FLANAGAN CONSULTING GROUP
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Ports North

CAIRNS SHIPPING DEVELOPMENT PROJECT

Revised Draft Environmental Impact Statement

Chapter B6: Water Resources

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B6.1 Introduction

B6.1.1 Overview

This chapter describes the existing water resources (surface water and groundwater) that may be impacted on by the Cairns Shipping Development Project (the CSD Project) and other surface water issues (drainage and flooding). Specifically, it deals with:

- surface water hydrology and hydraulics
- groundwater hydrology and hydraulics
- quality of surface water
- quality of groundwater
- use of surface water
- use of groundwater
- surface water / groundwater interaction
- impacts on surface water
- impacts on groundwater.

For the Draft EIS, a water quality model was set up to examine the effects of the channel dredging (and at the time, the marine placement campaign). This model has since been expanded to include the land placement works at the Northern Sands DMPA and Tingira Street DMPA and therefore includes parts of the Barron River and Trinity Inlet respectively in the model. Accordingly, the existing situation (values) and impacts of the CSD Project on the values of these water bodies is described in **Chapter B5** (Marine Water Quality).

Water-related hazards (i.e. flooding and stormtide) are described in **Chapter B17** (Hazard and Risk).

B6.1.2 The Study Area and Project Areas

The 'study area' for the EIS varies depending on the issue at hand while the 'project area' is the immediate footprint of the proposed works. In the consideration of water resources as defined above, the 'local scale' is appropriate. The local scale (**Figure B6-1**) is defined as follows:

- The township of Cairns.
- The marine environment including the Trinity Inlet, Trinity Bay and surrounding waters including:
  - all waters of Trinity Bay
  - the tidal waters of Trinity Inlet, including landward areas to the boundary of the Fish Habitat Area
  - Double Island
  - the coastline and nearshore waters of Cairns' Northern Beaches
  - Mission Bay
  - the coastline extending to Cape Grafton.

Project Areas are also shown on **Figure B6-1** and encompass:

- Channel Project Area including the shipping channel and the route to the pump-out point at the seaward end of the pipeline to the Northern Sands DMPA.
- Landside Works Project Area for wharf upgrades and berthing of cruise ships.
- Northern Sands DMPA Project Area (includes the DMPA, delivery pipeline, tailwater ponds, and tailwater outlet works).
- Tingira Street Stiff Clay DMPA Project Area.

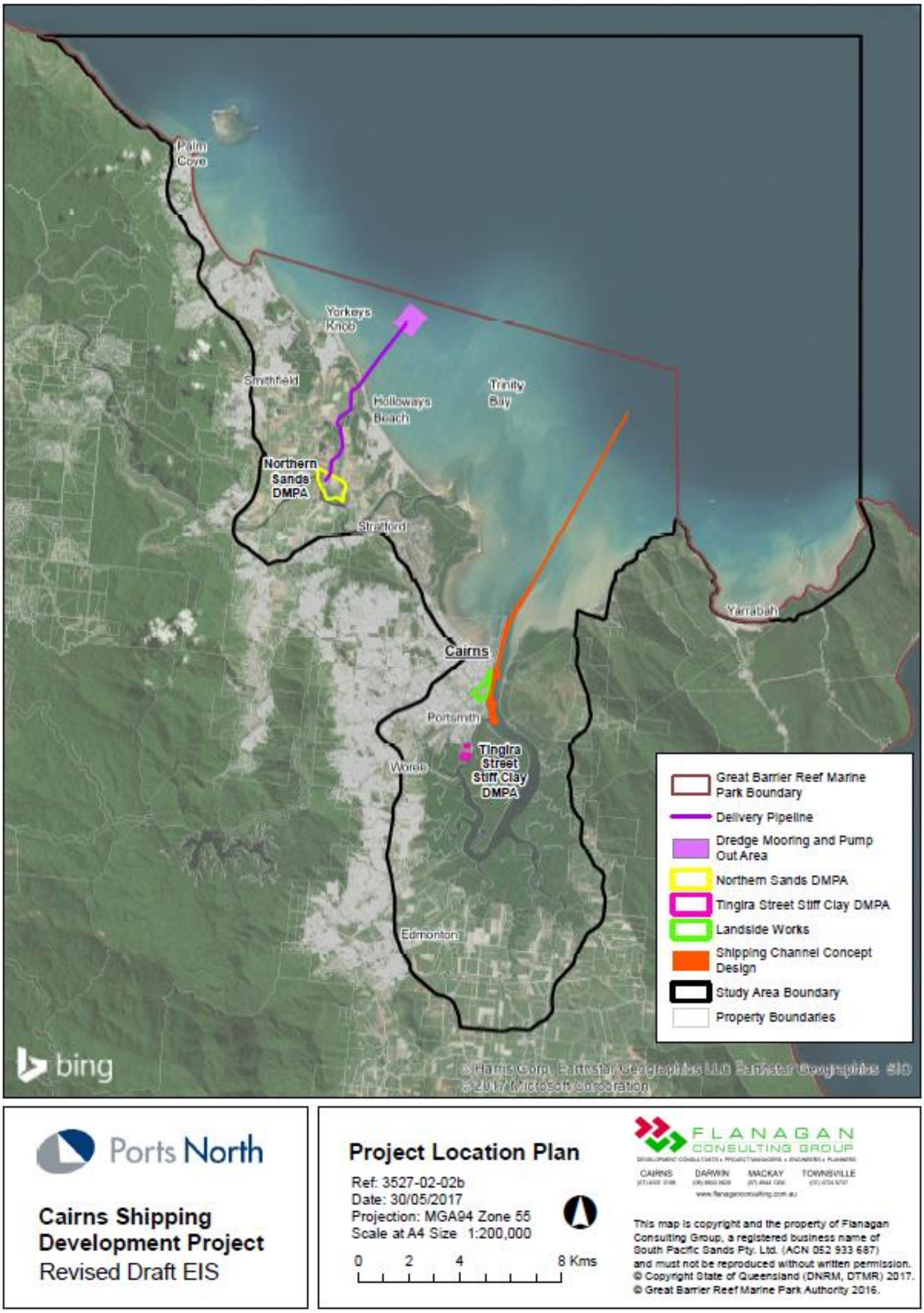

Figure B6-1 Study Area and Project Areas.

For the purposes of this chapter, the Channel and Landside Works Project Areas are excluded as they are described in **Chapter B5** (Marine Water Quality). Surface water quality impacts arising from the placement dredge material placement process are excluded for the same reasons.

B6.1.3 Overview of the CSD Project

The following is a brief discussion of the CSD Project as it relates to water resources (surface water and groundwater). A more detailed description is provided in **Chapter A3** (Project Description). Management is proposed via two plans documented elsewhere in this Revised Draft EIS:

- **Chapter C1** (Construction Environmental Management Plan). This covers the works necessary to prepare the DMPAs for receiving the soft clays (Northern Sands DMPA) and stiff clays (Tingira Street DMPA) and then remove all temporary works and make good.
- **Chapter C2** (Dredge Management Plan). This covers the actual placement activities and will be integrated with dredging operations.

B6.1.3.a Northern Sands Project Area

The Northern Sands DMPA contains an operating sand mine and a 25 ha water-filled void (known locally as Lake Narelle) that is to be enlarged and used for the placement of soft clays pumped to the site. The current void contains fresh water from groundwater seepage and rainfall.

Site preparation at the DMPA will involve bunding and enlargement of the existing void to the north as part of future ‘business as usual’ quarry expansion plans, forming a total bunded placement area of 29.6 ha. The DMPA operations will be separated from ongoing sand extraction and construction and demolition waste disposal by a lined rock wall.

Erosion and sedimentation control works in accordance with FNQROC requirements will be installed as soon as possible in the site preparation process. All establishment and disestablishment works will be as described in **Chapter C1** (Construction Environmental Management Plan).

Dredged material will be delivered into the lake as a slurry through the dredged material delivery pipeline in pulses as the TSHD completes approximately six circuits per 24 hours over the dredging program. As the prepared void fills with the dredge material slurry, solids will settle and commence consolidation on the floor of the void leaving turbid supernatant waters (tailwater). These will gradually clarify prior to discharge via a discharge pipeline to the Barron River, once they have met the adopted water quality discharge standards.

A contingency tailwater pond is included in the project concept in case it is required in order to meet water quality standards for tailwater. 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 DMPA.

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.

As described in this chapter, the salinity and water level in the enlarged void will change as the placement proceeds and again when it is completed. As this is a complex matter, the assessment of impacts on water resources has been undertaken in a comprehensive manner and has been used to inform the design and mitigation recommendations.

All placement and tailwater management operations are as described in **Chapter C2** (Dredge Management Plan).

B6.1.3.b Tingira Street Project Area

Site preparation at the DMPA will be minor and will involve clearing and grubbing to remove the existing grass and regrowth vegetation and then the formation of bunds (estimated to be < 0.5 m high) around the perimeter of the placement areas using insitu clay materials. Erosion and sedimentation control works in accordance with FNQROC requirements will be installed as soon as possible in the site preparation process. All establishment and disestablishment works will be as described in **Chapter C1** (Construction Environmental Management Plan).

The results of available laboratory testing on samples of the stiff clays proposed for dredging indicate that the clays are typically of high plasticity with <10% sand content. The stiff clays are not ASS. Dredging of these clays is likely to generate ‘chunks’ of material and relatively small amounts of seawater. Even with relatively small amounts of seawater these materials are likely to be ‘sticky’ and potentially difficult to handle until drying occurs.

The dredged material will progressively placed within the bunded area using heavy haulage vehicles and other plant. The average thickness is expected to be 2.0 m if the material is evenly spread. This is a simple procedure that is expected to involve minimal interference with surface water and groundwater. Accordingly, the assessment of impacts on water resources has been undertaken at a high level.

Run-off of seawater will be managed during the unloading, transporting, and placement operations as described in **Chapter C2** (Dredge Management Plan).

B6.1.4 End Use of DMPAs

End uses of the DMPAs are described below because an appreciation of these is critical to the assessment of impacts.

B6.1.4.a Northern Sands DMPA

The soft clay placement campaign will fill all or most of the void over a period of some three months after which it will settle over one wet season. Once this filling is complete, the DMPA will revert to the control of the owner who will then determine subsequent uses. No assumptions can be made about this use although current approvals imply that at some time the void is to be completely filled.

B6.1.4.b Delivery Pipeline

Soft clay will be delivered to the DMPA via the dredge material delivery pipeline which commences at the offshore pump out facility located between 2.7 and 3.7 km offshore from Yorkeys Knob. The marine section of the pipeline will be submerged, while the landward section will be constructed above ground and suspended on low (<0.5 m) earthen plinths. Up to three booster stations may be necessary because of the pipeline length. Booster stations will be placed in cleared grassland areas or cane headlands in consultation with landowners, to minimise interference with farming operations.

After the completion of the soft clay placement campaign, the inlet pipeline (landward and marine sections) and booster stations will be disassembled and removed. The disturbed area will be restored and the small amount of natural vegetation cleared for its construction will be rehabilitated using appropriate native species as described in **Chapter C1** (Construction Environmental Management Plan). A specific Restoration Plan will be prepared during the approvals phase and implemented for this purpose.

B6.1.4.c Tailwater Discharge Pipeline(s)

Similarly, the tailwater discharge pipelines will be disassembled and removed and the disturbed area restored and rehabilitated as described in **Chapter C1** (Construction Environmental Management Plan).

B6.1.4.d Tailwater Ponds

When no longer required, the tailwater ponds will be filled and the disturbed area restored such that the area can be re-used. No rehabilitation will be necessary.

B6.1.4.e Tingira Street Project Area

The Tingira Street DMPA is currently cleared (although some marine plants have recolonised much of the area not covered by anthropogenic grasslands) and in its past has been filled to above Highest Astronomical Tide. The placed stiff clay will be used to fill and preload the site to accelerate settlement. As a separate project, Ports North intends to import additional fill and construct industrial hardstands and other infrastructure. This project has been under consideration for many years and most of the necessary approvals have already been obtained.

B6.2 Methodology

B6.2.1 Detailed Technical Assessments

Several detailed technical assessments were undertaken in support of both the concept design of the project (documented in **Chapter A2** (Project Background)) and this chapter. These are listed in **Table B6-1** below. The final column shows where these reports are located in this Revised Draft EIS.

TABLE B6-1 DETAILED TECHNICAL ASSESSMENTS

STUDY	DETAILS	APPENDIX NO
Groundwater Impact Assessment – Northern Sands DMPA	Existing situation and assessment of groundwater impacts of the Northern Sands DMPA and pipeline corridor.	**Appendix AK**
Soils and Groundwater Impact Assessment – Tingira Street DMPA	Existing situation and assessment of soils and groundwater impacts at the Tingira Street DMPA.	**Appendix X**
Soils Impact Assessment Proposed Pipelines Northern Sands DMPA	Existing situation and assessment of soils impacts of the Northern Sands DMPA and pipeline corridor.	**Appendix Y**
Desktop Assessment of Storm Tide Risk at Tingira St Portsmith	Flooding assessment of the Tingira Street DMPA.	**Appendix AL**
Flood and Dredge Spoil Mobilisation Technical Studies Investigations for the Northern Sands Placement Site Option	Flooding assessment of the Northern Sands DMPA (remobilisation of placed material and afflux cause by the required protection works).	**Appendix AD**
Cairns Shipping Development Project Terrestrial Ecology Assessment Technical Report	Existing situation – wet season of the Northern Sands DMPA and pipeline corridor. Assessment of Impacts – Northern Sands DMPA and pipeline corridor and Tingira Street DMPA	**Appendix AM**

These studies are referred to where appropriate. While all relevant findings have been incorporated into this chapter, readers are referred to the original reports for further details if required. Together these technical studies involved:

- literature reviews to gather relevant information from previous studies
- desktop assessment of groundwater
- field investigations of groundwater in the Northern Sands Project Area undertaken in March 2017
- groundwater modelling (Northern Sands Project Area)
- hydrologic and hydraulic modelling (Northern Sands Project Area).

Summaries are provided below. In addition, many of the maps used in this chapter are extracted from appendices as noted while many detailed figures and tables are mentioned but not duplicated here. Readers requiring this detailed information are referred to the relevant material where appropriate.

In addition, several matters mentioned in this chapter are dealt with in more details in other chapters as follows:

- **Chapter B1** (Land) regarding related information on geology and soils.
- **Chapter 8** (Terrestrial Ecology) regarding groundwater dependent ecosystems
- **Chapter B5** (Marine Water Quality) regarding water quality in Trinity Inlet and the Barron River.
- **Chapter B17** (Hazard and Risk) regarding flooding and stormtide issues. This draws on **Appendix AL** and **Appendix AD**.

B6.2.2 Detailed Methodology

This assessment is based on a combination of a desktop study and monitoring / modelling using new and historic data. The main technical challenge was to develop an appropriate conceptual hydrogeological model for the Northern Sands Project Area. As later explained in detail, all available information on ground conditions from the current studies and from historical investigations in the vicinity was collated. 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.

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. This model was used to simulate saline water flow away from the lake during the period of increased lake water level associated with the placement process.

The stiff clay placement at the Tingira Street DMPA does not involve any significant risks to groundwater and assessment was based on desktop information and findings of previous work.

B6.3 Existing Situation

B6.3.1 Introduction

This section describes the existing situation with respect to water resources (surface water and groundwater). The initial discussion deals with matters that are relevant to the local study areas i.e. to both terrestrial project areas) and then provides details of each of these in turn.

B6.3.2 Local Study Area

B6.3.2.a Climate

The climate of the Cairns local area is tropical with weather patterns consisting of a wet season (typically December to April) and a dry season (typically May to November). Key climatological and weather data obtained from the nearest weather station, located at the Cairns Airport (Bureau of Meteorology Station Number 031011) is summarised below:

- Mean annual rainfall is 1999.7 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 highest humidity.
- Mean annual 3 pm humidity is 62% with February having highest humidity.

Mean monthly rainfall and mean monthly evaporation are reported in **Table B6-2** and the annual rainfall from 2005 to 2015 is reported in **Table B6-3**.

TABLE B6-2 MEAN RAINFALL (MM) AND CALCULATED EVAPORATION DATA (MM) AT THE CAIRNS AIRPORT

STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
Mean rainfall (1942 to 2016)	390	448	419	195	92	48	30	27	33	46	94	178
Mean evaporation (1965 to 2016)	198	164	180	162	152	141	155	174	201	233	225	223

Source: Bureau of Meteorology (2016) for Weather Station Number 031011. Note: data is rounded to the nearest millimetre.

TABLE B6-3 ANNUAL TOTAL RAINFALL DATA (MM) BETWEEN 2005 AND 2015 AT THE CAIRNS AIRPORT

Station	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015*
Cairns	1471	2289	1813	2215	2199	2660	2623	2003	1269	1826	1897

Source: Bureau of Meteorology (2016) for Weather Station Number 031011. 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 occurring every two to eight years. Significant rainfalls of 100 mm/day or greater and high intensity runoff would be expected. Due to the proximity of the two DMPAs to the coast, storm surges from the sea would also be expected. These are described in **Chapter B17** (Hazard and Risk).

B6.3.2.b Groundwater

Under Schedule 4 of the draft Water Resource (Wet Tropics) Plan 2013 (DEHP 2013), Trinity Inlet forms part of the Mulgrave-Russell groundwater catchment area, as shown in **Figure B6-2**. Groundwater in Trinity Inlet is a part of the former Cairns Coast sub-artesian areas (now known as Mulgrave-Russell catchment area) which is a designated Groundwater Management Area under this plan. The major objectives under the resource plan are to maintain access to groundwater for irrigation purposes, and groundwater-surface water connectivity.

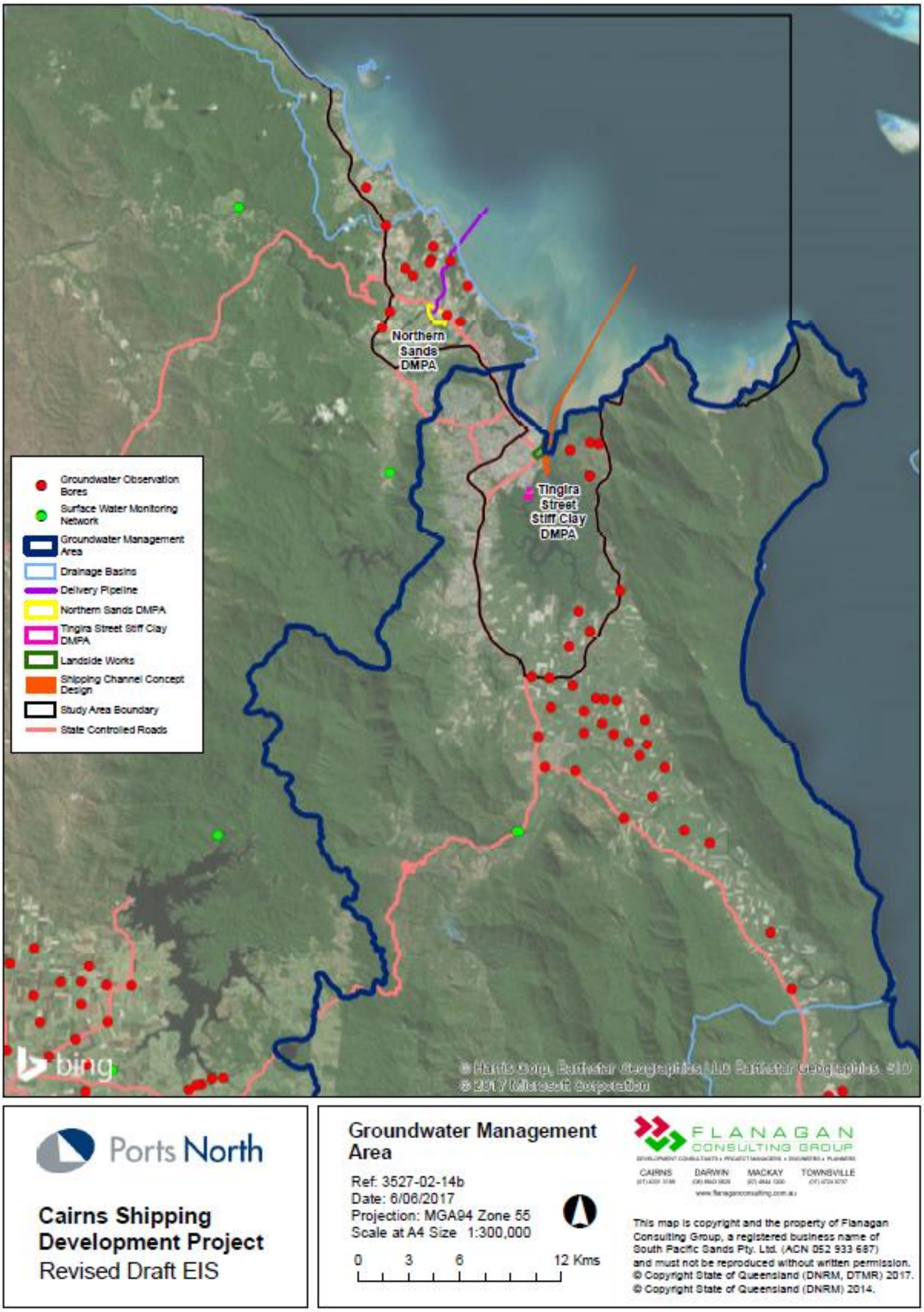

Figure B6-2 Groundwater Management Area.

Source: Ports North (2014).

Groundwater usage within the Wet Tropics region is generally observed to be in areas where there is no access to surface water for agriculture. The number of ground water licences in the region is significantly less than the surface water entitlements. No records of groundwater usage/licences are observed within the study area or the broader Cairns Coast sub-artesian area. Given the predominantly industrial and commercial nature of the study area, it is unlikely that there is any significant use of groundwater.

B6.3.3 Northern Sands Project Area

B6.3.3.a Location and Site Details

For the purposes of this chapter, the area covered by **Figure B6-3** is described as the Northern Sands Project Area (i.e. contains the DMPA, delivery pipeline corridor, tailwater ponds, and tailwater outlet works).

B6.3.3.b Site History

As described in **Chapter A2** (Project Background) the Northern Sands DMPA is currently used as an approved sand quarry and the existing void is approved for the disposal of inert construction and demolition waste, and up to 5000 m^3 / annum of potential acid sulfate soil (PASS). The void (known locally as Lake Narelle) contains water from groundwater seepage and rainfall and is mapped under the Queensland wetland mapping program as a ‘Lacustrine wetland’ as described in **Chapter B8** (Terrestrial Ecology). This mapping (see **Figure B6-9**) classifies all waterbodies and does not distinguish between natural and artificial waterbodies, nor classify for ecological importance of the ‘wetland’. The wetland values are currently reduced by constant disturbance resulting from the active use of the void and surrounds. Overall, the Northern Sands site displays low ecological values and is within an area of widespread anthropogenic disturbance.

B6.3.3.c Previously Proposed End Use

The ‘business as usual’ case for the Northern Sands void is a continuation of sand extraction and disposal of inert construction and demolition waste and up to 5000 m^3 / annum of PASS. This will all take place under water (the lake is linked to regional groundwater). Seasonal factors will result in the lake’s water level continuing to fluctuate from approximately -1.0 m AHD to +2.0 m AHD.

B6.3.3.d Topography

The topography of the Northern Sands site is characterised by alluvial terraces near the Barron River and flat coastal plains extending from the west of the site and east toward the ocean. Ground surface levels across the site typically range from about 2.0 m AHD to 5.5 m AHD. Recent hydrographic survey (July 2016 by Ports North) of the pit indicates excavation levels typically in the range of -1.5 m to -2.5 m AHD across the majority of the pit, apart from the southern and eastern portions 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 July 2016 hydrographic survey are shown on **Figure B6-4**.

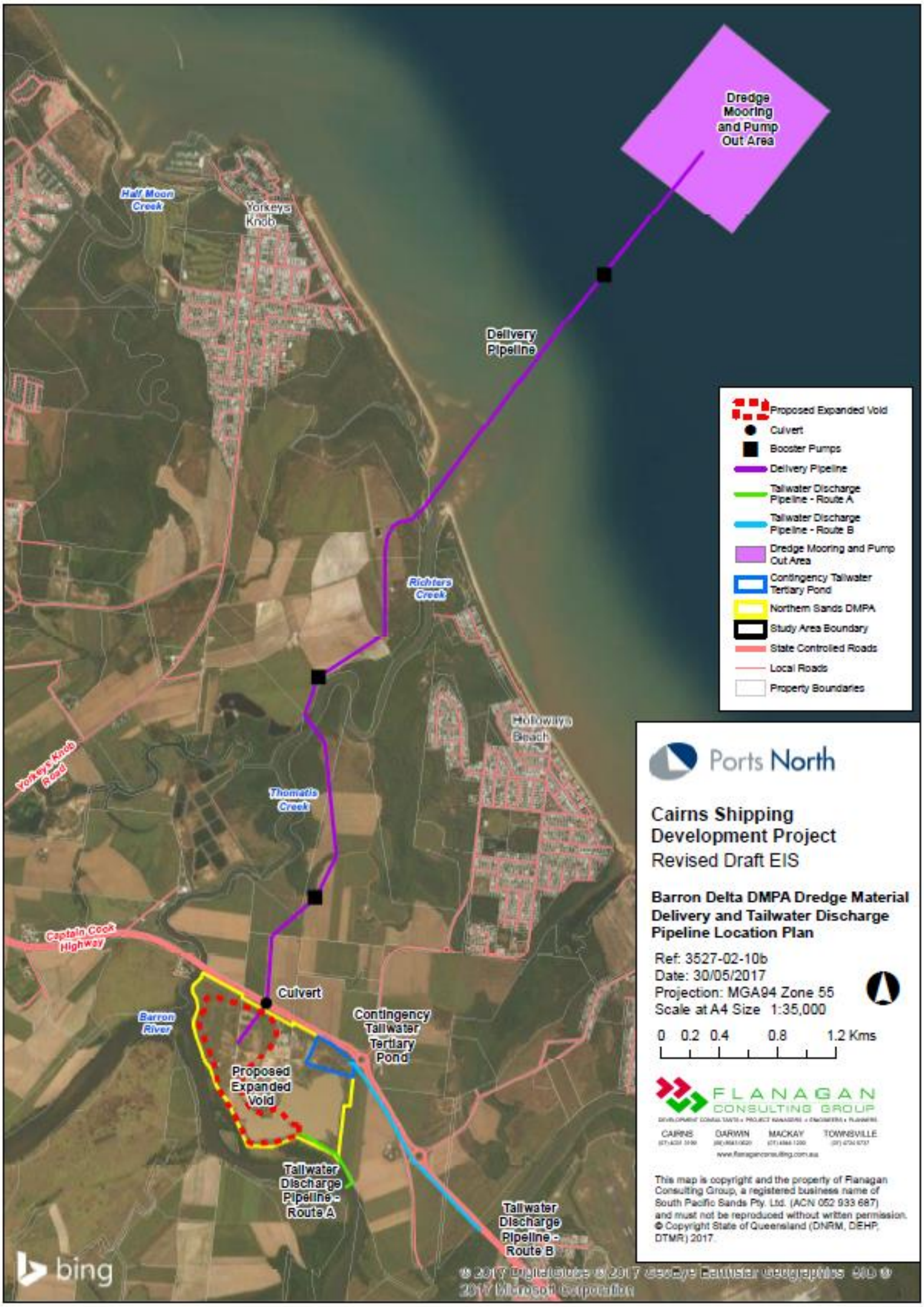

Figure B6-3 Northern Sands Project Area.

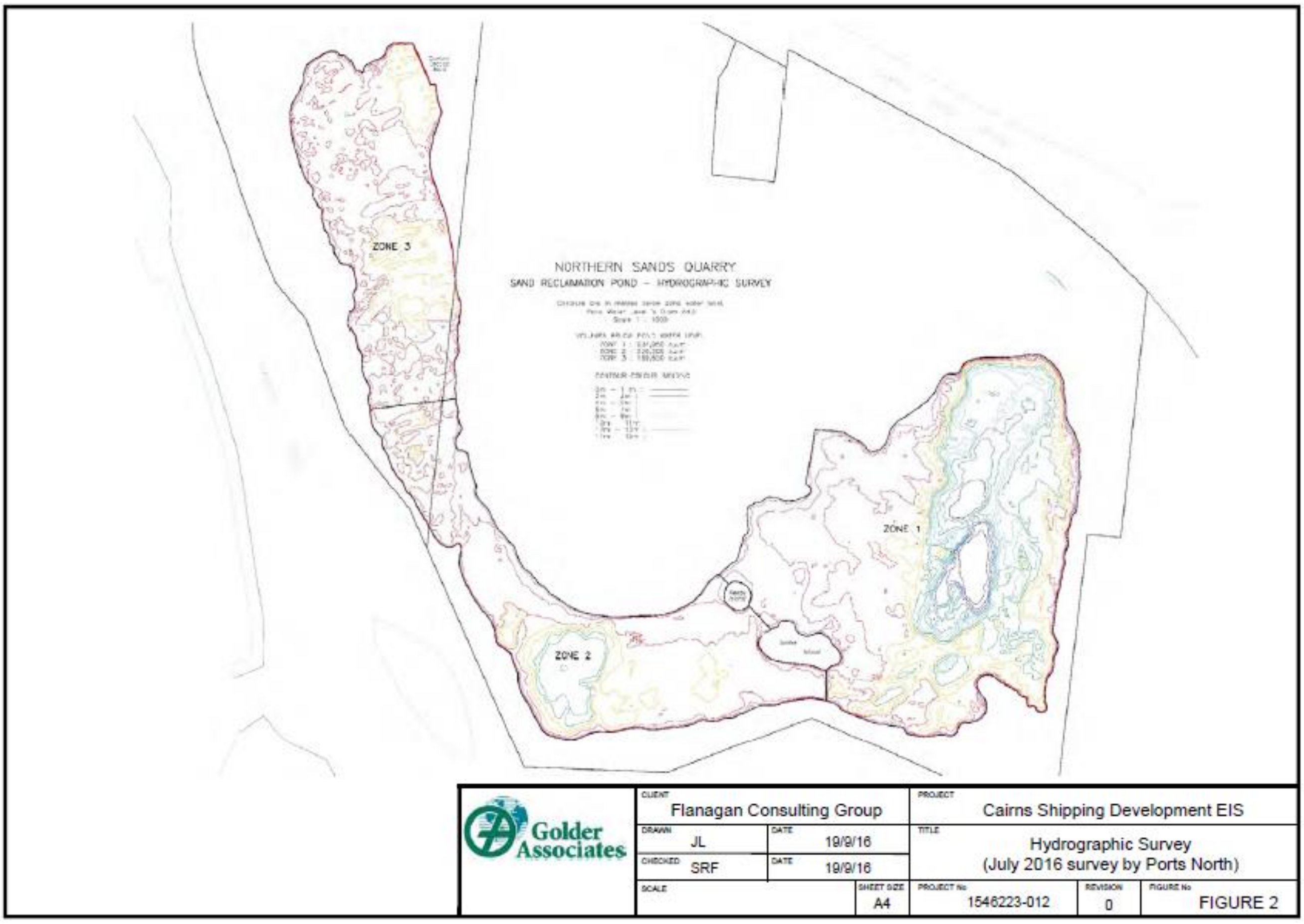

Figure B6-4 Lake Narelle site survey (Jul 2016).

Source: Appendix AK (Figure 2). A larger version of this figure is included in **Appendix AK**.

The Barron River, Thomatis Creek and Lake Narelle are the dominant drainage features in the site area. The Barron River lies to the immediate north and west of the site, and averages about 150 m in width with an assumed bed level of around -2 m AHD. Lake Narelle represents the main surface water feature on the proposed site with a water level around 0.5 m AHD indicated in July 2016 by hydrographic survey. This water level is known to fluctuate seasonally between about -1.0 m AHD and +2.0 m AHD.

B6.3.3.e Regional Geology and Hydrogeology

Surface geology in the area of the site is shown on **Figure B6-5**. 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 on (reproduced from QLD Water Resources Commission 1982).

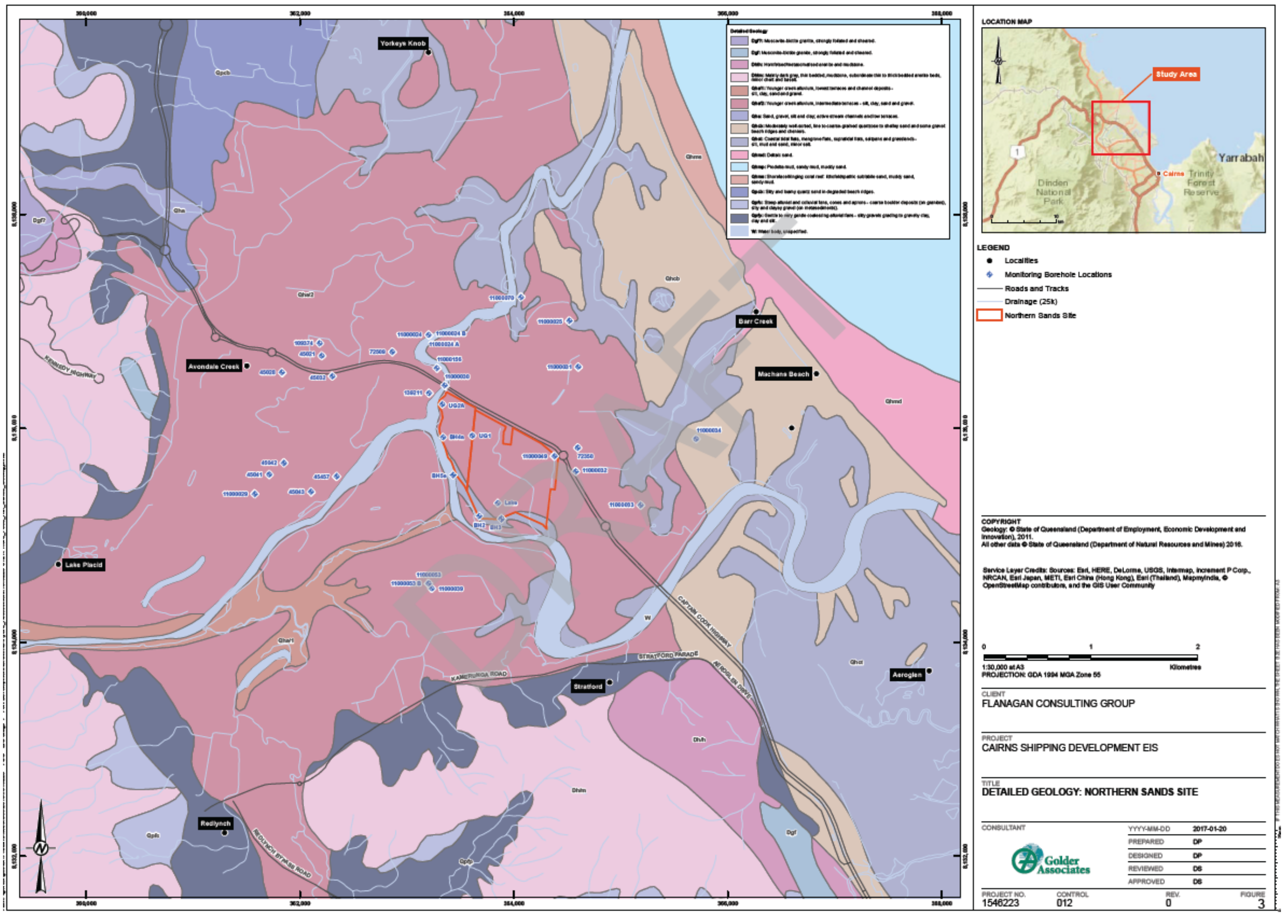

Figure B6-5 Regional geology – Northern Sands Project Area.

Source: Appendix AK (Figure 3).

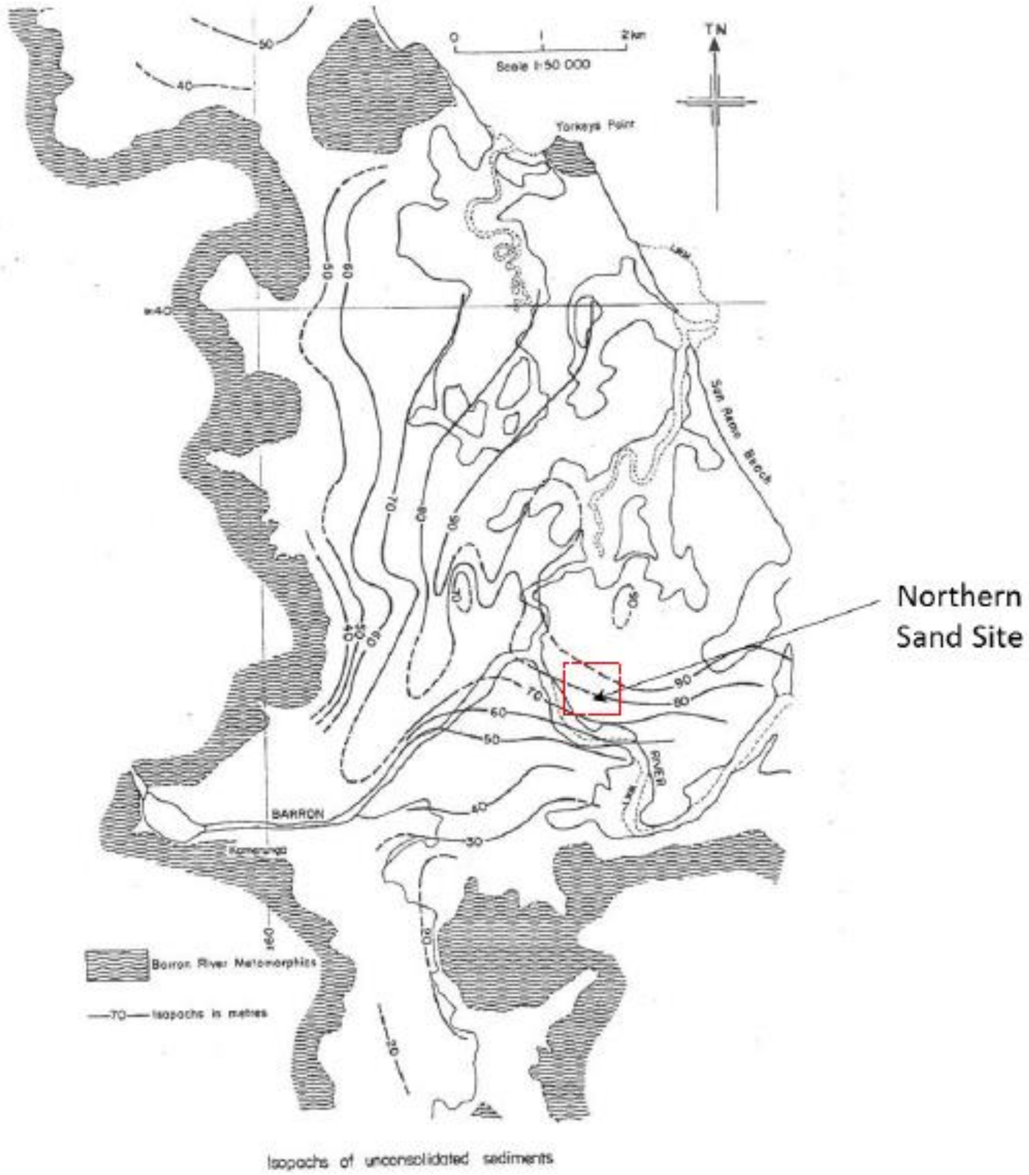

Figure B6-6 Thickness of unconsolidated alluvium.

Source: Appendix AK (Plate 1).

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 (Queensland Water Resources Commission 1982):

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

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

Twenty-four registered bores are located within 2 km of the Northern Sands site as shown on Figure 4 of **Appendix AK**, reproduced below as **Figure B6-13**. Summary details of the registered bores are provided in Appendix A of **Appendix AK**. The range of measured groundwater levels in these registered bores over the period from 1976 to 2016 are also shown on **Figure B6-13**. Hydrographs showing the variation in groundwater level over time for the registered groundwater bores are presented on Figure 5 of **Appendix AK**.

Figures 4 and 5 of **Appendix AK** indicate that groundwater levels are generally lower in the vicinity of Thomatis Creek. Queensland Water Resources (1982) states that 'it seems likely that for most of the year, Thomatis / Richter[s] 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 **Figure B6-7** 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 Lake Narelle, 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 Lake Narelle, or groundwater extraction.

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

Pumping tests carried out for the Queensland 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.

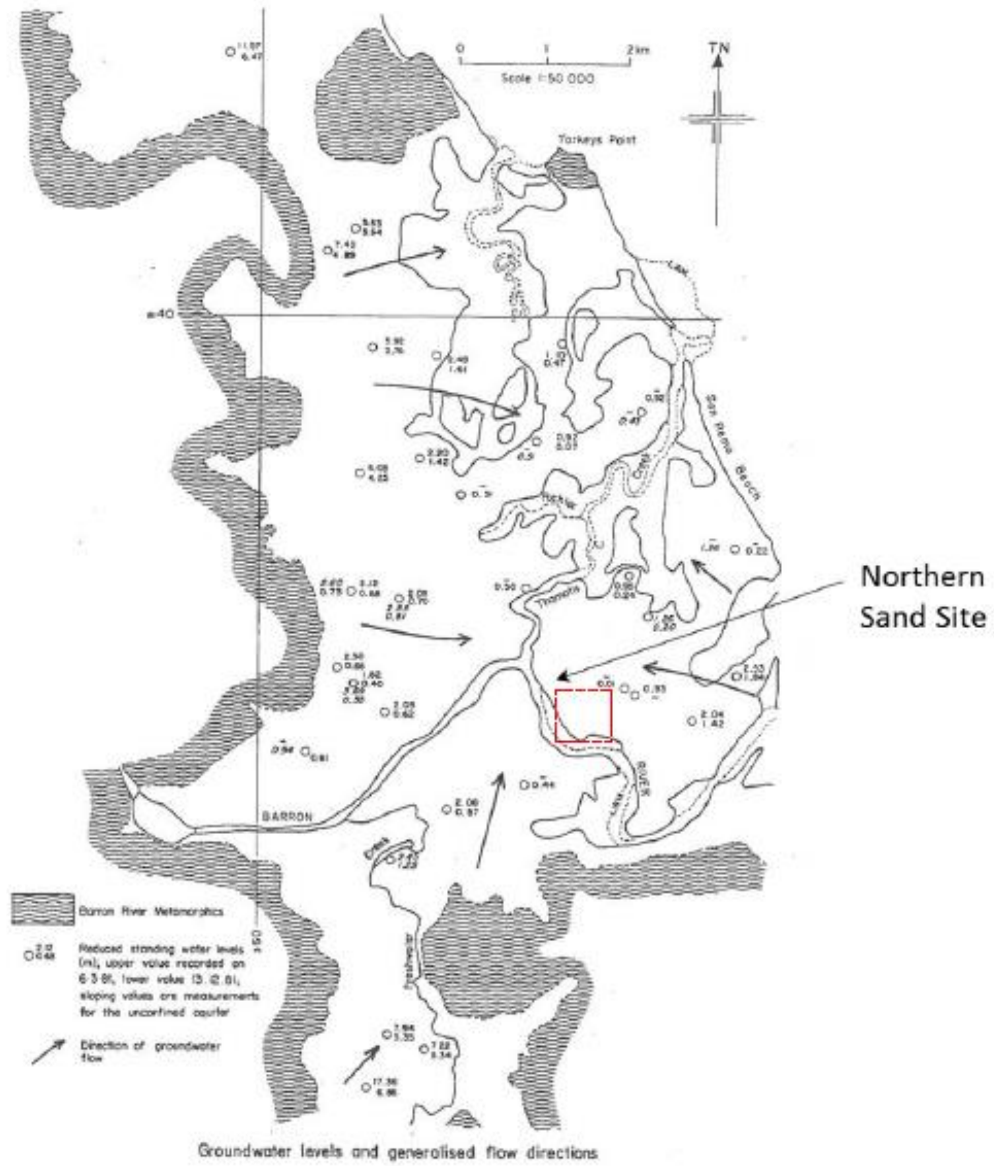

Figure B6-7 Groundwater flow across the Barron Delta.

Source: Queensland Water Resources (1982) in **Appendix AK** (Plate 2).

B6.3.3.f Surface Water

Hydrology

The Northern Sands DMPA and inlet and outlet pipelines are located in the catchment of the Barron River delta. This river has its headwater on the Atherton Tableland and a contributing catchment area of 217 500 ha. It drains into Trinity Bay (i.e. Coral Sea) between the Cairns airport and the township of Machans Beach. Barron River (Catchment 217 500 ha)

The catchment contains five major dams and / or weir(s) with an extensive irrigation network located in the upper reaches, before the river drops through the Barron Gorge and forms the Barron River delta. The delta is also extensively developed with agricultural activities and cane farming with fringing residential development, although this agricultural use is quickly being transformed by urban, commercial and industrial uses. The tidal limit of the Barron River is located some 4.5 km upstream of the site, at Kamerunga just upstream of where the Cairns Western Arterial Road crosses the river (refer to **Figure B6-8**).

Thomatis / Richters Creek (Catchment 449 ha)

Thomatis Creek is the tidal reach that commences at the confluence ('bifurcation') of the Barron River nearby the Northern Sands site and joins Richters Creek approximately 2.7 km downstream. Richters Creek is also largely tidal and receives runoff from a large predominantly agricultural area with a catchment area of 449 ha. The Ponderosa Prawn Farm is located on the opposite bank of Richters Creek south-east of Lot 4 RP746114, and draws water from—and discharges into—this creek. This facility has a licensed discharge for prawn farm exchange water.

Richters Creek is tidal up to Yorkeys Knob Road from where it discharges into Trinity Bay (i.e. the Coral Sea) approximately 5.6 km north of the Barron River and adjacent to the mouth of Yorkeys Creek. On occasions the mouth becomes highly restricted due to sand accretion. However, it is understood that the mouth rarely, if ever, closes completely.

The creek averages about 50 m in width with an estimated depth of 3 m to 4 m.

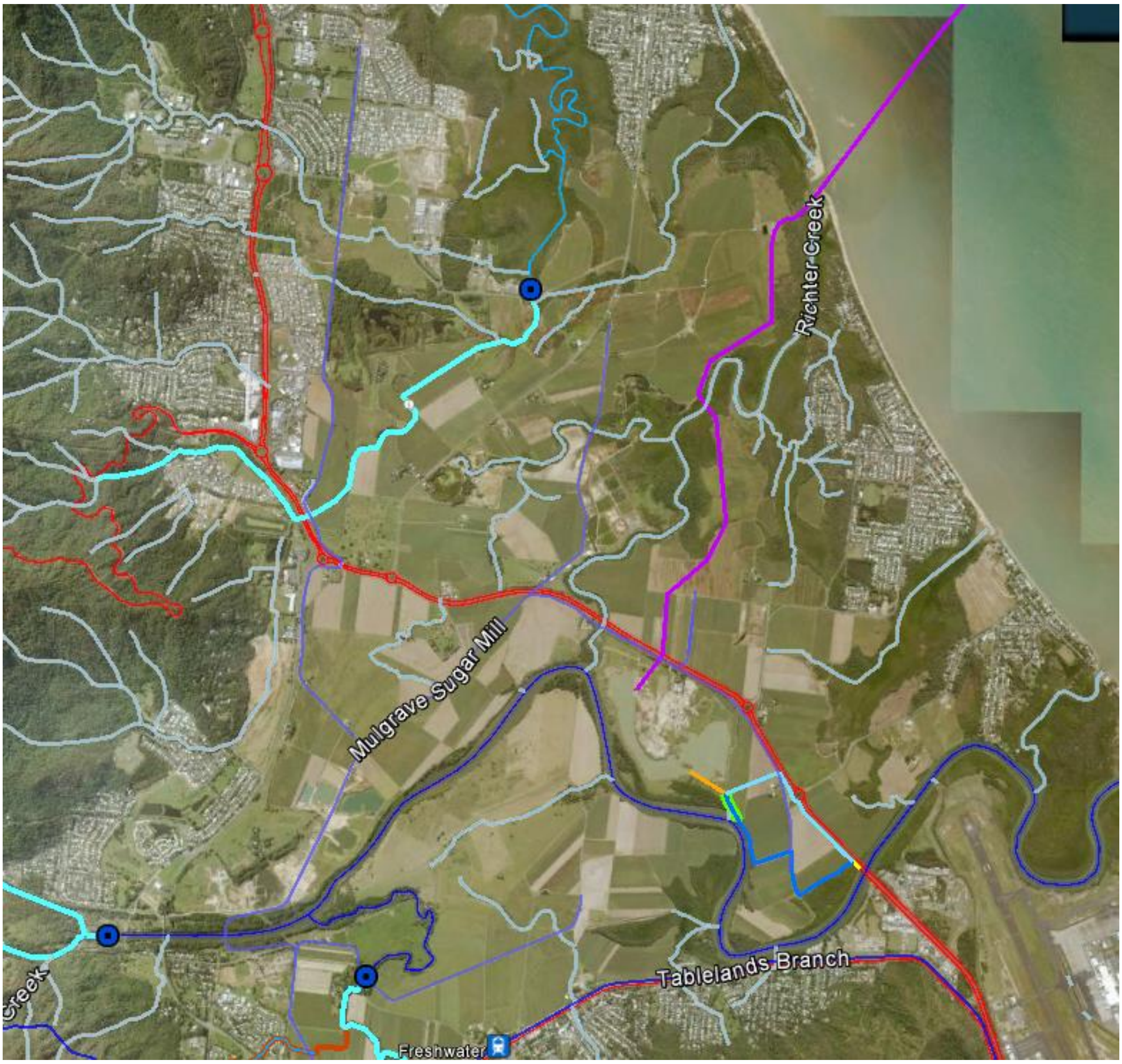

Figure B6-8 Barron River delta drainage features.

The combined Thomatis / Richters Creek system is a major distributary of the Barron River, with the confluence being approximately 9.2 km upstream from the mouth of the Barron River. Tidal exchange occurs between Thomatis / Richters Creek and the Barron River.

Yorkeys Creek (Catchment 267 ha)

Yorkeys Creek has a limited catchment area of 267 ha consisting of urban development in the north and agricultural (i.e. cane farming) use in the southern area of the Barron river delta. Yorkeys Creek runs along the boundary between Lot 60 RP835486 and Lot 100 NR3818. It has an estimated depth of 2 m to 3 m.

Yorkeys Creeks is tidal to just upstream of Yorkeys Knob Road although tide gates installed approximately 300 m upstream of the mouth restrict tidal influence. The vegetation, however, is marine to upstream of the culvert under Yorkeys Knob Road. Yorkeys Creek discharges into the Coral Sea at approximately the same location as Richters Creek.

Half Moon Creek (Catchment 3797 ha)

Half Moon Creek has a significant catchment area of 3797 ha consisting of urban, agricultural (i.e. cane farming) and natural vegetation at the headwaters of the catchment. The creek is 7 m to 9 m in width and its estimated depth is 2 m. Half Moon creek is tidal to approximately Dunne Road and discharges to the Coral sea approximately 250 m north-west of the Half Moon Bay Marina.

Other Water Bodies

The Barron River delta does not contain any water storages that could be considered to be water resources infrastructure. However, it does contain a range of natural and man-made waterbodies, such as:

- other lakes remaining from sand extraction (e.g. Pioneer North Queensland, Lemura Sands)
- natural freshwater ponds in melaleuca wetlands behind the frontal dues (e.g. on Lot 100 NR3818 – Pappalardo's Farm)
- large disused aquaculture ponds on Lot 1 RP800898 – Pappalardo's Farm
- the Ponderosa Prawn Farm (Lot 2/RP894172)
- small man-made dams throughout the delta
- agricultural drains constructed for stormwater drainage purposes throughout cane farms in low-lying areas.

These are mapped on EHP wetland mapping as shown on **Figure B6-9** extracted from **Appendix B8.1**.

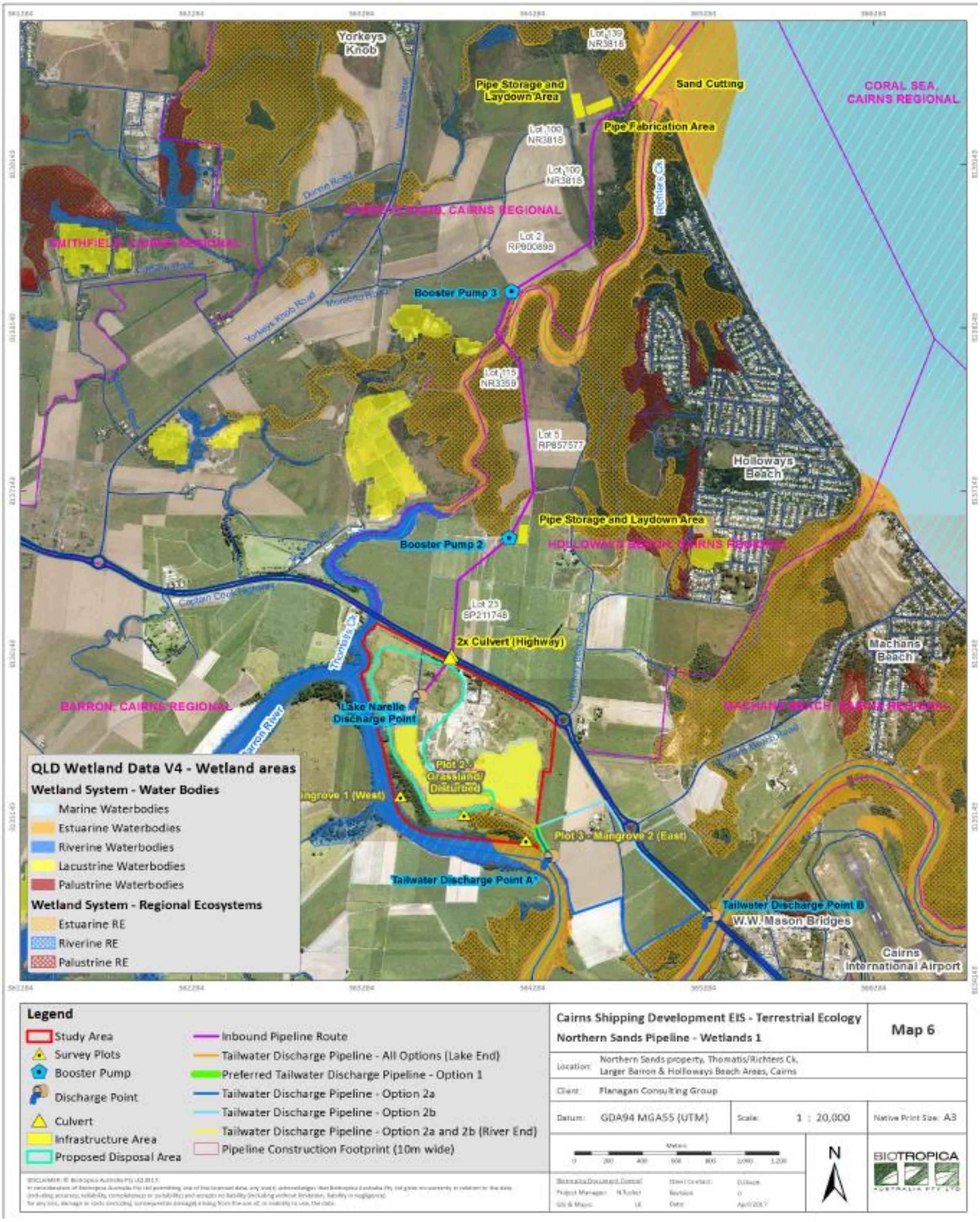

Figure B6-9 Barron River water bodies.

Source: Appendix B8.1 (Map 6).

Hydraulics

The Barron River and the Thomatis Creek / Richters Creek systems are hydraulically interconnected, sharing both drainage and tidal flows. Calibrated modelling (Aquis 2014) of the net seaward advection (i.e. net volume change) for the Barron River estuary reveals that:

- approximately 70% of the annual net seaward flow from the Barron River is discharged at the mouth of the Barron River
- approximately 30% of the annual net seaward flow from the Barron River is diverted first down Thomatis and then Richters Creek.

The net seaward advection was also calculated for the Thomatis and Richters Creek with the following results:

- approximately 95% of the annual flow from Richters Creek is contained within Richters Creek
- approximately 5% of the annual flow from the Richters Creek is diverted within the Thomatis Creek.

The net seaward flow rates are similar to those provided in the Barron River Delta Investigation (Department of Harbours and Marine 1981), indicating that the model is well-calibrated. %%

Flooding

Barron River flooding is described in **Chapter B17** (Hazard and Risk) and in more detail in **Appendix AD**. This is relevant to the CSD Project in two ways:

- protective structures (bunds) are required to contain the placed material at the Northern Sands DMPA and reduce the risk of remobilisation due to flooding during placement and until the place material achieves acceptable resistance to remobilisation)
- these protective bunds could impede floodwaters and hence result in undesirable afflux or velocities.

Neither of these effects is relevant to water resources.

Existing Use of Surface Water

Table B6-7 shows details of a number of bores in the Northern Sands Project Area and notes that many of these are used for water supply. This is a mixture of irrigation and domestic supply and the bores are usually accompanied by small farm dams that store the groundwater. In some cases these also collect incident rainfall and runoff from small local catchments. With the exception of these examples, little use is made of surface water in the Northern Sands Project Area. The watercourses described in **Section B6.3.3.f** are all saline or brackish and unsuitable for potable or irrigation water.

B6.3.3.g Groundwater

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 (bwl).
- Cone Penetrometer Testing (CPT) carried out by GEO Investigate in July 2016. This work comprised 30 No. CPTs 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.
- CPT testing carried out by GEO Investigate in July 2016. This work comprised 14 No. CPTs 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 of **Appendix AK**.
- CPT testing carried out by Golder in November 2016. This work comprised 7 No. CPTs 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 of **Appendix AK**.

The investigation locations are shown on **Figure B6-10**. Inferred subsurface cross-sections (utilising information from registered groundwater bores as well as the investigations outlined above) are presented in **Figure B6-11** and **Figure B6-12**.

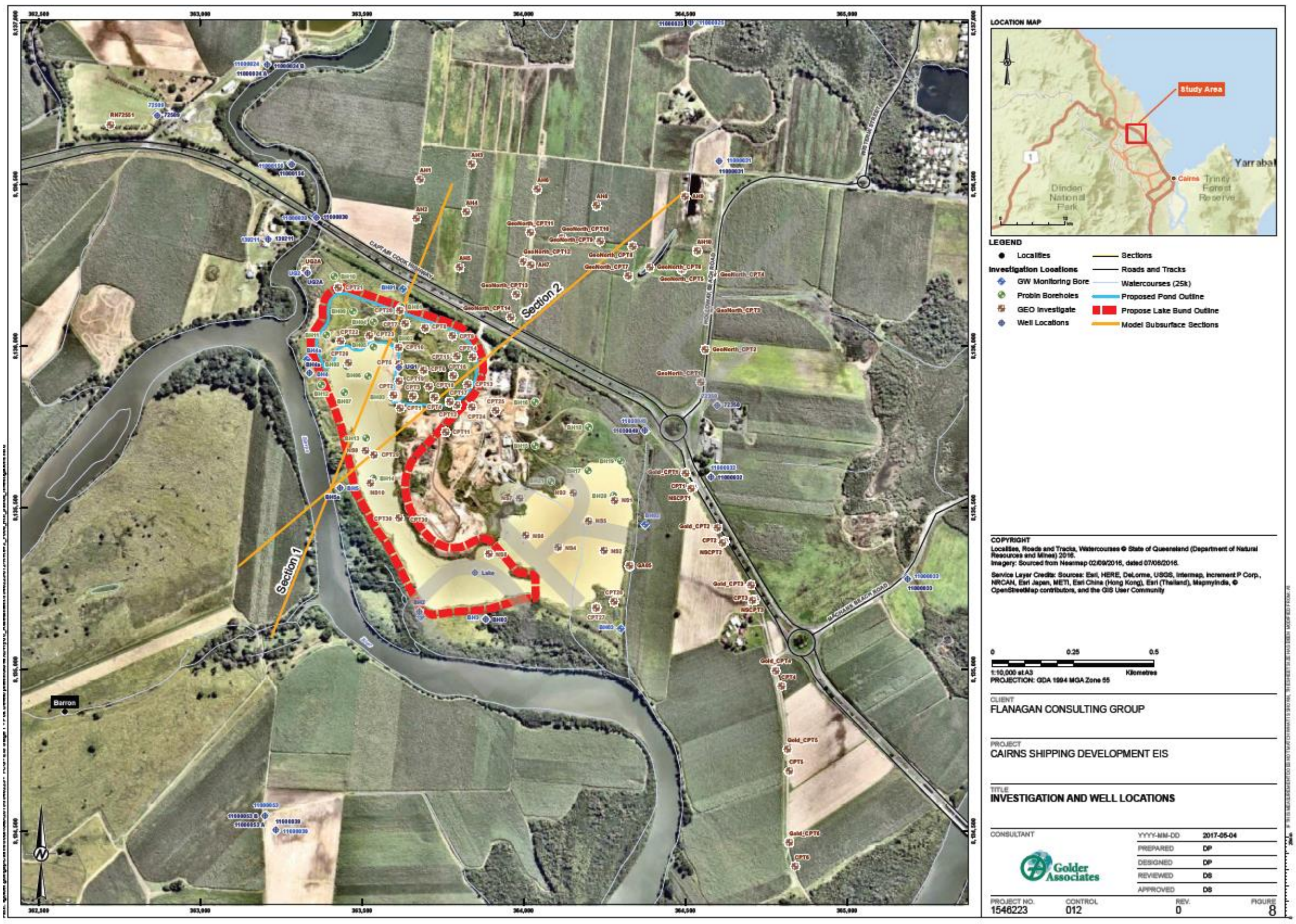

Figure B6-10 Investigation and well locations.

Source: Appendix AK (Figure 8). A larger version of this figure is included in **Appendix AK**

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.

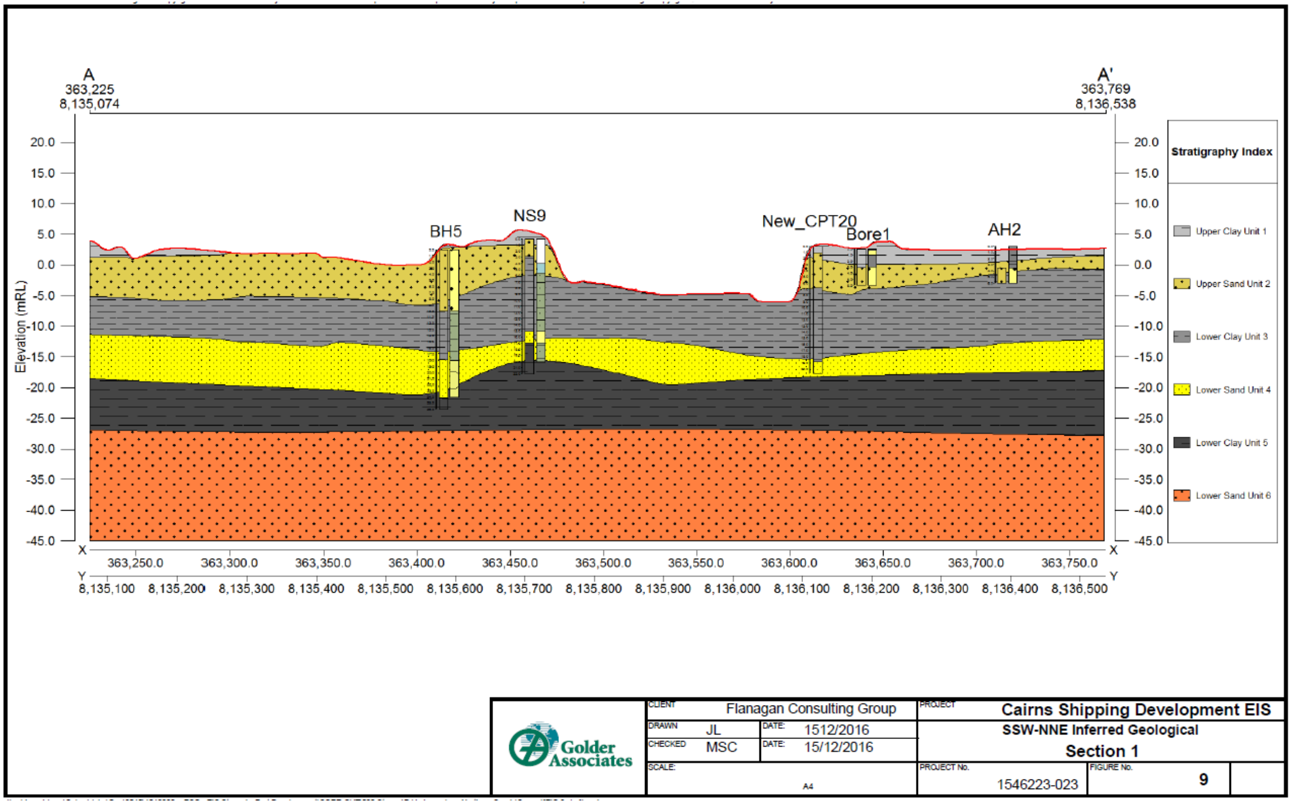

Figure B6-11 Inferred cross sections – Section 1.

Source: Appendix AK (Figure 9). A larger version of this figure is included in **Appendix AK**

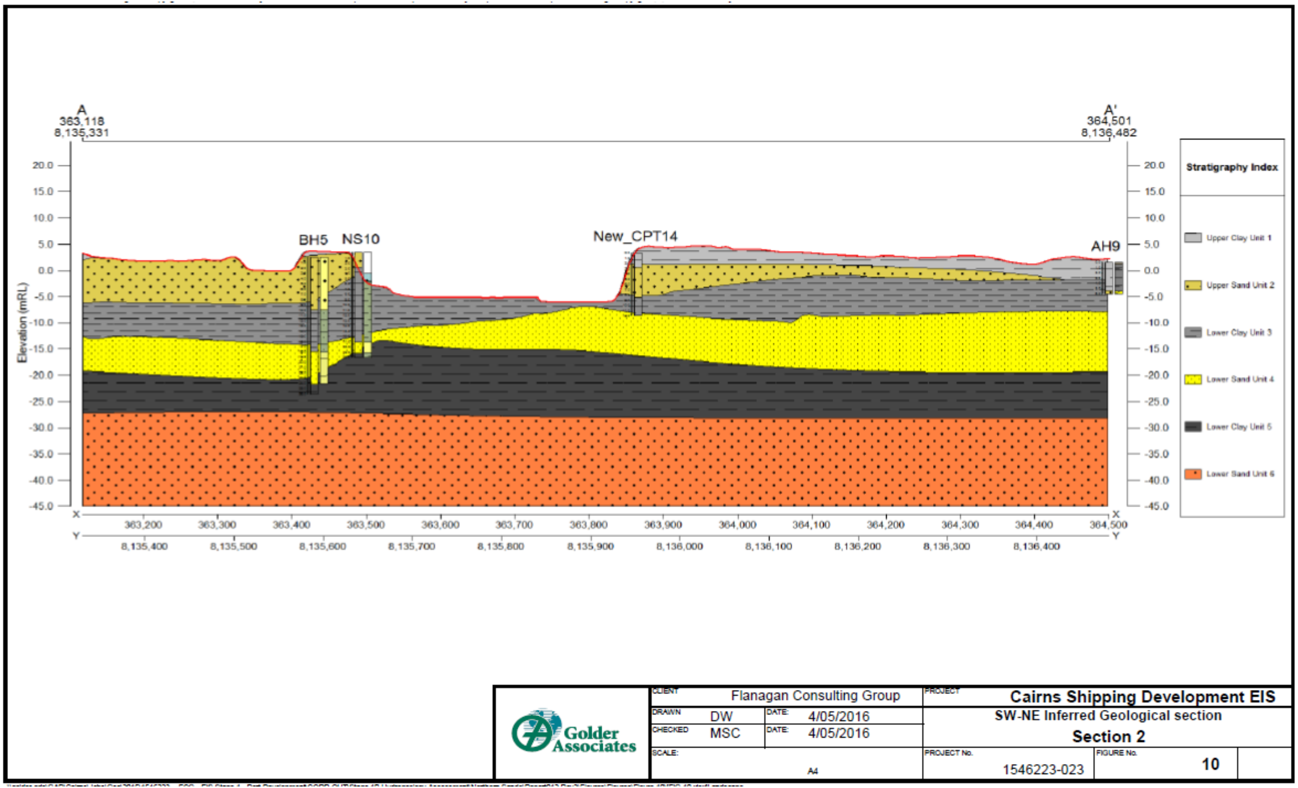

Figure B6-12 Inferred cross sections – Section 2.

Source: Appendix AK (Figure 10). A larger version of this figure is included in **Appendix AK**

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 -26 m AHD is interpreted to represent the lower semi-confined/confined regional aquifer.

Groundwater Levels

Six shallow groundwater monitoring bores were installed by others in the vicinity of the Northern Sands DMPA (see Figure 11 of **Appendix AK**). While it is known that the depth of the monitoring bores ranges between 3.9 m and 8.5 m below ground level (bgl), 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 of **Appendix AK**. Recent survey of groundwater and lake water levels as part of the preparation of **Appendix AK** confirms 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). 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 were installed by Golder at the locations shown on Figure 11 of **Appendix AK**). 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 of **Appendix AK** and summarised in Tables 3 & 4 of **Appendix AK**. These bores were developed after their installation by purging at least five 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 of **Appendix AK**. Groundwater level ranges are summarised in Table 4 of **Appendix AK**. The hydrographs for BH01 and BH03 show a response to rainfall and tidal influence of approximately 0.10 m.

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 of **Appendix AK** 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.

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 a suite of physical and chemical parameters (refer **Appendix AK**). Key findings are:

- Ranges of EC and pH at monitoring bores and regional groundwater bores in the area of Lake Narelle are shown on Figure 13 of **Appendix AK**. This figure needs to be viewed at a larger size than can be accommodated in this chapter. Copies of plots showing the results of water quality testing are presented in Appendix C of **Appendix AK**. Some relevant observations are:
  - The EC in Lake Narelle between September 2011 and March 2016 varied between 200 µS/cm and 1000 µS/cm. These results are indicative of fresh water.
  - It is noted that registered groundwater bores 11000049 and 11000033 to the immediate east of Lake Narelle 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. These results are indicative of brackish to saline water.
- Golder monitoring bores BH01, BH02, and BH03 were sampled on 29 September and 22 November 2016, and GA04 was sampled on 24 November 2016. The field data and laboratory results are presented in Appendix E of **Appendix AK** and key data on pH and salinity are summarised in **Table B6-4** below.

TABLE B6-4 FIELD AND LABORATORY PH AND SALINITY RESULTS

MONITORING BORE	PH RANGE LAB RESULTS	PH RANGE FIELD RESULTS	EC RANGE (MS/CM) LAB RESULTS	EC RANGE (MS/CM) FIELD RESULTS	SALINITY
BH01	6.8 to 7.0	6.5 to 7.2	230 to 250	300 to 373	Fresh water
BH02	7.7 to 7.9	6.7 to 8.0	9300 to 11 000	8000 to 10 000	Brackish water
BH03	7.9	7.2 to 10.2	24 000	25 500 to 26 540	Brackish water
GA04	6.5	5.74	160	148	Fresh water

Source: Appendix AK (Table 5).

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 of **Appendix AK** and summarised in **Table B6-5**.

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 of **Appendix AK**. The results of the Talsma tests are presented in Appendix G of **Appendix AK** and are summarised in **Table B6-5**.

TABLE B6-5 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

Source: Appendix AK (Table 6).

Porosity

Samples of the upper sands from GA04 and at GA05 teste 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 of **Appendix AK** and the assessed porosity results are presented in **Table B6-6**.

TABLE B6-6 ASSESSED POROSITY FOR UPPER SAND FORMATION

SAMPLE	INFERRED DENSITY RATIO (%) FROM CPT	INFERRED IN SITU DENSITY (T/M3)	INFERRED DRY DENSITY (T/M3)	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

Source: Appendix AK (Table 7).

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

Conceptual Hydrogeological Model

A conceptual hydrogeological model was developed to model the existing situation and test impacts. This is disused in **Section B6.4.2.b**.

Existing Use of Groundwater

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

Twenty-four registered bores are located within 2 km of the Northern Sands site as shown on **Figure B6-13**. (While **Figure B6-13** shows groundwater levels at registered bores, it also shows the location of bores in the vicinity of the Northern Sands DMPA). Summary details of the registered bores are shown in **Table B6-7** below.

TABLE B6-7 REGISTERED BORES

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

Source: Appendix AK (Appendix A).

As shown in this table, these bores are used for one of the following purposes:

- water supply
- water resources investigation
- sub-artesian monitoring.

Water supply use is a combination of domestic supply and irrigation for sugar cane.

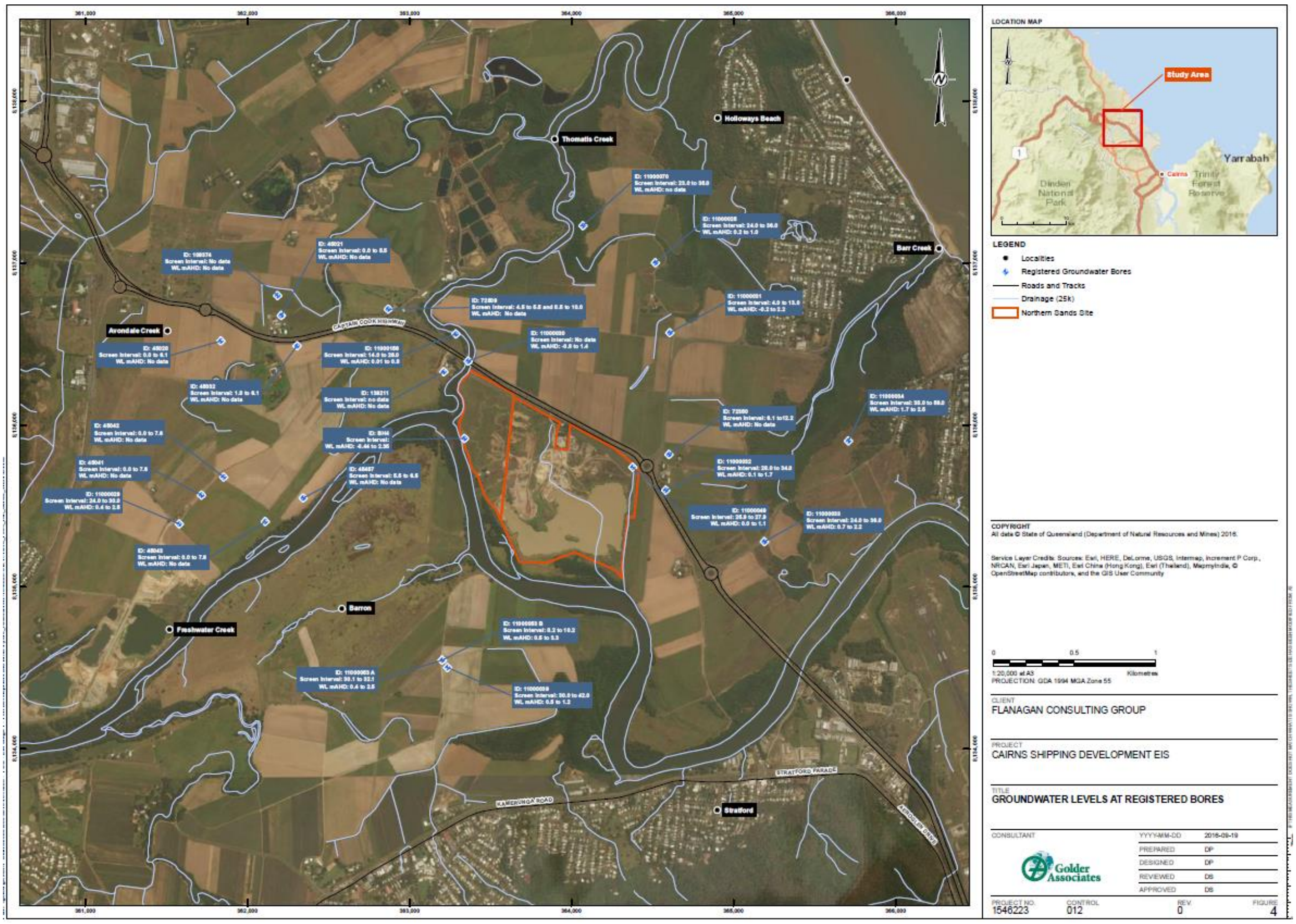

Figure B6-13 Groundwater levels at registered bores.

Source: Appendix AK (Figure 4). A larger version of this figure is included in **Appendix AK**.

Groundwater Dependent 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 on **Figure B6-14**. Further information on groundwater dependent ecosystems is provided in **Chapter B8** (Terrestrial Ecology). **Figure B6-14** indicates the presence of vegetation with a high potential for groundwater interaction between Lake Narelle 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.

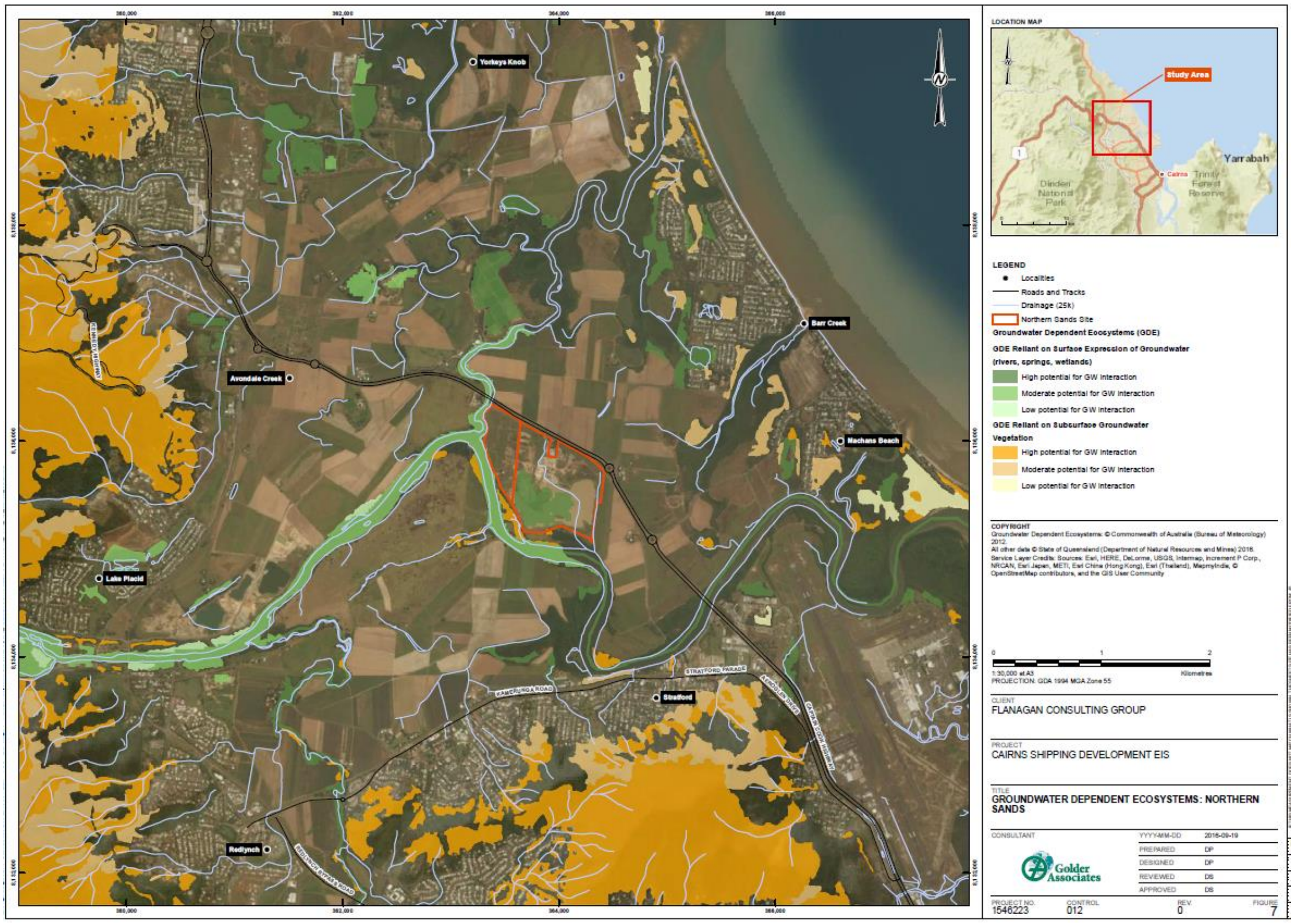

Figure B6-14 Groundwater dependent ecosystems – Northern Sands Project Area.

Source: Appendix AK (Figure 7). A larger version of this figure is included in **Appendix AK**.

Surface Water / Groundwater Interaction

As explained in **Section B6.4.2.b**, a numerical groundwater model was established for assessing impacts and this was used to investigate surface water / groundwater interaction.

B6.3.4 Tingira Street Project Area

B6.3.4.a Location and Site Details

The Tingira Street DMPA consists of two sites located on port land previously reclaimed by Ports North at the southern end of Tingira Street, Portsmith. The site is described as Lot 27 SP218291 and is located on the southern boundary of an industrial area within Strategic Port Land, abutting Smiths Creek to the east and a mangrove system to the west. Refer **Figure B6-15**. It has an area of 26.52 ha and contains

- Site 1 (southern site) 4.3 ha (approx.)
- Site 2 (northern site) 1.3 ha (approx.).

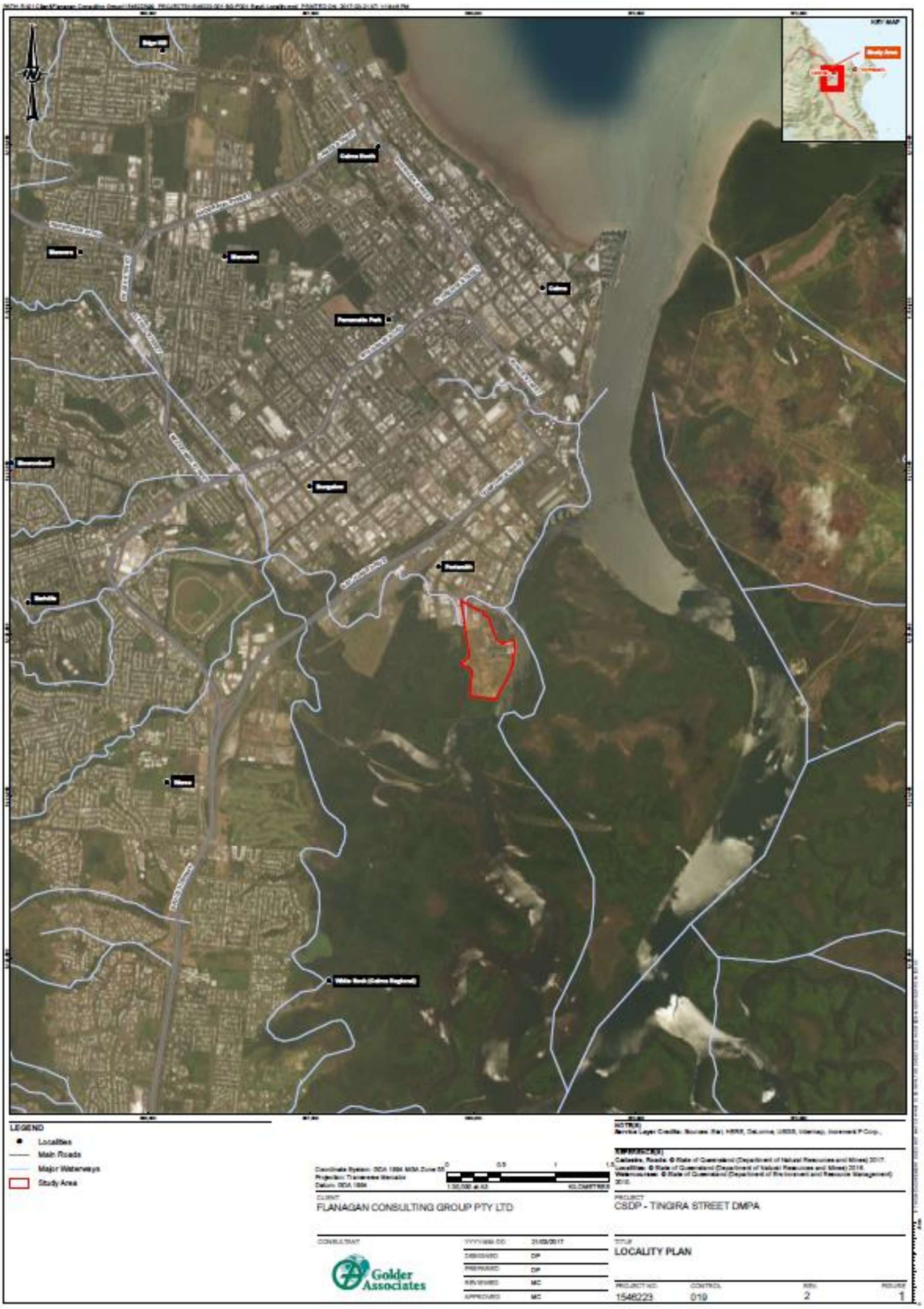

Figure B6-15 Locality plan – Tingira Street DMPA.

Source: Appendix X (Figure 1).

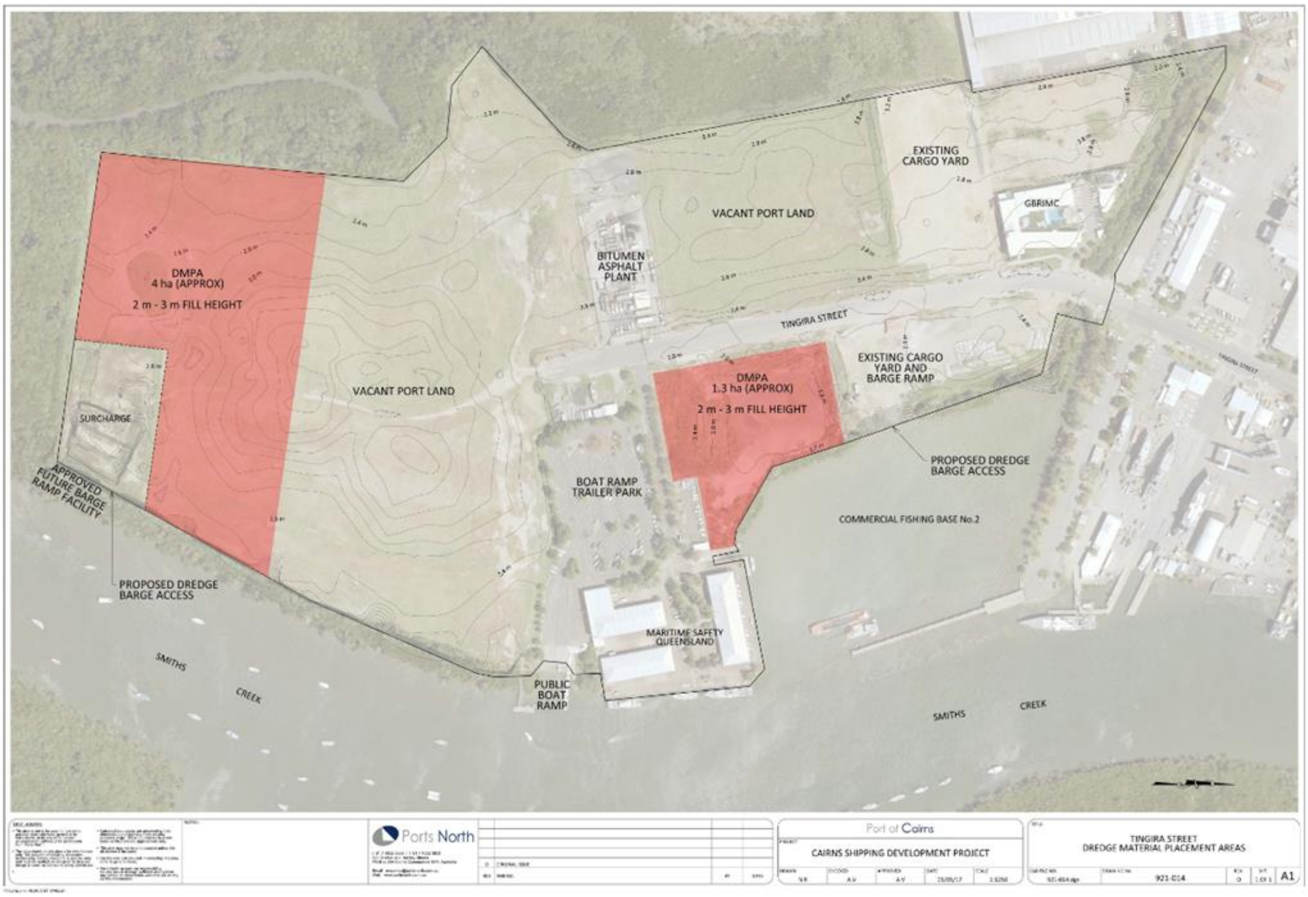

Figure B6-16 Site plan– Tingira Street DMPA.

Source: Ports North.

B6.3.4.b Site History

Available historical information for the overall Tingira Street site indicates the following:

- Prior to 1982 the overall Tingira Street site was mangrove wetland.
- In 1982 a bund was constructed around the portion of the site west of the present Tingira Street alignment. After construction of the bund some mangroves were cleared and about 0.5 m of dredged material from Commercial Fisherman's Base No 2 was hydraulically placed within the bunded area.
- In the late 1980s the remainder of the site was cleared of mangroves and imported quarry fill was placed to form and surcharge the proposed alignment of Tingira Street and the area of what is now the Harbours and Marine Base. Excess material from the surcharge was later used as fill in adjacent areas of the site.
- From the early 1990s the Cairns Port Authority began to accept small amounts of soil and pavement materials at the site from the Cairns City Council and building contractors. The Port Authority is also understood to have entered into agreements with several demolition contractors to accept demolition wastes (e.g. concrete rubble and soils). The majority of filling at the site is understood to have occurred between 1994 and 1996.
- From around 2008 various parts of the site were surcharged, with some areas subsequently being developed.

B6.3.4.c Previously Proposed End Use

As described in more detail in **Chapter B1** (Land) the area to be used as the Tingira Street DMPA is part of a larger lot planned to be used as an industrial subdivision. The proposal originally involved developing the site incrementally over a period of 10-15 years by filling and surcharging using imported material.

B6.3.4.d Topography

As outlined in **Section B6.3.4.b**, the Tingira Street DMPA site has been formed by reclamation filling. Ground surface levels across the site typically range from about 2.0 m AHD around the boundaries of the site to about 4.0 m AHD in the south central part of the site. Localised lower lying areas with surface levels of about 1.7 m AHD exist within proposed DMPA Site 2. It is noted that surcharge material for the proposed Common Users Barge Facility (CUBF) remains in place adjacent to proposed DMPA Site 1. **Figure B6-17** shows site levels from a site survey undertaken following the last filling exercise.

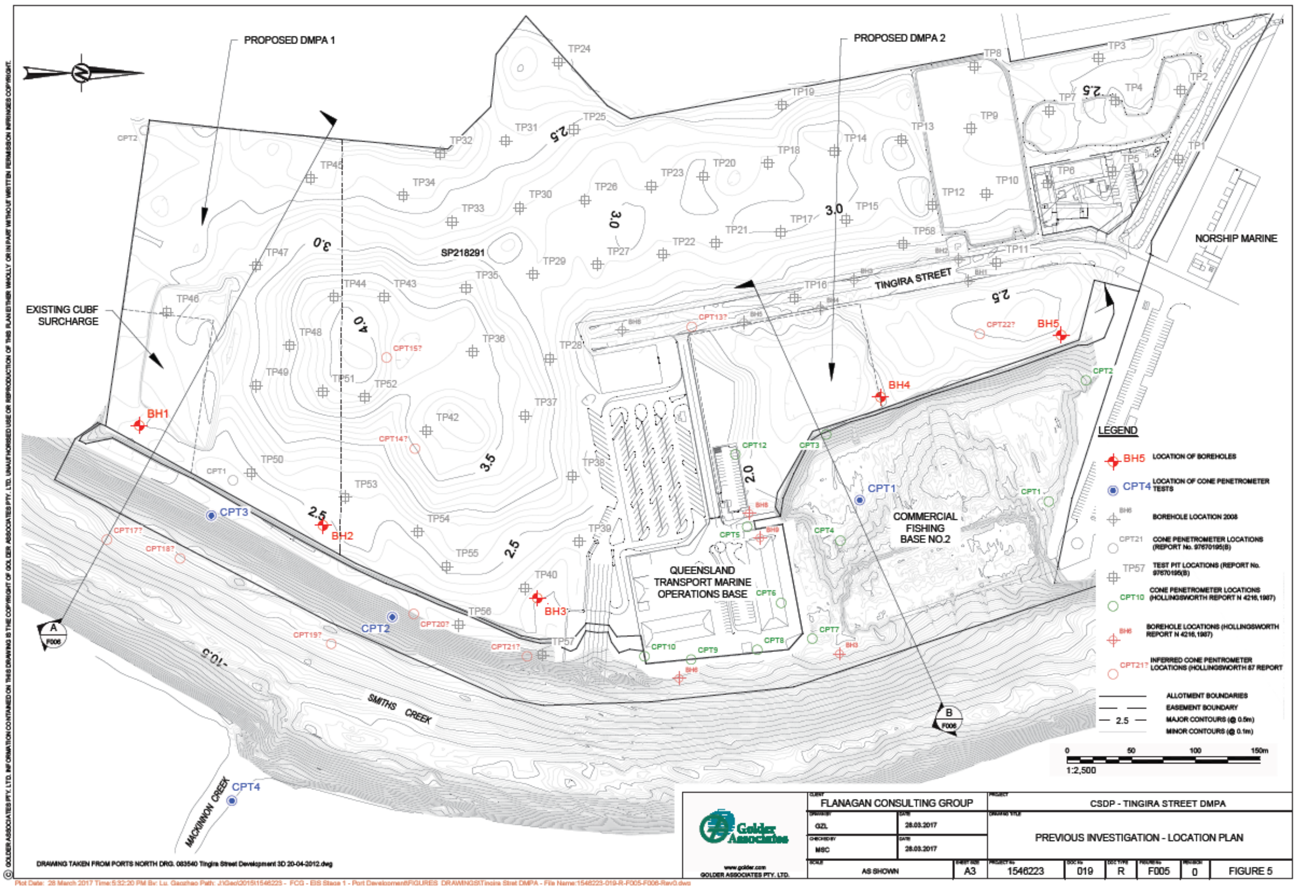

Figure B6-17 Site levels and location of test pits.

Source: Appendix X (Figure 5). See **Figure B6-18** for cross sections AA and BB. A larger version of this figure is included in **Appendix X**.

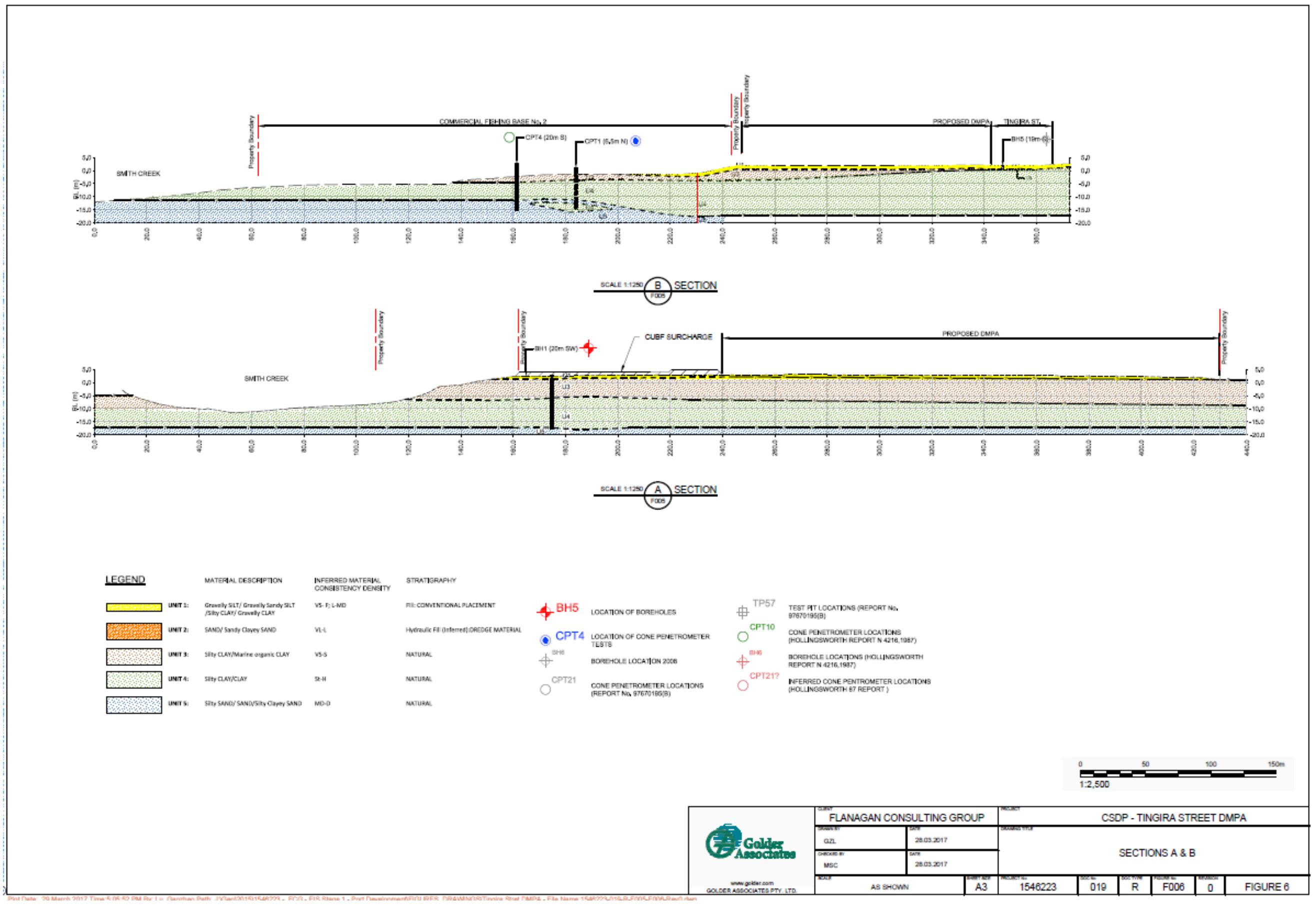

Figure B6-18 Sections through Tingira Street DMPA.

Source: Appendix X (Figure 6). Location of sections shown on **Figure B6-17**. A larger version of this figure is included in **Appendix X**.

B6.3.4.e Regional Geology and Hydrogeology

Published geological information from State of Queensland (Department of Employment, Economic Development and Innovation 2011) indicates that the Tingira Street site is underlain by Holocene aged coastal mangrove flats comprising mud, silt and sand. The Holocene aged deposits are underlain by older Pleistocene age consolidated alluvial deposits comprising clays and sands. An extract from the geology mapping showing the surface geology of the Tingira Street area is reproduced as **Figure B6-19**.

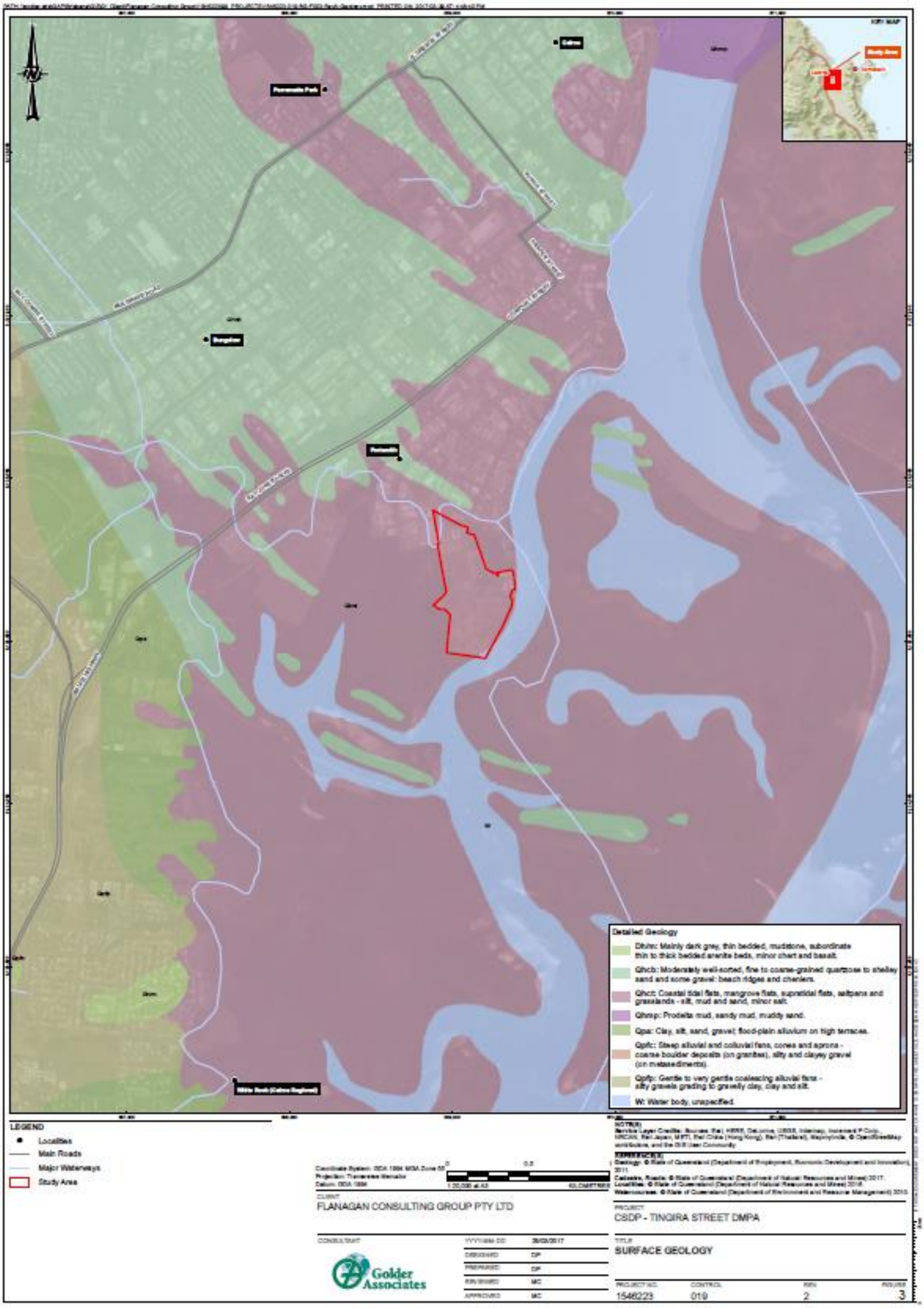

Figure B6-19 Surface geology – Tingira Street Project Area.

Source: Appendix X (Figure 3).

B6.3.4.f Surface Water

Hydrology

The Trinity Inlet catchment contains no major rivers (Environment Science & Services 1980). It comprises minor creeks and natural drainage lines, although there are none within or near the Tingira Street Project Area. Lily Creek is a minor creek located to the north of the study area. A minor open channel runs alongside Fearnley Street to the south west of the study area, draining to Smiths Creek. It is noted that the existing drainage lines, particularly the Fearnley St and Chinaman Creek drain have been heavily modified due to the urban development in the catchment. These drains were modified to reduce the volume of existing wetlands to reduce the risk of mosquitoes and tropical diseases.

For most of the year, the minor creeks and drainages within the study area experience low flows. During the wet season, however, a substantial amount of run-off can occur over short periods.

Hydraulics

Surface levels across the overall site are shown on **Figure B6-17**. This shows that surface levels across DMPA 1 range from about 2.0 m to 2.2 m AHD around the eastern, southern and western boundaries, and from about 2.0 to 4.0 m AHD along the northern boundary. DMPA Site 1 is bordered by mangroves to the west and south, Smiths Creek to the east and vacant land to the north. A bund has been constructed along Smiths Creek on the eastern boundary. Surcharge material for the proposed Common Users Barge Facility is located in the south east corner of the overall site adjacent to DMPA Site 1. The surface of DMPA Site 1 is generally grassed. Surface runoff is generally directed towards the eastern, southern and western boundaries.

Surface levels across DMPA Site 2 are generally about 2.0 m AHD around the eastern, northern and western boundaries, and range to about RL 2.5 m along the northern boundary. The central part of the area drops to about 1.7 m AHD. DMPA Site 2 is bordered by Tingira Street to the west, an access road and carpark to the south, Smiths Creek to the east and barge facilities to the north. The surface of DMPA Site 2 is generally covered with long grass, although the lower lying area is bare. Surface water tends to pond in the lower lying areas.

In terms of drainage, there are two sag points located along Tingira Street. There is also the channel located at the northern portion of the site and it is possible that overtopping of the road could occur at this point.

Flooding

Flooding is described in **Chapter B17** (Hazard and Risk). In summary, the site is not affected by flooding.

Existing Use of Surface Water

Groundwater in the site area is generally saline and is not a viable potable water supply source. There is no recorded surface water extraction within the Project Area or its surrounds.

B6.3.4.g Groundwater

Scope

The process of placing stiff clay at the Tingira Street DMPA is most unlikely to involve groundwater impacts. Accordingly, the assessment has been undertaken at a high (desktop) level, drawing on available data sets and a number of technical studies undertaken by Golder Associates over serval years.

Hydrogeology

In general terms the hydrogeology of the Tingira Street area is characterised by shallow groundwater systems in the Holocene sediments, and deeper aquifers within the Pleistocene age sediments. The deeper aquifers are isolated from surface waters and shallow aquifers and likely discharge well out into Trinity Bay.

Stratigraphy

Inferred geotechnical sections for DMPA Site 1 and Site 2 are presented on **Figure B6-18** and indicate the following stratigraphy.

- Reclamation fill materials – generally comprising gravelly sandy silts/clays with variable amounts of pavement and building materials. Typically extending from the surface to about 0.0 m AHD, overlying
- Holocene sediments – generally comprising soft marine clays. Typically extending from about 0.0 m AHD to between about -4.0 and -9.0 m AHD (note the upper parts of this unit may also include some hydraulically placed soft clay); overlying
- Pleistocene sediments – generally comprising stiff to hard silty/sandy clays and medium dense to dense silty/clayey sands. Typically extending from about -4.0 to -9.0 m AHD to greater than -20.0 m AHD.

Groundwater Levels

Groundwater is generally encountered within about 2 m to 3 m below the surface of the overall site (i.e. at about 0 m to 1 m AHD).

Groundwater levels are known to fluctuate on a tidal and seasonal basis. The direction of groundwater flow is expected to be east towards Smiths Creek.

Groundwater Quality

The groundwater is brackish, although a layer of freshwater is sometimes present on top of the brackish water (particularly during the wet season).

Hydraulic Conductivity

No assessment was made of hydraulic conductivity as it was not considered necessary for the level of assessment required.

Porosity

No assessment was made of porosity as it was not considered necessary for the level of assessment required.

Conceptual Hydrogeological Model

No conceptual hydrogeological model was developed as it was not considered necessary for the level of assessment required.

Existing Use of Groundwater

Use of the groundwater in developed areas to the north and west of the overall Tingira Street site is uncommon due to its brackish nature.

Groundwater Dependent Ecosystems

GDE distribution and extent is derived from mapping available from the National Atlas of Groundwater Dependent Ecosystems (GDE Atlas: www.bom.gov.au/water/groundwater/gde/). Mapping indicates that there are no areas of surface and sub-surface GDEs present in the vicinity of the Tingira Street Project Area (the nearest mapped are is over 1 km away – see **Figure B6-20**

Figure B6-20 Groundwater dependent ecosystems – Tingira Street Project Area.
Source: GDE Atlas: www.bom.gov.au/water/groundwater/gde/.

Surface Water / Groundwater Interaction

No consideration of surface water / groundwater interaction was undertaken as it was not considered necessary for the level of assessment required.

B6.4 Assessment of Potential Impacts

B6.4.1 Impact Assessment Methodology

B6.4.1.a Risk-based Assessment

The following impact assessment has been undertaken for each of the matters described in the previous chapter. It uses the risk-based process adopted for the Revised Draft EIS as outlined in **Chapter A1** (Introduction) and includes an assessment of the following:

- the magnitude of impacts (significance / consequence) as discussed below
- the duration of impact (from **Chapter A1** (Introduction)
- the likelihood of impact (from **Chapter A1** (Introduction)
- risk level (from **Chapter A1** (Introduction).

These are considered together to determine the final level of impact risk, which is described in **Table B6-14**. Care has been taken to select consequence and risk rating criteria that apply equally to both to surface water and groundwater.

B6.4.1.b Impact Significance / Consequence Criteria

Table B6-8 describes consequences (sometimes referred to as significance criteria). These have been developed specifically for the topics addressed in this chapter. Care has been taken to select consequence and risk rating criteria that can be used for both surface water and groundwater.

TABLE B6-8 SIGNIFICANCE / CONSEQUENCE CRITERIA

IMPACT SIGNIFICANCE / CONSEQUENCE	DESCRIPTION OF SIGNIFICANCE
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. Could lead to permanent loss of regionally-important groundwater or surface water resource. 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. Could lead to permanent loss of locally-important groundwater or surface water resource. 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. Could lead to medium term loss of locally-important groundwater or surface water resource. 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).

(Continued over)

IMPACT SIGNIFICANCE / CONSEQUENCE	DESCRIPTION OF SIGNIFICANCE
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. Could lead to short term loss of adjacent groundwater or surface water resource. 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 surface or groundwater quality as a result of the project.

Source: Appendix AK (Table 9) plus additional water resource criteria.

B6.4.1.c Duration of Impacts

Table B6-9 shows the general approach to classifying the duration of identified impacts. This applies to all topics and is identical to that contained in **Chapter A1** (Project Introduction).

TABLE B6-9 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

B6.4.1.d Likelihood

Likelihood of risk is described in **Table B6-10** below. This applies to all topics and is identical to that contained in **Chapter A1** (Project Introduction).

TABLE B6-10 LIKELIHOOD OF IMPACT

CATEGORY	DEFINITION
Almost Certain	Very likely to occur during construction or the operational phases.
Likely	Likely to occur during construction or operational phases.
Possible	Less than likely to occur but still appreciable with the probability of occurrence rated above 50 percent.
Unlikely	May occur during construction or during the life of the project with the probability of occurrence being below 50 percent, but not negligible.
Highly Unlikely/Rare	Highly unlikely to occur but theoretically possible.

B6.4.1.e Risk Matrix

Risk is described as the product of likelihood and consequence as shown in **Table B6-11** below. This applies to all topics and is identical to that contained in **Chapter A1** (Project Introduction).

TABLE B6-11 RISK MATRIX

LIKELIHOOD	**CONSEQUENCE**				
	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

B6.4.1.f Risk Rating

The rating of risk as assessed above is as shown in **Table B6-12** below. These have been developed specifically for the topics addressed in this chapter. Care has been taken to select consequence and risk rating criteria that apply equally to both to surface water and groundwater.

TABLE B6-12 RISK RATING LEGEND

Extreme Risk	An issue requiring change in project scope; almost certain to result in a 'significant' impact on the environment or a regionally-important groundwater or surface water resource
High Risk	An issue requiring further detailed investigation and planning to manage and reduce risk; likely to result in a 'significant' impact on the environment or a locally-important groundwater or surface water resource
Medium Risk	An issue requiring project specific controls and procedures to manage environmental or water resources values
Low Risk	Manageable by standard mitigation and similar operating procedures
Negligible Risk	No additional management required

Source: Appendix AK (Table 13) plus additional water resource criteria.

B6.4.2 Northern Sands Project Area

B6.4.2.a Surface Water

Discussion

As noted in **Section B6.3.3.f**, little use is made of surface water in the Northern Sands Project Area. The watercourses are all saline or brackish and unsuitable for potable or irrigation water. While some small storages have been constructed to store groundwater (either from infiltration or bores), the CSD Project will have little impact on these other than possible via groundwater as described in **Section B6.4.2.b**.

Impacts on marine water quality are discussed in **Chapter B5** (Marine Water Quality) while water-related hazards (i.e. flooding and stormtide), and potential spillage from the delivery pipeline are described in **Chapter B17** (Hazard and Risk).

Risk Assessment

Table B6-13 below summarises the assessment of impacts without mitigation.

TABLE B6-13 SUMMARY OF UNMITIGATED SURFACE WATER IMPACTS – NORTHERN SANDS PROJECT AREA

PRIMARY IMPACTING PROCESSES	INITIAL ASSESSMENT WITH STANDARD (STATUTORY) MITIGATION MEASURES IN PLACE		
	SIGNIFICANCE OF IMPACT	LIKELIHOOD OF IMPACT	RISK RATING
Impact of the construction and operation of the soft clay placement process on surface water resources.	Negligible	Unlikely	Negligible

Mitigation is not required.

B6.4.2.b Groundwater

Conceptual Hydrogeological Model

A conceptual hydrogeological model for the Northern Sands DMPA is illustrated on **Figure B6-21** based on the inferred subsurface cross-section shown on Figure 9 of **Appendix AK**.

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 semiconfined 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 Queensland Water Resources Commission (1982). Close to these streams, groundwater exchange will occur as a result of tidal fluctuations in the streams.
- Groundwater in the deep confined aquifer is towards the coast. Recharge to this aquifer occurs further to the west where the confining unit is absent in some areas.

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 of **Appendix AK**. The simplified cross-sectional models are shown on **Figure B6-22** below.

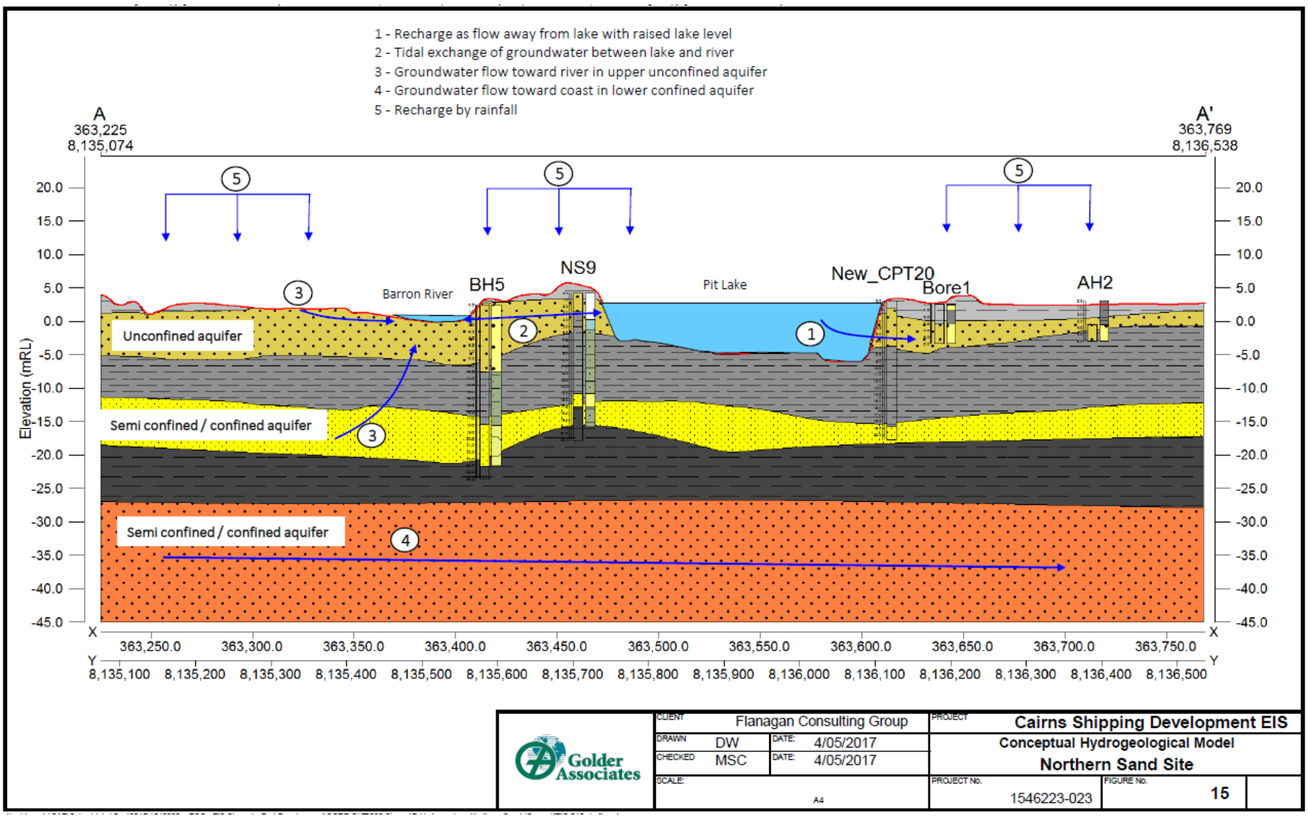

Figure B6-21 Conceptual hydrogeological model.

Source: Appendix AK (Figure 15).

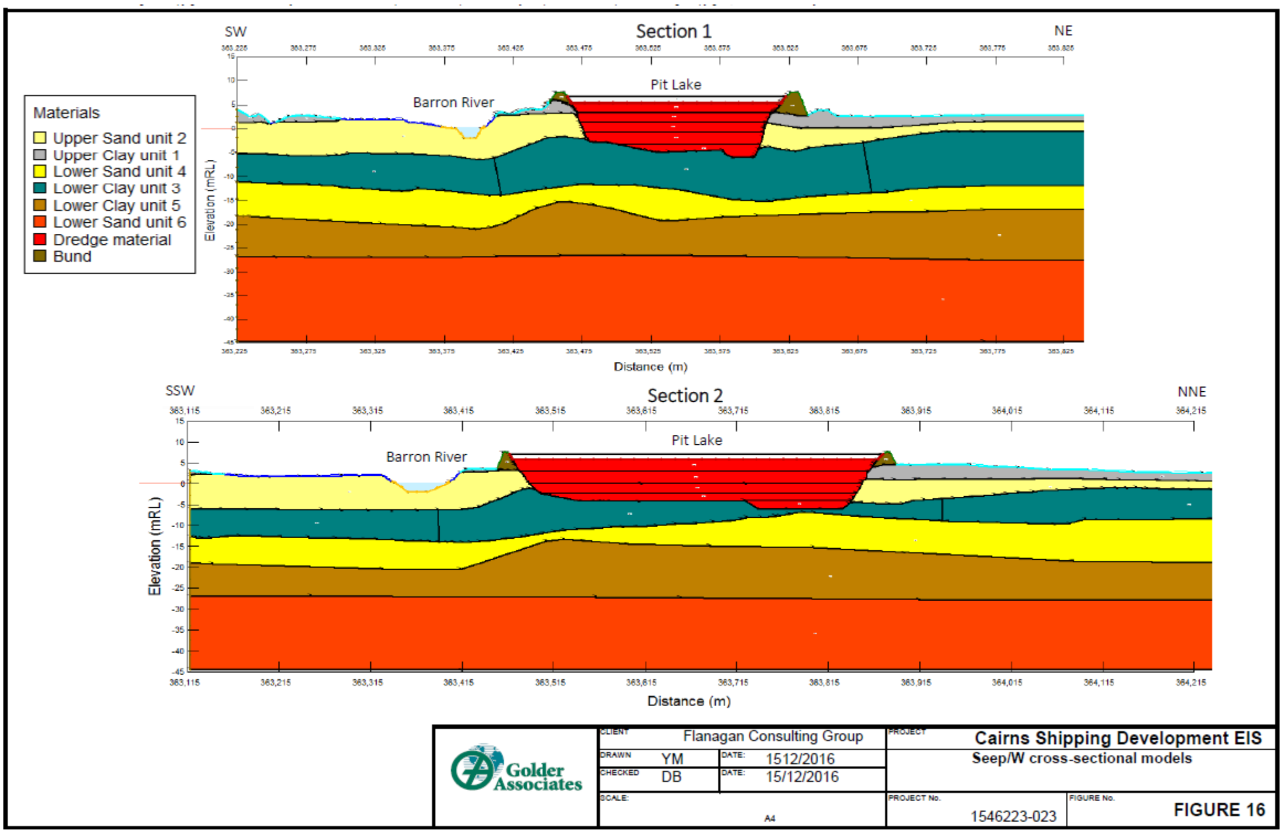

Figure B6-22 Simplified cross-sectional models.

Source: Appendix AK (Figure 16). A larger version of this figure is included in **Appendix AK**.

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 was carried out for maximum lake levels at 5.0 m AHD, 5.5 m AHD, 6.5 m AHD and 7.0 m AHD. Placement of the dredged material was modelled in four sequential steps, with placement of the dredged material in a series of horizontal lifts to raise the dredged material level a maximum level at 0.2 m below the maximum lake level over a period of 80 days. It was assumed that the dredged material will have a hydraulic conductivity of 1 x 10-7 m/s.

The adopted boundary conditions are shown on **Figure B6-23**. The water level in the lake was modelled as increasing from 0.25 m AHD to 3 m AHD over the first seven days of filling, and then being held constant at this level until the level of dredged material in the lake has risen t above the top of the upper sand layer.

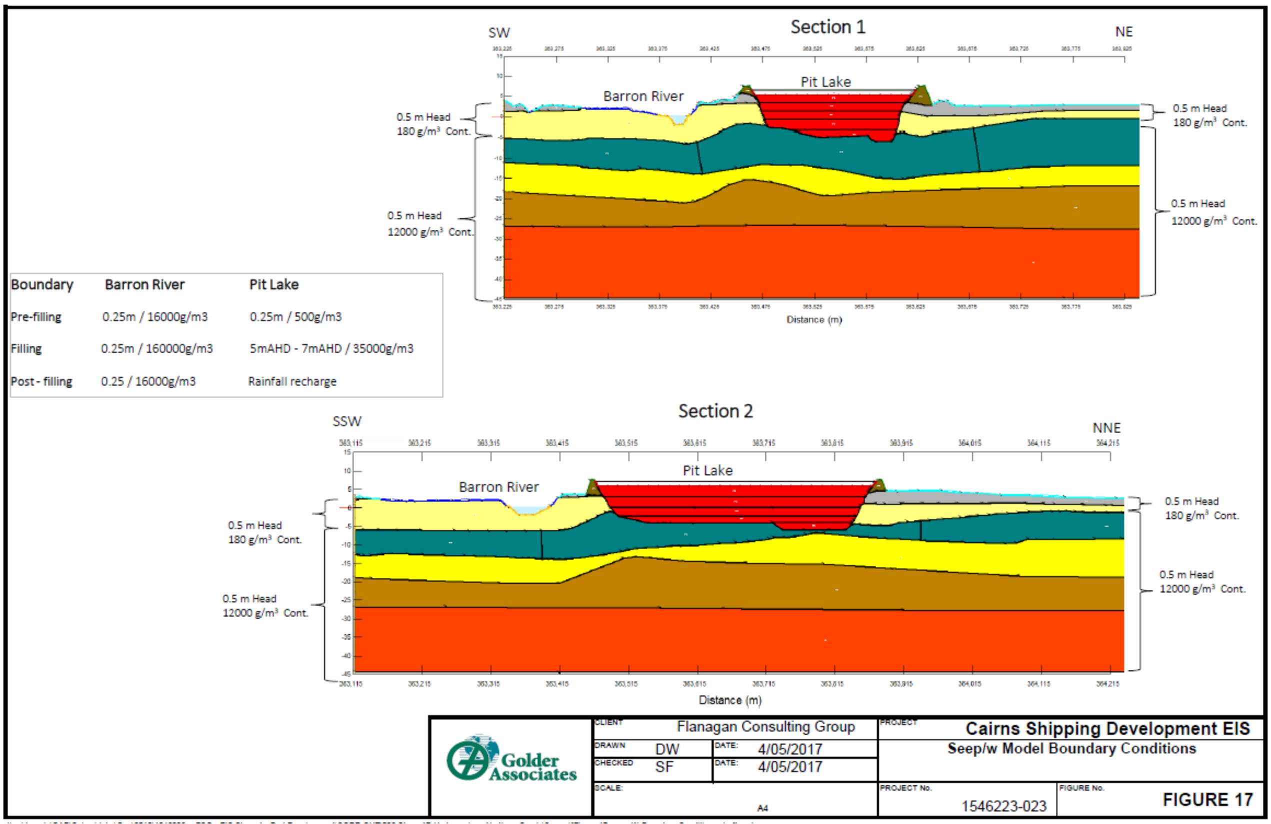

Figure B6-23 Model boundary conditions.

Source: Appendix AK (Figure 17). A larger version of this figure is included in **Appendix AK**.

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.

Impacts on Aquifers and Soils

Results from the groundwater models for Sections 1 and 2 as shown above are presented in Figures 18 to 25 of **Appendix AK**. These figures show contours of the salinity concentration under increased lake levels during the period of placement and for two years following filling as well as 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 B6-14**. These distances are shown on **Figure B6-24**.

TABLE B6-14 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	5.0 m AHD	110 m
	5.5 m AHD	120 m
	6.5 m AHD	90 m
	7.0 m AHD	80 m
Section 2	5.0 m AHD	115 m
	5.5 m AHD	110 m
	6.5 m AHD	105 m
	7.0 m AHD	105 m

Source: Appendix AK (Table 8).

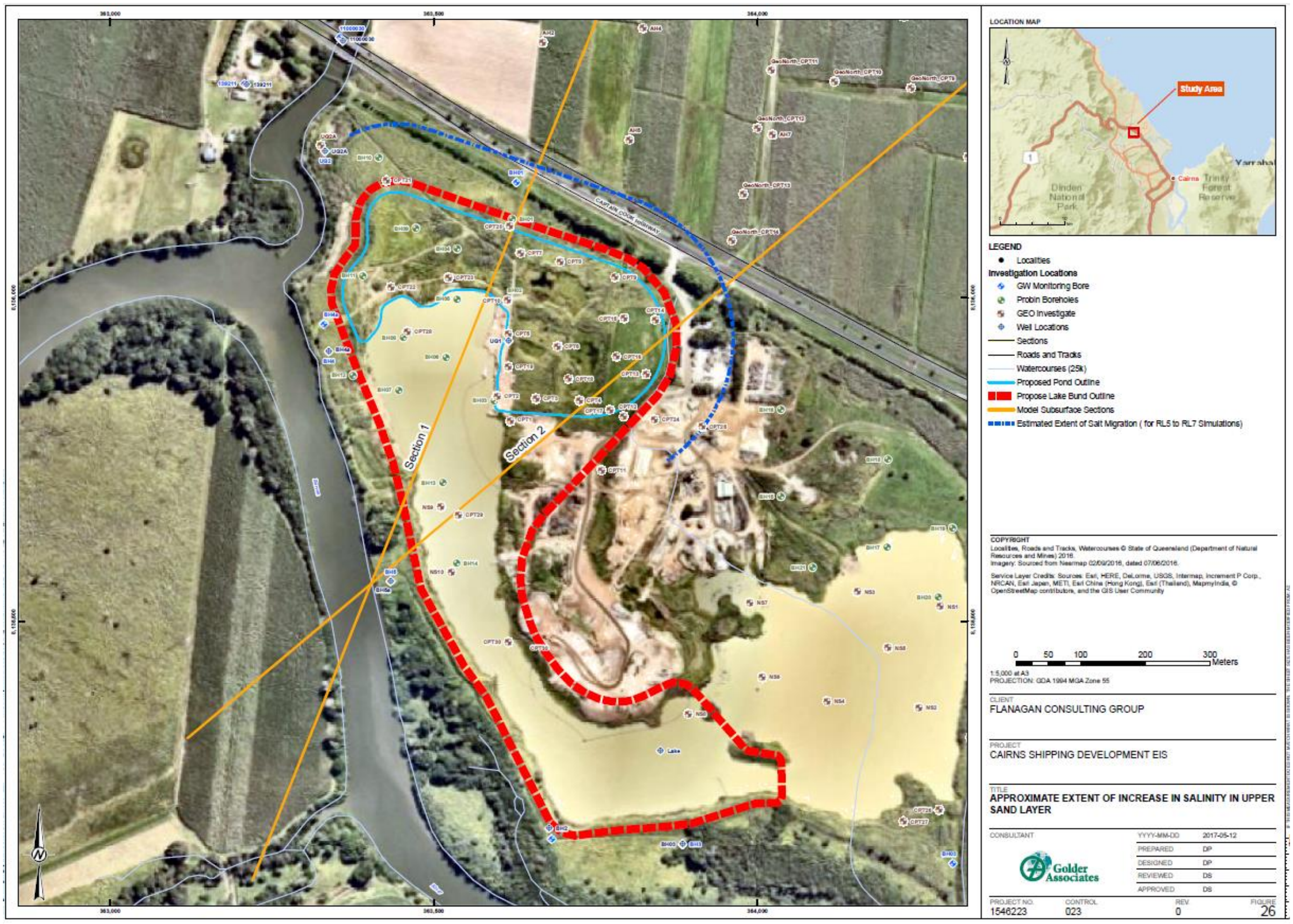

Figure B6-24 Approximate extent of increase in salinity of upper sand layer.

Source: Appendix AK (Figure 26). A larger version of this figure is included in **Appendix AK**.

The increased distance of salt migration for the lower water levels is influenced by the time required for the upper sand layer in the walls of the void 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 was based on the assumption that the water level will be held constant at 3.0 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 is the primary mitigation measure to limit this lateral migration.

The results of the modelling indicate the following:

- Lateral migration through the near-surface clay layer is significantly less than the extent of migration through the upper sand layer.
- The hydraulic gradient remains downwards throughout the period considered in the modelling (i.e. up to two 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 several years 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. While this will limit the rate at which salt will be flushed from the system, 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 the dredged materials.
- 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.

Impacts on the Barron River

The potential flow rate and solute transport rate between Lake Narelle and the Barron River during the period of increased lake water level was preliminarily assessed during preliminary studies undertaken during the concept design of the CSD Project, noting that at that time 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. For the project as now proposed, the length of lake adjacent to the river will be reduced and this 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 corresponding 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 DMPA, for a lake level of 7.0 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 are discussed in **Chapter B5** (Marine Water Quality).

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 are:

- 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. A detailed plan will be developed for investigations such as excavation of test pits to assess the nature of foundation materials. 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 sand extraction and processing 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.
- All PASS material will be placed below -3.0 (i.e. well below ground level) so there is no likelihood of discharge in the event of bund failure.

Risk Assessment

Table B6-15 below summarises the assessment of impacts with only statutory mitigation. The effect on risk levels of additional proposed mitigation is shown in **Table B6-19**.

TABLE B6-15 SUMMARY OF UNMITIGATED GROUNDWATER IMPACTS – NORTHERN SANDS PROJECT AREA

PRIMARY IMPACTING PROCESSES	INITIAL ASSESSMENT WITH STANDARD (INCLUDING STATUTORY) MITIGATION MEASURES IN PLACE		
	SIGNIFICANCE OF IMPACT	LIKELIHOOD OF IMPACT	RISK RATING
Lateral migration of saline water away from the dredge placement area causing impacts on water quality in the upper unconfined aquifer.	Moderate	Likely	Medium
Lateral migration of saline water away from the dredge placement area causing increased salinity in near surface soils.	Moderate	Unlikely	Low
Seepage beneath the bund causing increased saturation levels/water logging of surface soils close to the bund.	Minor	Possible	Low
Seepage beneath the bund wall adversely impacting on the integrity of the bund wall.	Moderate	Possible	Medium
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

Source: Appendix AK (Table 15 – part).

Mitigation of some of these impacts is feasible as discussed in **Section B6.5.1.b**.

B6.4.3 Tingira Street Project Area

B6.4.3.a Surface Water

Discussion

As noted in **Section B6.3.4.f**, the Tingira Street Project Area contains no surface water resources.

Impacts on marine water quality are discussed in **Chapter B5** (Marine Water Quality) while water-related hazards (i.e. flooding and stormtide) are described in **Chapter B17** (Hazard and Risk).

Risk Assessment

Table B6-16 below summarises the assessment of impacts without mitigation.

TABLE B6-16 SUMMARY OF UNMITIGATED SURFACE WATER IMPACTS – TINGIRA STREET PROJECT AREA

PRIMARY IMPACTING PROCESSES	INITIAL ASSESSMENT WITH STANDARD (STATUTORY) MITIGATION MEASURES IN PLACE		
	SIGNIFICANCE OF IMPACT	LIKELIHOOD OF IMPACT	RISK RATING
Impact of the construction and operation of the stiff clay placement process on surface water resources.	Negligible	Unlikely	Negligible

Mitigation is not required.

B6.4.3.b Groundwater

Discussion

Potential impacts relating to soils resulting from construction and operation of the DMPAs are:

- Groundwater in the site area is generally saline and is not a viable potable water supply source.
- Proposed dredged material placement operations are not likely to result in a lowering of groundwater levels within PASS materials such that acidic groundwater would be generated. Similarly proposed operations are not likely to increase groundwater levels surrounding the site and hence impacts on terrestrial vegetation with high salt tolerance is not likely.
- Surface water flows from the bunded areas are only likely to occur as a result of rainfall (as opposed to seawater associated with the deposition process). Such flows are not likely to impact groundwater levels or quality.
- There is a potential for acidic water to be generated if instability occurs (such that PASS is 'pushed' above the surface and oxidises). Although this is more likely to impact surface water, groundwater may also be impacted.

Risk Assessment

TABLE B6-17 SUMMARY OF UNMITIGATED GROUNDWATER IMPACTS – TINGIRA STREET PROJECT AREA

PRIMARY IMPACTING PROCESSES	INITIAL ASSESSMENT WITH STANDARD (STATUTORY) MITIGATION MEASURES IN PLACE		
	SIGNIFICANCE OF IMPACT	LIKELIHOOD OF IMPACT	RISK RATING
Breach of perimeter bunds results in discharge of water to the adjacent mangrove areas	Minor	Possible	Low
Lowering of groundwater levels within PASS materials such that acidic groundwater would be generated	Moderate	Unlikely	Low
Increase in saline groundwater levels surrounding the site	Moderate	Unlikely	Low
Groundwater adversely impacted by surface water run-off from site	Minor	Possible	Low
Acidic water generated following disturbance of PASS as a result of instability (such that PASS is 'pushed' above the surface and oxidises)	Moderate	Unlikely	Low

Source: Appendix X (Table 9 - part).

No mitigation measures over and above standard (statutory and best-practice) management procedures are required.

B6.5 Recommended Mitigation Measures

B6.5.1 Northern Sands Project Area

B6.5.1.a Surface Water

The impact risk is assessed as Negligible. No mitigation is required or feasible.

B6.5.1.b Groundwater

Section B6.4.2.b concludes that the potential groundwater impacts associated with the project are as summarised as follow. These are shown in **Table B16-18** along with the recommended mitigation.

TABLE B16-18 SUMMARY OF GROUNDWATER IMPACTS AND RECOMMENDED MITIGATION

<table>
<tr><th>IMPACT</th><th>RECOMMENDED MITIGATION</th></tr>
<tr><td>Seepage from the dredge placement area towards the Barron River causing increases in salinity in the river.</td><td rowspan="3">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</td></tr>
<tr><td>Lateral migration of saline water away from the dredge placement area causing impacts on water quality in the upper unconfined aquifer.</td></tr>
<tr><td>Lateral migration of saline water away from the dredge placement area causing increased salinity in near surface soils.</td></tr>
<tr><td>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.</td><td rowspan="3">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.</td></tr>
<tr><td>Seepage beneath the bund causing increased saturation levels/water logging of surface soils close to the bund.</td></tr>
<tr><td>Seepage beneath the bund wall adversely impacting on the integrity of the bund wall.</td></tr>
</table>

Source: Appendix AK (Table 14).

B6.5.2 Tingira Street Project Area

B6.5.2.a Surface Water

The impact risk is assessed as Negligible. No mitigation is required or feasible.

B6.5.2.b Groundwater

No mitigation measures over and above standard (statutory and best-practice) management procedures are required.

B6.6 Residual Impacts and Assessment Summary

B6.6.1 Northern Sands Project Area

B6.6.1.a Surface Water

The unmitigated risk of impact on surface water is assessed as Negligible. No mitigation is required or feasible and the residual impact is assessed to remain Negligible. No summary table is provided.

No surface water monitoring is required (see below for groundwater).

B6.6.1.b Groundwater

Risk Assessment

Table B6-19 below summarises the assessment of impacts with only statutory mitigation and then with additional (proposed) mitigation.

Discussion

The analysis reveals that the recommended mitigation will reduce all impacts to a risk rating of Low, with the exception of the following which remains as Medium:

- Lateral migration of saline water away from the dredge placement area causing impacts on water quality in the upper unconfined aquifer.

With reference to the modelling discussed in **Section B6.4.2.b**, these are impacts are likely to be limited to a distance of 80 m to 120 m from the disposal area. **Table B6-20** below provides further assessment of the consequences of these impacts. This shows that this impact is:

- long term (**Table B6-9**)
- reversible
- predictable.

A monitoring / intervention program is recommended (see **Section B6.6.3**).

TABLE B6-19 SUMMARY OF MITIGATED GROUNDWATER IMPACTS – NORTHERN SANDS PROJECT AREA

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 disposal 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 the surface.	Moderate	Possible	Medium	Moderate	Unlikely	Low

Source: Appendix AK (Table 15).

TABLE B6-20 GROUNDWATER IMPACT SUMMARY – NORTHERN SANDS PROJECT AREA

MATTER	ADVERSE IMPACT	BENEFICIAL IMPACT	CONSEQUENTIAL IMPACT	CUMULATIVE IMPACT	SHORT TERM	LONG TERM	REVERSIBLE	IRREVERSIBLE	PREDICTABLE	UNPREDICTABLE
Groundwater and surface water (Low residual risk)	Lateral migration of saline water away from disposal area causing increased salinity of the Barron River	Nil	Impacts on water quality.	Refer **Chapter B18** (Cumulative Impacts Assessment)	X		X		X	
Groundwater (Medium residual risk)	Lateral migration of saline water away from disposal area causing increased salinity of upper unconfined aquifer	Nil	Limitations on the potential to locate shallow groundwater bores close to the disposal area	Refer **Chapter B18** (Cumulative Impacts Assessment)		X	X		X	
Groundwater and soils (Low residual risk)	Lateral migration of saline water away from disposal area causing increased salinity of near surface soils	Nil	Decrease in productivity of agricultural land	Refer **Chapter B18** (Cumulative Impacts Assessment)	X		X		X	
Groundwater (Low residual risk)	Seepage beneath the bund causing increased saturation levels/water logging of surface soils close to the bund.	Nil	Poor trafficability in areas close to the bund.	Refer **Chapter B18** (Cumulative Impacts Assessment)	X		X		X	
Groundwater (Low residual risk)	Seepage beneath the bund wall adversely impacting on the integrity of the bund wall.	Nil	Failure of the bund wall with release of saline water and potential acid sulfate soils.	Refer **Chapter B18** (Cumulative Impacts Assessment)	X		X		X	
Groundwater (Low residual risk)	Elevated groundwater pressures in upper unconfined aquifer causing upward migration of potentially saline water.	Nil	Poor trafficability, impacts on surface infrastructure, decrease in productivity of agricultural land.	Refer **Chapter B18** (Cumulative Impacts Assessment)	X		X			X

Source: Appendix AK (Table 15).

B6.6.2 Tingira Street DMPA Project Area

B6.6.2.a Surface Water

The risk of impact on surface water is assessed as Negligible. No mitigation is required or feasible and the residual impact is assessed to remain Negligible.

B6.6.2.b Groundwater

Risk Assessment

Table B6-21 below summarises the assessment of impacts with only statutory mitigation and then with additional (proposed) mitigation. As noted previously, no mitigation measures over and above standard (statutory and best-practice) management procedures are required. However, the table includes provision for a mitigation component for consistency.

Discussion

As noted previously, no mitigation measures over and above standard (statutory and best-practice) management procedures are required. In all cases the risk of mitigated impacts is Low. This is defined as 'Manageable by standard mitigation and similar operating procedures'.

Table B6-22 below provides further assessment of the consequences of these impacts.

TABLE B6-21 SUMMARY OF MITIGATED GROUNDWATER IMPACTS – TINGIRA STREET PROJECT AREA

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
Breach of perimeter bunds results in discharge of water to the adjacent mangrove areas	Minor	Possible	Low	Minor	Possible	Low
Lowering of groundwater levels within PASS materials such that acidic groundwater would be generated	Moderate	Unlikely	Low	Moderate	Unlikely	Low
Increase in saline groundwater levels surrounding the site	Moderate	Unlikely	Low	Moderate	Unlikely	Low
Groundwater adversely impacted by surface water run-off from site	Minor	Possible	Low	Minor	Possible	Low
Acidic water generated following disturbance of PASS as a result of instability	Moderate	Unlikely	Low	Moderate	Unlikely	Low

Source: Appendix X (Table 9).

TABLE B6-22 GROUNDWATER IMPACT SUMMARY – TINGIRA STREET PROJECT AREA

MATTER	ADVERSE IMPACT	BENEFICIAL IMPACT	CONSEQUENTIAL IMPACT	CUMULATIVE IMPACT	SHORT TERM	LONG TERM	REVERSIBLE	IRREVERSIBLE	PREDICTABLE	UNPREDICTABLE
Groundwater (Low residual risk)	Decrease in groundwater levels. PASS could be exposed. Acidic waters could be generated	Nil	Minimal impact as risk can be mitigated with appropriate, monitoring, management and/or treatment during construction	Refer **Chapter B18** (Cumulative Impacts Assessment)	X		X		X	
Groundwater (Low residual risk)	Increase in groundwater levels with increase in saline groundwater surrounding the site	Nil	Minimal impact as risk can be mitigated with appropriate monitoring, management and/or treatment during construction	Refer **Chapter B18** (Cumulative Impacts Assessment)	X		X		X	
Groundwater (Low residual risk)	Sediment & surface water run-off from site with impact on groundwater quality	Nil	Minimal impact as risk can be mitigated with appropriate remedial works (e.g. excavation and treatment) during construction	Refer **Chapter B18** (Cumulative Impacts Assessment)	X		X		X	

Source: Appendix AK (Table 10 – part).

B6.6.3 Groundwater Monitoring

B6.6.3.a Northern Sands Project Area

As identified in **Section B6.4.2.b** the main potential impacts on groundwater are:

- localised increase in groundwater level adjacent to lake during dredged material placement
- 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 on **Figure B6-25**.

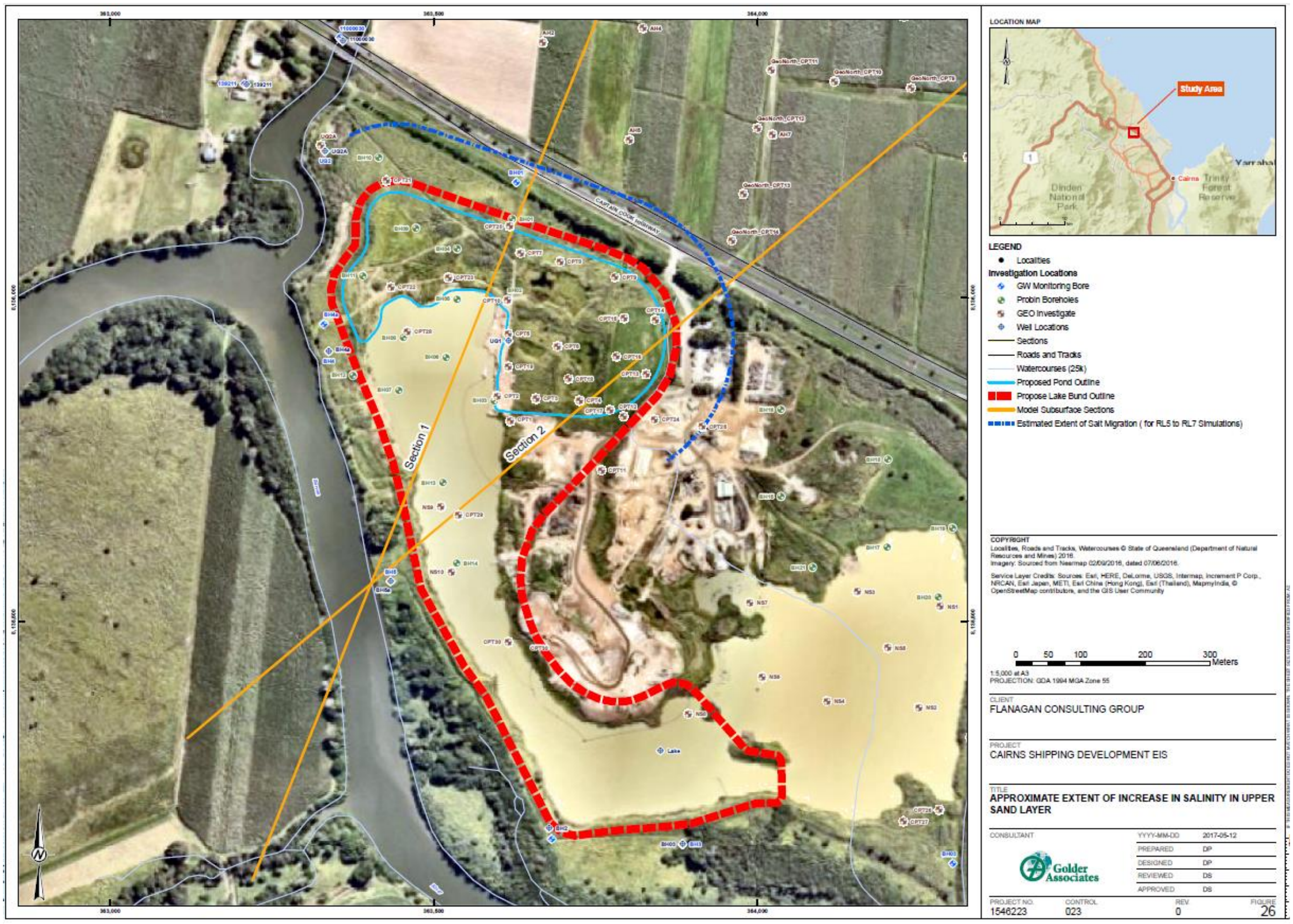

Figure B6-25 Proposed groundwater monitoring bores.

Source: Appendix AK (Figure 27). A larger version of this figure is included in **Appendix AK**.

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 B6-23 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. A conservative approach will be undertaken until sufficient information exists to establish meaningful trigger values. This will also include details of appropriate responses (i.e. actions to be taken should monitoring report a problem).

TABLE B6-23 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

Source: Appendix AK (Table 17).

* The duration of pre-work monitoring will be determined based on the adequacy of the baseline data set

** 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.

*** The duration of post-work monitoring will be determined based on periodic review of results and the need for any corrective actions, noting a full 24 months of monitoring may not be required if the risk of impacts are considered negligible following an initial period

B6.6.3.b Tingira Street Project Area

No groundwater monitoring is required.

B6.7 References

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