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CAIRNS SHIPPING DEVELOPMENT PROJECT

Revised Draft Environmental Impact Statement

APPENDIX AK: Groundwater Impact Assessment: Northern Sands DMPA Report (2017)

2 June 2017

GROUNDWATER IMPACT ASSESSMENT - NORTHERN SANDS DMPA

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 related to soils and groundwater issues as part of the Revised Draft Environmental Impact Statement for the Cairns Shipping Development Project (CSDP).

The CSDP will require the land based placement of approximately 900,000 m^3 of soft clays and up to 100,000 m^3 of stiff clays at separate Dredge Material Placement Areas (DMPA). The stiff clays are proposed to be placed at Port North’s Tingira Street property. The soft clays are proposed to be placed in the Northern Sands void DMPA.

The soft clays are to be dredged via a 5,600 m3 capacity Trailer Suction Hopper Dredge (TSHD) discharging to a temporary floating pump out facility that will be situated between approximately 2.6 and 3.6 km north east of Yorkeys Knob.

Dredge material will be pumped from the pump out facility via a submerged steel pipeline, which will make landfall near the Richters Creek mouth, thence to the Northern Sands DMPA mainly via cane farm headlands. Due to the ~8 km pipeline length that will be required to connect the pump out facility to the Northern Sands DMPA, up to three pipeline booster pumps may be required, depending on TSHD pumping capacity. Tailwater is proposed to be discharged adjacent to the site or pumped to an outfall at the Barron River highway bridge. This report 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.

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.

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 will be enlarged by extension into an area located to the north of the pit).

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. 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 and flat coastal plains of the Barron River Delta extending from the west of the site and east toward the ocean. Ground surface elevations across the site typically range from about 5.5 m to 2 m Australia Height Datum (m AHD).

Narelle Lake is the main surface water feature at the site. Recent hydrographic survey (July 2016 by Ports North) of the lake indicates excavation levels typically range from -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 water level in the lake varies, with measured water levels generally between -0.5 m

AHD and 0.5 m AHD, with higher levels up to approximately RL 1.8 m AHD (refer to Section 3.2 for discussion of lake levels).

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 has an average width of about 150 m with an assumed bed level of around -2 m AHD.

2.4 Regional Geology and Hydrogeology

Surface geology in the area of the site is shown on Figure 3. The Northern Sands site is located on the alluvial fan and delta of the Barron River. 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. These 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).

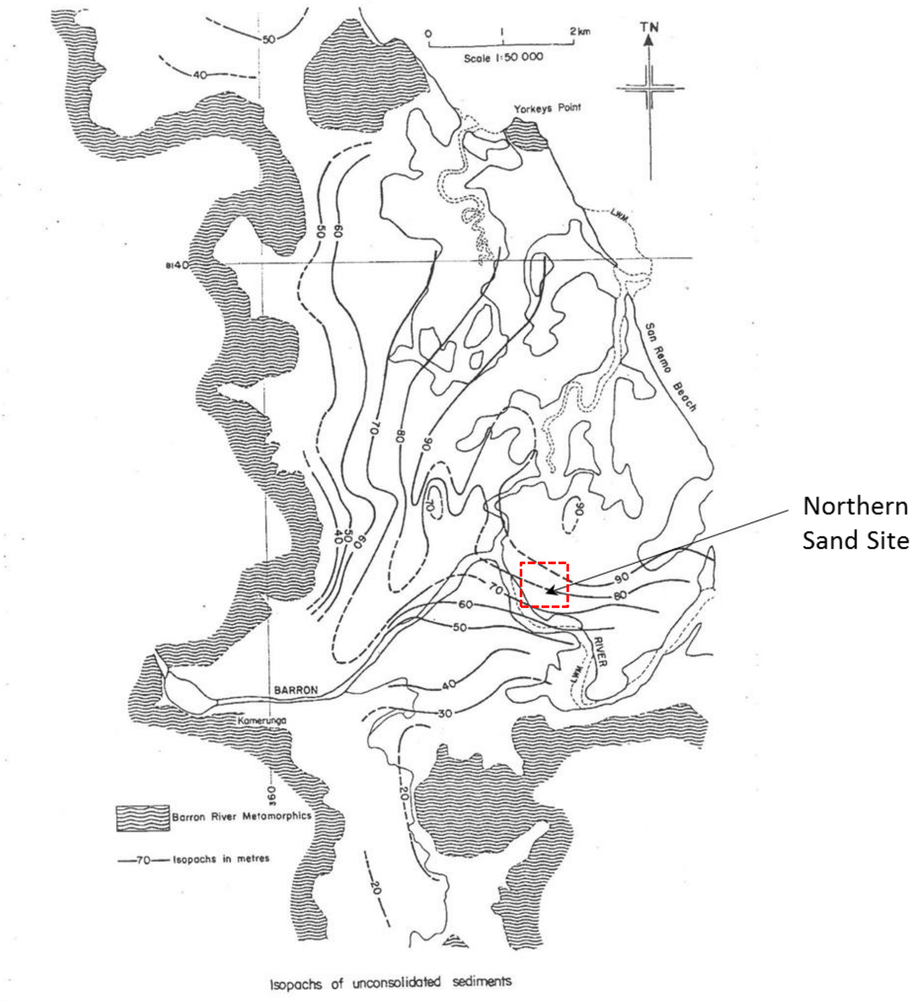

Plate 1 – Thickness of Unconsolidated Alluvium

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.

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 east of the site and consist of silt, sand and mud. This sequence was 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 within the unconsolidated sediments of the Barron River delta (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. Elevated salinity 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.

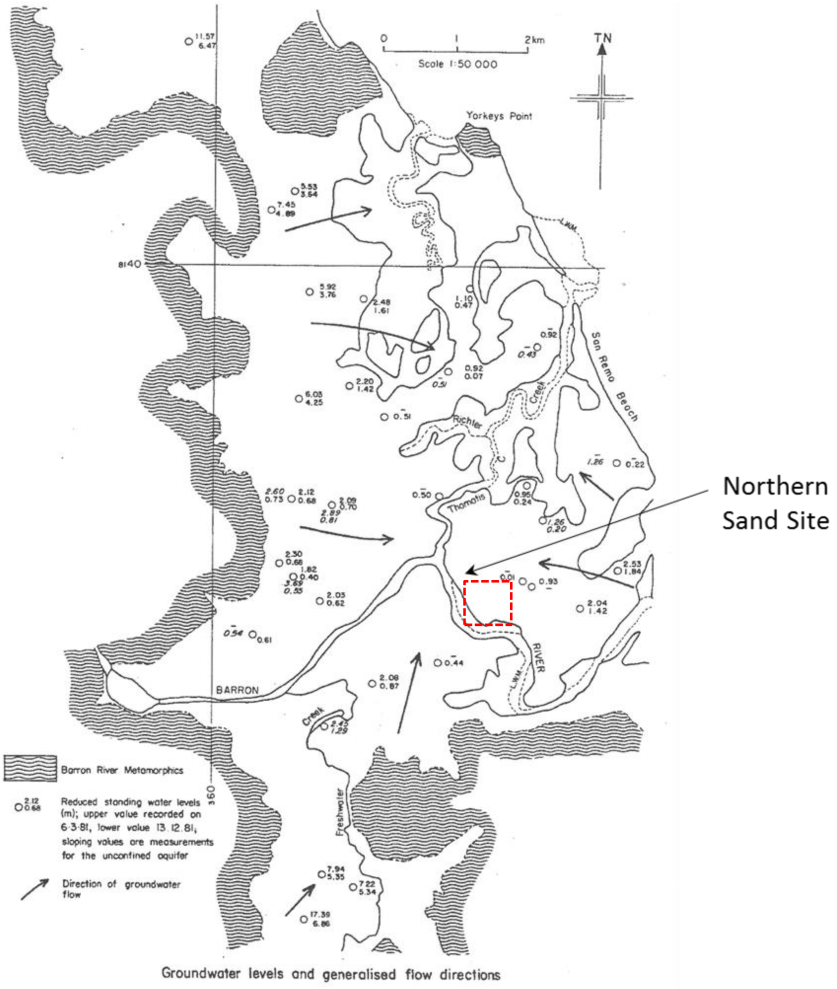

Plate 2 – Groundwater Flow across the Barron Delta

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 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 bore 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 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 10 m. This layer may not be continuous although it is shown to be so in Figures 9 and 10.
- Sand/gravelly sand broadly between -7 m AHD to -20 m AHD.
- Silty clay broadly between – 14 m AHD to -26 m AHD, and with a maximum thickness of around 12 m.
- Gravelly sand/sandy gravel below -26 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 10 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 -26m 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 Tables 3 & 4. These bore were developed after their installation by purging at least 5 well volumes to remove drilling and filter pack fines and to ensure hydraulic connection between the aquifer and the bore casing. Water quality parameters were monitored during development until parameters stabilised.

Pressure/temperature transducers were installed in BH01 and BH03 in September 2016 to record groundwater levels at one hourly intervals. Hydrographs of groundwater levels at BH01 and BH03 from 29 September to 6 April 2017 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	2.5 to 1.4	0.1 to 1.3
BH02	6.0	3.0 to 6.0	Clayey sand	Unconfined	2.0 to 1.2	-0.1 to 1.0
BH03	12.0	6.0 to 12.0	Clayey sand and clay	Unconfined	2.0 to 1.0	-0.06 to 0.97
GA04	5.5	3.5 to 5.5	Sand	Unconfined	3.4 to 1.8	0.2 to 1.7

**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. It is understood that the tide gauge does not accurately measure low water levels and is not able to read levels below approximately 0 m AHD. Records from this station are interpreted to indicate a long-term average river level of around 0.25 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	7.6 to 7.9	6.7 to 8.0	2,900 to 11,000	8,000 to 10,000	Brackish water
BH03	7.9 to 8.0	7.2 to 10.2	8,600 to 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 Appendix G 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 x 10^{-4}
BH02	3.0 to 6.0	Clayey sand	Hvorslev	9 x 10^{-7}
BH03	6.0 to 12.0	Clayey sand	Hvorslev	3 x 10^{-4}
GA04	3.5 to 5.5	Sand	Hvorslev	2 x 10^{-3}
GA04	0.3 to1.4	Sandy clay	Talsma equation	7 x 10^{-7}
GA05	0.3 to 1.5	Sandy clay	Talsma equation	1 x 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	0.39
GA04 (Brown Sand)	96	1.86	1.46	27.5	0.82	0.29
GA05 (Yellow Sand)	45	1.67	1.46	14.0	0.81	0.37
GA05 (Yellow Sand)	96	1.87	1.64	14.0	0.61	0.29

A porosity of 0.35 was adopted for the groundwater modelling for the upper sand layer.

3.6 Conceptual Hydrogeological Model

A conceptual hydrogeological model for the Northern Sands site is illustrated in Figure 15. 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 flow 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 dredged material placement 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, primarily through the upper sand layer as a result of the higher permeability of these sediments. Flow will diminish over time as a result of the low permeability of dredged material which will fill the base of the lake and “seal” the upper sand unit.

4.0 CONSTRAINTS AND OPPORTUNITIES

Dredged material will be placed in the sand pit along with large volumes of seawater, within a containment bund that will be constructed around the perimeter of the lake, and across the lake and across the two existing islands that are located within the lake (refer to the drawing included in Appendix H). The northern section of the pit will also be deepened to accommodate the volume of material that will be placed. Water levels in the lake will be raised to between 5 m to 7 m AHD during material placement. 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 western 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 horizontally through the sandy materials exposed around the edges of the lake with the potential to impact on water quality in this aquifer. There is also the potential for increased salinity in the near surface clay layer, either as a result of direct lateral migration from the lake, or as a result of upward migration of salt from the impacted extent of the upper unconfined aquifer.

The water level in the tailwater treatment ponds will be only slightly above typical lake levels, and will only be elevated for a short period of time. The potential for impact on groundwater is thus significantly less than for the disposal area.

The potential for unacceptable impacts on water quality in the Barron River and in the upper unconfined aquifer, and the potential for increased salinity in near surface soils has been assessed through groundwater modelling as discussed in the following section.

5.0 ASSESSMENT OF IMPACTS

5.1 Groundwater modelling to assess impacts on upper unconfined aquifer and shallow soils, and impacts on Barron River

5.1.1 Description of Groundwater Model

As discussed in Section 3.6, a conceptual hydrogeological model for the Northern Sands site was prepared as shown in Figure 15. 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 SSW to NNE and SW to NE oriented cross-sections as shown in Figure 8. The simplified cross-sectional models are shown in Figure 16.

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.

During the placement of dredged material, the water level in the lake will be raised and the pit filled with saline water. Modelling has been carried out for maximum lake levels at RL 5 m AHD, RL 5.5 m AHD, RL 6.5 m AHD and RL 7.0 m AHD. Placement of the dredged material has been modelled in 4 sequential steps, with placement of the dredged material in a series of horizontal lifts to raise the dredged material level a maximum level at 1.2 m below the maximum lake level over a period of 80 days. It has been assumed that the dredged material will have a hydraulic conductivity of 1 x 10^{-7} m/s.

The adopted boundary conditions are shown in Figure 17. The water level in the lake has been modelled as increasing from 0.25 m AHD to 3 m AHD over the first 7 days of filling, and then being held constant at this level until the level of dredged material in the lake has risen to above the top of the upper sand layer.

5.1.2 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 18 to 25. Figures 22 to 25 show contours of the salinity concentration under increased lake levels during the period of placement and for 2 years following filling. Figures 18 to 21 show profiles of the **increase** in salinity concentration above the existing concentration (i.e. prior to placement) 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. 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 26.

The increased distance of salt migration for the lower water levels relates to the time required for the upper sand layer to be covered by the dredged material. The rate of lateral migration reduces once this layer is covered by the low permeability dredged material, and the time required for the dredged material to rise to the level of the top of the sand layer is longer for the models with lower water levels. Note that, as discussed above, the boundary condition representing the water in the lake has been based on the assumption that the water level will be held constant at RL 3 m AHD until the level of dredged material in the lake has risen to above the top of the upper sand layer. This has the effect of limiting the head that drives the lateral migration and will be the primary mitigation measure to limit the extent of lateral migration.

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

Section	Level of water in placement area	Approximate maximum distance to which increased concentration extends
Section 1	RL 5m AHD	110m
	RL 5.5 m AHD	120m
	RL 6.5 m AHD	90 m
	RL 7.0 m AHD	80 m
Section 2	RL 5.0m AHD	115 m
	RL 5.5 m AHD	110 m
	RL 6.5m AHD	105 m
	RL 7 m AHD	105 m

The results of the modelling indicate that lateral migration through the near surface clay layer is significantly less than the extent of migration through the upper sand layer, and 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.

Within the extent of aquifer that is impacted by outward migration of salt during the period of placement of the dredged material, salt concentrations are likely to remain elevated for a in the long term[1] following the placement. Lateral flow of groundwater will be impacted by the change from the current situation with groundwater flow to the current lake, to groundwater flow around the infilled lake. This will limit the rate at which salt will be flushed from the system, however it is noted that in the area to the north of the placement area, groundwater flow towards Thomatis Creek will be unaffected by the placement of dredged materials.

5.1.3 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 placement 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 briefly reach a rate of 25,000 m^3/day with a maximum salt flux of 3500 g/s distributed along the approximately 1.1 km length of the Barron River that is located to the west of the placement area, for a lake level in the placement area of RL 7 m AHD. These seepage and salt flux rates impacts will be of short duration during the period before the dredge material rises above the level of the upper sand layer.

Potential impacts of the seepage on water quality in the Barron River have been addressed by BMT WBM in their Marine Water Quality Impact Assessment Technical Report, 2017.

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[1] Refer to Table 10 for definitions of duration of impact that are used in this report.

5.2 Other Impacts

Other impacts which could result from the proposed extension of the lake, construction of the bunds, and increased water level in the lake during placement of dredged material include:

- Seepage beneath the bund wall in areas where the foundation material beneath the bund comprises higher permeability sandy material leading to increased saturation levels/water logging with high salinity at the surface close to the bund wall. Upward migration of water, potentially with elevated salinity, could also occur at locations further from the bund wall as a result of increased groundwater pressures in the upper aquifer, where isolated areas of higher permeability sandy materials are present at surface and are directly connected with the upper aquifer. The potential for such impacts to occur close to the bund wall can be mitigated through appropriate subsurface investigations along the bund, and measures such as the removal of unsuitable material from the foundation. The potential for impacts at locations further from the bund wall can be mitigated through management of groundwater pressures in the upper aquifer. This mitigation will be achieved through controlling the water level in the lake until the level of the low permeability dredged material in the placement area has increased to the level where it limits the direct connection between the aquifer and the water in the placement area.

- If areas of high permeability sandy soils are not detected and addressed in the design and/or construction of the bund wall, the potential exists for piping through such materials, with the potential to impact on the integrity of the bund wall. This could lead to safety risks and risks to adjacent infrastructure, in addition to the environmental risks that would result from the potential release of large volumes of saline water and dredged material. The potential for such impacts to occur can be mitigated through appropriate subsurface investigations along the bund, appropriate design of the bund, and measures such as the removal of unsuitable material from the foundation.

5.3 Summary of Potential Impacts

The potential groundwater impacts associated with the project are summarised as follow:

- Impacts on water quality in the Barron River as a result of seepage from the dredge placement area to the river.
- Impacts on water quality in the upper unconfined aquifer.
- Increased salinity in near surface soils.
- Increased saturation levels/water logging of surface soils as a result of seepage beneath the bund wall.
- Seepage beneath the bund wall adversely impacting on the integrity of the bund wall.
- Upward migration of water, potentially with elevated salinity, at locations further from the bund wall where isolated areas of higher permeability sandy materials are present at surface and are directly connected with the laterally extensive upper aquifer.

Further assessment of soils related impacts is presented in Section 7.0

6.0 IMPACT ASSESSMENT – GROUNDWATER

6.1 Methodology

In order to address the terms of reference, guidelines and other requirements for the currently defined project, the following methodology was adopted:

- Assess impacts (based on the risk assessment format outlined below);
- Provide recommendations for mitigation by design changes; and
- Provide recommendations for mitigation by management.

Flanagan Consulting Group has extracted relevant items from the Queensland Government Terms of Reference and the Commonwealth Government Guidelines for groundwater studies. These items and relevant details are presented in Appendix I.

The initial assessment of impacts utilises a significance table based on that shown in Table 9.

Table 9: Significance criteria

Impact significance / consequence	Description of significance (examples)
Very High	The impact is considered critical to the decision-making process. Impacts tend to be permanent or irreversible or otherwise long term and can occur over large scale areas. Very high sensitivity of environmental receptors to impact (e.g. permanent loss of groundwater dependent ecosystems).
High	The impact is considered likely to be important to decision-making. Impacts tend to be permanent or irreversible or otherwise long to medium term. Impacts can occur over large or medium scale areas. High to moderate sensitivity of environmental receptors to impact (e.g. permanent increase in salinity of surface aquifer creating permanent decrease in cane crop yields and reduced health of riparian vegetation).
Moderate	The effects of the impact are relevant to decision making including the development of environmental mitigation measures Impacts can range from long term to short term in duration Impacts can occur over medium scale areas or otherwise represents a significant impact at the local scale Moderate sensitivity of environmental receptors to impact (e.g. bund failure resulting in discharge of saline waters and dredge material to riparian areas and Barron River and resulting in short term mortality of adjacent cane crops or short term suspended solids loading to the Barron River).).
Minor	Impacts are recognisable/detectable but acceptable. These impacts are unlikely to be of importance in the decision making process. Nevertheless, they are relevant in the consideration of standard mitigation measures. Impacts tend to be short term or temporary and/or occur at local scale. (e.g short term increase in salinity of surface aquifer creating short term decrease in cane crop yields and reduced health of riparian vegetation).
Negligible	Minimal change to the existing situation. This could include, for example, impacts which are beneath levels of detection, impacts that are within the normal bounds of variation, or impacts that are within the margin of forecasting error (e.g. minor short term salinity increases in adjacent surface aquifer salinity).
Beneficial	Impacts have a positive outcome on the existing situation. This could include for example, an improvement in vegetation management or an improvement in air quality as a result of the project.

The approach to classifying the duration of identified impacts is presented in Table 10.

Table 10: Classifications of the duration of identified impacts

Relative Duration Of Impacts	
Temporary	Days to months
Short Term	Up to one year
Medium Term	From one to five years
Long Term	From five to 50 years
Permanent/Irreversible	In excess of 50 years

The likelihood of an impact occurring is assessed as per Table 11.

Table 11: Likelihood of impact

Likelihood of Impacts	Risk probability categories
Highly Unlikely	Highly unlikely to occur but theoretically possible
Unlikely	May occur during construction of the project but probability well below 50%; unlikely, but not negligible
Possible	Less likely than not but still appreciable; probability of about 50%
Likely	Likely to occur during construction or during a 12 month timeframe; probability greater than 50%
Almost Certain	Very likely to occur as a result of the proposed project construction and/or operations; could occur multiple times during relevant impacting period

A risk rating is assigned by assessing significance versus likelihood within a risk matrix. Risk is described as the product of likelihood and significance as shown in Table 12.

Table 12: Risk matrix

Likelihood	Significance				
	Negligible	Minor	Moderate	High	Very high
Highly Unlikely/ Rare	Negligible	Negligible	Low	Medium	High
Unlikely	Negligible	Low	Low	Medium	High
Possible	Negligible	Low	Medium	Medium	High
Likely	Negligible	Medium	Medium	High	Extreme
Almost Certain	Low	Medium	High	Extreme	Extreme

The rating of risk assessed in the risk matrix is presented in Table 13.

Table 13: Risk Rating Legend

Extreme Risk	An issue requiring change in project scope; almost certain to result in a ‘significant’ impact on a Matter of National or State Environmental Significance
High Risk	An issue requiring further detailed investigation and planning to manage and reduce risk; likely to result in a ‘significant’ impact on a Matter of National or State Environmental Significance
Medium Risk	An issue requiring project specific controls and procedures to manage
Low Risk	Manageable by standard mitigation and similar operating procedures
Negligible Risk	No additional management required

After assessing the nature and severity of impacts they are summarised under the following categories:

- Adverse/beneficial;
- Consequential;
- Cumulative;
- Short-term/long term;
- Reversible/irreversible; and
- Predictable/unpredictable.

6.2 Results of impact assessment

Potential impacts related to groundwater and possible mitigation strategies have been outlined in Section 5.0.

An assessment of these impacts is presented in Table 15, based on the mitigation measures proposed in Table 14.

Table 14: Summary of Mitigation Measures

Impacting Processes	Proposed Mitigation Measures
Seepage from the dredge placement area towards the Barron River causing increases in salinity in the river.	Limit the water level in the lake until sufficient dredged material has been placed in the lake to create a low permeability barrier between the saline water in the lake, and the surrounding aquifer.
Lateral migration of saline water away from the dredge placement area causing impacts on water quality in the upper unconfined aquifer.	
Lateral migration of saline water away from the dredge placement area causing increased salinity in near surface soils.	
Elevated groundwater pressures in upper unconfined aquifer causing upward migration of potentially saline water, in areas where higher permeability sandy materials are present at surface.	
Seepage beneath the bund causing increased saturation levels/water logging of surface soils close to the bund.	Geotechnical investigation along the alignment of the wall to identify unsuitable foundation materials for the wall, engineering design to take into account foundation materials, and oversight of construction to ensure that the construction is adapted where necessary to ground conditions encountered on site.
Seepage beneath the bund wall adversely impacting on the integrity of the bund wall.	

Table 15: Assessment of impacts

Primary impacting processes	Initial assessment with standard (statutory) mitigation measures in Place			Residual assessment with additional (proposed) mitigation measures in place		
	Significance of impact	Likelihood of impact	Risk rating	Significance of impact	Likelihood of impact	Risk rating
Seepage from the dredge placement area towards the Barron River causing increases in salinity in the river.	Negligible	Almost certain	Low	Negligible	Almost certain	Low
Lateral migration of saline water away from the dredge placement area causing impacts on water quality in the upper unconfined aquifer.	Moderate	Likely	Medium	Minor	Likely	Medium
Lateral migration of saline water away from the dredge placement area causing increased salinity in near surface soils.	Moderate	Unlikely	Low	Moderate	Unlikely	Low
Seepage beneath the bund causing increased saturation levels/water logging of surface soils close to the bund.	Minor	Possible	Low	Minor	Unlikely	Low
Seepage beneath the bund wall adversely impacting on the integrity of the bund wall.	Moderate	Possible	Medium	Moderate	Unlikely	Low
Elevated groundwater pressures in upper unconfined aquifer causing upward migration of potentially saline water, in areas where higher permeability sandy materials are present at surface.	Moderate	Possible	Medium	Moderate	Unlikely	Low

Based on the above, the risks associated with potential impacts related to groundwater are assessed to be predominantly low, with a likely minor impact on water quality in the upper unconfined aquifer leading to a moderate risk. With reference to the modelling discussed in Section 5.0, these impacts are likely to be limited to a distance of 80 m to 120 m from the placement area. Further assessments of the impacts are presented in Table 16.

Table 16: Summary of assessed impacts

Element	Adverse impact	Beneficial impact	Consequential impact	Cumulative impact	Short term	Long term	Reversible	Irreversible	Predictable	Unpredictable
Groundwater and surface water	Lateral migration of saline water away from placement area causing increased salinity of the Barron River		Impacts on water quality.		X		X		X	
Groundwater	Lateral migration of saline water away from placement area causing increased salinity of upper unconfined aquifer		Limitations on the potential to locate shallow groundwater bores close to the placement area			X	X		X	
Groundwater and soils	Lateral migration of saline water away from placement area causing increased salinity of near surface soils		Decrease in productivity of agricultural land		X		X		X	
Groundwater	Seepage beneath the bund causing increased saturation levels/water logging of surface soils close to the bund.		Poor trafficability in areas close to the bund.		X		X		X	
Groundwater	Seepage beneath the bund wall adversely impacting on the integrity of the bund wall.		Failure of the bund wall with release of saline water and potential acid sulfate soils.		X		X		X	
Groundwater	Elevated groundwater pressures in upper unconfined aquifer causing upward migration of potentially saline water.		Poor trafficability, impacts on surface infrastructure, decrease in productivity of agricultural land.		X		X			X

7.0 MONITORING PROGRAM

As identified in Section 6.0 the main potential impacts on groundwater are:

- Localised increase in groundwater level adjacent to lake during dredged material placement; and
- Changes in groundwater quality (salinity) associated with flow of saline water outwards from the lake.

Groundwater monitoring will be carried out to assess changes in water level and water quality parameters, to assess whether such changes are within the expected range. The proposed groundwater monitoring network will make use of some of the existing monitoring bores at the site, and will also include additional bores located around the perimeter of the lake. The location of the existing and proposed monitoring bores is illustrated in Figure 27.

The groundwater monitoring network will be used to collect both groundwater level and water quality data prior to, during, and after placement of dredged material. Pressure/electrical conductivity transducers will be installed in selected bores to enable near real time monitoring of groundwater level, electrical conductivity and pH and to allow a greater understanding of the natural variability of these parameters. Trigger levels for water level and water quality parameters will be set relative to background values established through the pre-dredging period, and based on the predicted changes in water level and salinity.

Table 17 provides details of the proposed monitoring and sampling for different phases of the program.

A more detailed monitoring plan and approach to establishment of baseline values and trigger values will be developed in the detailed design phase.

Table 17: Proposed groundwater monitoring

Monitoring Phase	Parameter	Sampling Frequency
12 months prior to placement of dredged material	Water Level	Hourly (data logger) and manually during monthly sampling events
	Electrical Conductivity and pH	Hourly (data logger) and monthly during sampling events
	Field physicochemical parameters (EC, pH, DO, Redox, Temp)	Monthly during sampling events
	Major Ions	Monthly
	Metals (Total / Dissolved)	Monthly
During placement of dredged material	Water Level	Hourly (data logger) and manually during monthly sampling events
	Electrical Conductivity and pH	Hourly (data logger) and monthly during sampling events
	Field physicochemical parameters (EC, pH, DO, Redox, Temp)	Weekly during sampling events
	Major Ions	Weekly
	**Metals (Total / Dissolved)	Weekly
24 months after placement of dredged material	Water Level	Hourly (data logger) and manually during monthly sampling events
	Electrical Conductivity and pH	Hourly (data logger) and monthly during sampling events
	Field physicochemical parameters (EC, pH, DO, Redox Temp)	Monthly during sampling events
	Major Ions	Monthly
	**Metals (Total / Dissolved)	Monthly

**The need for on-going metal analysis will be assessed based on background concentrations and exceedances observed during filling. pH will be systematically monitoring and should pH values show a decrease to below 6, them metals testing would be recommenced.

8.0 REFERENCES

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- Landline Consulting, 2016, *Northern Sands Lake and Bore Stats,* Prepared for Flanagan Consulting Group, Queensland, Australia, 20 July 2016.
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- Golder Associates Pty Ltd (Golder), 2016, *Stage1B-Groundwater Report Northern Sands*, Prepared for Flanagan Consulting Group, Cairns shipping development project.

9.0 IMPORTANT INFORMATION

Your attention is drawn to the document - “Important Information relating to this report”, which is included as Appendix J. 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

Scott Fidler
Principal

SRF/MSC/ow

A.B.N. 64 006 107 857

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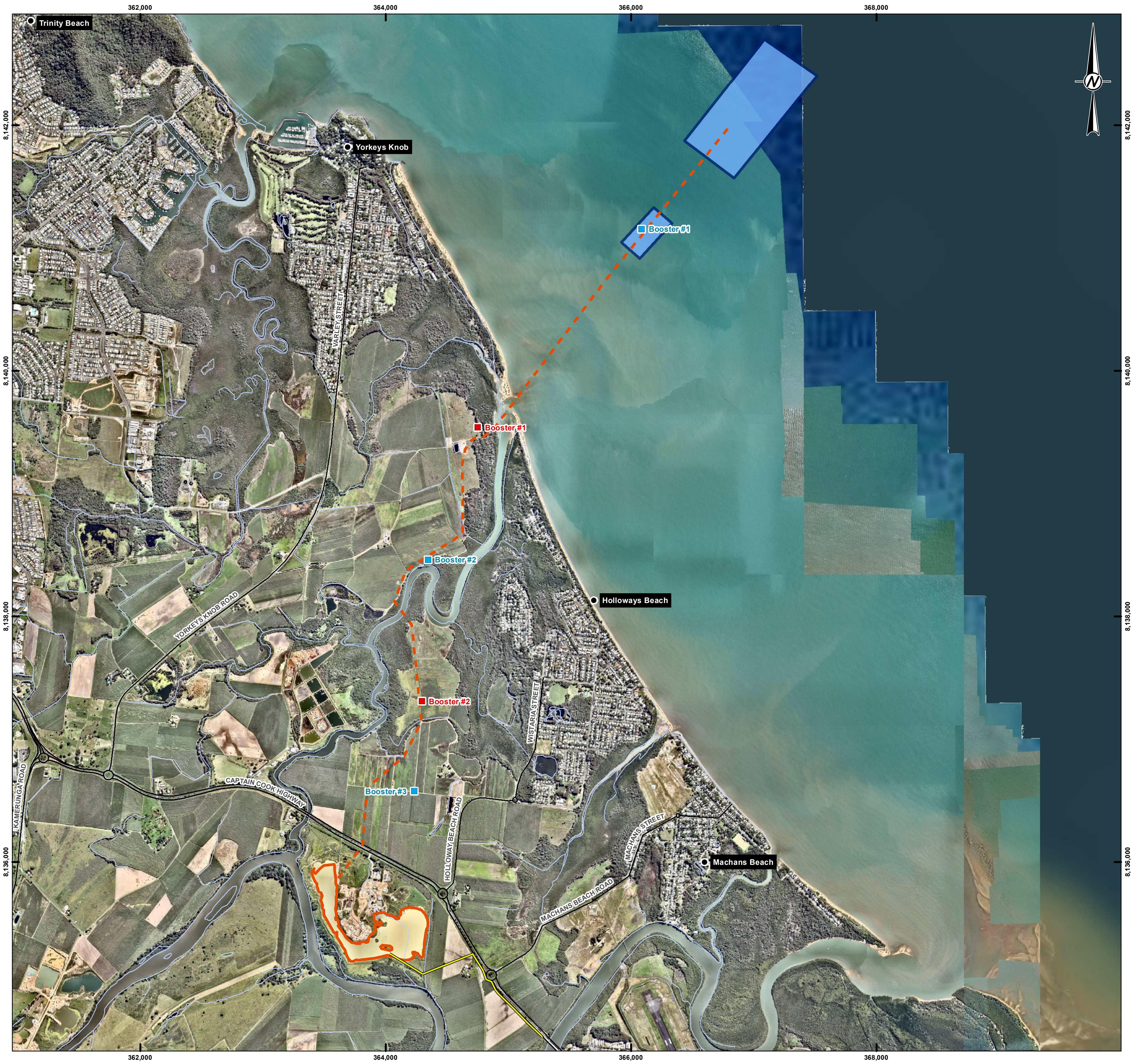
FIGURES



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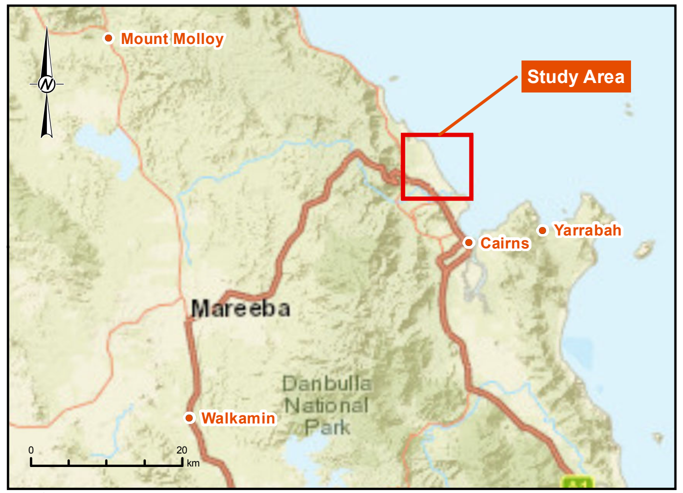

LEGEND

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

Pipeline Routes

Delivery Pipeline

- 🟦 Booster Locations (with Marine Booster)
- 🟥 Booster Locations (no Marine Booster)
- - - Delivery Pipeline
- ═ Discharge Pipeline
- ▭ Northern Sands DMPA
- ▭ Dredge Pumpost and Marine Booster Areas

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CLIENT
FLANAGAN CONSULTING GROUP

PROJECT
CSDP NORTHERN SANDS DMPA

TITLE
LOCALITY PLAN

CONSULTANT
Golder Associates

YYYY-MM-DD	2017-04-20
PREPARED	DP
DESIGNED	DP
REVIEWED	MSC
APPROVED	MSC

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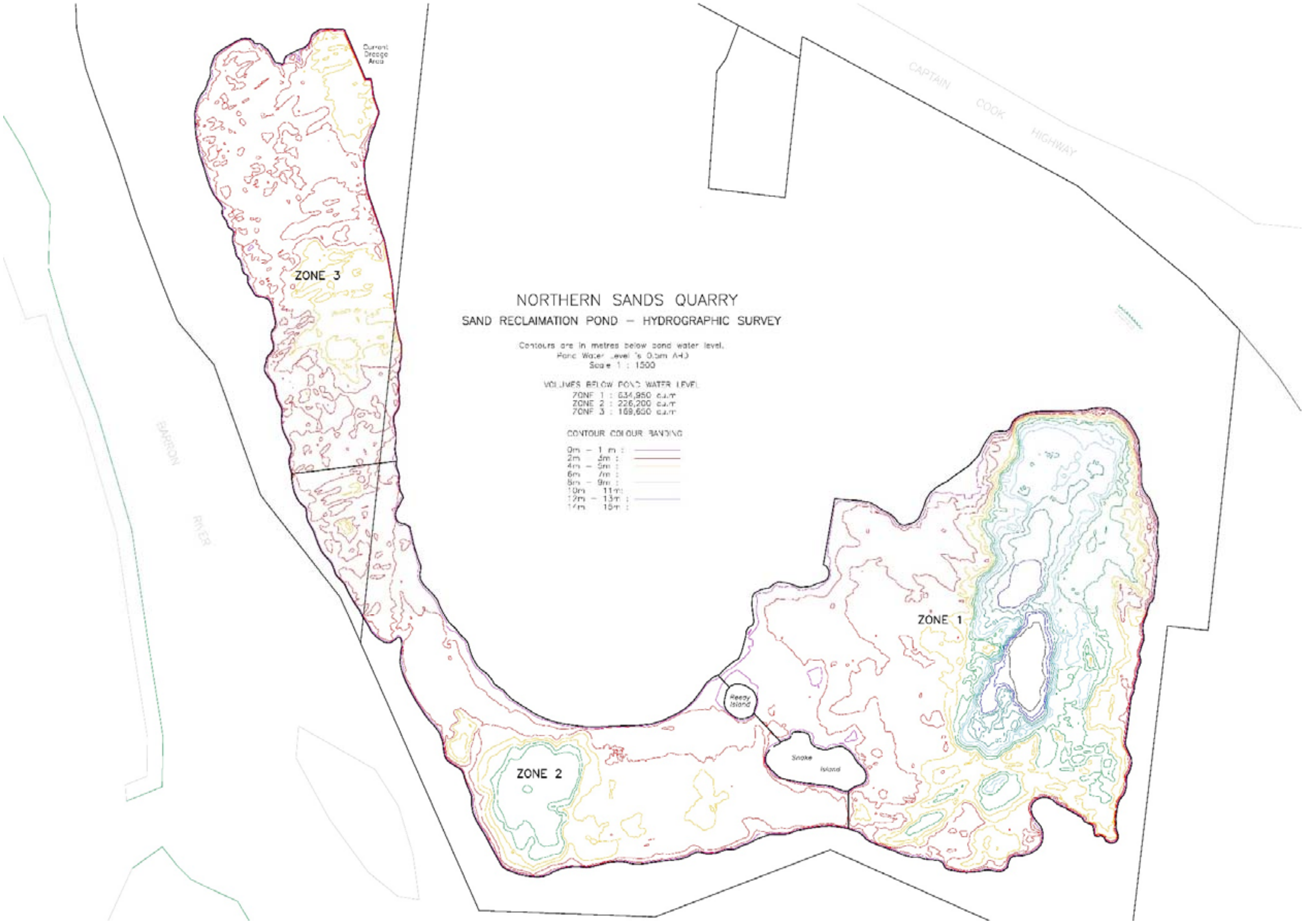

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CHECKED SRF	DATE 19/9/16			
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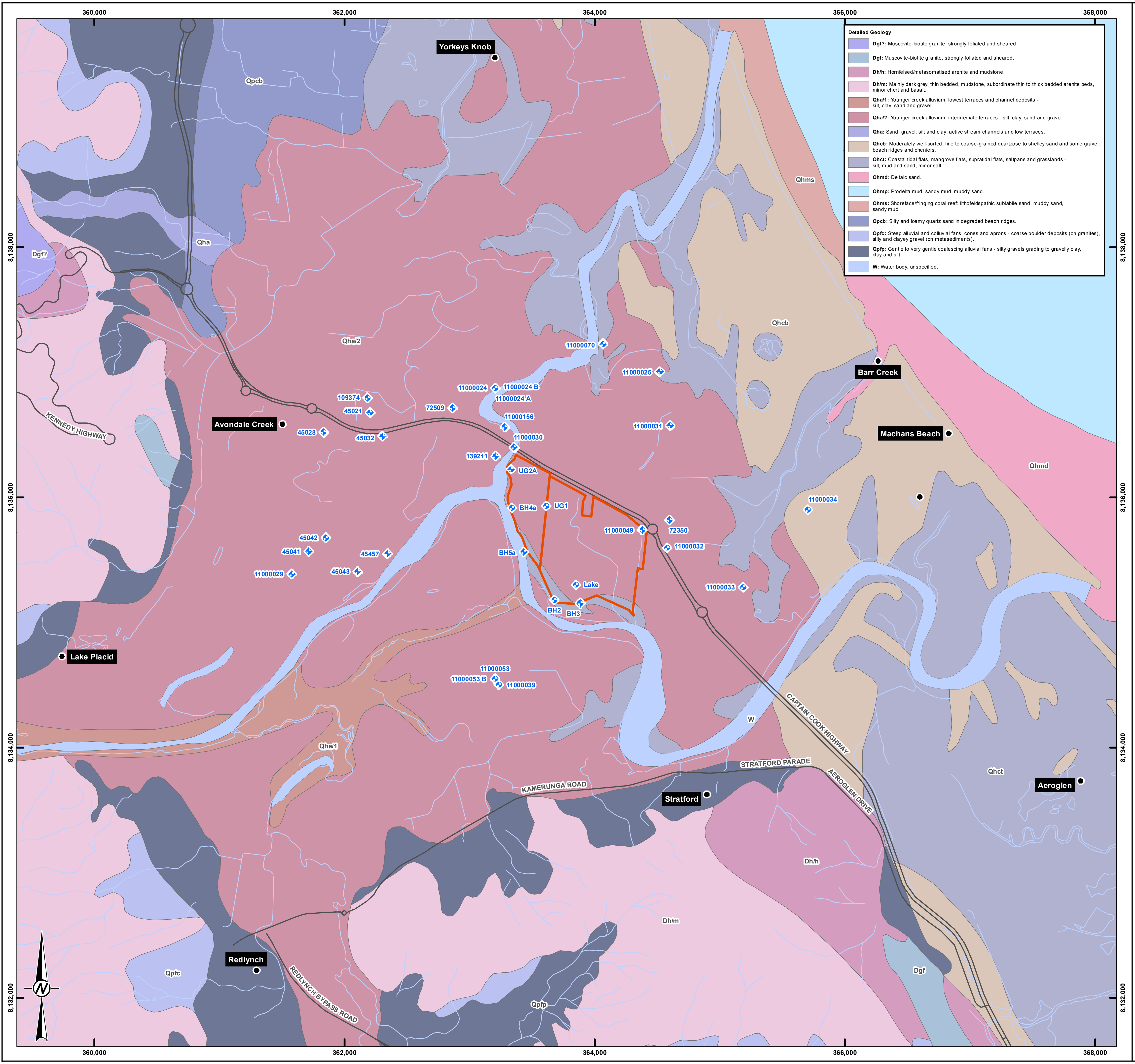

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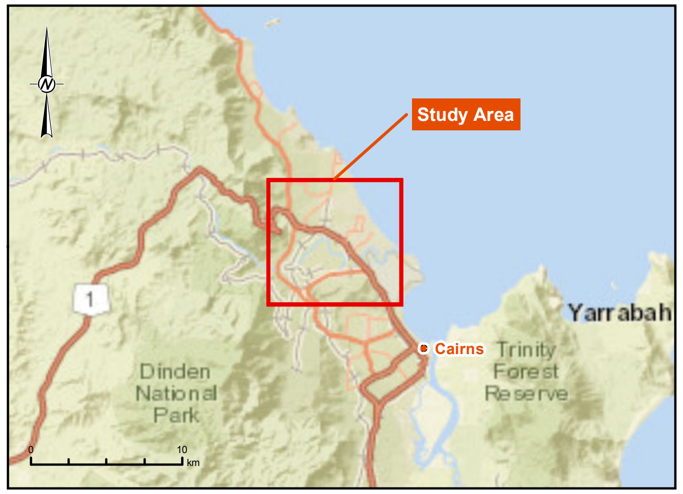

LEGEND

● Localities

Monitoring Borehole Locations

Roads and Tracks

Drainage (25k)

Northern Sands Site

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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

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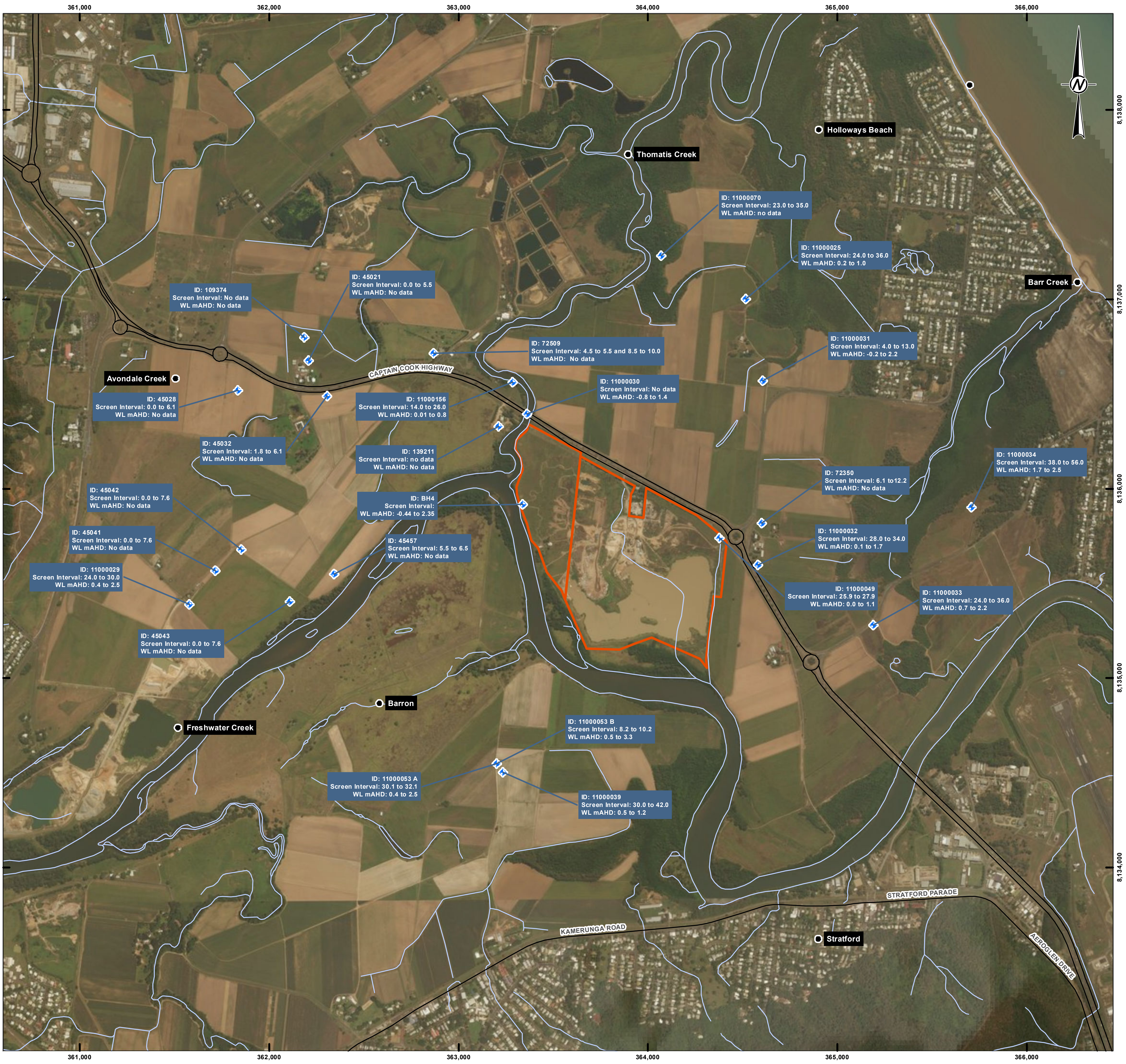

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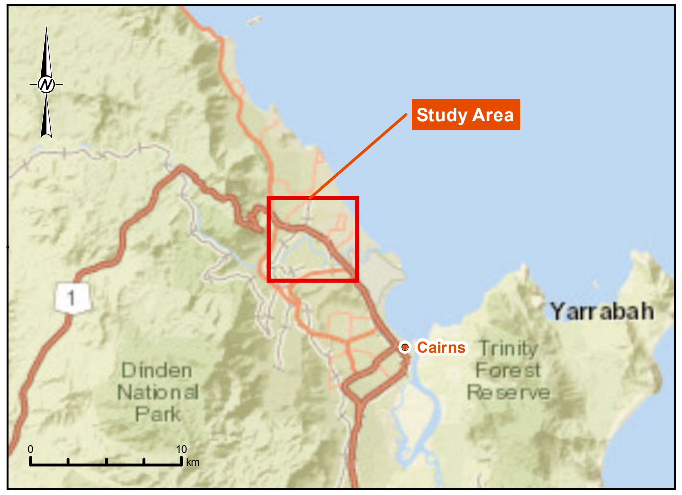

LEGEND

●	Localities
⌖	Registered Groundwater Bores
—	Roads and Tracks
—	Drainage (25k)
▭	Northern Sands Site

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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
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DESIGNED	DP
REVIEWED	DS
APPROVED	DS

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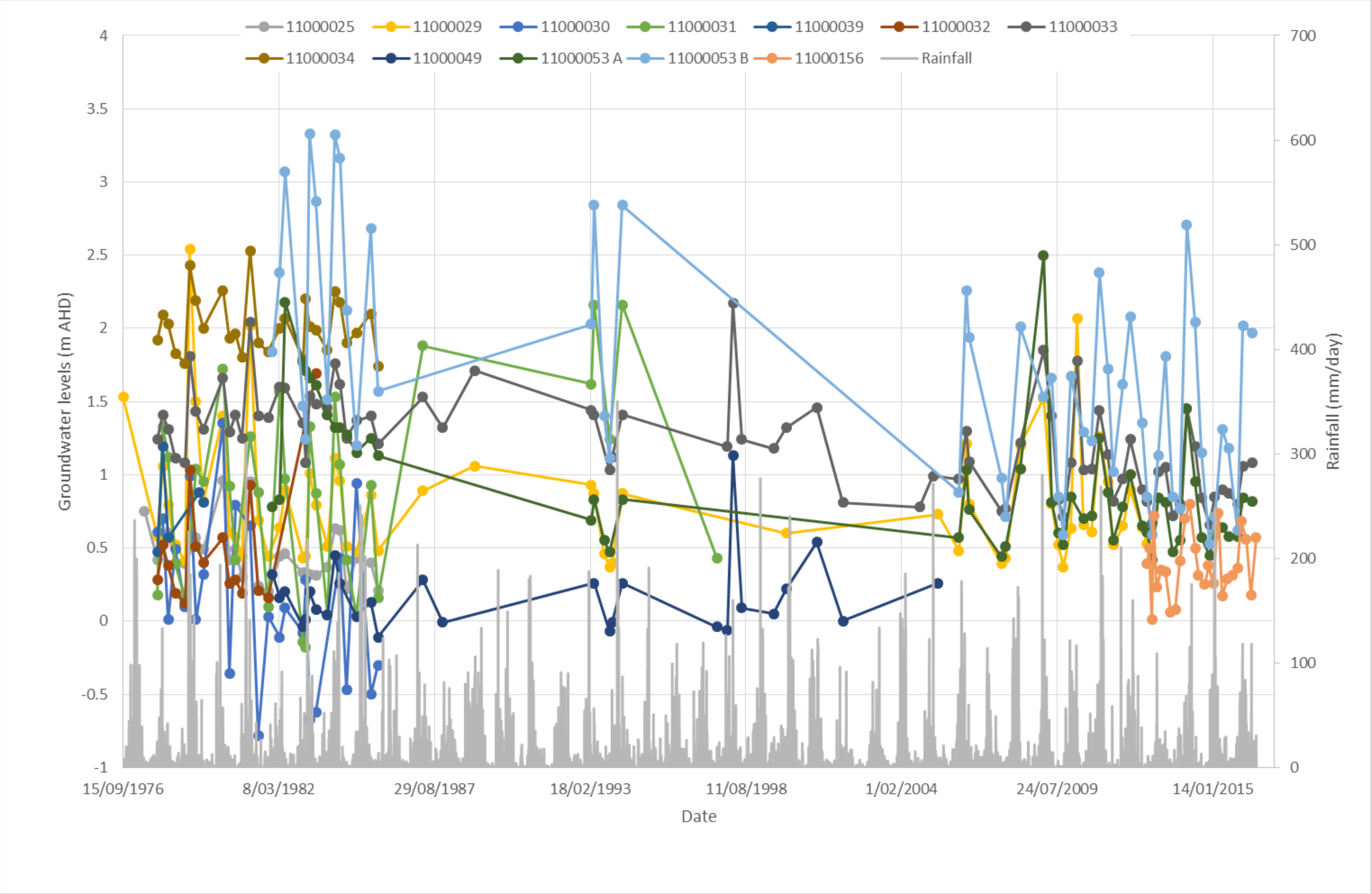

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CHECKED SRF	DATE 19/9/16		
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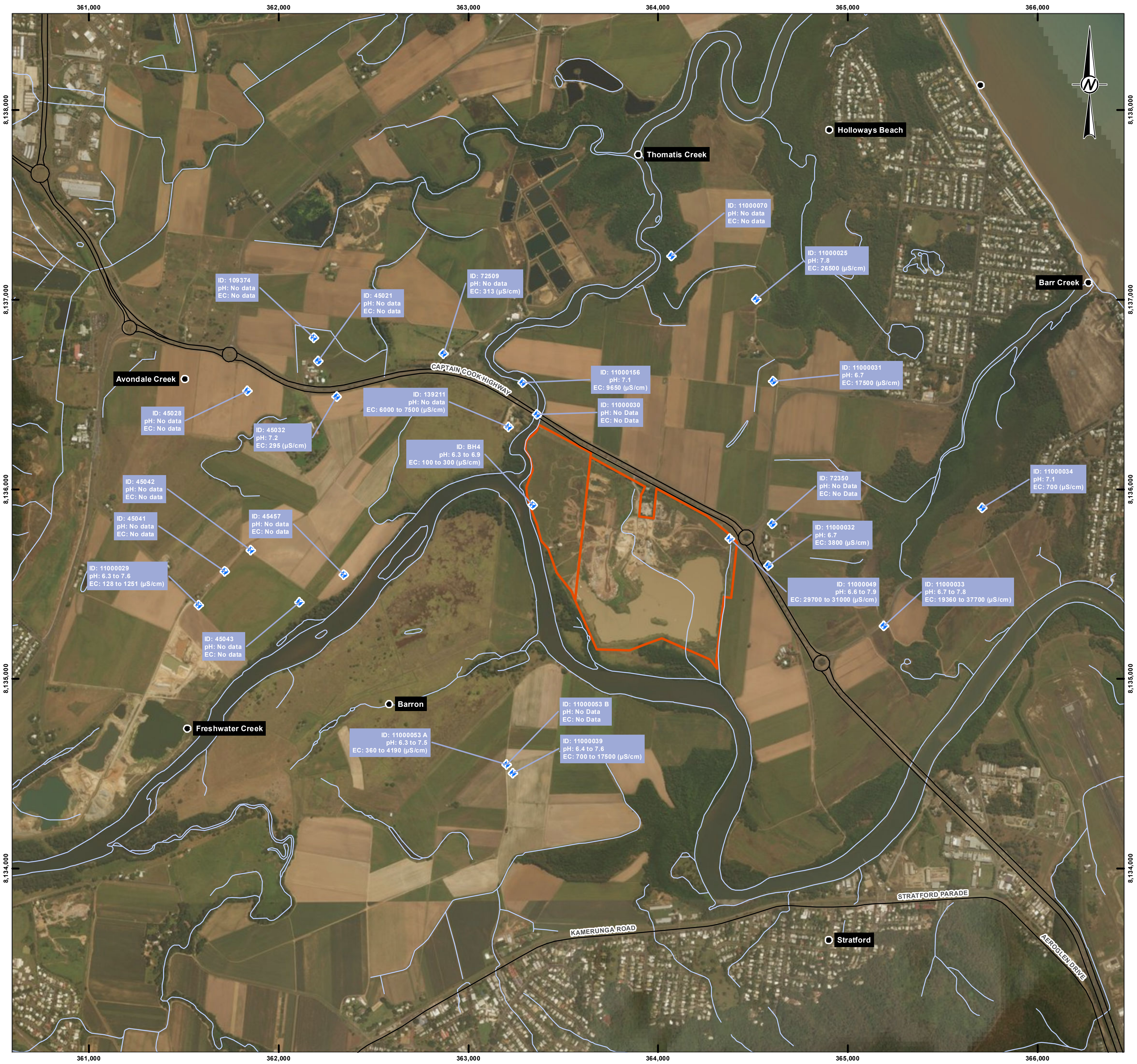
Golder Associates



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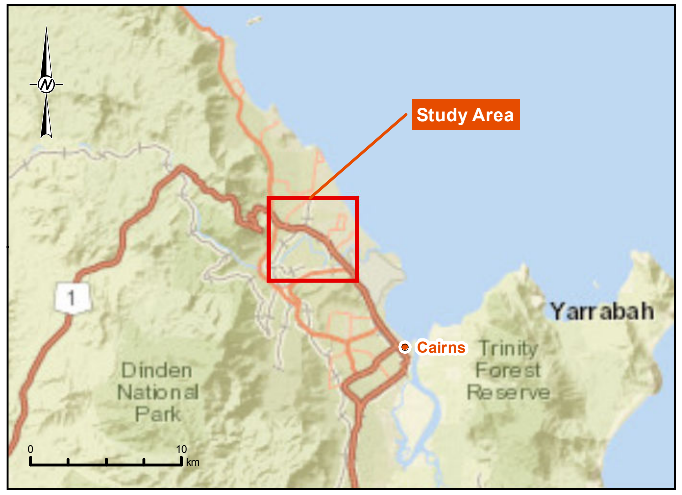

LEGEND

●	Localities
⚡	Registered Groundwater Bores
—	Roads and Tracks
—	Drainage (25k)
▭	Northern Sands Site

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0 0.5 1

1:20,000 at A3 Kilometres

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

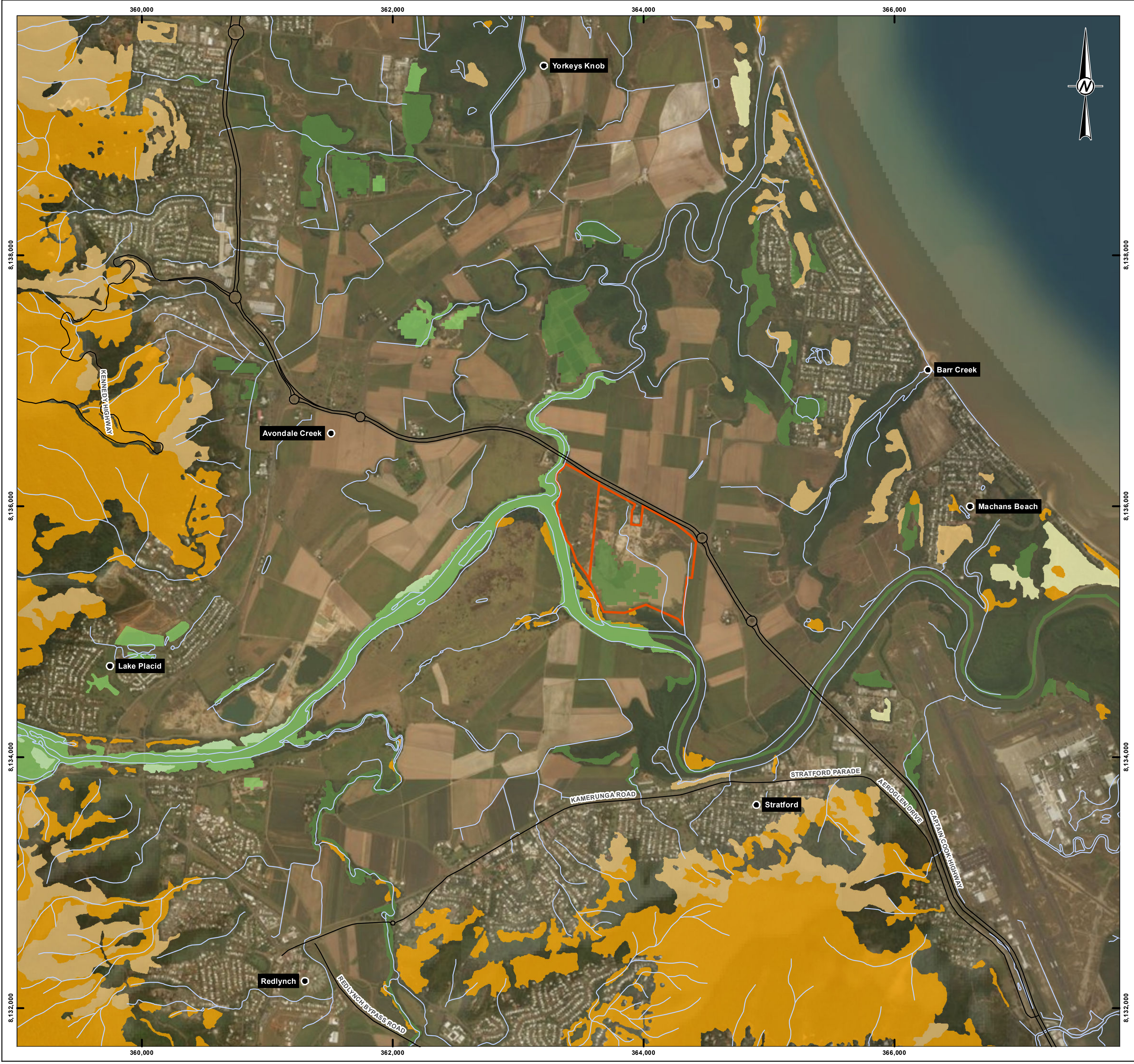
PROJECT NO.	CONTROL	REV.	FIGURE
1546223	023	0	6

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

25mm

0

Path: \\golder.gds\GAP\Cairns\Jobs\Geo\2015\1546223 - FCG - EIS Stage 1 - Port Development\GIS\MXD\Hydro_Assessment\1546223-012-R-Rev0_F006_Nth_Sands_Conductivity.mxd



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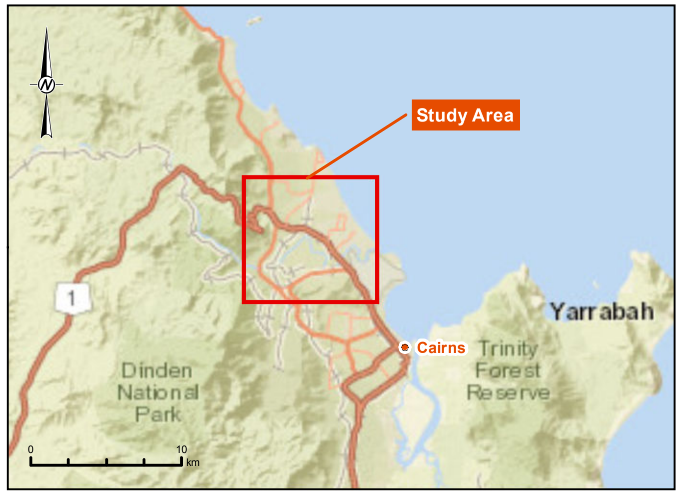
LOCATION MAP



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

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Groundwater Dependent Ecosystems: © Commonwealth of Australia (Bureau of Meteorology) 2012.
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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	023	0	7

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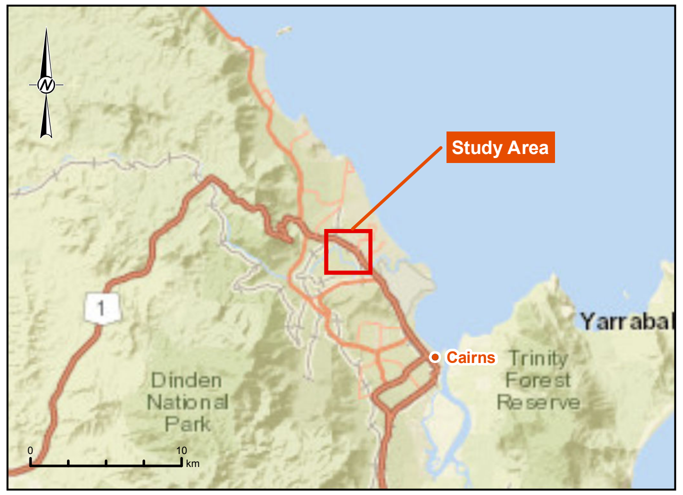
LOCATION MAP



LEGEND

●	Localities	═	Sections
Investigation Locations		—	Roads and Tracks
⊕	GW Monitoring Bore	—	Watercourses (25k)
◐	Probin Boreholes	—	Proposed Pond Outline
▨	GEO Investigate	■ ■	Propose Lake Bund Outline
⊕	Well Locations	—	Model Subsurface Sections

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

CLIENT
FLANAGAN CONSULTING GROUP

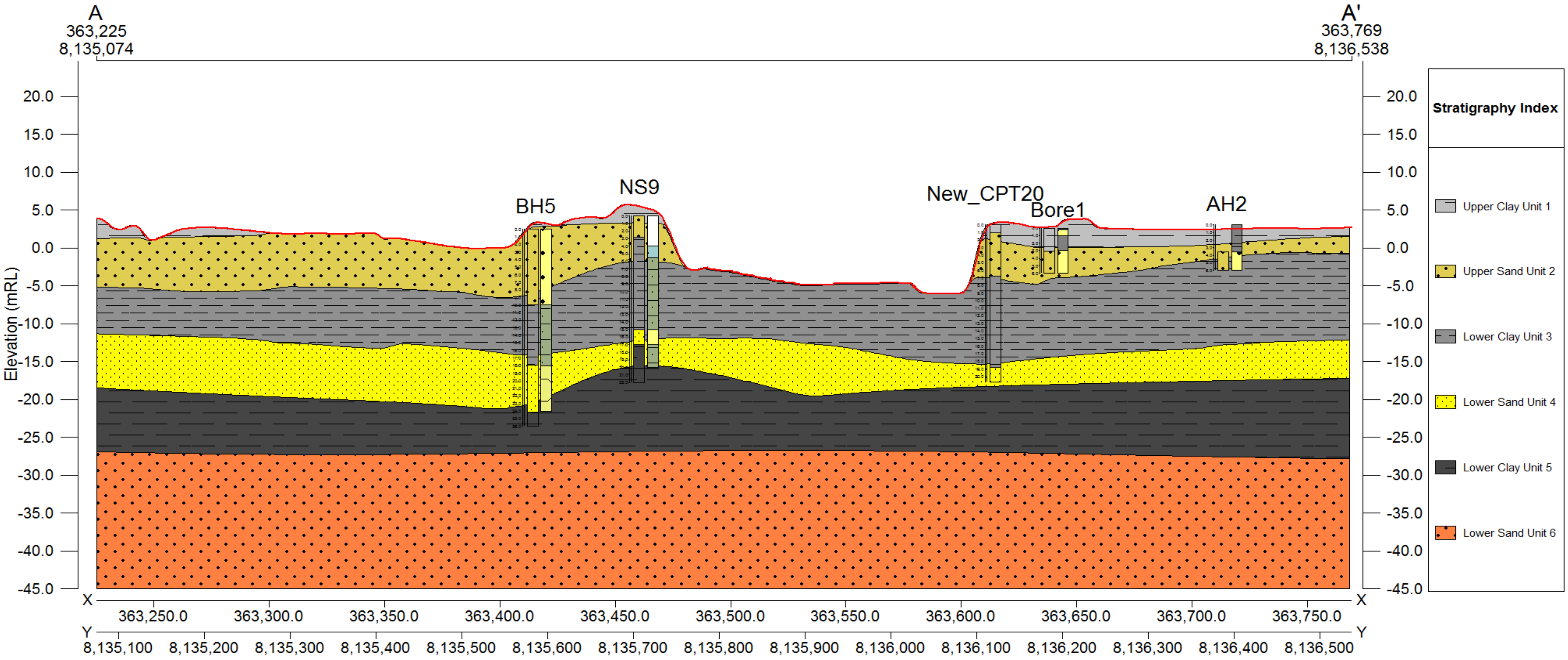
PROJECT
CAIRNS SHIPPING DEVELOPMENT EIS

TITLE
INVESTIGATION AND WELL LOCATIONS

CONSULTANT
Golder Associates

YYYY-MM-DD	2017-05-04
PREPARED	DP
DESIGNED	DP
REVIEWED	DS
APPROVED	DS

PROJECT NO.	CONTROL	REV.	FIGURE
1546223	023	0	8



Golder Associates

CLIENT	Flanagan Consulting Group		
DRAWN	JL	DATE:	1512/2016
CHECKED	MSC	DATE:	15/12/2016
SCALE:	A4		

PROJECT

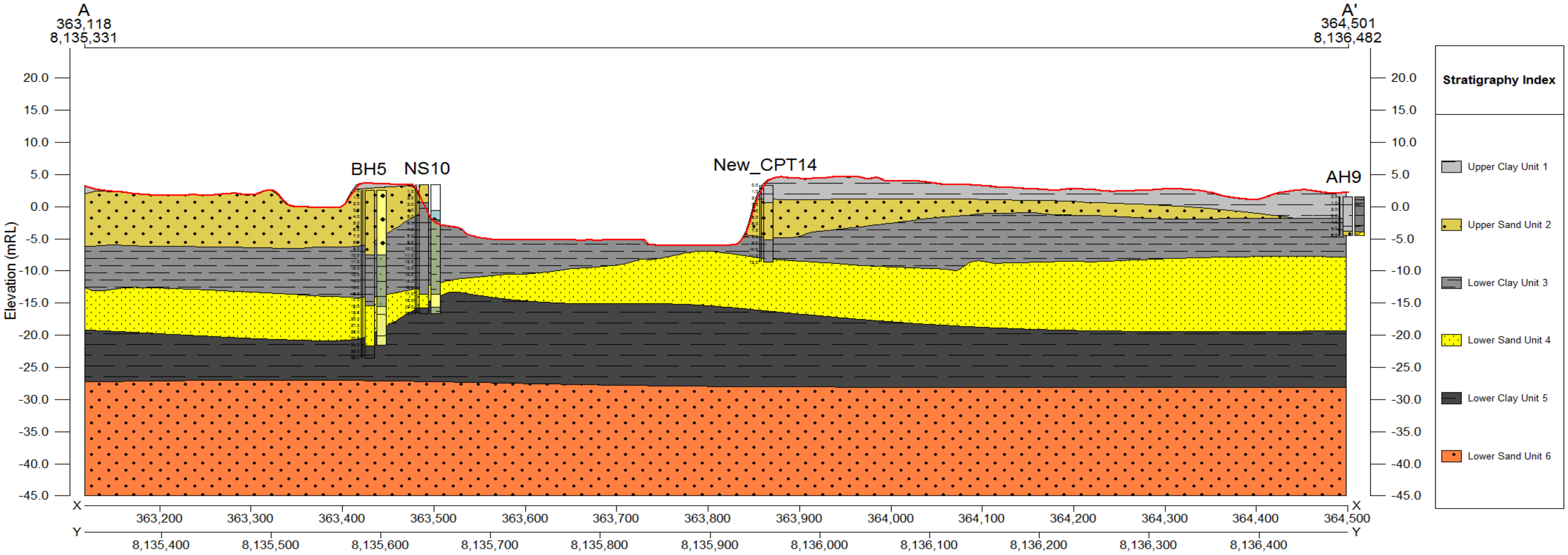
Cairns Shipping Development EIS

SSW-NNE Inferred Geological

Section 1

PROJECT No. 1546223-023

FIGURE No. 9



Golder Associates

CLIENT	Flanagan Consulting Group		
DRAWN	DW	DATE:	4/05/2016
CHECKED	MSC	DATE:	4/05/2016
SCALE:	A4		

PROJECT

Cairns Shipping Development EIS

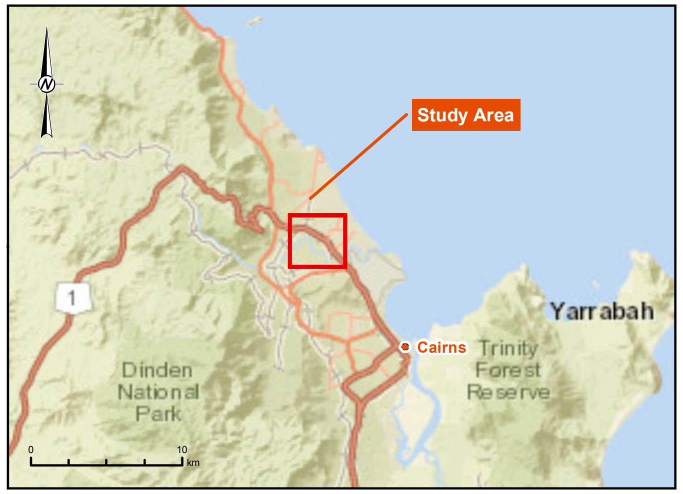
SW-NE Inferred Geological section

Section 2

PROJECT No.	FIGURE No.
1546223-023	**10**

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

LOCATION MAP



LEGEND

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

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0 0.25 0.5

1:12,500 at A3 Kilometres
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	023	0	11

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

25mm
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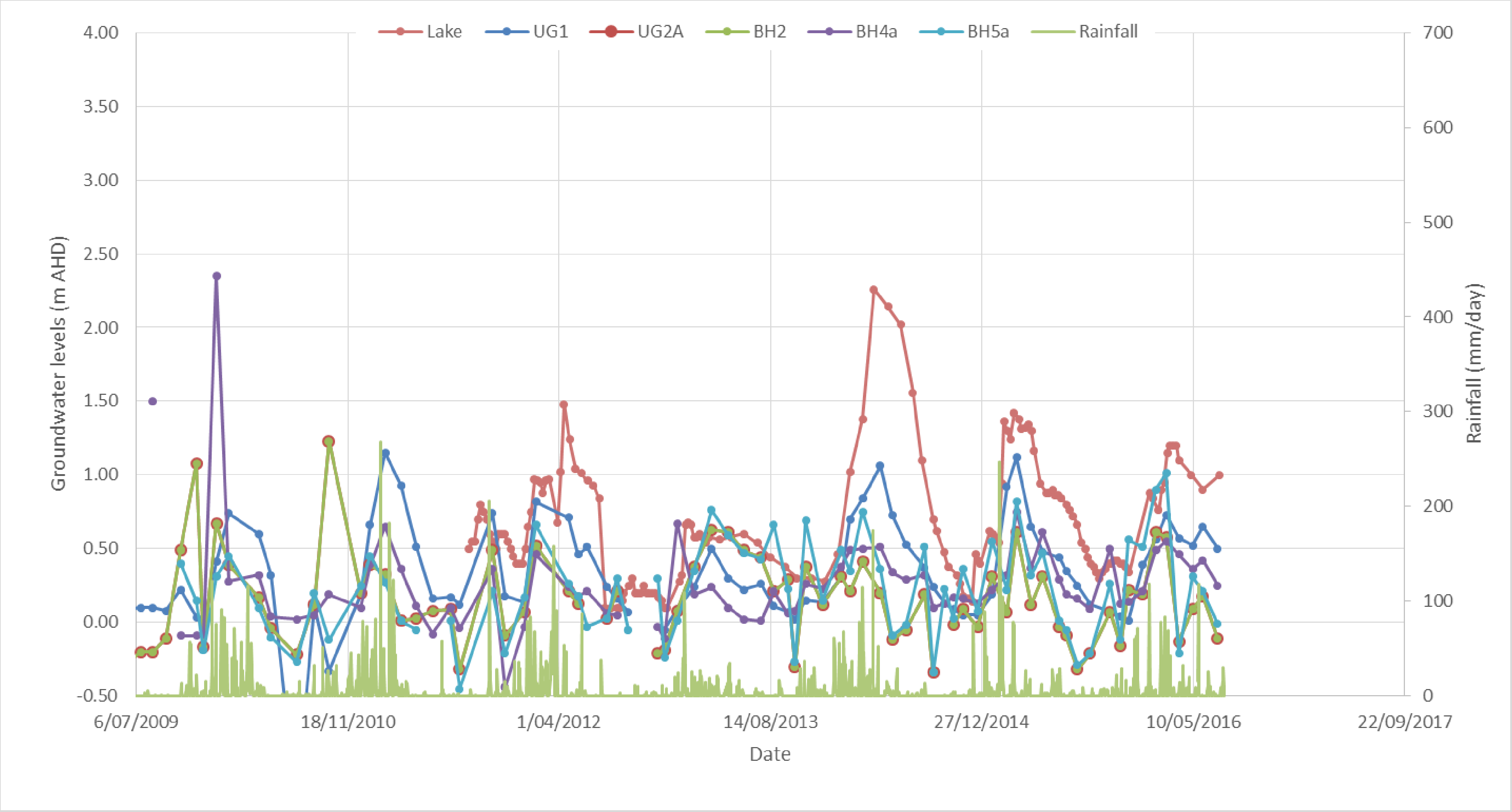
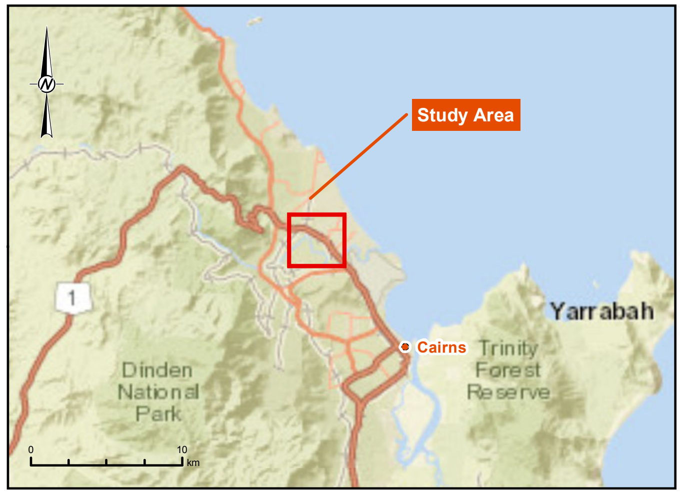


Golder Associates

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 1546223-023	REVISION 0	FIGURE No FIGURE 12

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

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0 0.25 0.5

1:12,500 at A3 Kilometres

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

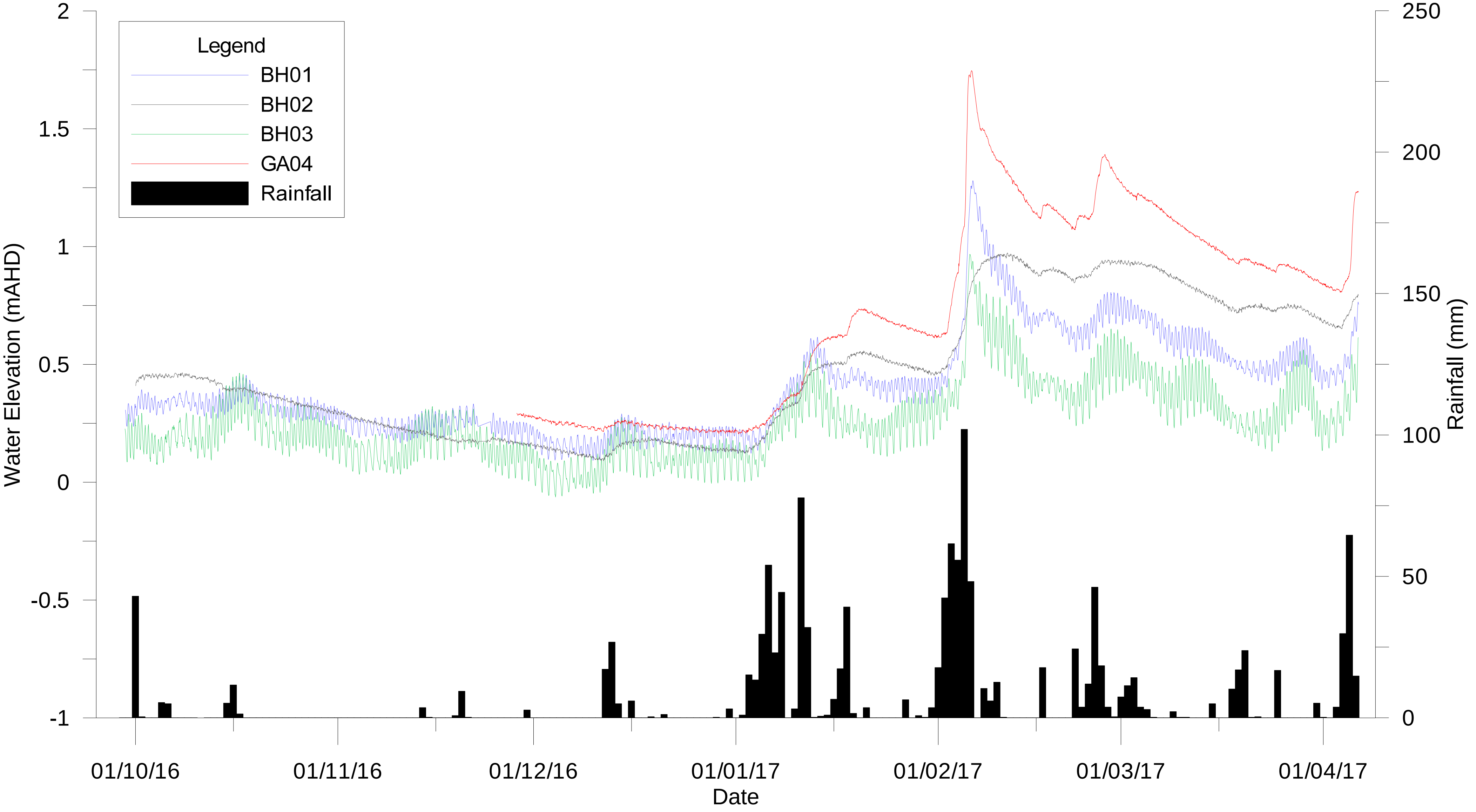
YYYY-MM-DD	2017-01-20
PREPARED	DP
DESIGNED	DP
REVIEWED	SF
APPROVED	SF

PROJECT NO.	CONTROL	REV.	FIGURE
1546223	023	0	13

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

25mm

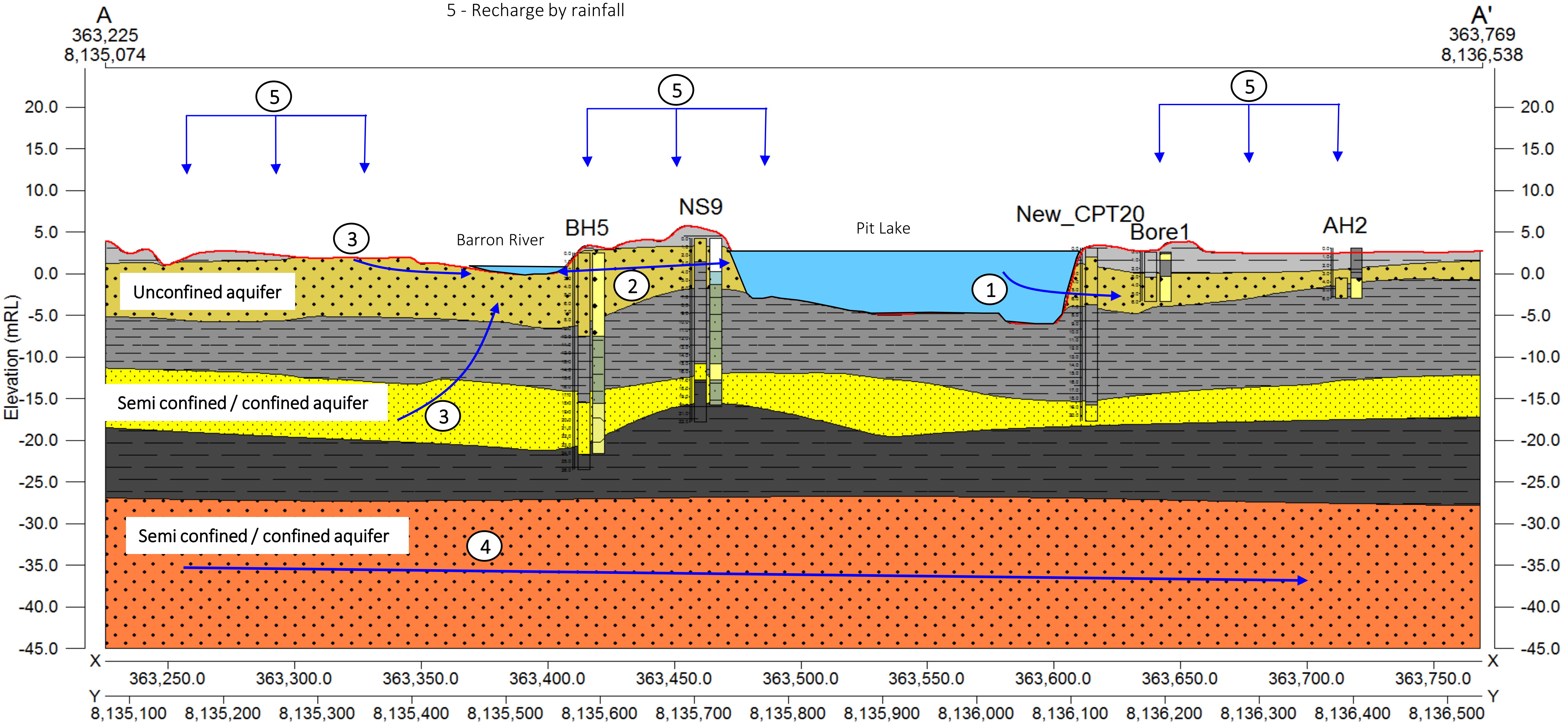
0



Golder Associates

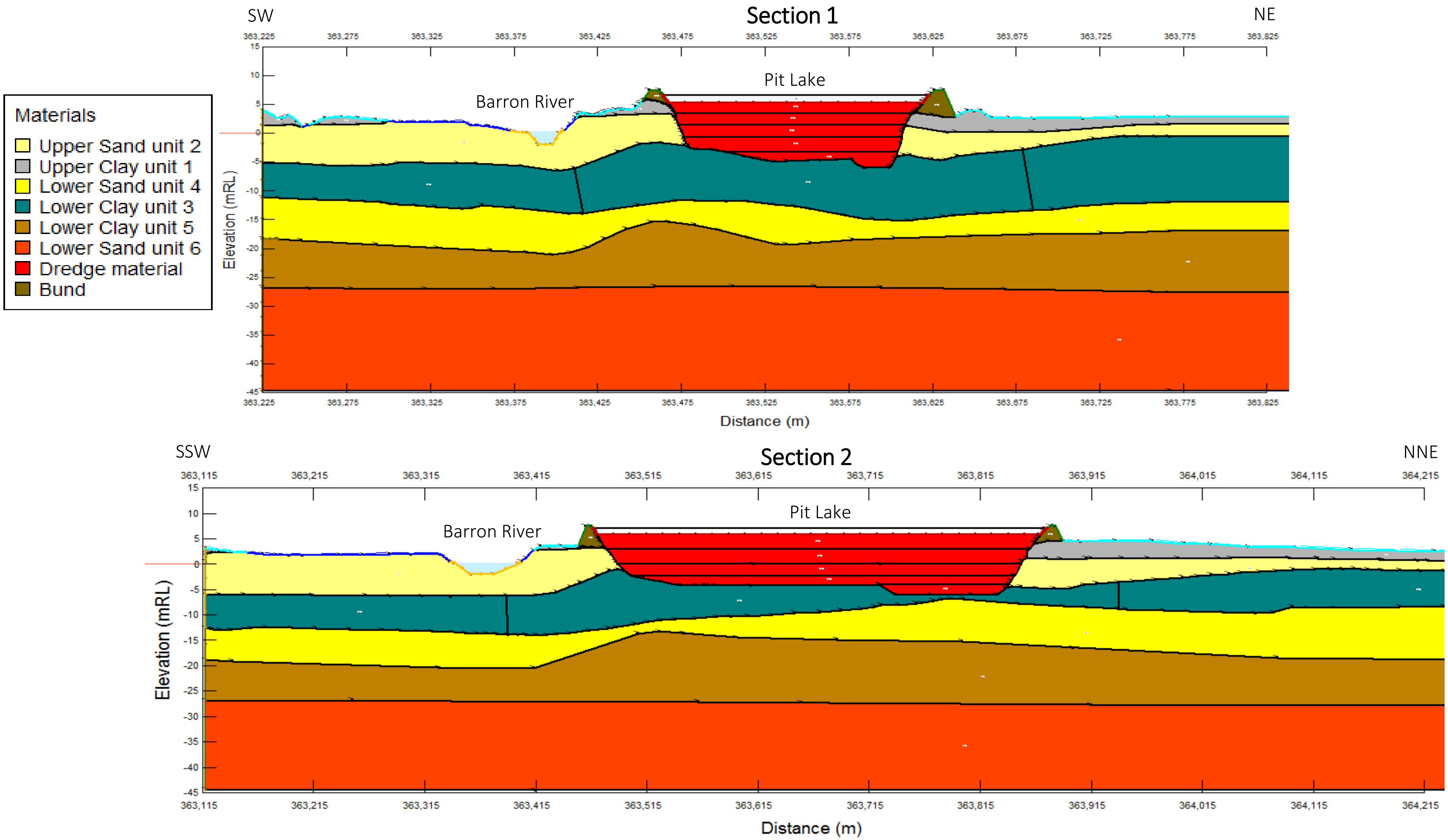
Drawn	DW	Project: Cairns Shipping Development EIS	
Checked	SF	Title: Hydrographs for Monitoring Bores at the Northern Sands Site	
Date	24/04/17	Project No. 1546223-023	Figure No. FIGURE 14

1 - Recharge as flow away from lake with raised lake level
2 - Tidal exchange of groundwater between lake and river
3 - Groundwater flow toward river in upper unconfined aquifer
4 - Groundwater flow toward coast in lower confined aquifer
5 - Recharge by rainfall



CLIENT	Flanagan Consulting Group		PROJECT	**Cairns Shipping Development EIS**
DRAWN	DW	DATE: 4/05/2017		**Conceptual Hydrogeological Model** **Northern Sand Site**
CHECKED	MSC	DATE: 4/05/2017		
SCALE:	A4		PROJECT No. 1546223-023	FIGURE No. **15**

\\golder.gds\GAP\Cairns\Jobs\Geo\2015\1546223 - FCG - EIS Stage 1 - Port Development\CORR OUT\023 Stage 1D Hydrogeology Northern Sands\figures\[FIG 015.xlsx]Landscape



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CLIENT Flanagan Consulting Group

DRAWN YM DATE: 1512/2016

CHECKED DB DATE: 15/12/2016

SCALE: A4

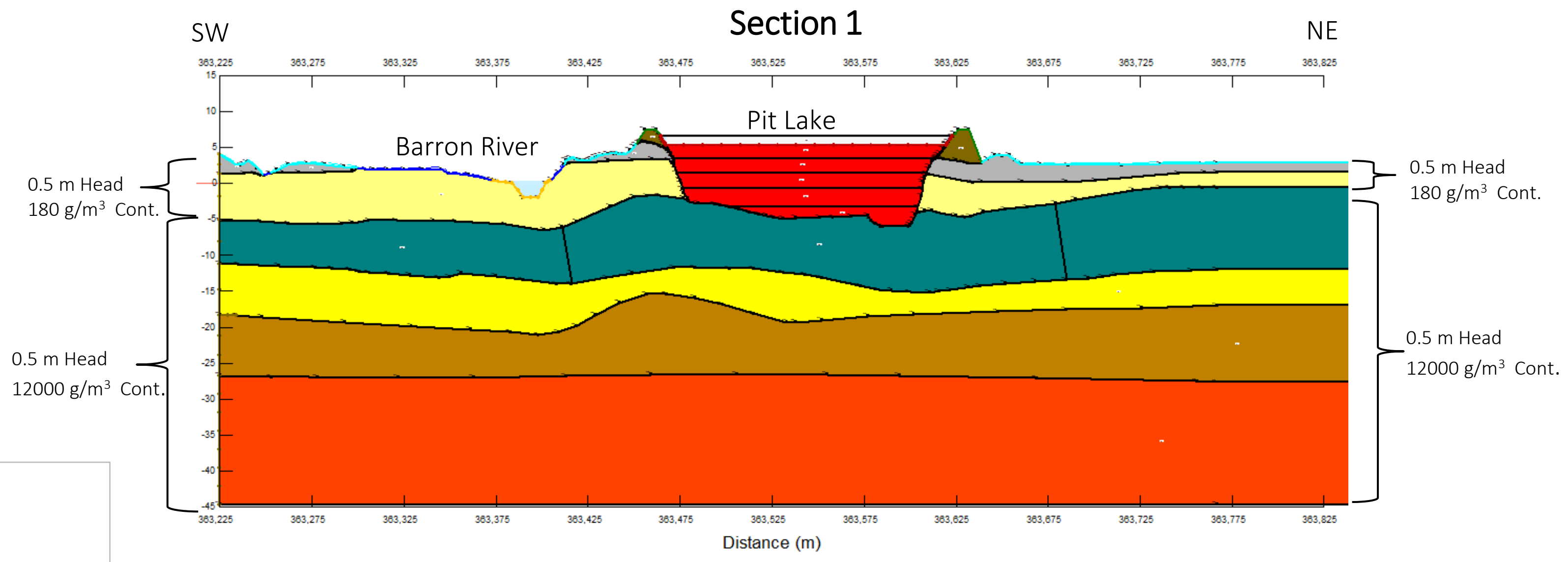
PROJECT **Cairns Shipping Development EIS**

Seep/W cross-sectional models

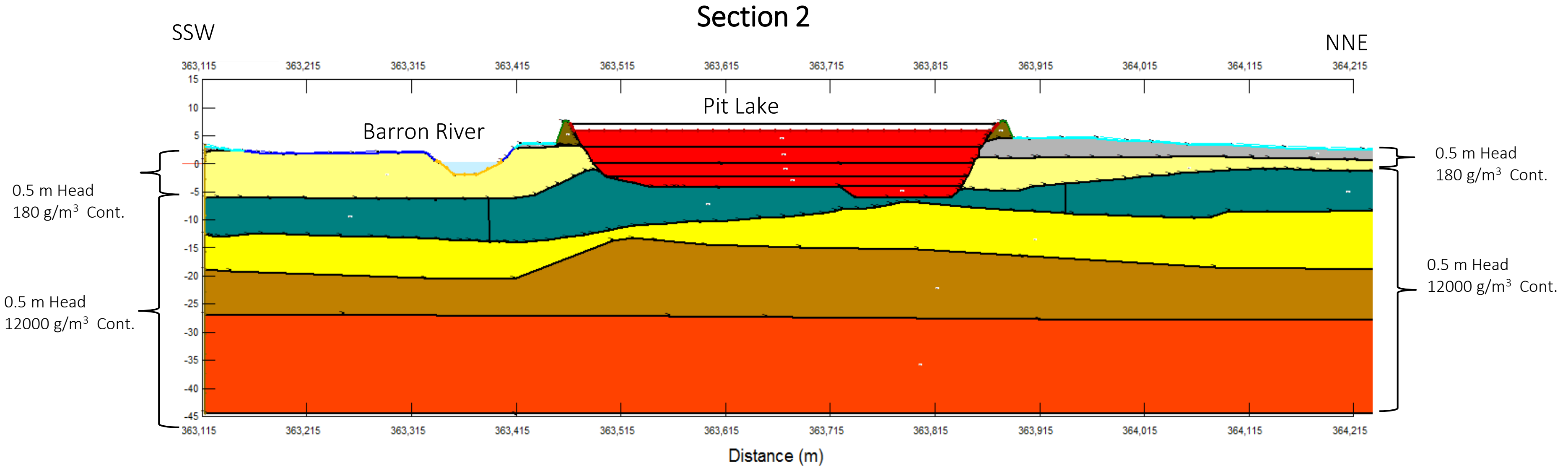
PROJECT No. 1546223-023

FIGURE No. **FIGURE 16**

\\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



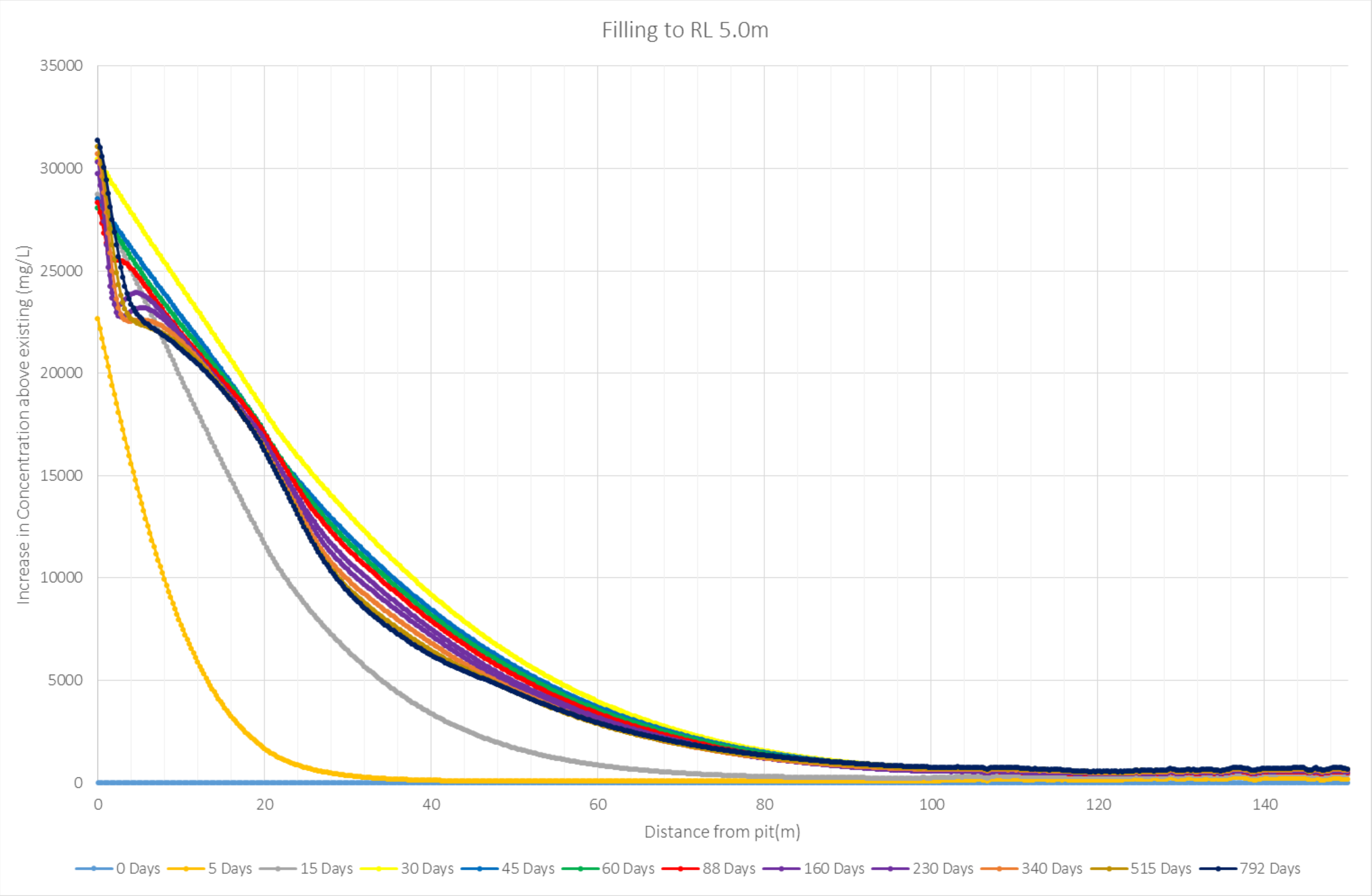
Boundary	Barron River	Pit Lake
Pre-filling	0.25m / 16000g/m3	0.25m / 500g/m3
Filling	0.25m / 160000g/m3	5mAHD - 7mAHD / 35000g/m3
Post - filling	0.25 / 16000g/m3	Rainfall recharge

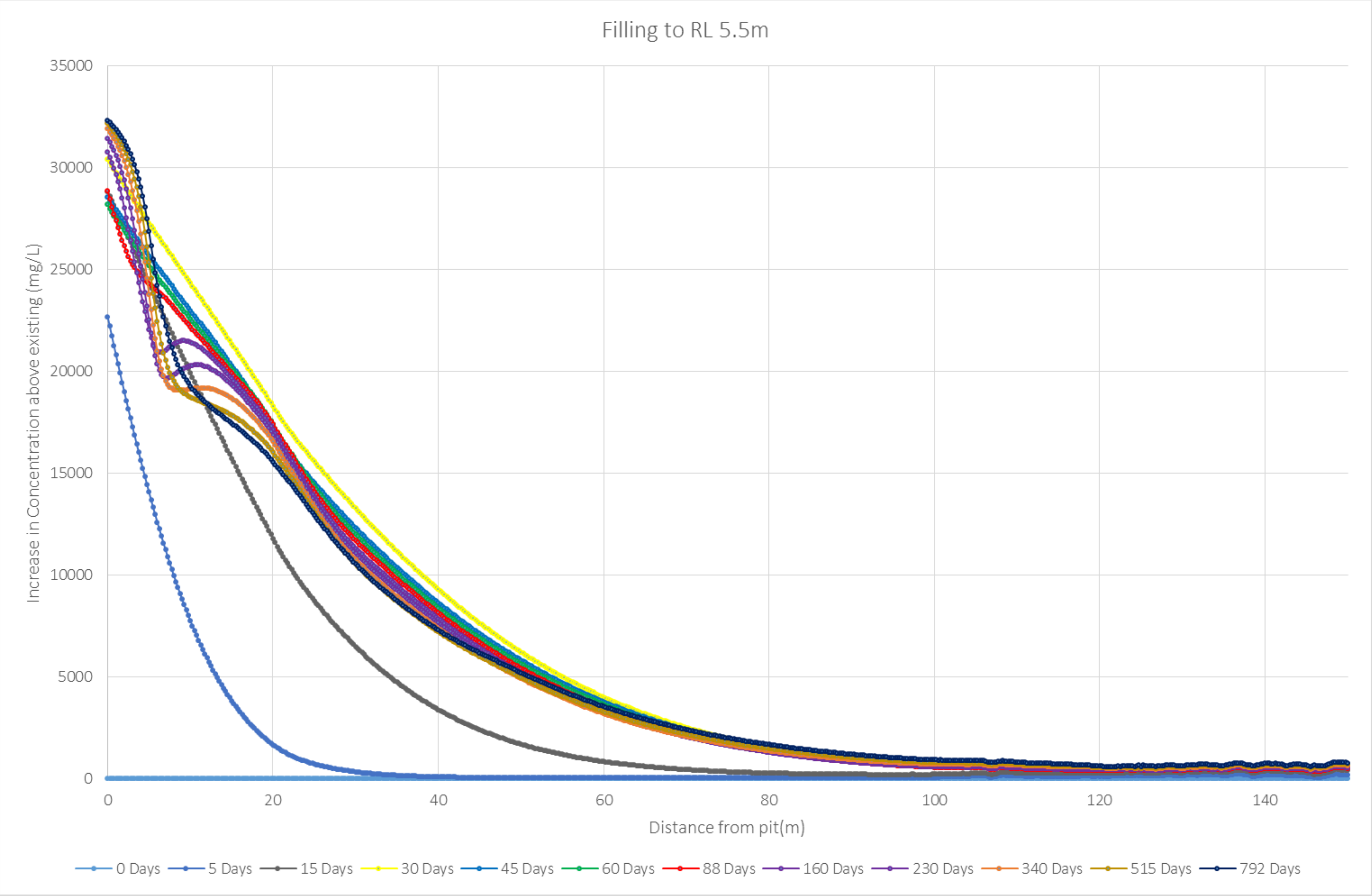


Golder Associates

CLIENT	Flanagan Consulting Group			PROJECT	**Cairns Shipping Development EIS**
DRAWN	DW	DATE:	4/05/2017		**Seep/w Model Boundary Conditions**
CHECKED	SF	DATE:	4/05/2017		
SCALE:	A4			PROJECT No. 1546223-023	FIGURE No. **FIGURE 17**

\\golder.gds\GAP\Cairns\Jobs\Geo\2015\1546223 - FCG - EIS Stage 1 - Port Development\CORR OUT\023 Stage 1D Hydrogeology Northern Sands\figures\[Figure 17 seep_W Boundary Conditions.xlsx]Landscape

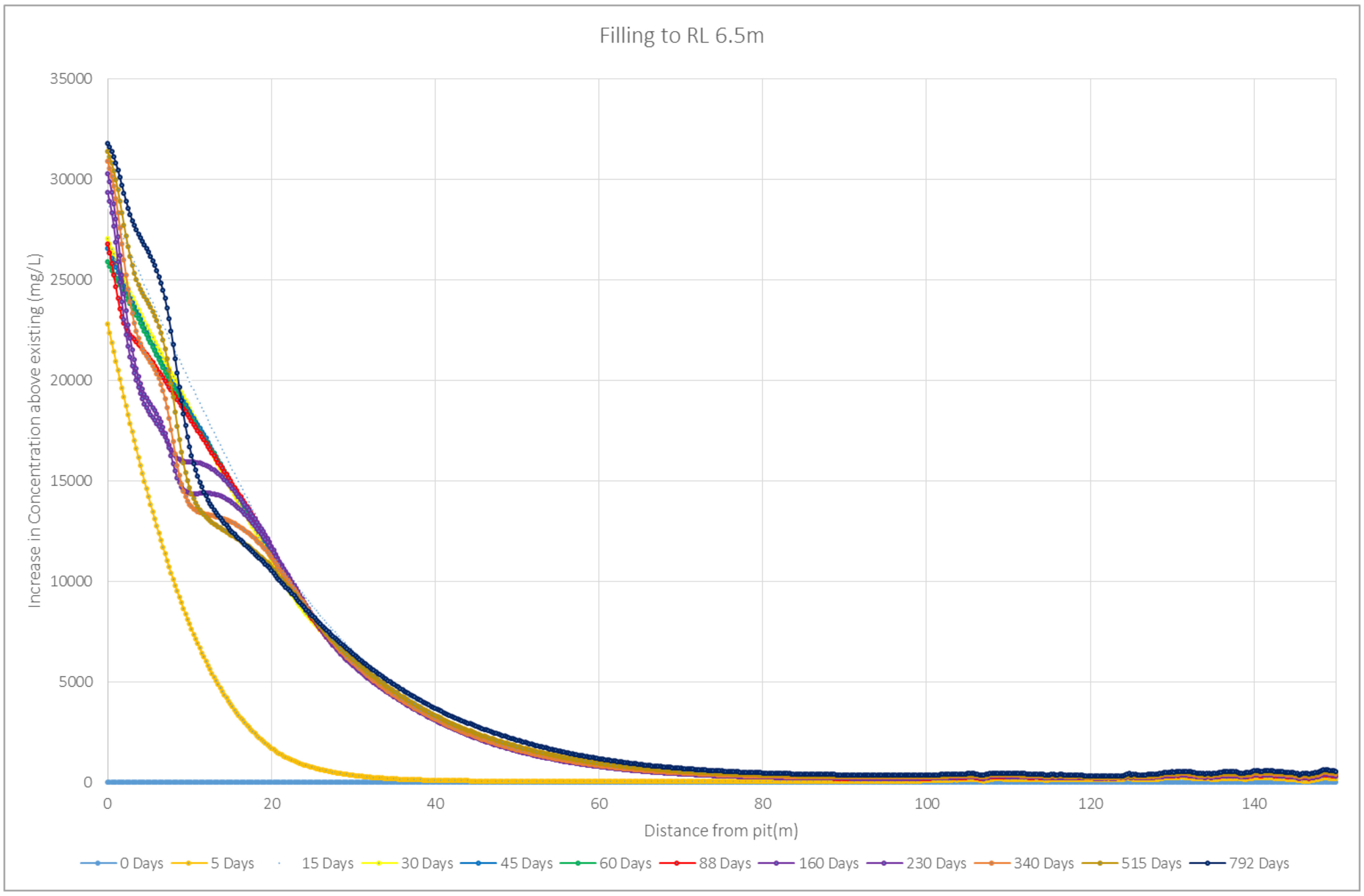


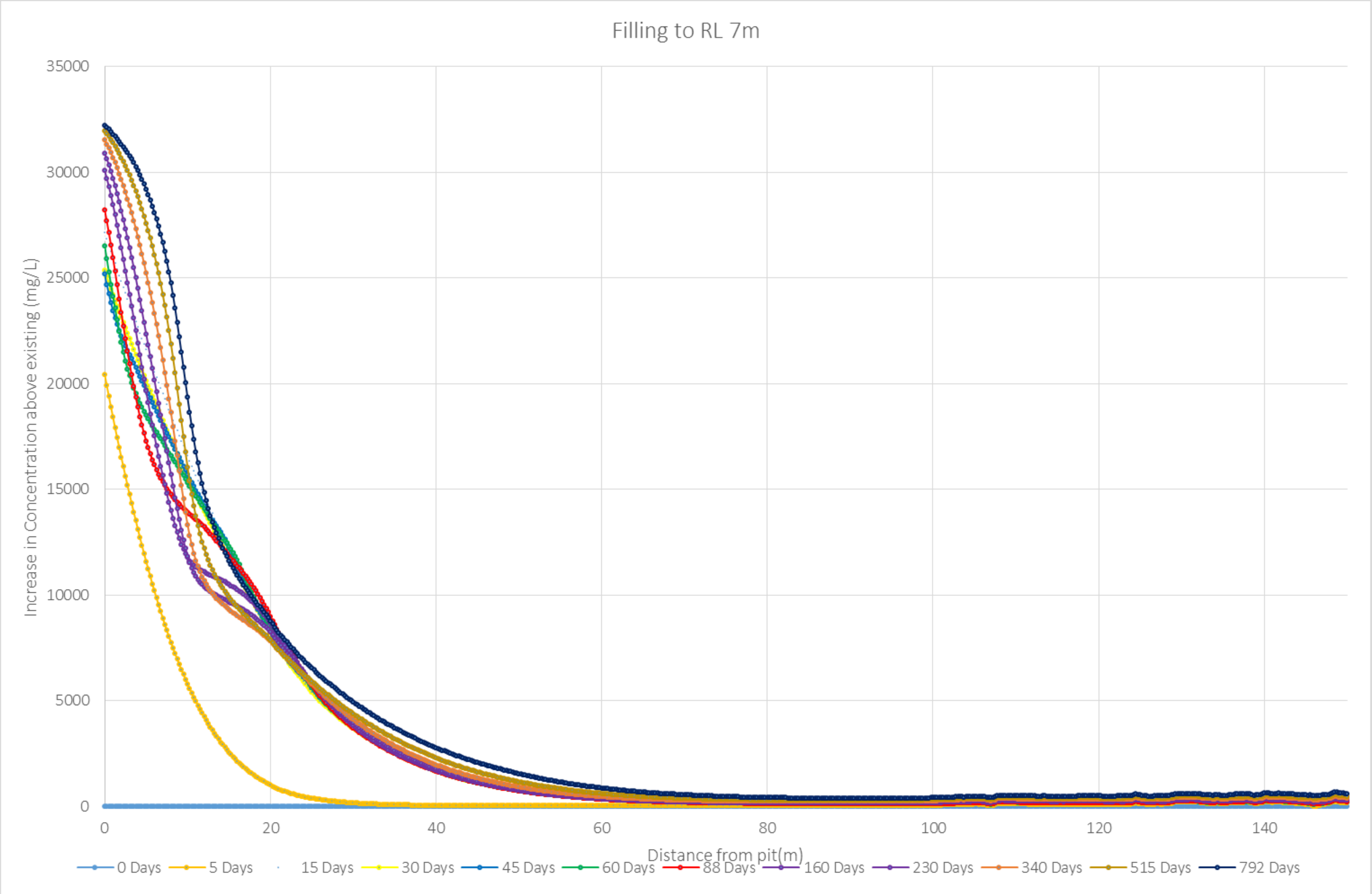


Profiles based on concentrations in the upper sand layer immediately below the upper clay layer

Golder Associates

CLIENT Flanagan Consulting Group		PROJECT Cairns Shipping Development EIS	
DRAWN DW	DATE 04/05/17	TITLE **Profiles of increase in concentration with distance from lake – Section 1 (5.0 to 5.5 mRL)**	
CHECKED SRF	DATE 04/05/17		
SCALE Not to Scale		PROJECT No 1546223-023	FIGURE No **18** REV No **0** **A3**





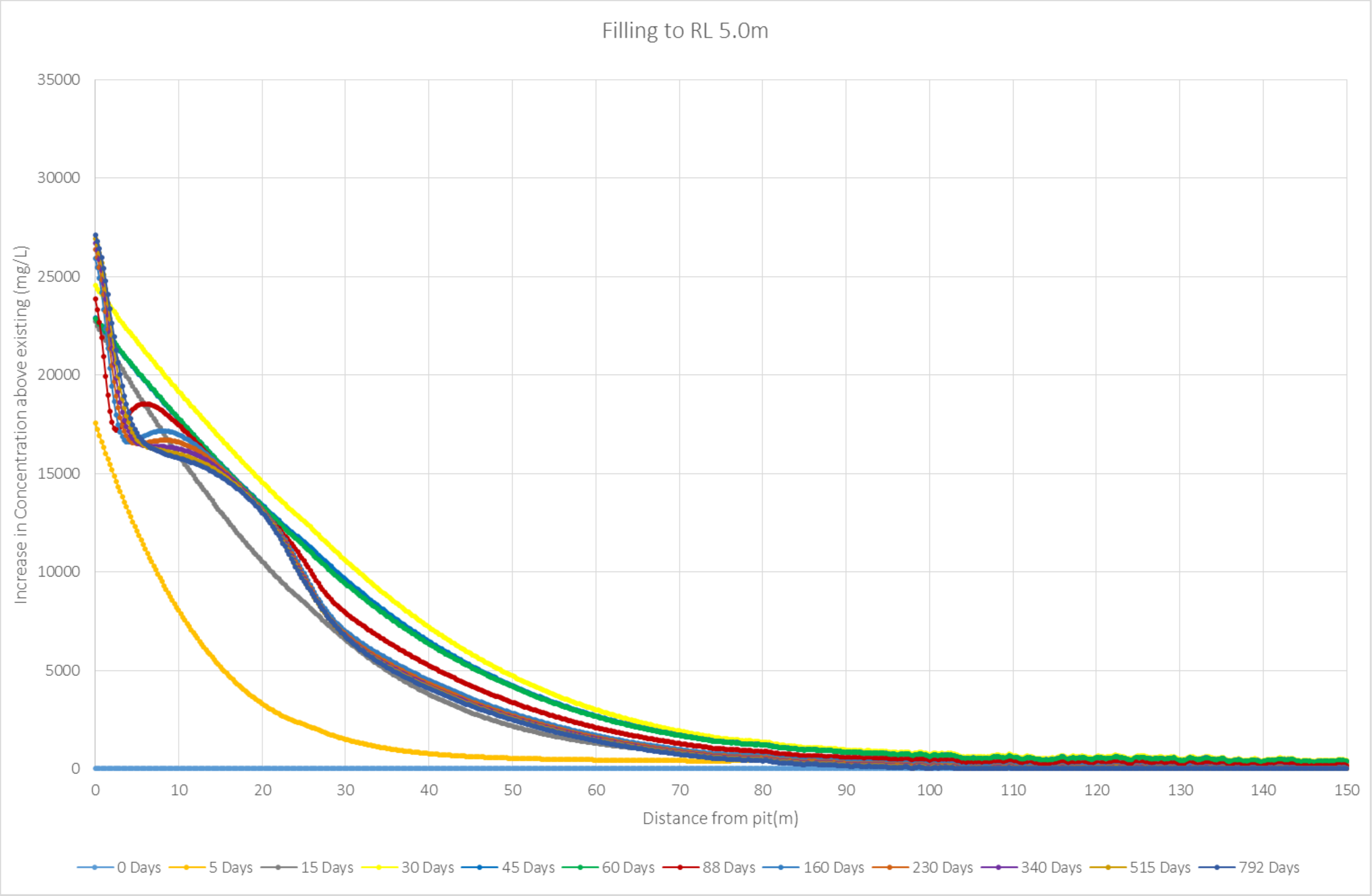
Profiles based on concentrations in the upper sand layer immediately below the upper clay layer

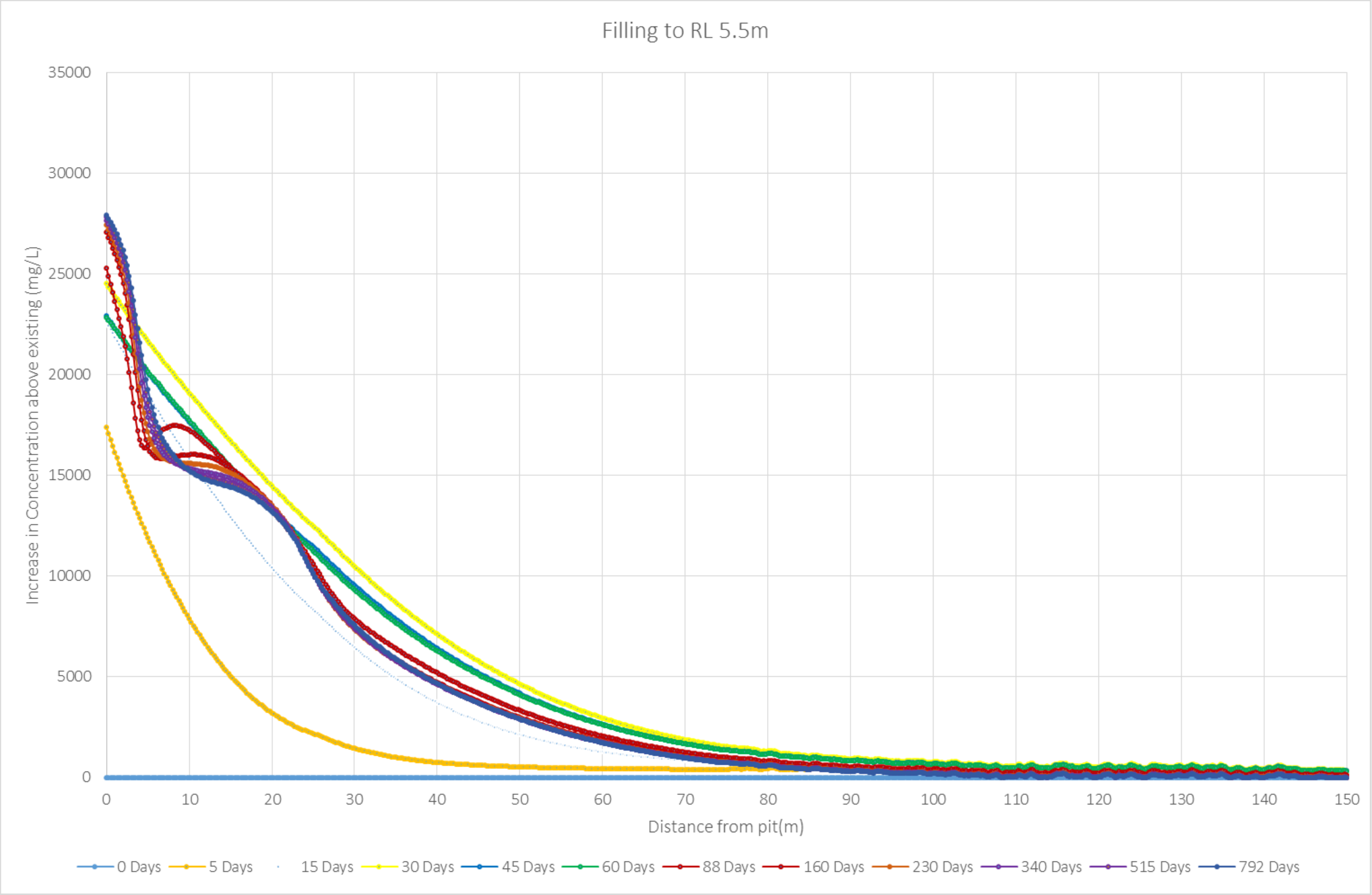
Golder Associates

CLIENT	Flanagan Consulting Group	PROJECT	Cairns Shipping Development EIS
DRAWN	DW	DATE	04/05/17
CHECKED	SRF	DATE	04/05/17
SCALE	Not to Scale		

TITLE
Profiles of increase in concentration with distance from lake – Section 1 (6.5 to 7.0 mAHD)

PROJECT No	FIGURE No	REV No	
1546223-023	19	0	A3

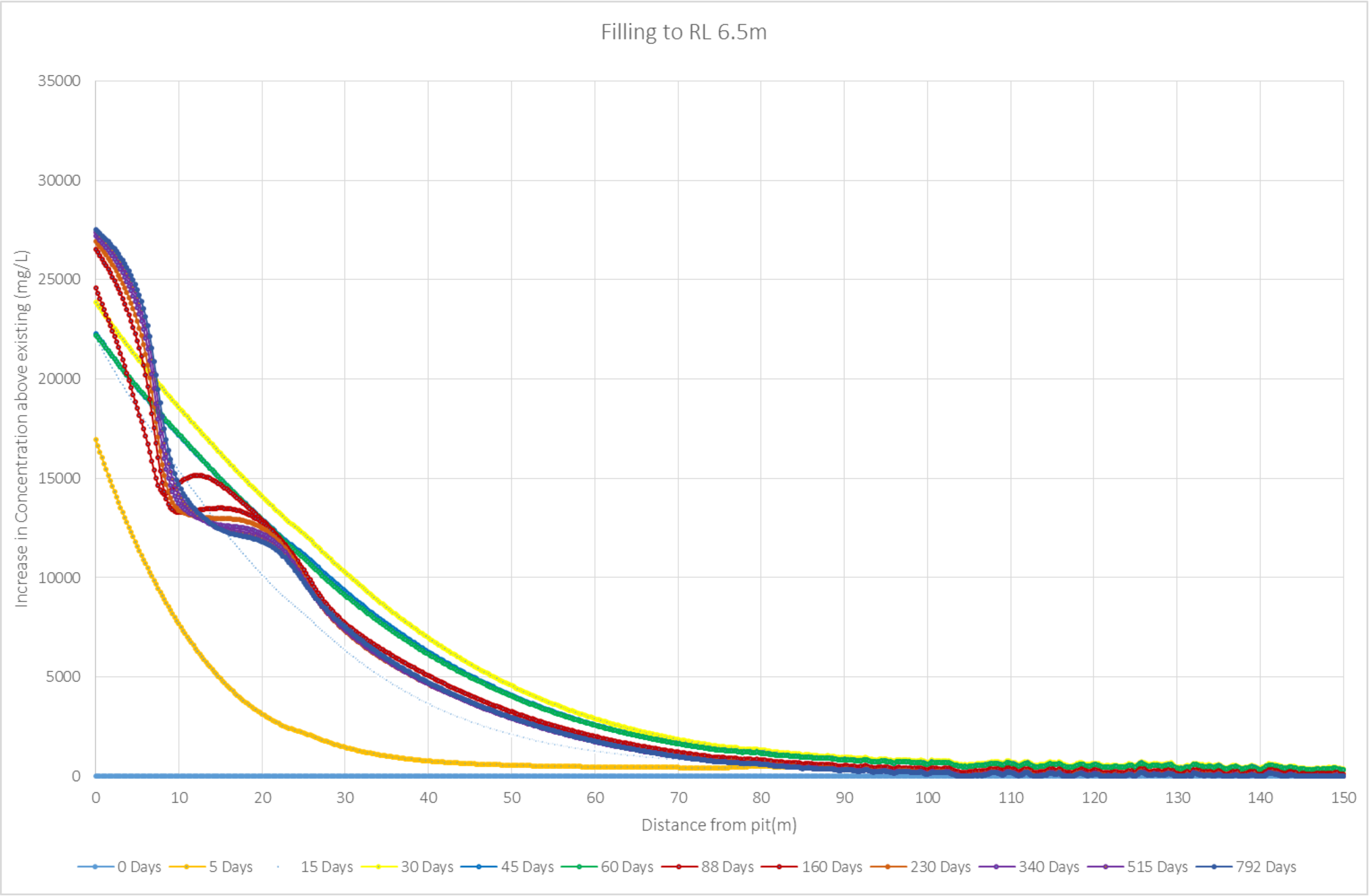




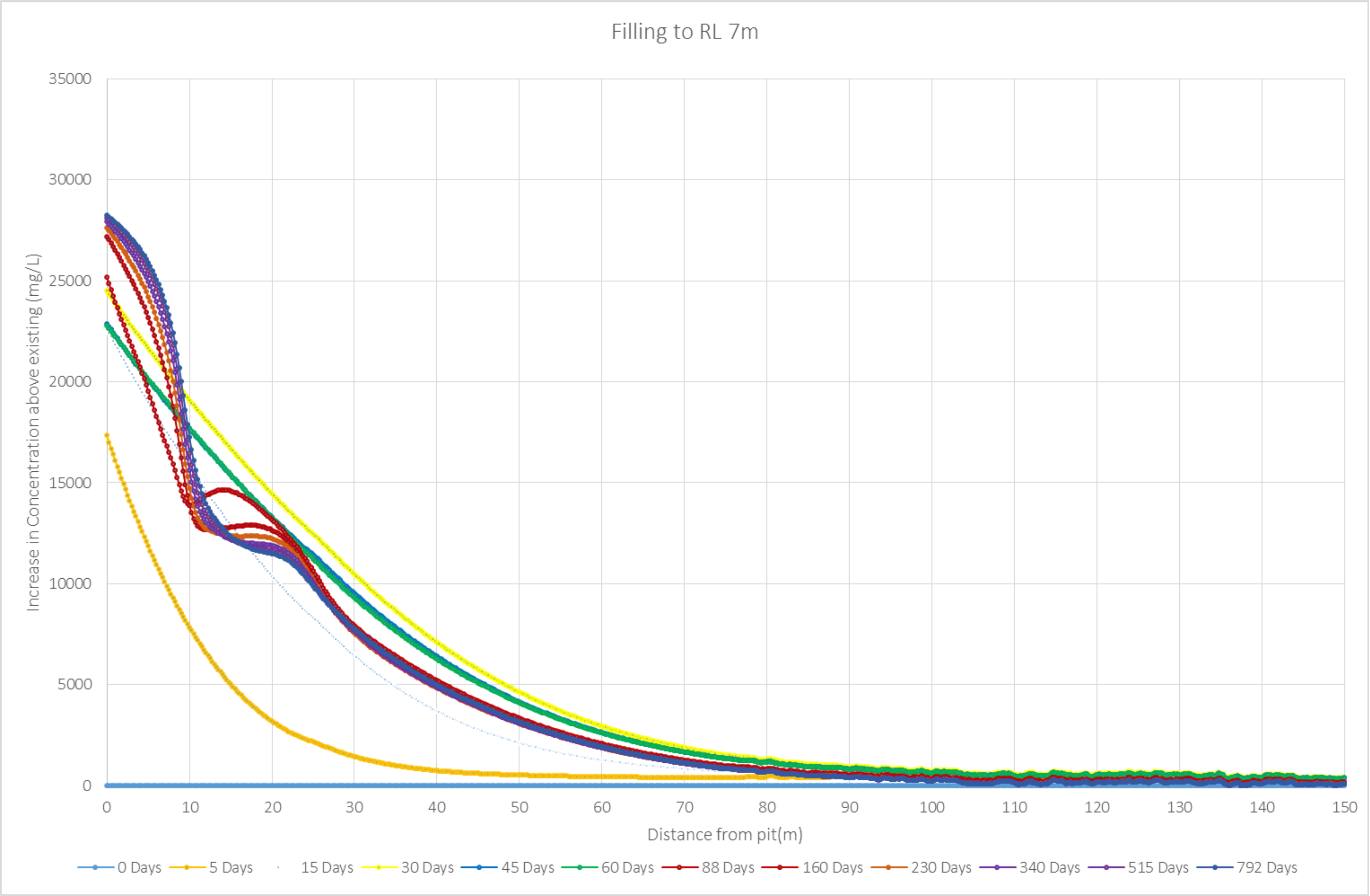
Profiles based on concentrations in the upper sand layer immediately below the upper clay layer

Golder Associates

CLIENT Flanagan Consulting Group		PROJECT Cairns Shipping Development EIS	
DRAWN DW	DATE 04/05/17	TITLE **Profiles of increase in concentration with distance from lake – Section 2 (5.0 to 5.5 mAHD)**	
CHECKED SRF	DATE 04/05/17		
SCALE Not to Scale		PROJECT No 1546223-023	FIGURE No **20** REV No **0** **A3**



Filling to RL 6.5m



Filling to RL 7m

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 DW

DATE 04/05/17

CHECKED SRF

DATE 04/051/17

TITLE **Profiles of increase in concentration with distance from lake – Section 2 (6.5 to 7.0 mAHD)**

SCALE Not to Scale

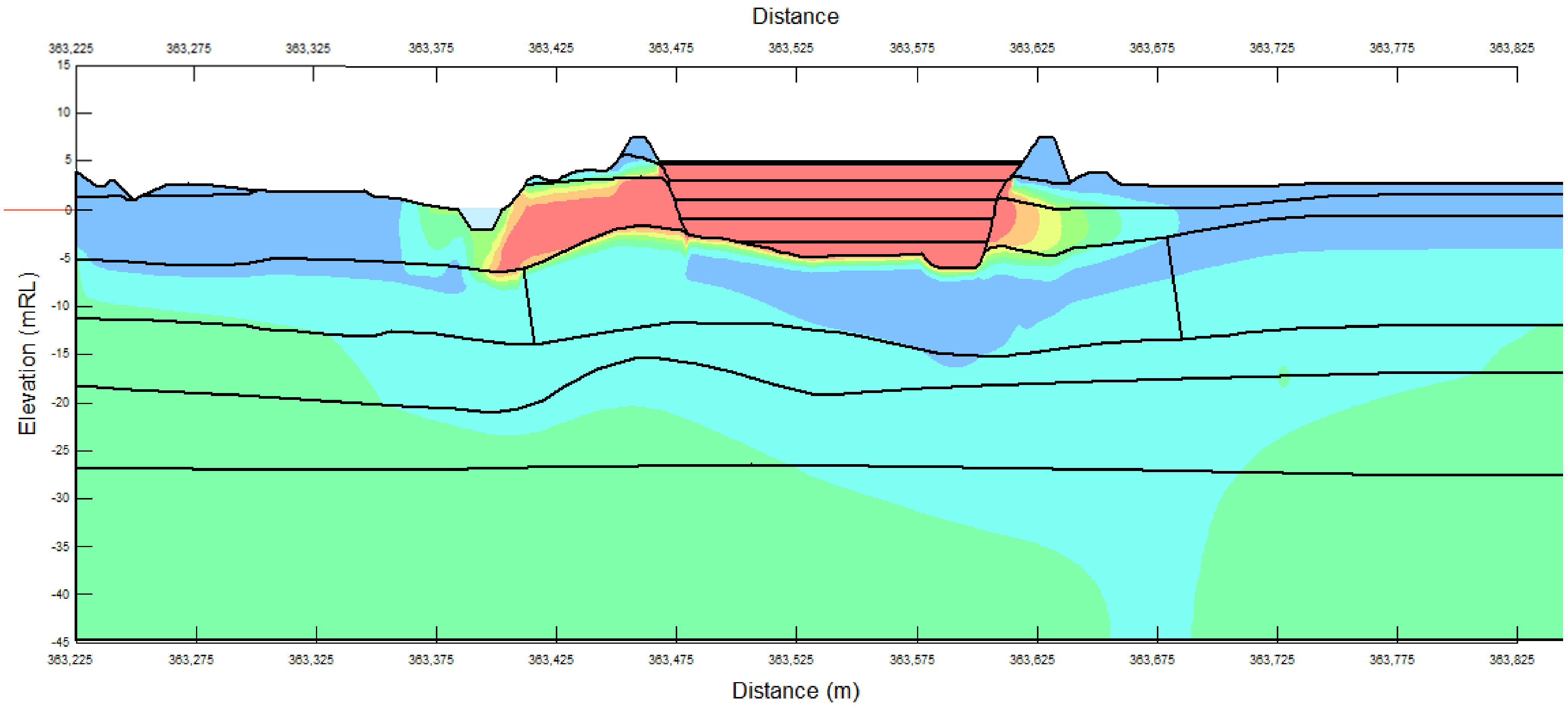
PROJECT No 1546223-023

FIGURE No **21**

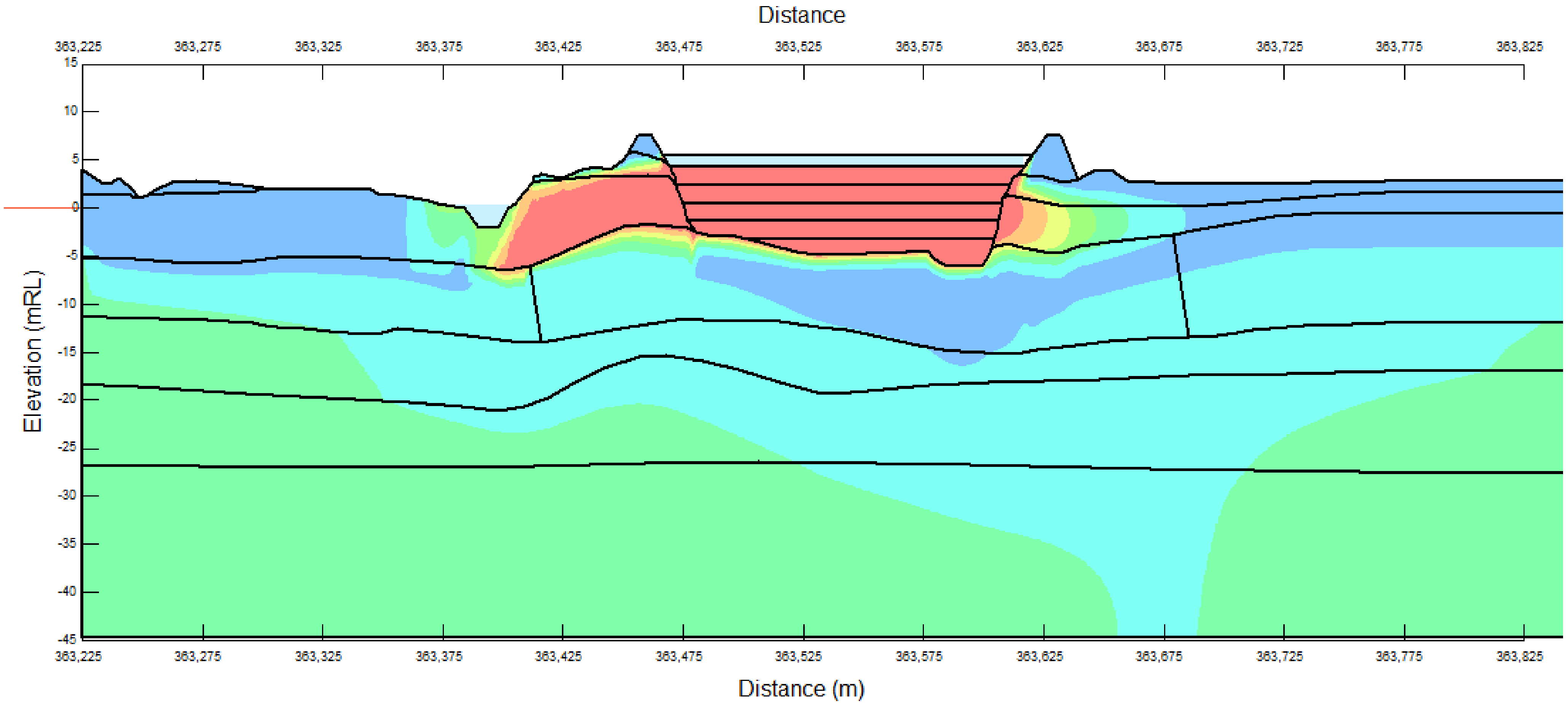
REV No **0**

A3

Filling to RL 5 m with dredge material top at 4.8 m



Filling to RL 5.5 m with dredge material top at 4.3 m

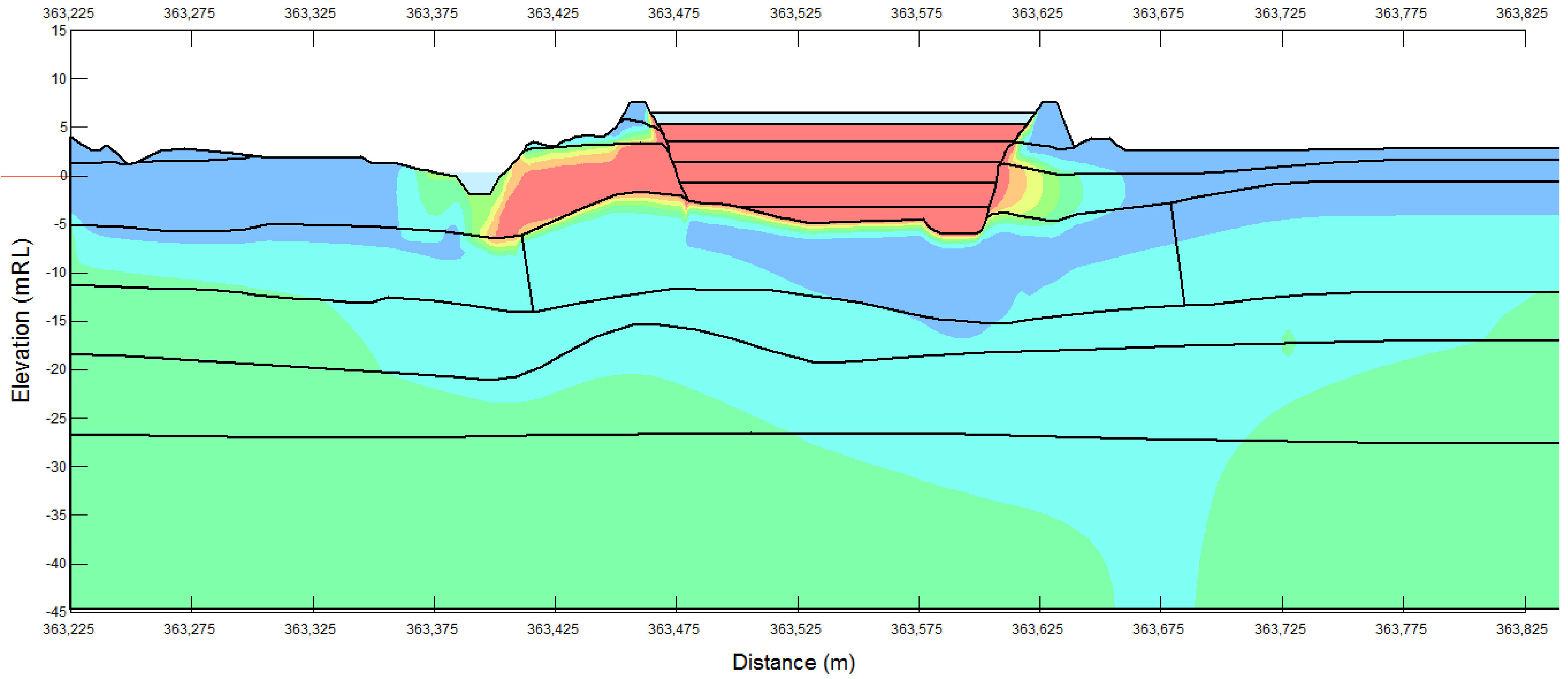


Concentration
🟦 0 - 5,000 g/m³
🟦 5,000 - 10,000 g/m³
🟩 10,000 - 15,000 g/m³
🟩 15,000 - 20,000 g/m³
🟨 20,000 - 25,000 g/m³
🟧 25,000 - 30,000 g/m³
🟥 30,000 - 35,000 g/m³

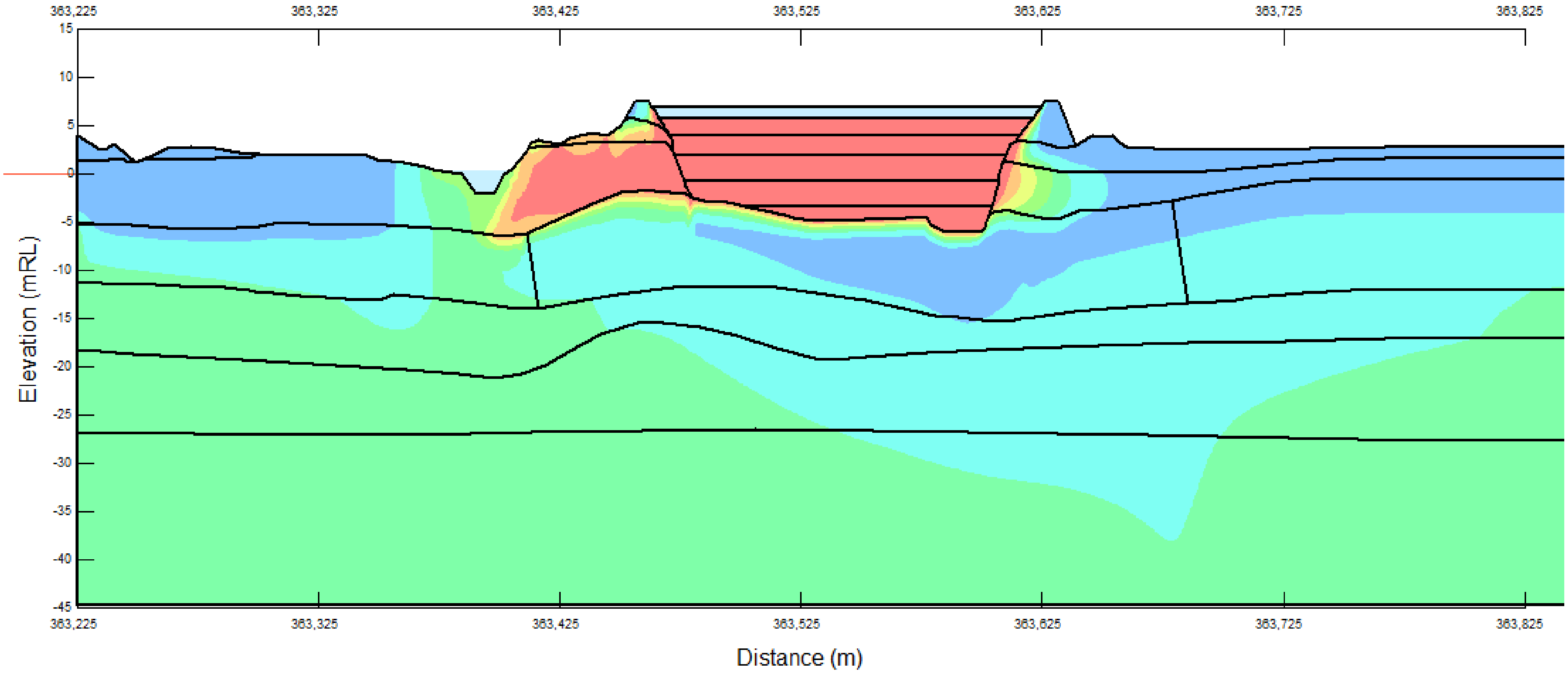
Golder Associates

CLIENT Flanagan Consulting Group
PROJECT Cairns Shipping Development EIS
DRAWN DW
DATE 05/05/17
CHECKED SF
DATE 05/05/17
SCALE Not to Scale
TITLE **Concentration contours at completion of filling for Water levels at 5 and 5.5 m – Section 1**
PROJECT No 1546223-023
FIGURE No **22**
REV No **0**
A3

Filling to RL 6.5 m with dredge material top at 5.3 m



Filling to RL 7.0 m with dredge material top at 5.8 m



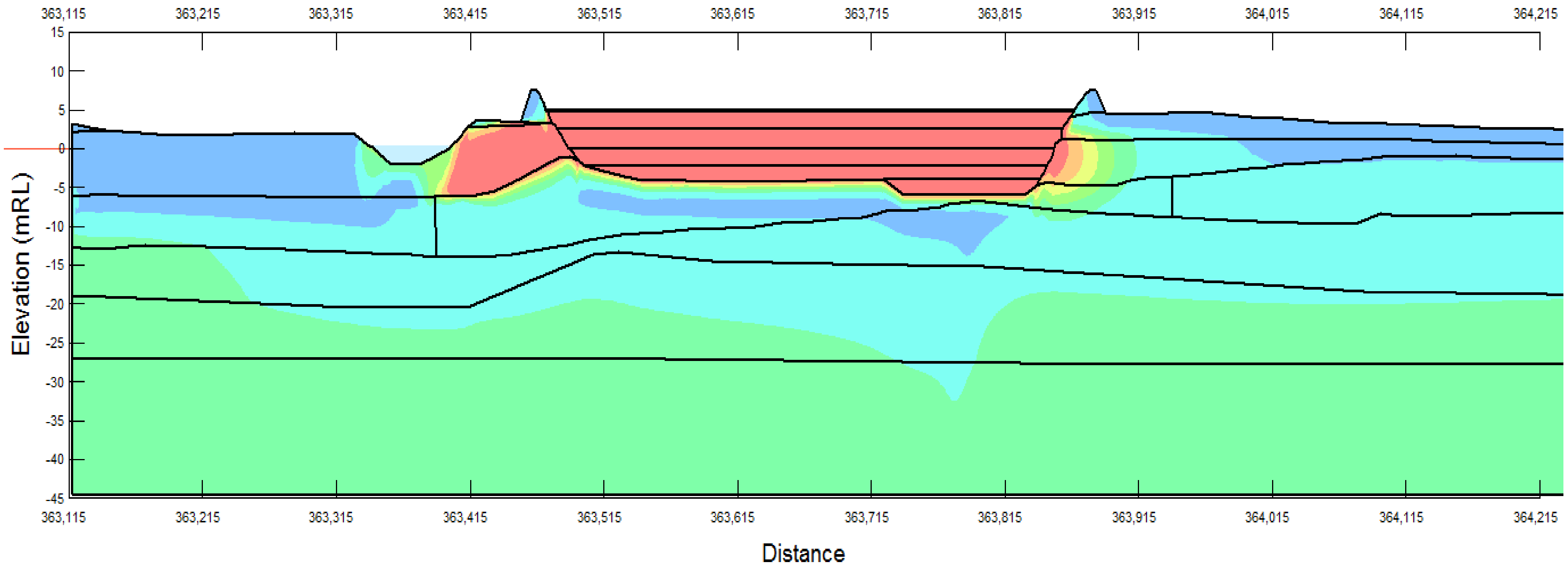
Concentration

- 🟦 0 - 5,000 g/m³
- 🟦 5,000 - 10,000 g/m³
- 🟩 10,000 - 15,000 g/m³
- 🟩 15,000 - 20,000 g/m³
- 🟨 20,000 - 25,000 g/m³
- 🟧 25,000 - 30,000 g/m³
- 🟥 30,000 - 35,000 g/m³

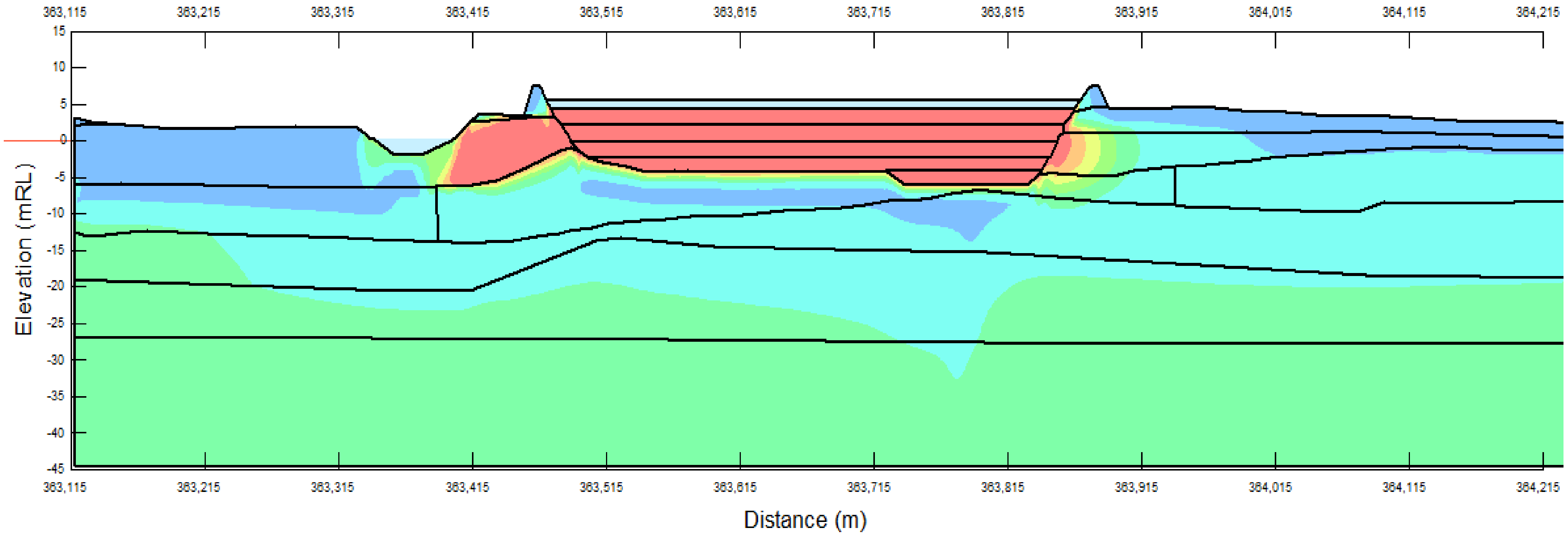
Golder Associates

CLIENT	Flanagan Consulting Group	PROJECT	Cairns Shipping Development EIS
DRAWN	DW	DATE	05/0517
CHECKED	SF	DATE	05/05/17
TITLE	Concentration contours at completion of filling for Water levels at 6.5 and 7.0 m – Section 1		
SCALE	Not to Scale		
PROJECT No	1546223-023	FIGURE No	23
REV No	0	A3	

Filling to RL 5.0 m with dredge material top at 4.8m



Filling to RL 5.5 m with dredge material top at 4.3m

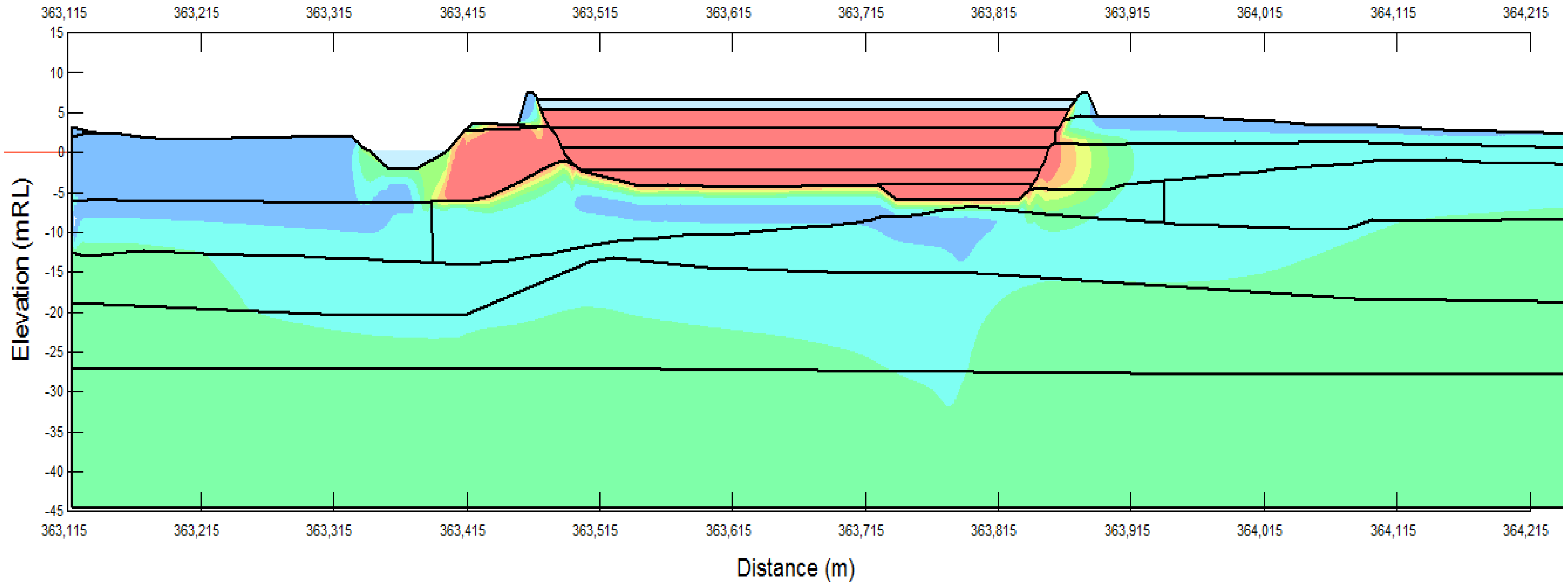


Concentration

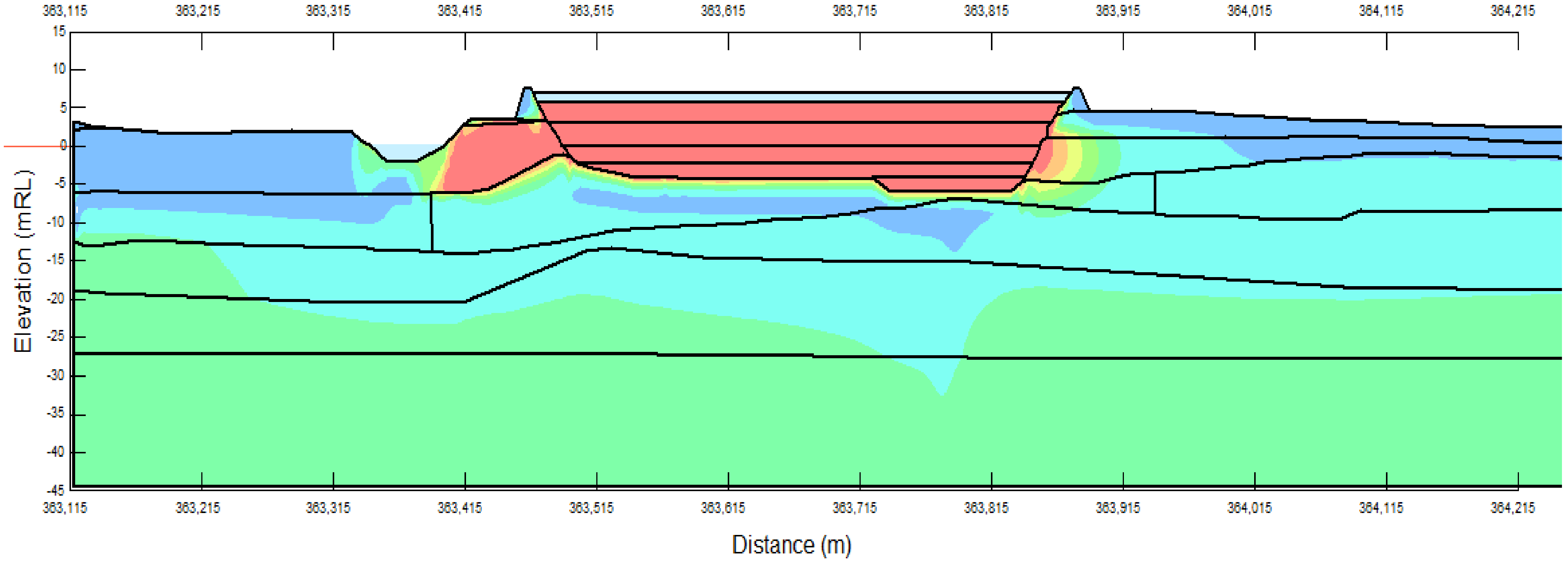
- 🟦 0 - 5,000 g/m³
- 🟦 5,000 - 10,000 g/m³
- 🟩 10,000 - 15,000 g/m³
- 🟩 15,000 - 20,000 g/m³
- 🟨 20,000 - 25,000 g/m³
- 🟧 25,000 - 30,000 g/m³
- 🟥 30,000 - 35,000 g/m³

Golder Associates	CLIENT Flanagan Consulting Group		PROJECT Cairns Shipping Development EIS	
	DRAWN SRF	DATE 05/05/17	TITLE Concentration contours at completion of filling for Water levels at 5 and 5.5 m – Section 2	
	CHECKED MSC	DATE 05/05/17		
	SCALE Not to Scale		PROJECT No 1546223-023	FIGURE No 24 · REV No 0 · A3

Filling to RL 6.5 m with dredge material top at 5.3m



Filling to RL 5.5 m with dredge material top at 5.8m

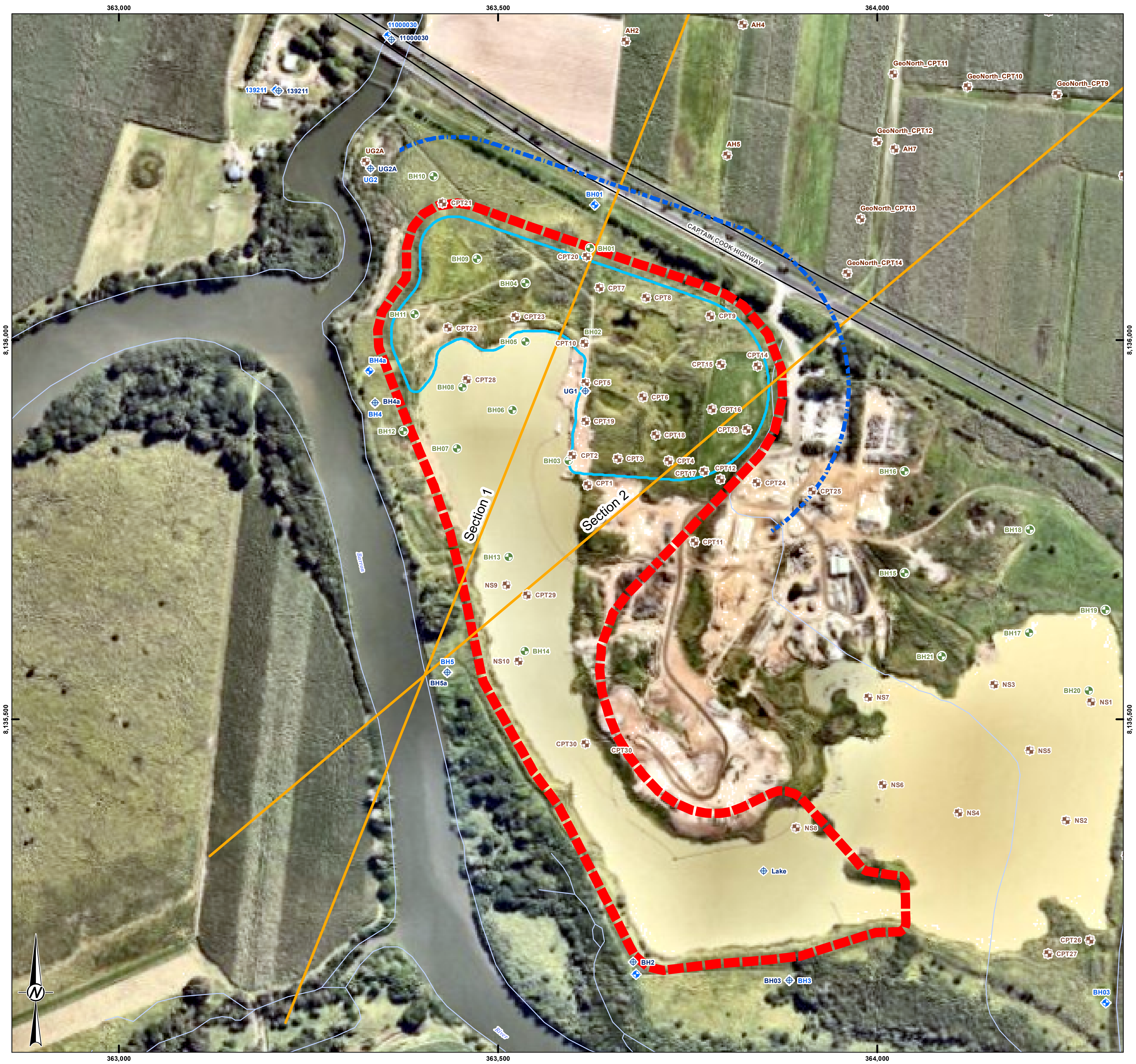


Concentration

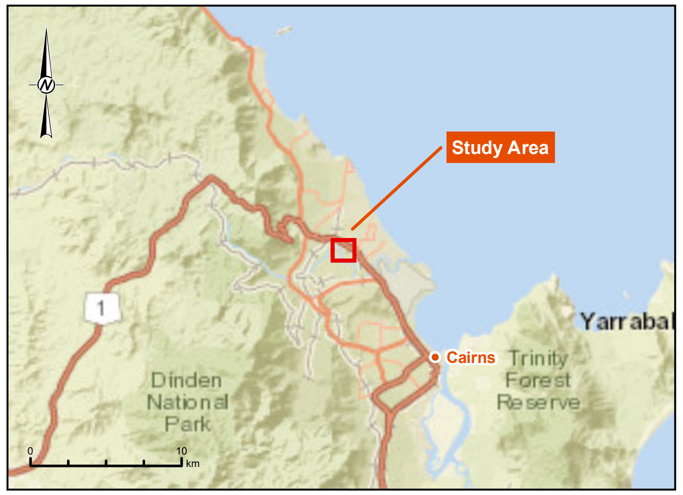
- 🟦 0 - 5,000 g/m^3
- 🟦 5,000 - 10,000 g/m^3
- 🟩 10,000 - 15,000 g/m^3
- 🟩 15,000 - 20,000 g/m^3
- 🟨 20,000 - 25,000 g/m^3
- 🟧 25,000 - 30,000 g/m^3
- 🟥 30,000 - 35,000 g/m^3

Golder Associates

CLIENT	Flanagan Consulting Group		PROJECT	Cairns Shipping Development EIS		
DRAWN	DW	DATE 05/05/17	TITLE	Concentration contours at completion of filling for Water levels at 6.5 and 7.0 m – Section 2		
CHECKED	SF	DATE 05/05/17				
SCALE	Not to Scale		PROJECT No	1546223-023	FIGURE No 25	REV No 0	A3



LOCATION MAP



LEGEND

●	Localities

Investigation Locations

⌖	GW Monitoring Bore
●	Probin Boreholes
⊕	GEO Investigate
⌖	Well Locations
═	Sections
─	Roads and Tracks
─	Watercourses (25k)
─	Proposed Pond Outline
▬	Propose Lake Bund Outline
─	Model Subsurface Sections
‐ ‐	Estimated Extent of Salt Migration (for RL5 to RL7 Simulations)

0 50 100 200 300
Meters

1:5,000 at A3
PROJECTION: GDA 1994 MGA Zone 55

CLIENT
FLANAGAN CONSULTING GROUP

PROJECT
CAIRNS SHIPPING DEVELOPMENT EIS

TITLE
APPROXIMATE EXTENT OF INCREASE IN SALINITY IN UPPER SAND LAYER

CONSULTANT
Golder Associates

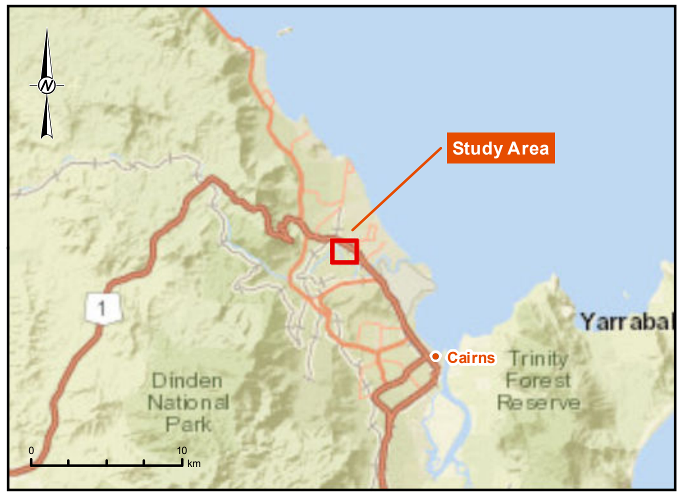
YYYY-MM-DD	2017-05-12
PREPARED	DP
DESIGNED	DP
REVIEWED	DS
APPROVED	DS

PROJECT NO.	CONTROL	REV.	FIGURE
1546223	023	0	26

Path: \\golder.gds\gap\Cairns\Jobs\Geo\2015\1546223 - FCG - EIS Stage 1 - Port Development\GIS\MXD\Hydro_Assessment\1546223-012-R-Rev2_F026_Extent of Salinity.mxd

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

LOCATION MAP



LEGEND

- ⌖ Proposed Monitoring Bore
- ― Roads and Tracks
- ― Watercourses (25k)
- ― Proposed Pond Outline
- ▬ ▬ Propose Lake Bund Outline
- -·-· Potential Extent of Salinity

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0 50 100 200 300 400
Meters

1:5,398 at A3
PROJECTION: GDA 1994 MGA Zone 55

CLIENT
FLANAGAN CONSULTING GROUP

PROJECT
CAIRNS SHIPPING DEVELOPMENT EIS

TITLE
PROPOSED GROUNDWATER MONITORING BORES

CONSULTANT
Golder Associates

YYYY-MM-DD	2017-05-31
PREPARED	DP
DESIGNED	DP
REVIEWED	DS
APPROVED	DS

PROJECT NO.	CONTROL	REV.	FIGURE
1546223	023	0	27

Path: \\golder.gds\GAP\Cairns\Jobs\Geo\2015\1546223 - FCG - EIS Stage 1 - Port Development\GIS\MXD\Hydro_Assessment\1546223-012-R-Rev3_F027_Monitoring Program.mxd

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

25mm

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 below ground level)	Screened Interval (m below ground level)	Screened formation (m below ground level)	Stratigraphy	Aquifer type	Standing Water Level Range	
						*(m below ground level)	*(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

Borehole ID	Bore depth (m below ground level)	Screened Interval (m below ground level)	Screened formation (m below ground level)	Stratigraphy	Aquifer type	Standing Water Level Range	
						*(m below ground level)	*(m AHD)
11000039	72.0	30.0 to 42.0	Gravel	Quaternary sediment	Deep	3.0 to 4.2	0.5 to 1.2
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.

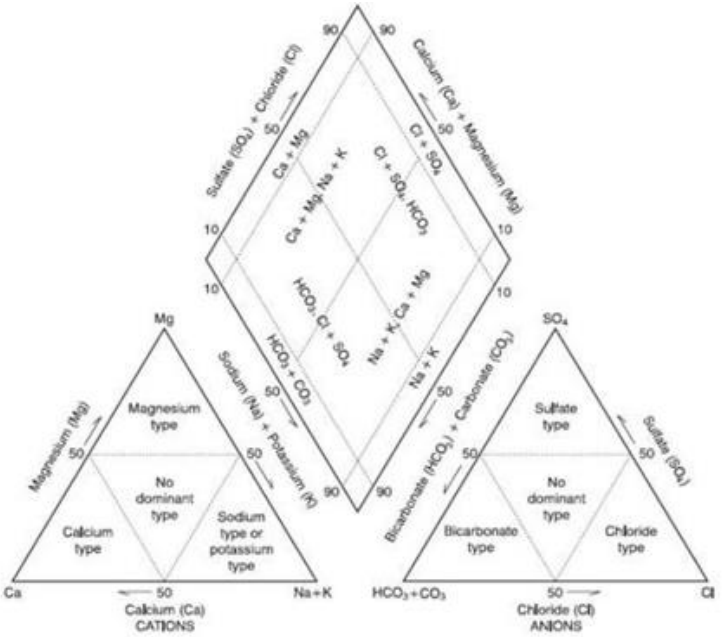
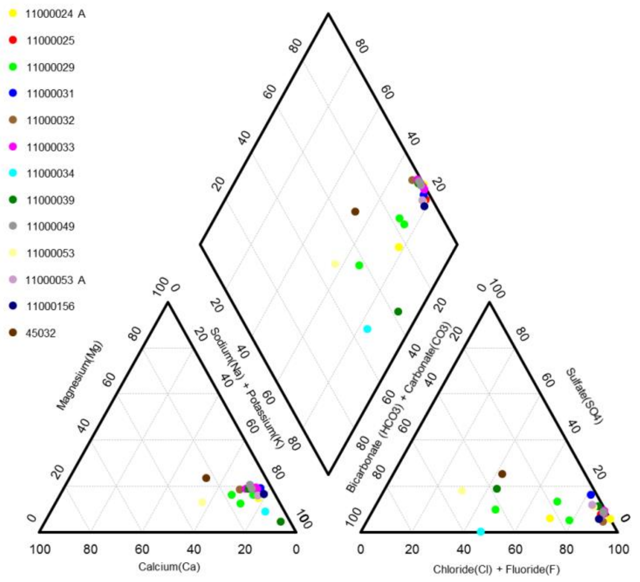
Classification of hydrochemical facies using Piper Diagrams	
Water types of groundwater samples from monitoring bores within 2 km of the Northern Sand site.	

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

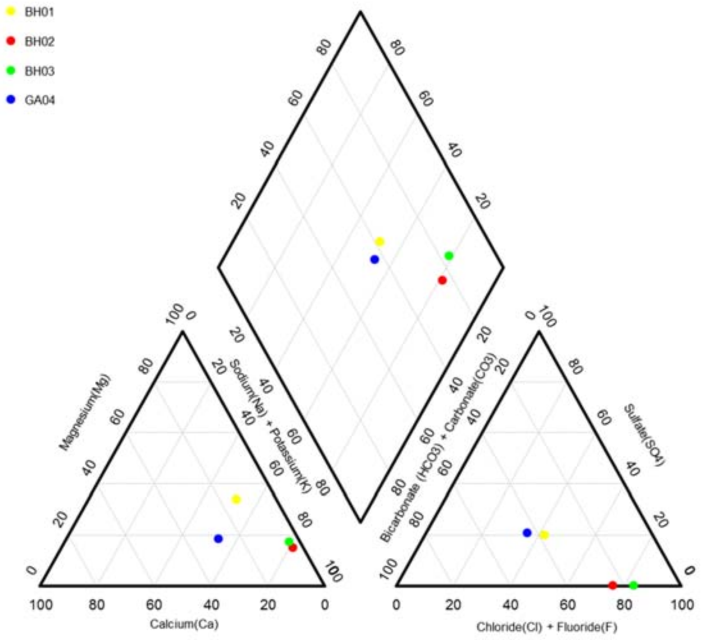
Classification of hydrochemical facies using Piper Diagrams	
Water types of groundwater samples from monitoring bores present on site during the November sampling event.	

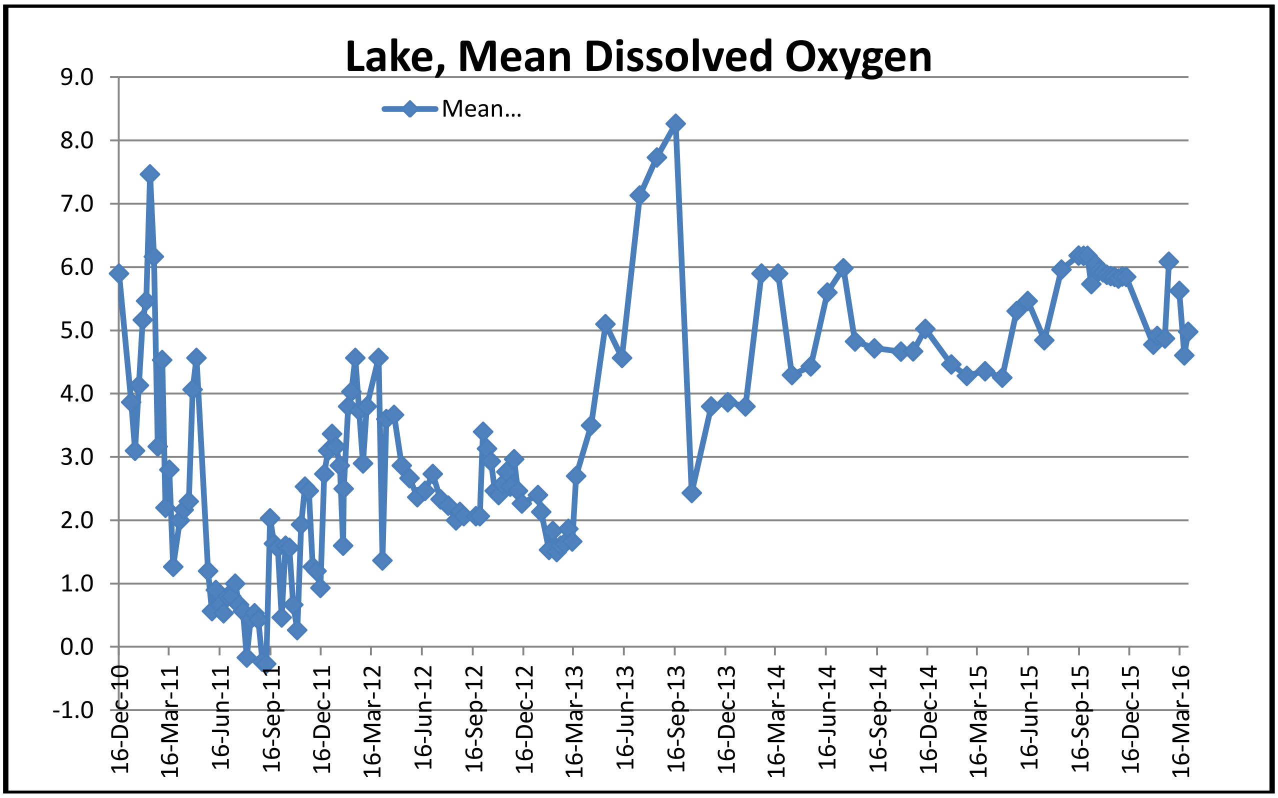
Figure B2: Piper diagram for samples from BH01, BH02, BH03 and GA04.

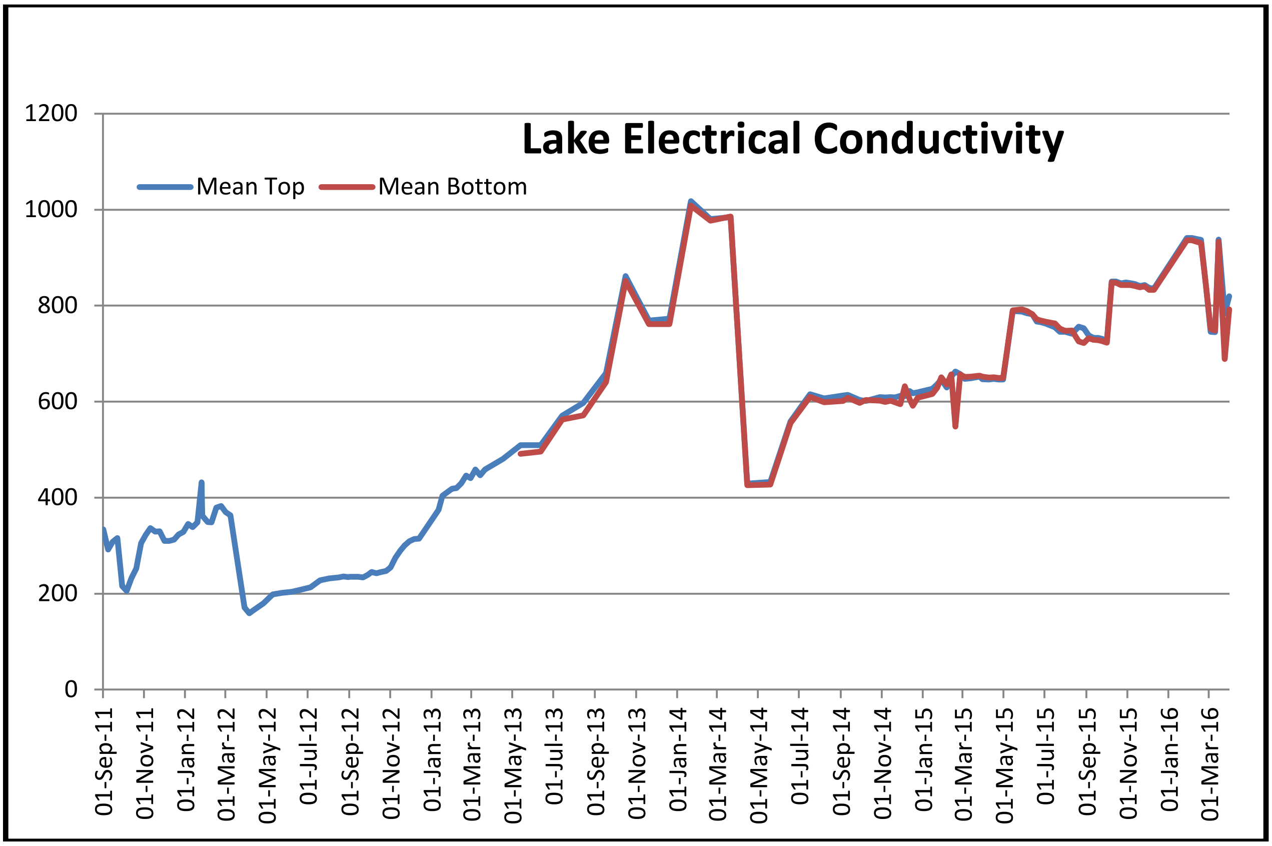
20 July 2016

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
0
200
400
600
800
1000
1200
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
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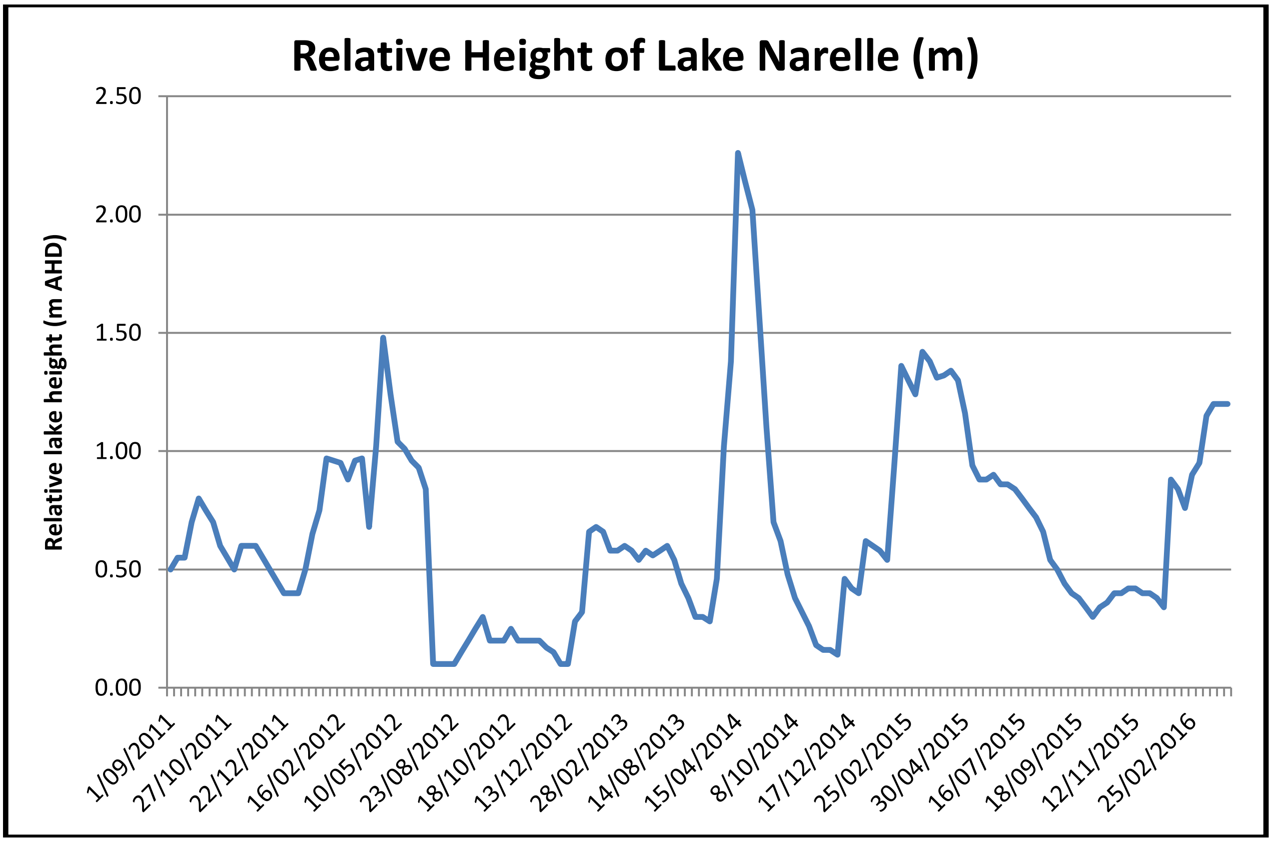
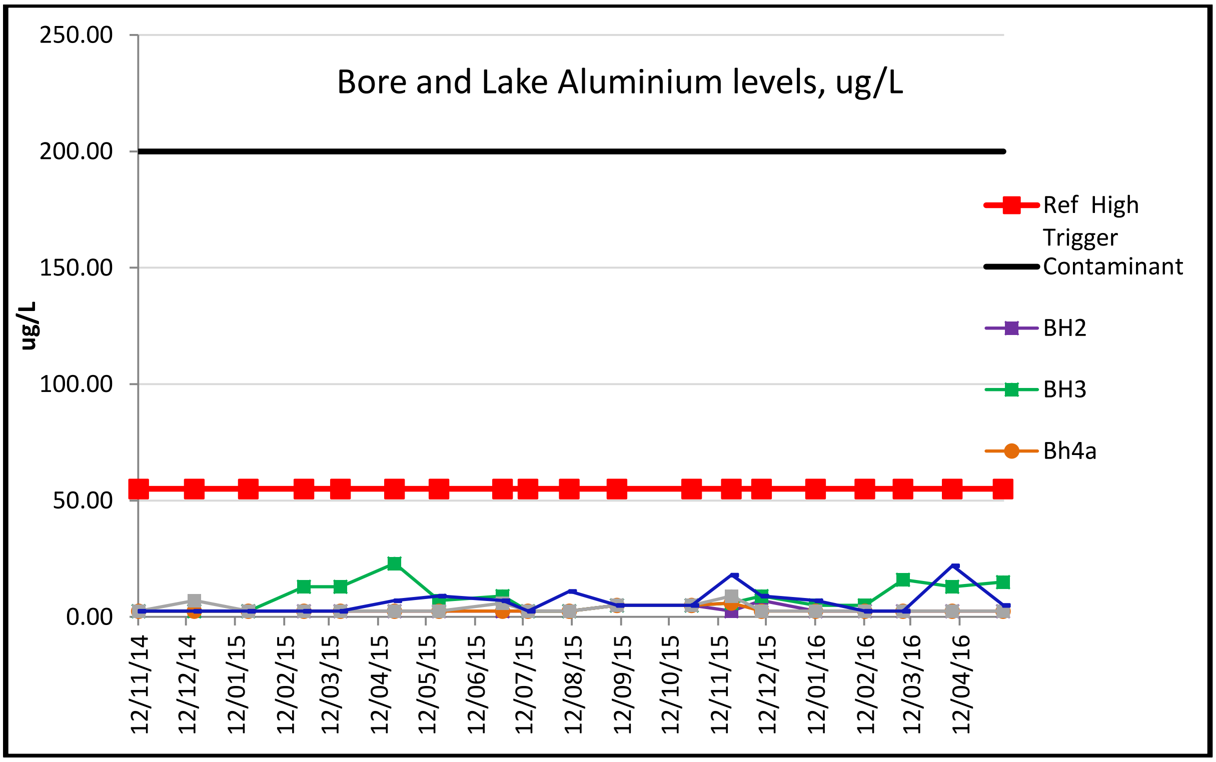
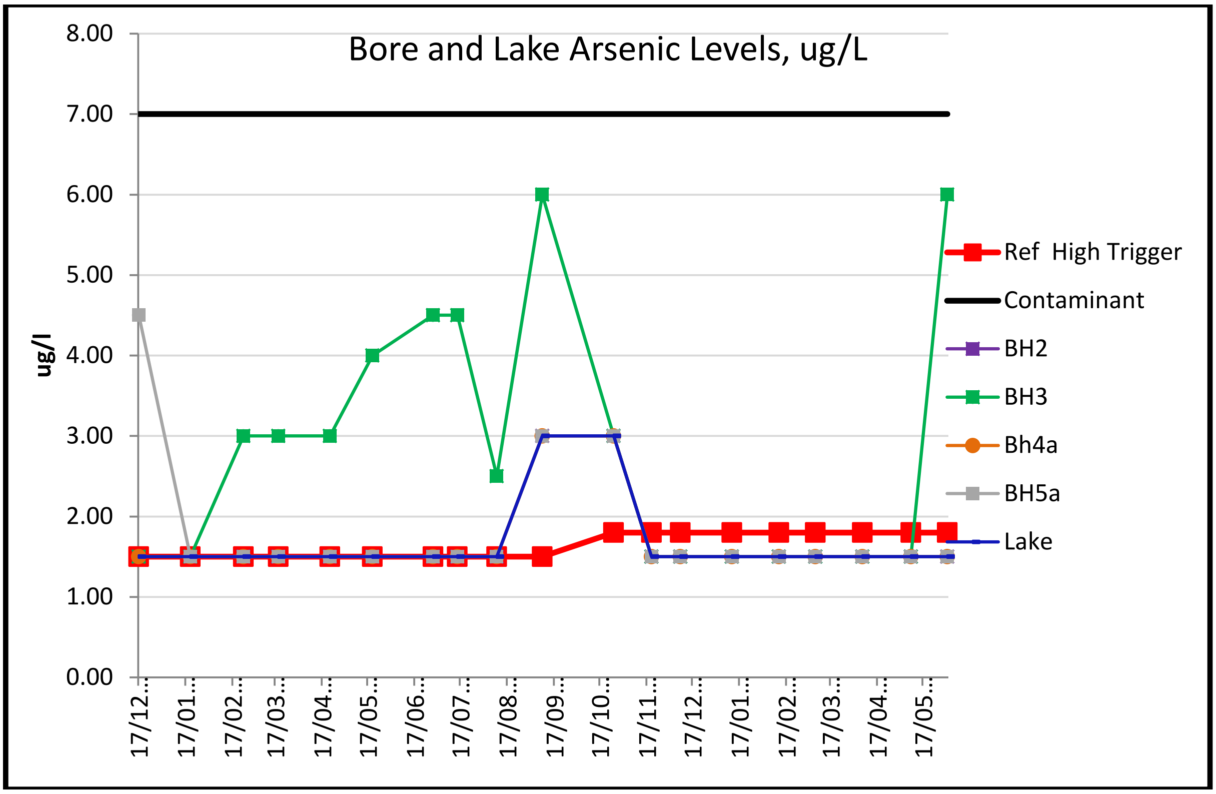
01-May-15
01-Jul-15
01-Sep-15
01-Nov-15
01-Jan-16
01-Mar-16

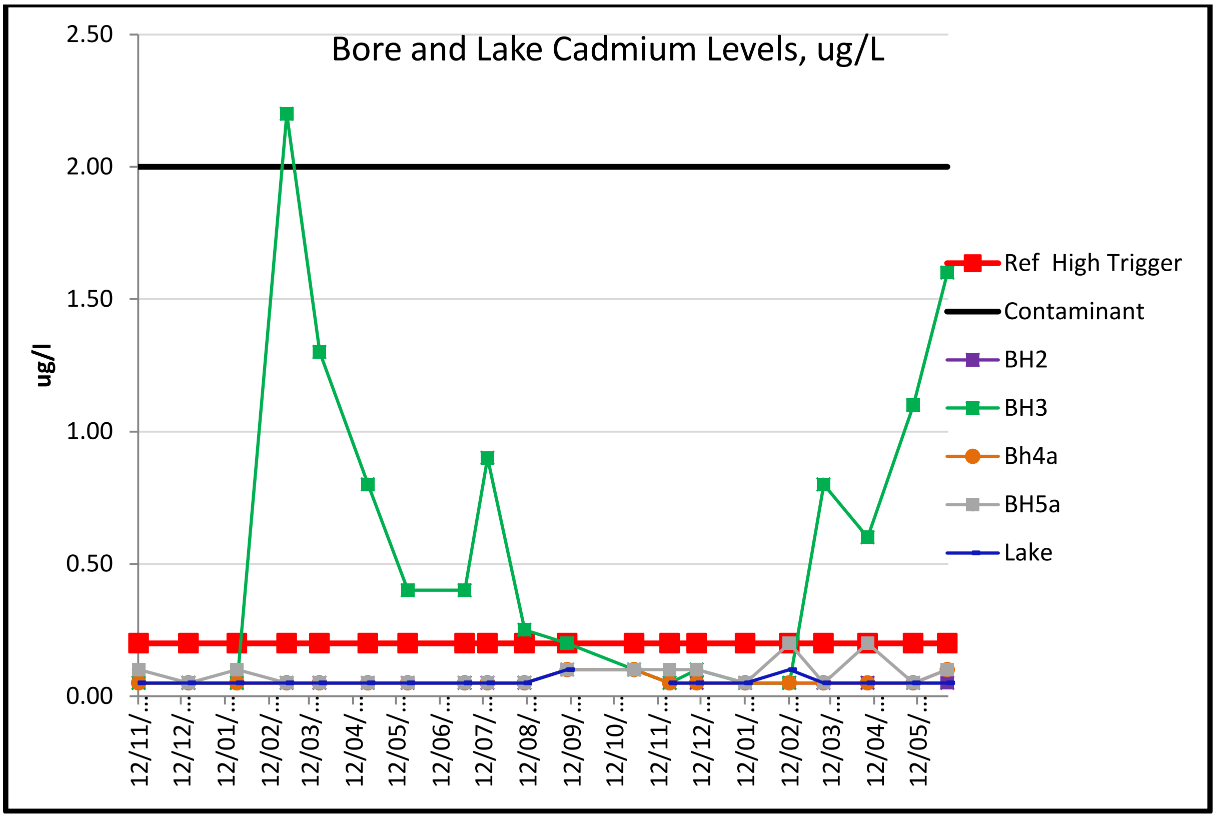

Relative Height of Lake Narelle (m)
Relative lake height (m AHD)
0.00
0.50
1.00
1.50
2.00
2.50
1/09/2011
27/10/2011
22/12/2011
16/02/2012
10/05/2012
23/08/2012
18/10/2012
13/12/2012
28/02/2013
14/08/2013
15/04/2014
8/10/2014
17/12/2014
25/02/2015
30/04/2015
16/07/2015
18/09/2015
12/11/2015
25/02/2016

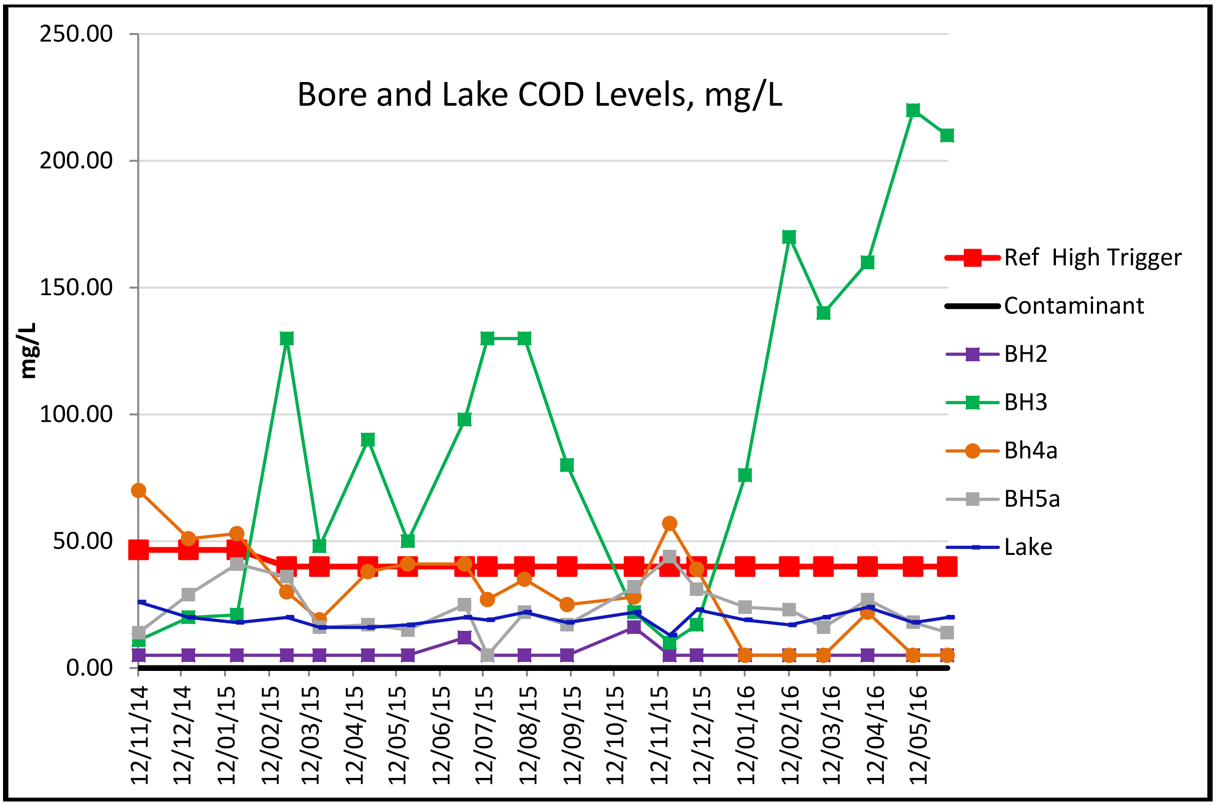
The next group of charts represent samples collected from Northern Sand site bores and lake. Samples are collected monthly and analysed by NATA approved facility. Most charts represent data collected over the last 24 months which is used for examination and interpretation for regular report. Additional 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.

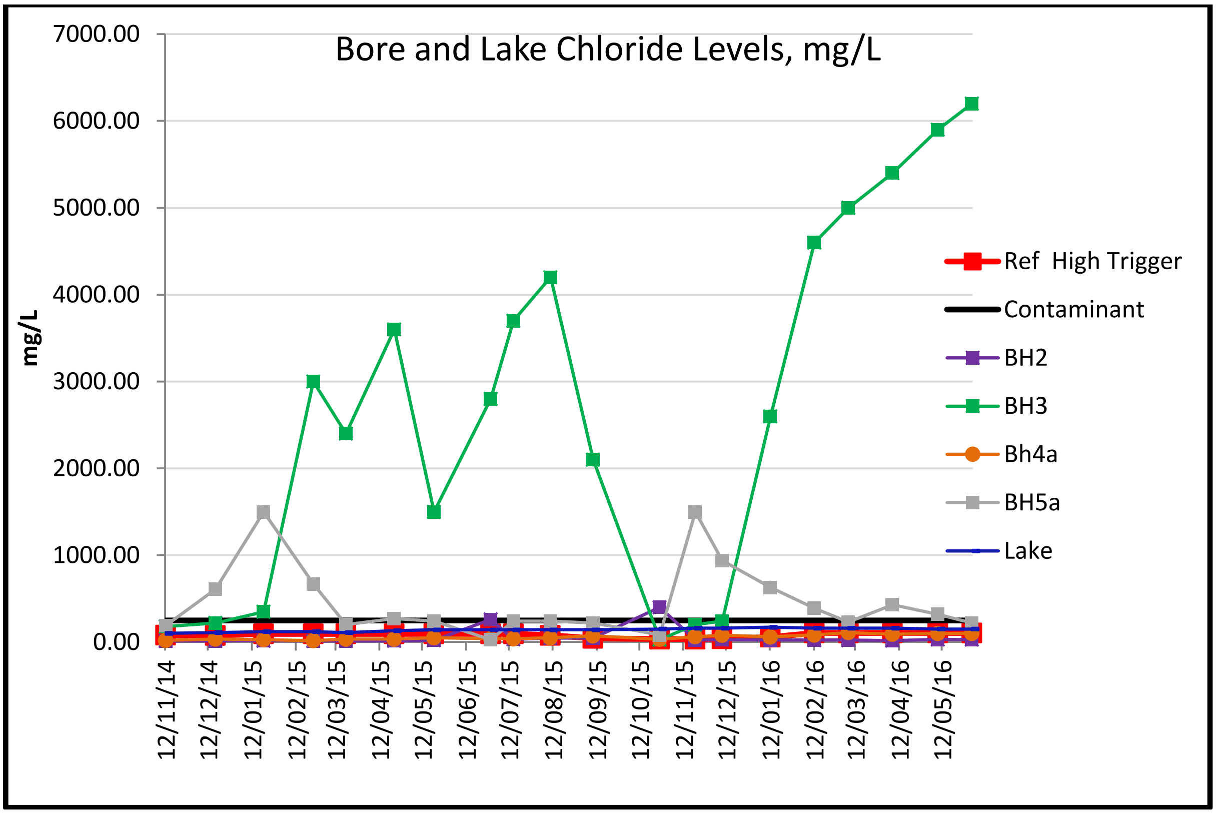
Please note that Bore 3 (BH3) experiences regular exceedences across many parameters. However it's close proximity to the Barron is believed to be responsible for these irregularities and not related to the Lake.

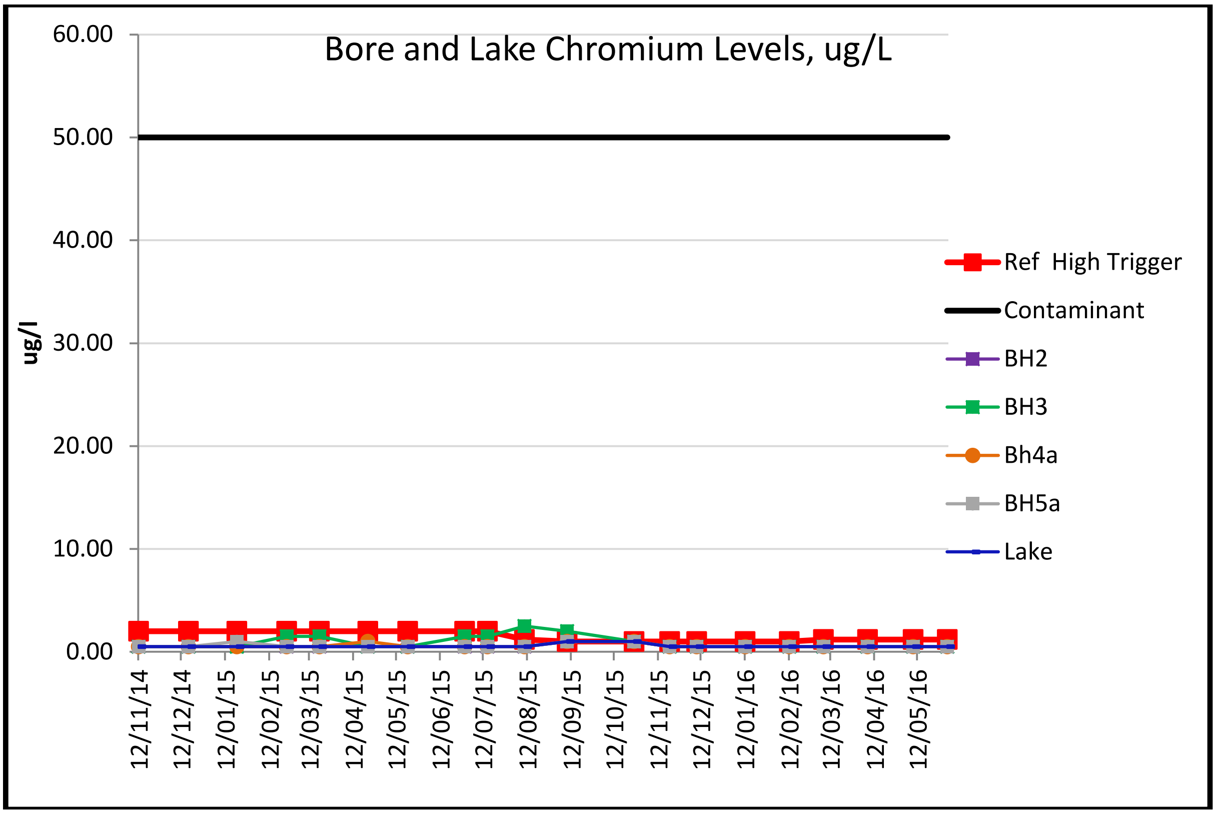


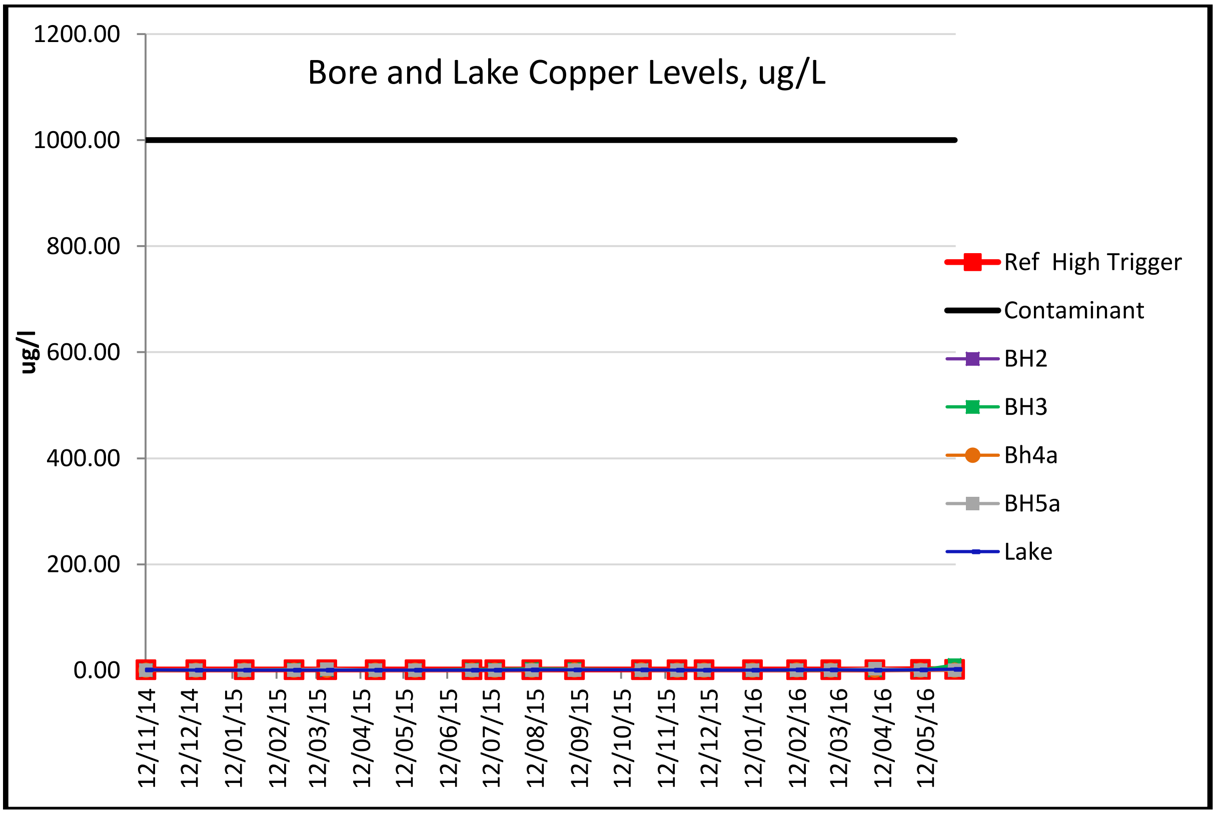

Bore and Lake Arsenic Levels, ug/L
ug/l
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
17/12…
17/01…
17/02…
17/03…
17/04…
17/05…
17/06…
17/07…
17/08…
17/09…
17/10…
17/11…
17/12…
17/01…
17/02…
17/03…
17/04…
17/05…
Ref High Trigger
Contaminant
BH2
BH3
Bh4a
BH5a
Lake

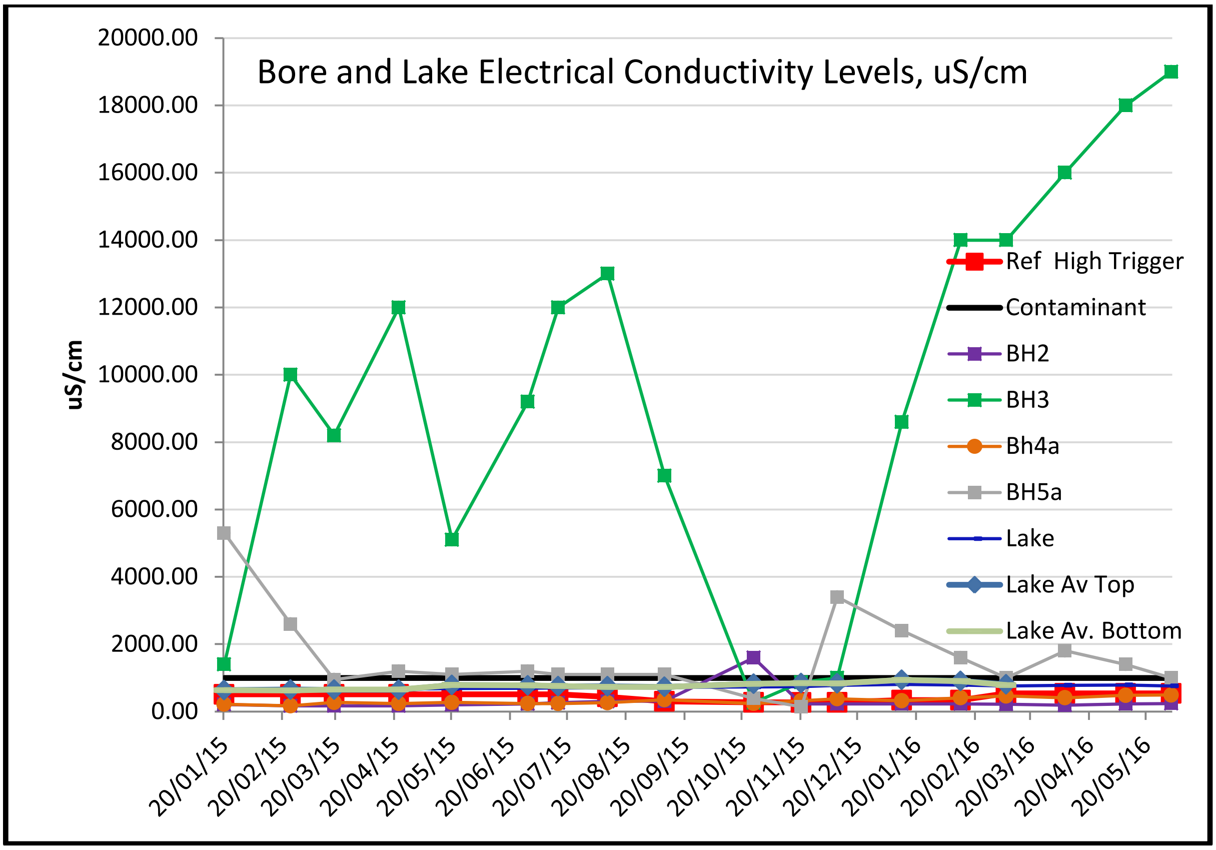

Bore and Lake Cadmium Levels, ug/L
ug/l
2.50
2.00
1.50
1.00
0.50
0.00
12/11/…
12/12/…
12/01/…
12/02/…
12/03/…
12/04/…
12/05/…
12/06/…
12/07/…
12/08/…
12/09/…
12/10/…
12/11/…
12/12/…
12/01/…
12/02/…
12/03/…
12/04/…
12/05/…
Ref High Trigger
Contaminant
BH2
BH3
Bh4a
BH5a
Lake

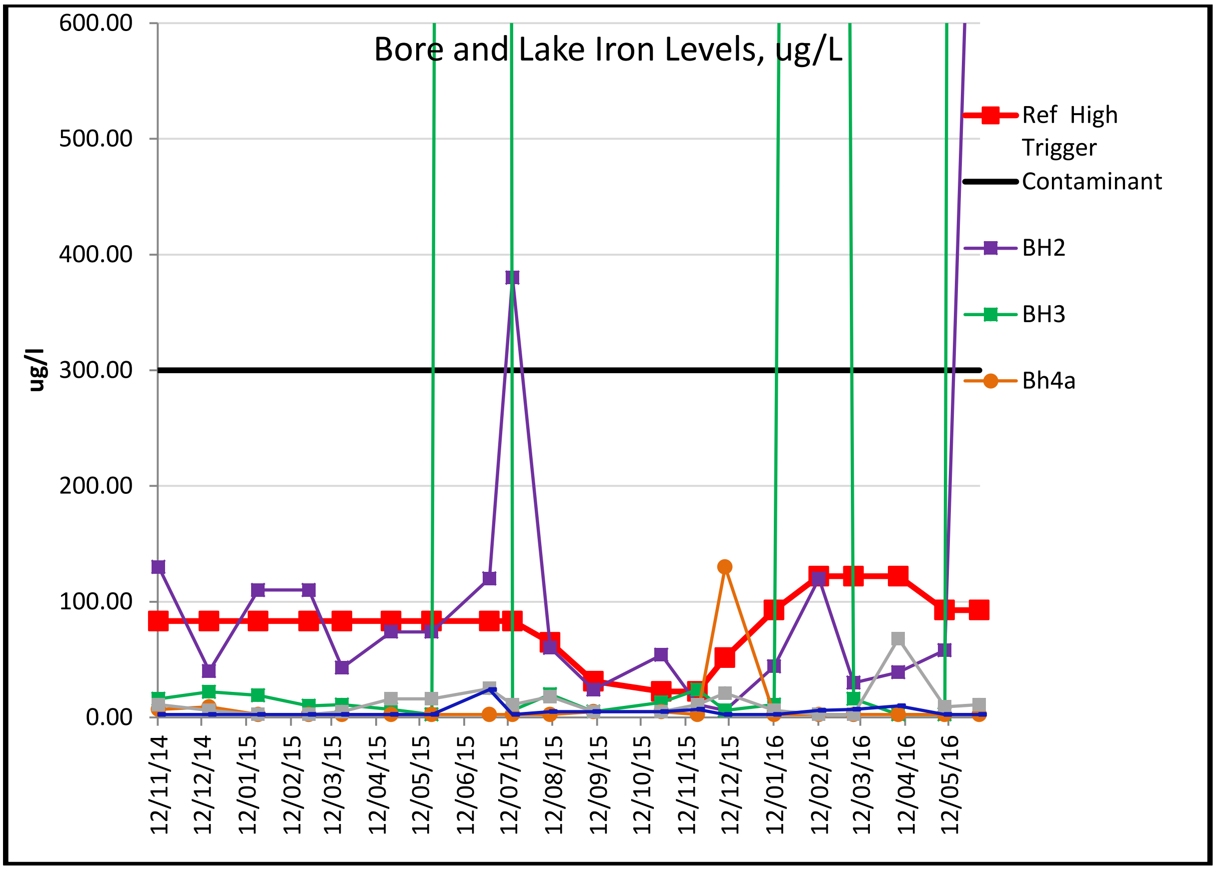

Bore and Lake COD Levels, mg/L
mg/L
250.00
200.00
150.00
100.00
50.00
0.00
12/11/14
12/12/14
12/01/15
12/02/15
12/03/15
12/04/15
12/05/15
12/06/15
12/07/15
12/08/15
12/09/15
12/10/15
12/11/15
12/12/15
12/01/16
12/02/16
12/03/16
12/04/16
12/05/16
Ref High Trigger
Contaminant
BH2
BH3
Bh4a
BH5a
Lake

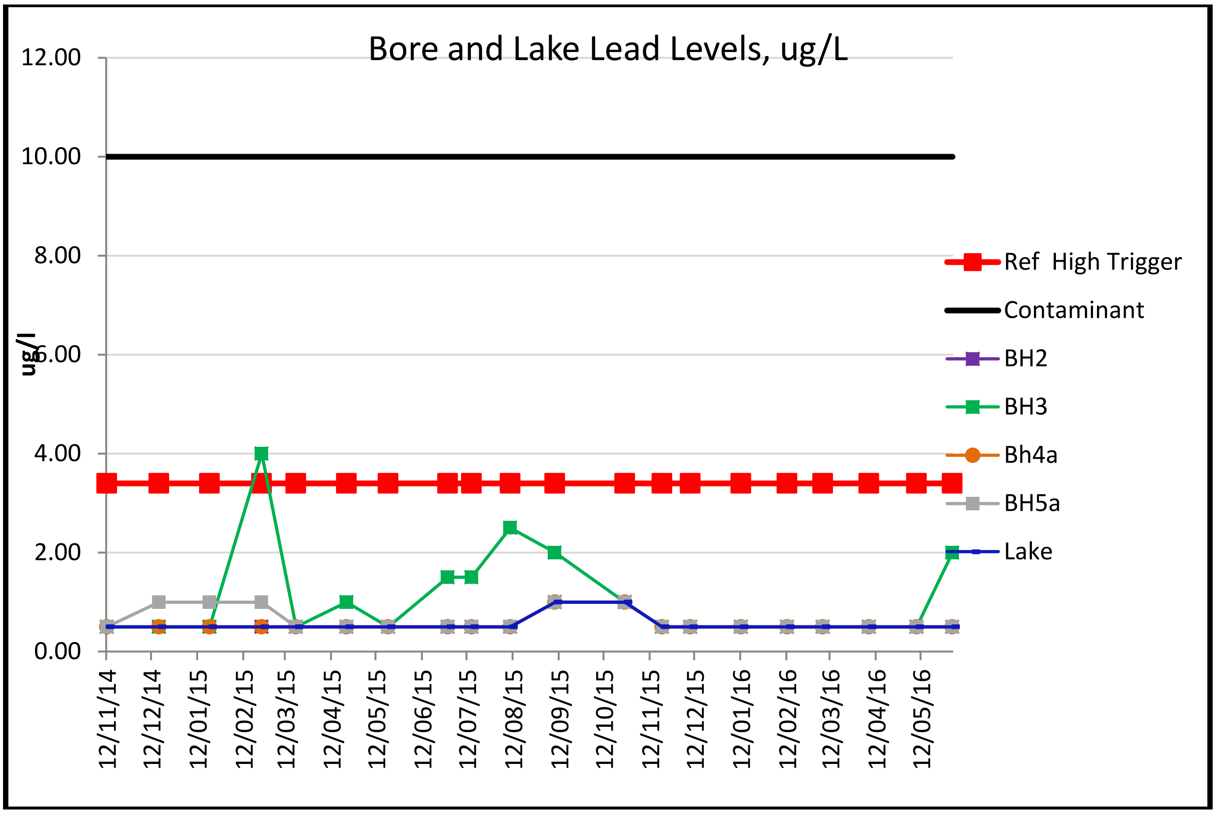

Bore and Lake Chloride Levels, mg/L
mg/L
7000.00
6000.00
5000.00
4000.00
3000.00
2000.00
1000.00
0.00
12/11/14
12/12/14
12/01/15
12/02/15
12/03/15
12/04/15
12/05/15
12/06/15
12/07/15
12/08/15
12/09/15
12/10/15
12/11/15
12/12/15
12/01/16
12/02/16
12/03/16
12/04/16
12/05/16
Ref High Trigger
Contaminant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

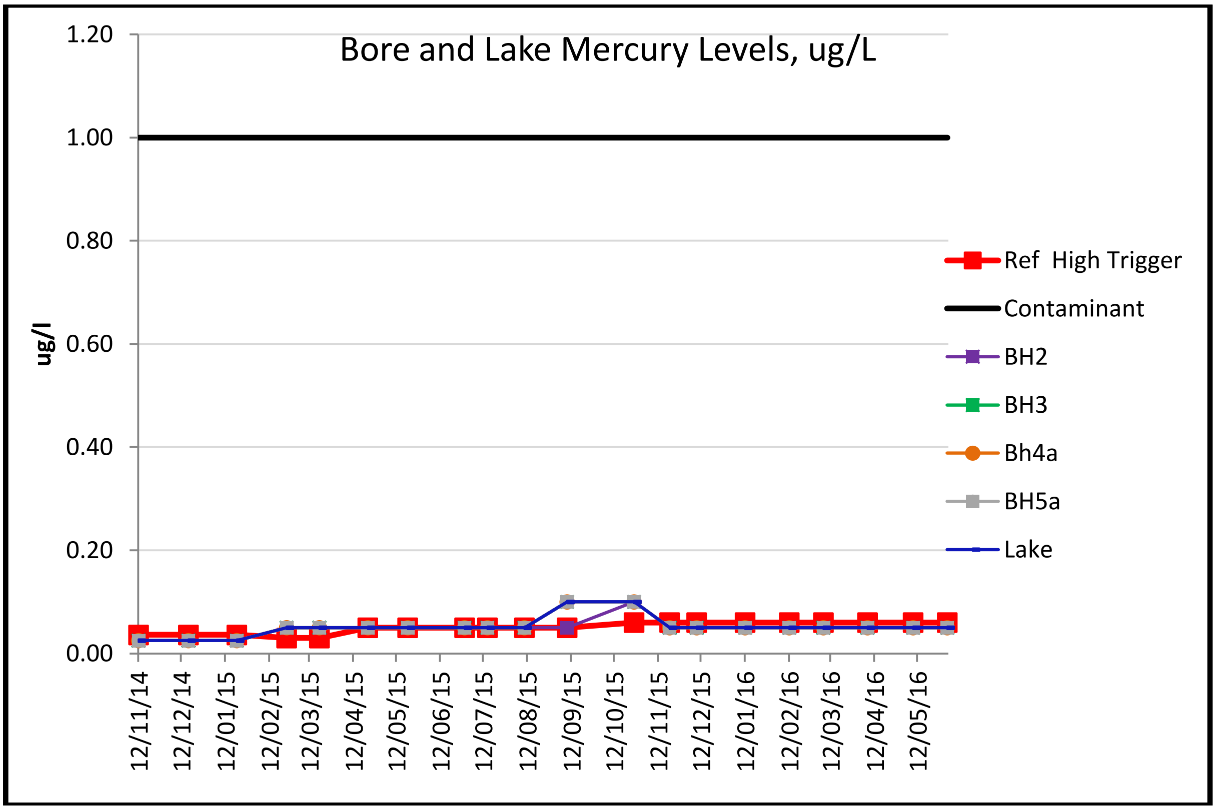

Bore and Lake Chromium Levels, ug/L
ug/l
60.00
50.00
40.00
30.00
20.00
10.00
0.00
12/11/14
12/12/14
12/01/15
12/02/15
12/03/15
12/04/15
12/05/15
12/06/15
12/07/15
12/08/15
12/09/15
12/10/15
12/11/15
12/12/15
12/01/16
12/02/16
12/03/16
12/04/16
12/05/16
Ref High Trigger
Contaminant
BH2
BH3
Bh4a
BH5a
Lake

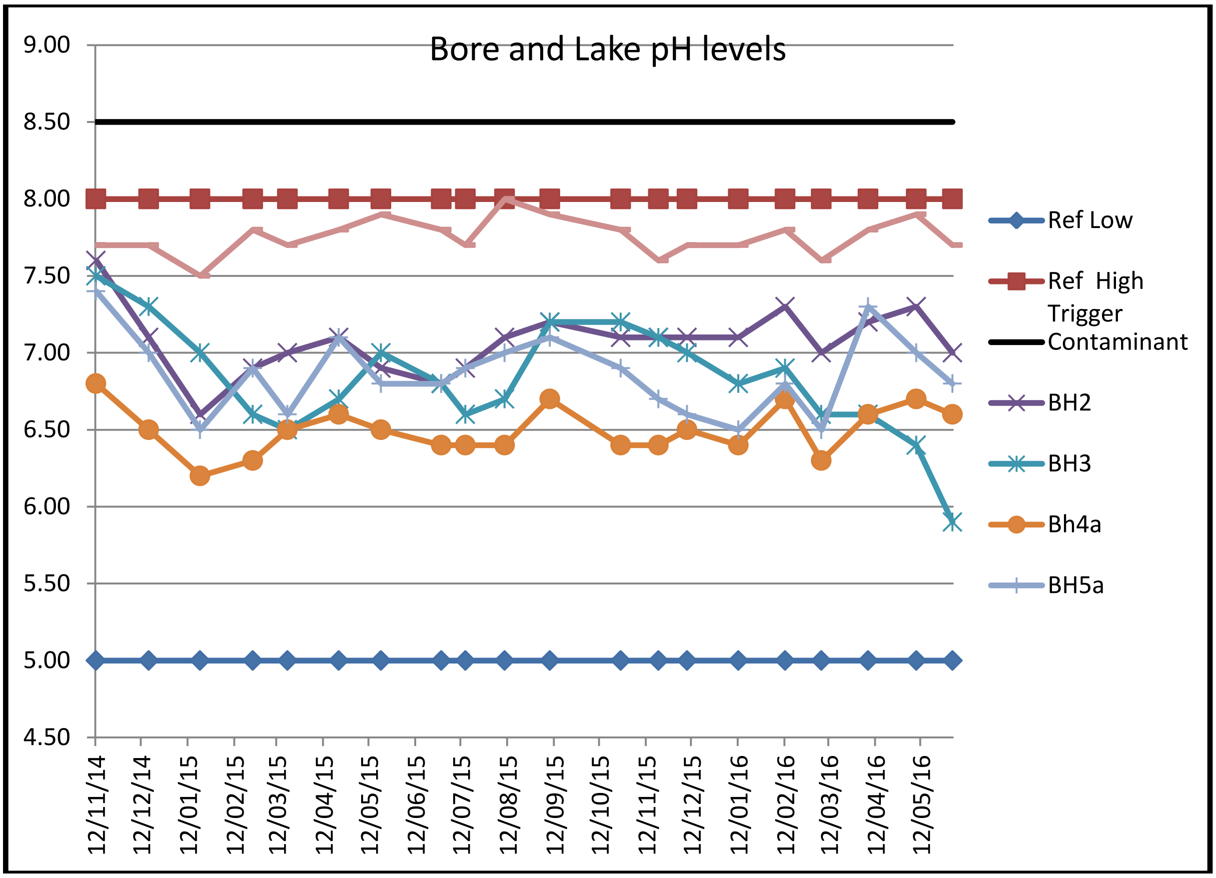

Bore and Lake Copper Levels, ug/L
ug/l
1200.00
1000.00
800.00
600.00
400.00
200.00
0.00
12/11/14
12/12/14
12/01/15
12/02/15
12/03/15
12/04/15
12/05/15
12/06/15
12/07/15
12/08/15
12/09/15
12/10/15
12/11/15
12/12/15
12/01/16
12/02/16
12/03/16
12/04/16
12/05/16
Ref High Trigger
Contaminant
BH2
BH3
Bh4a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

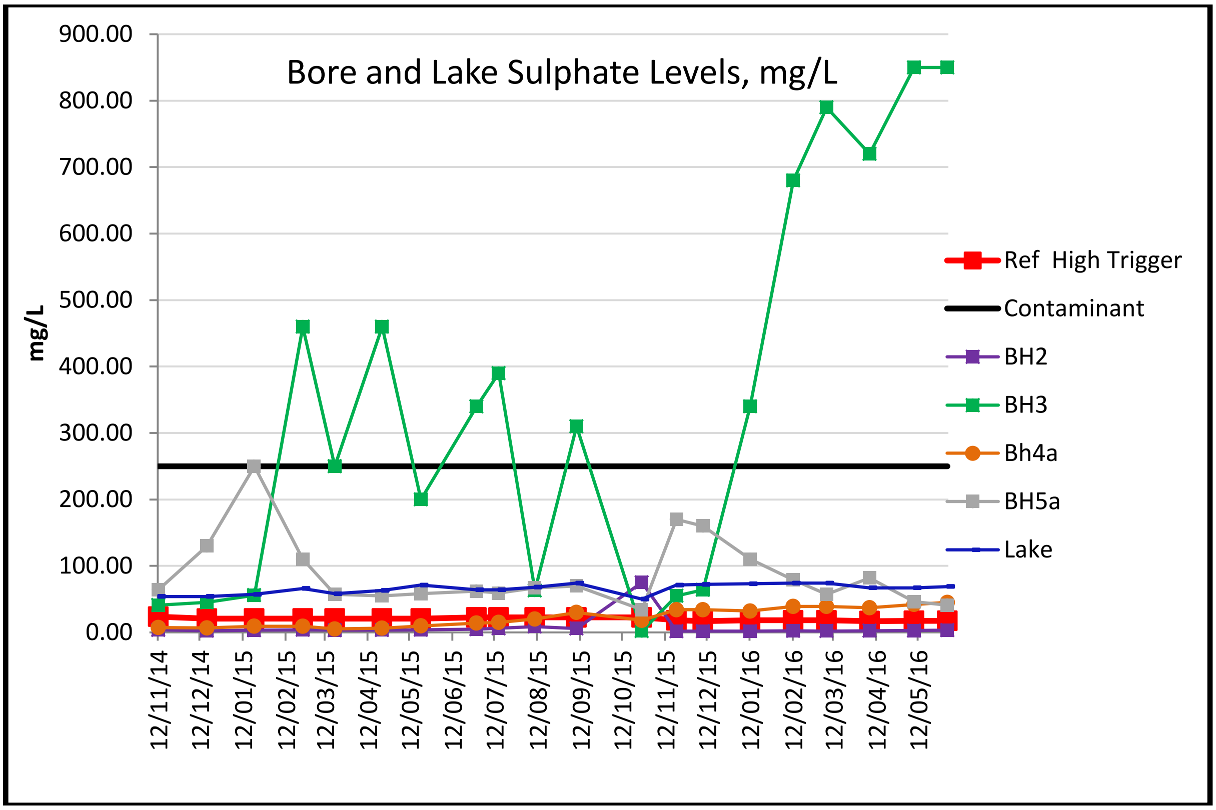

Bore and Lake Electrical Conductivity Levels, uS/cm
uS/cm
20000.00
18000.00
16000.00
14000.00
12000.00
10000.00
8000.00
6000.00
4000.00
2000.00
0.00
20/01/15
20/02/15
20/03/15
20/04/15
20/05/15
20/06/15
20/07/15
20/08/15
20/09/15
20/10/15
20/11/15
20/12/15
20/01/16
20/02/16
20/03/16
20/04/16
20/05/16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

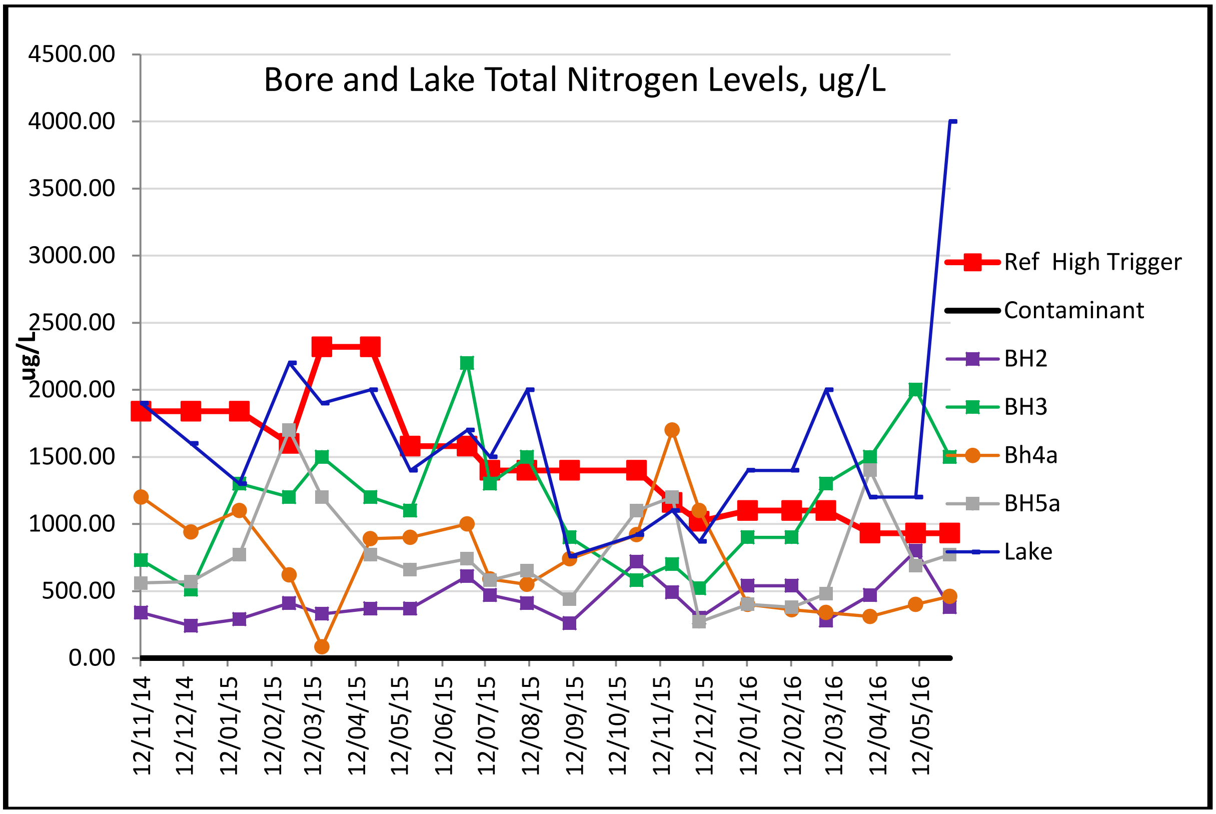

Bore and Lake Iron Levels, ug/L
ug/l
600.00
500.00
400.00
300.00
200.00
100.00
0.00
12/11/14
12/12/14
12/01/15
12/02/15
12/03/15
12/04/15
12/05/15
12/06/15
12/07/15
12/08/15
12/09/15
12/10/15
12/11/15
12/12/15
12/01/16
12/02/16
12/03/16
12/04/16
12/05/16
Ref High Trigger
Contaminant
BH2
BH3
Bh4a

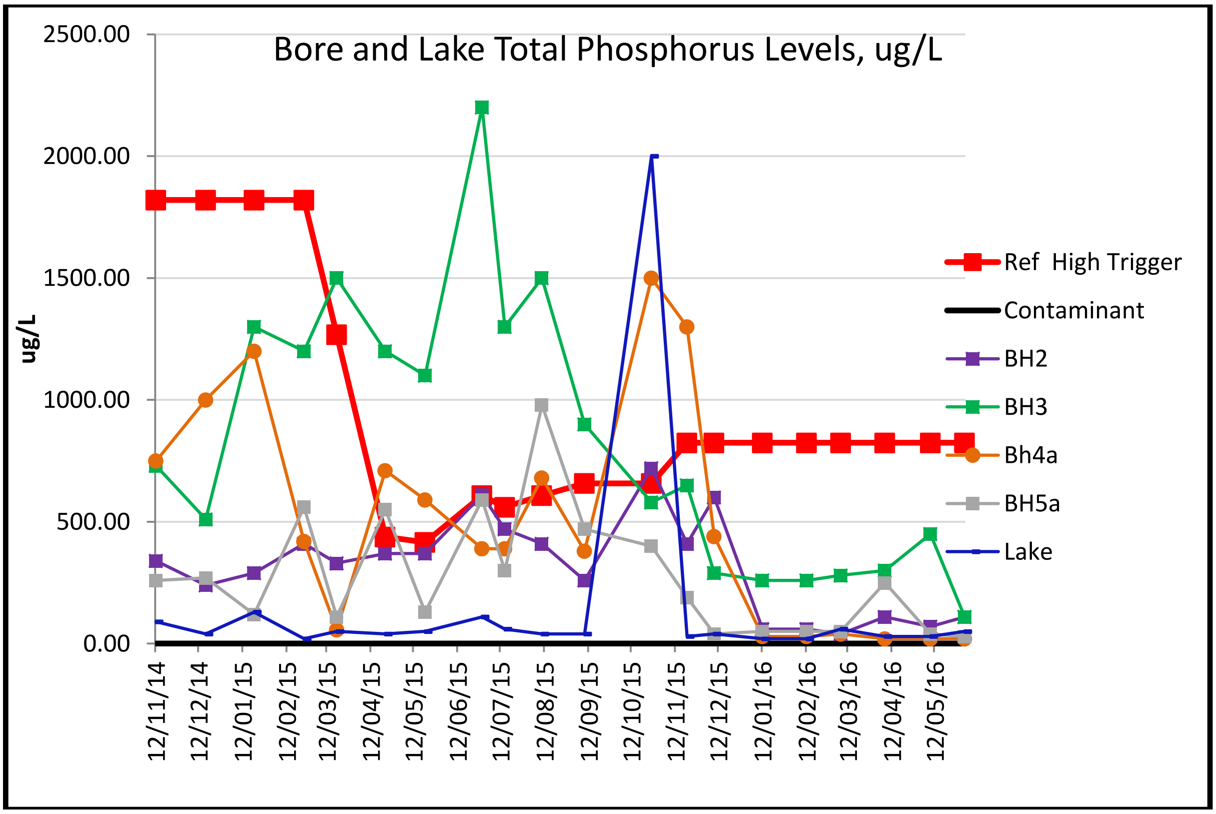

Bore and Lake Lead Levels, ug/L
ug/l
12.00
10.00
8.00
6.00
4.00
2.00
0.00
12/11/14
12/12/14
12/01/15
12/02/15
12/03/15
12/04/15
12/05/15
12/06/15
12/07/15
12/08/15
12/09/15
12/10/15
12/11/15
12/12/15
12/01/16
12/02/16
12/03/16
12/04/16
12/05/16
Ref High Trigger
Contaminant
BH2
BH3
Bh4a
BH5a
Lake

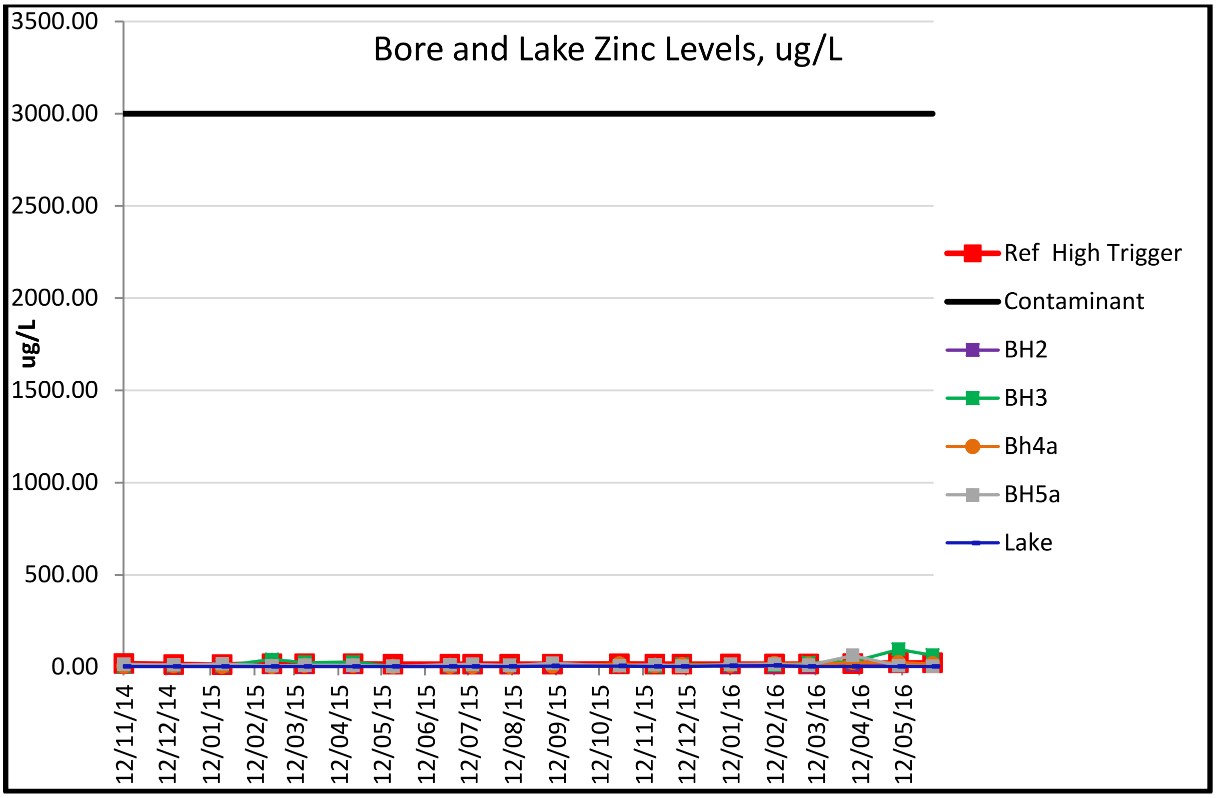

Bore and Lake Mercury Levels, ug/L
ug/l
1.20
1.00
0.80
0.60
0.40
0.20
0.00
12/11/14
12/12/14
12/01/15
12/02/15
12/03/15
12/04/15
12/05/15
12/06/15
12/07/15
12/08/15
12/09/15
12/10/15
12/11/15
12/12/15
12/01/16
12/02/16
12/03/16
12/04/16
12/05/16
Ref High Trigger
Contaminant
BH2
BH3
Bh4a
BH5a
Lake

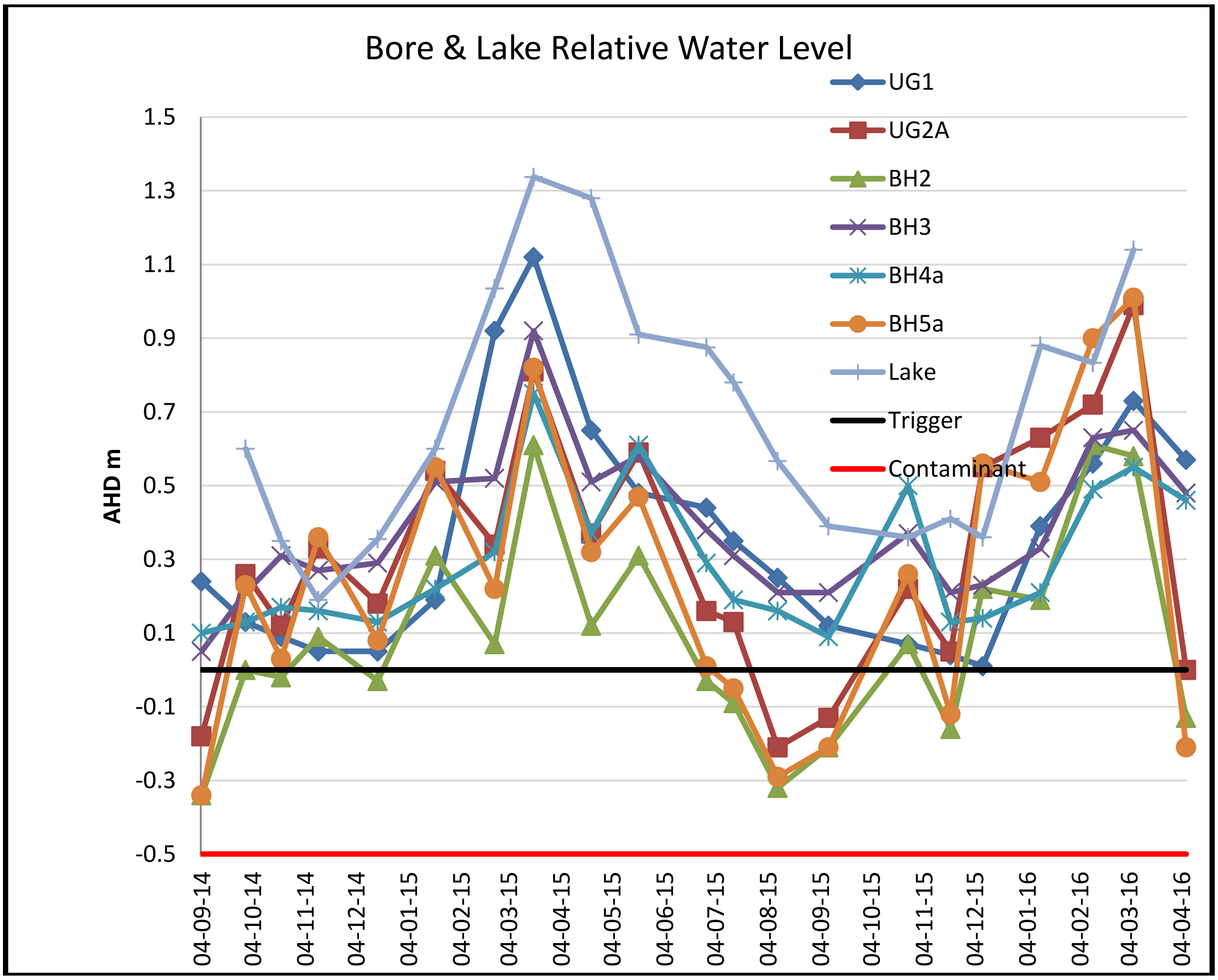

Bore and Lake pH levels
9.00
8.50
8.00
7.50
7.00
6.50
6.00
5.50
5.00
4.50
12/11/14
12/12/14
12/01/15
12/02/15
12/03/15
12/04/15
12/05/15
12/06/15
12/07/15
12/08/15
12/09/15
12/10/15
12/11/15
12/12/15
12/01/16
12/02/16
12/03/16
12/04/16
12/05/16
Ref Low
Ref High Trigger
Contaminant
BH2
BH3
Bh4a
BH5a

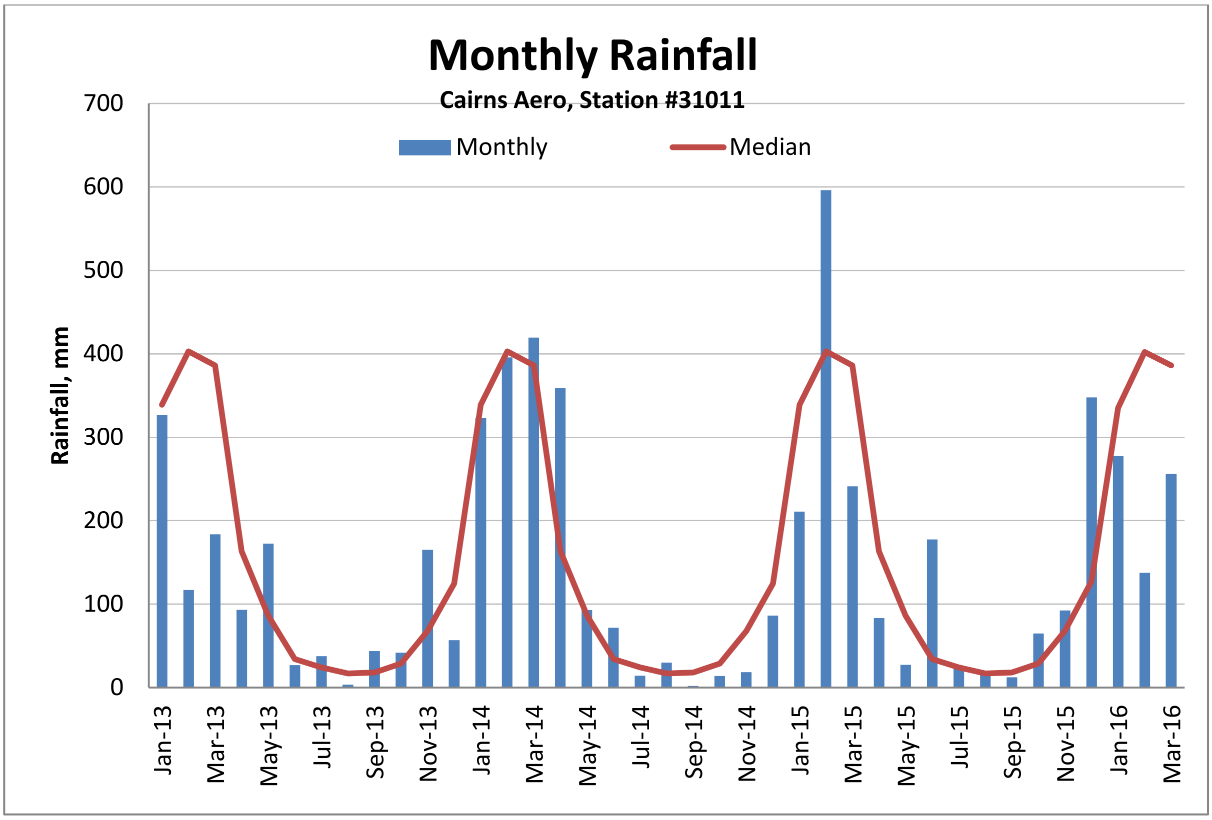

Bore and Lake Sulphate Levels, mg/L
mg/L
900.00
800.00
700.00
600.00
500.00
400.00
300.00
200.00
100.00
0.00
12/11/14
12/12/14
12/01/15
12/02/15
12/03/15
12/04/15
12/05/15
12/06/15
12/07/15
12/08/15
12/09/15
12/10/15
12/11/15
12/12/15
12/01/16
12/02/16
12/03/16
12/04/16
12/05/16
Ref High Trigger
Contaminant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

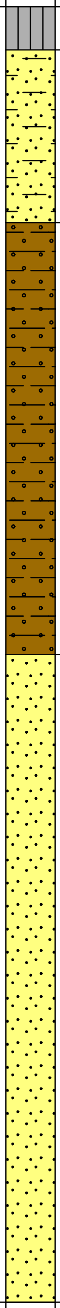
Golder Associates

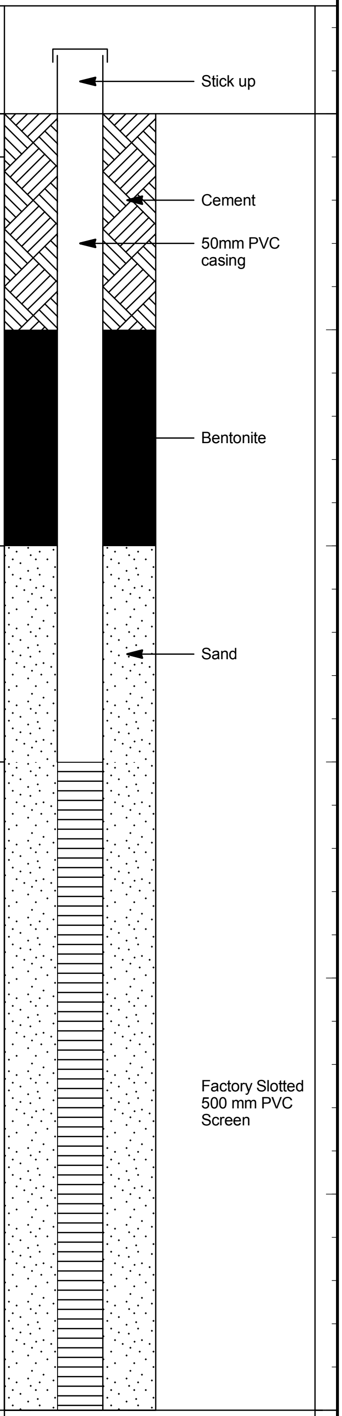
REPORT OF BOREHOLE: BH1

SHEET: 1 OF 1

CLIENT: FCG	COORDS: 363630.0 m E 8136179.0 m N MGA94 56	DRILL RIG: HV1	
PROJECT: Revised EIA	SURFACE RL: DATUM: AHD	CONTRACTOR:	
LOCATION: Northern Sands	INCLINATION: -90°	LOGGED: DSS	DATE: 20/9/16
JOB NO: 1546223	HOLE DEPTH: 6.00 m	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	
				1.00					Clayey SAND grey		S	
			1	3.00					Sandy CLAY grey	D		
			2							W	VS	
			3						SAND coarse grained, grey		S	
			6						END OF BOREHOLE @ 6.00 m GROUNDWATER NOT ENCOUNTERED			





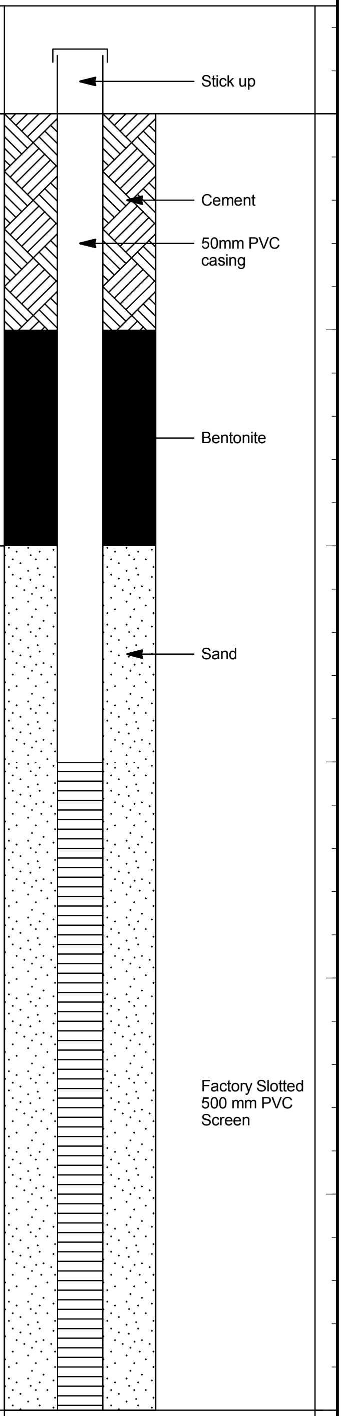
This report of borehole must be read in conjunction with accompanying notes and abbreviations. It has been prepared for environmental purposes only, without attempt to consider geotechnical properties or the geotechnical significance of the materials encountered. As such it should not be relied upon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

Golder Associates

REPORT OF BOREHOLE: BH2

CLIENT: FCG	COORDS: 364376.0 m E 8135443.0 m N MGA94 56	SHEET: 1 OF 1	
PROJECT: Revised EIA	SURFACE RL: DATUM: AHD	DRILL RIG: HV1	
LOCATION: Northern Sands	INCLINATION: -90°	CONTRACTOR:	
JOB NO: 1546223	HOLE DEPTH: 6.00 m	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						TOPSOIL			
			1	0.20					Clayey SAND medium grained, grey	M	VS	
		2m	2	2.00					Clayey SAND fine grained, grey	W M	S	
			3									
			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.

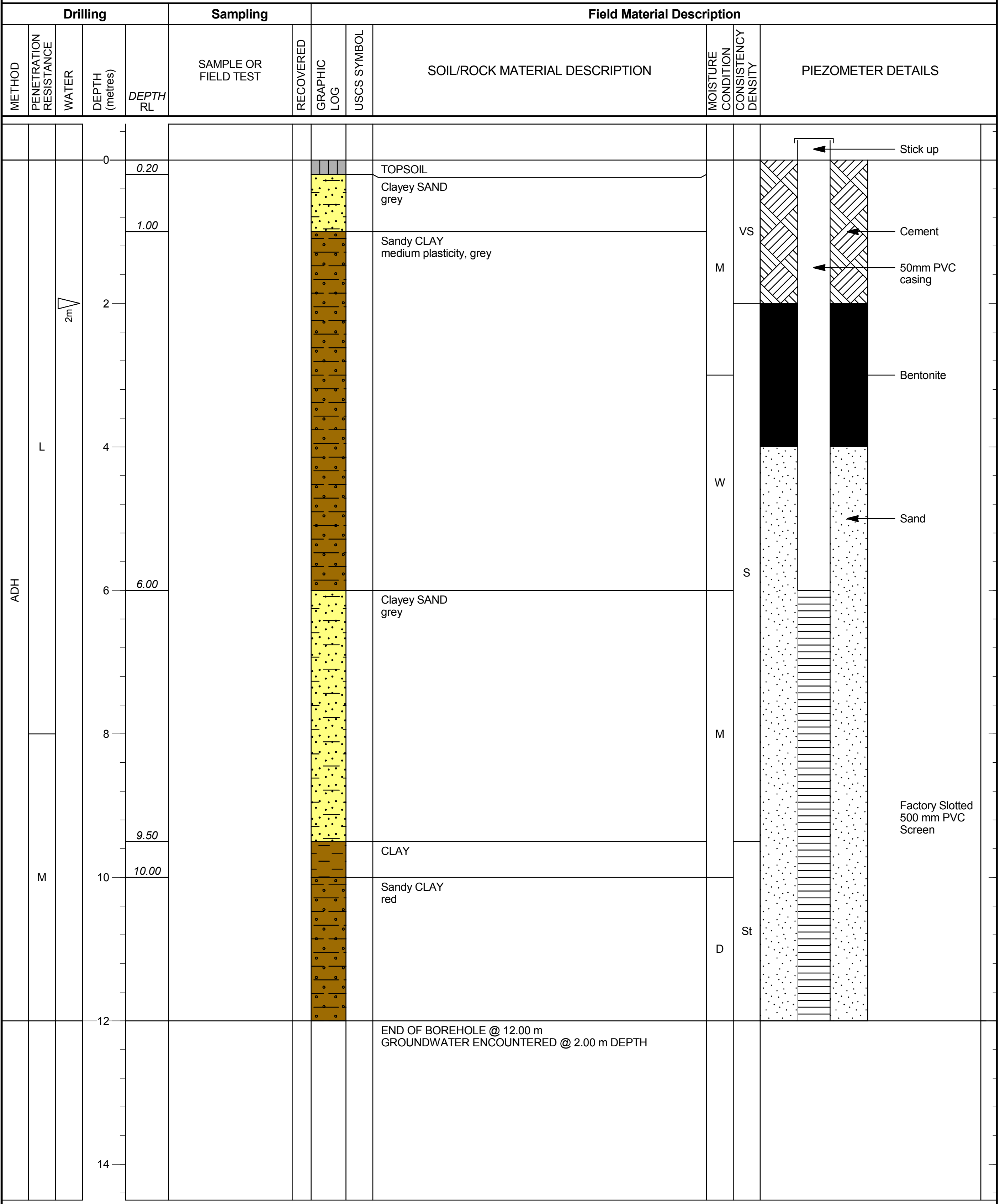
REPORT OF BOREHOLE: BH3

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



DEPTH RL	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY
0.20	TOPSOIL	M	VS
1.00	Clayey SAND grey		
6.00	Sandy CLAY medium plasticity, grey	W	S
9.50	Clayey SAND grey	M	
10.00	CLAY		St
	Sandy CLAY red	D	

END OF BOREHOLE @ 12.00 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.

REPORT OF BOREHOLE: GA04

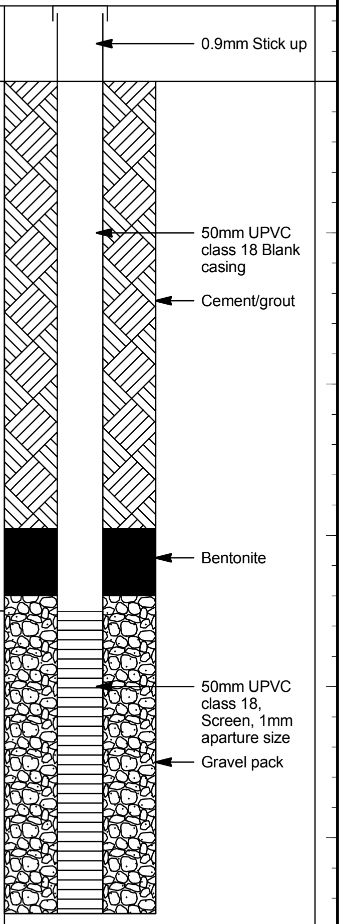
Golder Associates

SHEET: 1 OF 1

CLIENT: Flanagan Consulting Group	COORDS: 364331.6 m E 8135689.9 m N MGA94 56	DRILL RIG: Ezi Probe	
PROJECT: EIS Stage 1- Port Development	SURFACE RL: 3.58 m DATUM: AHD	CONTRACTOR:	
LOCATION: Northern Sands	INCLINATION: -90°	LOGGED: JL	DATE: 23/11/16
JOB NO: 1546223	HOLE DEPTH: 6.00 m	CHECKED: MSC	DATE: 19/12/16

METHOD	PENETRATION RESISTANCE	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	USCS SYMBOL	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY
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	D - M	F
			1	1.00 2.58				Sandy Silty CLAY high plasticity, pale brown, orange, fine to coarse grained sand, trace fine quartz gravel		
			2	2.46 1.12				Silty SAND fine to coarse grained, brown, orange brown, with some fine grained, subangular gravel		
			3	2.70 0.78				Sandy Silty CLAY high plasticity, brown, grey, fine to coarse grained sand		
								Silty SAND fine to coarse grained, grey, brown, orange brown, with some fine quartz gravel		
		▽		3.50 0.08				SAND medium to coarse grained, orange brown, with some fine to medium quartz gravel	W	L
			4							
			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		
			6	-2.42				END OF BOREHOLE @ 6.00 m		
			7							
			8							
			9							

PIEZOMETER DETAILS



This report of borehole must be read in conjunction with accompanying notes and abbreviations. It has been prepared for hydrogeological purposes only, without attempt to assess geotechnical properties or possible contamination. Any reference to geotechnical properties or potential contamination are for information only and do not necessarily indicate the presence or absence of the properties stated.

REPORT OF BOREHOLE: GA05

SHEET: 1 OF 1

CLIENT: Flanagan Consulting Group	COORDS: MGA94 56	DRILL RIG: Eziprobe	
PROJECT: Port Development ETS S1	SURFACE RL: DATUM: AHD	CONTRACTOR: Golder	
LOCATION: Northern Sands	INCLINATION: -90°	LOGGED: JJP	DATE: 28/1/16
JOB NO: 1546223	HOLE DEPTH: 1.50 m	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	
			0.5	0.45	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									

This report of borehole 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.

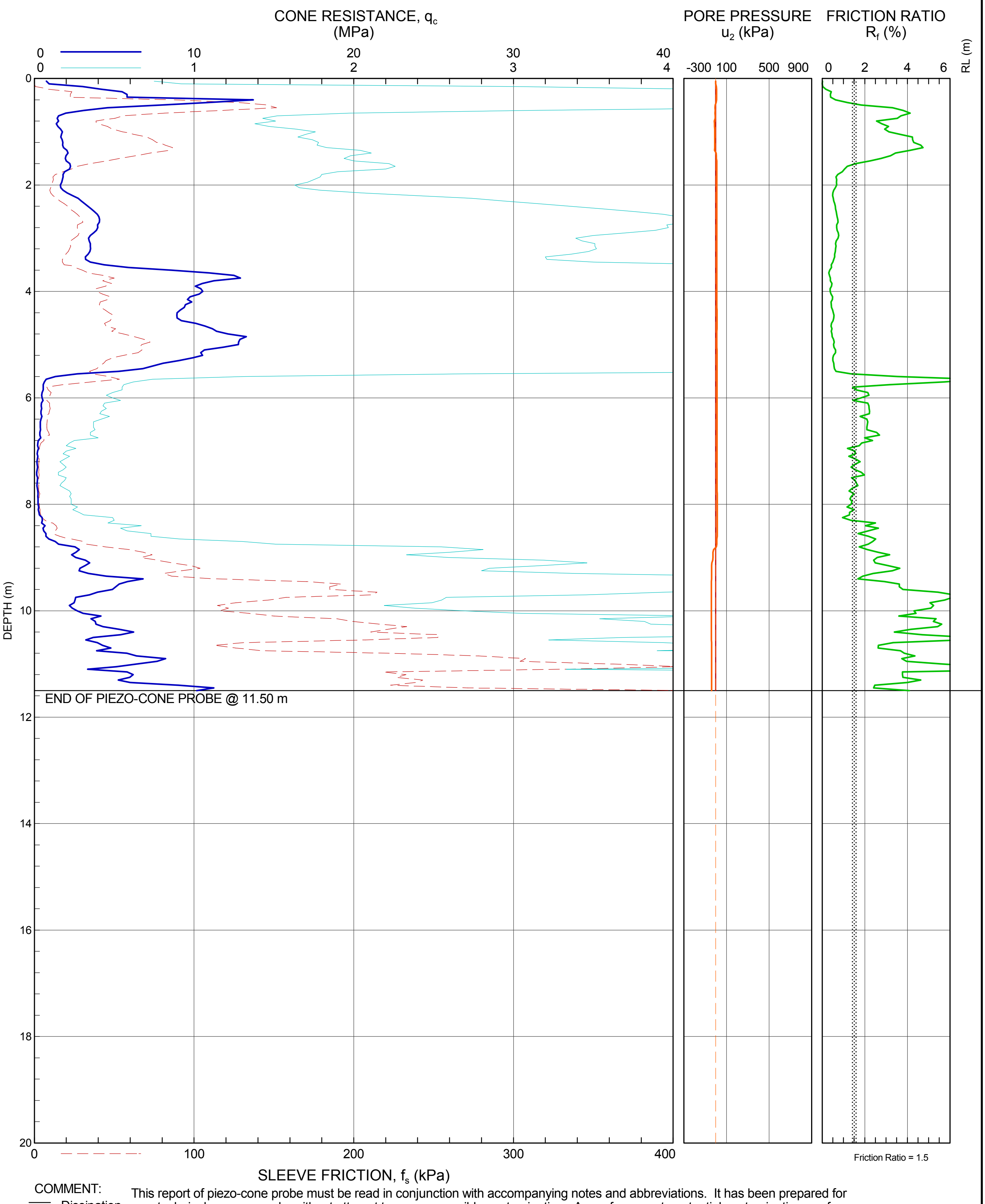
REPORT OF PIEZO-CONE PROBE: CPT1

SHEET: 1 OF 1
CONE No.:

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

RIG:
CONTRACTOR: Geo Investigate
RECORDED: GZL DATE: 31/10/16
CHECKED: MSC DATE: 31/10/16



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.

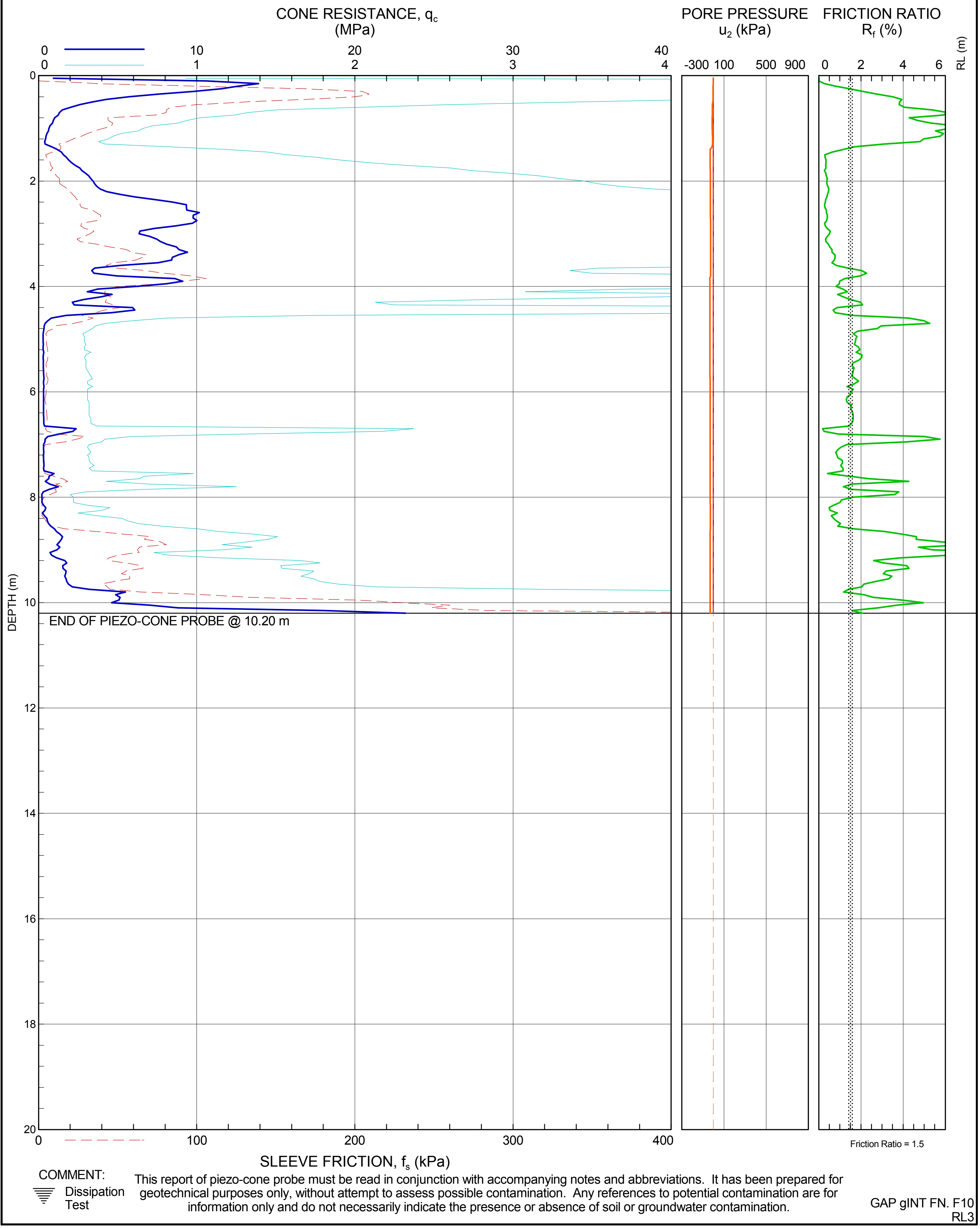
GAP gINT FN. F10
RL3

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: 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

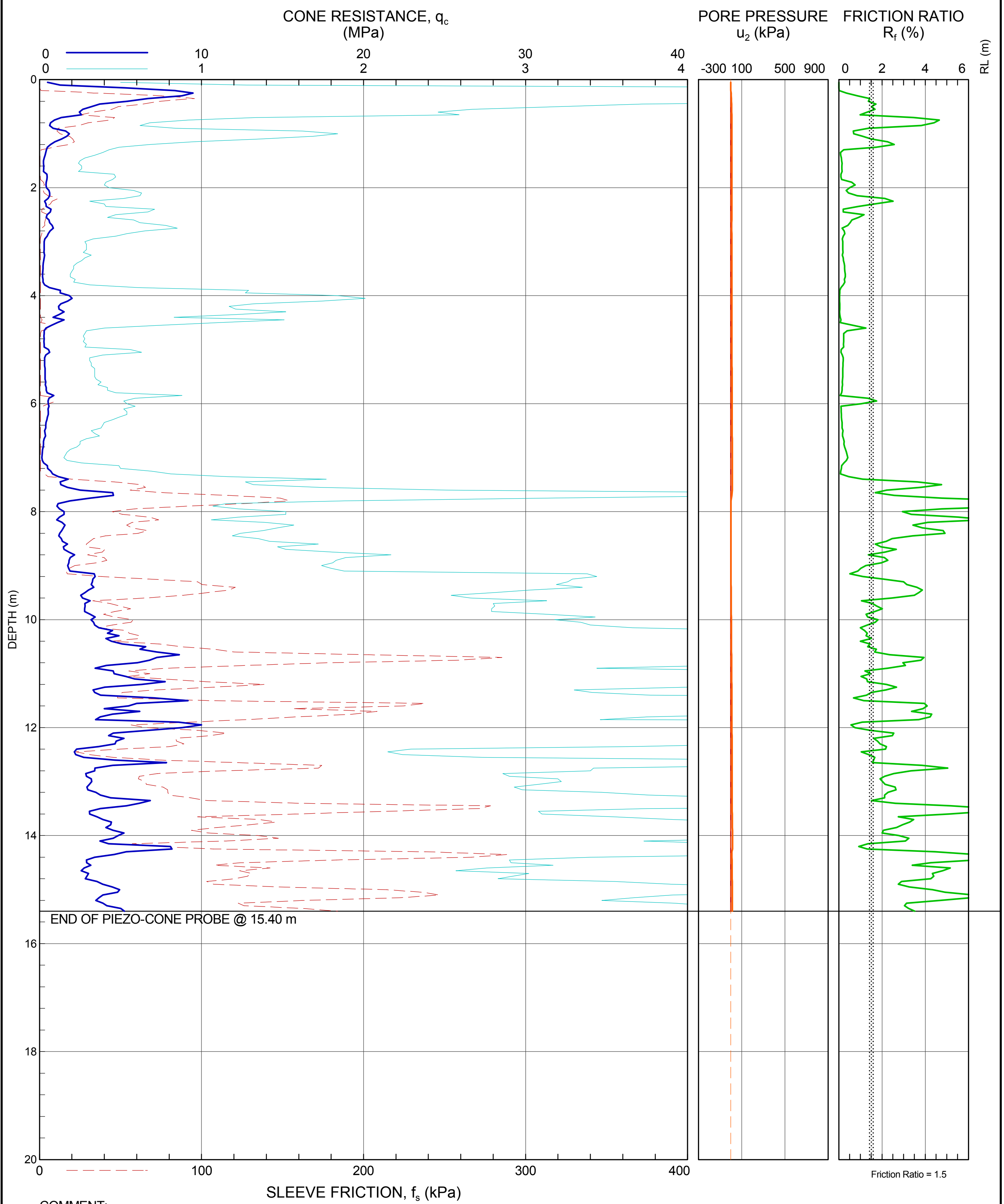
Golder Associates

REPORT OF PIEZO-CONE PROBE: CPT3

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

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



COMMENT:
☰ Dissipation Test

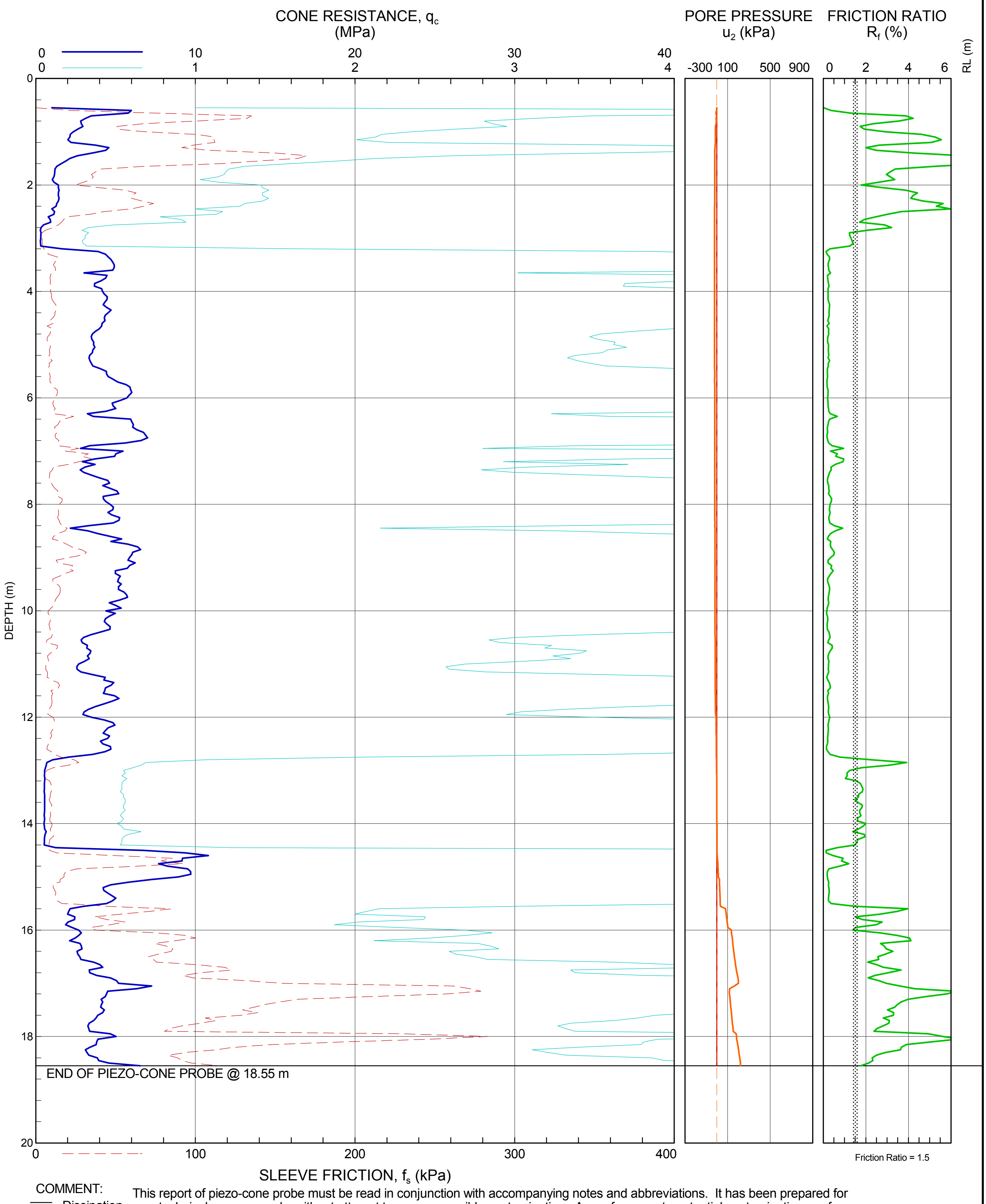
This report of piezo-cone probe must be read in accompanying notes and abbreviations. It has been prepared for geotechnical purposes only, without attempt to assess possible contamination. Any references to potential contamination are for information only and do not necessarily indicate the presence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

GAP gINT FN. F10
RL3

Golder Associates

REPORT OF PIEZO-CONE PROBE: CPT4

CLIENT:	Flanagan Consulting Group	COORDS: MGA94 56		SHEET: 1 OF 1	
PROJECT:	Cairns Shipping Development	SURFACE RL: DATUM: AHD		CONE No.:	
LOCATION:	Northern Sands	INCLINATION: -90°		RIG:	
JOB NO:	1546223	HOLE DEPTH: 18.55 m		CONTRACTOR: Geo Investigate	
				RECORDED: GZL	DATE: 28/10/16
				CHECKED: MSC	DATE: 28/10/16



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

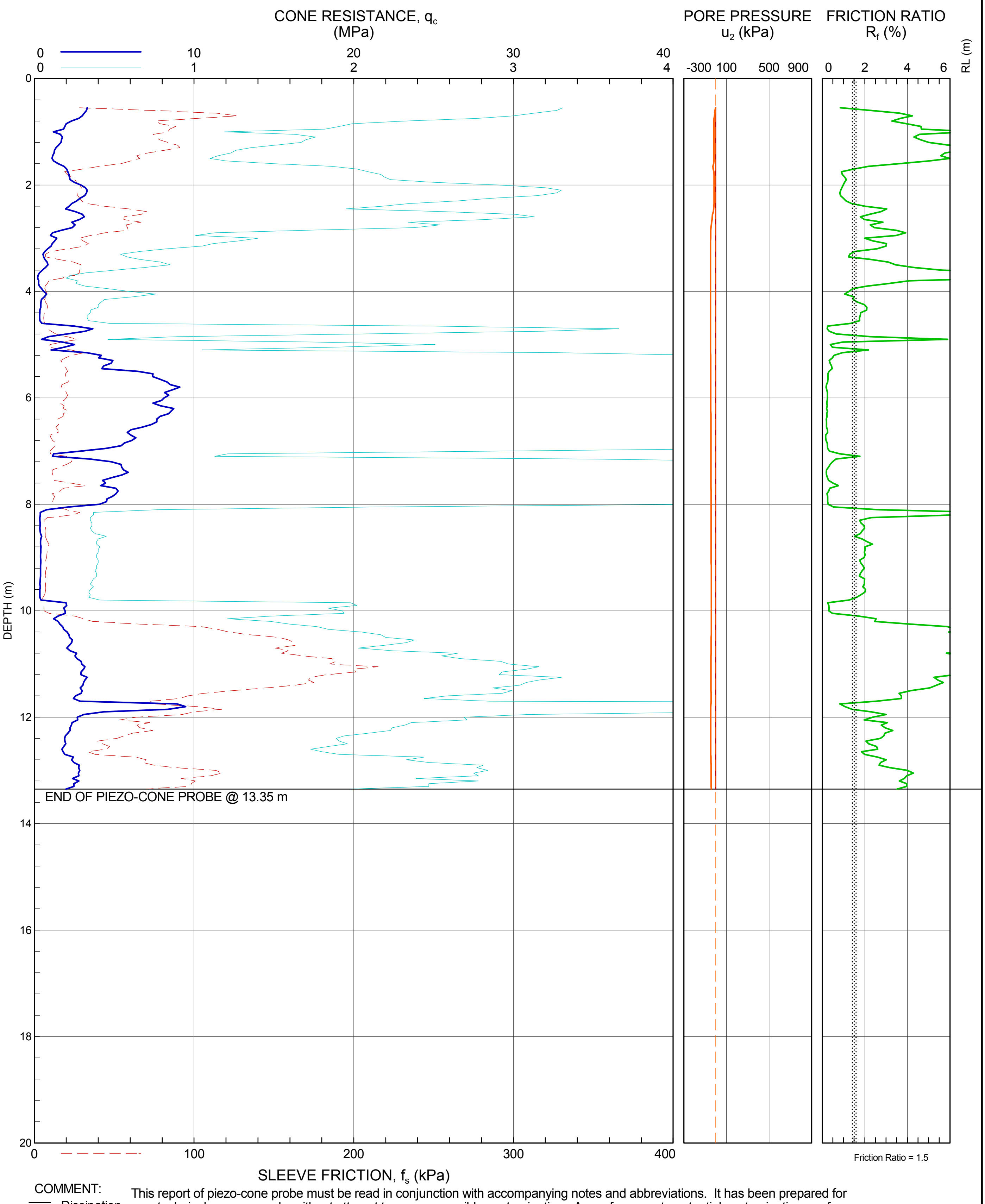
Golder Associates

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: 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.

≡ Dissipation Test

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

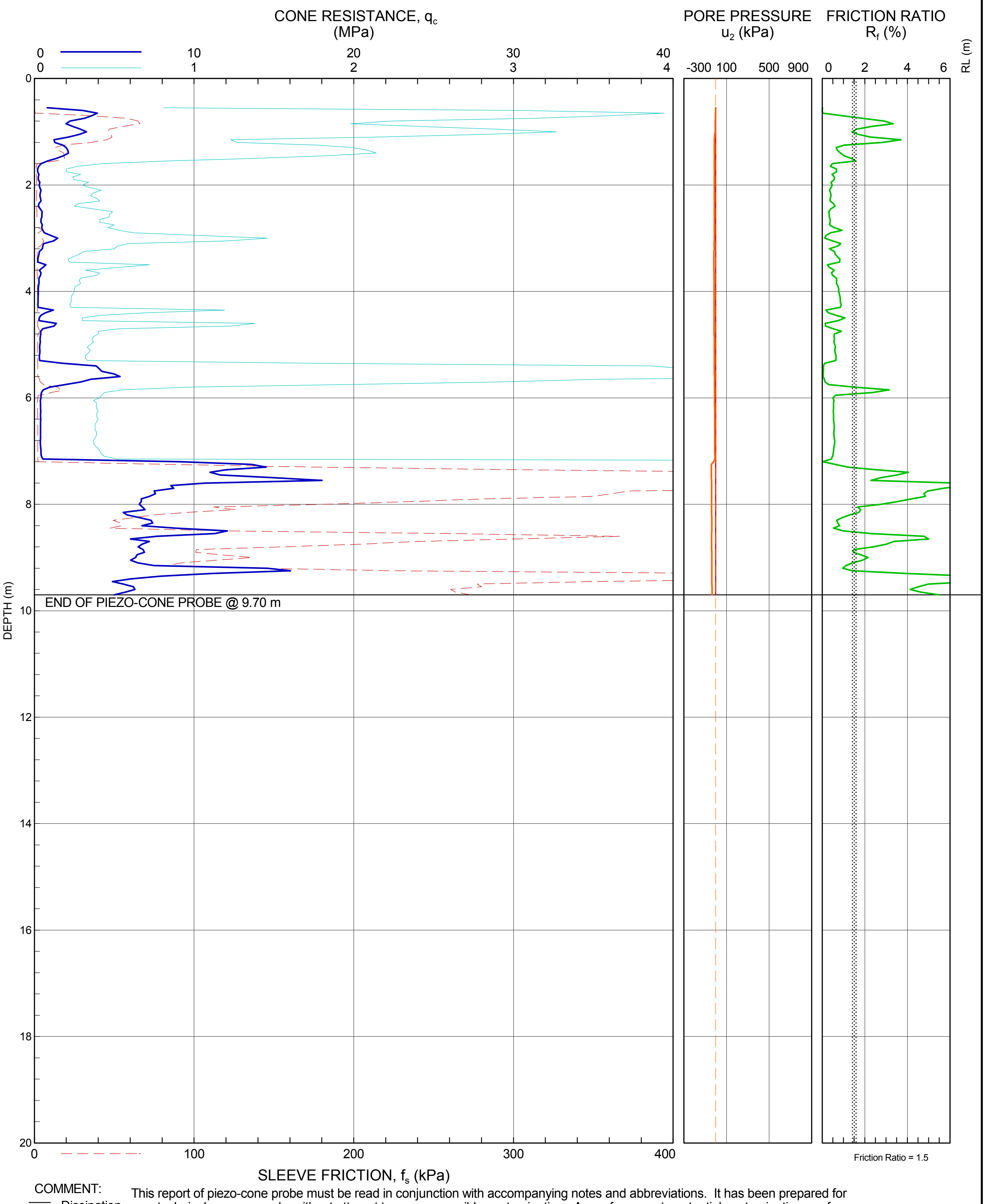
Golder Associates

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

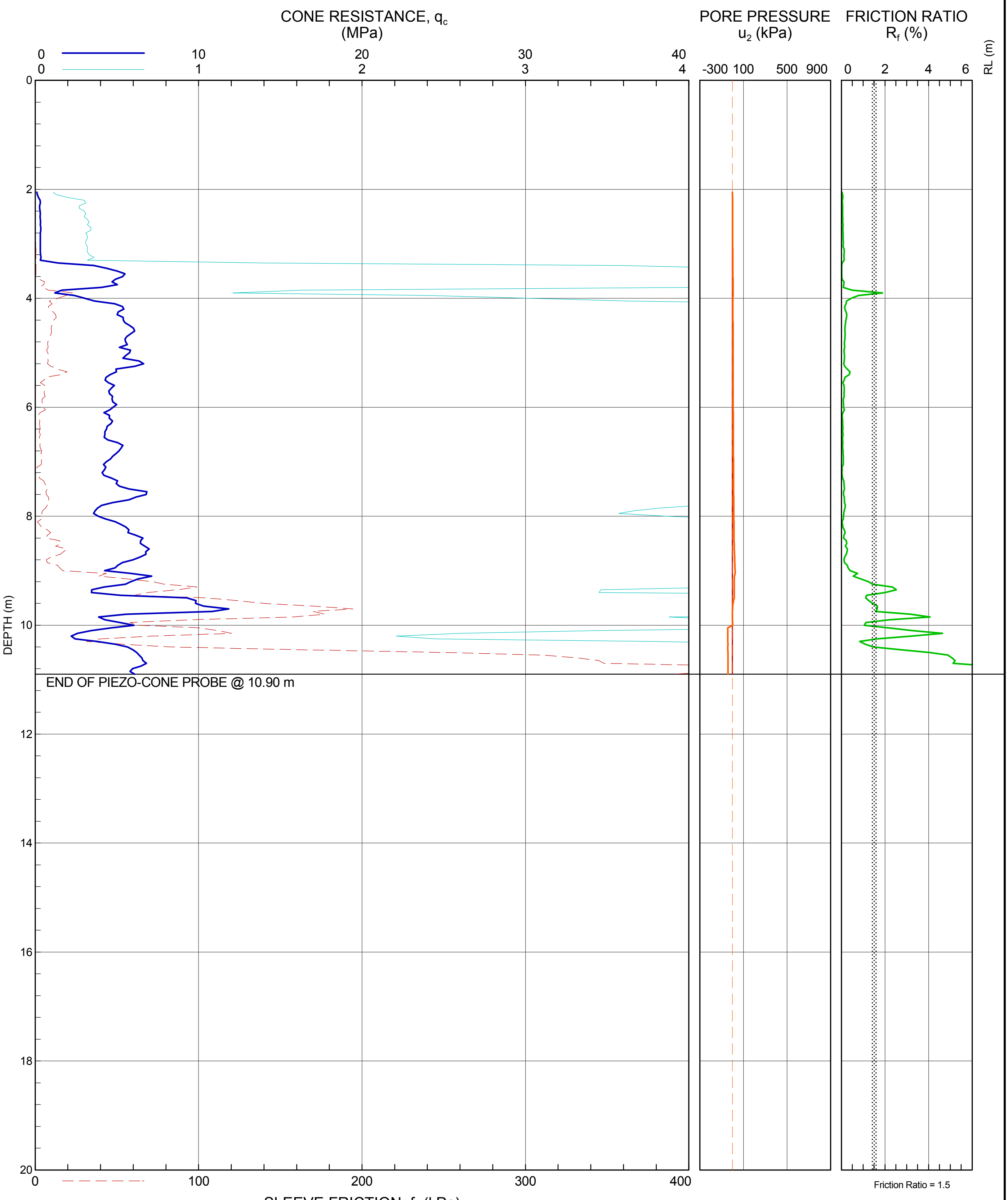
GAP 8_10.0 LIB.GLB Log GAP CPTU PIEZO CONE 2 1546223 CPT DATA ONLY.GPJ <<DrawingFile>> 23/01/2017 14:19 8.30.004 Datgel Tools

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

Golder Associates

METHOD OF SOIL DESCRIPTION USED ON BOREHOLE AND TEST PIT REPORTS

▨	FILL	▤	CLAY (CL, CI or CH)
▨	GRAVEL (GP or GW)	▨	ORGANIC SOILS (OL or OH or Pt)
▨	SAND (SP or SW)	▨	COBBLES or BOULDERS
▨	SILT (ML or MH)		

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

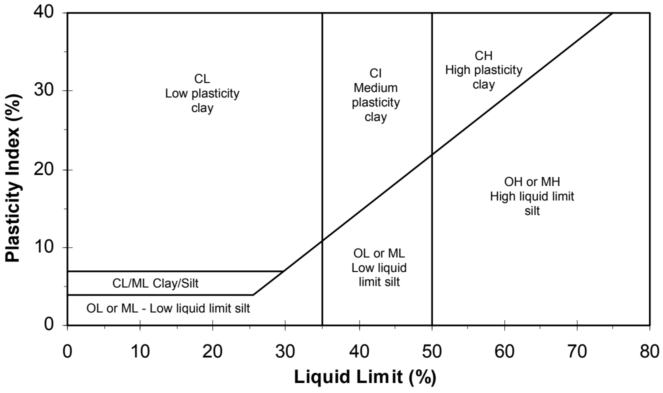
CLASSIFICATION AND INFERRED STRATIGRAPHY

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.

Golder Associates

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

Contact	Darcy Simpson
Client	GOLDER ASSOCIATES PTY LTD
Address	PO BOX 5823 216 DRAPER ST CAIRNS QLD 4870
Telephone	07 4054 8200
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Email	dasimpson@golder.com.au
Project	**1546223 Northern Sands**
Order Number	(Not specified)
Samples	3

LABORATORY DETAILS

Manager	Jon Dicker
Laboratory	SGS Cairns Environmental
Address	Unit 2, 58 Comport St Portsmith QLD 4870
Telephone	+61 07 4035 5111
Facsimile	+61 07 4035 5122
Email	AU.Environmental.Cairns@sgs.com
SGS Reference	**CE123168 R0**
Date Received	29 Sep 2016
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	CE123168.002	CE123168.003
		Sample Matrix	Water	Water	Water
		Sample Date	29 Sep 2016	29 Sep 2016	29 Sep 2016
		Sample Name	BH01	BH02	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

		Sample Number	CE123168.001	CE123168.002	CE123168.003
		Sample Matrix	Water	Water	Water
		Sample Date	29 Sep 2016	29 Sep 2016	29 Sep 2016
		Sample Name	BH01	BH02	BH03
Parameter	**Units**	**LOR**			
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

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.
LNR	Sample listed, but not received.
*	NATA accreditation does not cover the performance of this service.
**	Indicative data, theoretical holding time exceeded.
LOR	Limit of Reporting
↑↓	Raised or Lowered Limit of Reporting
QFH	QC result is above the upper tolerance
QFL	QC result is below the lower tolerance
-	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

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ANALYTICAL REPORT

Accreditation No. 2562

CLIENT DETAILS

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

LABORATORY DETAILS

Manager	Jon Dicker
Laboratory	SGS Cairns Environmental
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Telephone	+61 07 4035 5111
Facsimile	+61 07 4035 5122
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SGS Reference	**CE124163 R0**
Date Received	23 Nov 2016
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

		Sample Number	CE124163.001	CE124163.002	CE124163.003
		Sample Matrix	Water	Water	Water
		Sample Date	22 Nov 2016	22 Nov 2016	22 Nov 2016
		Sample Name	BH01	BH02	BH03
Parameter	Units	LOR			

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
Client	GOLDER ASSOCIATES PTY LTD
Address	PO BOX 5823 216 DRAPER ST CAIRNS QLD 4870
Telephone	07 4054 8200
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Email	dasimpson@golder.com.au
Project	**1546223 Northern Sands**
Order Number	(Not specified)
Samples	3

LABORATORY DETAILS

Manager	Jon Dicker
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Telephone	+61 07 4035 5111
Facsimile	+61 07 4035 5122
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

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

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

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	41.9440002441	41.4734611511	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 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 SPIKES

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

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.

FOOTNOTES

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

Contact	Darcy Simpson
Client	GOLDER ASSOCIATES PTY LTD
Address	PO BOX 5823 216 DRAPER ST CAIRNS QLD 4870
Telephone	07 4054 8200
Facsimile	07 4054 8201
Email	dasimpson@golder.com.au
Project	**1546223 Northern Sands**
Order Number	(Not specified)
Samples	1

LABORATORY DETAILS

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SGS Reference	**CE124214 R0**
Date Received	25 Nov 2016
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

		Sample Number	CE124214.001
		Sample Matrix	Water
		Sample Date	25 Nov 2016
		Sample Name	GA04
Parameter	Units	LOR	

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
**	Indicative data, theoretical holding time exceeded.	QFL	QC result is below the lower tolerance
		-	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

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STATEMENT OF QA/QC PERFORMANCE

CE124214 R0

CLIENT DETAILS

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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

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

SURROGATES

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.

METHOD BLANKS

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 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

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.

FOOTNOTES

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.

FOOTNOTES

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.

SGS

ANALYTICAL REPORT

Accreditation No. 2562

CLIENT DETAILS

Contact	Darcy Simpson
Client	GOLDER ASSOCIATES PTY LTD
Address	PO BOX 5823 216 DRAPER ST CAIRNS QLD 4870
Telephone	07 4054 8200
Facsimile	07 4054 8201
Email	dasimpson@golder.com.au
Project	**1546223 Northern Sands**
Order Number	(Not specified)
Samples	2

LABORATORY DETAILS

Manager	Jon Dicker
Laboratory	SGS Cairns Environmental
Address	Unit 2, 58 Comport St Portsmith QLD 4870
Telephone	+61 07 4035 5111
Facsimile	+61 07 4035 5122
Email	AU.Environmental.Cairns@sgs.com
SGS Reference	**CE126723 R0**
Date Received	06 Apr 2017
Date Reported	18 Apr 2017

COMMENTS

Accredited for compliance with ISO/IEC 17025-Testing. 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

Aj. Bergamo

Alyson Bergamo
Senior Laboratory Technician

Anthony Nilsson
Operations Manager

Jon Dicker
Manager Northern QLD

Maristela Ganzan
Metals Team Leader

		Sample Number	CE126723.001	CE126723.002
		Sample Matrix	Water	Water
		Sample Date	06 Apr 2017	06 Apr 2017
		Sample Name	BH02	BH03
Parameter	Units	LOR		

pH in water Method: AN101/MA1490(Melb) Tested: 6/4/2017

pH**	pH Units	0.1	7.6	8.0

Conductivity and TDS by Calculation - Water Method: AN106/MA1489(Melb) Tested: 6/4/2017

Conductivity @ 25 C	µS/cm	5	2900	8600

Alkalinity Method: AN135/MA1127(Melb) Tested: 6/4/2017

Total Alkalinity as CaCO3	mg/L	5	430	670
Bicarbonate Alkalinity as CaCO3	mg/L	5	430	670
Carbonate Alkalinity as CaCO3	mg/L	5	<5	<5
Hydroxide Alkalinity as CaCO3	mg/L	5	<5	<5

Chloride by Discrete Analyser in Water Method: AN274 Tested: 10/4/2017

Chloride, Cl	mg/L	1	660	2400

Metals in Water (Dissolved) by ICPOES Method: AN320/AN321 Tested: 10/4/2017

Calcium, Ca	mg/L	0.1	20	68
Magnesium, Mg	mg/L	0.1	39	190
Potassium, K	mg/L	0.1	40	99
Sodium, Na	mg/L	0.5	570	1500
Sulphur as Sulphate, SO4	mg/L	0.5	7.3	3.5
Total Hardness by Calculation	mg CaCO3/L	1	210	940

Calculation of Anion-Cation Balance (SAR Calc) Method: AN121 Tested: 18/4/2017

Sum of Cation Milliequivalents*	meq/L	-	30.0	86.0
Sum of Anion Milliequivalents*	meq/L	-	27.3	81.8
Anion-Cation Balance	%	-100	4.6	2.5

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/MA1127(Melb)

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
Total Alkalinity as CaCO3	LB045094	mg/L	5	<5	2%	98 - 112%
Bicarbonate Alkalinity as CaCO3	LB045094	mg/L	5	<5		
Carbonate Alkalinity as CaCO3	LB045094	mg/L	5	<5		
Hydroxide Alkalinity as CaCO3	LB045094	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	LB045153	mg/L	1	<1	0 - 1%	107 - 108%

Conductivity and TDS by Calculation - Water Method: ME-(AU)-[ENV]AN106/MA1489(Melb)

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
Conductivity @ 25 C	LB045094	µS/cm	5	<5	0 - 1%	98 - 99%

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	LB045144	mg/L	0.1	<0.1	0%	102%	103%
Magnesium, Mg	LB045144	mg/L	0.1	<0.1	0%	103%	97%
Potassium, K	LB045144	mg/L	0.1	<0.1	0%	97%	117%
Sodium, Na	LB045144	mg/L	0.5	<0.5	0%	97%	
Sulphur as Sulphate, SO4	LB045144	mg/L	0.5	<0.5	0%	NA	
Total Hardness by Calculation	LB045144	mg CaCO3/L	1	<1			

pH in water Method: ME-(AU)-[ENV]AN101/MA1490(Melb)

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
pH**	LB045094	pH Units	0.1	5.5 - 5.7	0 - 3%	NA

METHOD SUMMARY

METHOD	METHODOLOGY SUMMARY
AN101/MA1490(Melb)	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/MA1489(Melb)	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/MA1127(Melb)	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
**	Indicative data, theoretical holding time exceeded.	QFL	QC result is below the lower tolerance
		-	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	**CE126058 R0**
Order Number	(Not specified)	Date Received	03 Mar 2017
Samples	2	Date Reported	15 Mar 2017

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

Bergamo

Alyson Bergamo
Senior Laboratory Technician

Anthony Nilsson
Operations Manager

Jon Dicker
Manager Northern QLD

Maristela Ganzan
Metals Team Leader

		Sample Number	CE126058.001	CE126058.002
		Sample Matrix	Water	Water
		Sample Date	03 Mar 2017	03 Mar 2017
		Sample Name	BH01	BH04
Parameter	Units	LOR		

pH in water Method: AN101 Tested: 3/3/2017

pH**	pH Units	0.1	**6.9**	**6.2**

Conductivity and TDS by Calculation - Water Method: AN106 Tested: 3/3/2017

Conductivity @ 25 C	µS/cm	5	**250**	**140**

Alkalinity Method: AN135 Tested: 3/3/2017

Total Alkalinity as CaCO3	mg/L	5	**41**	**15**
Bicarbonate Alkalinity as CaCO3	mg/L	5	**41**	**15**
Carbonate Alkalinity as CaCO3	mg/L	5	<5	<5
Hydroxide Alkalinity as CaCO3	mg/L	5	<5	<5

Chloride by Discrete Analyser in Water Method: AN274 Tested: 6/3/2017

Chloride, Cl	mg/L	1	**39**	**17**

Metals in Water (Dissolved) by ICPOES Method: AN320/AN321 Tested: 9/3/2017

Calcium, Ca	mg/L	0.1	**5.7**	**4.1**
Magnesium, Mg	mg/L	0.1	**8.2**	**2.8**
Potassium, K	mg/L	0.1	**1.8**	**0.5**
Sodium, Na	mg/L	0.5	**28**	**19**
Sulphur as Sulphate, SO4	mg/L	0.5	**22**	**24**
Total Hardness by Calculation	mg CaCO3/L	1	**48**	**22**

Calculation of Anion-Cation Balance (SAR Calc) Method: AN121 Tested: 15/3/2017

Sum of Cation Milliequivalents*	meq/L	-	**2.23**	**1.26**
Sum of Anion Milliequivalents*	meq/L	-	**2.36**	**1.28**
Anion-Cation Balance	%	-100	**-2.9**	**-0.8**

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.

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

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
Total Alkalinity as CaCO3	LB044113	mg/L	5	<5	0%	112%
Bicarbonate Alkalinity as CaCO3	LB044113	mg/L	5	<5		
Carbonate Alkalinity as CaCO3	LB044113	mg/L	5	<5		
Hydroxide Alkalinity as CaCO3	LB044113	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	LB044132	mg/L	1	<1	0 - 1%	109%

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

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
Conductivity @ 25 C	LB044113	µS/cm	5	<5	1%	101%

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	LB044236	mg/L	0.1	<0.1	1%	110%	99%
Magnesium, Mg	LB044236	mg/L	0.1	<0.1	1 - 2%	107%	104%
Potassium, K	LB044236	mg/L	0.1	<0.1	1 - 3%	105%	111%
Sodium, Na	LB044236	mg/L	0.5	<0.5	0 - 1%	97%	96%
Sulphur as Sulphate, SO4	LB044236	mg/L	0.5	<0.5	1%	NA	
Total Hardness by Calculation	LB044236	mg CaCO3/L	1	<1			

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

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
pH**	LB044113	pH Units	0.1	5.8	1%	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.
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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
**	Indicative data, theoretical holding time exceeded.	QFL	QC result is below the lower tolerance
		-	The sample was not analysed for this analyte
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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.

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Note that in terms of units of radioactivity:
a. 1 Bq is equivalent to 27 pCi
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This document is issued, on the Client's behalf, by the Company under its General Conditions of Service available on request and accessible at http://www.sgs.com/en/terms-and-conditions. The Client's attention is drawn to the limitation of liability, indemnification and jurisdiction issues defined therein.

Any other holder of this document is advised that information contained hereon reflects the Company's findings at the time of its intervention only and within the limits of Client's instructions, if any. The Company's sole responsibility is to its Client and this document does not exonerate parties to a transaction from exercising all their rights and obligations under the transaction documents.

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GROUNDWATER SAMPLING RECORD FORM
FOR THREE WELL VOLUME METHOD

Golder Associates

PROJECT INFORMATION

Project Number: 1546223
Client:
Site Location: Northern sand project
Date: 22/09/16
Sampled By: JC

GROUNDWATER WELL DATA

13:23 3.087 → 3x2=6L
6x3 = 20litres

BORE ID	~~Rad~~ 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)	

Note:

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	4	347	26.04	7.18	220	2	light grey / low to medium
1.32.5	~15	329	26.02	8.71	276	3.2	//
1.33.5	~20	315	26.01	9.93	293	3.8	//
1.35	~25	307	25.93	7.21	292	0.5	//
1.36	~30	298	25.91	7.24	293	-0.1	// ✗
1.37	~40	297	26.02	106.5	316	0.6	
5.40		373	12.85	7.18	263	-1	
Total vol. purged (L)			No. bore vol. purged			Purging Time (minutes)	

at Cairns LAB

✗ Something going wrong with wq meter

Depth to water at end of purging (mbRP) ___

Purging Method: watera 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
Duplicate sample taken? / Dup ID.:

Sample Container and Preservation:

1 green bottle.

OBSERVATIONS

Weather Conditions: Temperature: 35
Precipitation : NO

Wl: 1593.08 before data logger
2003.084 after

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

GROUNDWATER SAMPLING RECORD FORM
FOR THREE WELL VOLUME METHOD

Golder Associates

PROJECT INFORMATION

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

Date: 22/12/16
Sampled By: JC

GROUNDWATER WELL DATA

Information from file

7L : 21L

BORE ID BH02

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

Note:

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	2:20
Depth to water (~~mbRP~~) m BToC	2.523
Total depth of well (mbRP) m BToc	6m
Thickness of sediment on base of well (m)	
Height of water in standpipe (m)	
Well volume (L)	

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	5	8000	26.44	9.02	77	0.8	Brown high turbidity
2:26	10	8000	26.39	9.86	39	0.8	//
2:27	20	7880	26.34	8.09	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 on it
2:36	37	8000	26.94	6.80	89	-0.1	
Total vol. purged (L)			No. bore vol. purged			Purging Time (minutes)	

2:39 6.76

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 ID. BH02
Samples filtered for metals?: Yes / [✓ No]
Turbidity Low / Medium / [✓ High]
Hydrocarbon sheen? NO
Duplicate sample taken? / Dup ID.: NO

Sample Container and Preservation:
1 green bottle

OBSERVATIONS

Weather Conditions: Temperature: 35
Precipitation : NO

2:53: WL: 2
2:55 WL

Notes: 2.19 pull up Data logger

GROUNDWATER SAMPLING RECORD FORM FOR THREE WELL VOLUME METHOD

Golder Associates

PROJECT INFORMATION

Project Number: 1546223

Client:

Site Location: Nathan 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)	

Note:

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

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 ? 12m
Thickness of sediment on base of well (m)	
Height of water in standpipe (m)	
Well volume (L)	

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

3 ~ 60 liters to remove
well volume

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	25.92	8.86	165	0.5	Brown/Medium turbidity
3.15	20	25.5	25.86	8.52	165	〃	〃
3.17	30	25.55	25.83	8.47	144	0.7	〃
3.20	40	25.42	25.82	8.10	148	0.8	〃
3.21	47	25.40	26.03	6.98	157	0.9	〃
3.23	48	25.29	26.07	6.91	152	0.7	〃
3.25	58	25.15	26.09	7.24	140	0.3	
Total vol. purged (L)			No. bore vol. purged			Purging Time (minutes)	

3.26 60 〃 7.23 〃 〃

Depth to water at end of purging (mbRP)

Purging Method: watena pump

SAMPLING RECORD

Sampling method: watena pump

Time sampled: 3.30

Sample Appearance:

Colour: orange brown

Odour: no

Sample Container and Preservation: 1 green bottle

Sample ID. BH03

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: pull out at 3.10 wl: 2.68 3.1
wl: 2.48 per bucket

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 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:
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: CLEARING RED
Odour: –
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

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: DCS

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	B408

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 (~~uS,~~ mS)	Redox Potential	Turbidity (NTU)	Other
15	0.0	23.03	5.95	8.89	10.54	19	77.0	HEAVY S.L.T 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: IP
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

15

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: DJS

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

285
850

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	600	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)	

4

(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.)

20L

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: IP
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
Odour: NIL
Turbidity Low / Medium / [✓ High]
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 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

45

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: DJS

GROUNDWATER WELL DATA

BORE ID ~~[illegible]~~ GA04

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 ~~0.9~~
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

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)	4.171
Thickness of product (m)	

Water column above filter pack, well volume wihtin 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/HI/600 NTU
0733	14	140	22.76	5.70	~~55~~ 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
Time sampled: 0740
Sample ID. GA04
Samples filtered for metals?: Yes / [✓ No]
Sample Appearance:
Colour BROWN
Turbidity Low / Medium / [✓ High]
Odour ~
Hydrocarbon sheen? ~
Sample Container and Preservation: NIL
Duplicate sample taken? / Dup ID.: ~

OBSERVATIONS

Weather Conditions: Temperature: HOT
Precipitation : ~

Notes:

GAP Form No. 37
RL 0

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

Laborator **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

pproved Signatory: Peter Gode
Form ID: W19Rep Rev 1

Cardno Construction Sciences
ABN: 74 128 806 735

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Earlville QLD 4870

Laborator **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

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

NATA

Accreditation Number: 1986
Corporate Site Number: 11512

pproved Signatory: Peter Gode
Form ID: W19Rep Rev 1

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ABN: 74 128 806 735

Address:
Shed 3, 5 Commercial Place
Earlville QLD 4870

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

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 GA04 Brown Sand	QAA Sample GA05 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

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

pproved Signatory: Peter Gode
Form ID: W20Rep Rev 1

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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

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

NATA

Accreditation Number: 1986
Corporate Site Number: 11512

pproved Signatory: Peter Gode
Form ID: W11bRep Rev 1

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

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

pproved Signatory: Peter Gode
Form ID: W11bRep Rev 1

Cardno Construction Sciences
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Laboratory: **Cairns Laboratory**
Phone: 0740337815 **Fax:** 0740546632

Email: cnz.lab@cardno.com.au

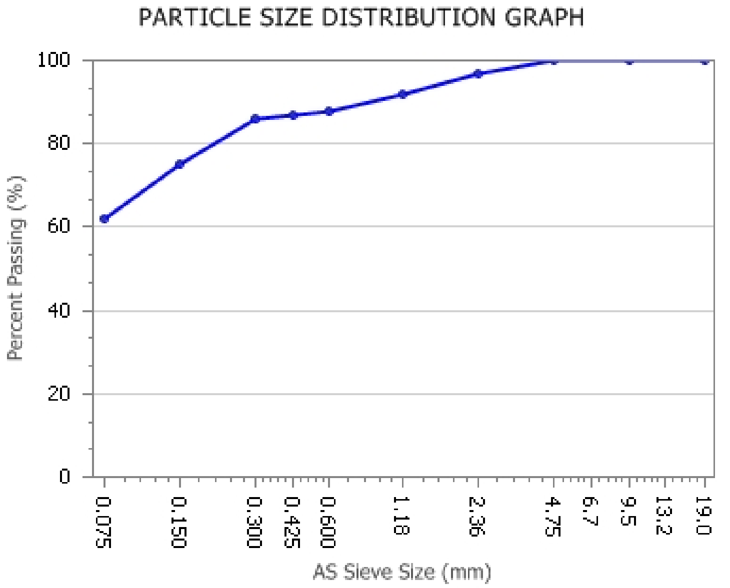
QUALITY OF MATERIALS REPORT

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**	



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

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

Accreditation Number: 1986
Corporate Site Number: 11512

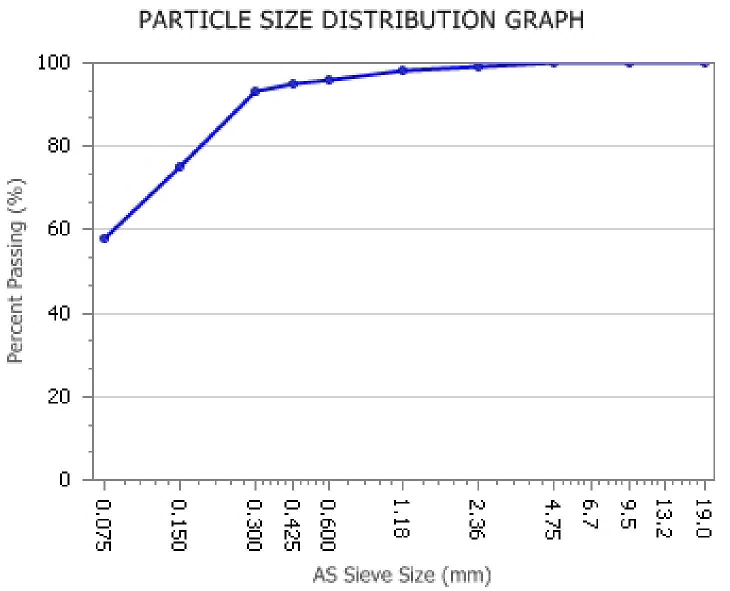
Approved Signatory: Kyle Jeffries
Form ID: W85MCRep Rev 1

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 Depth: 1.2-1.5m
Sampling Method	Tested As Received		
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**	



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

NATA

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Accreditation Number:	1986
Corporate Site Number:	11512

Approved Signatory: Kyle Jeffries
Form ID: W85MCRep Rev 1

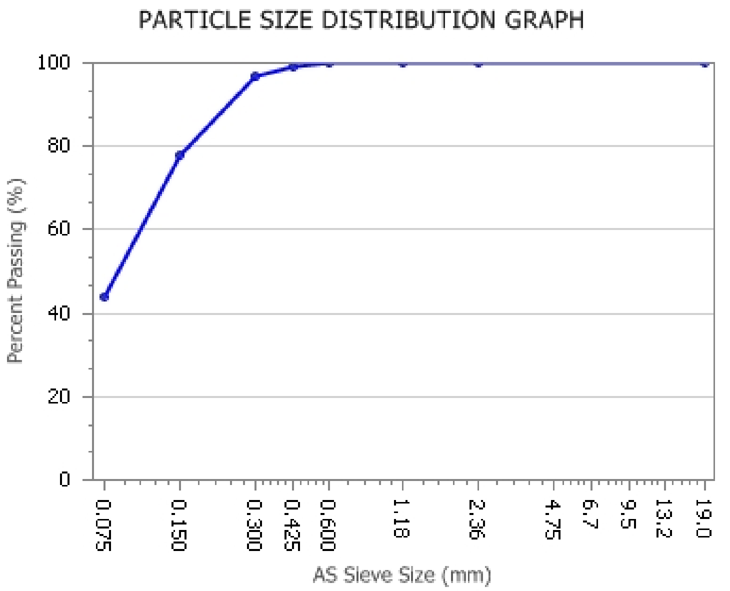
QUALITY OF MATERIALS REPORT

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**	



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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Accreditation Number: 1986
Corporate Site Number: 11512

Approved Signatory: Kyle Jeffries
Form ID: W85MCRep 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

QUALITY OF MATERIALS REPORT

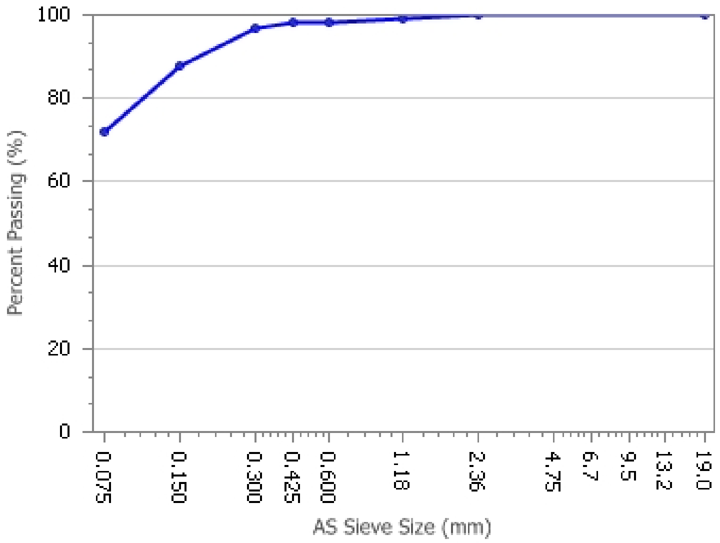
Client:	Golder Associates Pty Ltd	Report Number:	11512/R/11246-1
Client Address:	216, Draper Street, Cairns	Project Number:	11512/P/677
Project:	Project No.: 1546223 Contact: Joseph Parisi	Lot Number:	
Location:	Cairns	Internal Test Request:	11512/T/6529
Component:	Soil Testing	Client Reference/s:	PO: 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 Depth: 1.2-1.5m	
Sampling Method	Tested As Received		
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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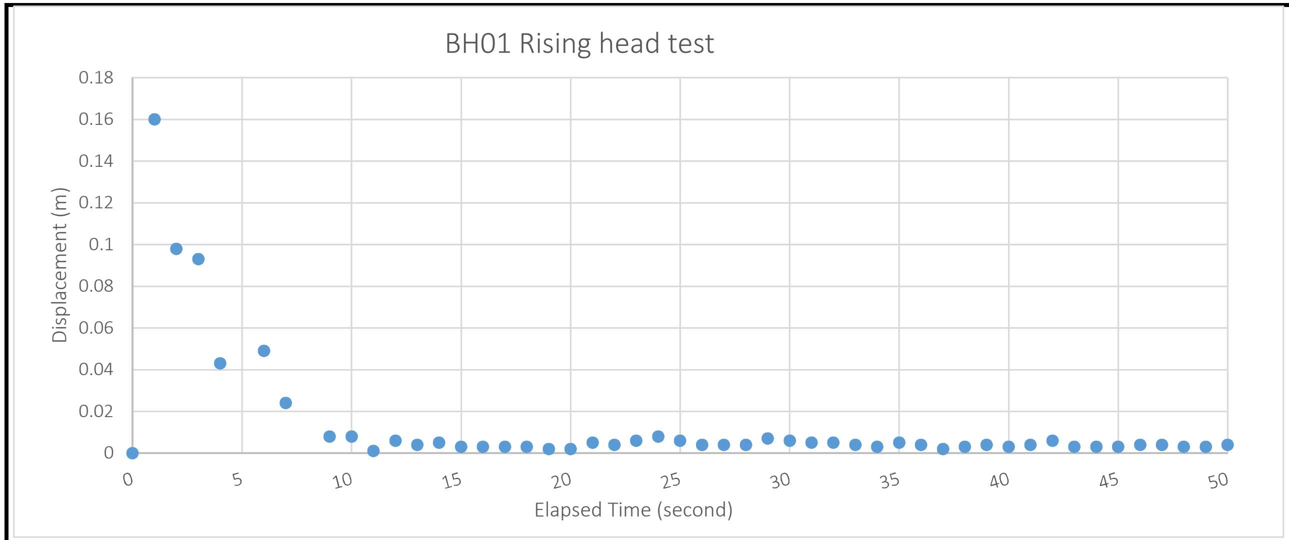
Accreditation Number: 1986
Corporate Site Number: 11512

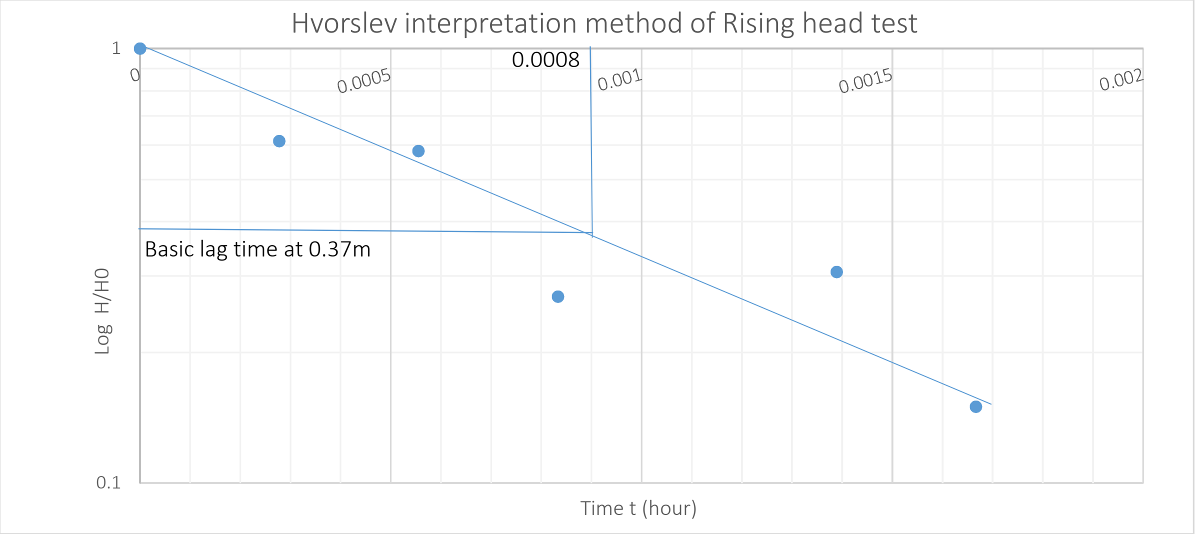
Approved Signatory: Kyle Jeffries
Form ID: W85MCRep Rev 1

Appendix G

Permeability Test Results



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**

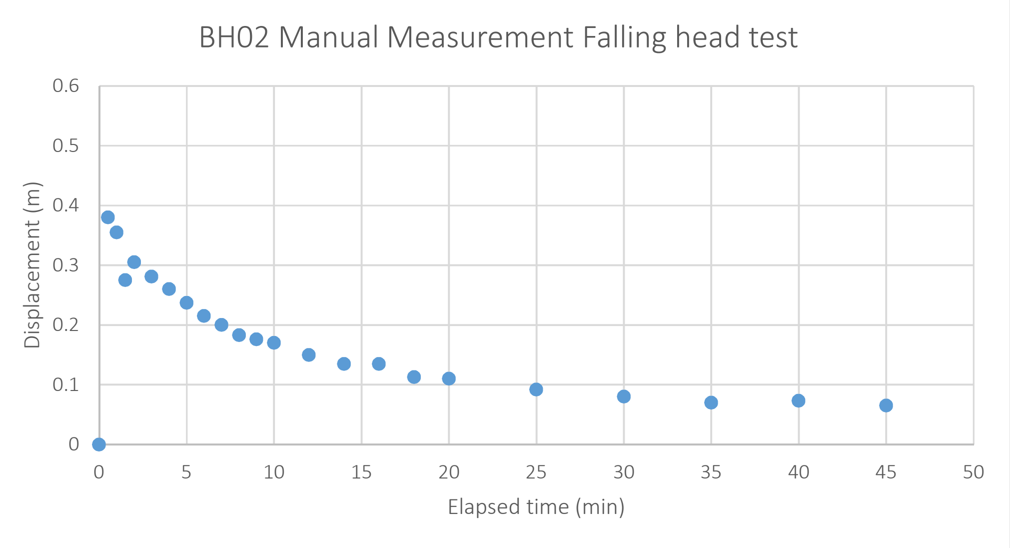


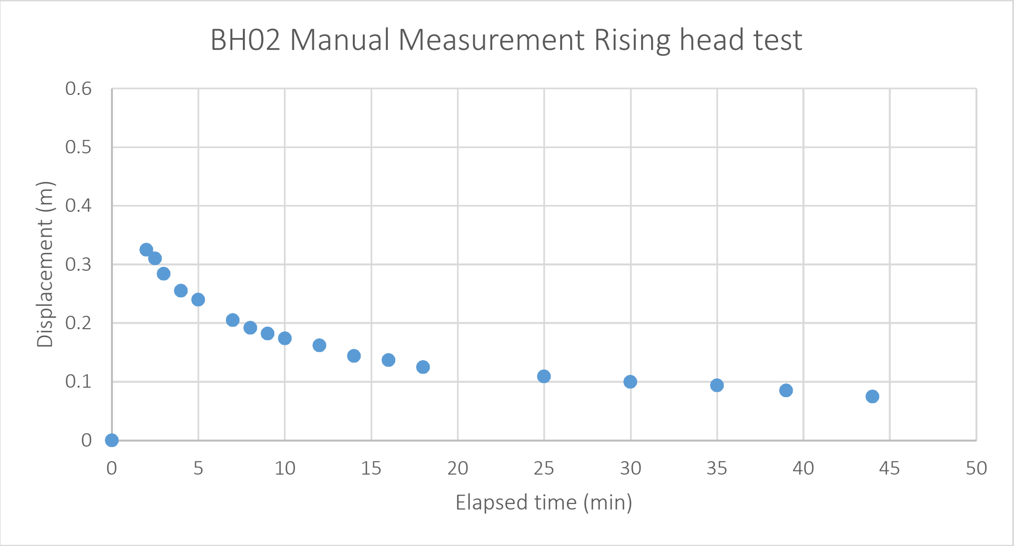
Golder Associates

CLIENT Flanagan Consulting Group
DRAWN JL
DATE: 1512/2016
CHECKED SRF
DATE: 15/12/2016
SCALE: A4

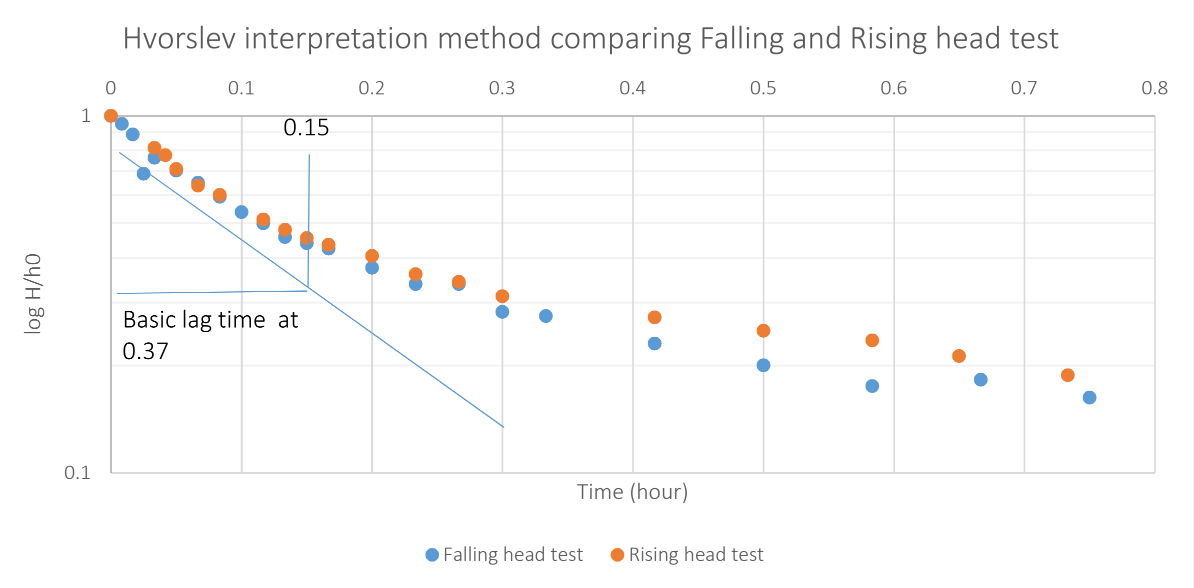
PROJECT **Cairns Shipping Development EIS**
BH01 Slug test analysis using Hvorslev method
PROJECT No. 1546223-013
FIGURE No. **G1**

\\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

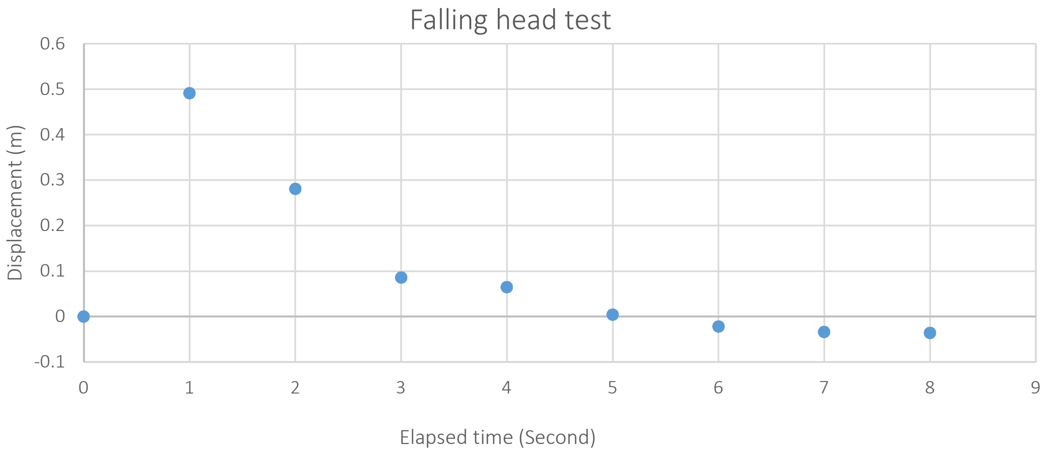

BH02 Manual Measurement Falling head test


BH02 Manual Measurement Rising head test

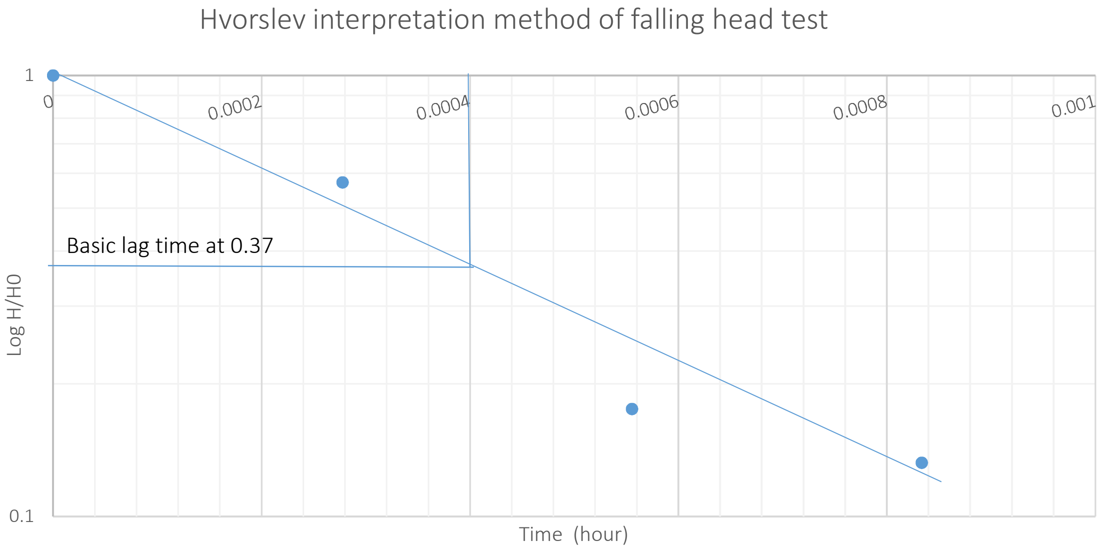
r^2 (m)	0.000625
A (m^2)	0.0019625
T (Hours)	0.15
F (shape factor)	3.9352548
k (m/hour)	0.0033246
k (m/s)	**9.235E-07**


Hvorslev interpretation method comparing Falling and Rising head test

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. **G2**



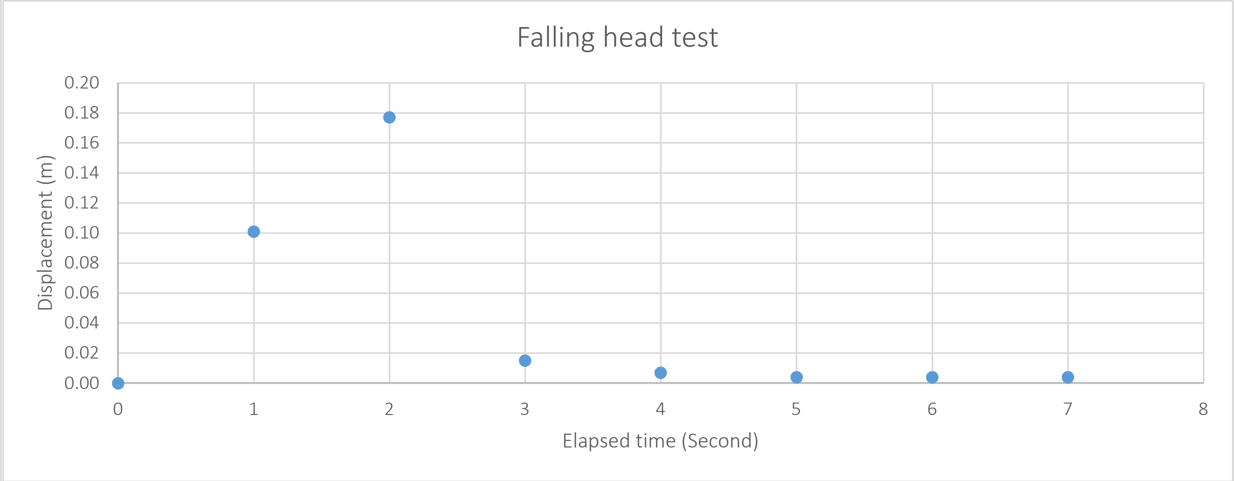
r^2 (m)	0.000625
A (m^2)	0.0019625
T (Hours)	0.0004
F (shape factor)	4.447913896
k (m/hour)	1.103045184
k (m/s)	**3.06E-04**



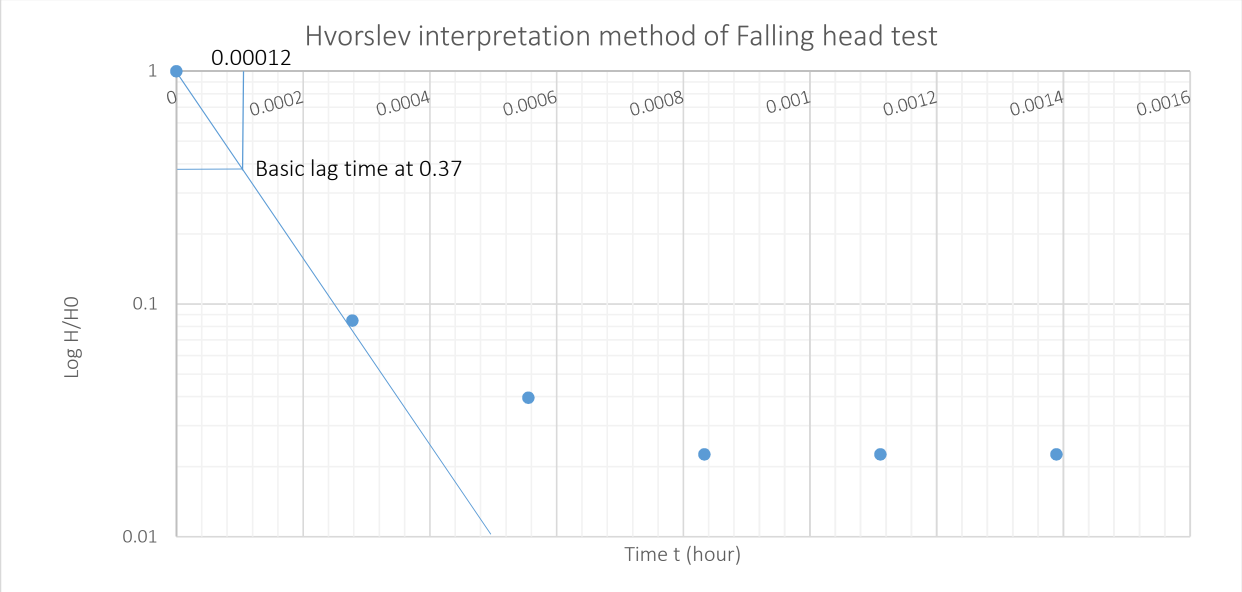
CLIENT	Flanagan Consulting Group		PROJECT	**Cairns Shipping Development EIS**
DRAWN	JL	DATE: 1512/2016		**BH03 Slug test analysis using Hvorslev method**
CHECKED	SRF	DATE: 15/12/2016		
SCALE:	A4		PROJECT No. 1546223-013	FIGURE No. **G3**

Golder Associates

\\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**



Golder Associates

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. **G4**

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

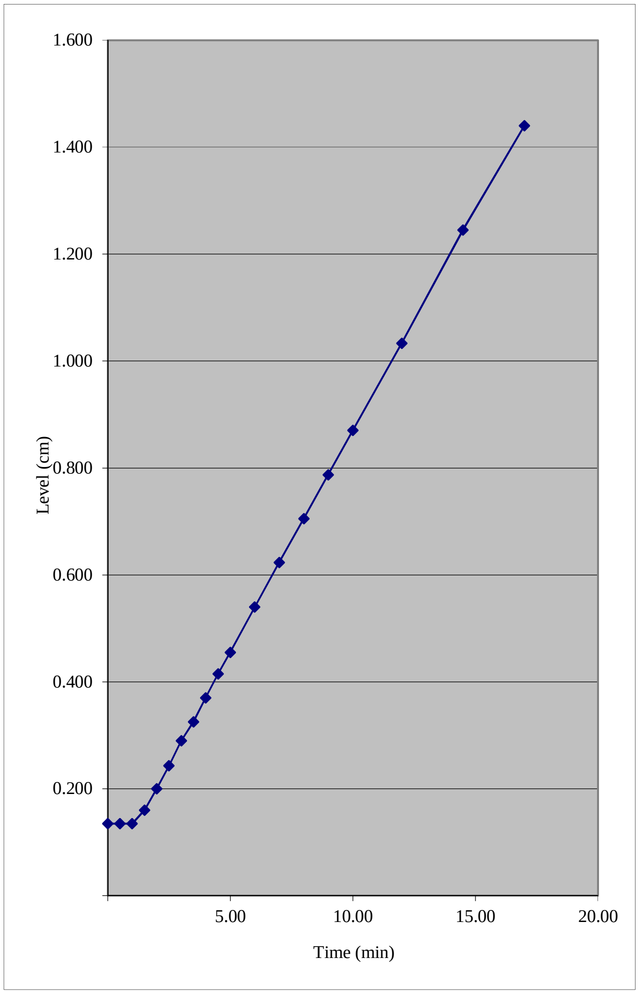
Site: Northern Sands
Project Number: 1546223 **Test Location:** GA04
Date: 24/11/2016
Staff: JL **Method:** **AS/NZS 1547:2000

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)

Golder Associates

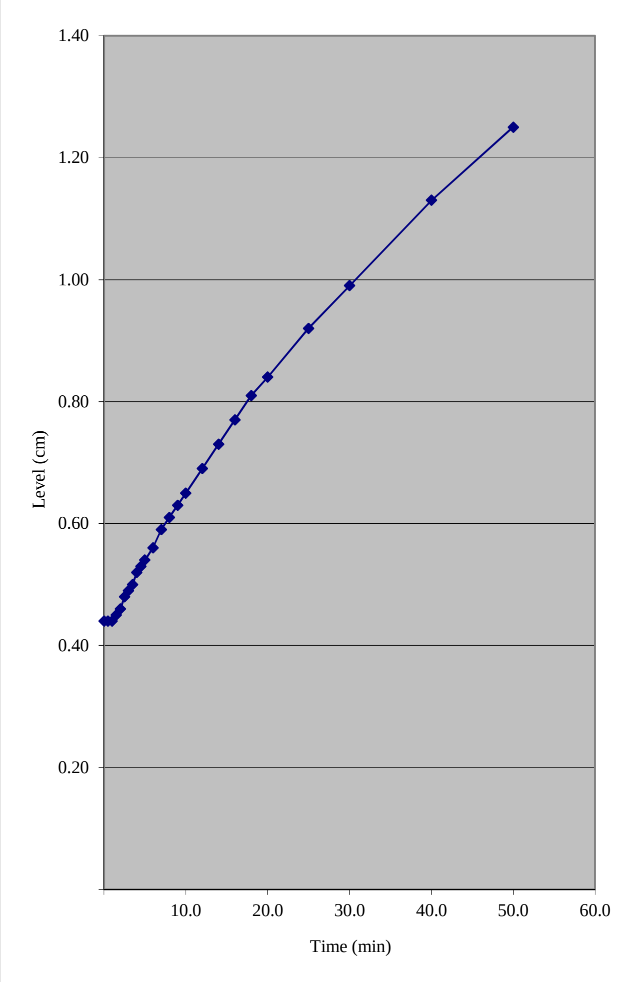
Site:	Northern Sands		
Project Number:	1546223	**Test Location:**	GA05
Date:	24/11/2016		
Staff:	DS	**Method:**	**AS/NZS 1547:2000

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

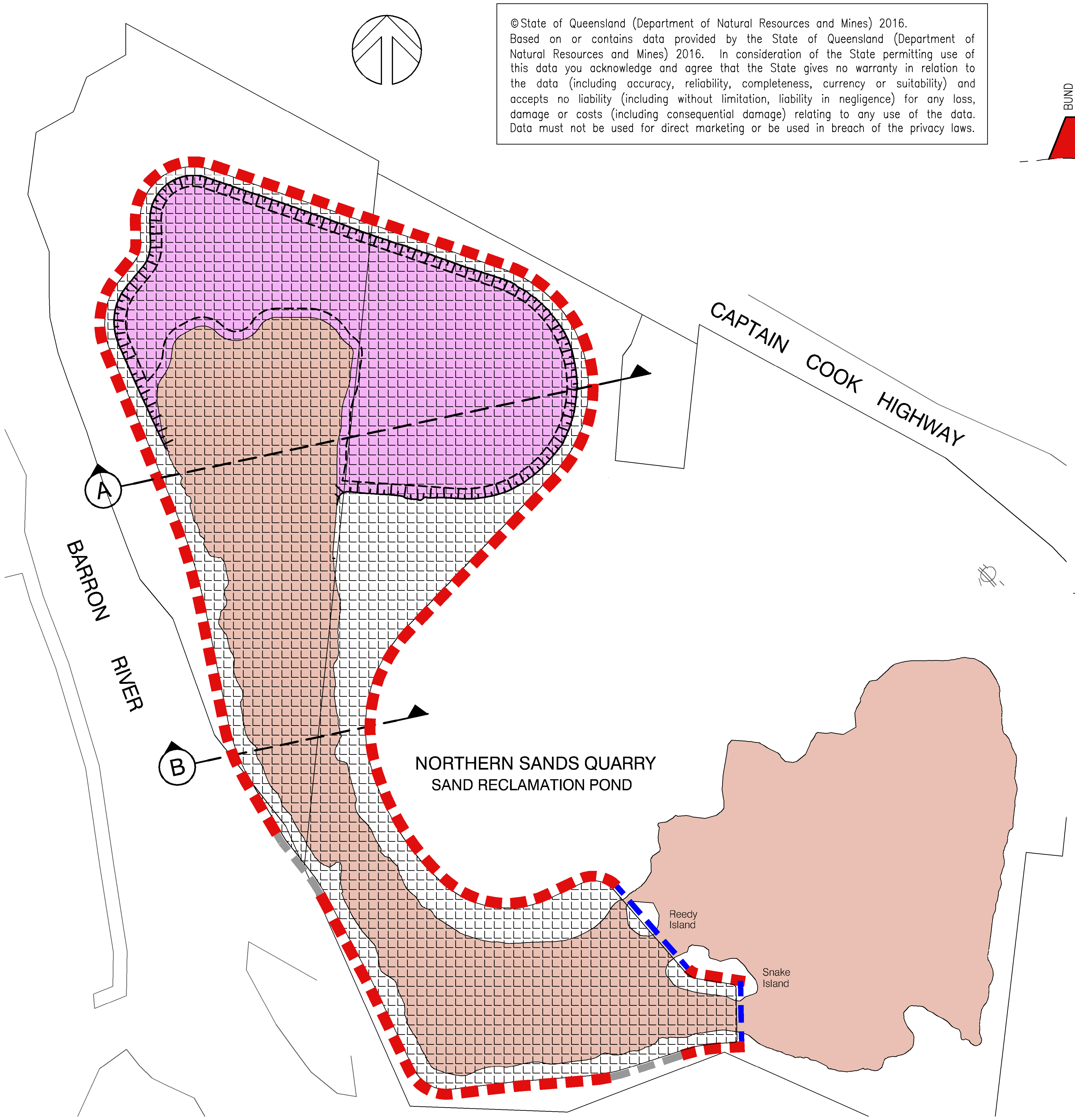
Apply Steady State (See graph above)

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

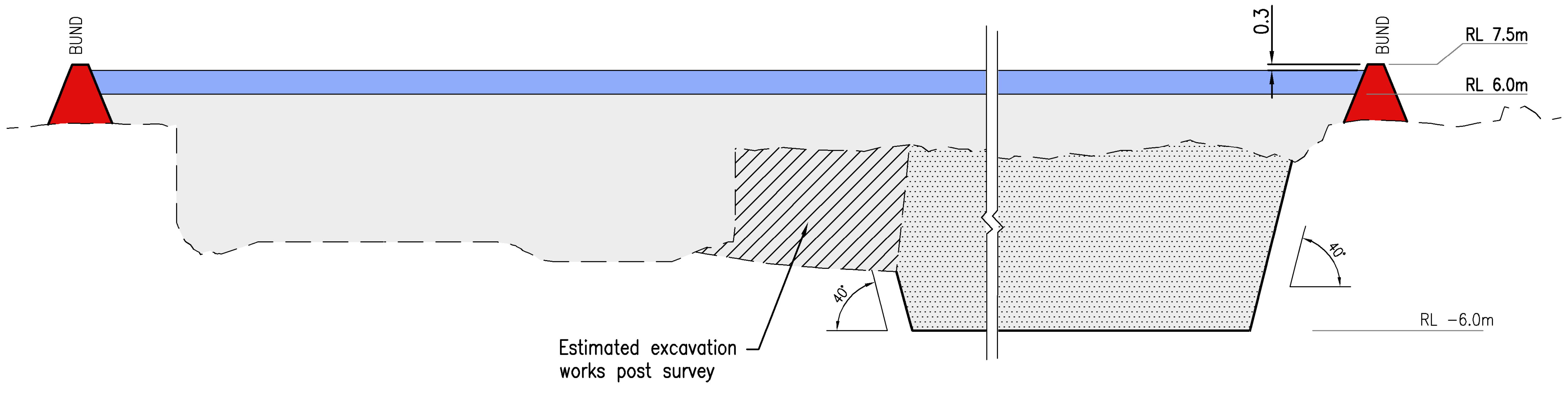
Input By:	JJP	**Date:**	25/11/2016
Reviewed By:	MSC	**Date:**	25/11/2016

Appendix H

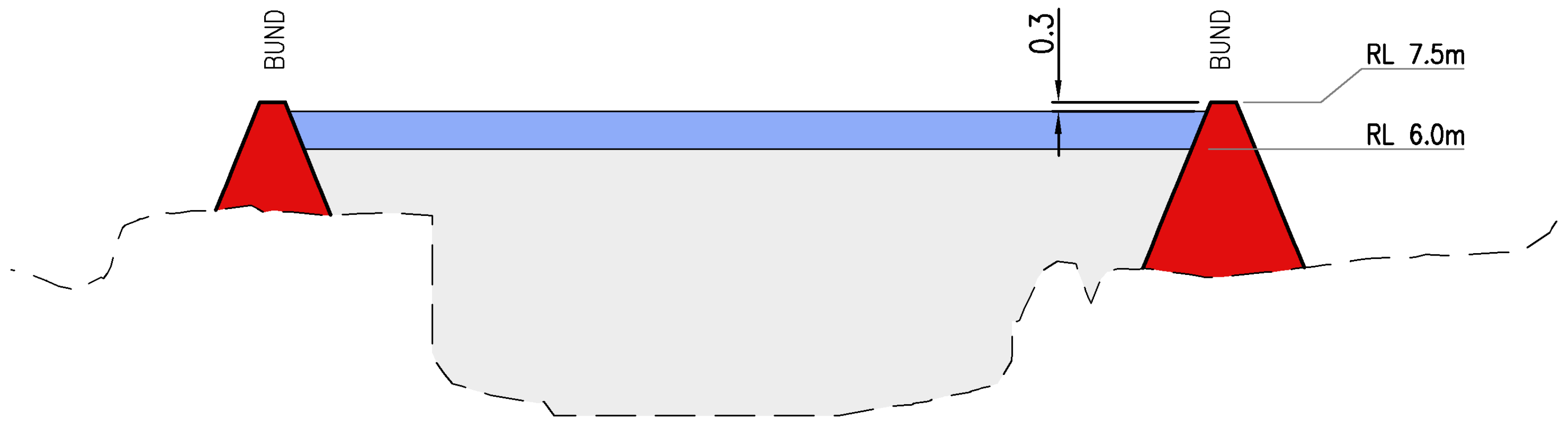
Proposed Expansion of Lake for Placement of Dredge Spoil (Drawing 3527-SK09C)



DREDGE MATERIAL PLACEMENT ZONE
1:3000



SECTION A
1:1000 Horiz / 1:200 Vert



SECTION B
1:1000 Horiz / 1:200 Vert

VOLUMES

░	EXCAVATION (778,000 m^3 approx)
🟥	PERIMETER EARTH BUND (124,000 m^3 approx)
▒	POTENTIAL DREDGED MATERIAL STORAGE (2,371,120 m^3 approx)
🟦	POTENTIAL WATER STORAGE (357,360 m^3 approx)

NOTES

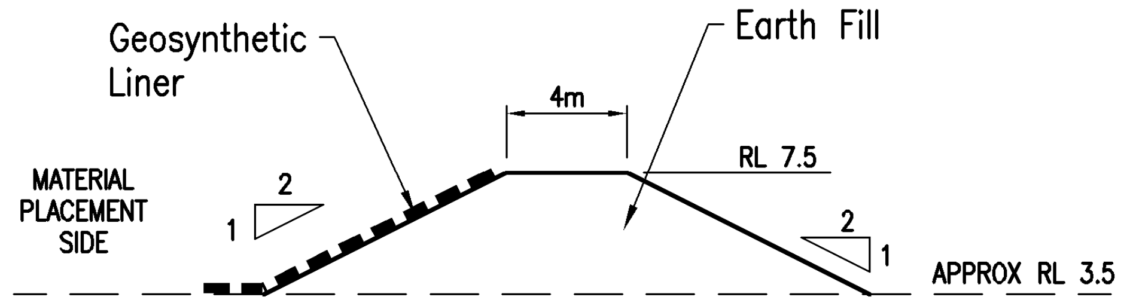
1. Volumes shown are approximate only and based on a combination of site hydrographic survey and LiDAR survey.

STORAGE VOLUMES

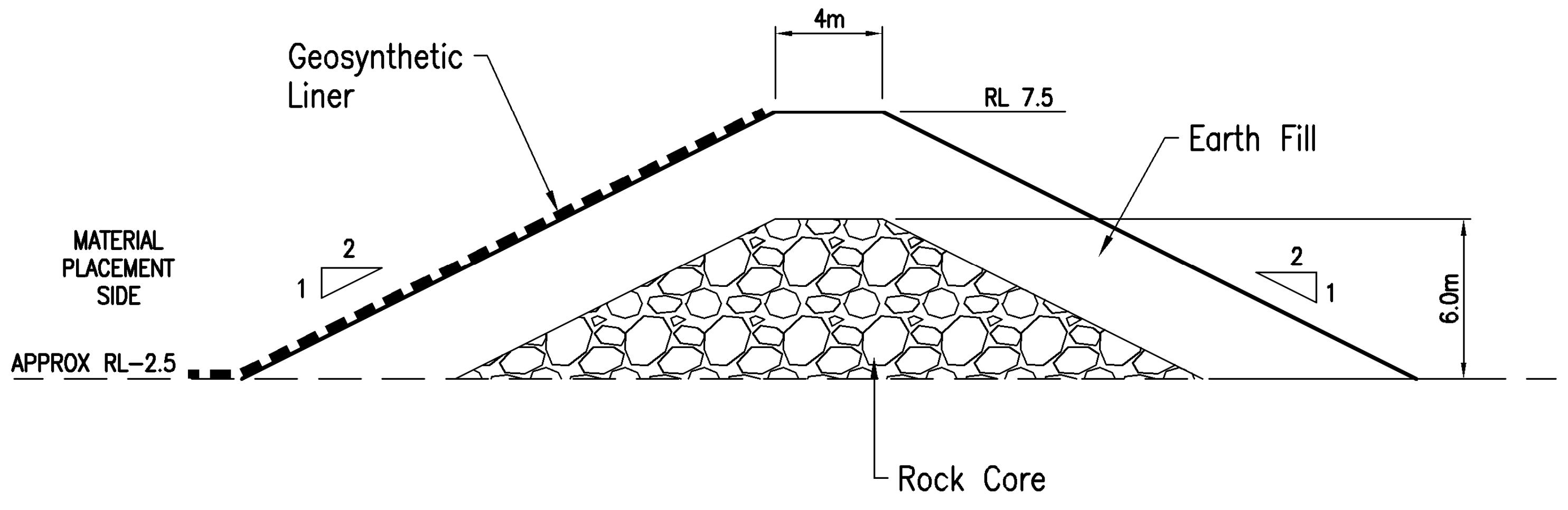
LEVEL (AHD) (m)	VOLUME BELOW (m^3)	COMMENT
7.5	2,819,327	Top of Bund
7.2	2,728,482	Max Water Level
7.0	2,668,257	
6.5	2,518,856	
6.0	2,371,126	Top of Placed Material
5.5	2,225,163	
5.0	2,081,394	
4.5	1,939,774	
4.0	1,803,912	
3.5	1,674,465	
3.0	1,549,057	
2.5	1,427,232	
2.0	1,307,750	
1.5	1,189,951	
1.0	1,073,634	
0.68	1,000,000	Settled Volume
0.5	960,161	
0.0	851,455	
−0.5	743,178	
−1.0	636,100	
−1.5	531,122	
−2.0	440,915	
−2.5	357,815	
−3.0	289,916	
−3.5	229,943	
−4.0	179,996	
−4.5	132,535	
−5.0	88,373	
−5.5	45,085	
−6.0	2,735	
−6.5	0	

LEGEND

🟫	EXISTING SAND RECLAMATION AREA	▬ ▬ ▬	EARTH BUND (APPROX 2,750m)
🟪	FUTURE SAND RECLAMATION AREA (TO RL −6.0)	▬ ▬ ▬	SEPARATION BUND (APPROX 195m)
▦	DREDGE MATERIAL PLACEMENT ZONE (293,700 m^2 – SURFACE AREA AT RL 6.0)	▬ ▬ ▬	EXISTING EARTH BUND (APPROX 165m)



PERIMETER EARTH BUND
NTS



SEPARATION BUND
NTS

FLANAGAN
CONSULTING GROUP
DEVELOPMENT CONSULTANTS • PROJECT MANAGERS • ENGINEERS • PLANNERS

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NORTHERN SANDS

Dredge Material Placement
Bund Height RL 7.5m
Concept Only

3527-SK09C
1:3000
A1 Full Size

Acad No. 3527-SK09C
16 March 2017

Appendix I

Queensland Government Terms of Reference
Commonwealth Guidelines

Queensland Government Terms of Reference

Flanagan Consulting Group has extracted relevant items from the Queensland Government Terms of Reference for soils and groundwater studies. These items and relevant details are presented below. Items that are not in scope are shaded grey in the table. The section of this report where each item is discussed is also shown in the table.

Relevant Queensland Government ToR - Groundwater

ToR	Title	Details	Comments
5.2	Land	Detail the existing land environment values for all areas associated with the project.	Not addressed in this report.
5.2.1	Land use and tenure	· declared water storage catchments	Not addressed in this report
5.3.2	Water quality	groundwater quality for likely discharge, runoff or seepage waters from any dredge spoil structures using the ANZECC Guidelines (Australian and New Zealand	Section 2.4 Section 3.3
5.5.1	Water resources	Provide an overview of the quality and quantity of any water resources in the vicinity of the project area and the relevance to the project.	Section 2.4 Section 3.2 Section 3.3 Section 3.4
5.5.2	Water resources	potential impacts on the flow and the quality of surface and groundwater from all phases of the project, with reference to their suitability for the current and potential downstream uses and discharge licences	Section 4 Section 5
5.5.2	Water resources	an assessment of all likely impacts on groundwater depletion or recharge regimes	Not addressed in this report
5.5.2	Water resources	where placement of dredge spoil to land is being considered, the use of the ANZECC Guidelines methodology is required to derive water quality trigger values and investigate surface and groundwater quality of the receiving environment that are likely to receive discharge, runoff or seepage waters from any dredge spoil	Not addressed in this report
5.5.2	Water resources	an assessment of the potential to contaminate surface and groundwater resources and measures to prevent, mitigate and remediate such contamination	Section 5
5.5.2	Water resources	details of a monitoring program for the groundwater resources, using existing deep bores, to establish the base line yield and water quality of the supply from those bores	Section 3.3

Commonwealth Guidelines

Flanagan Consulting Group has extracted relevant items from the Commonwealth Guidelines for soils and groundwater studies. These items and relevant details are presented below. Items that are not in scope are shaded grey in the table. The section of this report where each item is discussed is also shown in the table.

Relevant Commonwealth Government Guidelines

Guideline	Title	Details	Comments
5.9	The Existing Environment	This section must provide a description of the project area including baseline condition and trends of coastal, terrestrial and marine environments, including hydrology, sediment characteristics, sediment flows, geography, flora and fauna, cultural and heritage values, and all relevant socio-economic considerations. This section must link to the proposal description, potential impacts, and proposed avoidance, mitigation, adaptive management framework and/or offset measures throughout the life of the project including pre-construction, construction, operation, and any decommissioning. This section is to also identify and reference any relevant (published and unpublished) studies undertaken in the area which will assist in describing patterns and trends in the environment. Acute and chronic) from geotechnical activities (such as blasting (such as blasting (such as blasting (such as blasting pile driving), impacts of increased marine underwater marine species, including the impacts from noise at varying from each project component (considering the variables e.g. depth, wave height, bottom profile); impacts from proposal on air quality impacts; dredged material and impacts from increased shipping	Section 2 Section 3
5.9	The Existing Environment	The section must include a description of the environment of the proposal site and the surrounding areas that may be affected by the action. This must include the following information:	Section 2 Section 3
5.9	The Existing Environment	b) A detailed assessment of the nature, extent, likelihood and consequence of the likely short-term and long-term impacts including but not limited to: description of the risks and potential impacts placement impacts	Section 5 Section 6
5.9	The Existing Environment	e) Any technical data, including modelling, and other information used or needed to make a detailed assessment of the relevant impacts;	Section 3 Section 5
5.9	The Existing Environment	h) Consideration of potential impacts throughout the life of the proposal – from preconstruction, construction through to operation and any decommissioning;	Section 5 Section 6
5.9	The Existing Environment	l) Impacts on the existing use of the area and nearby areas that may be affected by the proposed action;	Section 5 Section 6

Guideline	Title	Details	Comments
5.10	Relevant Impact of the Proposed Action	The EIS must include a description of all of the relevant impacts of the action. Relevant impacts (both direct and indirect) are impacts that the action will have or is likely to have on a matter protected by a controlling provision (as listed in the preamble of this document). This section must provide clear linkages with the existing environmental values described in section 5.9 and proposed avoidance, safeguards, management and mitigation measures described in section 5.11. Impacts during all phases of the project must be addressed. This section must include:	Section 5 Section 6
5.10	Relevant Impact of the Proposed Action	a) A description of the framework used to assess impacts, including risk assessment processes based on an approved standard;	Section 6
5.10	Relevant Impact of the Proposed Action	b) A detailed assessment of the nature, extent, likelihood and consequence of the likely short-term and long-term impacts including but not limited to: description of the risks and potential impacts (acute and chronic) from geotechnical activities (such as blasting and pile driving), impacts of increased marine underwater noise on marine species, including the impacts from noise at varying distances from each project component (considering the environmental variables e.g. depth, wave height, bottom profile); impacts from the proposal on air quality impacts; dredging and dredged material placement impacts and impacts from increased shipping;	Section 5 Section 6
5.10	Relevant Impact of the Proposed Action	c) A statement whether any relevant impacts are likely to be unknown, unpredictable, irreversible or sub-lethal (reversible over time) and what confidence level is placed on the predictions of relevant impacts;	Section 6.2
5.10	Relevant Impact of the Proposed Action	d) Analysis of the significance of the impacts;	Section 6.2
5.10	Relevant Impact of the Proposed Action	e) Any technical data, including modelling, and other information used or needed to make a detailed assessment of the relevant impacts;	Section 2 Section 3 Section 5
5.10	Relevant Impact of the Proposed Action	f) Consideration of potential impacts throughout the life of the proposal – from preconstruction, construction through to operation and any decommissioning;	Section 6
5.10.9	Dredging and Dredged Material	h) Assessment of the risk and potential impacts of acid sulfate soils (ASS) and potential acid sulfate soils (PASS);	Not considered in this report

Guideline	Title	Details	Comments
5.11	Proposed avoidance, safeguards, management and mitigation measures	The EIS must provide information on proposed avoidance, safeguards and mitigation measures to deal with the impacts of the action. Specific and detailed descriptions of proposed measures must be provided and substantiated, based on best available practices/standards and must include the following elements.	Section 5
5.11	Proposed avoidance, safeguards, management and mitigation measures	a) Identify the level of risk associated with potential impacts already identified and those that require mitigation, monitoring or management to avoid or reduce impacts to an acceptable level;	Section 6.2
5.11	Proposed avoidance, safeguards, management and mitigation measures	b) A consolidated list of measures proposed to be undertaken to avoid, prevent, minimise or compensate (in priority order) for the impacts of the action (as specified in section 5.10), including: i. A description of proposed avoidance, safeguards and mitigation measures to deal with impacts of the action, including measures proposed to be taken by State governments, local governments or the proponent; ii. Assessment of the expected or predicted effectiveness of the measures; iii. Any statutory or policy basis for the mitigation measures; iv. The cost of the mitigation measures; and v. The resulting risk level for that impact post- avoidance, mitigation and/or management.	Section 5 Section 6
5.11	Proposed avoidance, safeguards, management and mitigation	c) Particular focus must be given to: i. Determining factors in the planning of the proposal so as to avoid damage to the environment;	Section 5

Appendix J

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.

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