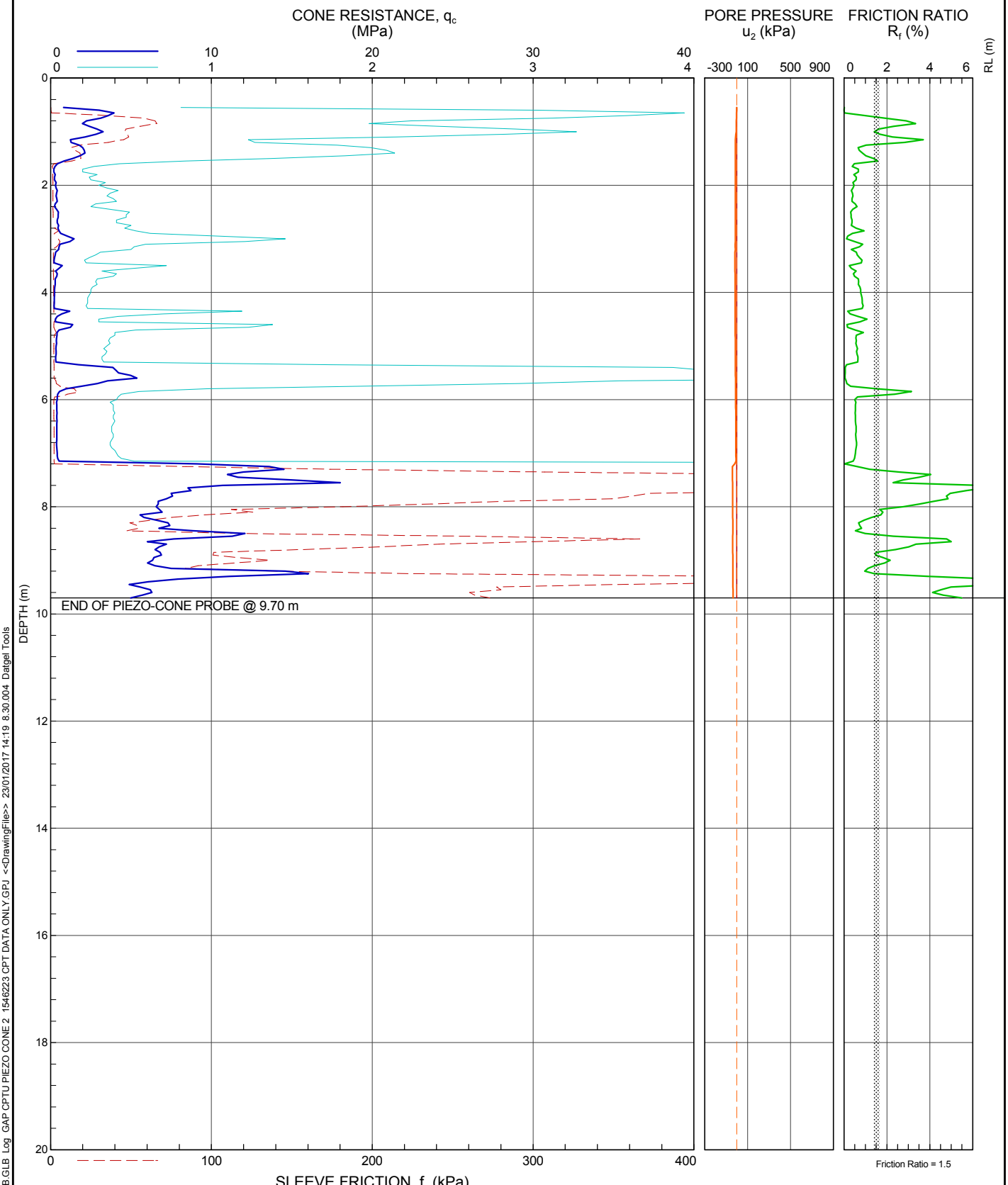
GAP 8_10.0 LIB.GLB Log GAP CPTU PIEZO CONE 2 1546223 CPT DATA ONLY.GPJ <<DrawingFile>> 23/01/2017 14:19 8.30.004 Datgel Tools

REPORT OF PIEZO-CONE PROBE: CPT6

SHEET: 1 OF 1
CONE No.:
RIG:
CONTRACTOR: Geo Investigate
RECORDED: GZL DATE: 28/10/16
CHECKED: MSC DATE: 28/10/16

CLIENT: Flanagan Consulting Group
PROJECT: Cairns Shipping Development
LOCATION: Northern Sands
JOB NO: 1546223

COORDS: MGA94 56
SURFACE RL: DATUM: AHD
INCLINATION: -90°
HOLE DEPTH: 9.70 m



COMMENT:
Dissipation Test

This report of piezo-cone probe must be read in conjunction with accompanying notes and abbreviations. It has been prepared for geotechnical purposes only, without attempt to assess possible contamination. Any references to potential contamination are for information only and do not necessarily indicate the presence or absence of soil or groundwater contamination.

GAP gINT FN. F10
RL3

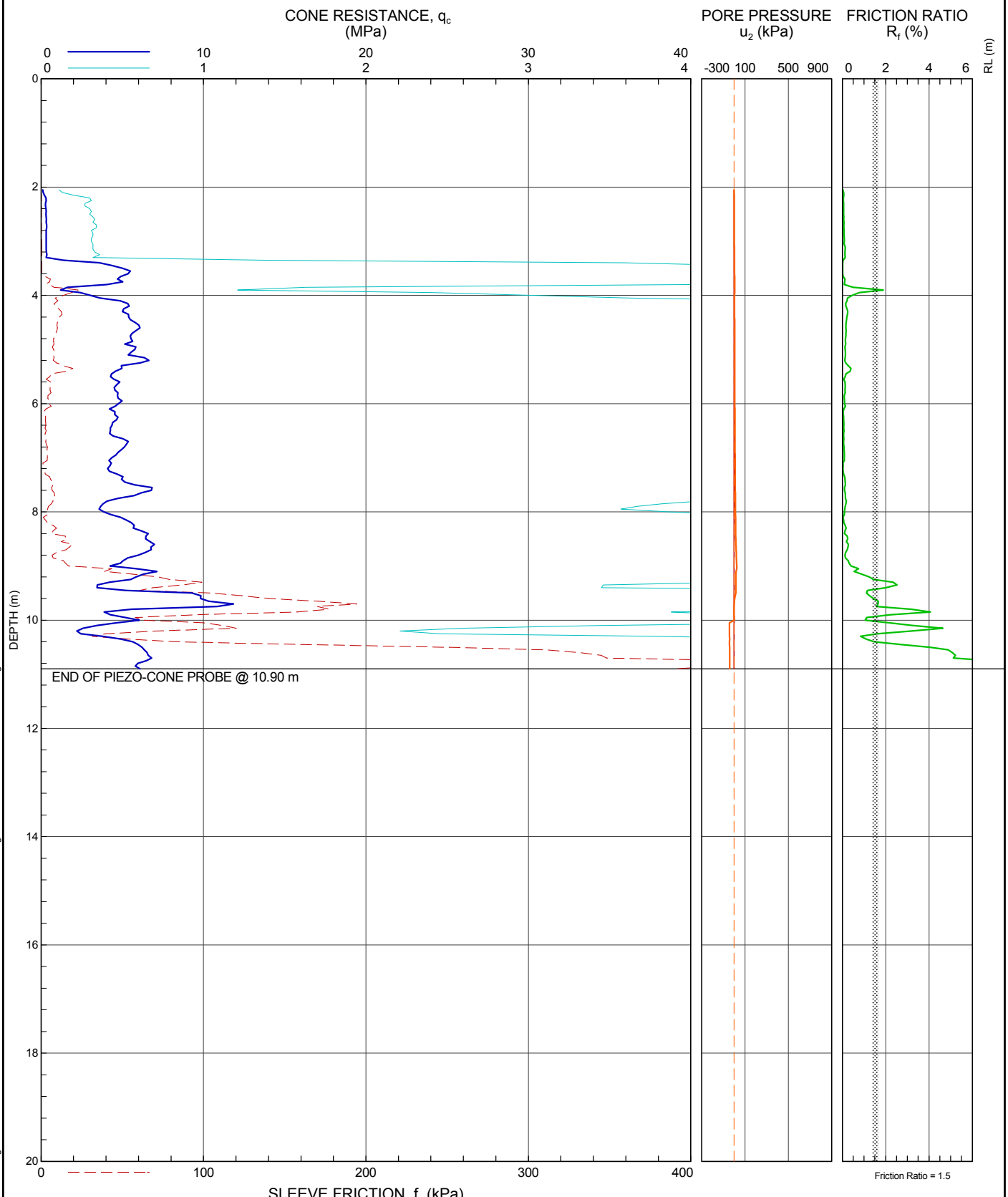
GAP 8_10.0 LIB.GLB Log GAP CPTU PIEZO CONE 2 1546223 CPT DATA ONLY.GPJ <<DrawingFile>> 23/01/2017 14:19 8.30.004 Datgel Tools

REPORT OF PIEZO-CONE PROBE: CPT7

SHEET: 1 OF 1
CONE No.:
RIG:
CONTRACTOR: Geo Investigate
RECORDED: GZL DATE: 28/10/16
CHECKED: MSC DATE: 28/10/16

CLIENT: Flanagan Consulting Group
PROJECT: Cairns Shipping Development
LOCATION: Northern Sands
JOB NO: 1546223

COORDS: MGA94 56
SURFACE RL: DATUM: AHD
INCLINATION: -90°
HOLE DEPTH: 10.90 m



COMMENT:
Dissipation Test

This report of piezo-cone probe must be read in conjunction with accompanying notes and abbreviations. It has been prepared for geotechnical purposes only, without attempt to assess possible contamination. Any references to potential contamination are for information only and do not necessarily indicate the presence or absence of soil or groundwater contamination.

GAP gINT FN. F10
RL3

GAP 8_10.0 LIB.GLB Log GAP CPTU PIEZO CONE 2 1546223 CPT DATA ONLY.GPJ <<DrawingFile>> 23/01/2017 14:19 8.30.004 Datgel Tools

METHOD OF SOIL DESCRIPTION USED ON BOREHOLE AND TEST PIT REPORTS

 FILL

 GRAVEL (GP or GW)

 SAND (SP or SW)

 SILT (ML or MH)

 CLAY (CL, CI or CH)

 ORGANIC SOILS (OL or OH or Pt)

 COBBLES or BOULDERS

Combinations of these basic symbols may be used to indicate mixed materials such as sandy clay.

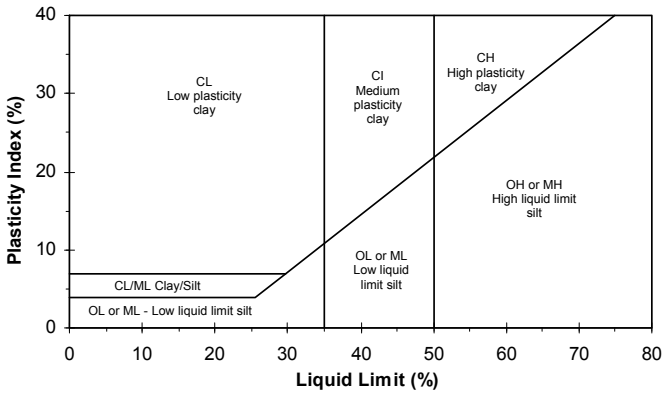
CLASSIFICATION AND INFERRED STRATIGRAPHY

Soil and Rock is classified and described in Reports of Boreholes and Test Pits using the preferred method given in AS1726 – 1993, (Amdt1 – 1994 and Amdt2 – 1994), Appendix A. The material properties are assessed in the field by visual/tactile methods.

Particle Size

Major Division	Sub Division	Particle Size
BOULDERS		> 200 mm
COBBLES		63 to 200 mm
GRAVEL	Coarse	20 to 63 mm
	Medium	6.0 to 20 mm
	Fine	2.0 to 6.0 mm
SAND	Coarse	0.6 to 2.0 mm
	Medium	0.2 to 0.6 mm
	Fine	0.075 to 0.2 mm
SILT		0.002 to 0.075 mm
CLAY		< 0.002 mm

Plasticity Properties



MOISTURE CONDITION

AS1726 - 1993

Symbol	Term	Description
D	Dry	Sands and gravels are free flowing. Clays & Silts may be brittle or friable and powdery.
M	Moist	Soils are darker than in the dry condition & may feel cool. Sands and gravels tend to cohere.
W	Wet	Soils exude free water. Sands and gravels tend to cohere.

CONSISTENCY AND DENSITY

AS1726 - 1993

Symbol	Term	Undrained Shear Strength
VS	Very Soft	0 to 12 kPa
S	Soft	12 to 25 kPa
F	Firm	25 to 50 kPa
St	Stiff	50 to 100 kPa
VSt	Very Stiff	100 to 200 kPa
H	Hard	Above 200 kPa

Symbol	Term	Density Index %	SPT "N" #
VL	Very Loose	Less than 15	0 to 4
L	Loose	15 to 35	4 to 10
MD	Medium Dense	35 to 65	10 to 30
D	Dense	65 to 85	30 to 50
VD	Very Dense	Above 85	Above 50

In the absence of test results, consistency and density may be assessed from correlations with the observed behaviour of the material.

SPT correlations are not stated in AS1726 – 1993, and may be subject to corrections for overburden pressure and equipment type.

EXPLANATION OF NOTES, ABBREVIATIONS & TERMS USED ON BOREHOLE AND TEST PIT REPORTS

DRILLING/EXCAVATION METHOD

AS*	Auger Screwing	RD	Rotary blade or drag bit	NQ	Diamond Core - 47 mm
AD*	Auger Drilling	RT	Rotary Tricone bit	NMLC	Diamond Core - 52 mm
*V	V-Bit	RAB	Rotary Air Blast	HQ	Diamond Core - 63 mm
*T	TC-Bit, e.g. ADT	RC	Reverse Circulation	HMLC	Diamond Core □63mm
HA	Hand Auger	PT	Push Tube	BH	Tractor Mounted Backhoe
ADH	Hollow Auger	CT	Cable Tool Rig	EX	Tracked Hydraulic Excavator
DTC	Diatube Coring	JET	Jetting	EE	Existing Excavation
WB	Washbore or Bailer	NDD	Non-destructive digging	HAND	Excavated by Hand Methods

PENETRATION/EXCAVATION RESISTANCE

L **Low resistance.** Rapid penetration possible with little effort from the equipment used.

M **Medium resistance.** Excavation/possible at an acceptable rate with moderate effort from the equipment used.

H **High resistance** to penetration/excavation. Further penetration is possible at a slow rate and requires significant effort from the equipment.

R **Refusal or Practical Refusal.** No further progress possible without the risk of damage or unacceptable wear to the digging implement or machine.

These assessments are subjective and are dependent on many factors including the equipment power, weight, condition of excavation or drilling tools, and the experience of the operator.

WATER

▽	Water level at date shown	◁	Partial water loss
▷	Water inflow	◀	Complete water loss

GROUNDWATER NOT OBSERVED	The observation of groundwater, whether present or not, was not possible due to drilling water, surface seepage or cave in of the borehole/test pit.
GROUNDWATER NOT ENCOUNTERED	The borehole/test pit was dry soon after excavation. However, groundwater could be present in less permeable strata. Inflow may have been observed had the borehole/test pit been left open for a longer period.

SAMPLING AND TESTING

SPT	Standard Penetration Test to AS1289.6.3.1-2004
4,7,11 N□18	4,7,11 □ Blows per 150mm. N □ Blows per 300mm penetration following 150mm seating
30/80mm	Where practical refusal occurs, the blows and penetration for that interval are reported
RW	Penetration occurred under the rod weight only
HW	Penetration occurred under the hammer and rod weight only
HB	Hammer double bouncing on anvil
DS	Disturbed sample
BDS	Bulk disturbed sample
G	Gas Sample
W	Water Sample
FP	Field permeability test over section noted
FV	Field vane shear test expressed as uncorrected shear strength (s_v □ peak value, s_r □ residual value)
PID	Photoionisation Detector reading in ppm
PM	Pressuremeter test over section noted
PP	Pocket penetrometer test expressed as instrument reading in kPa
U63	Thin walled tube sample - number indicates nominal sample diameter in millimetres
WPT	Water pressure tests
DCP	Dynamic cone penetration test
CPT	Static cone penetration test
CPTu	Static cone penetration test with pore pressure (u) measurement

Ranking of Visually Observable Contamination and Odour (for specific soil contamination assessment projects)

R □ 0	No visible evidence of contamination	R □ A	No non-natural odours identified
R □ 1	Slight evidence of visible contamination	R □ B	Slight non-natural odours identified
R □ 2	Visible contamination	R □ C	Moderate non-natural odours identified
R □ 3	Significant visible contamination	R □ D	Strong non-natural odours identified

ROCK CORE RECOVERY

TCR □ Total Core Recovery (%)

$$= \frac{\text{Length of core recovered}}{\text{Length of core run}} \times 100$$

SCR □ Solid Core Recovery (%)

$$= \frac{\sum \text{Length of cylindrical core recovered}}{\text{Length of core run}} \times 100$$

RQD □ Rock Quality Designation (%)

$$= \frac{\sum \text{Axial lengths of core} > 100 \text{ mm}}{\text{Length of core run}} \times 100$$

APPENDIX E

Water Quality Laboratory Results and Field Data.

ANALYTICAL REPORT

Accreditation No. 2562

CLIENT DETAILS		LABORATORY DETAILS	
Contact	Darcy Simpson	Manager	Jon Dicker
Client	GOLDER ASSOCIATES PTY LTD	Laboratory	SGS Cairns Environmental
Address	PO BOX 5823 216 DRAPER ST CAIRNS QLD 4870	Address	Unit 2, 58 Comport St Portsmith QLD 4870
Telephone	07 4054 8200	Telephone	+61 07 4035 5111
Facsimile	07 4054 8201	Facsimile	+61 07 4035 5122
Email	dasimpson@golder.com.au	Email	AU.Environmental.Cairns@sgs.com
Project	**1546223 Northern Sands**	SGS Reference	**CE123168 R0**
Order Number	(Not specified)	Date Received	29 Sep 2016
Samples	3	Date Reported	11 Oct 2016

COMMENTS

Accredited for compliance with ISO/IEC 17025. NATA accredited laboratory 2562(3146)

SIGNATORIES

Anthony Nilsson
Operations Manager

Jon Dicker
Manager Northern QLD

Leanne Orsmond
Quality & Microbiology Coordinator

Maristela Ganzan
Metals Team Leader

Parameter	Units	LOR	Sample Number: CE123168.001 Sample Matrix: Water Sample Date: 29 Sep 2016 Sample Name: BH01	CE123168.002 Water 29 Sep 2016 BH02	CE123168.003 Water 29 Sep 2016 BH03
pH in water Method: AN101 Tested: 29/9/2016					
pH**	pH Units	0.1	**7.0**	**7.7**	**7.9**
Conductivity and TDS by Calculation - Water Method: AN106 Tested: 29/9/2016					
Conductivity @ 25 C	µS/cm	5	**230**	**11000**	**24000**
Total Dissolved Solids (by calculation)	mg/L	10	**140**	**6300**	**15000**
Alkalinity Method: AN135 Tested: 29/9/2016					
Total Alkalinity as CaCO3	mg/L	5	**41**	**1000**	**2300**
Bicarbonate Alkalinity as CaCO3	mg/L	5	**41**	**1000**	**2300**
Carbonate Alkalinity as CaCO3	mg/L	5	<5	<5	<5
Hydroxide Alkalinity as CaCO3	mg/L	5	<5	<5	<5
Acidity and Free CO2 Method: AN140 Tested: 29/9/2016					
Acidity to pH 8.3	mg CaCO3/L	5	**58**	**200**	**250**
Chloride by Discrete Analyser in Water Method: AN274 Tested: 5/10/2016					
Chloride, Cl	mg/L	1	**36**	**3000**	**7900**
Metals in Water (Dissolved) by ICPOES Method: AN320/AN321 Tested: 10/10/2016					
Aluminium, Al	mg/L	0.005	<0.005	**0.012**	**0.021**
Iron, Fe	mg/L	0.005	**0.048**	**0.31**	**0.16**
Sulphur as Sulphate, SO4	mg/L	0.5	**28**	**14**	**7.4**

Parameter	Units	LOR	Sample Number Sample Matrix Sample Date Sample Name	CE123168.001 Water 29 Sep 2016 BH01	CE123168.002 Water 29 Sep 2016 BH02	CE123168.003 Water 29 Sep 2016 BH03
Metals in Water (Total) by ICPOES	**Method: AN022/AN320**	**Tested: 5/10/2016**				
Total Iron	mg/L	0.005		**10**	**470**	**1.8**

QC SUMMARY

MB blank results are compared to the Limit of Reporting
LCS and MS spike recoveries are measured as the percentage of analyte recovered from the sample compared the the amount of analyte spiked into the sample.
DUP and MSD relative percent differences are measured against their original counterpart samples according to the formula : *the absolute difference of the two results divided by the average of the two results as a percentage*. Where the DUP RPD is 'NA' , the results are less than the LOR and thus the RPD is not applicable.

Acidity and Free CO2 Method: ME-(AU)-[ENV]AN140

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
Acidity to pH 8.3	LB039825	mg CaCO3/L	5	<5	0%	NA

Alkalinity Method: ME-(AU)-[ENV]AN135

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
Total Alkalinity as CaCO3	LB039828	mg/L	5	<5	3 - 11%	103%
Bicarbonate Alkalinity as CaCO3	LB039828	mg/L	5	<5		
Carbonate Alkalinity as CaCO3	LB039828	mg/L	5	<5		
Hydroxide Alkalinity as CaCO3	LB039828	mg/L	5	<5		

Chloride by Discrete Analyser in Water Method: ME-(AU)-[ENV]AN274

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
Chloride, Cl	LB039925	mg/L	1	<1	1 - 3%	107%

Conductivity and TDS by Calculation - Water Method: ME-(AU)-[ENV]AN106

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
Conductivity @ 25 C	LB039828	µS/cm	5	<5	0 - 1%	99%
Total Dissolved Solids (by calculation)	LB039828	mg/L	10	<10	1%	NA

Metals in Water (Total) by ICPOES Method: ME-(AU)-[ENV]AN022/AN320

Parameter	QC Reference	Units	LOR	LCS %Recovery
Total Iron	LB039917	mg/L	0.005	102%

Metals in Water (Dissolved) by ICPOES Method: ME-(AU)-[ENV]AN320/AN321

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
Aluminium, Al	LB040030	mg/L	0.005	<0.005	3%	99%
Iron, Fe	LB040030	mg/L	0.005	<0.005	0%	105%
Sulphur as Sulphate, SO4	LB040030	mg/L	0.5	<0.5	3%	NA

QC SUMMARY

MB blank results are compared to the Limit of Reporting
LCS and MS spike recoveries are measured as the percentage of analyte recovered from the sample compared the the amount of analyte spiked into the sample.
DUP and MSD relative percent differences are measured against their original counterpart samples according to the formula : *the absolute difference of the two results divided by the average of the two results as a percentage*. Where the DUP RPD is 'NA' , the results are less than the LOR and thus the RPD is not applicable.

pH in water **Method: ME-(AU)-[ENV]AN101**

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
pH**	LB039828	pH Units	0.1	5.5	0%	NA

METHOD SUMMARY

METHOD	METHODOLOGY SUMMARY
AN022/AN320	Total (acid soluble) Metals by ICP-OES: Samples are digested in nitric or nitric and hydrochloric acids prior to analysis for a wide range of metals and some non-metals. This solution is measured by Inductively Coupled Plasma. Solutions are aspirated into an argon plasma at 8000-10000K and emit characteristic energy or light as a result of electron transitions through unique energy levels. The emitted light is focused onto a diffraction grating where it is separated into components.
AN101	pH in Soil Sludge Sediment and Water: pH is measured electrometrically using a combination electrode (glass plus reference electrode) and is calibrated against 3 buffers purchased commercially. For soils, an extract with water is made at a ratio of 1:5 and the pH determined and reported on the extract. Reference APHA 4500-H+.
AN106	Conductivity and TDS by Calculation: Conductivity is measured by meter with temperature compensation and is calibrated against a standard solution of potassium chloride. Conductivity is generally reported as µmhos/cm or µS/cm @ 25°C. For soils, an extract with water is made at a ratio of 1:5 and the EC determined and reported on the extract, or calculated back to the as-received sample. Total Dissolved Salts can be estimated from conductivity using a conversion factor, which for natural waters, is in the range 0.55 to 0.75. SGS use 0.6. Reference APHA 2510 B.
AN135	Alkalinity (and forms of) by Titration: The sample is titrated with standard acid to pH 8.3 (P titre) and pH 4.5 (T titre) and permanent and/or total alkalinity calculated. The results are expressed as equivalents of calcium carbonate or recalculated as bicarbonate, carbonate and hydroxide. Reference APHA 2320. Internal Reference AN135
AN140	Acidity by Titration: The water sample is titrated with sodium hydroxide to designated pH end point. In a sample containing only carbon dioxide, bicarbonates and carbonates, titration to pH 8.3 at 25°C corresponds to stoichiometric neutralisation of carbonic acid to bicarbonate. Method reference APHA 2310 B.
AN274	Chloride by Aquakem DA: Chloride reacts with mercuric thiocyanate forming a mercuric chloride complex. In the presence of ferric iron, highly coloured ferric thiocyanate is formed which is proportional to the chloride concentration. Reference APHA 4500Cl-
AN320	Photomultipliers or CCDs are used to measure the light intensity at specific wavelengths. This intensity is directly proportional to concentration. Corrections are required to compensate for spectral overlap between elements. Reference APHA 3120 B.
AN320/AN321	Metals by ICP-OES: Samples are preserved with 10% nitric acid for a wide range of metals and some non-metals. This solution is measured by Inductively Coupled Plasma. Solutions are aspirated into an argon plasma at 8000-10000K and emit characteristic energy or light as a result of electron transitions through unique energy levels. The emitted light is focused onto a diffraction grating where it is separated into components .
AN320/AN321	Photomultipliers or CCDs are used to measure the light intensity at specific wavelengths. This intensity is directly proportional to concentration. Corrections are required to compensate for spectral overlap between elements. Reference APHA 3120 B.
Calculation	Free and Total Carbon Dioxide may be calculated using alkalinity forms only when the samples TDS is <500mg/L. If TDS is >500mg/L free or total carbon dioxide cannot be reported. APHA4500CO2 D.

FOOTNOTES

IS	Insufficient sample for analysis.	LOR	Limit of Reporting
LNR	Sample listed, but not received.	↑↓	Raised or Lowered Limit of Reporting
*	NATA accreditation does not cover the performance of this service.	QFH	QC result is above the upper tolerance
		QFL	QC result is below the lower tolerance
**	Indicative data, theoretical holding time exceeded.	-	The sample was not analysed for this analyte
		NVL	Not Validated

Samples analysed as received.
Solid samples expressed on a dry weight basis.

Where "Total" analyte groups are reported (for example, Total PAHs, Total OC Pesticides) the total will be calculated as the sum of the individual analytes, with those analytes that are reported as <LOR being assumed to be zero. The summed (Total) limit of reporting is calcuated by summing the individual analyte LORs and dividing by two. For example, where 16 individual analytes are being summed and each has an LOR of 0.1 mg/kg, the "Totals" LOR will be 1.6 / 2 (0.8 mg/kg). Where only 2 analytes are being summed, the " Total" LOR will be the sum of those two LORs.

Some totals may not appear to add up because the total is rounded after adding up the raw values.

If reported, measurement uncertainty follow the ± sign after the analytical result and is expressed as the expanded uncertainty calculated using a coverage factor of 2, providing a level of confidence of approximately 95%, unless stated otherwise in the comments section of this report.

Results reported for samples tested under test methods with codes starting with ARS-SOP, radionuclide or gross radioactivity concentrations are expressed in becquerel (Bq) per unit of mass or volume or per wipe as stated on the report. Becquerel is the SI unit for activity and equals one nuclear transformation per second.
Note that in terms of units of radioactivity:

a. 1 Bq is equivalent to 27 pCi
b. 37 MBq is equivalent to 1 mCi

For results reported for samples tested under test methods with codes starting with ARS-SOP, less than (<) values indicate the detection limit for each radionuclide or parameter for the measurement system used. The respective detection limits have been calculated in accordance with ISO 11929.

The QC criteria are subject to internal review according to the SGS QAQC plan and may be provided on request or alternatively can be found here : http://www.sgs.com.au/~/media/Local/Australia/Documents/Technical%20Documents/MP-AU-ENV-QU-022%20QA%20QC%20Plan.pdf

ANALYTICAL REPORT

Accreditation No. 2562

CLIENT DETAILS		LABORATORY DETAILS	
Contact	Darcy Simpson	Manager	Jon Dicker
Client	GOLDER ASSOCIATES PTY LTD	Laboratory	SGS Cairns Environmental
Address	PO BOX 5823 216 DRAPER ST CAIRNS QLD 4870	Address	Unit 2, 58 Comport St Portsmith QLD 4870
Telephone	07 4054 8200	Telephone	+61 07 4035 5111
Facsimile	07 4054 8201	Facsimile	+61 07 4035 5122
Email	dasimpson@golder.com.au	Email	AU.Environmental.Cairns@sgs.com
Project	**1546223 Northern Sands**	SGS Reference	**CE124163 R0**
Order Number	(Not specified)	Date Received	23 Nov 2016
Samples	3	Date Reported	02 Dec 2016

COMMENTS

Accredited for compliance with ISO/IEC 17025. NATA accredited laboratory 2562(3146)

For determination of soluble metals, filtered sample was not received so samples were laboratory filtered on receipt. This may give soluble metals results that do not represent the concentrations present at the time of sampling.

SIGNATORIES

Anthony Nilsson
Operations Manager

Jon Dicker
Manager Northern QLD

Leanne Orsmond
Quality & Microbiology Coordinator

Maristela Ganzan
Metals Team Leader

Parameter	Units	LOR	Sample Number: CE124163.001 Sample Matrix: Water Sample Date: 22 Nov 2016 Sample Name: BH01	CE124163.002 Water 22 Nov 2016 BH02	CE124163.003 Water 22 Nov 2016 BH03
pH in water Method: AN101 Tested: 23/11/2016					
pH**	pH Units	0.1	**6.8**	**7.9**	**7.9**
Conductivity and TDS by Calculation - Water Method: AN106 Tested: 23/11/2016					
Conductivity @ 25 C	µS/cm	5	**250**	**9300**	**24000**
Total Dissolved Solids (by calculation)	mg/L	10	**150**	**5600**	**14000**
Alkalinity Method: AN135 Tested: 23/11/2016					
Total Alkalinity as CaCO3	mg/L	5	**46**	**1100**	**2200**
Bicarbonate Alkalinity as CaCO3	mg/L	5	**46**	**1100**	**2200**
Carbonate Alkalinity as CaCO3	mg/L	5	<5	<5	<5
Hydroxide Alkalinity as CaCO3	mg/L	5	<5	<5	<5
Chloride by Discrete Analyser in Water Method: AN274 Tested: 25/11/2016					
Chloride, Cl	mg/L	1	**36**	**2500**	**7800**
Metals in Water (Dissolved) by ICPOES Method: AN320/AN321 Tested: 28/11/2016					
Calcium, Ca	mg/L	0.1	**6.5**	**65**	**200**
Magnesium, Mg	mg/L	0.1	**9.6**	**160**	**580**
Potassium, K	mg/L	0.1	**3.0**	**100**	**270**
Sodium, Na	mg/L	0.5	**26**	**1600**	**4800**
Sulphur as Sulphate, SO4	mg/L	0.5	**23**	**11**	**13**
Total Hardness by Calculation	mg CaCO3/L	1	**56**	**810**	**2900**
Calculation of Anion-Cation Balance (SAR Calc) Method: AN121 Tested: 2/12/2016					
Sum of Cation Milliequivalents*	meq/L	-	**2.32**	**90.2**	**272**
Sum of Anion Milliequivalents*	meq/L	-	**2.43**	**93.5**	**264**
Anion-Cation Balance	%	-100	**-2.4**	**-1.8**	**1.5**

QC SUMMARY

MB blank results are compared to the Limit of Reporting
LCS and MS spike recoveries are measured as the percentage of analyte recovered from the sample compared the the amount of analyte spiked into the sample.
DUP and MSD relative percent differences are measured against their original counterpart samples according to the formula : *the absolute difference of the two results divided by the average of the two results as a percentage*. Where the DUP RPD is 'NA' , the results are less than the LOR and thus the RPD is not applicable.

Alkalinity Method: ME-(AU)-[ENV]AN135

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
Total Alkalinity as CaCO3	LB041247	mg/L	5	<5	0 - 5%	107 - 115%
Bicarbonate Alkalinity as CaCO3	LB041247	mg/L	5	<5		
Carbonate Alkalinity as CaCO3	LB041247	mg/L	5	<5		
Hydroxide Alkalinity as CaCO3	LB041247	mg/L	5	<5		

Chloride by Discrete Analyser in Water Method: ME-(AU)-[ENV]AN274

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
Chloride, Cl	LB041309	mg/L	1	<1	0 - 1%	104%

Conductivity and TDS by Calculation - Water Method: ME-(AU)-[ENV]AN106

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
Conductivity @ 25 C	LB041247	µS/cm	5	<5	0 - 1%	98 - 101%
Total Dissolved Solids (by calculation)	LB041247	mg/L	10	<10	0 - 1%	NA

Metals in Water (Dissolved) by ICPOES Method: ME-(AU)-[ENV]AN320/AN321

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery	MS %Recovery
Calcium, Ca	LB041329	mg/L	0.1	<0.1		103%	111%
Magnesium, Mg	LB041329	mg/L	0.1	<0.1		100%	106%
Potassium, K	LB041329	mg/L	0.1	<0.1		103%	113%
Sodium, Na	LB041329	mg/L	0.5	<0.5	0%	96%	100%
Sulphur as Sulphate, SO4	LB041329	mg/L	0.5	<0.5	0%	NA	
Total Hardness by Calculation	LB041329	mg CaCO3/L	1	<1			

pH in water Method: ME-(AU)-[ENV]AN101

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
pH**	LB041247	pH Units	0.1	5.6 - 6.2	0 - 4%	NA

METHOD SUMMARY

METHOD	METHODOLOGY SUMMARY
AN101	pH in Soil Sludge Sediment and Water: pH is measured electrometrically using a combination electrode (glass plus reference electrode) and is calibrated against 3 buffers purchased commercially. For soils, an extract with water is made at a ratio of 1:5 and the pH determined and reported on the extract. Reference APHA 4500-H+.
AN106	Conductivity and TDS by Calculation: Conductivity is measured by meter with temperature compensation and is calibrated against a standard solution of potassium chloride. Conductivity is generally reported as µmhos/cm or µS/cm @ 25°C. For soils, an extract with water is made at a ratio of 1:5 and the EC determined and reported on the extract, or calculated back to the as-received sample. Total Dissolved Salts can be estimated from conductivity using a conversion factor, which for natural waters, is in the range 0.55 to 0.75. SGS use 0.6. Reference APHA 2510 B.
AN121	This method is used to calculation the balance of major Anions and Cations in water samples and converts major ion concentration to milliequivalents and then summed. Anions sum and Cation sum is calculated as a difference and expressed as a percentage.
AN135	Alkalinity (and forms of) by Titration: The sample is titrated with standard acid to pH 8.3 (P titre) and pH 4.5 (T titre) and permanent and/or total alkalinity calculated. The results are expressed as equivalents of calcium carbonate or recalculated as bicarbonate, carbonate and hydroxide. Reference APHA 2320. Internal Reference AN135
AN274	Chloride by Aquakem DA: Chloride reacts with mercuric thiocyanate forming a mercuric chloride complex. In the presence of ferric iron, highly coloured ferric thiocyanate is formed which is proportional to the chloride concentration. Reference APHA 4500Cl-
AN320/AN321	Metals by ICP-OES: Samples are preserved with 10% nitric acid for a wide range of metals and some non-metals. This solution is measured by Inductively Coupled Plasma. Solutions are aspirated into an argon plasma at 8000-10000K and emit characteristic energy or light as a result of electron transitions through unique energy levels. The emitted light is focused onto a diffraction grating where it is separated into components .
AN320/AN321	Photomultipliers or CCDs are used to measure the light intensity at specific wavelengths. This intensity is directly proportional to concentration. Corrections are required to compensate for spectral overlap between elements. Reference APHA 3120 B.
Calculation	Free and Total Carbon Dioxide may be calculated using alkalinity forms only when the samples TDS is <500mg/L. If TDS is >500mg/L free or total carbon dioxide cannot be reported. APHA4500CO2 D.

FOOTNOTES

IS	Insufficient sample for analysis.	LOR	Limit of Reporting
LNR	Sample listed, but not received.	↑↓	Raised or Lowered Limit of Reporting
*	NATA accreditation does not cover the performance of this service.	QFH	QC result is above the upper tolerance
		QFL	QC result is below the lower tolerance
**	Indicative data, theoretical holding time exceeded.	-	The sample was not analysed for this analyte
		NVL	Not Validated

Samples analysed as received.
Solid samples expressed on a dry weight basis.

Where "Total" analyte groups are reported (for example, Total PAHs, Total OC Pesticides) the total will be calculated as the sum of the individual analytes, with those analytes that are reported as <LOR being assumed to be zero. The summed (Total) limit of reporting is calcuated by summing the individual analyte LORs and dividing by two. For example, where 16 individual analytes are being summed and each has an LOR of 0.1 mg/kg, the "Totals" LOR will be 1.6 / 2 (0.8 mg/kg). Where only 2 analytes are being summed, the " Total" LOR will be the sum of those two LORs.

Some totals may not appear to add up because the total is rounded after adding up the raw values.

If reported, measurement uncertainty follow the ± sign after the analytical result and is expressed as the expanded uncertainty calculated using a coverage factor of 2, providing a level of confidence of approximately 95%, unless stated otherwise in the comments section of this report.

Results reported for samples tested under test methods with codes starting with ARS-SOP, radionuclide or gross radioactivity concentrations are expressed in becquerel (Bq) per unit of mass or volume or per wipe as stated on the report. Becquerel is the SI unit for activity and equals one nuclear transformation per second.
Note that in terms of units of radioactivity:

a. 1 Bq is equivalent to 27 pCi
b. 37 MBq is equivalent to 1 mCi

For results reported for samples tested under test methods with codes starting with ARS-SOP, less than (<) values indicate the detection limit for each radionuclide or parameter for the measurement system used. The respective detection limits have been calculated in accordance with ISO 11929.

The QC criteria are subject to internal review according to the SGS QAQC plan and may be provided on request or alternatively can be found here : http://www.sgs.com.au/~/media/Local/Australia/Documents/Technical%20Documents/MP-AU-ENV-QU-022%20QA%20QC%20Plan.pdf

STATEMENT OF QA/QC PERFORMANCE

CE124163 R0

CLIENT DETAILS

Contact	Darcy Simpson
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Project	**1546223 Northern Sands**
Order Number	(Not specified)
Samples	3

LABORATORY DETAILS

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Email	AU.Environmental.Cairns@sgs.com
SGS Reference	**CE124163 R0**
Date Received	23 Nov 2016
Date Reported	02 Dec 2016

COMMENTS

All the laboratory data for each environmental matrix was compared to SGS' stated Data Quality Objectives (DQO). Comments arising from the comparison were made and are reported below.

The data relating to sampling was taken from the Chain of Custody document and was supplied by the Client.
This QA/QC Statement must be read in conjunction with the referenced Analytical Report.
The Statement and the Analytical Report must not be reproduced except in full.

All Data Quality Objectives were met (within the SGS Cairns Environmental laboratory).

SAMPLE SUMMARY

HOLDING TIME SUMMARY

CE124163 R0

SGS holding time criteria are drawn from current regulations and are highly dependent on sample container preservation as specified in the SGS “Field Sampling Guide for Containers and Holding Time” (ref: GU-(AU)-ENV.001). Soil samples guidelines are derived from NEPM "Schedule B(3) Guideline on Laboratory Analysis of Potentially Contaminated Soils". Water sample guidelines are derived from "AS/NZS 5667.1 : 1998 Water Quality - sampling part 1" and APHA "Standard Methods for the Examination of Water and Wastewater" 21st edition 2005.

Extraction and analysis holding time due dates listed are calculated from the date sampled, although holding times may be extended after laboratory extraction for some analytes. The due dates are the suggested dates that samples may be held before extraction or analysis and still be considered valid.

Extraction and analysis dates are shown in **Green** when within suggested criteria or **Red** with an appended dagger symbol (†) when outside suggested criteria. If the sampled date is not supplied then compliance with criteria cannot be determined. If the received date is after one or both due dates then holding time will fail by default.

Alkalinity

Method: ME-(AU)-[ENV]AN135

Sample Name	Sample No.	QC Ref	Sampled	Received	Extraction Due	Extracted	Analysis Due	Analysed
BH01	CE124163.001	LB041247	22 Nov 2016	23 Nov 2016	23 Nov 2016	23 Nov 2016	23 Nov 2016	23 Nov 2016
BH02	CE124163.002	LB041247	22 Nov 2016	23 Nov 2016	23 Nov 2016	23 Nov 2016	23 Nov 2016	23 Nov 2016
BH03	CE124163.003	LB041247	22 Nov 2016	23 Nov 2016	23 Nov 2016	23 Nov 2016	23 Nov 2016	23 Nov 2016

Chloride by Discrete Analyser in Water

Method: ME-(AU)-[ENV]AN274

Sample Name	Sample No.	QC Ref	Sampled	Received	Extraction Due	Extracted	Analysis Due	Analysed
BH01	CE124163.001	LB041309	22 Nov 2016	23 Nov 2016	20 Dec 2016	25 Nov 2016	20 Dec 2016	28 Nov 2016
BH02	CE124163.002	LB041309	22 Nov 2016	23 Nov 2016	20 Dec 2016	25 Nov 2016	20 Dec 2016	28 Nov 2016
BH03	CE124163.003	LB041309	22 Nov 2016	23 Nov 2016	20 Dec 2016	25 Nov 2016	20 Dec 2016	28 Nov 2016

Conductivity and TDS by Calculation - Water

Method: ME-(AU)-[ENV]AN106

Sample Name	Sample No.	QC Ref	Sampled	Received	Extraction Due	Extracted	Analysis Due	Analysed
BH01	CE124163.001	LB041247	22 Nov 2016	23 Nov 2016	20 Dec 2016	23 Nov 2016	20 Dec 2016	23 Nov 2016
BH02	CE124163.002	LB041247	22 Nov 2016	23 Nov 2016	20 Dec 2016	23 Nov 2016	20 Dec 2016	23 Nov 2016
BH03	CE124163.003	LB041247	22 Nov 2016	23 Nov 2016	20 Dec 2016	23 Nov 2016	20 Dec 2016	23 Nov 2016

Metals in Water (Dissolved) by ICPOES

Method: ME-(AU)-[ENV]AN320/AN321

Sample Name	Sample No.	QC Ref	Sampled	Received	Extraction Due	Extracted	Analysis Due	Analysed
BH01	CE124163.001	LB041329	22 Nov 2016	23 Nov 2016	21 May 2017	28 Nov 2016	21 May 2017	28 Nov 2016
BH02	CE124163.002	LB041329	22 Nov 2016	23 Nov 2016	21 May 2017	28 Nov 2016	21 May 2017	28 Nov 2016
BH03	CE124163.003	LB041329	22 Nov 2016	23 Nov 2016	21 May 2017	28 Nov 2016	21 May 2017	28 Nov 2016

pH in water

Method: ME-(AU)-[ENV]AN101

Sample Name	Sample No.	QC Ref	Sampled	Received	Extraction Due	Extracted	Analysis Due	Analysed
BH01	CE124163.001	LB041247	22 Nov 2016	23 Nov 2016	23 Nov 2016	23 Nov 2016	23 Nov 2016	23 Nov 2016
BH02	CE124163.002	LB041247	22 Nov 2016	23 Nov 2016	23 Nov 2016	23 Nov 2016	23 Nov 2016	23 Nov 2016
BH03	CE124163.003	LB041247	22 Nov 2016	23 Nov 2016	23 Nov 2016	23 Nov 2016	23 Nov 2016	23 Nov 2016

SURROGATES

CE124163 R0

Surrogate results are evaluated against upper and lower limit criteria established in the SGS QA/QC plan (Ref: MP-(AU)-[ENV]QU-022). At least two of three routine level soil sample surrogate spike recoveries for BTEX/VOC are to be within 70-130% where control charts have not been developed and within the established control limits for charted surrogates. Matrix effects may void this as an acceptance criterion. Water sample surrogate spike recoveries are to be within 40-130%. The presence of emulsions, surfactants and particulates may void this as an acceptance criterion.

Result is shown in **Green** when within suggested criteria or **Red** with an appended reason identifer when outside suggested criteria. Refer to the footnotes section at the end of this report for failure reasons.

No surrogates were required for this job.

Blank results are evaluated against the limit of reporting (LOR), for the chosen method and its associated instrumentation, typically 2.5 times the statistically determined method detection limit (MDL).

Result is shown in **Green** when within suggested criteria or **Red** with an appended dagger symbol (†) when outside suggested criteria.

Alkalinity

Method: ME-(AU)-[ENV]AN135

Sample Number	Parameter	Units	LOR	Result
LB041247.001	Total Alkalinity as CaCO3	mg/L	5	<5
LB041247.028	Total Alkalinity as CaCO3	mg/L	5	<5
LB041247.055	Total Alkalinity as CaCO3	mg/L	5	<5
LB041247.082	Total Alkalinity as CaCO3	mg/L	5	<5

Chloride by Discrete Analyser in Water

Method: ME-(AU)-[ENV]AN274

Sample Number	Parameter	Units	LOR	Result
LB041309.001	Chloride, Cl	mg/L	1	<1
LB041309.024	Chloride, Cl	mg/L	1	<1

Conductivity and TDS by Calculation - Water

Method: ME-(AU)-[ENV]AN106

Sample Number	Parameter	Units	LOR	Result
LB041247.001	Conductivity @ 25 C	µS/cm	5	<5
	Total Dissolved Solids (by calculation)	mg/L	10	<10
LB041247.028	Conductivity @ 25 C	µS/cm	5	<5
	Total Dissolved Solids (by calculation)	mg/L	10	<10
LB041247.055	Conductivity @ 25 C	µS/cm	5	<5
	Total Dissolved Solids (by calculation)	mg/L	10	<10
LB041247.082	Conductivity @ 25 C	µS/cm	5	<5
	Total Dissolved Solids (by calculation)	mg/L	10	<10

Metals in Water (Dissolved) by ICPOES

Method: ME-(AU)-[ENV]AN320/AN321

Sample Number	Parameter	Units	LOR	Result
LB041329.001	Calcium, Ca	mg/L	0.1	<0.1
	Magnesium, Mg	mg/L	0.1	<0.1
	Potassium, K	mg/L	0.1	<0.1
	Sodium, Na	mg/L	0.5	<0.5

pH in water

Method: ME-(AU)-[ENV]AN101

Sample Number	Parameter	Units	LOR	Result
LB041247.001	pH**	pH Units	0.1	5.6
LB041247.028	pH**	pH Units	0.1	6.2
LB041247.055	pH**	pH Units	0.1	5.8
LB041247.082	pH**	pH Units	0.1	5.8

Duplicates are calculated as Relative Percentage Difference (RPD) using the formula: RPD = | OriginalResult - ReplicateResult | x 100 / Mean

The RPD is evaluated against the Maximum Allowable Difference (MAD) criteria and can be graphically represented by a curve calculated from the Statistical Detection Limit (SDL) and Limiting Repeatability (LR) using the formula: MAD = 100 x SDL / Mean + LR

Where the Maximum Allowable Difference evaluates to a number larger than 200 it is displayed as 200.

RPD is shown in **Green** when within suggested criteria or **Red** with an appended reason identifer when outside suggested criteria. Refer to the footnotes section at the end of this report for failure reasons.

Alkalinity

Method: ME-(AU)-[ENV]AN135

Original	Duplicate	Parameter	Units	LOR	Original	Duplicate	Criteria %	RPD %
CE124106.001	LB041247.123	Total Alkalinity as CaCO3	mg/L	5	81	80	21	2
	LB041247.132	Total Alkalinity as CaCO3	mg/L	5	81	80	21	2
CE124111.001	LB041247.125	Total Alkalinity as CaCO3	mg/L	5	380	380	16	0
CE124122.001	LB041247.126	Total Alkalinity as CaCO3	mg/L	5	5	6	105	5
CE124125.001	LB041247.127	Total Alkalinity as CaCO3	mg/L	5	200	200	17	1
CE124133.001	LB041247.128	Total Alkalinity as CaCO3	mg/L	5	120	130	19	1
CE124141.001	LB041247.129	Total Alkalinity as CaCO3	mg/L	5	20	17	42	15
CE124142.001	LB041247.130	Total Alkalinity as CaCO3	mg/L	5	240	240	17	0
CE124145.001	LB041247.134	Total Alkalinity as CaCO3	mg/L	5	510	500	16	1
CE124145.011	LB041247.135	Total Alkalinity as CaCO3	mg/L	5	830	850	16	2
CE124146.001	LB041247.137	Total Alkalinity as CaCO3	mg/L	5	14	14	50	1
CE124163.001	LB041247.140	Total Alkalinity as CaCO3	mg/L	5	46	46	26	0

Chloride by Discrete Analyser in Water

Method: ME-(AU)-[ENV]AN274

Original	Duplicate	Parameter	Units	LOR	Original	Duplicate	Criteria %	RPD %
CE124143.001	LB041309.005	Chloride, Cl	mg/L	1	33	32	18	1
CE124145.006	LB041309.016	Chloride, Cl	mg/L	1	450	450	15	0
CE124146.005	LB041309.030	Chloride, Cl	mg/L	1	17	17	21	0

Conductivity and TDS by Calculation - Water

Method: ME-(AU)-[ENV]AN106

Original	Duplicate	Parameter	Units	LOR	Original	Duplicate	Criteria %	RPD %
CE124106.001	LB041247.123	Conductivity @ 25 C	µS/cm	5	150	150	16	1
		Total Dissolved Solids (by calculation)	mg/L	10	88	88	17	1
	LB041247.132	Conductivity @ 25 C	µS/cm	5	150	150	16	1
		Total Dissolved Solids (by calculation)	mg/L	10	88	88	17	1
CE124111.001	LB041247.125	Conductivity @ 25 C	µS/cm	5	1000	1100	15	1
CE124125.001	LB041247.127	Conductivity @ 25 C	µS/cm	5	770	780	15	0
CE124133.001	LB041247.128	Conductivity @ 25 C	µS/cm	5	530	530	15	0
		Total Dissolved Solids (by calculation)	mg/L	10	320	320	16	0
CE124141.001	LB041247.129	Conductivity @ 25 C	µS/cm	5	11.944000244	11.4734611511	20	1
CE124142.001	LB041247.130	Conductivity @ 25 C	µS/cm	5	680	680	15	1
	LB041247.131	Conductivity @ 25 C	µS/cm	5	680	680	15	1
CE124146.001	LB041247.144	Conductivity @ 25 C	µS/cm	5	89	88	17	1
		Total Dissolved Solids (by calculation)	mg/L	10	53	53	19	1
CE124163.001	LB041247.147	Conductivity @ 25 C	µS/cm	5	250	250	16	1
		Total Dissolved Solids (by calculation)	mg/L	10	150	150	16	1

Metals in Water (Dissolved) by ICPOES

Method: ME-(AU)-[ENV]AN320/AN321

Original	Duplicate	Parameter	Units	LOR	Original	Duplicate	Criteria %	RPD %
CE124171.001	LB041329.014	Sodium, Na	mg/L	0.5	35	35	16	0
		Sulphur as Sulphate, SO4	mg/L	0.5	28	28	17	0

pH in water

Method: ME-(AU)-[ENV]AN101

Original	Duplicate	Parameter	Units	LOR	Original	Duplicate	Criteria %	RPD %
CE124106.001	LB041247.123	pH**	pH Units	0.1	7.7	7.8	16	0
	LB041247.132	pH**	pH Units	0.1	7.7	7.8	16	0
CE124111.001	LB041247.125	pH**	pH Units	0.1	7.4	7.3	16	2
	LB041247.134	pH**	pH Units	0.1	7.4	7.3	16	2
CE124122.001	LB041247.126	pH**	pH Units	0.1	6.4	6.6	17	3
	LB041247.135	pH**	pH Units	0.1	6.4	6.6	17	3
CE124125.001	LB041247.127	pH**	pH Units	0.1	7.9	7.9	16	0
	LB041247.136	pH**	pH Units	0.1	7.9	7.9	16	0
CE124133.001	LB041247.128	pH**	pH Units	0.1	8.0	8.1	16	1
	LB041247.137	pH**	pH Units	0.1	8.0	8.1	16	1
CE124141.001	LB041247.129	pH**	pH Units	0.1	6.8	6.6	16	2
	LB041247.138	pH**	pH Units	0.1	6.8	6.6	16	2
CE124142.001	LB041247.130	pH**	pH Units	0.1	7.5	7.5	16	0
	LB041247.131	pH**	pH Units	0.1	7.5	7.8	16	4
	LB041247.139	pH**	pH Units	0.1	7.5	7.5	16	0
	LB041247.140	pH**	pH Units	0.1	7.5	7.8	16	4
CE124145.001	LB041247.141	pH**	pH Units	0.1	7.9	7.9	16	0

Duplicates are calculated as Relative Percentage Difference (RPD) using the formula: RPD = | OriginalResult - ReplicateResult | x 100 / Mean

The RPD is evaluated against the Maximum Allowable Difference (MAD) criteria and can be graphically represented by a curve calculated from the Statistical Detection Limit (SDL) and Limiting Repeatability (LR) using the formula: MAD = 100 x SDL / Mean + LR

Where the Maximum Allowable Difference evaluates to a number larger than 200 it is displayed as 200.

RPD is shown in **Green** when within suggested criteria or **Red** with an appended reason identifer when outside suggested criteria. Refer to the footnotes section at the end of this report for failure reasons.

pH in water (continued) — Method: ME-(AU)-[ENV]AN101

Original	Duplicate	Parameter	Units	LOR	Original	Duplicate	Criteria %	RPD %
CE124145.011	LB041247.142	pH**	pH Units	0.1	7.9	8.0	16	1
CE124146.001	LB041247.144	pH**	pH Units	0.1	7.1	7.0	16	1
CE124157.001	LB041247.145	pH**	pH Units	0.1	6.8	6.9	16	2
CE124157.011	LB041247.146	pH**	pH Units	0.1	7.0	7.0	16	0
CE124163.001	LB041247.147	pH**	pH Units	0.1	6.8	6.8	16	0

LABORATORY CONTROL SAMPLES

CE124163 R0

Laboratory Control Standard (LCS) results are evaluated against an expected result, typically the concentration of analyte spiked into the control during the sample preparation stage, producing a percentage recovery. The criteria applied to the percentage recovery is established in the SGS QA /QC plan (Ref: MP-(AU)-[ENV]QU-022). For more information refer to the footnotes in the concluding page of this report.

Recovery is shown in **Green** when within suggested criteria or **Red** with an appended dagger symbol (†) when outside suggested criteria.

Alkalinity

Method: ME-(AU)-[ENV]AN135

Sample Number	Parameter	Units	LOR	Result	Expected	Criteria %	Recovery %
LB041247.002	Total Alkalinity as CaCO3	mg/L	5	64	59.5	80 - 120	107
LB041247.003	Total Alkalinity as CaCO3	mg/L	5	240	229	80 - 120	104
LB041247.029	Total Alkalinity as CaCO3	mg/L	5	69	59.5	80 - 120	115
LB041247.030	Total Alkalinity as CaCO3	mg/L	5	240	229	80 - 120	103
LB041247.056	Total Alkalinity as CaCO3	mg/L	5	67	59.5	80 - 120	113
LB041247.057	Total Alkalinity as CaCO3	mg/L	5	240	229	80 - 120	104
LB041247.083	Total Alkalinity as CaCO3	mg/L	5	65	59.5	80 - 120	108
LB041247.084	Total Alkalinity as CaCO3	mg/L	5	240	229	80 - 120	103

Chloride by Discrete Analyser in Water

Method: ME-(AU)-[ENV]AN274

Sample Number	Parameter	Units	LOR	Result	Expected	Criteria %	Recovery %
LB041309.002	Chloride, Cl	mg/L	1	130	125	80 - 120	103
LB041309.003	Chloride, Cl	mg/L	1	10	10	80 - 120	104
LB041309.025	Chloride, Cl	mg/L	1	130	125	80 - 120	103
LB041309.026	Chloride, Cl	mg/L	1	10	10	80 - 120	104

Conductivity and TDS by Calculation - Water

Method: ME-(AU)-[ENV]AN106

Sample Number	Parameter	Units	LOR	Result	Expected	Criteria %	Recovery %
LB041247.004	Conductivity @ 25 C	µS/cm	5	300	303	90 - 110	98
LB041247.005	Conductivity @ 25 C	µS/cm	5	59000	58670	90 - 110	100
LB041247.031	Conductivity @ 25 C	µS/cm	5	290	303	90 - 110	97
LB041247.032	Conductivity @ 25 C	µS/cm	5	59000	58670	90 - 110	100
LB041247.058	Conductivity @ 25 C	µS/cm	5	310	303	90 - 110	102
LB041247.059	Conductivity @ 25 C	µS/cm	5	59000	58670	90 - 110	100
LB041247.085	Conductivity @ 25 C	µS/cm	5	310	303	90 - 110	101
LB041247.086	Conductivity @ 25 C	µS/cm	5	59000	58670	90 - 110	100

Metals in Water (Dissolved) by ICPOES

Method: ME-(AU)-[ENV]AN320/AN321

Sample Number	Parameter	Units	LOR	Result	Expected	Criteria %	Recovery %
LB041329.002	Calcium, Ca	mg/L	0.1	21	20	80 - 120	103
	Magnesium, Mg	mg/L	0.1	20	20	80 - 120	100
	Potassium, K	mg/L	0.1	21	20	80 - 120	103
	Sodium, Na	mg/L	0.5	19	20	80 - 120	96

pH in water

Method: ME-(AU)-[ENV]AN101

Sample Number	Parameter	Units	LOR	Result	Expected	Criteria %	Recovery %
LB041247.006	pH**	pH Units	0.1	7.4	7.415	98 - 102	100
LB041247.033	pH**	pH Units	0.1	7.4	7.415	98 - 102	100
LB041247.060	pH**	pH Units	0.1	7.4	7.415	98 - 102	100
LB041247.087	pH**	pH Units	0.1	7.4	7.415	98 - 102	100

Matrix Spike (MS) results are evaluated as the percentage recovery of an expected result, typically the concentration of analyte spiked into a field sub -sample during the sample preparation stage. The original sample's result is subtracted from the sub-sample result before determining the percentage recovery. The criteria applied to the percentage recovery is established in the SGS QA/QC plan (ref: MP-(AU)-[ENV]QU-022). For more information refer to the footnotes in the concluding page of this report.

Recovery is shown in **Green** when within suggested criteria or **Red** with an appended reason identifer when outside suggested criteria. Refer to the footnotes section at the end of this report for failure reasons.

Metals in Water (Dissolved) by ICPOES — **Method: ME-(AU)-[ENV]AN320/AN321**

QC Sample	Sample Number	Parameter	Units	LOR	Result	Original	Spike	Recovery%
CE124146.001	LB041329.004	Calcium, Ca	mg/L	0.1	57	1.8	50	111
		Magnesium, Mg	mg/L	0.1	55	1.6	50	106
		Potassium, K	mg/L	0.1	58	1.3	50	113
		Sodium, Na	mg/L	0.5	62	13	50	100

MATRIX SPIKE DUPLICATES

CE124163 R0

Matrix spike duplicates are calculated as Relative Percent Difference (RPD) using the formula: RPD = | OriginalResult - ReplicateResult | x 100 / Mean

The original result is the analyte concentration of the matrix spike. The Duplicate result is the analyte concentration of the matrix spike duplicate.

The RPD is evaluated against the Maximum Allowable Difference (MAD) criteria and can be graphically represented by a curve calculated from the Statistical Detection Limit (SDL) and Limiting Repeatability (LR) using the formula: MAD = 100 x SDL / Mean + LR

Where the Maximum Allowable Difference evaluates to a number larger than 200 it is displayed as 200.

RPD is shown in **Green** when within suggested criteria or **Red** with an appended reason identifer when outside suggested criteria. Refer to the footnotes section at the end of this report for failure reasons.

No matrix spike duplicates were required for this job.

Samples analysed as received.

Solid samples expressed on a dry weight basis.

QC criteria are subject to internal review according to the SGS QA/QC plan and may be provided on request or alternatively can be found here: http://www.sgs.com.au/~/media/Local/Australia/Documents/Technical Documents/MP-AU-ENV-QU-022 QA QC Plan.pdf

*	NATA accreditation does not cover tthe performance of this service.
-	Sample not analysed for this analyte.

IS	Insufficient sample for analysis.
LNR	Sample listed, but not received.
LOR	Limit of reporting.
QFH	QC result is above the upper tolerance.
QFL	QC result is below the lower tolerance.

①	At least 2 of 3 surrogates are within acceptance criteria.
②	RPD failed acceptance criteria due to sample heterogeneity.
③	Results less than 5 times LOR preclude acceptance criteria for RPD.
④	Recovery failed acceptance criteria due to matrix interference.
⑤	Recovery failed acceptance criteria due to the presence of significant concentration of analyte (i.e. the concentration of analyte exceeds the spike level).
⑥	LOR was raised due to sample matrix interference.
⑦	LOR was raised due to dilution of significantly high concentration of analyte in sample.
⑧	Reanalysis of sample in duplicate confirmed sample heterogeneity and inconsistency of results.
⑨	Low surrogate recovery due to the sample emulsifying during extraction.
⑩	Legionella Test Result <10 cfu/mL Control Strategy (1) Maintain Monthly Program or at least 3-monthly monitoring. Maintain water treatment program
⑪	Legionella Test Result <1000 cfu/mL Control Strategy (2) Investigate problem. Review water treatment program. Take necessary remedial action (including immediate online disinfection) and undertake control strategy 3.
⑫	Control Strategy (3) Retest water within 3 to 7 days of plant operation. If not detected, continue to retest water every 3 to 7 days until 2 consecutive samples return readings of 'not detected', then repeat control strategy (1). If detected at <100 cfu/mL, repeat control strategy (2). If detected at >100 cfu/mL, investigate the problem and review water treatment program, and immediately carry out online decontamination. If detected at >1000 cfu/mL, undertake control strategy (4).
⑬	Legionella Test Result >1000 cfu/mL Control Strategy (4) Investigate problem. Review water treatment program. Take necessary remedial action (including immediate online decontamination) and undertake control strategy (5).
⑭	Control Strategy (5) Retest water within 3 to 7 days of plant operation. If not detected, continue to retest water every 3 to 7 days until 2 consecutive samples return readings of 'not detected', then repeat control strategy (1). If detected at <100 cfu/mL, repeat control strategy (1) If detected at >100 and <1000 cfu/mL, investigate the problem and review water treatment program, immediately carry out online decontamination, and repeat control strategy (5). If detected at >1000 cfu/mL, investigate and review the water treatment program, immediately carry out system decontamination and repeat control strategy (5).
⑮	HPC - Test Result < 100 000 cfu/mL Control Strategy (1) Maintain Monthly Program. Maintain water treatment program.

Samples analysed as received.

Solid samples expressed on a dry weight basis.

QC criteria are subject to internal review according to the SGS QA/QC plan and may be provided on request or alternatively can be found here: http://www.sgs.com.au/~/media/Local/Australia/Documents/Technical Documents/MP-AU-ENV-QU-022 QA QC Plan.pdf

⑯ HPC Test Result > 100 000 cfu/mL <5 000 000 cfu/mL
Control Strategy (2)
Investigate problem. Review water treatment program. Take necessary remedial action (including immediate online disinfection)
and undertake control strategy 3.

⑰ Control Strategy (3)
Retest water within 3 to 7 days of plant operation. If the test result is <100 000 cfu/mL, repeat control strategy (1)
If the test result is >100 000 cfu/mL but <5 000 000 cfu/mL, undertake control strategy (2).
If the test result is >5 000 000 cfu/mL, undertake control strategy (4).

⑱ HPC Test Result >5 000 000 cfu/mL
Control Strategy (4)
Investigate problem. Review water treatment program. Take necessary remedial action (including immediate online disinfection)
and undertake control strategy (5).

⑲ Control Strategy (5)
Retest water within 3 to 7 days of plant operation. If the test result is <100 000 cfu/mL, repeat control strategy (1)
If the test result is >100 000 cfu/mL but <5 000 000 cfu/mL, undertake control strategy (4).
If the test result is >5 000 000 cfu/mL, investigate the problem.
review the water treatment program, and carry out immediate online decontamination.

⑳ Enterococci - Median result should not exceed 230 cfu/100mL
(maximum number in any one sample: 450-700 cfu/100mL)
Sourced from NHMRC (National Health and Medical Research Council)
& NWQMS (National Water Quality Management Strategy)
-Australian Guidelines for Recreational Use of Water. Version Oct 2000.

† Refer to Analytical Report comments for further information.

ANALYTICAL REPORT

Accreditation No. 2562

CLIENT DETAILS		LABORATORY DETAILS	
Contact	Darcy Simpson	Manager	Jon Dicker
Client	GOLDER ASSOCIATES PTY LTD	Laboratory	SGS Cairns Environmental
Address	PO BOX 5823 216 DRAPER ST CAIRNS QLD 4870	Address	Unit 2, 58 Comport St Portsmith QLD 4870
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Facsimile	07 4054 8201	Facsimile	+61 07 4035 5122
Email	dasimpson@golder.com.au	Email	AU.Environmental.Cairns@sgs.com
Project	**1546223 Northern Sands**	SGS Reference	**CE124214 R0**
Order Number	(Not specified)	Date Received	25 Nov 2016
Samples	1	Date Reported	07 Dec 2016

COMMENTS

Accredited for compliance with ISO/IEC 17025. NATA accredited laboratory 2562(3146)

SIGNATORIES

Anthony Nilsson
Operations Manager

Jon Dicker
Manager Northern QLD

Leanne Orsmond
Quality & Microbiology Coordinator

Maristela Ganzan
Metals Team Leader

Parameter	Units	LOR	Sample Number: CE124214.001 Sample Matrix: Water Sample Date: 25 Nov 2016 Sample Name: GA04
pH in water Method: AN101 Tested: 25/11/2016			
pH**	pH Units	0.1	**6.5**
Conductivity and TDS by Calculation - Water Method: AN106 Tested: 25/11/2016			
Conductivity @ 25 C	µS/cm	5	**160**
Total Dissolved Solids (by calculation)	mg/L	10	**93**
Alkalinity Method: AN135 Tested: 25/11/2016			
Total Alkalinity as CaCO3	mg/L	5	**50**
Bicarbonate Alkalinity as CaCO3	mg/L	5	**50**
Carbonate Alkalinity as CaCO3	mg/L	5	<5
Hydroxide Alkalinity as CaCO3	mg/L	5	<5
Chloride by Discrete Analyser in Water Method: AN274 Tested: 30/11/2016			
Chloride, Cl	mg/L	1	**29**
Metals in Water (Dissolved) by ICPOES Method: AN320/AN321 Tested: 5/12/2016			
Calcium, Ca	mg/L	0.1	**8.0**
Magnesium, Mg	mg/L	0.1	**3.2**
Potassium, K	mg/L	0.1	**0.8**
Sodium, Na	mg/L	0.5	**17**
Sulphur as Sulphate, SO4	mg/L	0.5	**23**
Total Hardness by Calculation	mg CaCO3/L	1	**33**

Parameter	Units	LOR	Sample Number: CE124214.001 Sample Matrix: Water Sample Date: 25 Nov 2016 Sample Name: GA04
Calculation of Anion-Cation Balance (SAR Calc) Method: AN121 Tested: 6/12/2016			
Sum of Cation Milliequivalents*	meq/L	-	**1.43**
Sum of Anion Milliequivalents*	meq/L	-	**2.27**
Anion-Cation Balance	%	-100	**-23**

QC SUMMARY

MB blank results are compared to the Limit of Reporting
LCS and MS spike recoveries are measured as the percentage of analyte recovered from the sample compared the the amount of analyte spiked into the sample.
DUP and MSD relative percent differences are measured against their original counterpart samples according to the formula : *the absolute difference of the two results divided by the average of the two results as a percentage*. Where the DUP RPD is 'NA' , the results are less than the LOR and thus the RPD is not applicable.

Alkalinity Method: ME-(AU)-[ENV]AN135

Parameter	QC Reference	Units	LOR	MB	LCS %Recovery
Total Alkalinity as CaCO3	LB041324	mg/L	5	<5	110 - 119%
Bicarbonate Alkalinity as CaCO3	LB041324	mg/L	5	<5	
Carbonate Alkalinity as CaCO3	LB041324	mg/L	5	<5	
Hydroxide Alkalinity as CaCO3	LB041324	mg/L	5	<5	

Chloride by Discrete Analyser in Water Method: ME-(AU)-[ENV]AN274

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
Chloride, Cl	LB041417	mg/L	1	<1	0 - 2%	104%

Conductivity and TDS by Calculation - Water Method: ME-(AU)-[ENV]AN106

Parameter	QC Reference	Units	LOR	MB	LCS %Recovery
Conductivity @ 25 C	LB041324	µS/cm	5	<5	99 - 100%
Total Dissolved Solids (by calculation)	LB041324	mg/L	10	<10	NA

Metals in Water (Dissolved) by ICPOES Method: ME-(AU)-[ENV]AN320/AN321

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery	MS %Recovery
Calcium, Ca	LB041532	mg/L	0.1	<0.1		103%	NVL
Magnesium, Mg	LB041532	mg/L	0.1	<0.1		101%	NVL
Potassium, K	LB041532	mg/L	0.1	<0.1		107%	NVL
Sodium, Na	LB041532	mg/L	0.5	<0.5		97%	NVL
Sulphur as Sulphate, SO4	LB041532	mg/L	0.5	<0.5	NVL	NA	
Total Hardness by Calculation	LB041532	mg CaCO3/L	1	<1			

pH in water Method: ME-(AU)-[ENV]AN101

Parameter	QC Reference	Units	LOR	MB	LCS %Recovery
pH**	LB041324	pH Units	0.1	5.6 - 5.7	100%

METHOD SUMMARY

METHOD	METHODOLOGY SUMMARY
AN101	pH in Soil Sludge Sediment and Water: pH is measured electrometrically using a combination electrode (glass plus reference electrode) and is calibrated against 3 buffers purchased commercially. For soils, an extract with water is made at a ratio of 1:5 and the pH determined and reported on the extract. Reference APHA 4500-H+.
AN106	Conductivity and TDS by Calculation: Conductivity is measured by meter with temperature compensation and is calibrated against a standard solution of potassium chloride. Conductivity is generally reported as µmhos/cm or µS/cm @ 25°C. For soils, an extract with water is made at a ratio of 1:5 and the EC determined and reported on the extract, or calculated back to the as-received sample. Total Dissolved Salts can be estimated from conductivity using a conversion factor, which for natural waters, is in the range 0.55 to 0.75. SGS use 0.6. Reference APHA 2510 B.
AN121	This method is used to calculation the balance of major Anions and Cations in water samples and converts major ion concentration to milliequivalents and then summed. Anions sum and Cation sum is calculated as a difference and expressed as a percentage.
AN135	Alkalinity (and forms of) by Titration: The sample is titrated with standard acid to pH 8.3 (P titre) and pH 4.5 (T titre) and permanent and/or total alkalinity calculated. The results are expressed as equivalents of calcium carbonate or recalculated as bicarbonate, carbonate and hydroxide. Reference APHA 2320. Internal Reference AN135
AN274	Chloride by Aquakem DA: Chloride reacts with mercuric thiocyanate forming a mercuric chloride complex. In the presence of ferric iron, highly coloured ferric thiocyanate is formed which is proportional to the chloride concentration. Reference APHA 4500Cl-
AN320/AN321	Metals by ICP-OES: Samples are preserved with 10% nitric acid for a wide range of metals and some non-metals. This solution is measured by Inductively Coupled Plasma. Solutions are aspirated into an argon plasma at 8000-10000K and emit characteristic energy or light as a result of electron transitions through unique energy levels. The emitted light is focused onto a diffraction grating where it is separated into components .
AN320/AN321	Photomultipliers or CCDs are used to measure the light intensity at specific wavelengths. This intensity is directly proportional to concentration. Corrections are required to compensate for spectral overlap between elements. Reference APHA 3120 B.
Calculation	Free and Total Carbon Dioxide may be calculated using alkalinity forms only when the samples TDS is <500mg/L. If TDS is >500mg/L free or total carbon dioxide cannot be reported. APHA4500CO2 D.

FOOTNOTES

IS	Insufficient sample for analysis.	LOR	Limit of Reporting
LNR	Sample listed, but not received.	↑↓	Raised or Lowered Limit of Reporting
*	NATA accreditation does not cover the performance of this service.	QFH	QC result is above the upper tolerance
		QFL	QC result is below the lower tolerance
**	Indicative data, theoretical holding time exceeded.	-	The sample was not analysed for this analyte
		NVL	Not Validated

Samples analysed as received.
Solid samples expressed on a dry weight basis.

Where "Total" analyte groups are reported (for example, Total PAHs, Total OC Pesticides) the total will be calculated as the sum of the individual analytes, with those analytes that are reported as <LOR being assumed to be zero. The summed (Total) limit of reporting is calcuated by summing the individual analyte LORs and dividing by two. For example, where 16 individual analytes are being summed and each has an LOR of 0.1 mg/kg, the "Totals" LOR will be 1.6 / 2 (0.8 mg/kg). Where only 2 analytes are being summed, the " Total" LOR will be the sum of those two LORs.

Some totals may not appear to add up because the total is rounded after adding up the raw values.

If reported, measurement uncertainty follow the ± sign after the analytical result and is expressed as the expanded uncertainty calculated using a coverage factor of 2, providing a level of confidence of approximately 95%, unless stated otherwise in the comments section of this report.

Results reported for samples tested under test methods with codes starting with ARS-SOP, radionuclide or gross radioactivity concentrations are expressed in becquerel (Bq) per unit of mass or volume or per wipe as stated on the report. Becquerel is the SI unit for activity and equals one nuclear transformation per second.
Note that in terms of units of radioactivity:

a. 1 Bq is equivalent to 27 pCi
b. 37 MBq is equivalent to 1 mCi

For results reported for samples tested under test methods with codes starting with ARS-SOP, less than (<) values indicate the detection limit for each radionuclide or parameter for the measurement system used. The respective detection limits have been calculated in accordance with ISO 11929.

The QC criteria are subject to internal review according to the SGS QAQC plan and may be provided on request or alternatively can be found here : http://www.sgs.com.au/~/media/Local/Australia/Documents/Technical%20Documents/MP-AU-ENV-QU-022%20QA%20QC%20Plan.pdf

STATEMENT OF QA/QC PERFORMANCE

CE124214 R0

CLIENT DETAILS

Contact	Darcy Simpson
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Address	PO BOX 5823 216 DRAPER ST CAIRNS QLD 4870
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Email	dasimpson@golder.com.au
Project	**1546223 Northern Sands**
Order Number	(Not specified)
Samples	1

LABORATORY DETAILS

Manager	Jon Dicker
Laboratory	SGS Cairns Environmental
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Email	AU.Environmental.Cairns@sgs.com
SGS Reference	**CE124214 R0**
Date Received	25 Nov 2016
Date Reported	07 Dec 2016

COMMENTS

All the laboratory data for each environmental matrix was compared to SGS' stated Data Quality Objectives (DQO). Comments arising from the comparison were made and are reported below.

The data relating to sampling was taken from the Chain of Custody document and was supplied by the Client.
This QA/QC Statement must be read in conjunction with the referenced Analytical Report.
The Statement and the Analytical Report must not be reproduced except in full.

All Data Quality Objectives were met (within the SGS Cairns Environmental laboratory).

SAMPLE SUMMARY

Samples clearly labelled	Yes	Complete documentation received	Yes
Sample container provider	SGS	Sample cooling method	Ice
Samples received in correct containers	Yes	Sample counts by matrix	1 water
Date documentation received	25/11/2016	Type of documentation received	COC
Number of eskies/boxes received	1	Samples received in good order	Yes
Samples received without headspace	Yes	Sample temperature upon receipt	Chilled
Sufficient sample for analysis	Yes	Turnaround time requested	standard

HOLDING TIME SUMMARY

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SGS holding time criteria are drawn from current regulations and are highly dependent on sample container preservation as specified in the SGS “Field Sampling Guide for Containers and Holding Time” (ref: GU-(AU)-ENV.001). Soil samples guidelines are derived from NEPM "Schedule B(3) Guideline on Laboratory Analysis of Potentially Contaminated Soils". Water sample guidelines are derived from "AS/NZS 5667.1 : 1998 Water Quality - sampling part 1" and APHA "Standard Methods for the Examination of Water and Wastewater" 21st edition 2005.

Extraction and analysis holding time due dates listed are calculated from the date sampled, although holding times may be extended after laboratory extraction for some analytes. The due dates are the suggested dates that samples may be held before extraction or analysis and still be considered valid.

Extraction and analysis dates are shown in **Green** when within suggested criteria or **Red** with an appended dagger symbol (†) when outside suggested criteria. If the sampled date is not supplied then compliance with criteria cannot be determined. If the received date is after one or both due dates then holding time will fail by default.

Alkalinity

Method: ME-(AU)-[ENV]AN135

Sample Name	Sample No.	QC Ref	Sampled	Received	Extraction Due	Extracted	Analysis Due	Analysed
GA04	CE124214.001	LB041324	25 Nov 2016	25 Nov 2016	26 Nov 2016	25 Nov 2016	26 Nov 2016	25 Nov 2016

Chloride by Discrete Analyser in Water

Method: ME-(AU)-[ENV]AN274

Sample Name	Sample No.	QC Ref	Sampled	Received	Extraction Due	Extracted	Analysis Due	Analysed
GA04	CE124214.001	LB041417	25 Nov 2016	25 Nov 2016	23 Dec 2016	30 Nov 2016	23 Dec 2016	01 Dec 2016

Conductivity and TDS by Calculation - Water

Method: ME-(AU)-[ENV]AN106

Sample Name	Sample No.	QC Ref	Sampled	Received	Extraction Due	Extracted	Analysis Due	Analysed
GA04	CE124214.001	LB041324	25 Nov 2016	25 Nov 2016	23 Dec 2016	25 Nov 2016	23 Dec 2016	25 Nov 2016

Metals in Water (Dissolved) by ICPOES

Method: ME-(AU)-[ENV]AN320/AN321

Sample Name	Sample No.	QC Ref	Sampled	Received	Extraction Due	Extracted	Analysis Due	Analysed
GA04	CE124214.001	LB041532	25 Nov 2016	25 Nov 2016	24 May 2017	05 Dec 2016	24 May 2017	06 Dec 2016

pH in water

Method: ME-(AU)-[ENV]AN101

Sample Name	Sample No.	QC Ref	Sampled	Received	Extraction Due	Extracted	Analysis Due	Analysed
GA04	CE124214.001	LB041324	25 Nov 2016	25 Nov 2016	26 Nov 2016	25 Nov 2016	26 Nov 2016	25 Nov 2016

Surrogate results are evaluated against upper and lower limit criteria established in the SGS QA /QC plan (Ref: MP-(AU)-[ENV]QU-022). At least two of three routine level soil sample surrogate spike recoveries for BTEX/VOC are to be within 70-130% where control charts have not been developed and within the established control limits for charted surrogates. Matrix effects may void this as an acceptance criterion. Water sample surrogate spike recoveries are to be within 40-130%. The presence of emulsions, surfactants and particulates may void this as an acceptance criterion.

Result is shown in **Green** when within suggested criteria or **Red** with an appended reason identifer when outside suggested criteria. Refer to the footnotes section at the end of this report for failure reasons.

No surrogates were required for this job.

Blank results are evaluated against the limit of reporting (LOR), for the chosen method and its associated instrumentation, typically 2.5 times the statistically determined method detection limit (MDL).

Result is shown in **Green** when within suggested criteria or **Red** with an appended dagger symbol (†) when outside suggested criteria.

Alkalinity

Method: ME-(AU)-[ENV]AN135

Sample Number	Parameter	Units	LOR	Result
LB041324.001	Total Alkalinity as CaCO3	mg/L	5	<5
LB041324.028	Total Alkalinity as CaCO3	mg/L	5	<5

Chloride by Discrete Analyser in Water

Method: ME-(AU)-[ENV]AN274

Sample Number	Parameter	Units	LOR	Result
LB041417.001	Chloride, Cl	mg/L	1	<1
LB041417.024	Chloride, Cl	mg/L	1	<1
LB041417.047	Chloride, Cl	mg/L	1	<1
LB041417.070	Chloride, Cl	mg/L	1	<1

Conductivity and TDS by Calculation - Water

Method: ME-(AU)-[ENV]AN106

Sample Number	Parameter	Units	LOR	Result
LB041324.001	Conductivity @ 25 C	µS/cm	5	<5
	Total Dissolved Solids (by calculation)	mg/L	10	<10
LB041324.028	Conductivity @ 25 C	µS/cm	5	<5
	Total Dissolved Solids (by calculation)	mg/L	10	<10

Metals in Water (Dissolved) by ICPOES

Method: ME-(AU)-[ENV]AN320/AN321

Sample Number	Parameter	Units	LOR	Result
LB041532.001	Calcium, Ca	mg/L	0.1	<0.1
	Magnesium, Mg	mg/L	0.1	<0.1
	Potassium, K	mg/L	0.1	<0.1
	Sodium, Na	mg/L	0.5	<0.5

pH in water

Method: ME-(AU)-[ENV]AN101

Sample Number	Parameter	Units	LOR	Result
LB041324.001	pH**	pH Units	0.1	5.7
LB041324.028	pH**	pH Units	0.1	5.6

Duplicates are calculated as Relative Percentage Difference (RPD) using the formula: RPD = | OriginalResult - ReplicateResult | x 100 / Mean

The RPD is evaluated against the Maximum Allowable Difference (MAD) criteria and can be graphically represented by a curve calculated from the Statistical Detection Limit (SDL) and Limiting Repeatability (LR) using the formula: MAD = 100 x SDL / Mean + LR

Where the Maximum Allowable Difference evaluates to a number larger than 200 it is displayed as 200.

RPD is shown in **Green** when within suggested criteria or **Red** with an appended reason identifer when outside suggested criteria. Refer to the footnotes section at the end of this report for failure reasons.

Chloride by Discrete Analyser in Water — Method: ME-(AU)-[ENV]AN274

Original	Duplicate	Parameter	Units	LOR	Original	Duplicate	Criteria %	RPD %
CE124193.001	LB041417.005	Chloride, Cl	mg/L	1	590	590	15	1
CE124202.010	LB041417.016	Chloride, Cl	mg/L	1	167.414	168.798	16	1
CE124202.030	LB041417.041	Chloride, Cl	mg/L	1	173.93	169.787	16	2
CE124202.040	LB041417.055	Chloride, Cl	mg/L	1	731.413	722.563	15	1
CE124241.002	LB041417.066	Chloride, Cl	mg/L	1	16974.816	16908.926	15	0
CE124241.012	LB041417.080	Chloride, Cl	mg/L	1	544.711	536.859	15	1
CE124242.001	LB041417.091	Chloride, Cl	mg/L	1	210	210	15	0

Metals in Water (Dissolved) by ICPOES — Method: ME-(AU)-[ENV]AN320/AN321

Original	Duplicate	Parameter	Units	LOR	Original	Duplicate	Criteria %	RPD %
CE124298.006	LB041532.014	Sulphur as Sulphate, SO4	mg/L	0.5	44.9664	45.0432	16	0
CE124298.009	LB041532.018	Sulphur as Sulphate, SO4	mg/L	0.5	0.2559888	0.2457522	200	0

LABORATORY CONTROL SAMPLES

CE124214 R0

Laboratory Control Standard (LCS) results are evaluated against an expected result, typically the concentration of analyte spiked into the control during the sample preparation stage, producing a percentage recovery. The criteria applied to the percentage recovery is established in the SGS QA /QC plan (Ref: MP-(AU)-[ENV]QU-022). For more information refer to the footnotes in the concluding page of this report.

Recovery is shown in **Green** when within suggested criteria or **Red** with an appended dagger symbol (†) when outside suggested criteria.

Alkalinity

Method: ME-(AU)-[ENV]AN135

Sample Number	Parameter	Units	LOR	Result	Expected	Criteria %	Recovery %
LB041324.002	Total Alkalinity as CaCO3	mg/L	5	71	59.5	80 - 120	119
LB041324.003	Total Alkalinity as CaCO3	mg/L	5	230	229	80 - 120	102
LB041324.029	Total Alkalinity as CaCO3	mg/L	5	66	59.5	80 - 120	110
LB041324.030	Total Alkalinity as CaCO3	mg/L	5	230	229	80 - 120	102

Chloride by Discrete Analyser in Water

Method: ME-(AU)-[ENV]AN274

Sample Number	Parameter	Units	LOR	Result	Expected	Criteria %	Recovery %
LB041417.002	Chloride, Cl	mg/L	1	130	125	80 - 120	104
LB041417.003	Chloride, Cl	mg/L	1	10	10	80 - 120	104
LB041417.025	Chloride, Cl	mg/L	1	130	125	80 - 120	104
LB041417.026	Chloride, Cl	mg/L	1	10	10	80 - 120	104
LB041417.048	Chloride, Cl	mg/L	1	130	125	80 - 120	104
LB041417.049	Chloride, Cl	mg/L	1	10	10	80 - 120	104
LB041417.071	Chloride, Cl	mg/L	1	130	125	80 - 120	104
LB041417.072	Chloride, Cl	mg/L	1	10	10	80 - 120	104

Conductivity and TDS by Calculation - Water

Method: ME-(AU)-[ENV]AN106

Sample Number	Parameter	Units	LOR	Result	Expected	Criteria %	Recovery %
LB041324.004	Conductivity @ 25 C	µS/cm	5	310	303	90 - 110	102
LB041324.005	Conductivity @ 25 C	µS/cm	5	58000	58670	90 - 110	100
LB041324.031	Conductivity @ 25 C	µS/cm	5	310	303	90 - 110	102
LB041324.032	Conductivity @ 25 C	µS/cm	5	58000	58670	90 - 110	99

Metals in Water (Dissolved) by ICPOES

Method: ME-(AU)-[ENV]AN320/AN321

Sample Number	Parameter	Units	LOR	Result	Expected	Criteria %	Recovery %
LB041532.002	Calcium, Ca	mg/L	0.1	21	20	80 - 120	103
	Magnesium, Mg	mg/L	0.1	20	20	80 - 120	101
	Potassium, K	mg/L	0.1	21	20	80 - 120	107
	Sodium, Na	mg/L	0.5	19	20	80 - 120	97

pH in water

Method: ME-(AU)-[ENV]AN101

Sample Number	Parameter	Units	LOR	Result	Expected	Criteria %	Recovery %
LB041324.006	pH**	pH Units	0.1	7.4	7.415	98 - 102	100
LB041324.033	pH**	pH Units	0.1	7.4	7.415	98 - 102	100

Matrix Spike (MS) results are evaluated as the percentage recovery of an expected result, typically the concentration of analyte spiked into a field sub -sample during the sample preparation stage. The original sample's result is subtracted from the sub-sample result before determining the percentage recovery. The criteria applied to the percentage recovery is established in the SGS QA/QC plan (ref: MP-(AU)-[ENV]QU-022). For more information refer to the footnotes in the concluding page of this report.

Recovery is shown in **Green** when within suggested criteria or **Red** with an appended reason identifer when outside suggested criteria. Refer to the footnotes section at the end of this report for failure reasons.

Metals in Water (Dissolved) by ICPOES — **Method: ME-(AU)-[ENV]AN320/AN321**

QC Sample	Sample Number	Parameter	Units	LOR	Result	Original	Spike	Recovery%
CE124214.001	LB041532.004	Calcium, Ca	mg/L	0.1	59	8.0	50	103
		Magnesium, Mg	mg/L	0.1	52	3.2	50	98
		Potassium, K	mg/L	0.1	54	0.8	50	106
		Sodium, Na	mg/L	0.5	63	17	50	93

MATRIX SPIKE DUPLICATES

CE124214 R0

Matrix spike duplicates are calculated as Relative Percent Difference (RPD) using the formula: RPD = | OriginalResult - ReplicateResult | x 100 / Mean

The original result is the analyte concentration of the matrix spike. The Duplicate result is the analyte concentration of the matrix spike duplicate.

The RPD is evaluated against the Maximum Allowable Difference (MAD) criteria and can be graphically represented by a curve calculated from the Statistical Detection Limit (SDL) and Limiting Repeatability (LR) using the formula: MAD = 100 x SDL / Mean + LR

Where the Maximum Allowable Difference evaluates to a number larger than 200 it is displayed as 200.

RPD is shown in **Green** when within suggested criteria or **Red** with an appended reason identifer when outside suggested criteria. Refer to the footnotes section at the end of this report for failure reasons.

No matrix spike duplicates were required for this job.

Samples analysed as received.

Solid samples expressed on a dry weight basis.

QC criteria are subject to internal review according to the SGS QA/QC plan and may be provided on request or alternatively can be found here: http://www.sgs.com.au/~/media/Local/Australia/Documents/Technical Documents/MP-AU-ENV-QU-022 QA QC Plan.pdf

*	NATA accreditation does not cover tthe performance of this service.
-	Sample not analysed for this analyte.

IS	Insufficient sample for analysis.
LNR	Sample listed, but not received.
LOR	Limit of reporting.
QFH	QC result is above the upper tolerance.
QFL	QC result is below the lower tolerance.

①	At least 2 of 3 surrogates are within acceptance criteria.
②	RPD failed acceptance criteria due to sample heterogeneity.
③	Results less than 5 times LOR preclude acceptance criteria for RPD.
④	Recovery failed acceptance criteria due to matrix interference.
⑤	Recovery failed acceptance criteria due to the presence of significant concentration of analyte (i.e. the concentration of analyte exceeds the spike level).
⑥	LOR was raised due to sample matrix interference.
⑦	LOR was raised due to dilution of significantly high concentration of analyte in sample.
⑧	Reanalysis of sample in duplicate confirmed sample heterogeneity and inconsistency of results.
⑨	Low surrogate recovery due to the sample emulsifying during extraction.
⑩	Legionella Test Result <10 cfu/mL Control Strategy (1) Maintain Monthly Program or at least 3-monthly monitoring. Maintain water treatment program
⑪	Legionella Test Result <1000 cfu/mL Control Strategy (2) Investigate problem. Review water treatment program. Take necessary remedial action (including immediate online disinfection) and undertake control strategy 3.
⑫	Control Strategy (3) Retest water within 3 to 7 days of plant operation. If not detected, continue to retest water every 3 to 7 days until 2 consecutive samples return readings of 'not detected', then repeat control strategy (1). If detected at <100 cfu/mL, repeat control strategy (2). If detected at >100 cfu/mL, investigate the problem and review water treatment program, and immediately carry out online decontamination. If detected at >1000 cfu/mL, undertake control strategy (4).
⑬	Legionella Test Result >1000 cfu/mL Control Strategy (4) Investigate problem. Review water treatment program. Take necessary remedial action (including immediate online decontamination) and undertake control strategy (5).
⑭	Control Strategy (5) Retest water within 3 to 7 days of plant operation. If not detected, continue to retest water every 3 to 7 days until 2 consecutive samples return readings of 'not detected', then repeat control strategy (1). If detected at <100 cfu/mL, repeat control strategy (1) If detected at >100 and <1000 cfu/mL, investigate the problem and review water treatment program, immediately carry out online decontamination, and repeat control strategy (5). If detected at >1000 cfu/mL, investigate and review the water treatment program, immediately carry out system decontamination and repeat control strategy (5).
⑮	HPC - Test Result < 100 000 cfu/mL Control Strategy (1) Maintain Monthly Program. Maintain water treatment program.

Samples analysed as received.

Solid samples expressed on a dry weight basis.

QC criteria are subject to internal review according to the SGS QA/QC plan and may be provided on request or alternatively can be found here: http://www.sgs.com.au/~/media/Local/Australia/Documents/Technical Documents/MP-AU-ENV-QU-022 QA QC Plan.pdf

⑯ HPC Test Result > 100 000 cfu/mL <5 000 000 cfu/mL
Control Strategy (2)
Investigate problem. Review water treatment program. Take necessary remedial action (including immediate online disinfection)
and undertake control strategy 3.

⑰ Control Strategy (3)
Retest water within 3 to 7 days of plant operation. If the test result is <100 000 cfu/mL, repeat control strategy (1)
If the test result is >100 000 cfu/mL but <5 000 000 cfu/mL, undertake control strategy (2).
If the test result is >5 000 000 cfu/mL, undertake control strategy (4).

⑱ HPC Test Result >5 000 000 cfu/mL
Control Strategy (4)
Investigate problem. Review water treatment program. Take necessary remedial action (including immediate online disinfection)
and undertake control strategy (5).

⑲ Control Strategy (5)
Retest water within 3 to 7 days of plant operation. If the test result is <100 000 cfu/mL, repeat control strategy (1)
If the test result is >100 000 cfu/mL but <5 000 000 cfu/mL, undertake control strategy (4).
If the test result is >5 000 000 cfu/mL, investigate the problem.
review the water treatment program, and carry out immediate online decontamination.

⑳ Enterococci - Median result should not exceed 230 cfu/100mL
(maximum number in any one sample: 450-700 cfu/100mL)
Sourced from NHMRC (National Health and Medical Research Council)
& NWQMS (National Water Quality Management Strategy)
-Australian Guidelines for Recreational Use of Water. Version Oct 2000.

† Refer to Analytical Report comments for further information.

GROUNDWATER SAMPLING RECORD FORM FOR THREE WELL VOLUME METHOD

Golder Associates

PROJECT INFORMATION

Project Number: 1546223
Client:
Site Location: Nuttern sand project

Date: 22/09/16
Sampled By: JC

GROUNDWATER WELL DATA

13:23 3.087 = 3x2 = 6L
6x3 = Note? olitres

BORE ID: ~~BH01~~ BH01

Information from file	
Surveyed reference point	
Depth of well (from log)	6m
Diameter of well (inc filter pack) (mm)	
Height of filter pack (m)	

Standard reference point is top of PVC standpipe
mbRP - metres below top of reference point

Information recorded on site	
Diameter of standpipe (mm)	50mm
Standpipe stick up (m)	
Time	1:23
Depth to water (mbRP) mBTOC	
Total depth of well (mbRP) mBTOC	6m
Thickness of sediment on base of well (m)	
Height of water in standpipe (m)	3.087
Well volume (L)	6

Interface probe used?	YES / NO
Depth to product (mbRP)	
Depth to water (mbRP)	
Thickness of product (m)	

Water column above filter pack, well volume wihtin 50mm standpipe is 2 litres/m

Estimation of Standing Well Volumes for 50 mm diameter standpipes, for height of water column within filter pack

Well diameter (standpipe plus filter pack)	100mm	115mm	120mm	125mm	150mm	200mm
Litres per lineal meter of water in bore	3.7	4.5	4.8	5.1	6.7	10.8

PURGING RECORD

Time	Volume Purged (L)	Conductivity (mS or µS)	Temp (°C)	pH	Redox Potential (mV)	Dissolved Oxygen (mg/L)	Appearance (colour, turbidity, odour, etc)
1:31	7	347	26.64	7.18	220	2	light grey / low reaction
1:32.5	215	329	26.02	8.71	276	3.3	//
1:33.5	230	315	26.01	9.93	293	2.5	//
1:35	245	307	25.93	7.21	292	0.5	//
1:36	230	298	25.91	7.24	293	0.1	//
1:37	210	297	26.02	6.5	316	0.6	//
5:40		373	12.85	7.18	263	-1	
Total vol. purged (L)			No. bore vol. purged			Purging Time (minutes)	

at camp LAB

Depth to water at end of purging (mbRP)
Purging Method: Waterra pump

x Something going on wrong with the pump

SAMPLING RECORD

Sampling method: Waterra pump
Time sampled: 1.45
Sample Appearance:
Colour: light grey
Odour: No

Sample ID. BH01
Samples filtered for metals?: Yes / No

Turbidity: Low / Medium / High
Hydrocarbon sheen? No

Sample Container and Preservation: 1 green bottle.

Duplicate sample taken? / Dup ID.:

OBSERVATIONS

Weather Conditions: Temperature: 3.5
Precipitation: No

Notes: 1.24 : take out data loggers
2.00 : put back data loggers

wl: 1.59 3.08 before data logger
2.00 3.084 after

GROUNDWATER SAMPLING RECORD FORM FOR THREE WELL VOLUME METHOD

Golder Associates

PROJECT INFORMATION

Project Number: 1546223
Client:
Site Location: Northern Sand project

Date: 22/11/16
Sampled By: JC

GROUNDWATER WELL DATA

7L : 21L

BORE ID: BH02

Information from file

Surveyed reference point	
Depth of well (from log)	6m
Diameter of well (inc filter pack) (mm)	
Height of filter pack (m)	

Information recorded on site

Diameter of standpipe (mm)	50mm
Standpipe stick up (m)	
Time	7:20
Depth to water (~~mbRP~~) mBGL	2.523
Total depth of well (mbRP) mBGL	6m
Thickness of sediment on base of well (m)	
Height of water in standpipe (m)	
Well volume (L)	

Note:

Standard reference point is top of PVC standpipe
mbRP - metres below top of reference point

Interface probe used?	YES / NO
Depth to product (mbRP)	
Depth to water (mbRP)	
Thickness of product (m)	

Water column above filter pack, well volume wihtin 50mm standpipe is 2 litres/m

Estimation of Standing Well Volumes for 50 mm diameter standpipes, for height of water column within filter pack

Well diameter (standpipe plus filter pack)	100mm	115mm	120mm	125mm	150mm	200mm
Litres per lineal meter of water in bore	3.7	4.5	4.8	5.1	6.7	10.8

PURGING RECORD

Time	Volume Purged (L)	Conductivity (mS or µS)	Temp (°C)	pH	Redox Potential (mV)	Dissolved Oxygen (mg/L)	Appearance (colour, turbidity, odour, etc)
2:24	25	8000	26.44	9.82	77	0.3	Brown High turbidity
2:26	30	8000	26.39	9.86	39	0.3	11
2:27	2.70	7880	26.34	8.9	30	-0.6	
2:30	25	8000	26.68	7.65	55	-0	
2:32	30	8000	26.82	7.96	70	-0.1	
2:34	33	8000	26.91	7.60	82	-0.1	lot of Silt content
2:37	37	8000	26.94	6.80	89	-0.1	
Total vol. purged (L) 2.39			No. bore vol. purged 6.40			Purging Time (minutes)	

Depth to water at end of purging (mbRP)
Purging Method: Waterra pump.

SAMPLING RECORD

Sampling method: Waterra pump
Time sampled: 2.40
Sample Appearance:
Colour: Brown
Odour: Slight organic
Sample Container and Preservation: 1 green bottle

Sample ID: BH02
Samples filtered for metals?: Yes / (No)
Turbidity: Low / Medium / (High)
Hydrocarbon sheen? NO
Duplicate sample taken? / Dup ID.: NO

OBSERVATIONS

Weather Conditions: Temperature: 35
Precipitation: No
Notes: 2.19 pull up Datalogger 2.53: WL: ?
2.55 WL

1

GROUNDWATER SAMPLING RECORD FORM FOR THREE WELL VOLUME METHOD

Golder Associates

PROJECT INFORMATION

Project Number: 154 223
Client:
Site Location: Nathern Sand project

Date: 22/11/16
Sampled By: JC

GROUNDWATER WELL DATA

BORE ID: BH03

Information from file

Surveyed reference point	
Depth of well (from log)	
Diameter of well (inc filter pack) (mm)	
Height of filter pack (m)	

Information recorded on site

Diameter of standpipe (mm)	
Standpipe stick up (m)	
Time	3.10
Depth to water (~~mbRP~~) mBTOC	2.50
Total depth of well (~~mbRP~~) / mBTOC	11.31 2.12m
Thickness of sediment on base of well (m)	
Height of water in standpipe (m)	
Well volume (L)	3 ~~L~~ litres to remove

Note:

Standard reference point is top of PVC standpipe
mbRP - metres below top of reference point

Interface probe used?	YES / NO
Depth to product (mbRP)	
Depth to water (mbRP)	
Thickness of product (m)	

Water column above filter pack, well volume wihtin 50mm standpipe is 2 litres/m

Estimation of Standing Well Volumes for 50 mm diameter standpipes, for height of water column within filter pack

Well diameter (standpipe plus filter pack)	100mm	115mm	120mm	125mm	150mm	200mm
Litres per lineal meter of water in bore	3.7	4.5	4.8	5.1	6.7	10.8

PURGING RECORD

Time	Volume Purged (L)	Conductivity (mS or µS)	Temp (°C)	pH	Redox Potential (mV)	Dissolved Oxygen (mg/L)	Appearance (colour, turbidity, odour, etc)
3:14	10	25.46	25.94	8.86	165	0.5	Brown/H GOH Turbidity
3:15	20	25.5	25.86	8.52	165	0.7	"
3:17	30	25.55	25.83	8.47	144	0.7	"
3:20	40	25.42	25.82	8.40	148	0.8	"
3:21	47	25.40	26.03	6.98	157	0.9	"
3:23	43	25.29	26.07	6.91	153	0.7	"
3:25	38	25.15	26.09	7.24	146	0.3	
Total vol. purged (L)			No. bore vol. purged			Purging Time (minutes)	
3:26 60		"	10.23	"	"		

Depth to water at end of purging (mbRP)
Purging Method: Waterra Pump

SAMPLING RECORD

Sampling method: Waterra pump
Time sampled: 3:30
Sample Appearance:
Colour: orange brown
Odour: NO

Sample ID. BH03
Samples filtered for metals?: Yes / No

Turbidity: Low / Medium / High
Hydrocarbon sheen? NO

Sample Container and Preservation: 1 poly bottle

Duplicate sample taken? / Dup ID.: NO

OBSERVATIONS

Weather Conditions: Temperature: 35
Precipitation :

Notes: pull contact NO 3.10 wl: 2.48 3.1
wl: 2.48 purge

Golder Associates

GROUNDWATER SAMPLING RECORD FORM
FIELD PARAMETER MEASUREMENTS

PROJECT INFORMATION

Client: FCG

Project: Northern Sands

Location: NS

Project No: 1546223

Date of Sampling: 29.9.16

Sampled By: DS

GROUNDWATER BORE DATA

Diameter of Column (mm)	125
Diameter of Bore (mm)	50
Standing Water Level (m TOC)	2.99
Total Depth of Bore (m TOC)	6.57
Depth of Water in Column (m)	3.5
Standpipe stick up (m)	0.5

BORE ID BH01

Interface probe used?	(Yes) / No
Depth to product (m TOC)	—
Depth to water (m TOC)	2.99
Thickness of product (mm)	—

PURGING RECORD

Volume Purged (L)	Dissolved Oxygen (mg/L)	Temperature (C)	TDS (ppm / ppt)	pH	Conductivity (uS, mS)	Redox Potential	Turbidity (NTU)	Other %
10	0.9	22.37	0.15	9.23	0.30	99	600	10.0
15	0.4	22.25	0.15	6.52	0.30	142	196.	10
30	0.5	22.25	0.15	6.49	0.30	170	175	10.9

Total volume purged (L)	45	No. bore volumes purged	3	Purging Time (minutes)	9

(Prior to sampling consecutive measurements for pH vaule should be within 0.1 pH units, for conductivity, salinity and dissolved oxygen should be within 10% and temperature should be within 0.5 °C.)

SAMPLING RECORD

Samples Taken? (YES) / NO

Duplicate sample taken? YES / (NO)

Samples filtered? YES / (NO) for Metals / other:

Filter Method: 0.45 mm filter & syringe / other :

Water Quality Meter type:

Water Dipper type:

Pumping Method: Submersible Pump / Disposable Bailer / other:

Container:	Preservation:
Vial ☐	H_2SO_4 / other:
500ml Glass ☐	none / other:
500 ml Plastic ☑	none / ~~other:~~
1 l Plastic ☐	H_2SO_4 / other:
200 ml Plastic ☑	~~NaOH~~ / ~~other:~~ ACID WASH
200 mL Glass ☐	HNO_3 / other:

OBSERVATIONS

Samples: Colour: CLEAR & RED Turbidity Low / Medium / High

Odour: — Hydrocarbon sheen? Yes / No

Weather Conditions: *Sampling Day* Rain — Temperature 31

Previous Week Rain ____ Temperature ____

Notes:

Reference Information: Estimation of Standing Well Volumes for 50mm diameter Wells

Well Diameter (Casing plus filter pack)	75mm	100mm	125mm	150mm	200mm
Litres per lineal meter of water in well	2.7	3.7	5.1	6.7	10.8

Note: Typical Eziprobe well diameter =75mm

Sampling procedures are based on AS/NZS 5667.11:1998 Water Quality - Sampling Part 11: Guidance on sampling of groundwaters

Golder Associates

GROUNDWATER SAMPLING RECORD FORM
FIELD PARAMETER MEASUREMENTS

PROJECT INFORMATION

Client: FCG

Project: NORTHERN SANDS

Location: NS

Project No: 1546223

Date of Sampling: 29.9.16

Sampled By: DS

GROUNDWATER BORE DATA

Diameter of Column (mm)	125
Diameter of Bore (mm)	50
Standing Water Level (m TOC)	2.294
Total Depth of Bore (m TOC)	5.220
Depth of Water in Column (m)	3.0
Standpipe stick up (m)	0.6

3m

BORE ID: BH02 (B402)

Interface probe used?	Yes / No
Depth to product (m TOC)	—
Depth to water (m TOC)	2.294
Thickness of product (mm)	—

PURGING RECORD

Volume Purged (L)	Dissolved Oxygen (mg/L)	Temperature (C)	TDS (ppm / ppt)	pH	Conductivity (µS, mS)	Redox Potential	Turbidity (NTU)	Other
15	0.0	23.03	5.95	8.89	10.54	19	77.0	HEAVY SILT DARK GREY
30	0.0	22.72	5.59	8.00	10.08	-22	127.5	
Total volume purged (L)			No. bore volumes purged			Purging Time (minutes)		

(Prior to sampling consecutive measuements for pH vaule should be within 0.1 pH units, for conductivity, salinity and dissolved oxygen should be within 10% and temperature should be within 0.5 °C.)

SAMPLING RECORD

Samples Taken? YES / NO

Duplicate sample taken? YES / NO

Samples filtered? YES / NO for Metals / other:

Filter Method: 0.45 mm filter & syringe / other:

Water Quality Meter type: YEOKAL

Water Dipper type: 1P

Pumping Method: Submersible Pump / Disposable Bailer / other: WATERRA

Container:	Preservation:
Vial ☐	H_2SO_4 / other:
500ml Glass ☐	none / other:
500 ml Plastic ☑	none / other:
1 l Plastic ☐	H_2SO_4 / other:
200 ml Plastic ☐	NaOH / other:
200 mL Glass ☑	~~HNO_3~~ / other: NONE / ACID WASHED

OBSERVATIONS

Samples: Colour: GREY

Odour: NIL

Turbidity: Low / Medium / High

Hydrocarbon sheen? Yes / No

Weather Conditions: *Sampling Day* Rain — Temperature 31

Previous Week Rain ____ Temperature ____

Notes:

Reference Information: Estimation of Standing Well Volumes for 50mm diameter Wells

Well Diameter (casing plus filter pack)	75mm	100mm	125mm	150mm	200mm
Litres per lineal meter of water in well	2.7	3.7	5.1	6.7	10.8

Note: Typical Eziprobe well diameter =75mm

Sampling procedures are based on AS/NZS 5667.11:1998 Water Quality - Sampling Part 11: Guidance on sampling of groundwaters

AST'S

CAR SCRAPPING

Golder Associates

GROUNDWATER SAMPLING RECORD FORM
FIELD PARAMETER MEASUREMENTS

PROJECT INFORMATION

Client: FCG

Project: NORTHERN SANDS HYDRO

Location: NORTHERN SANDS

Project No: 1546223

Date of Sampling: 29.9.16

Sampled By: DCS

GROUNDWATER BORE DATA

Diameter of Column (mm)	125
Diameter of Bore (mm)	50
Standing Water Level (m TOC)	2.41
Total Depth of Bore (m TOC)	11.28
Depth of Water in Column (m)	
Standpipe stick up (m)	0.65

BORE ID B403

Interface probe used?	(Yes) / No
Depth to product (m TOC)	—
Depth to water (m TOC)	2.41
Thickness of product (mm)	—

PURGING RECORD

Volume Purged (L)	Dissolved Oxygen (mg/L)	Temperature (C)	TDS (ppm / ppt)	pH	Conductivity (~~uS~~ mS)	Redox Potential	Turbidity (NTU)	Other
5	0.0	22.32	16.11	8.52	26.36	65	600	RED/BROWN
25	0.0	22.28	16.19	9.58	26.45	7	660	CLEARING
50	0.0	22.28	16.23	10.21	26.54	-3	600	" "
Total volume purged (L)			No. bore volumes purged			Purging Time (minutes)		

(Prior to sampling consecutive measurements for pH vaule should be within 0.1 pH units, for conductivity, salinity and dissolved oxygen should be within 10% and temperature should be within 0.5 °C.)

SAMPLING RECORD

Samples Taken? (YES) / NO

Duplicate sample taken? YES / (NO)

Samples filtered? YES / (NO) for Metals / other:

Filter Method: 0.45 mm filter & syringe / other :

Water Quality Meter type: YEOKAL

Water Dipper type: 1P

Pumping Method: Submersible Pump / Disposable Bailer / other:

Container:	Preservation:
Vial ☐	H_2SO_4 / other:
500ml Glass ☐	none / other:
500 ml Plastic ☑	none / other:
1 l Plastic ☐	H_2SO_4 / other:
200 ml Plastic ☑	NaOH / other:
200 mL Glass ☐	HNO_3 / other:

OBSERVATIONS

Samples: Colour: BROWN-RED Turbidity Low / Medium / (High)

Odour: NIL Hydrocarbon sheen? Yes / (No)

Weather Conditions: *Sampling Day* Rain — Temperature 31

Previous Week Rain ____ Temperature ____

Notes: WELL DIPPED AFTER SAMPLING IN ERROR.

Reference Information: Estimation of Standing Well Volumes for 50mm diameter Wells

Well Diameter (Casing plus liner pack)	75mm	100mm	125mm	150mm	200mm
Litres per lineal meter of water in well	2.7	3.7	5.1	6.7	10.8

Note: Typical Eziprobe well diameter =75mm

Sampling procedures are based on AS/NZS 5667.11:1998 Water Quality - Sampling Part 11: Guidance on sampling of groundwaters

Well	DTW	DTL
B403	2.41	10.0
BH02	2.294	5.3
BH01	2.99	5.3

GROUNDWATER SAMPLING RECORD FORM FOR THREE WELL VOLUME METHOD

Golder Associates

PROJECT INFORMATION

Project Number: 1546223
Client: FCG
Site Location: NORTHERN SANDS

Date: 25.11.18
Sampled By: DLS

GROUNDWATER WELL DATA

BORE ID: ~~GA02~~ GA04

Note:

Standard reference point is top of PVC standpipe
mbRP - metres below top of reference point

Information from file

Surveyed reference point	TOC
Depth of well (from log)	6.4
Diameter of well (inc filter pack) (mm)	100
Height of filter pack (m)	4.3

Information recorded on site

Diameter of standpipe (mm)	50
Standpipe stick up (m)	0.9
Time	0730
Depth to water (mbRP)	4.171
Total depth of well (mbRP)	6.4
Thickness of sediment on base of well (m)	—
Height of water in standpipe (m)	2.3
Well volume (L)	7

Interface probe used?	YES / NO
Depth to product (mbRP)	
Depth to water (mbRP)	4.171
Thickness of product (m)	

Water column above filter pack, well volume within 50mm standpipe is 2 litres/m 2L

Estimation of Standing Well Volumes for 50 mm diameter standpipes, for height of water column within filter pack

Well diameter (standpipe plus filter pack)	100mm	115mm	120mm	125mm	150mm	200mm
Litres per lineal meter of water in bore	3.7	4.5	4.8	5.1	6.7	10.8

PURGING RECORD

Time	Volume Purged (L)	Conductivity (mS or µS)	Temp (°C)	pH	Redox Potential (mV)	Dissolved Oxygen (mg/L)	Appearance (colour, turbidity, odour, etc)
0730	7	142	22.56	5.67	453	-0.9	BROWN/HP/600 NTU
0733	14	140	22.76	5.70	~~545~~ 450	-0.9	" / "
0736	21	148	22.68	5.74	457	-0.9	" / "
Total vol. purged (L)		No. bore vol. purged			Purging Time (minutes)		

Depth to water at end of purging (mbRP) 4.17
Purging Method: WATERRA 3 well vol

SAMPLING RECORD

Sampling method: WATERRA 3 well vol
Sample ID. GA04
Time sampled: 0740
Samples filtered for metals?: Yes / No
Sample Appearance:
Colour BROWN
Odour —
Turbidity Low / Medium / High
Hydrocarbon sheen? —
Sample Container and Preservation: NIL
Duplicate sample taken? / Dup ID.: —

OBSERVATIONS

Weather Conditions: Temperature: HOT
Precipitation: —
Notes:

6.4
4.1
2.3

APPENDIX F

Soil Laboratory Test Results

Cardno Shaping the Future

Cardno Construction Sciences
ABN: 74 128 806 735

Address:
Shed 3, 5 Commercial Place
Earlville QLD 4870

Laboratory **Cairns Laboratory**
Phone: 0740337815 **Fax:** 0740546632

Email: cnz.lab@cardno.com.au

MINIMUM / MAXIMUM DENSITY REPORT

Client:	Golder Associates Pty Ltd	Report Number:	11512/R/11062-1
Client Address:	216, Draper Street, Cairns	Project Number:	11512/P/592
Project:	General Testing	Lot Number:	BH1-002
Location:	North Queensland	Internal Test Request:	11512/T/6454
Component:	Compliance Testing	Client Reference/s:	Baron River Delta
Area Description:		Report Date / Page:	1/12/2016 Page 1 of 2

Test Procedures:	AS1289.5.5.1		GA04
Sample Number	11512/S/31833		Brown Sand
Sampling Method	Tested As Received		
Date Sampled	25/11/2016		
Sampled By	Client Sampled	Material Source	Supplied Samples
Date Tested	30/11/2016	Material Type	QAA Sample

Maximum Dry Density Result	
Size of Mould Used (Litres)	1.0
Maximum Dry Density (t/m³)	**1.88**

Minimum Dry Density Result	
Size of Mould Used (Litres)	1.0
Minimum Dry Density (t/m³)	**1.46**

Remarks

NATA

e results of the tests, calibrations and/or measurements included in document are traceable to Australian/national standards.
Accredited for compliance with ISO/IEC 17025

Accreditation Number: 1986
Corporate Site Number: 11512

Approved Signatory: Peter Gode
Form ID: W19Rep Rev 1

Cardno Shaping the Future

Cardno Construction Sciences
ABN: 74 128 806 735

Address:
Shed 3, 5 Commercial Place
Earlville QLD 4870

Laboratory Cairns Laboratory
Phone: 0740337815 **Fax:** 0740546632

Email: cnz.lab@cardno.com.au

MINIMUM / MAXIMUM DENSITY REPORT

Client:	Golder Associates Pty Ltd	Report Number:	11512/R/11062-1
Client Address:	216, Draper Street, Cairns	Project Number:	11512/P/592
Project:	General Testing	Lot Number:	BH1-002
Location:	North Queensland	Internal Test Request:	11512/T/6454
Component:	Compliance Testing	Client Reference/s:	Baron River Delta
Area Description:		Report Date / Page:	1/12/2016 Page 2 of 2

Test Procedures:	AS1289.5.5.1		GA05
Sample Number	11512/S/31834		Yellow Sand
Sampling Method	Tested As Received		
Date Sampled	25/11/2016		
Sampled By	Client Sampled	Material Source	Supplied Samples
Date Tested	29/11/2016	Material Type	QAA Sample

Maximum Dry Density Result	
Size of Mould Used (Litres)	1.0
Maximum Dry Density (t/m³)	**1.89**

Minimum Dry Density Result	
Size of Mould Used (Litres)	1.0
Minimum Dry Density (t/m³)	**1.52**

Remarks

NATA

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Accreditation Number: 1986
Corporate Site Number: 11512

Approved Signatory: Peter Gode
Form ID: W19Rep Rev 1

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Email: cnz.lab@cardno.com.au

MOISTURE CONTENT REPORT

Client:	Golder Associates Pty Ltd	Report Number:	11512/R/11061-1
Client Address:	216, Draper Street, Cairns	Project Number:	11512/P/592
Project:	General Testing	Lot Number:	BH1-002
Location:	North Queensland	Internal Test Request:	11512/T/6454
Component:	Compliance Testing	Client Reference/s:	Baron River Delta
Area Description:		Report Date / Page:	1/12/2016 Page 1 of 1

Test Procedures:	AS1289.2.1.1

Sample Number	11512/S/31833	11512/S/31834		
ID / Client ID	-	-		
Lot Number	BH1-002	BH1-002		
Date / Time Sampled	25/11/2016	25/11/2016		
Sampling Method	Tested As Received	Tested As Received		
Date Tested	29/11/2016	29/11/2016		
Material Source	Supplied Samples	Supplied Samples		
Material Type	QAA Sample	QAA Sample		
	GA04	GA05		
	Brown Sand	Yellow Sand		
Moisture Content (%)	**27.5**	**14.0**		

Sample Number				
ID / Client ID				
Lot Number				
Date / Time Sampled				
Sampling Method				
Date Tested				
Material Source				
Material Type				
Moisture Content (%)				

Remarks

NATA

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Accreditation Number: 1986
Corporate Site Number: 11512

Approved Signatory: Peter Gode
Form ID: W20Rep Rev 1

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Laboratory Cairns Laboratory
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Email: cnz.lab@cardno.com.au

ATTERBERG LIMITS REPORT

Client:	Golder Associates Pty Ltd	Report Number:	11512/R/11063-1
Client Address:	216, Draper Street, Cairns	Project Number:	11512/P/592
Project:	General Testing	Lot Number:	BH1-002
Location:	North Queensland	Internal Test Request:	11512/T/6454
Component:	Compliance Testing	Client Reference/s:	Baron River Delta
Area Description:		Report Date / Page:	1/12/2016 Page 1 of 2

Test Procedures:	AS1289.3.1.2, AS 1289.3.3.1, AS1289.3.2.1, AS1289.3.4.1		
Sample Number	11512/S/31833	Sample Location	
Sampling Method	Tested As Received		GA04
Date Sampled	25/11/2016		Brown Sand
Sampled By	Client Sampled		
Date Tested	30/11/2016		
Att. Drying Method	-	Material Source	Supplied Samples
Atterberg Preparation	-	Material Type	QAA Sample
Material Description	-		

Atterberg Limits Results

Atterberg Limit	Specification Minimum	Test Result	Specification Maximum
Liquid Limit (%)		**Not Obtainable**	
Plastic Limit (%)		**Not Obtainable**	
Plasticity Index (%)		**Non Plastic**	
Linear Shrinkage (%)		-	
Linear Shrinkage Defects:	-		

Remarks

NATA

e results of the tests, calibrations and/or measurements included in document are traceable to Australian/national standards.
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Accreditation Number: 1986
Corporate Site Number: 11512

Approved Signatory: Peter Gode
Form ID: W11bRep Rev 1

Cardno Shaping the Future

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Laborator Cairns Laboratory
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Email: cnz.lab@cardno.com.au

ATTERBERG LIMITS REPORT

Client:	Golder Associates Pty Ltd	Report Number:	11512/R/11063-1
Client Address:	216, Draper Street, Cairns	Project Number:	11512/P/592
Project:	General Testing	Lot Number:	BH1-002
Location:	North Queensland	Internal Test Request:	11512/T/6454
Component:	Compliance Testing	Client Reference/s:	Baron River Delta
Area Description:		Report Date / Page:	1/12/2016 Page 2 of 2

Test Procedures:	AS1289.3.1.2, AS 1289.3.3.1, AS1289.3.2.1, AS1289.3.4.1		
Sample Number	11512/S/31834	Sample Location	
Sampling Method	Tested As Received		GA05
Date Sampled	25/11/2016		Yellow Sand
Sampled By	Client Sampled		
Date Tested	1/12/2016		
Att. Drying Method	-	Material Source	Supplied Samples
Atterberg Preparation	-	Material Type	QAA Sample
Material Description	-		

Atterberg Limits Results			
Atterberg Limit	Specification Minimum	Test Result	Specification Maximum
Liquid Limit (%)		**Not Obtainable**	
Plastic Limit (%)		**Not Obtainable**	
Plasticity Index (%)		**Non Plastic**	
Linear Shrinkage (%)		-	
Linear Shrinkage Mould Length / Defects:	Mould Length: 150.0mm / -		

Remarks

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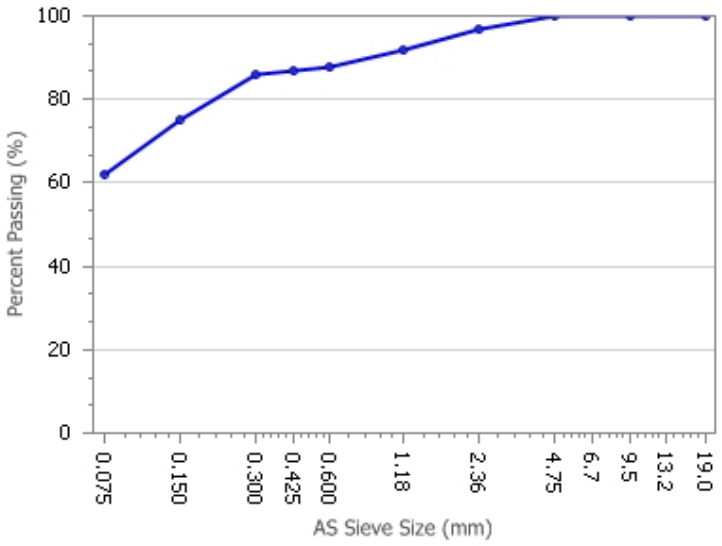
QUALITY OF MATERIALS REPORT

Client:	Golder Associates Pty Ltd	Report Number:	11512/R/11246-1
Client Address:	216, Draper Street, Cairns	Project Number:	11512/P/677
Project:	Project No.: 1546223 Contact: Joseph Parisi	Lot Number:	
Location:	Cairns	Internal Test Request:	11512/T/6529
Component:	Soil Testing	Client Reference/s:	PO: Q003655 | Submitted 02-12-16
Area Description:	Submitted samples	Report Date / Page:	9/12/2016 Page 1 of 4

Test Procedures	AS1289.3.6.1, AS1289.3.1.2, AS1289.3.2.1, AS1289.3.4.1, AS1289.2.1.1, AS 1289.3.3.1		
Sample Number	11512/S/32143		GA04-DS1
Sampling Method	Tested As Received		Depth: 0.5-0.8m
Date Sampled	2/12/2016		
Sampled By	Client Sampled		
Date Tested	6/12/2016	Material Source	Not Supplied
Att. Drying Method	Oven Dried	Material Type	Not Supplied (Not Supplied)
Atterberg Preparation	Dry Sieved	Material Description	-

AS Sieve (mm)	Specification Minimum	Percent Passing (%)	Specification Maximum
19.0		**100**	
9.5		**100**	
4.75		**100**	
2.36		**97**	
1.18		**92**	
0.600		**88**	
0.425		**87**	
0.300		**86**	
0.150		**75**	
0.075		**62**	

PARTICLE SIZE DISTRIBUTION GRAPH



Test Result	Specification Minimum	Result	Specification Maximum	Test Result	Specification Minimum	Result	Specification Maximum
Liquid Limit (%)		**27**		0.075/0.425 Fines Ratio		**0.71**	
Plastic Limit (%)		**19**		PI x 0.425 Ratio (%)		**696.0**	
Plastic Index (%)		**8**		LS x 0.425 Ratio (%)		**435.0**	
Linear Shrinkage (%)		**5.0**		Particle Size Dist. Moisture Content (%)		7.9	
Linear Shrinkage Defects	Nil						

Remarks

NATA

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Accreditation Number: 1986
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Approved Signatory: Kyle Jeffries
Form ID: W85MCRep Rev 1

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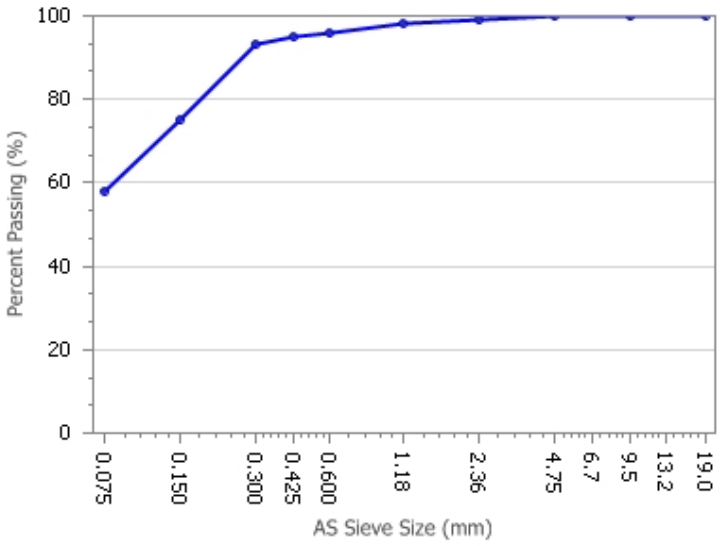
QUALITY OF MATERIALS REPORT

Client:	Golder Associates Pty Ltd	Report Number:	11512/R/11246-1
Client Address:	216, Draper Street, Cairns	Project Number:	11512/P/677
Project:	Project No.: 1546223 Contact: Joseph Parisi	Lot Number:	
Location:	Cairns	Internal Test Request:	11512/T/6529
Component:	Soil Testing	Client Reference/s:	PO: Q003655 | Submitted 02-12-16
Area Description:	Submitted samples	Report Date / Page:	9/12/2016 Page 2 of 4

Test Procedures	AS1289.3.6.1, AS1289.3.1.2, AS1289.3.2.1, AS1289.3.4.1, AS1289.2.1.1, AS 1289.3.3.1		
Sample Number	11512/S/32144		GA04-DS2
Sampling Method	Tested As Received		Depth: 1.2-1.5m
Date Sampled	2/12/2016		
Sampled By	Client Sampled		
Date Tested	6/12/2016	Material Source	Not Supplied
Att. Drying Method	Oven Dried	Material Type	Not Supplied (Not Supplied)
Atterberg Preparation	Dry Sieved	Material Description	-

AS Sieve (mm)	Specification Minimum	Percent Passing (%)	Specification Maximum
19.0		**100**	
9.5		**100**	
4.75		**100**	
2.36		**99**	
1.18		**98**	
0.600		**96**	
0.425		**95**	
0.300		**93**	
0.150		**75**	
0.075		**58**	

PARTICLE SIZE DISTRIBUTION GRAPH



Test Result	Specification Minimum	Result	Specification Maximum	Test Result	Specification Minimum	Result	Specification Maximum
Liquid Limit (%)		**29**		0.075/0.425 Fines Ratio		**0.61**	
Plastic Limit (%)		**19**		PI x 0.425 Ratio (%)		**954.0**	
Plastic Index (%)		**10**		LS x 0.425 Ratio (%)		**572.4**	
Linear Shrinkage (%)		**6.0**		Particle Size Dist. Moisture Content (%)		11.5	
Linear Shrinkage Defects	Nil						

Remarks

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Accreditation Number: 1986
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Approved Signatory: Kyle Jeffries
Form ID: W85MCRep Rev 1

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QUALITY OF MATERIALS REPORT

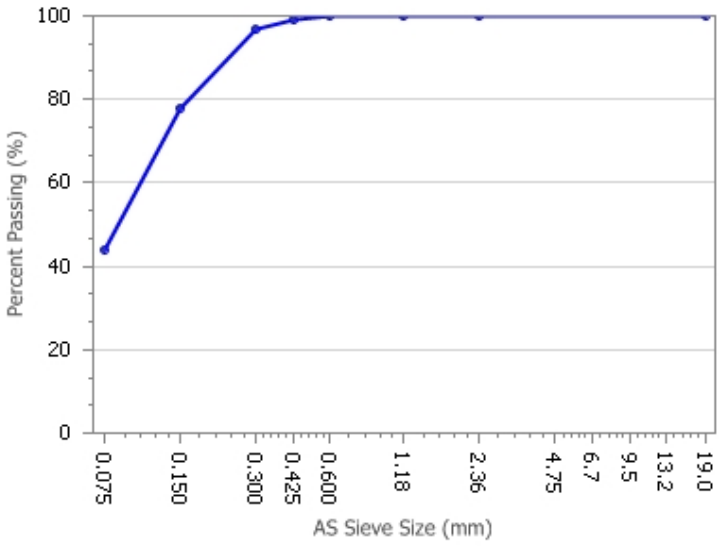
Client:	Golder Associates Pty Ltd	Report Number:	11512/R/11246-1
Client Address:	216, Draper Street, Cairns	Project Number:	11512/P/677
Project:	Project No.: 1546223 Contact: Joseph Parisi	Lot Number:	
Location:	Cairns	Internal Test Request:	11512/T/6529
Component:	Soil Testing	Client Reference/s:	PO: Q003655 | Submitted 02-12-16
Area Description:	Submitted samples	Report Date / Page:	9/12/2016 Page 3 of 4

Test Procedures	AS1289.3.6.1, AS1289.3.1.2, AS1289.3.2.1, AS1289.3.4.1, AS1289.2.1.1, AS 1289.3.3.1

Sample Number	11512/S/32145		GA05-DS1
Sampling Method	Tested As Received		Depth: 0.6-0.9m
Date Sampled	2/12/2016		
Sampled By	Client Sampled		
Date Tested	6/12/2016	Material Source	Not Supplied
Att. Drying Method	Oven Dried	Material Type	Not Supplied (Not Supplied)
Atterberg Preparation	Dry Sieved	Material Description	-

AS Sieve (mm)	Specification Minimum	Percent Passing (%)	Specification Maximum
19.0		**100**	
2.36		**100**	
1.18		**100**	
0.600		**100**	
0.425		**99**	
0.300		**97**	
0.150		**78**	
0.075		**44**	

PARTICLE SIZE DISTRIBUTION GRAPH



Test Result	Specification Minimum	Result	Specification Maximum	Test Result	Specification Minimum	Result	Specification Maximum
Liquid Limit (%)		**21**		0.075/0.425 Fines Ratio		**0.45**	
Plastic Limit (%)		**17**		PI x 0.425 Ratio (%)		**396.4**	
Plastic Index (%)		**4**		LS x 0.425 Ratio (%)		**99.1**	
Linear Shrinkage (%)		**1.0**		Particle Size Dist. Moisture Content (%)		9.6	
Linear Shrinkage Defects	Nil						

Remarks

NATA

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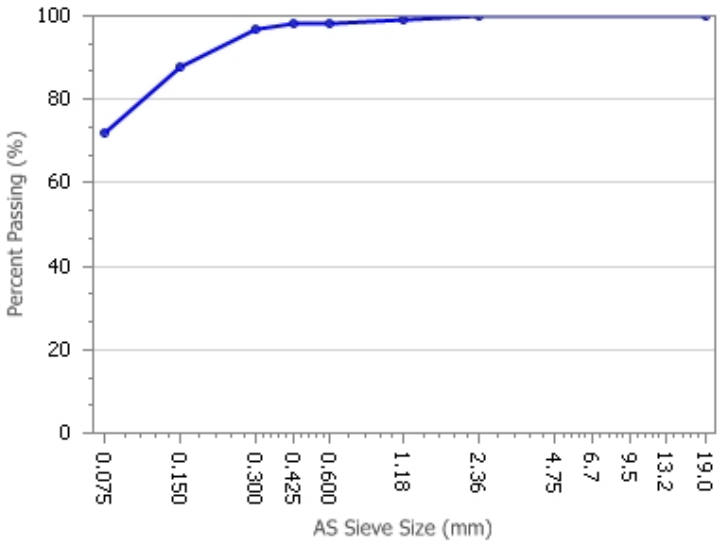
QUALITY OF MATERIALS REPORT

Client:	Golder Associates Pty Ltd	Report Number:	11512/R/11246-1
Client Address:	216, Draper Street, Cairns	Project Number:	11512/P/677
Project:	Project No.: 1546223 Contact: Joseph Parisi	Lot Number:	
Location:	Cairns	Internal Test Request:	11512/T/6529
Component:	Soil Testing	Client Reference/s:	PO: Q003655 | Submitted 02-12-16
Area Description:	Submitted samples	Report Date / Page:	9/12/2016 Page 4 of 4

Test Procedures	AS1289.3.6.1, AS1289.3.1.2, AS1289.3.2.1, AS1289.3.4.1, AS1289.2.1.1, AS 1289.3.3.1		
Sample Number	11512/S/32146		GA05-DS2
Sampling Method	Tested As Received		Depth: 1.2-1.5m
Date Sampled	2/12/2016		
Sampled By	Client Sampled		
Date Tested	6/12/2016	Material Source	Not Supplied
Att. Drying Method	Oven Dried	Material Type	Not Supplied (Not Supplied)
Atterberg Preparation	Dry Sieved	Material Description	-

AS Sieve (mm)	Specification Minimum	Percent Passing (%)	Specification Maximum
19.0		**100**	
2.36		**100**	
1.18		**99**	
0.600		**98**	
0.425		**98**	
0.300		**97**	
0.150		**88**	
0.075		**72**	

PARTICLE SIZE DISTRIBUTION GRAPH



Test Result	Specification Minimum	Result	Specification Maximum	Test Result	Specification Minimum	Result	Specification Maximum
Liquid Limit (%)		**35**		0.075/0.425 Fines Ratio		**0.74**	
Plastic Limit (%)		**20**		PI x 0.425 Ratio (%)		**1464.0**	
Plastic Index (%)		**15**		LS x 0.425 Ratio (%)		**829.6**	
Linear Shrinkage (%)		**8.5**		Particle Size Dist. Moisture Content (%)		28.8	
Linear Shrinkage Defects	Curling						

Remarks

NATA

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Accreditation Number: 1986
Corporate Site Number: 11512

Approved Signatory: Kyle Jeffries
Form ID: W85MCRep Rev 1

APPENDIX G

Hydraulic Conductivity Testing Results.

Hydraulic Conductivity Test - Constant Head Test (Talsma-Method)

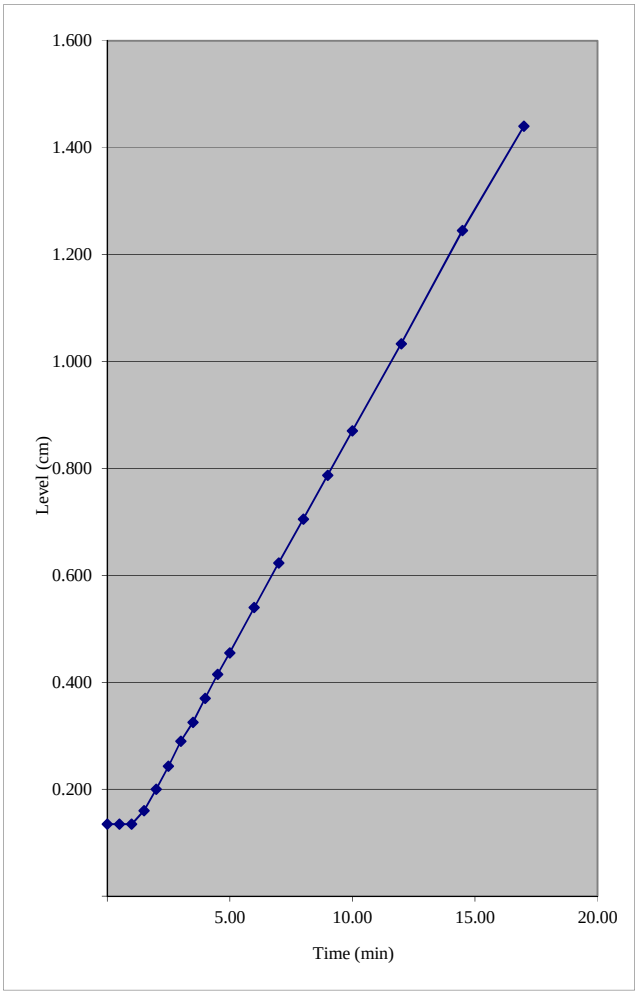
Site:	Northern Sands		
Project Number:	1546223	**Test Location:**	GA04
Date:	24/11/2016		
Staff:	JL	**Method:**	**AS/NZS 1547:2000

Talsma-Hallam method for determining the permeability of soil using a constantly maintained head of water.

Field Results

Time (min)	Level (m)
	0.135
0.50	0.135
1.00	0.135
1.50	0.160
2.00	0.200
2.50	0.243
3.00	0.290
3.50	0.325
4.00	0.370
4.50	0.415
5.00	0.455
6.00	0.540
7.00	0.623
8.00	0.705
9.00	0.787
10.00	0.870
12.00	1.033
14.50	1.245
17.00	1.440

Talsma Tube - Level vs Time



$$K_{SAT} = \frac{4.4Q\left[0.5\sinh^{-1}\left(\frac{H}{2r}\right) - \sqrt{\left\{\left(\frac{r}{H}\right)^2 + 0.25\right\}} + \frac{r}{H}\right]}{2\pi H^2}$$

Where

Ksat = saturated hydraulic conductivity of soil in cm/min

4.4 = correction factor for a systematic under-estimate of soil permeability in the mathematical derivation of the equation.

Q = rate of loss of water from the reservoir in cm^3/min

H = depth to water in test hole in cm.

r = radius of the test hole in cm.

Talsma outflow / minute =	8.21 cm/min
Permeameter cross-sec area =	10.86 cm²
Q =	89.14 cm³/min
H =	133.00 cm
r =	5.00 cm
Correction factor =	4.4

Apply Steady State (See graph above)

Ksat =	**4.15E-03**	**cm/min**
=	**6.92E-07**	**m/sec**
=	**5.98E-02**	**m/day**

Input By:	JJP	**Date:**	28/11/2016
Reviewed By:	MSC	**Date:**	28/11/2016

Hydraulic Conductivity Test - Constant Head Test (Talsma-Method)

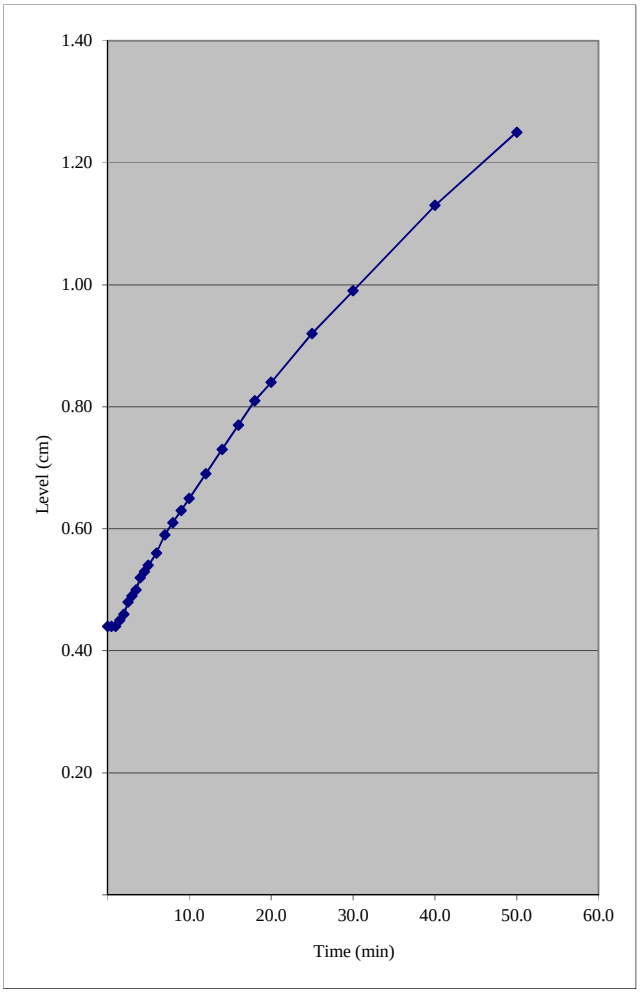
Site:	Northern Sands		
Project Number:	1546223	**Test Location:**	GA05
Date:	24/11/2016		
Staff:	DS	**Method:**	**AS/NZS 1547:2000

Talsma-Hallam method for determining the permeability of soil using a constantly maintained head of water.

Field Results

Time (min)	Level (m)
	0.44
0.50	**0.44**
1.00	0.44
1.50	0.45
2.00	0.46
2.50	0.48
3.00	0.49
3.50	0.50
4.00	**0.52**
4.5	**0.53**
5.0	**0.54**
6.0	**0.56**
7.0	**0.59**
8.0	**0.61**
9.0	**0.63**
10.0	**0.65**
12.0	**0.69**
14.0	**0.73**
16.0	**0.77**
18.0	**0.81**
20.0	**0.84**
25.0	**0.92**
30.0	**0.99**
40.0	**1.13**
50.0	**1.25**

Talsma Tube - Level vs Time



$$K_{SAT} = \frac{4.4Q\left[0.5\sinh^{-1}\left(\frac{H}{2r}\right) - \sqrt{\left\{\left(\frac{r}{H}\right)^2 + 0.25\right\}} + \frac{r}{H}\right]}{2\pi H^2}$$

Where

Ksat = saturated hydraulic conductivity of soil in cm/min

4.4 = correction factor for a systematic under-estimate of soil permeability in the mathematical derivation of the equation.

Q = rate of loss of water from the reservoir in cm^3/min

H = depth to water in test hole in cm.

r = radius of the test hole in cm.

Talsma outflow / minute =	1.32 cm/min
Permeameter cross-sec area =	10.86 cm²
Q =	14.34 cm³/min
H =	143.00 cm
r =	3.75 cm
Correction factor =	4.4

Apply Steady State (See graph above)

Ksat =	**6.61E-04**	**cm/min**
=	**1.10E-07**	**m/sec**
=	**9.52E-03**	**m/day**

Input By:	JJP	**Date:**	25/11/2016
Reviewed By:	MSC	**Date:**	25/11/2016

APPENDIX H

Important information relating to this document

IMPORTANT INFORMATION RELATING TO THIS REPORT

The document ("Report") to which this page is attached and which this page forms a part of, has been issued by Golder Associates Pty Ltd ("Golder") subject to the important limitations and other qualifications set out below.

This Report constitutes or is part of services ("Services") provided by Golder to its client ("Client") under and subject to a contract between Golder and its Client ("Contract"). The contents of this page are not intended to and do not alter Golder's obligations (including any limits on those obligations) to its Client under the Contract.

This Report is provided for use solely by Golder's Client and persons acting on the Client's behalf, such as its professional advisers. Golder is responsible only to its Client for this Report. Golder has no responsibility to any other person who relies or makes decisions based upon this Report or who makes any other use of this Report. Golder accepts no responsibility for any loss or damage suffered by any person other than its Client as a result of any reliance upon any part of this Report, decisions made based upon this Report or any other use of it.

This Report has been prepared in the context of the circumstances and purposes referred to in, or derived from, the Contract and Golder accepts no responsibility for use of the Report, in whole or in part, in any other context or circumstance or for any other purpose.

The scope of Golder's Services and the period of time they relate to are determined by the Contract and are subject to restrictions and limitations set out in the Contract. If a service or other work is not expressly referred to in this Report, do not assume that it has been provided or performed. If a matter is not addressed in this Report, do not assume that any determination has been made by Golder in regards to it.

At any location relevant to the Services conditions may exist which were not detected by Golder, in particular due to the specific scope of the investigation Golder has been engaged to undertake. Conditions can only be verified at the exact location of any tests undertaken. Variations in conditions may occur between tested locations and there may be conditions which have not been revealed by the investigation and which have not therefore been taken into account in this Report.

Golder accepts no responsibility for and makes no representation as to the accuracy or completeness of the information provided to it by or on behalf of the Client or sourced from any third party. Golder has assumed that such information is correct unless otherwise stated and no responsibility is accepted by Golder for incomplete or inaccurate data supplied by its Client or any other person for whom Golder is not responsible. Golder has not taken account of matters that may have existed when the Report was prepared but which were only later disclosed to Golder.

Having regard to the matters referred to in the previous paragraphs on this page in particular, carrying out the Services has allowed Golder to form no more than an opinion as to the actual conditions at any relevant location. That opinion is necessarily constrained by the extent of the information collected by Golder or otherwise made available to Golder. Further, the passage of time may affect the accuracy, applicability or usefulness of the opinions, assessments or other information in this Report. This Report is based upon the information and other circumstances that existed and were known to Golder when the Services were performed and this Report was prepared. Golder has not considered the effect of any possible future developments including physical changes to any relevant location or changes to any laws or regulations relevant to such location.

Where permitted by the Contract, Golder may have retained subconsultants affiliated with Golder to provide some or all of the Services. However, it is Golder which remains solely responsible for the Services and there is no legal recourse against any of Golder's affiliated companies or the employees, officers or directors of any of them.

By date, or revision, the Report supersedes any prior report or other document issued by Golder dealing with any matter that is addressed in the Report.

Any uncertainty as to the extent to which this Report can be used or relied upon in any respect should be referred to Golder for clarification.

As a global, employee-owned organisation with over 50 years of experience, Golder Associates is driven by our purpose to engineer earth's development while preserving earth's integrity. We deliver solutions that help our clients achieve their sustainable development goals by providing a wide range of independent consulting, design and construction services in our specialist areas of earth, environment and energy.

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