3.5 Water Resources

This chapter describes the ground and surface water resource issues associated with the GKI Revitalisation Plan, including the Island's existing environmental values, potential impacts of the Project and mitigation measures.

3.5.1 Groundwater Resources

Groundwater resources on the Island have been assessed in multiple hydrogeological investigations conducted by Douglas Partners Pty Ltd (DP 2007a, 2007b, 2011a). The objective of these hydrogeological investigations was to identify groundwater resources on the Island which could be viable as potable water supplies.

Published geology (Department of Natural Resources, Mines & Water (DNRMW), 2006) indicates that the Island is primarily underlain by the Carboniferous aged Shoalwater Formation of the Curtis Island Group (Drawing 3 in **Appendix Z(v)**). Late Palaeozoic quartose, arenite and mudstone of the Shoalwater formation make up the major hills and slopes on the Island. Thin veneers of Quaternary sand, alluvium and estuarine mud overly the Carboniferous sequence in three separate, lower lying areas of the Island.

Based on the geological mapping of the Island, potential for groundwater resources was identified within the north-east and south-western Quaternary dune sand deposits (**Appendix Z(i)**). It was considered by Douglas Partners that these dune sand deposits would contain unconfined permeable aquifers with fresh groundwater.

3.5.1.1 Groundwater Resources - Aquifers

Areas of the Island underlain by the Carboniferous Shoalwater Formation, including the central valley region, were not considered as potential groundwater resources due to the metamorphic rock type and its typical very low permeability and porosity (**Appendix Z(i)**). However, recent site investigations within the central region (**Appendix Z(iii)**) confirmed that the dune sand deposit was more extensive than that indicated by the published geology (DNRMW, 2006). This indicated potential for the central region to contain a viable groundwater resource.

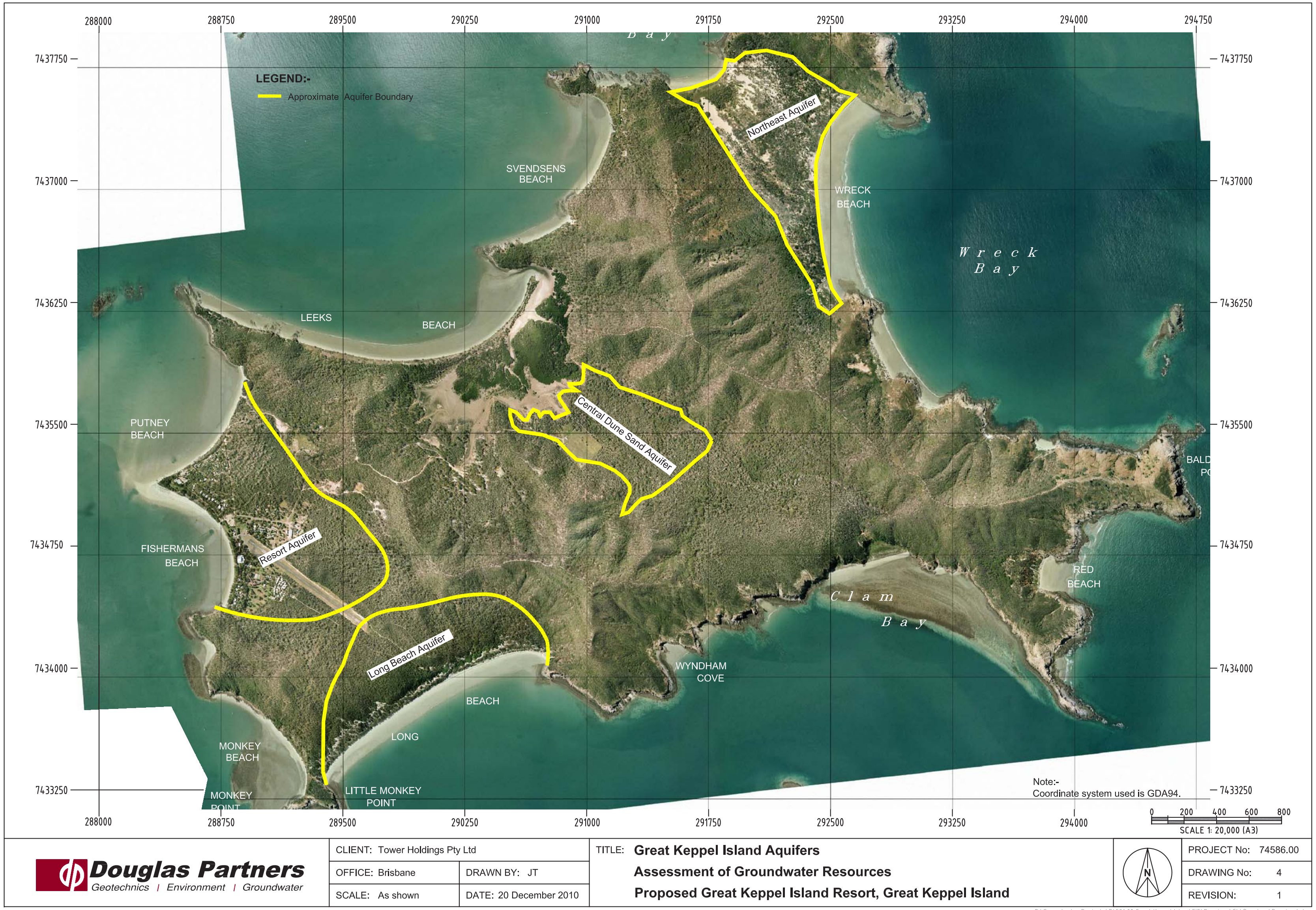
Refer to **Section 3.5.3** for potential impacts and mitigation measures.

Hydrogeological investigations (**Appendices Z(i)**, **Z(ii)**, **Z(iii)**) have confirmed the presence of the following four groundwater resources (aquifers) on the Island (refer **Figure 3.56)**

- North-East Aquifer;
- Resort Aquifer;
- Long Beach Aquifer; and
- Central Dune Sand Aquifer.

The North-East, Long Beach, and Central Dune Sand aquifers all contain viable groundwater resources suitable for potable water supply, based on the available groundwater quantity and its quality (Douglas Partners Pty Ltd 2007a, 2011a, 2011b). Groundwater quality in the Resort Aquifer has been impacted by saltwater intrusion along Fisherman's Beach and Putney Beach due to past over-extraction from the aquifer. The Resort Aquifer was therefore not considered suitable as a groundwater resource (Douglas Partners Pty Ltd 2007a).

Figure 3.56 GKI AQUIFERS



SOURCE: ASSESSMENT OF GROUNDWATER RESOURCES (2011) - DOUGLAS PARTNERS

Proposed redevelopment areas will extend across sections of the Resort, Long Beach and Central Dune Sand Aquifers catchment areas. The North-East Aquifer is located outside the redevelopment areas and will not be impacted by the Project.

Hydrogeological features of each of the four aquifers are further described below.

(a) North-East Aquifer

The North-East Aquifer (refer **Figure 3.56**) is an unconfined aquifer that receives the majority of its recharge through direct infiltration of rainfall over its entire surface. The aquifer comprises Quaternary dune sand to depths of between 7.5 metres to greater than 21.5 metres (Drawing 6 of **Appendix Z(i)**) and extends from Wreck Bay to Butterfish Bay. It occupies a surface area of approximately 0.7 square kilometres. The aquifer basement comprises residual sandy clay or weathered rock belonging to the Carboniferous Shoalwater formation. Permeability of the aquifer is high and was estimated to be 21 metres per day.

Depth to groundwater across the aquifer varies between 3.8 metres and 6.3 metres (Douglas Partners Pty Ltd 2007a). Groundwater flows from a central groundwater mound developed through the infiltration of rainfall, and flows to the north-west and south-east from this central mound. Groundwater from the aquifer discharges to the Pacific Ocean via both Butterfish Bay and Wreck Bay. As no creeks or rivers are present on the surface of the aquifer, there is no direct interaction between groundwater and surface water. Seasonal variations in groundwater levels have not been monitored. However, they would be expected to vary between one metre and two metres.

Groundwater quality in the North-East Aquifer is fresh, has a low dissolved salt content, and a pH which varies from slightly acidic within the central region of the aquifer to slightly alkaline close to the beaches. Laboratory testing indicated that the water is potable, or fit for human consumption (**Table 5 Appendix Z(i)**).

At present there are no existing groundwater supply facilities installed within the North-East Aquifer.

(b) Resort Aquifer

The Resort Aquifer (refer **Figure 3.56**) is an unconfined aquifer that receives the majority of its recharge through direct infiltration of rainfall over its entire surface. The aquifer is composed of Quaternary dune sand to depths of between six metres and 12 metres (**Appendix Z(i)**). The aquifer is separated from the Long Beach Aquifer by a rise in the bedrock underlying the sand beneath the southern end of the air strip and occupies a surface area of approximately 1.1 square kilometres. The basement bedrock comprises weathered rock belonging to the Carboniferous Shoalwater formation. Permeability of the aquifer is high and was estimated to be 20 metres per day.

Depth to groundwater across the aquifer varies between 2.5 metres and 11.8 metres depending on location and surface elevation. Groundwater flows from the eastern end of the airstrip and flows to the west where it discharges to the Pacific Ocean via Fisherman's Beach and Putney Beach. During wet climatic periods, when groundwater levels are high, groundwater may also discharge into Putney Creek. Monitoring indicates the groundwater levels vary seasonally between one metre and 1.5 metres (**Appendix Z(i)**).

Groundwater quality in the Resort Aquifer varies from fresh to saline due to salt water intrusion from the beaches bordering the aquifer. However recent monitoring in 2010 (**Appendix Z(i)**) during a wet year, indicated that the aquifer is recovering from salt water intrusion and salinity levels have decreased since 2006.

Groundwater from the Resort Aquifer has historically been extracted as a supplementary water supply for the former resort, local Island residents, and local businesses. Groundwater supply facilities include production bores within the former resort (labelled golf course bore, oval bores 1 and 2), and spear points within the local residential properties.

(c) Long Beach Aquifer

The Long Beach Aquifer (refer **Figure 3.56**) is an unconfined aquifer that receives its recharge through direct infiltration of rainfall over its entire surface area. The aquifer comprises Quaternary dune sand to depths of between six metres and 17 metres (**Appendix Z(i)**) and occupies a surface area of approximately 0.5 square kilometres. The basement comprises residual sandy clay or weathered rock belonging to the Carboniferous Shoalwater formation. Permeability of the aquifer is high and was estimated to be 20 metres per day.

Depth to groundwater across the aquifer varies between 4.7 metres and 11.5 metres depending on location and surface elevation. Groundwater flows from central groundwater mounds near the eastern end of the airstrip developed through the infiltration of rainfall, and flows in a south-easterly direction towards Long Beach, where it discharges to the Pacific Ocean (Drawing 11 of **Appendix Z(i)**). As no watercourses are present on the surface of the aquifer, there is no direct interaction between groundwater and surface water. Monitoring data from 2006 and 2010 indicates that seasonal variations in groundwater levels are between 0.5 metres and one metre (**Appendices Z(i) and Z(iv)**).

Groundwater quality in the Long Beach Aquifer is generally fresh with a low dissolved salt content and a pH which varies from slightly acidic within the central regions of the aquifer to slightly alkaline close to Long Beach. Monitoring in 2006 and 2007 indicated that salt water had intruded into the aquifer near the existing Long Beach Pump House (**Appendices Z(i) and Z(ii)**). The most recent monitoring event in 2010 (**Appendix**

Z(iv)) reported the groundwater in this location was fresh. This indicates that the aquifer is recovering from salt water intrusion due to the higher rainfall and recharge over the previous year, and no groundwater extraction.

Groundwater from the Long Beach Aquifer has historically been extracted as a supplementary potable water supply for the former resort. Existing groundwater supply facilities include:

- Long Beach Pump House – comprising four production bores and one monitoring bore, associated pumping infrastructure, pipe work, an above ground concrete storage tank, and storage shed. All these facilities have not been in use for some years.
- Long Beach Bores – three former production bores exist in the vicinity of the Long Beach Bore 1 (LBB1) monitoring bore. None of these production bores have been used for some years.
- Production Bores (PB1 and PB2) – new production bores installed in 2007 (**Appendix Z(ii)**). No pumps, pipe work or protective infrastructure exist at these bore locations.

Laboratory testing in 2007 indicated the water extracted from PB1 and PB2 is potable, or fit for human consumption (**Appendix Z(i)**).

(d) Central Dune Sand Aquifer

The Central Dune Sand Aquifer (refer **Figure 3.56**) is an unconfined aquifer that receives the majority of its recharge through direct infiltration of rainfall over its entire surface and the remainder via run-off from the surrounding hills. The aquifer comprises Quaternary dune sand to depths of between 2.5 metres to greater than 17 metres and occupies a surface area of approximately 0.5 square kilometres. The aquifer basement comprises residual sandy clay or weathered rock belonging to the Carboniferous Shoalwater formation. Permeability of the aquifer is low to medium and was estimated to be five metres per day.

Depth to groundwater across the aquifer varies between one metre and seven metres (**Appendix Z(iii)**). Groundwater generally flows to the north-west through the aquifer towards the tidal wetland and Leeke's Beach. Groundwater within the aquifer will discharge directly into surface water associated with the wetland. During wet climatic periods, when groundwater levels are high, groundwater may also discharge into Blackall Creek and Leeke's Creek. Seasonal variations in groundwater levels have not been monitored. However, they would be expected to vary between one metre and three metres.

Groundwater quality is generally fresh in the Central Dune Sand Aquifer (MB12, MB14, and MB16, refer Drawing 8 in **Appendix Z (iv)**) and potable. However, the quality varies across the aquifer to slightly brackish (MB13). The groundwater has a slightly acidic pH.

There are no existing users of groundwater or groundwater supply facilities installed within the Central Dune Sand Aquifer.

3.5.1.2 Aquifer Sustainable Yields

Numerical modelling was used to estimate the sustainable yield of the three viable groundwater resources (**Appendices Z(i) and Z(iii)**). The long-term sustainable yields were estimated to be:

- 270 kilolitres per day for the North-East Aquifer;
- no testing undertaken at the Resort Aquifer (unviable groundwater resource);
- 100 kilolitres per day for the Long Beach Aquifer; and
- 90 kilolitres per day for the Central Dune Sand Aquifer.

Modelling was used to estimate the long-term sustainable yields by simulating a uniform and continuous extraction rate from each borefield. Yields are dependent upon the location and extraction rates of the bores comprising the borefield. They represent the maximum extraction rates which did not cause excessive drawdown around the bores or groundwater dependent ecosystems, or salt water intrusion during modelling.

Higher extraction rates or short-term yields may also be possible over shorter time periods or during wet climatic periods. However, additional modelling would be required to confirm the rates and duration of pumping.

3.5.1.3 Groundwater Vulnerability/ Potential Exposure to Pollution

Groundwater resources within the dune sand deposits on the Island are considered to be vulnerable to surface contamination sources due to the shallow depth of groundwater, the highly permeable sandy soils on the surface, and high hydraulic conductivity of the aquifers. These characteristics of the aquifer systems allow for any potential surface contamination to infiltrate into the subsurface and be dispersed through the aquifer relatively easily, thereby impacting upon the groundwater quality and its potential beneficial use.

Potential exposure of groundwater to pollution can be minimised and managed by implementation of a Groundwater Management Plan (GMP) for each aquifer including Well-head Protection Plans (WPP), an Effluent Disposal Management Plan (EDMP) and implementation of the EMP. This will help to ensure that any high risk surface activities with a high potential to cause contamination are not located above the vulnerable groundwater resources. Frameworks for these plans are provided in **Appendix Z(iv)** and are described further in **Section 3.5.2.2 – Mitigation Measures**.

3.5.1.4 Previous/ Current Groundwater Users

A search of the DERM (DNRM) groundwater database identified nine registered groundwater bores on the Island (Douglas Partners Pty Ltd 2011b). Bores are located in the former resort area (Resort Aquifer) and near Long Beach (Long Beach Aquifer). Subsurface conditions reportedly comprised sand, more specifically Keppel dune sands in the Long Beach Aquifer, and sand beach ridges in the Resort Aquifer. Depths of the sand deposit were reported to vary between six metres and 19 metres within this south-western region of the Island. Standing groundwater levels varied between one metre and nine metres depth depending on the location and surface elevation of the bores. Groundwater quality was reported to be fresh with a slightly acidic pH. Available information relating to the DERM (now known as DNRM) registered groundwater bore conditions is summarised in **Appendix Z(i)**.

Additional unregistered bores exist within most of the private residential and commercial properties along Fisherman's Beach and Putney Beach.

Groundwater has previously been extracted from the Resort and Long Beach aquifers located in the south-western dune sand deposit. Groundwater users include the commercial and private residential properties along Fisherman's Beach and the former resort when it was in operation. Groundwater has been used in the past for irrigation of gardens and the Resort golf course. However, reportedly due to past over-extraction of groundwater, water quality in the Resort Aquifer has been impacted by salt water intrusion near Fisherman's Beach and Putney Beach, causing it to currently be brackish and unsuitable for irrigation.

3.5.1.5 Environmental Values

Current uses and environmental values of each of the shallow aquifers as described in **Appendix Z (iv)** are discussed below:

(a) North-East Aquifer

- No existing or proposed groundwater extraction bores known to be utilising this aquifer.
- Groundwater dependent ecosystems, including deep-rooted vegetation and marine ecosystems at Butterfish Bay and Wreck Bay potentially dependent on fresh water discharges from this aquifer.
- Water quality suitable for raw drinking water (human consumption), irrigation of crops, stock watering and groundwater dependent ecosystems.

(b) Resort Aquifer

- A number of registered groundwater extraction bores are installed within this aquifer but these are not currently used by the Proponent and are not known to be used currently by any other landowners on the Island.
- Water quality suitable for raw drinking water (for human consumption), irrigation of crops and stock watering.

(c) Long Beach Aquifer

- Although a number of registered groundwater extraction bores are installed within this aquifer, none of these bores are currently being utilised.
- Groundwater dependent ecosystems, including deep-rooted vegetation and marine ecosystems at Long Beach potentially dependent on fresh water discharges from this aquifer.
- Water quality suitable for raw drinking water (for human consumption), irrigation of crops, stock watering and groundwater dependent ecosystems.

(d) Central Dune Aquifer

- No existing or proposed groundwater extraction bores known to be utilising this aquifer.
- Field water testing indicates significant salt water intrusion into the aquifer from Fisherman's Beach and Putney Beach.
- Water quality suitable for raw drinking water (for human consumption), irrigation of crops, stock watering and groundwater dependent ecosystems.

3.5.1.6 Water Quality Objectives

On the basis of the above, the following water quality objectives have been established for groundwater resources within the study area:

(a) North-East Aquifer

No groundwater extraction, storage or irrigation of recycled water, storage or handling of hazardous substances will occur within the catchment of the North-East Aquifer.

As such, no water quality objectives have been set for this aquifer.

(b) Resort Aquifer

- A number of existing registered groundwater bores access this aquifer.
- It is understood that these bores are not currently used by any local residents or businesses on the Island but they have historically been used for supply of drinking water to the former resort and possibly Island residents.
- The Resort Aquifer should not be considered as a potential water supply due to its poor water quality from salt water intrusion.

(c) Long Beach Aquifer

- A number of existing registered groundwater bores access this aquifer.
- These bores may potentially be used for supply of construction water for the GKI Revitalisation Plan.
- As such, water quality objectives for this aquifer are based on the Australian Drinking *Water Guidelines* (ADWG) (NHMRC, 2004).

(d) Central Dune Aquifer

- No groundwater extraction or use currently occurs or is proposed to occur from this aquifer.
- As such, water quality objectives for the purpose of assessing the proposed water cycle management scheme have been based on those established for the point of discharge or interaction between groundwater and surface waters, which comprises Leeke's Creek. As described above, water quality objectives (WQOs) for Leeke's Creek have been based on:
  - trigger values for mid-estuarine waters of the Central Coast Queensland Region (slightly to moderately disturbed waters) from QWQG (DERM, 2009); and
  - 99 percent protection trigger values from ANZECC and ARMCANZ (2000) were used as these values were most similar to the GBRMPA trigger values outlined in the Water Quality Guidelines for the Great Barrier Reef Marine Park (GBRMPA, 2009).

3.5.2 Surface Water

3.5.2.1 Overview

Fourteen distinct catchments for surface drainage have been identified on the Island. The location of the various drainage catchments identified on the Island is shown on the Catchment Plan contained in Appendix B of **Appendix AN** - *Water Cycle Management Report* and shown in **Figure 3.57**. A summary of relevant catchment characteristics is provided in **Table 3.65**.

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Figure 3.57 WATER CATCHMENT PLAN

Source: 'Water Cycle Management Report' (2011) – Opus International Consultants Pty Ltd

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(To allow for A3 pages to be included within hardcopy submissions.)

TABLE 3.65 STORMWATER CATCHMENT CHARACTERISTICS

ID	Location	Approximate Catchment Area (Ha)	Discharge Location	Proposed Development within Catchment
1	Eastern side of headland between Secret Beach and Wreck Bay	13.716	Discharges in a dispersed manner via localised flow paths to the rocky shore. No main waterway.	Nil.
2	Wreck Bay – Wreck Beach	178.304	Discharges in a dispersed manner via localised flow paths to Wrecks Beach. No main waterway.	Nil.
3	Wreck Bay – Little Wreck Beach	86.740	Discharges in a dispersed manner via localised flow paths to Little Wreck Beach. No main waterway.	Nil.
4	Red Beach	86.834	Discharges in a dispersed manner via localised flow paths to various small beaches / coves and Red Beach. No main waterway.	Nil.
5	Clam Bay	66.781	Discharges in a dispersed manner via localised flow paths to the small beaches of Clam Bay. No main waterway.	Part of golf course and small number of Eco Resort Villas.
6	Southern side of headland between Wyndham Cove and Long Beach	7.473	Discharges in a dispersed manner via localised flow paths to the rocky shoreline of north eastern Long Beach. No main waterway.	Nil.
7	Long Beach	39.100	Discharges in a dispersed manner along the eastern section of Long Beach. There are few recognisable flow paths.	Small number of Eco Resort Villas and small part of airstrip.
8	Fisherman's Beach	57.900	Largely discharges in a dispersed manner along the southern half of Fishermen's Beach, with few recognisable flow paths.	Resort hotel, Eco Resort Villas and apartments, sporting fields.
9	Putney Creek	110.700	Contains Putney Creek, which discharges at Putney Beach.	Eco-apartments and villas, resort commercial / retail, staff accommodation, airport terminal and part of airstrip, and the facilities maintenance compound.

TABLE 3.65 STORMWATER CATCHMENT CHARACTERISTICS (CONTINUED)

ID	Location	Approximate Catchment Area (Ha)	Discharge Location	Proposed Development within Catchment
10	Leeke's Beach	0.284	Contains Leeke's Creek, which discharges to Leeke's Beach through the existing wetland.	Nil – but downstream of Catchment 11.
11	Central area between Clam Bay and Leeke's Beach	324.447	Discharges via Leeke's Creek in Catchment 10 to Leeke's Beach through the existing wetland.	Majority of golf course including clubhouse commercial / retail and Eco Resort Villas.
12	Ridgeline inland of Svendsen's Beach	13.716	Discharges in a dispersed manner via localised flow paths towards Svendsen's Beach via Catchment 10. No main waterway.	Nil.
13	Western side of headland at Secret Beach	12.391	Discharges in a dispersed manner via localised flow paths to Secret Beach. No main waterway.	Nil.
14	Marine Services Precinct	17.628	The Marina Precinct is to be constructed along the existing beachfront at the northern end of Putney Beach.	Marina retail / commercial and apartments.

As noted in **Table 3.65**, the precincts proposed under the GKI Revitalisation Plan primarily fall within the following catchments:

- 5 - Clam Bay;
- 7 - Long Beach;
- 8 - Fisherman's Beach;
- 9 - Putney Creek;
- 10 - Leeke's Creek;
- 11 – Central Clam Bay / Leeke's Beach (discharging via Leeke's Beach); and
- 14 – Marine Services Precinct.

No development is proposed in the remaining catchments and no changes to runoff behaviour will occur in those areas as a result of the GKI Revitalisation Plan.

Waterways on the Island are largely ephemeral, flowing only during and shortly after storm events. Only two of the catchments affected by the GKI Revitalisation Plan discharge to ephemeral freshwater streams, these being Catchment 9, which discharges to Putney Creek and Catchment 11, which discharges to Leeke's Creek. In the lower reaches, gradients in the main waterways are relatively low and ponding can occur after periods of rain. There are no gauging facilities on any of the waterways and no historical flow records are available. No artificial impoundments or water extraction infrastructure is known to exist along these waterways.

A tidal wetland known as Leeke's Estuary is located behind Leeke's Beach. A wetland area also exists along Putney Creek near the mouth. Based on observations made by Douglas Partners during a site visit in October 2010 and discussions with a local resident, it is understood that the mouth of Putney Creek is regularly blocked by a sand bar. The sand bar is washed out occasionally (refer **Photograph 3.13**) by large storm runoff events and is then slowly rebuilt by normal wave processes on the beach. The sand bar effectively provides a sediment trap at the mouth of Putney Creek for smaller flow events (i.e., those that do not wash out the bar) (refer to frc - **Appendix W**).

Photograph 3.13 WASHED OUT BAR

When the bar is washed out, tidal flows are able to move in and out of the mouth until beach wave processes rebuild the bar and the wetland gradually reforms until the next large storm event. As a result, ecosystems present at the creek mouth are influenced by both periodic tidal and freshwater flows. Depending on the duration of the tidal / freshwater phases, observations made during the site visit indicate that dieback of more salt-tolerant vegetation may occur during prolonged periods of sand bar formation.

The natural hydrology of Putney Creek is believed to have been modified as a result of a number of previous land use activities, including but not limited to, construction of the existing airstrip, which it is understood, was built over semi-permanent waterholes and lagoons and blocked the natural drainage (**Appendix AB** CEPLA, 2011). Construction of the existing airstrip would have modified flows within Putney Creek. However, it is uncertain whether past modification of flows has contributed totally to the current sand bar building process or whether it has also been impacted by long standing natural processes.

3.5.2.2 Surface Water Quality

Surface water quality monitoring was undertaken by frc environmental at a number of sites on and surrounding the Island and at two mainland sites during the EIS. Refer to **Section 3.3.4** for further details on environmental values, water quality objectives and water quality within the catchment of the Island. A detailed description of existing water quality is contained in **Appendix W** – frc environmental 2011.

3.5.3 Potential Impacts and Mitigation Measures

3.5.3.1 Groundwater

The following section describes aspects of the GKI Revitalisation Plan that have the potential to impact on groundwater resources and proposed mitigation measures to avoid or minimise those impacts.

(a) Groundwater Extraction

Extraction of groundwater is only proposed during the Stage 1 construction phase and as an emergency back-up following completion of the initial construction works.

Extraction of groundwater from aquifers exceeding the sustainable yield has the potential to reverse the hydraulic gradient along the coastline and boundary of the aquifers. If this occurs, saltwater could potentially migrate into the aquifer causing decreased water quality and resulting in groundwater resources becoming unsuitable for certain uses due to high salinity (e.g., irrigation, drinking water supply).

Over-extraction from the aquifer will also reduce the volume of groundwater available for potential beneficial use and existing groundwater users. Given the Resort Aquifer is the only aquifer potentially being accessed by other users, this issue is only relevant where extraction from the Resort Aquifer is proposed. Extraction of groundwater from aquifers also reduces the volume of fresh groundwater discharging at the freshwater/saltwater interface along the coastline. This has the potential to reduce the volume of groundwater available for estuarine/coastal ecosystems and deep rooted vegetation.

Given the poor history of managing valuable groundwater resources on the Island, the water cycle management strategy proposed for the GKI Revitalisation Plan has been designed to avoid any need for long term extraction of groundwater resources. Extraction of groundwater from existing production bores within the Long Beach Aquifer is proposed during Stage 1 of construction only. The maximum sustainable yield of 100 kilolitres per day is well in excess of the estimated daily demand for water during Stage 1 of construction, which is a maximum of 90 kilolitres per day. Flow metres will be installed on these bores to monitor extraction and records will be kept to ensure the sustainable yield is not exceeded. Extraction from the Long Beach Aquifer will cease as soon as the proposed mainland water supply connection has been constructed.

No extraction is proposed from any existing or proposed bores within the Resort Aquifer, and no groundwater extraction is proposed from the North-East Aquifer or the Central Dune Aquifer as part of the water supply strategy for the proposed Revitalisation Plan. In addition to reducing the potential for future impacts on groundwater resources the proposed water supply strategy will provide water security for the GKI Revitalisation Plan.

Groundwater Management Plans (GMPs) will be developed for the Long Beach Aquifer to be used for water supply during Stage 1 of construction. The GMP would include recommendations relating to sustainable yields, monitoring/regulation of extraction rates, of well-head protection plans and ongoing groundwater monitoring requirements to enable the detection of any adverse impact to the groundwater resource. Monitoring of groundwater levels and water quality will also be undertaken for any aquifers potentially affected by proposed recycled water irrigation on the Island (e.g., Central Dune Aquifer) as outlined in the preliminary Irrigation Management Plan.

(b) Leakage from Sewerage Collection Systems

Leakage from the sewerage collection system, including sewer mains and pump station overflows, will have the potential to cause contamination of groundwater given the high permeability of sandy soils that are present across much of the Island, including many areas containing sewerage infrastructure.

To mitigate potential impacts associated with leakage from the sewerage collection system, the system installed for the GKI Revitalisation Plan to deliver sewage to the Island-based Waste Water Treatment Plants (WWTPs) will primarily consist of a gravity system utilising "NuSewers" or similar. These systems comprise fully welded polyethylene (PE) pipes, fittings and maintenance shafts. The elimination of rubber ring joints minimises groundwater infiltration and potential for leakage, which is particularly important on the Island due to the high water tables that occur across much of the Island. These types of systems are characterised by substantially lower infiltration rates compared to traditional sewers.

Overflows from sewerage pumping stations will be minimised by the provision of 100 percent standby pumping capacity, storage within the pumping station wet well and reticulation system (for short term power outages or pump blockages) and the provision of back-up power generators (in the event of mains power failure).

(c) Irrigation of Recycled Water

Water quality issues arise when irrigation of recycled water occurs at a rate exceeding the water and nutrient assimilation capacity of soils and vegetation within the irrigation area. This may result in leaching of nutrients and other contaminants into groundwater aquifers. Water quality may also be affected by irrigation of recycled water not treated to a suitable standard causing excessive leaching of nutrients and other contaminants to groundwater. It is noted that a small part of the proposed recycled water irrigation area (i.e., golf course) overlies the Central Dune Sand Aquifer as identified by Douglas Partners (refer **Appendix Z**).

Contamination of groundwater as a result of recycled water irrigation may impact on the availability of suitable water quality to support current and future beneficial uses (e.g., drinking water supply, irrigation supply) or impact on the health of aquatic ecosystems into which the groundwater ultimately discharges.

To mitigate these potential impacts, minimum water quality requirements for treatment of sewage effluent to be used for irrigation on the Island have been specified. These water quality requirements have been determined to comply with the minimum water quality requirements specified for "Municipal Use – open spaces, sports grounds, golf courses, dust suppression, etc or unrestricted access and application" under the *Australian Water Quality Guidelines for Water Recycling: Managing Health and Environmental Risks* (Phase 1) (ANZECC, 2006) to ensure recycled water is 'fit for purpose'. The proposed treatment standard is characterised by an E. coli level of less than one colony-forming unit per 100 millilitres, which will significantly reduce the potential for impacts on human health should recycled water drain through the soil profile into groundwater aquifers.

In addition, nutrient levels for treatment of sewage effluent to be used for irrigation on the Island have been specified based on comprehensive water and nutrient balance modelling of the proposed recycled water irrigation scheme using site specific climate and soil data to determine a sustainable strategy for application of recycled water for irrigation that will result in no adverse impacts on groundwater quality. The computer-based MEDLI (Model for Effluent Disposal using Land Irrigation) Version 1.30 program developed by the former DNRMW was used for this purpose.

A sustainable recycled water irrigation strategy was modelled on the following:

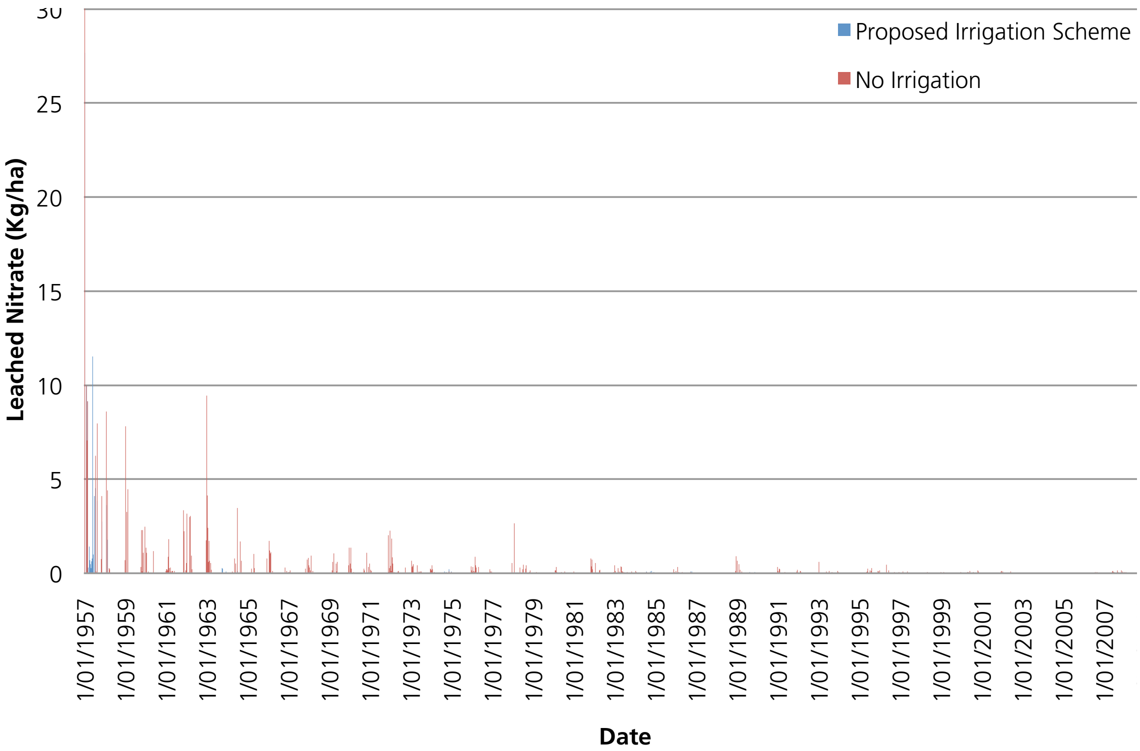
- total nitrogen concentration of 20 milligrams per litre;
- total phosphorous concentration of seven milligrams per litre;
- minimum irrigation area of 31 hectares;
- minimum wet weather storage of 37 megalitres; and
- application rate based on 80 percent Plant Available Water Capacity (PAWC) up to five millimetres beyond Drained Upper Limit (DUL).

The proposed irrigation area will primarily comprise the 18 hole championship golf course, which will be located within the Clam Bay Precinct. Greg Norman Golf Course Design has indicated that the proposed championship golf course is likely to comprise a total area of maintained turf (including tees, greens, fairways and rough) of approximately 31 hectares, and will therefore be capable of receiving all recycled water expected to be produced by the Island-based WWTP servicing the Project.

MEDLI modelling of the proposed recycled water irrigation scheme indicates that the average rate of deep drainage from the irrigation area predicted for the proposed irrigation scheme (446.1 millimetres per year) is only slightly higher (i.e., less than five percent) than the deep drainage rate predicted for the area when no irrigation occurs (426.2 millimetres per year). MEDLI modelling also indicates that the rate of nitrogen uptake by plant growth (105.4 kilograms per hectare per year) exceeds the amount of nitrogen applied by irrigation (69.6 kilograms per hectare per year), while the amount of nitrogen leached below the root zone under the proposed irrigation scheme (2.4 kilograms per hectare per year) and the concentration of nitrogen in deep drainage (0.5 milligrams per litre) is substantially lower than for the baseline or no irrigation scenario (6.9 kilograms per hectare per year and 1.6 milligrams per litre respectively). **Figure 3.58** provides a comparison of the amount of nitrogen leached below the soil profile during the proposed irrigation scheme and with no irrigation (based on historic rainfall data between 1957 to 2009).

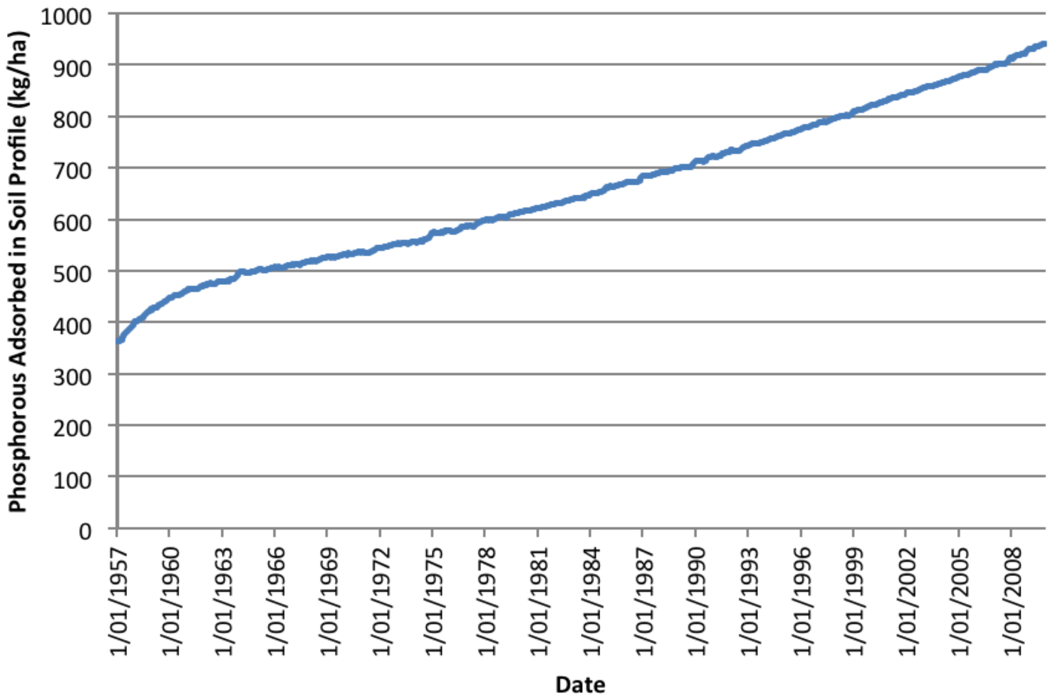
The results of MEDLI modelling for the proposed irrigation scheme indicate that the rate of phosphorous uptake by plant growth (24.4 kilograms per hectare per year) will be less than the amount of phosphorous applied by irrigation (35.3 kilograms per hectare per year). However, the remaining phosphorous will largely be adsorbed within the soil profile. **Figure 3.59** illustrates phosphorous adsorption within the soil profile over the life of the scheme and demonstrates that the phosphorous adsorption capacity of the soils will not be exceeded even after 50+ years of irrigation (based on historic data). The combination of plant uptake and soil adsorption ensures that the amount of phosphorous leached below the soil profile is comparable with the amount predicted with no irrigation.

Figure 3.58 COMPARISON OF NITROGEN LEACHED BELOW THE SOIL PROFILE UNDER NO IRRIGATION AND PROPOSED IRRIGATION SCHEME [1]



1. *Based on historic data*

Figure 3.59 PHOSPHOROUS ADSORPTION IN SOIL PROFILE OVER 53 YEARS OF TREATED EFFLUENT IRRIGATION



Based on the above, the proposed recycled water irrigation scheme is not anticipated to result in any increase in nutrients entering groundwater compared to the amount of nutrients expected to leach into groundwater with no irrigation. Further details on MEDLI modelling are provided in **Appendix AN - Water Cycle Management Report**.

Although the proposed irrigation scheme has been designed to result in no worsening of nutrient leaching below the soil profile compared to a no irrigation scenario, further modelling of potential groundwater impacts was undertaken by Douglas Partners using the MODFLOW groundwater model developed to simulate the Central Dune Aquifer. Further details on the modelling process are provided in **Appendix Z(vii) - Report on Groundwater Nutrient Transport Modelling**.

Table 3.66 provides a summary of relevant outputs from MEDLI modelling and inputs used in MODLFOW to model potential groundwater impacts and demonstrates that a conservative approach has been taken by increasing the MEDLI output nutrient concentrations by about 10 percent for incorporation into the groundwater model.

TABLE 3.66 SUMMARY OF MEDLI OUTPUTS VS MODFLOW INPUTS

Attribute	MEDLI Output Data	Data Used in MODFLOW
Irrigation Area (within catchment of Central Dune Aquifer)	31 hectares	31 hectares
Average Groundwater Recharge	378.6 m^3/year	378.6 m^3/year
Average Nitrate Concentration of Groundwater Recharge	0.5 mg/L	0.55 mg/L1
Average Phosphate Concentration Below Root Zone	0.0 mg/L	0.03 mg/L1

Note: Buffer added to MEDLI output data for conservative assessment of impacts.

Groundwater pollutant modelling undertaken by Douglas Partners based on the above inputs from the proposed irrigation scheme, indicates that the concentrations of total nitrogen and total phosphorous within groundwater comply with the relevant water quality objectives of 0.3 milligrams per litre of total nitrogen and 0.025 milligrams per litre of total phosphorous at the point of discharge into Leeke's Creek and associated tidal wetlands (refer to **Appendix Z(vii)** - *Report on Groundwater Nutrient Modelling*).

As such, the proposed irrigation of recycled water containing an average concentration of 20 milligrams per litre of nitrogen and seven milligrams per litre of phosphorous is not expected to result in any adverse impacts on water quality or environmental values associated with Leeke's Creek and associated tidal wetlands.

In addition, groundwater pollutant modelling undertaken by Douglas Partners estimated that based on an average recharge rate of 378.6 cubic metres per year, the concentrations of nitrogen and phosphorous leached below the soil profile must not exceed 0.65 milligrams per litre and 0.05 milligrams per litre respectively in order to comply with water quality objectives for Leeke's Creek.

To assist in developing a golf course maintenance plan for the Project, further modelling was undertaken to determine the total annual load of nitrogen and phosphorous that could be applied to the proposed golf course irrigation area, either through recycled water irrigation or fertilisation, without exceeding the nitrogen and phosphorous levels nominated for Leeke's Creek. To do this, initial effluent concentrations in the MEDLI model were increased substantially from 20 milligrams per litre nitrogen up to 115 milligrams per litre and from seven milligrams per litre phosphorous up to 25 milligrams per litre. Based on these concentrations, modelling of recycled water irrigation triggered at 80 percent Plant Available Water Capacity (PAWC) up to five millimetres beyond Drained Upper Limit (DUL) over a 31 hectare irrigation area resulted in the following:

nitrogen applied in irrigation:	= 115.4 kilograms per hectare per year;
phosphorous applied in irrigation:	= 47.2 kilograms per hectare per year;
average nitrate concentration of groundwater recharge:	= 0.6 milligrams per litre;
average phosphate concentration below root zone:	= 0.0 milligrams per litre; and
average groundwater recharge:	= 377.5 cubic metres per year.

As the concentrations of nitrogen and phosphorous leached below the soil profile are predicted to be less than the limits identified by Douglas Partners to achieve the required water quality objectives at Leeke's Creek, it is considered that up to approximately 115.4 kilograms per hectare per year of nitrogen and 47.2 kilograms per hectare per year of phosphorous could be applied to the irrigation area either within recycled water or applied fertilisers without impacting on water quality or environmental values within Leeke's Creek.

It is proposed that these rates be used as a guide for managing fertiliser application on the proposed golf course, with records of all fertiliser application and recycled water irrigation to be maintained. Combined with regular monitoring of soils and groundwater that will be required under the conditions of development approval that will need to be obtained for the proposed wastewater treatment plant, this approach to fertiliser management is considered to substantially reduce the potential for maintenance of the proposed golf course to impact on water quality within groundwater, Leeke's Creek and other downstream receiving waters. Proposed water quality monitoring is outlined in the preliminary Irrigation Management Plan (refer **Appendix AN**).

(d) Storage of Recycled Water, Harvested Stormwater and Emergency Sewage Overflows

Given the high permeability of soils on the Island, potential exists for contaminants contained in these storages to leach into groundwater as a result of seepage from the base and sides of these ponds. The potential for contamination of groundwater to occur as a result of these storages will be quite low in relation to proposed wet weather storage ponds containing recycled water and ponds containing harvested stormwater runoff from the golf course due to the relatively low levels of contaminants in these waters. Seepage from emergency overflow ponds containing untreated or partially untreated sewage would be more likely to contaminate groundwater given the higher level of contaminants.

To reduce the potential seepage of contaminants to groundwater from storage ponds, proposed wet weather storage ponds and stormwater harvesting ponds will be constructed with a clay or synthetic liner to limit the seepage rate. The proposed emergency overflow ponds to contain diverted sewage will be designed and constructed with an impermeable liner. All wet weather storage ponds, stormwater harvesting ponds and emergency overflow ponds will be designed and constructed such that the base of the ponds is above the high water table level.

(e) Storage and Handling of Hazardous Substances

Spillage or leakage from hazardous substance storage areas, and other locations containing potential contaminants has the potential to infiltrate to groundwater impacting on water quality in the aquifer and other receiving waters. High risk areas for potential contamination include:

- proposed waste storage and handling facilities;
- maintenance workshops and fuel / chemical storage;
- existing underground fuel tanks, bowsers and associated infrastructure from the former resort; and
- leachate seepage from the former landfill.

To mitigate potential impacts on groundwater quality associated with these contaminant sources, the following measures are proposed:

- all hazardous substances and materials will be stored in a manner that prevents or minimises the impact of any accidental spills or releases. Hazardous substance storage areas will be designed and constructed in accordance with AS1940:2004 – *Storage and Handling of Flammable and Combustible Liquids* and other relevant standards;
- procurement procedures will be established to ensure that only the minimum essential stocks of items such as chemicals and fuels are to be stored on site at any one time, and wherever possible, non-hazardous alternatives will be identified and used;
- refuelling of vehicles during construction and operation of the Resort will occur only within designated bunded hardstand areas provided with a stormwater containment system to prevent discharge of any leaks of spills to surrounding soil or water bodies;
- spill kits will be kept on-site at all times and located where hazardous substances are stored and used. All site personnel (including contractors) are to be trained in the use of spill kits;
- Material Safety Data Sheets (MSDS) for all hazardous substances stored or handled on site will be kept on site and are to be made readily available to personnel. MSDS will be kept up-to-date at all times. Hazardous substances and materials will only be handled by trained personnel and in accordance with MSDS;

- any stormwater captured within bunded areas used for the storage or handling of wastes or other hazardous materials will be pumped out and disposed of at an appropriately licensed facility. Regular inspections will be undertaken for stormwater drainage systems in areas used for the storage or handling of wastes and other hazardous materials to ensure all drains are free of litter and operating at optimum efficiency;
- all hazardous substance storage areas will be located at least 50 metres from any watercourse or drainage line;
- any leakage or spillage of hazardous substances will trigger immediate spill response and clean up procedures, and repair or improvement of storage areas and/or equipment;
- any existing underground storage tanks will be decommissioned / removed using a licensed tank removal contractor, and any contaminated soils will be remediated / removed and validated to ensure that all potential contamination has been removed from these areas; and
- a groundwater quality monitoring program will be implemented around the golf course, storage ponds and the former landfill to assess whether leachate is impacting on groundwater and any necessary remediation works as required will be undertaken to prevent further contamination.

A commercial waste contractor holding the appropriate licence under the *Environmental Protection Act 1994* will be engaged to collect bulk bins containing general waste and recyclable wastes from the Island, and to transport these materials to appropriately licensed disposal and recycling facilities on the mainland.

3.5.3.2 Surface Water

The following section describes aspects of the GKI Revitalisation Plan that have the potential to impact on surface water resources and proposed mitigation measures:

(a) Vegetation Clearing and Earthworks

Construction of the Project will involve clearing of vegetation and earthworks. These activities have the potential to increase the risk of erosion and sedimentation in downstream waterways, which could result in declining water quality, loss of in-stream habitat (e.g., filling of pool habitats), alteration of species composition and diversity, and possibly decreased fisheries productivity. Removal of riparian vegetation and marine plants (e.g., mangroves) for construction of essential infrastructure such as roads and pipeline crossings also has the potential to result in loss of habitat for native flora and fauna, and potential impacts on fisheries productivity.

Exact positioning of infrastructure within tidal and non-tidal waters will be determined as part of the detailed design in consultation with relevant authorities based on ecological assessments to determine the least impact alignment feasible. Preference will be given to the use of construction techniques and equipment (e.g. tunnel boring) that result in the minimum level of disturbance and footprint feasible.

Where possible, essential infrastructure requiring trenching will be co-located with other infrastructure to reduce the extent of vegetation clearing required. Proposed stormwater drainage systems have been designed to maximise the use of surface flow paths (e.g., swales) for conveying stormwater from source to destination to reduce the need for installation of extensive underground piped drainage systems. Sandy subsoils will enable filtered stormwater from bio-retention treatment systems to infiltrate into natural soils to recharge groundwater and mimic the natural hydrologic system on the Island, which will also reduce the need for installation of extensive underground piped drainage systems.

Best practice erosion and sediment control measures will be implemented for all construction works. A preliminary Erosion and Sediment Control Plan (ESCP) has been prepared to outline a range of controls that should be implemented during construction of the Project to reduce erosion and sedimentation issues (refer to **Appendix AN - Water Cycle Management Report**).

Stormwater diversion systems will be designed to prevent inundation of work sites and erosion and sediment control measures will be designed to remain effective during more intense rainfall events projected to occur as a result of climate change. A 20 percent buffer is to be applied to maximum design flows to allow for a possible 16 percent increase in the intensity of a 24-hour rain event projected for 2070 (refer to **Appendix X - Climate Change Report**).

Rehabilitation of all disturbed areas will occur progressively throughout construction to minimise the duration of soil exposure to erosive forces. Rehabilitation will utilise local native species wherever possible to restore disturbed habitats. Where necessary, environmental offsets will be provided for cleared vegetation in accordance with the relevant guidelines and policies for providing such offsets (refer to **Appendix P - Offset Report**).

(b) Interfering with the Flow of Water

Construction of road crossings, pipelines and other infrastructure has the potential to interfere with the flow of water and introduce barriers to fish movement in certain waterways. This could potentially result in decreased biodiversity and fisheries productivity, within such waterways.

To mitigate these potential impacts, the location of proposed roads and other infrastructure will be selected during detailed design to minimise the need for waterway crossings or where possible, existing crossings will be utilised to avoid further interference. All works within waterways supporting the movement of fish and other aquatic fauna will be designed in accordance with Fisheries Queensland's *Self Assessable Codes for Temporary and Minor Waterway Barrier Works* (DEEDI, 2011) and other relevant design guidelines for maintaining fish passage through such structures.

In addition to infrastructure crossings, it is proposed to remove the sand bar at the mouth of Putney Creek as outlined in detail in the Water Cycle technical report (**Appendix AN**). This will result in increased tidal exchange within the lower reaches of the channel, possibly altering riparian vegetation and in-stream flora and fauna. Based on consideration of available options, creation of an 'open' tidal creek system was considered to be the most appropriate solution from both an ecological, amenity and maintenance perspective.

By reopening the creek mouth to regular tidal movement, the productivities of fisheries within the lower reaches of Putney Creek is expected to be increased significantly (**Appendix W**). In addition, more regular flushing of the creek will reduce the potential for accumulation of high levels of nutrients identified within Putney Creek during water quality monitoring by frc environmental. Accumulation of high levels of nutrients could potentially create eutrophied conditions that could result in algal blooms with potential for consequent impacts on aquatic fauna and odour generation. For these reasons, reopening of the Putney Creek mouth to reinstate what is likely to resemble the more natural hydrology prior to construction of the existing runway, is considered the preferred option for managing flows at the Putney Creek mouth.

Accordingly, at the discharge point of Putney Creek into the marina, a permanent, lined, discharge channel will be established below the boardwalk and esplanade. The boardwalk and esplanade will bridge over the channel. A lined transition zone will be established within the channel upstream of the bridged area. Lining of the channel is required to prevent scouring, which would result in increased deposition of sediment within the marina basin. A range of options are available for lining the channel to prevent scouring with the preferred material to be selected on the basis of not only being able to reduce scour, but also to provide fisheries habitat and contribute to the aesthetics of the Marine Services Precinct. This may involve the use of placed rock, which will provide a relatively natural substrate for establishment of various encrusting marine species, as well as creating crevices and gaps to provide habitat and refuge for a wide range of marine flora and fauna.

Based on advice from International Marina Consultants, a sediment basin will be incorporated into the proposed works at the Putney Creek mouth. The sediment basin will be constructed in the lined transition section of the channel. The sediment basin will reduce siltation within the marina thereby avoiding the need for ongoing maintenance dredging within the marina basin, which would result in ongoing disturbance of the marine environment. The design will include full provision for easy maintenance access by appropriate de-silting equipment.

(c) Acid Sulfate Soil Disturbance

Douglas Partners Pty Ltd concluded that no indications of actual or potential acid sulfate soil (ASS) were identified during the EIS investigation. The potential for acid generation by disturbance of acid sulfate soils during earthworks and construction is therefore considered to be negligible.

Regardless, all construction works in areas containing potential acid sulfate soils will be undertaken in accordance with a site specific Acid Sulfate Soil Management Plan prepared in accordance with *SPP 2 / 02 – Planning and Managing Development Involving Acid Sulfate Soils and the Queensland Acid Sulfate Soil Technical Manual.*

(d) Stormwater Runoff – Quantity

Construction of buildings and infrastructure associated with the GKI Revitalisation Plan will increase the total area of impervious surfaces on the Island and will therefore decrease the area of pervious surfaces. An increase in impervious area has the potential to increase peak discharge velocities and runoff volumes, and also the frequency of small runoff events. These factors have the potential to cause scouring and erosion, and decreased stability within receiving waterways while also increasing the risk of flooding and potentially altering in-stream ecology.

Modelling of annual surface runoff volumes, indicates that an increase in the annual volume of surface runoff will occur post-development, with some increases in groundwater recharge also predicted to occur to a lesser extent in some catchments.

To mitigate potential impacts of increased surface runoff and peak discharge velocities, the following measures are proposed:

- rainwater tanks will be installed for capture and reuse of roofwater runoff;
- infiltration into the naturally high permeability sandy soils will be facilitated by the use of detention and retention basins; and
- stormwater runoff from the golf course and possibly other areas around the Resort will be harvested and reused for irrigation water supply.

Based on implementation of these measures, it can reasonably be expected that actual surface runoff volumes discharging to the main waterways post-development will be somewhat less than the modelling predicts.

Modelling of pre-development and post-development peak flow rates in catchments containing elements of the GKI Revitalisation Plan (except Catchment 14 – Marine Services Precinct), indicates that the Project could potentially increase peak flow rates by amounts ranging from 0.5 percent (Catchment 5 – Clam Bay Precinct) to 90.2 percent (Catchment 9 – Putney Creek).

To achieve non-worsening of peak flow rates and demonstrate compliance with the waterway stability objective of SPP 4/10, it is proposed to install a series of detention basins within each of the affected catchments. Preliminary detention basin sizes required for each catchment to mitigate all runoff events up to the 100 year recurrence interval and achieve non-worsening of peak flow rates in downstream waterways. Maintaining existing flow velocities means there will be no adverse impact on scouring or erosion rates, potential flooding or in-stream habitat within downstream waterways.

Proposed detention structures will comprise low impact designs utilising relatively low grassed or vegetated mounds enclosing open space, which will be integrated with landscaped areas to provide multi-purpose stormwater management and landscape amenity. Detention structures will be located such that runoff from storm events exceeding the detention basin design event can bypass safely around the outside of the structure to reduce the risk of embankment collapse that could occur if ponds are allowed to overflow in an uncontrolled manner. Civil designs (building pads, roads, surface flow paths and piped networks) will direct stormwater runoff from catchments to the relevant detention basins, primarily though the use of overland flow paths consisting of grassed swales or similar to contribute further to stormwater quality improvement and environmental health.

To mitigate potential impacts of an increased frequency of small runoff events affecting in-stream ecology in Leeke's Creek and Putney Creek, proposed bio-retention and detention structures in these two catchments will be designed to intercept all runoff from impervious surfaces before it reaches the respective defined waterways. In both catchments, the daily infiltration capacity of the treatment structures far exceeds the volume of the first 10 millimetres of rainfall on the respective impervious surfaces, which suggests that the proposed treatment structures provide more than sufficient capacity to manage frequent flows in accordance with SPP 4/10.

Stormwater drainage systems installed on the Island will be designed to manage flows up to a one in 100 year Annual Exceedance Probability (AEP) storm event. However, it is predicted that rainfall intensity in this region may increase as a result of projected climate change and this could potentially impact on the effectiveness of stormwater drainage infrastructure resulting in flooding of buildings and other facilities, and possible flooding of neighbouring properties, or resulting in release of untreated stormwater runoff.

To reduce the risk of rainfall events exceeding the design capacity of stormwater treatment and drainage systems it is proposed that stormwater infrastructure be designed with an increased capacity sized to account for projected increases in rainfall intensity, which are expected to comprise a 48 percent increase in rainfall during a two-hour event, a 16 percent increase in rainfall during a 24 hour event and a 14 percent increase in rainfall during a 72 hour event.

(e) Stormwater Runoff - Quality

Stormwater runoff from developed areas within the GKI Revitalisation Plan has the potential to transport pollutants via stormwater drainage systems to downstream waterways. The main pollutants of concern from this type of development typically comprise gross pollutants, sediment and nutrients, particularly nitrogen and phosphorous. Potential impacts associated with these pollutants include:

- gross pollutants (e.g., litter) which can harm native fauna, particularly marine wildlife through choking and entanglement, while also impacting on visual amenity;
- high levels of suspended sediment in runoff can result in sedimentation of waterways, destroying in-stream pool habitats and smothering benthic flora and fauna, as well as impacting on visual amenity, clogging pipework and irrigation systems, and potentially increasing flooding potential by reducing waterway capacity; and
- high levels of nitrogen and phosphorous in stormwater runoff can result in eutrophication of receiving water causing algal blooms, which can be toxic to flora and fauna, and harmful to humans. As algal blooms die-off, decomposition of the large amounts of algal matter may generate odour nuisance while also decreasing dissolved oxygen in the water causing fish mortality and other marine biology impacts.

To mitigate potential impacts from pollutants in stormwater runoff discharging to downstream waterways, a range of stormwater quality improvement devices will be installed within the stormwater drainage system for the Project.

The primary means of improving stormwater quality as part of the Revitalisation Plan will involve the installation of a series of bio-retention basins, bio-retention swales and infiltration areas. These devices utilise bio-filters comprised of native vegetation and natural sand materials to remove sediment and nutrients from stormwater before allowing the stormwater to infiltrate into the natural sandy soils mimicking the natural process of groundwater recharge through rainwater infiltration that occurs on the Island.

Bio-retention basins, bio-retention swales and infiltration areas comprise low impact structures that are robust and well proven as key components of best practice water sensitive urban design. These devices are not visually intrusive and can generally be integrated with landscaping features. Maintenance requirements for such systems are not onerous and performance can be readily monitored by visual means, which assists in maintaining the effectiveness of these devices over time. Regular maintenance of these devices is generally limited to plant health checks and removal of sediments and litter, which can largely be carried out by general landscaping maintenance personnel.

Preliminary sizing of bio-retention systems required to achieve the relevant water quality objectives has been determined through MUSIC modelling as described in **Chapter 2** of this EIS. To enhance the overall environmental benefits, it is proposed that a distributed or decentralised network of smaller bio retention "cells" be provided, rather than larger, centralised catchment scale structures.

It is proposed that stormwater runoff from all hardstand areas (roads, paved and sealed areas, airstrip and apron, parking areas), including hardstand areas within the Marine Services Precinct, will drain off the sealed area in a dispersed flow via flush kerbs or the like, and into adjoining bio-retention "cells". Where bio-retention cells are not able to be sited immediately adjacent to the sealed area, flows will be directed to the relevant bio-retention cell via vegetated swales (as opposed to piped systems) wherever possible. Where piping is unavoidable, gully inlets should be sited in collector swales adjoining the sealed area, rather than in the sealed area itself.

Roof water runoff from the Resort and marina facilities will be collected in gutters and piped to rainwater storage tanks for reuse. All rainwater tank overflows will be directed to bio-retention cells. Where rainwater tanks are not provided, roof runoff will be taken directly to the bio-retention cells for treatment prior to absorption into the natural underlying sandy soils.

Although bio-retention systems are capable of removing gross pollutants such as litter, frequent removal of debris is required to maintain effectiveness. In order to prevent litter from the Resort entering waterways where it may harm wildlife, proprietary gross pollutant traps will be installed as part of the stormwater treatment train in key locations where litter generation is most likely to be concentrated and where the risk of entering waterways is greatest (e.g. the Marine Services Precinct).

(f) Golf Course Maintenance

The use of fertilisers and pesticides on the golf course will have the potential to impact on water quality and environmental values within receiving waterways where such pollutants are transported via unmitigated stormwater runoff. The proposed 18 hole championship golf course will be located primarily within Catchment 11 (**Figure 3.57**), which subsequently drains into Leeke's Creek and via Catchment 10 to discharge at Leeke's Beach. A small part of the golf course will be located within Catchment 5, which drains in dispersed flow to discharge into Clam Bay.

Accordingly, a range of measures will be implemented to minimise the potential for stormwater to come into contact with pollutants that may exist on the golf course and to ensure any stormwater that does come into contact with potential contaminants on the golf course is managed in a manner that reduces the risk of causing adverse impacts on water quality in receiving waters.

Stormwater management measures proposed for the golf course will consist of the following:

- all surface runoff from areas outside of the golf course will be prevented from draining onto the golf course through the use of diversion drains incorporating grassed swales;
- all surface runoff from the proposed golf course will be diverted to stormwater harvesting ponds for reuse for irrigation of the golf course;
- golf course stormwater runoff will be directed to the stormwater harvesting ponds through a series of grassed swales and / or bio-retention basins to facilitate removal of gross pollutants (e.g., litter) sediment and nutrients prior to entering the stormwater harvesting ponds;
- stormwater harvesting ponds will incorporate an overflow pond provided with appropriate scour protection and outletting to a grassed overland flow channel providing further treatment prior to ultimately discharging to Leeke's Creek;
- stormwater will be prevented from draining into wet weather storage ponds containing recycled water for irrigation of the golf course through detailed design engineering; and
- monitoring of water quality within the stormwater harvesting ponds will be undertaken as part of the Irrigation Management Plan proposed for the golf course to ensure water quality is 'fit for purpose' (refer **Appendix AN - Water Cycle Management Report**).

(g) Sewerage Collection and Treatment Systems

A mechanical malfunction or electricity failure affecting the sewerage collection and treatment system has the potential to result in the uncontrolled release of untreated or partially treated sewage to the environment. In terms of the sewerage collection system, the flow of sewage through the gravity sewer system would be unaffected by a power outage up until the collection well of sewage pump stations.

The potential for electricity supply to the sewerage collection and treatment systems to be interrupted will be significantly reduced by the intention to install solar panels on the Island to provide all of the electricity supply needs for the Project. Given the proposed installation of a mainland electricity supply connection as a back-up, sewerage collection and treatment systems will have access to dual electricity supply systems. In addition, electricity distribution around the Island is proposed to be provided underground thus significantly reducing the risk of damage during a cyclonic event. Given the relatively high security of electricity supply for the sewerage collection and treatment systems, the risk of sewage overflows occurring is considered to be relatively low.

Nevertheless, given the high environmental significance of the Island and surrounding waters, to further mitigate this risk it is proposed that a dedicated stand-by generator (or capacity within the main resort stand-by generator) will be provided for the WWTP(s) (refer to **Appendix AG - Power and Communications Report**) to provide an emergency power supply in the event that electricity supply from solar panel systems and the mainland connection is not available.

Furthermore, in the event of a power outage, the WWTP(s) will be designed to contain up to approximately 10 hours x Average Dry Weather Flow (ADWF) within various components of the treatment plant and / or within a separate emergency overflow storage pond. After power is restored, the bypassed flow would then be returned from the emergency overflow storage pond back through the WWTP(s) for treatment. The emergency storage capacity (within the plant and / or separate storage pond) would be approximately 312 kilolitres based on 200 L/EP/day x 3,750EP (98 percent occupancy) over 10 hours. This storage capacity has been determined to provide sufficient storage for the estimated time required for maintenance staff to respond to system monitoring with warnings of overflows and any issues with the starting up of stand-by generators.

Due to staging requirements and operational flexibility, the sewerage treatment system would involve duplication (or triplication) of treatment plant processes. This will allow for one system to be out of service for short periods in the event of maintenance requirements (programmed maintenance being undertaken at low flow / low occupancy times) or emergency breakdown situations due to mechanical malfunction.

To ensure contingency measures for preventing sewage overflows are implemented effectively, as part of the contingency planning for the operation of the wastewater treatment the following would also be established:

- A 24/7 Emergency Response Plan incorporating remediation and clean up procedures investigation and improvement plans. Remediation and clean up in this case would be expected to mainly involve ensuring the return of any overflow from the storage pond and clean up of the storage pond area on completion;
- "Due Diligence" practices imbedded in design and operation including risk management principles (including the features outlined above), to minimise the potential for overflows and environmental harm, community exposure to overflows minimised with any overflow contained within the WWTP and associated overflow storage pond within the fenced WWTP compound;

- organisational management with clearly defined accountabilities within the maintenance hierarchy for the appropriate operational and maintenance aspects of the wastewater system, pumping stations, WWTP and back-up generators; and
- reporting procedures to the authorities.

To reduce the potential for uncontrolled releases from the sewerage collection system due to loss of electricity supply or mechanical malfunction, the following measures are proposed:

- any individual unit grinder pump stations (where installed to villas) would have a storage capacity within the pump collection well for at least four hours at ADWF. This would typically involve around 100 litres of storage within the collection well for each villa; and
- main sewage pump stations would be provided with:
  - 100 percent stand-by pumping capacity within the pump station to cover pump mechanical breakdown;
  - an alarm system to advise maintenance staff of power or mechanical failure;
  - capacity within the emergency back-up generator for the Resort and / or provision (i.e., power bypass switch) within the pumping station to connect up an individual emergency generator brought to the pumping station to cover power failures; and
  - minimum of three hours storage capacity at ADWF within the pump station wet wells and contributing reticulation mains (and overflow storage if required with any overflow being returned to the wet well).

(h) Recycled Water Irrigation

Irrigation of recycled water at a rate exceeding the water and nutrient assimilation capacity of soils and vegetation within the irrigation area may result in runoff of contaminants (e.g., nutrients) impacting on environmental values (e.g., ecosystem protection, recreation) within downstream waterways. Irrigation of recycled water not treated to a suitable standard would increase the risk of contaminants in any runoff impacting on surface waters.

Elevated nutrient concentrations in surface waters may result in eutrophication causing algal blooms, which can be toxic to flora and fauna, and harmful to humans. As algal blooms die-off, decomposition of the large amounts of algal matter may generate odour nuisance while also decreasing dissolved oxygen in the water causing fish kills and other marine biology impacts. Runoff of recycled water potentially containing human pathogens may also impact on the suitability of receiving waters for recreational use.

To mitigate these potential impacts, best-practice water quality requirements for treatment of sewage effluent to be used for irrigation on the Island have been specified. These minimum water quality requirements have been determined to comply with the minimum water quality requirements specified for "Municipal Use – open spaces, sports grounds, golf courses, dust suppression, etc or unrestricted access and application" under the *Australian Water Quality Guidelines for Water Recycling: Managing Health and Environmental Risks* (Phase 1) (ANZECC, 2006). Nutrient levels will be reduced to 20 milligrams per litre of total nitrogen and 7 milligrams per litre of total phosphorous.

Proposed recycled water irrigation areas are located within sandy soils characterised by high permeability and therefore low likelihood of runoff. Nevertheless, a detailed water and nutrient balance has been undertaken and based on the proposed irrigation regime, no direct runoff of recycled water will occur. Furthermore, runoff rates predicted by MEDLI modelling for the proposed irrigation scheme will be less than predicted rates of runoff under no irrigation due to the enhanced rates of evapo-transpiration achieved by increased plant coverage supported by irrigation.

Implementation of the proposed irrigation scheme in accordance with Appendix H of **Appendix AN - Water Cycle Management Report** combined with the naturally low risk of runoff will therefore significantly reduce the risk of recycled water runoff from the irrigation area. However, monitoring of surface water quality, including within Leeke's Creek located downstream of the proposed irrigation area, is proposed as part of the preliminary Irrigation Management Plan developed for the Project.

(i) Discharge of Recycled Water via Ocean Outfall

Discharge of contaminants in recycled water to coastal waters via ocean outfall has the potential to impact on water quality and ecological communities in the vicinity of the outfall. As noted previously, elevated nutrient concentrations in receiving waters may result in eutrophication causing algal blooms, which can be toxic to flora and fauna, and harmful to humans. As algal blooms die-off, decomposition of the large amounts of algal matter may generate odour nuisance while also decreasing dissolved oxygen in the water causing fish kills, etc. Discharge of recycled water potentially containing human pathogens may also impact on the suitability of receiving waters for recreational use.

To mitigate these potential impacts, recycled water, if discharged via ocean outfall, will be treated to achieve a total nitrogen concentration of less than 20 milligrams per litre, a total phosphorous concentration of less than seven milligrams per litre and an *E. coli* level less than one colony-forming unit per 100 millilitres and as per GBRMPA guidelines and permit conditions.

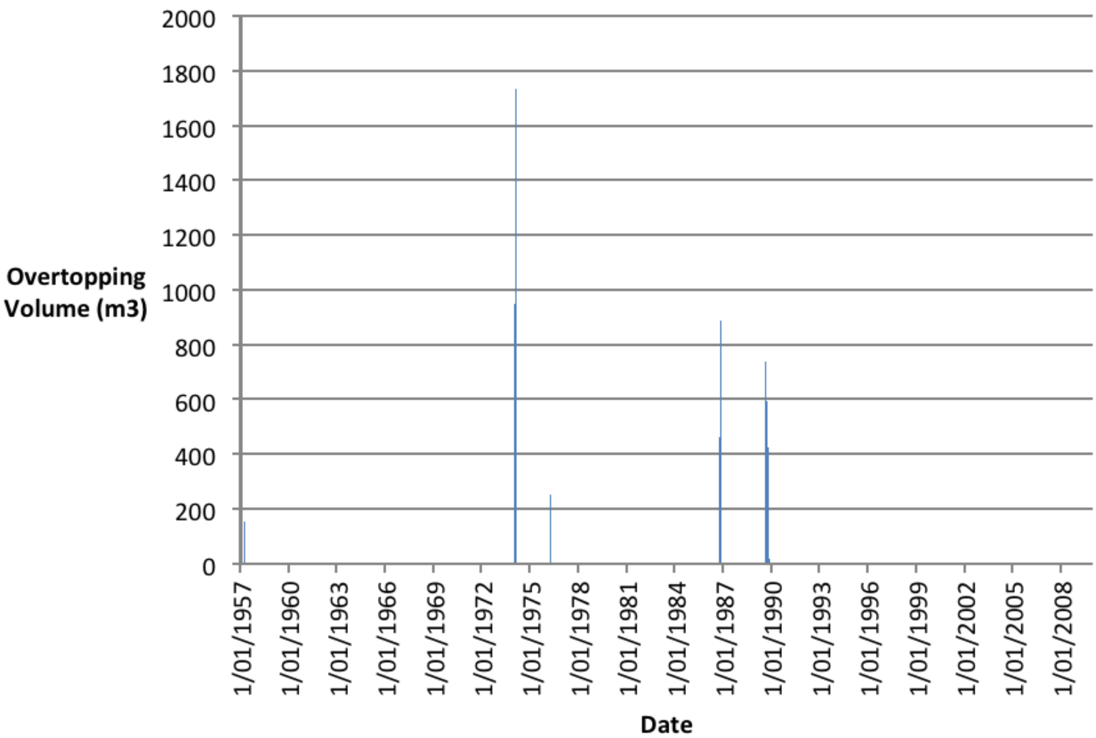
MEDLI modelling for the proposed recycled water irrigation scheme indicates that in most years, 100 percent of all recycled water generated by the Project will be reused on the Island for irrigation of the golf course and possibly other landscaped garden and turf areas. During prolonged or extreme wet weather events, expected to occur approximately once every 10 years on average, wet weather storage ponds may reach capacity and a proportion of the recycled water may subsequently be discharged via an ocean outfall.

The likelihood of ocean discharge occurring is expected to be somewhat less than the one in 10 years predicted by MEDLI given that the MEDLI modelling was based on provision of a 37 megalitres wet weather storage. However, to account for potential increases in rainfall intensity that are predicted to occur as a result of climate change, it is proposed to provide 44 megalitres wet weather storage or almost 20 percent more storage than considered in the MEDLI modelling. This is considered to be an extremely conservative approach to sizing of the wet weather storage given that although increased rainfall intensity is predicted to occur as a result of climate change, a decrease in average annual rainfall is also expected to occur meaning that:

- irrigation is likely to be triggered more often based on a soil water deficit, resulting in more recycled water being used for irrigation and less recycled water going into wet weather storage; and
- less direct rainfall will be captured by the open wet weather storage ponds providing more capacity for storage of recycled water.

On this basis, MEDLI modelling indicates that less than one percent of all recycled water produced will be discharged via ocean outfall over the life of the Project. Based on provision of a 37 megalitres wet weather storage, MEDLI modelling indicates that the average annual volume of overtopping over the life of the Project would be in the order of 0.76 megalitres per year. MEDLI modelling based on provision of a 37 megalitres wet weather storage pond also indicates that discharge will occur on average, once every 10 years during extreme or prolonged wet weather events similar to those rain events that occurred in 1957, 1974 and 1989 (refer to **Figure 3.60**). It would have also occurred in January 2011 due to the extreme wet weather events. During these conditions the recycled water will be diluted and the water quality of the receiving environment is likely to be already impacted by land-based sources of runoff (e.g. Fitzroy discharge).

Figure 3.60 OVERTOPPING EVENTS PREDICTED ASSUMING PROVISION OF 37 MEGALITRES WET WEATHER STORAGE



To determine the location of the proposed ocean outfall, consideration has been given to GBRMPA's *Sewage Discharge Policy - Sewage Discharges from Marine Outfalls to the Great Barrier Reef Marine Park, March 2005*. This policy states that:

Marine outfalls should not be constructed:

i. Within 50 metres of a permitted mooring or anchorage; or

ii. Within 1000 metres of aquaculture operations, or an area regularly used for

iii. Swimming or other water-based activities, unless it can be demonstrated that there will be no adverse impacts on the operation or activities; or Within 1000 metres of sensitive environments, unless it can be demonstrated that there will be no adverse impacts on the protection of aquatic ecosystems.

For a marine outfall to be approved the GBRMPA will require that:

i. The outfall structure be of a design which optimises diffusion and dispersal; and

ii. The design of the system includes consideration of water depth (deep water is preferred i.e. greater than 10 metres), current velocity, tidal range and proximity to reefs or other sensitive environments.

A bathymetric survey has been conducted offshore to the south of Long Beach. This location was selected to provide adequate distance away from the shore, sufficient depth and exposure to offshore ocean currents to facilitate dispersion of recycled water. This location avoids identified coral reefs and has minimal impacts to existing seagrass beds (frc environmental, 2011).

The proposed ocean outfall will comprise a pipeline of approximately 1,000 metres in length extending from Long Beach. The outfall will be located within an area of water at least 10 metres deep to ensure sufficient depth of water is available above the diffuser across the full tidal range. The outfall will incorporate a T-shaped diffuser comprising two ports approximately 75 millimetres diameter. Modelling of predicted dispersion of discharges from the ocean outfall has been undertaken by Water Technology and is contained in **Appendix Y - Coastal Environment Technical Report.**

Based on the estimated volume and duration of discharge events predicted by MEDLI modelling and assuming effluent nutrient concentrations of 20 milligrams per litre for total nitrogen and seven milligrams per litre of total phosphorous, dispersion modelling by Water Technology has predicted that concentrations of total nitrogen and total phosphorous will reduce to below relevant trigger values within a small mixing zone in the immediate vicinity of the outfall. On this basis, the proposed emergency wet weather discharge of recycled water via an ocean outfall is not anticipated to have any significant impact on ecological communities near the outfall.

Regular inspections of the ocean outfall pipeline will be conducted and any necessary repairs undertaken promptly to ensure it is available for use when required. In the extremely unlikely event that the ocean outfall pipeline is not available at a time when wet weather storage facilities reach capacity due to prolonged wet weather, to prevent uncontrolled overtopping of the storage facility, the level of recycled water contained within the storage will be reduced, in consultation with the relevant authorities, by irrigation to the designated irrigation area regardless of soil moisture levels.

(j) Storage of Recycled Water and Harvested Stormwater

The storage of recycled water and harvested stormwater from golf course runoff in open ponds will have the potential to create conditions suitable for algal blooms, due to the presence of nutrients combined with exposure to sunlight. The storage of recycled water in open ponds also has the potential to result in uncontrolled releases of recycled water draining to downstream waterways, such as Leeke's Creek in the event of overtopping.

In order to minimise these potential impacts, all recycled water discharged to wet weather storage ponds will be treated to a standard suitable for irrigation of public open space with unrestricted access in accordance with the *Australian Guidelines for Water Recycling: Managing Health and Environmental Risks* (Phase 1) (ANZECC, 2006) with nutrient levels reduced to a total nitrogen concentration of less than 20 milligrams per litre, a total phosphorous concentration of less than seven milligrams per litre and an *E. coli* level less than onecolony-forming units per 100 millilitres.

The proposed standard of treatment is characterised by relatively low levels of nutrients to reduce the potential for cyano-bacterial and other algal blooms, and low levels of organic matter that reduce the risk of odour generation. The potential for algal blooms will be significantly reduced by maintaining regular turnover of water within the storage through inflows and outflows associated with irrigation of recycled water to the golf course. In addition, it is proposed that floating native plants be established within recycled water storage and stormwater harvesting ponds to assist with the uptake of nutrients. Where necessary, additional mechanical aeration may be required to reduce risk of algal blooms.

To reduce potential health risks associated with the open recycled water storages, signage will be provided around all wet weather storage ponds notifying the public that the storage contains recycled water and contact should be avoided. In addition, access to the ponds for retrieval of balls etc will be further discouraged by planting of vegetation (e.g., sedges, reeds) around the perimeter of the ponds.

Regular maintenance of open water storage ponds will be carried out to control pests in accordance with relevant statutory requirements, including managing excessive wildlife populations that may reduce water quality within the storage.

To prevent uncontrolled releases from the open recycled water storages, a diversion system to discharge in a controlled manner via an ocean outfall pipeline will be implemented. To reduce the likelihood of overtopping due to possible increases in rainfall intensity as a result of climate change, open recycled water storages will be designed to contain an additional seven mega-litres of storage, which equates to about a 20 percent increase in the storage requirements identified by MEDLI modelling for the proposed irrigation scheme. Stormwater diversion systems will be installed to divert surface runoff away from recycled water storages to reduce the likelihood of overtopping.

(k) Storage and Handling of Hazardous Substances

Spillage or leakage from hazardous substance storage areas, and other locations containing potential contaminants (e.g., waste storage and handling facilities, maintenance workshops etc) has the potential to impact on water quality in downstream waterways where such contaminants are able to enter the stormwater drainage system.

Specific stormwater management measures will be provided in high risk areas likely to contain significant quantities or types of contaminants. In general, such areas will be designed to prevent stormwater coming into contact with contaminants through the use of perimeter diversion systems, to divert surface runoff from flowing into these areas, possibly combined with covering or roofing of the area where appropriate to prevent direct rainfall runoff.

In addition, use of perimeter bunding and hardstand surfaces will be used for particularly high risk areas to prevent the release of contaminants accidentally spilled or leaked within the area. Any stormwater that does enter such areas would be collected and tested to ensure compliance with relevant water quality standards prior to disposal. Where appropriate, additional treatment devices may be installed including triple interceptors to separate oils and grease from water prior to release.

Further measures to manage spills and leaks associated with the storage and handling of hazardous substances are provided in **Appendix AN - Water Cycle Management Report** and **Appendix AM - Waste Management Report**.

3.5.3.3 Potential Impacts and Mitigation Summary

A risk assessment of potential environmental impacts associated with proposed water cycle management aspects of the GKI Revitalisation Plan has been undertaken and is described in the following section, along with proposed mitigation measures to address each identified risk. A standard risk assessment matrix as presented in **Table 3.1** has been used for the purpose of assessing risks associated with water supply, wastewater and stormwater drainage strategies proposed for the GKI Revitalisation Plan.

The following risk assessment has been based on the proposed water supply, wastewater and stormwater management strategies outlined in **Appendix AN**.

A summary of potential impacts and proposed mitigation measures associated with water cycle management as part of the GKI Revitalisation Plan is provided in **Table 3.67**.

TABLE 3.67 SUMMARY OF POTENTIAL WATER SUPPLY, WASTEWATER AND STORMWATER IMPACTS AND PROPOSED MITIGATION MEASURES

Potential Impact	Risk Level (Unmitigated)	Risk Level (Mitigated)	Mitigation Measures
Construction of Water Cycle Infrastructure			
Removal of vegetation for construction of water cycle infrastructure resulting in loss of habitat and increased risk of erosion and sedimentation of waterways.	**High**	**Low**	Refer **Section 3.5.3.2 (a).**
Excavation and filling for construction of water cycle infrastructure resulting in increased risk of erosion and sedimentation of waterways.	**Low**	**Low**	Refer **Section 3.5.3.2 (a).**
Disturbance of acid sulfate soils for construction of water cycle infrastructure (e.g., mainland water supply connection, emergency ocean outfall) resulting in release of acid discharge and heavy metals impacting on water quality and ecological communities.	**Medium**	**Low**	Refer **Section 3.5.3.2 (c).**
Construction of water cycle infrastructure within watercourses interfering with the flow of water and providing barriers to fish movement (e.g., pipeline and access road crossings, detention basins) resulting in decreased biodiversity.	**Medium**	**Low**	Refer **Section 3.5.3.2 (b).**

TABLE 3.67 SUMMARY OF POTENTIAL WATER SUPPLY, WASTEWATER AND STORMWATER IMPACTS AND PROPOSED MITIGATION MEASURES (CONTINUED)

Potential Impact	Risk Level (Unmitigated)	Risk Level (Mitigated)	Mitigation Measures
Construction of water cycle infrastructure in tidal waters (e.g., mainland water supply connection, emergency ocean outfall) resulting in disturbance of marine plants and benthic habitat and increased turbidity.	**High**	**Medium**	Exact positioning of water cycle infrastructure within tidal waters will be determined in consultation during detailed design with relevant authorities based on ecological assessments to determine the least impact alignment feasible. Preference will be given to the use of construction techniques and equipment that result in the minimum level of disturbance and footprint feasible. Best practice erosion and sediment control measures will be implemented for all works within tidal waters. Rehabilitation of all disturbed areas will be provided in accordance with the requirements of relevant statutory authorities. Where necessary, environmental offsets will be provided for all marine plant removal in accordance with the relevant guidelines and policies for providing such offsets. Refer also **Section 3.5.3.2 (i)**.

TABLE 3.67 SUMMARY OF POTENTIAL WATER SUPPLY, WASTEWATER AND STORMWATER IMPACTS AND PROPOSED MITIGATION MEASURES (CONTINUED)

Potential Impact	Risk Level (Unmitigated)	Risk Level (Mitigated)	Mitigation Measures
Operation of Water Supply Infrastructure			
Water consumption within Resort facilities exceeds projected water demands resulting in increased supply costs, need for infrastructure upgrades and increased pressure on valuable water resources.	**Medium**	**Low**	Periodic water efficiency audits will be undertaken approximately every five years, to ensure fixtures and fittings continue to achieve desired levels of water use efficiency and to identify any losses in the water supply system due to leakage or unauthorised connections. To enable monitoring of water usage and to inform water efficiency audits, flow metres will be installed on all water supply sources, including the mainland water supply connection, distribution systems for reuse of recycled water and harvested stormwater and groundwater production bores for Stage 1 construction. Records shall be kept of all water usage for at least five years. Critical water supply infrastructure such as the mainland water supply connection will be sized using appropriate peaking factors considering potential internal demands associated with peak occupancy and peak irrigation demands associated with low rainfall periods. Regular awareness training shall be provided to all staff in relation to the importance of water use efficiency. Information shall be provided to guests through resort signage and other applications (e.g., smartphone apps). Information relating to water usage by the GKI Revitalisation Plan, including water supply sources used, will regularly be made available to the public through the Resort's website or other means to demonstrate the Resort's sustainability performance.
Damage to mainland water supply connection resulting in disruption to water supply services on the Island.	**High**	**Medium**	In the event of damage to the mainland water supply connection, preservation of stored water will be a priority and water restrictions applied. Where necessary, potable water supplies may be transported to the Island by barge. In the event of extended disruption to the mainland water supply connection, consideration will be given to reducing guest occupancy and staffing to preserve the available water supply.

TABLE 3.67 SUMMARY OF POTENTIAL WATER SUPPLY, WASTEWATER AND STORMWATER IMPACTS AND PROPOSED MITIGATION MEASURES (CONTINUED)

Potential Impact	Risk Level (Unmitigated)	Risk Level (Mitigated)	Mitigation Measures
Excessive extraction of groundwater resulting in lowering of water tables impacting on groundwater dependent ecosystems.	**Medium**	**Low**	Refer **Section 3.5.3.1 (a).**
Excessive extraction of groundwater resulting in lowering of water tables and saline intrusion, which could impact on availability of suitable water supply to other users.	**Medium**	**Low**	Refer **Section 3.5.3.1 (a).**
Operation of Wastewater Infrastructure			
Irrigation of recycled water resulting in runoff of nutrients causing contamination of surface water resources.	**Medium**	**Low**	Refer **Section 3.5.3.2 (h).**
Irrigation of recycled water resulting in excessive leaching of nutrients causing contamination of groundwater resources.	**High**	**Low**	Refer **Section 3.5.3.1 (c).**
Irrigation of recycled water resulting in raised water tables, saturation of soils and / or ponding within the irrigation area.	**Medium**	**Low**	Refer **Section 3.5.3.2 (c).**
Irrigation of recycled water resulting in decreased plant health and soil quality within the irrigation area due to excessive salinity.	**Medium**	**Low**	Refer **Section 3.5.3.1 (c)** and **Section 3.5.3.2 (h).**

TABLE 3.67 SUMMARY OF POTENTIAL WATER SUPPLY, WASTEWATER AND STORMWATER IMPACTS AND PROPOSED MITIGATION MEASURES (CONTINUED)

Potential Impact	Risk Level (Unmitigated)	Risk Level (Mitigated)	Mitigation Measures
Exposure of the public to recycled water as a result of spray drift during recycled water irrigation causing nuisance or illness.	**High**	**Low**	Refer **Section 3.5.3.2 (h).**
Exposure of the public to recycled water as a result of storage of recycled water in open ponds on the golf course causing illness.	**High**	**Low**	Refer **Section 3.5.3.2 (j).**
Deterioration of water quality within recycled water storage ponds causing algal blooms and odour nuisance.	**Medium**	**Low**	Refer **Section 3.5.3.2 (j).**
Emergency discharge of recycled water via ocean outfall reducing water quality and impacting on ecological communities.	**Medium**	**Low**	Refer **Section 3.5.3.2 (i).**
Damage to ocean outfall pipeline preventing emergency discharge of recycled water when required resulting in uncontrolled overtopping of storage facilities.	**Medium**	**Low**	Refer **Section 3.5.3.2 (i).**

TABLE 3.67 SUMMARY OF POTENTIAL WATER SUPPLY, WASTEWATER AND STORMWATER IMPACTS AND PROPOSED MITIGATION MEASURES (CONTINUED)

Potential Impact	Risk Level (Unmitigated)	Risk Level (Mitigated)	Mitigation Measures
Generation of odour caused by operation of the sewerage treatment plant and associated collection and storage systems causing nuisance at a sensitive place.	**High**	**Low**	To reduce the potential for odours at the sewerage treatment plant, a packaged plant such as MBR is proposed as the process components are effectively sealed within the plant. Odour issues may arise in the event of power failure when effluent is diverted to temporary storage in open ponds adjacent to the plant; however such events are expected to be rare. Nevertheless, appropriate buffer distances will be provided between the WWTP and sensitive receivers to reduce the potential for odour nuisance. Odour control within the collection system would be achieved by sealing of all manholes and pumping stations, thus containing any odours within the system. Refer also **Section 3.7 – Air Quality.**
Mechanical malfunction or electricity failure affecting the sewerage collection system resulting in release of untreated sewage to the environment.	**High**	**Low**	Refer **Section 3.5.3.2 (g).**
Mechanical malfunction of the sewerage treatment plant resulting in release of untreated sewage to the environment.	**High**	**Low**	Refer **Section 3.5.3.2 (g).**
Loss of electricity supply resulting in shutdown of sewerage collection and treatment systems resulting in release of untreated sewage to the environment.	**High**	**Low**	Refer **Section 3.5.3.2 (g).**
Operation of Stormwater Infrastructure			
Increased peak discharge velocities causing scouring and erosion in downstream drainage lines and impacting on waterway stability.	**High**	**Low**	Refer **Section 3.5.3.2 (d).**

TABLE 3.67 SUMMARY OF POTENTIAL WATER SUPPLY, WASTEWATER AND STORMWATER IMPACTS AND PROPOSED MITIGATION MEASURES (CONTINUED)

Potential Impact	Risk Level (Unmitigated)	Risk Level (Mitigated)	Mitigation Measures
Increased frequency of small runoff events altering flow regimes and in-stream habitat within receiving waters, impacting on biodiversity.	**Medium**	**Low**	Refer **Section 3.5.3.2 (d).**
Rainfall events exceed the design capacity of stormwater drainage systems resulting in flooding of buildings and other facilities, and possible flooding of neighbouring properties.	**High**	**Medium**	Refer **Section 3.5.3.2 (d).**
Rainfall events exceed the design capacity of stormwater treatment systems resulting in release of untreated stormwater runoff.	**Medium**	**Low**	Refer **Section 3.5.3.2 (d)** and **Section 3.5.3.2 (e).**
Discharge of contaminated stormwater runoff from high risk areas to receiving waters impacting on water quality and environmental values.	**Medium**	**Low**	Refer **Section 3.5.3.2 (e)** and **Section 3.5.3.2 (k).**
Removal of sand bar at mouth of Putney Creek resulting in increased tidal exchange within the lower reaches of the channel, possibly altering riparian vegetation and in-stream flora and fauna.	**Medium**	**Low[1]**	All proposed works within the mouth of Putney Creek will be undertaken in accordance with statutory requirements and based on comprehensive ecological assessments. Ecological advice indicates that opening up of the Putney Creek mouth to tidal movement will increase fisheries productivity and increase flushing that will reduce potential for creation of eutrophied conditions and odour nuisance. Refer also **Section 3.5.3.2 (e)** and **Section 3.5.3.2 (d).**

1. *Associated benefit = improved condition of saltmarsh and mangrove communities in Putney Creek.*

3.5.4 Summary

Substantial groundwater resources are available on the Island and have the potential to supply a significant proportion of the total mains water demand for the GKI Revitalisation Plan. However, the use of groundwater as a primary water supply source during operation is not considered appropriate due to the potential for saline intrusion, other water quality impacts and the unreliability of supplies as a result of drought. As such, it is intended that the extraction of water from aquifers be limited to Stage 1 construction, prior to establishing a mainland connection. This will also protect the aquifers from overuse and provide a better quality and more sustainable resource for other Island users.

A comprehensive water and nutrient balance has been modelled and demonstrates that the proposed recycled water irrigation scheme will not increase nutrient leaching or runoff rates compared to modelling of a no irrigation scenario. Modelling of nutrient concentrations in groundwater at the point of discharge to Leeke's Creek has demonstrated compliance with relevant water quality objectives. Modelling of possible emergency discharge of recycled water via ocean outfall has also demonstrated that nutrient levels will achieve compliance with relevant water quality objectives within a very small mixing zone and are therefore unlikely to impact on ecological communities.

The high standard of treatment proposed for recycled water will not only mitigate potential impacts on the environment, but will also significantly reduce potential human health impacts should persons come into contact with recycled water. To further reduce this risk, additional controls have been proposed including the use of large droplet fixtures on spray irrigators, use of sub-surface or surface dripper systems in the vicinity of sensitive receivers, scheduling irrigation to occur at night and installing signage for all irrigation areas and recycled water storages.

By maximising beneficial reuse of wastewater generated by the GKI Revitalisation Plan and ensuring such reuse is undertaken in a manner to prevent adverse impacts on the environment or human health, the GKI Revitalisation Plan will establish a benchmark in sustainable tourism development within the Great Barrier Reef Marine Park.

The proposed stormwater management strategy for the GKI Revitalisation Plan has been designed to:

- comply with the requirements of the *State Planning Policy 4/10 Healthy Waters and the draft Urban Stormwater - Queensland Best Practice Environment Management Guidelines 2009*;
- minimise the use of underground piped drainage systems by utilising surface drainage techniques that reduce the need for extensive excavation while enabling drainage systems to be integrated into landscape design and reducing the concentration of drainage flows to a limited number of discharge points;

- support the collection and reuse of rainwater from impervious roof surfaces to mitigate peak flow rates while also providing an alternative water supply for resort facilities; and
- support the harvesting of stormwater runoff from the golf course and possibly other areas around the Resort, to reduce the potential discharge of pollutants while also providing an alternative water supply for irrigation.

A series of detention basins and bio-retention systems will be installed throughout catchments containing the GKI Revitalisation Plan to:

- attenuate peak discharge flow rates to lower than existing levels for all standard average recurrence interval storm events from one year to 100 years;
- facilitate infiltration of increased surface runoff volumes into highly permeable, sandy subsoils mimicking the natural groundwater recharge process that occurs on the Island; and
- intercept and temporarily store surface flows from small runoff events so as to avoid any increase in the number of small runoff events discharging to ephemeral waterways that could potentially alter in-stream ecology.

Detention structures will comprise low impact designs utilising low grassed or vegetated mounds enclosing open space that can be readily incorporated as part of the landscape design for the Project.

Best practice vegetated bio-retention systems, including bio-retention basins, swales and infiltration areas will be installed to remove gross pollutants, sediments and nutrients from stormwater flows prior to discharge. Modelling demonstrates that proposed stormwater quality improvement measures will readily achieve required annual pollutant load reduction targets and will result in no worsening of stormwater pollutant concentrations compared to modelling of the pre-developed catchment.

It has also been proposed to permanently reopen the mouth of Putney Creek to tidal movements, which will increase fisheries productivity and flushing to prevent the formation of eutrophied conditions that may contribute to algal blooms and subsequent odour nuisance. To achieve this, a lined discharge channel will be constructed below the boardwalk and esplanade, with a sediment basin incorporated towards the upstream end of the new channel. This will reduce the potential for silting up of the marina basin thereby reducing the need for ongoing maintenance dredging.

3.6 Coastal Environment

Water Technology and frc environmental were engaged by the Proponent to undertake coastal environment investigations for the EIS. Refer to the full reports for the findings, potential impacts and proposed mitigations measures in **Appendix Y – Coastal Environment Technical Report** and **Appendix W – Aquatic Ecology**.

3.6.1 Hydrodynamics and Sedimentation

3.6.1.1 Geomorphology

(a) Keppel Bay

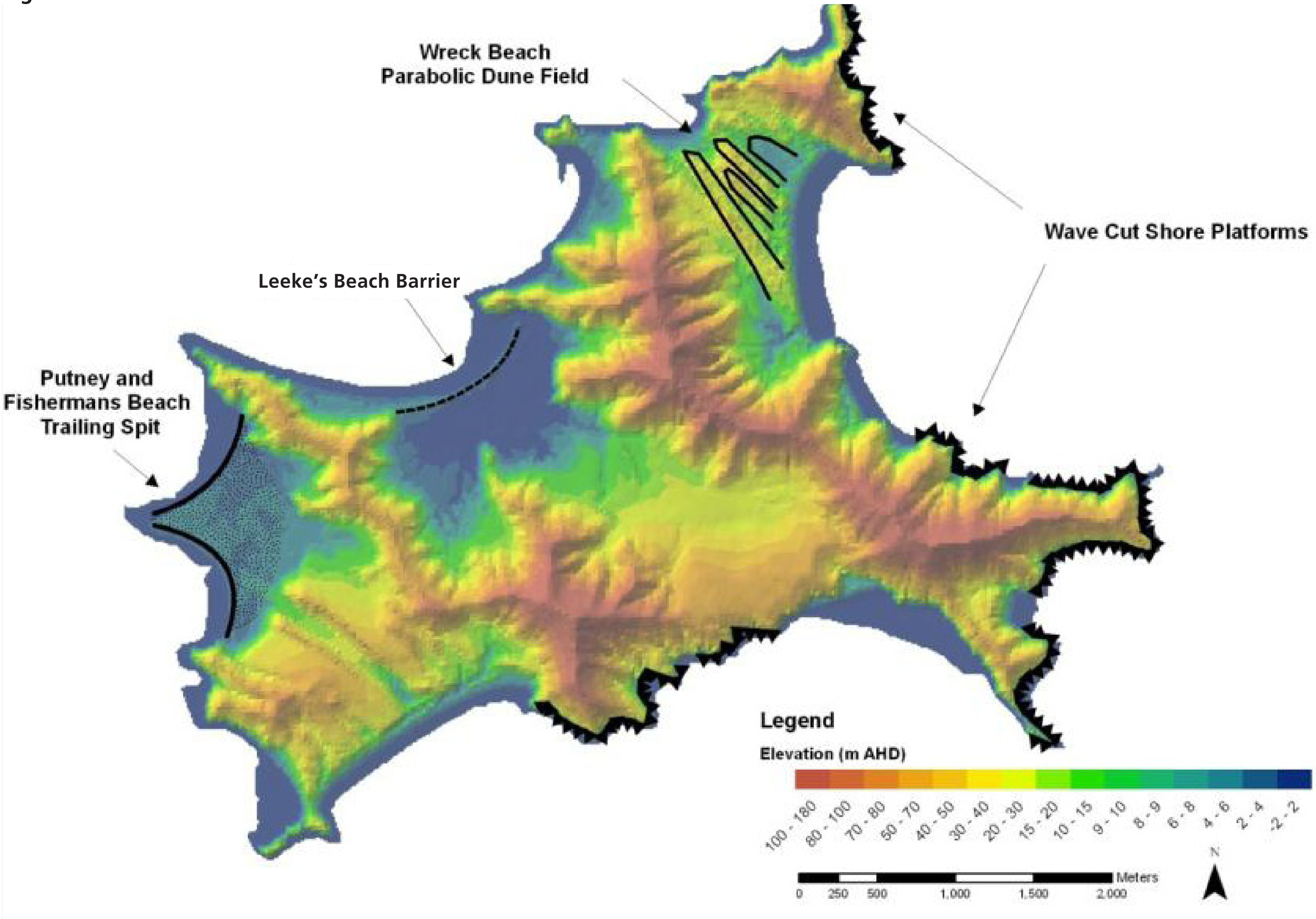
Keppel Bay is bounded to the north by the Keppel Island group and to the south by Curtis Island. The morphology of Keppel Bay is the product of a complicated history of marine transgressions and regressions, fluvial erosion and deposition and littoral and sublittoral sediment transport processes. Further discussion on the geomorphological values associated with Keppel Bay is included in **Appendix Y** .

(b) Great Keppel Island

The Island is one of a series of continental bedrock island outcrops defining the northern edge of Keppel Bay. The Island bedrock is Carboniferous aged Shoalwater Formation comprising metamorphic quartzose and lithic sandstones, with some minor mudstones and schist (QWRC, 1980).

The Island bedrock is overlaid by a relatively thin veneer of Quaternary deposits. These deposits are comprised of fine to medium relict sands that have a terrigenous origin having been formed when Keppel Bay was a sandy coastal plain during previous glacial phases. Wave and tidal current action are slowly transporting these sediments shoreward across the continental shelf. A small percentage of these shoreward migrating sediments have accreted around the bedrock outcrop of the Island following the re-submergence of Keppel Bay in the Holocene. Nearshore wave and current action and Aeolian processes have subsequently reworked and shaped these deposits into a variety of gemorphological features such as beaches, dunes and spits that in combination with the outcropping of bedrock, give rise to the present day Island topography and plan form. The main coastal geomorphologic features of the Island are displayed in **Figure 3.61**.

Figure 3.61 COASTAL MORPHOLOGY OF GKI



Source: 'COASTAL ENVIRONMENT TECHNICAL REPORT' (2011) WATER TECHNOLOGY

3.6.1.2 Bathymetry

The following sources of bathymetric data have been utilised for the assessment:

- 3DGBR Project DEM – an approximately 100 metre grid resolution DEM of the Great Barrier Reef and Coral Sea developed from ship-based multibeam and single beam echo sounder surveys, airborne LiDAR bathymetric surveys and satellite data (Beaman, R. J. 2010); and
- Project specific single beam hydrographic survey in the vicinity of Putney Beach, Fisherman's Beach and their approaches (Bennett and Bennett, 2011).

The main features of the bathymetry are summarised as follows:

- the profiles offshore of Putney Beach and Fisherman's Beach are relatively shallow, with mean depths generally less than five metres; and
- strong tidal current flows between Middle Island and GKI have scoured deeper channels between the bedrock outcrop of Passage Rocks, with mean depths exceeding 12.0 metres.

3.6.1.3 Wind Climate

The wind climate in Keppel Bay is dominated by the subtropical belt of high pressure that is generally centred around latitudes of 30 degrees south in winter and 40 degrees south in summer. The high pressure systems generate predominately south-east to north-east winds over the Keppel Bay Region.

3.6.1.4 Tides and Currents

(a) Astronomical Tides

Astronomical tides in Keppel Bay are semi-diurnal (two tides a day) with only a minor diurnal inequality. The tide resonates on the shallow shelf bathymetry of the southern Great Barrier Reef Lagoon such that Keppel Bay is macro tidal with the spring tidal range of approximately four metres. The tide propagates from south to north in Keppel Bay. Tidal plane information for the Island is provided below in **Table 3.68.**

TABLE 3.68 ASTRONOMICAL TIDAL PLANES FOR GKI (ANTT 2010)

Datum	HAT	MHWS	MHWN	MSL	MLWN	MLWS	LAT
LAT (m)	5.0	4.2	3.2	2.4	1.6	0.6	0.0
AHD (m)	2.6	1.8	0.8	0.0	-0.8	-1.8	-2.4

(b) Wind Setup/Shear

Wind forcing on the ocean's surface transfers momentum to the water column generating wind driven currents. At the surface and in shallow water, wind driven currents flow in the direction of the wind, however a return current in the opposite direction is often evident in deeper water. Wind shear and resulting wind driven currents constitute a significant source of current variability in the vicinity of the Island due to the relatively shallow depths of Keppel Bay. The following observations regarding the predicted seasonal residual current fields at the Island are provided:

- during winter, relatively light and more variable winds generate weak residual currents around the Island. Residual currents are generally north-west flowing at speeds of approximately 0.1 metres per second; and
- in comparison to winter, prevailing south easterly winds of moderate strength generate significantly stronger north-west flowing residual currents throughout Keppel Bay. At the Island, northward flowing residual currents of approximately 0.3 metres per second are generally observed in summer. These currents are however accelerated further around the eastern and western ends of the Island.

(c) Continental Shelf Waves

Distant meteorological forcing along the southern margins of the Australian continent generate low frequency waves that are trapped on the continental shelf by refraction and the Coriolis forces. These waves propagate up the east coast of Australia and into Keppel Bay, and can produce irregular variations in water levels and currents over periods of a few days to one week. They contribute a small component to the magnitude and overall variability of water levels and currents in the vicinity of the Island. More locally generated shelf waves in Keppel Bay can also be generated by variations in atmospheric pressure and wind shear associated with tropical and extra tropical cyclone disturbances on the east coast of Australia.

(d) Western Boundary Currents

The East Australian Current (EAC) is a western boundary current that generates warm, southward surface flows primarily along the margin of the continental shelf. The southward surface flows of the EAC peak in November to December and are at a minimum in April to May (Steinberg, 2007). Meandering of the EAC in response to changes in bathymetry and width of the continental shelf can generate large scale eddies that can contribute to minor changes to water level and current variability in Keppel Bay.

3.6.1.5 Wave Climate

(a) Regional Wave Climate

Long-term statistics on the wave climate in the vicinity of the Island can be derived from the Emu Park waverider buoy deployed approximately 20 kilometres to the south-east of the Island. This waverider buoy is operated by DERM (now known as DEHP). Review of the directional distribution of wave heights for the 15 years (1996-2010) of available record from this buoy shows the following main features of the regional wave climate at the Island:

- prevailing south-east to north-east winds generate relatively short five to seven second period wind waves with significant wave heights generally less than 1.5 metres;
- approximately five to 10 percent of the time, significant wave heights from the south-east through to north-east exceed 1.5 metres;
- the summer months generally experience greater wave activity than the winter months;
- waves from the west above 0.5 metres are almost completely absent from the record; and
- the higher proportion of low long period waves (Tp greater than 7.5 seconds) over winter indicates that swells from the Coral Sea make a larger contribution to the wave climate in winter.

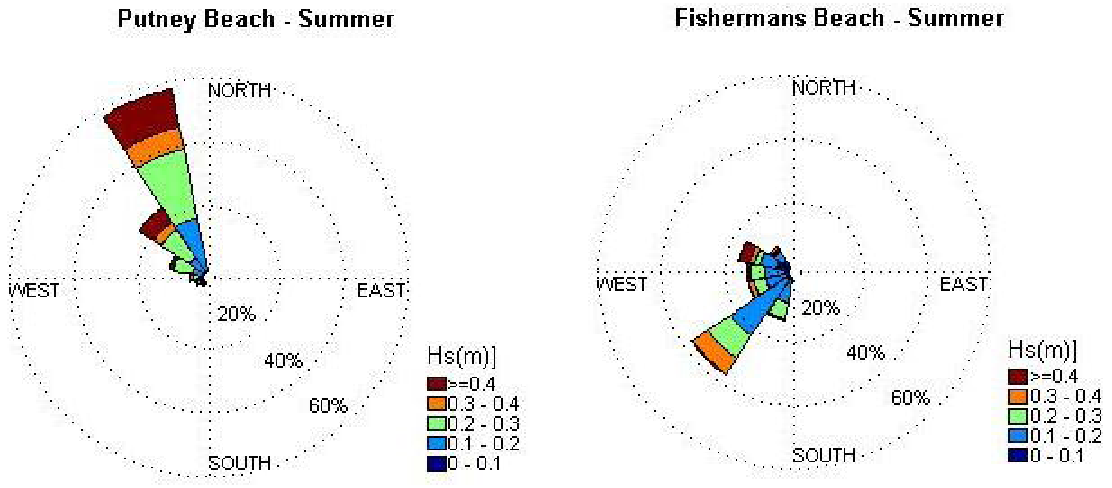
Since the installation of the Emu Park waverider buoy in 1996, there has been no near passage of a tropical cyclone. Extreme wave conditions associated with tropical cyclones are therefore absent from this record.

(b) Putney and Fisherman's Beach Wave Climate

Putney and Fisherman's Beach experience a significantly different wave climate in comparison to other beaches on the Island. This is due to their westerly aspect and the degree of sheltering afforded by the bounding headlands and offshore islands adjacent to these two beaches. The regional wave climate is therefore significantly modified by shadowing, refraction and diffraction wave processes at Putney and Fisherman's Beach. In order to define the long-term wave climate at these two beaches, a calibrated spectral wave model was employed to hindcast the wave climate over a period of five years (2004 – 2009). The summer and winter wave roses for Putney and Fisherman's Beach are displayed in **Figure 3.62** and **Figure 3.63** respectively. The following comparisons between the regional wave climate discussed above and the Putney and Fisherman's Beach wave climate are provided below:

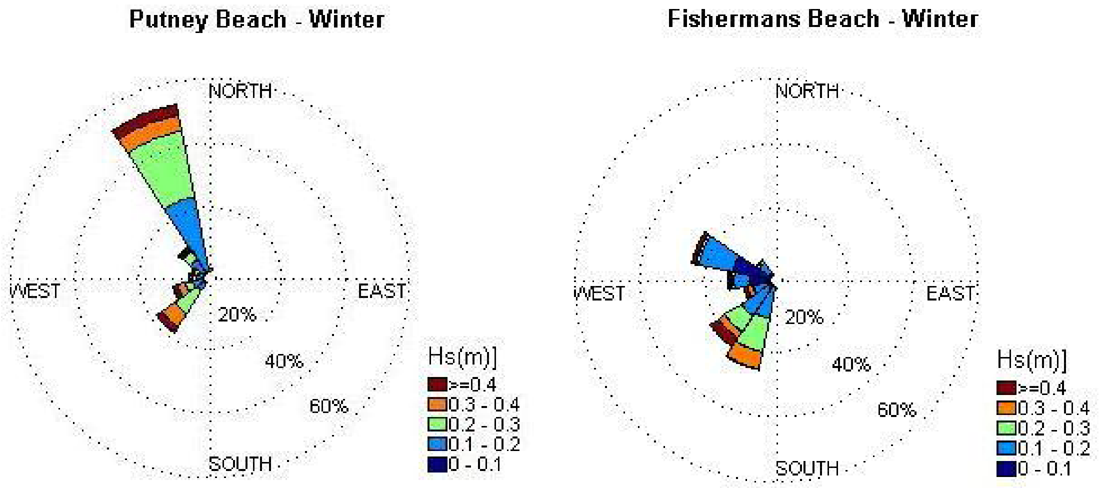
- waves generally arrive at Putney Beach from a very narrow directional band centred around the north-north-west These waves are generally small (less than 0.5 metre significant wave heights) and generally have periods exceeding 7.5 seconds. Wave energy impacting Putney Beach originates largely from the remnants of longer period north-east to easterly waves that propagate into Keppel Bay from the Coral Sea and have refracted around the northern headland of Putney Beach. Putney Beach is only occasionally impacted by significant, locally generated wind-waves;
- in comparison to Putney Beach, waves arrive at Fisherman's Beach from a wider directional band extending generally from the south through to west. These waves tend to be smaller than at Putney Beach with significant wave heights generally less than 0.3 metres. The waves arriving at Fisherman's Beach also have a wider distribution of periods than Putney Beach with a larger percentage of short (less than five second) waves apparent. This is most pronounced in winter when larger, short period waves locally generated from the south to south-west winds can impact Fisherman's Beach directly; and
- tropical cyclones have the potential to generate very large (relatively to background condition) waves on both Putney and Fisherman's Beach over short durations.

Figure 3.62 PUTNEY AND FISHERMAN'S BEACH SUMMER WAVE ROSE



Source: 'COASTAL ENVIRONMENT TECHNICAL REPORT' (2011) WATER TECHNOLOGY

Figure 3.63 PUTNEY AND FISHERMAN'S BEACH WINTER WAVE ROSE



Source: 'COASTAL ENVIRONMENT TECHNICAL REPORT' (2011) WATER TECHNOLOGY

(c) Tropical Cyclones

The Island can be subject to tropical cyclone activity originating within the Coral Sea as well as the Gulf of Carpentaria. Tropical cyclone activity is generally concentrated between the months of January to March although tropical cyclones can and do occur outside this period.

The BOM maintains a database of cyclone tracks within Australia. Thirteen tropical cyclones since 1960 have been tracked within a 200 kilometre radius of the Island. Review of historical cyclone tracks shows no discernible pattern of movement of cyclones in the area, with cyclones passing in the vicinity of the Island from both the landward and seaward direction and travelling both parallel to the coast and offshore.

Table 3.69 summarises the landfall central pressure (or minimum central pressure if the cyclone did make land fall) for each of the tracked tropical cyclones.

TABLE 3.69 TROPICAL CYCLONES WITHIN 200 KILOMETRES OF GKI (BOM 200)

Tropical Cyclone	Year	Landfall central pressure or minimum central pressure within 200 km radius (hPa)
(Unnamed)	1961	
Dinah	1966	945
Fiona	1970	993
Emily	1971	985
David	1975	969
Beth	1975	996
Kerry	1978	995
Paul	1979	992
Simon	1979	950
Elinor	1982	935
Pierre	1984	998
Fran	1991	985
Rewa	1993	920

(d) Storm Surges

The potential magnitude of a storm surge is dependent on the direction and speed of the storm track, the radius to maximum wind speed and the wind strength. Storm surge comprises a direct wind set-up component and an atmospheric pressure component. In shallow continental shelf areas the pressure component of the surge can interact with the bathymetry and coastal forms and be dynamically amplified at the coastline to levels significantly greater than offshore, deepwater levels.

The combination of the meteorological storm surge and astronomical tide at any one location and point in time gives rise to an overall mean water level called the storm tide. The storm tide level can be referenced to an absolute datum such as AHD and is of particular importance when considering the design of infrastructure on the coastline.

Extensive analysis of storm tide recurrence intervals has been carried out for the majority of the Queensland coast in the *Queensland Climate Change and Vulnerability to Tropical Cyclones* study (Queensland Government, 2004). Keppel Bay has a generally high storm tide risk profile compared to many other locations along the Queensland coast. The storm tide return period curves for Yeppoon are however considered conservatively high for the Island. In order to provide relevant estimates of the storm tide recurrence intervals at the Island, additional analysis of cyclonic storm surge behaviour has been undertaken to relate the storm tide recurrence interval statistics that exist for Yeppoon to Putney and Fisherman's Beach on the Island. **Table 3.70** displays the corresponding storm tide recurrence interval estimates for Putney and Fisherman's Beach.

TABLE 3.70 STORM TIDE AEP FOR PUTNEY AND FISHERMAN'S BEACH

Annual Exceedance Probability (AEP)	Yeppoon m AHD	Putney Beach m AHD	Fisherman's Beach m AHD
2%	2.75	2.32	2.37
1%	2.94	2.67	2.74
0.2%	3.49	2.75	2.83

(e) Extreme Wave Conditions

The most extreme waves observed at Putney Beach are generated by tropical cyclones when the cyclone track results in northerly, through to west and southerly winds. To estimate the magnitude and recurrence intervals of extreme wave conditions at Putney Beach, a spectral wave model was employed to model the generation and propagation of waves under extreme cyclonic wind conditions at Putney Beach.

To provide appropriately conservative water depths for the extreme wave condition modelling, the MHWS tidal water level of 1.8 metres AHD was adopted for the one and 50 year ARI wind events. For the 200 year ARI wind event, the one in 100 year ARI storm tide level of 2.95 metres AHD was adopted. The design wind speed and water level conditions adopted for the extreme wave condition modelling are displayed in **Table 3.71**.

TABLE 3.71 DESIGN WIND SPEED AND WATER LEVEL CONDITIONS FOR EXTREME WAVE CONDITION MODELLING

Average Recurrence Interval (ARI) (Years)	Design Wind Speed (m/s)	Water Level (m AHD)
1 year	20.0	1.8
50 year	34.0	1.8
200 years/100 years	38.4	2.95

m/s = metres per second

The degree of exposure to extreme wave conditions along Putney Beach is complicated by the existence of Middle Island to the immediate west. Critical wind/wave directions therefore vary considerably along Putney Beach. To provide an indication of these variations, the extreme wave condition modelling results have been returned at both a northern Putney Beach and southern Putney Beach location. **Table 3.72** summarises the one, 50 and 200 year ARI design wave condition modelling results at both the northern Putney Beach and southern Putney Beach locations.

TABLE 3.72 SUMMARY OF EXTREME WAVE CONDITION MODELLING RESULTS AT PUTNEY BEACH

Wind Direction	Wind Speed ARI (yr)	Hs (m)		Tp (s)		Mean Wave Direction (Deg)	
		Northern	Southern	Northern	Southern	Northern	Southern
N	1	2.8	2.1	8.1	8.3	4	350
	50	3.1	2.2	10.2	10.2	5	350
	200	3.7	2.7	11.2	11.2	7	352
NW	1	2.3	1.9	6.2	6.2	340	332
	50	2.8	2.3	8.0	7.5	345	334
	200	3.4	2.8	8.8	8.3	346	335
W	1	1.5	1.6	4.8	4.8	283	274
	50	2.0	2.0	5.3	5.3	289	279
	200	2.4	2.5	5.8	5.8	289	279
SW	1	1.7	1.8	5.1	5.1	229	231
	50	2.0	2.0	5.7	5.7	234	234
	200	2.2	2.5	7.1	6.2	216	231
S	1	1.5	1.5	5.8	5.8	218	214
	50	1.8	1.8	6.6	6.6	219	215
	200	2.4	2.2	7.1	7.1	216	212

3.6.1.6 Sediment Transport and Coastal Processes

The alignment of Putney and Fisherman's Beach is primarily controlled by the diffraction and refraction of north-easterly and south-easterly waves around the northern and southern headlands of the Island respectively. The refracted waves approach these beaches with small oblique angles and subsequently drift sand into the westerly projecting, trailing spit formation that divides these two beaches. The alignment of the spit is therefore in dynamic equilibrium between the influence of the refracted south easterly and northerly waves and subsequent rates of sediment transport. The westward projection of the sand spit is curtailed by the increasing exposure to strong tidal current action that is generated between Middle Island and GKI, as well as increasing exposure to wave action as the end of the spit extends beyond the sheltered zone afforded by the northern and southern headlands.

Sediment transport in the vicinity of Putney and Fisherman's Beach (**Photograph 3.14**) is a complicated function of tidal and wind driven currents, wave action and sediment characteristics (refer **Figure 3.64**). In order to characterise the existing sediment transport potentials in the vicinity of Putney and Fisherman's Beach, the following detailed sediment transport modelling analysis has been undertaken:

- tidal and wind driven current sediment transport analysis; and
- wave driven sediment transport analysis.

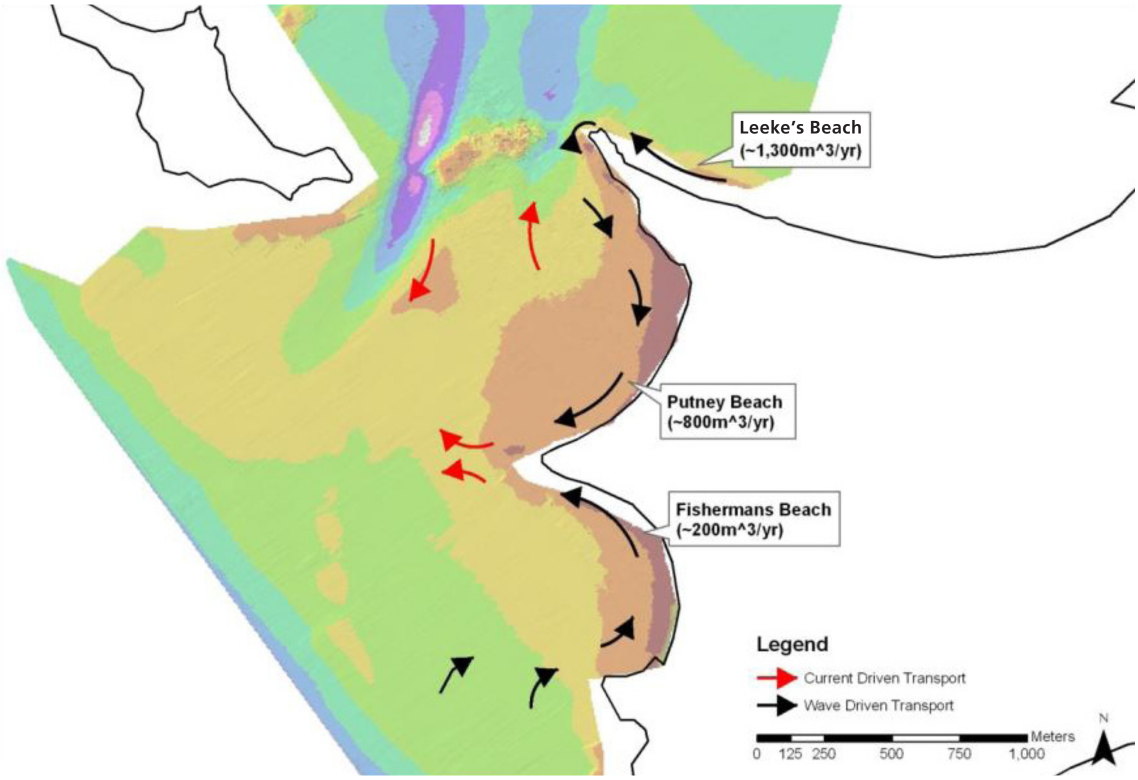
Photograph 3.14 FISHERMAN AND PUTNEY BEACH

The results from this modelling show that away from the non-erodable rock and reef outcrops around Middle Island, Passage Rocks and Putney Point, annual net sand transport potentials are relatively small, indicating that large sand transport fluxes are not a general feature of the Region between GKI and Middle Island under ambient (non cyclonic) conditions. The main areas of active net sediment transport under ambient, existing conditions are in general confined to the following locations:

- an area of active southward net sand transport is predicted to occur across the relatively shallow, sandy shoal that exists to the southwest of Passage Rocks. Net southerly sediment transport rates across this shoal are estimated at approximately 2-4m^3/yr/m;
- an area of minor net sediment transport is predicted to occur adjacent to the Putney and Fisherman's Beach spit head. Both flood and ebb tide currents sweep past the spit head resulting in a net offshore sand transport potential to the west. The magnitude of this sediment transport potential is estimated under existing conditions at approximately 1-2 m^3/yr/m;

- approximately 800 cubic metres per year of net southerly transport has been estimated due to wave action along Putney Beach; and
- approximately 200 cubic metres per year of net northerly transport has been estimated due to wave action along Fisherman's Beach.

Figure 3.64 OVERVIEW OF SEDIMENT TRANSPORT AND COASTAL PROCESSES



Source: 'COASTAL ENVIRONMENT TECHNICAL REPORT' (2011) WATER TECHNOLOGY

To document the historical shoreline variations on Putney and Fisherman's Beach, historical aerial photography of the Island was obtained and geo-referenced to a common coordinate system and scaled to enable more precise interpretation. A total of six historical photographs were analysed spanning from 1961 – 2010, with one photograph per decade providing an approximate 50 year timeseries of coastal change. These are shown in **Figure 3.65**.

The main shoreline changes identified over the 50 year timeseries of historical aerial photographs were as follows:

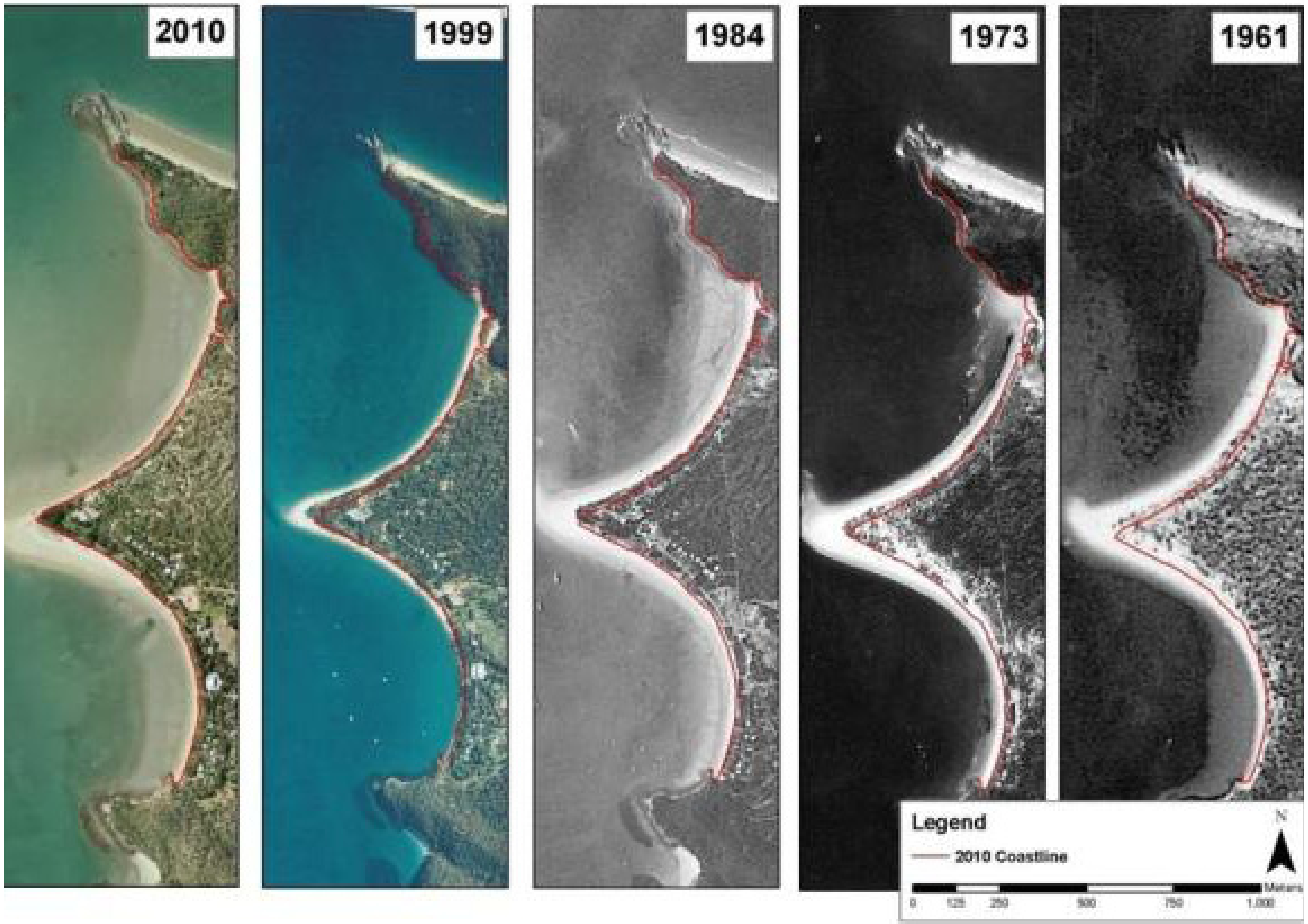
- the location of the head of the spit has shifted to the south. This change in alignment began around the year 2000 and has progressed through to the present day. A large lobe of sand has accreted on the southern side of the spit in conjunction with the southerly migration of the spit head over approximately the last decade;

- the southern end of Putney Beach has experienced significant shoreline recession over the last decade, corresponding with the change in the spit alignment. A site inspection of Putney Beach showed the low beach profile, eroding dune scarp and loss of mature dune vegetation synonymous with long-term shoreline recession at this location (refer **Photograph 3.15**);
- there appears to have been a general and consistent decline in beach widths on both Putney and Fisherman's Beach since the earliest aerial photos; and
- a new southerly entrance to Putney Creek was initiated sometime between 1984 and 1999, this secondary entrance shows evidence of still being active at times of high creek flows and/or elevated coastal water level conditions.

Photograph 3.15 EROSION ON PUTNEY BEACH

The shoreline changes observed on Putney and Fisherman's Beach over the last 50 years are considered to reflect the relatively mobile nature of this trailing spit landform and the dynamic processes operating on it. The variability observed in this landform is of the magnitude that could be expected with this type of landform, which is in a dynamic equilibrium with the physical processes operating on it.

Figure 3.65 HISTORICAL AERIAL PHOTOGRAPHIC TIME SERIES OF PUTNEY AND FISHERMAN'S BEACH



Source: 'COASTAL ENVIRONMENT TECHNICAL REPORT' (2011) WATER TECHNOLOGY

3.6.2 Potential Impacts and Mitigation

Potential impacts to hydrodynamics, coastal processes, marine water quality and sediments associated with the construction and operation of the GKI Revitalisation Plan have been investigated and quantified. Options and methods to avoid or mitigate adverse impacts have been tested and refined with numerical models to provide recommendations for minimising the impact of the GKI Revitalisation Plan on the coastal environment.

The potential impacts of the following two marine components of the proposed Revitalisation Plan have been considered in the impact and mitigation assessment:

A 250 berth marina facility incorporating a passenger ferry terminal, barge handling area and day boat storage is proposed to be constructed in the northern corner of Putney Beach. The main physical components of this facility include the following:

- a 90,000 cubic metre marina basin that will be constructed to provide minimum depths ranging between 2.5 metres and 3.5 metres LAT;
- a western breakwater to exclude wave and current action from the marina basin;
- an approximately 190 metre long by 45 metre wide access channel to the marina basin that will be maintained at a minimum depth of 3.5 metres LAT;
- abunded reclamation area of approximately 46,000 cubic metres on the northern and eastern side of the marina basin; and
- Putney Creek entrance will remain open to the marina, however a sediment and gross pollutant trap within the structure of the marina will prevent sediment from Putney Creek depositing into the marine facility.

A wet weather treated wastewater outfall is proposed as part of the Project. The treated wastewater is to be discharged via an outfall diffuser approximately 1,000 metres offshore of Long Beach in approximately 11 metres depth. The Project is expected to generate approximately 208 megalitres per year of wastewater. This wastewater is to be treated to Class A+ standard and will comply with the nutrient levels specified by GBRMPA (Opus, 2011). The vast majority of the treated wastewater is to be reused on the Island. A 37 megalitre wet weather storage facility is to be constructed to store treated effluent during periods of wet weather. It is anticipated that the capacity of this storage facility may be exceeded during an extreme wet weather event that could be expected to occur, on average, once every 10 years. Under these conditions, the excess treated effluent will be discharged via the ocean outfall.

Based on the estimated volume and duration of discharge events predicted by MEDLI modelling and assuming effluent nutrient concentrations of 20 mg/L for total nitrogen and 7 mg/L of total phosphorous, dispersion modelling by Water Technology has predicted that concentrations of total nitrogen and total phosphorous will reduce to below relevant trigger values within a small mixing zone in the immediate vicinity of the outfall. On this basis, the proposed emergency wet weather discharge of recycled water via an ocean outfall is not anticipated to have any significant impact on ecological communities near the outfall.

3.6.2.1 Tidal Flows and Hydrodynamic Assessment

Potential changes to tidal water levels and currents associated with the proposed marine facility were assessed in the hydrodynamic model. The hydrodynamic model geometry was changed to represent the main physical components of the marine facility including the breakwaters, reclaimed land and navigation channel and marina basin.

Hydrodynamic model simulations incorporating the marine facility were undertaken over a representative month of summer wind conditions and astronomical tides and compared to the same period under existing conditions to enable the impact of the marina to be quantified relative to existing conditions. Current speed impact contour plots and vectors at peak spring flood and ebb tidal conditions relative to existing conditions have been presented in **Figure 3.66** and **Figure 3.67** respectively. The tidal water level and current field impacts can be summarised as follows:

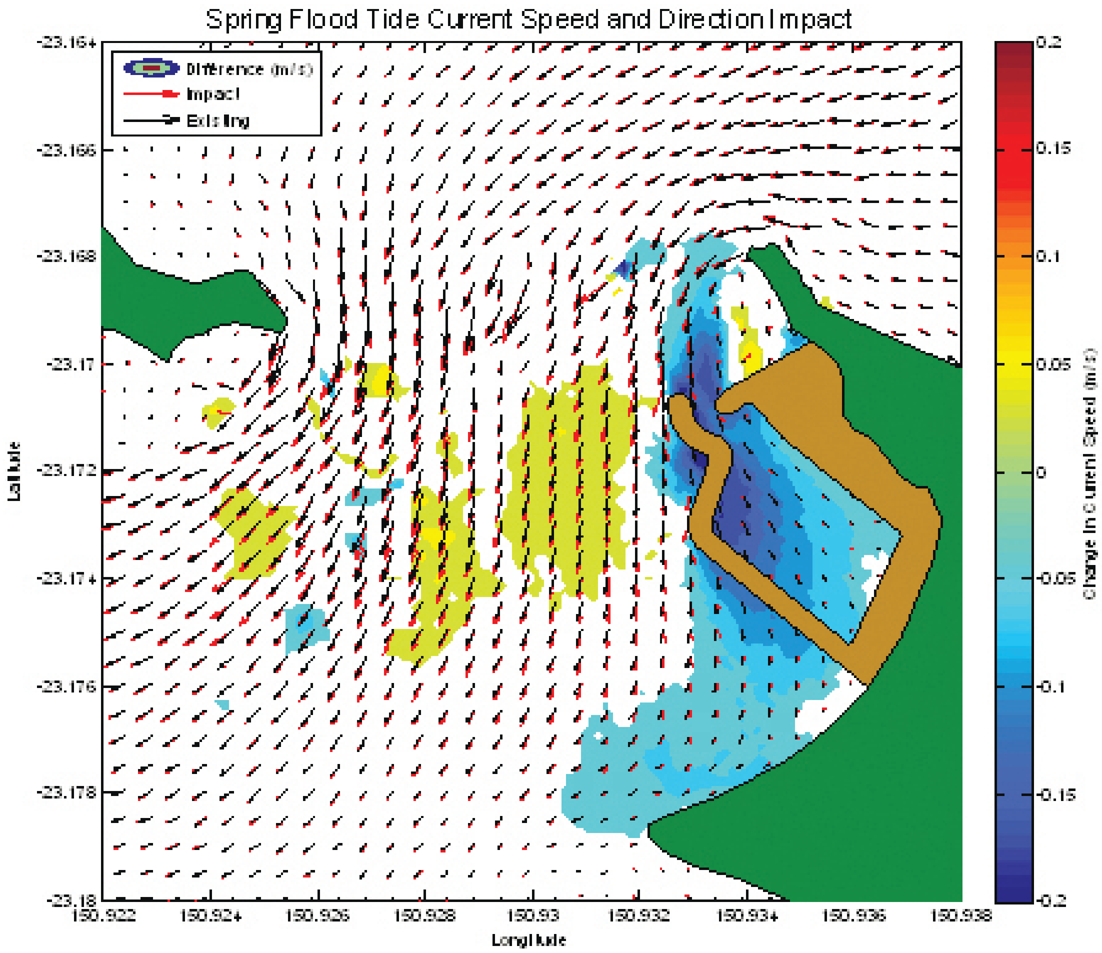
(a) Peak Spring Flood Tidal Currents

- Flood tide currents will be diverted around the western side of the marine facility resulting in acceleration of peak current speeds generally less than 0.05 metres per second compared to existing conditions to the west of the marine facility.
- Peak flood tide current speeds in the lee of the marine facility along Putney Beach are predicted to reduce by 0.05 – one metre per second.
- A negligible impact on water levels and tidal phase is predicted.

(b) Peak Spring Ebb Tidal Currents

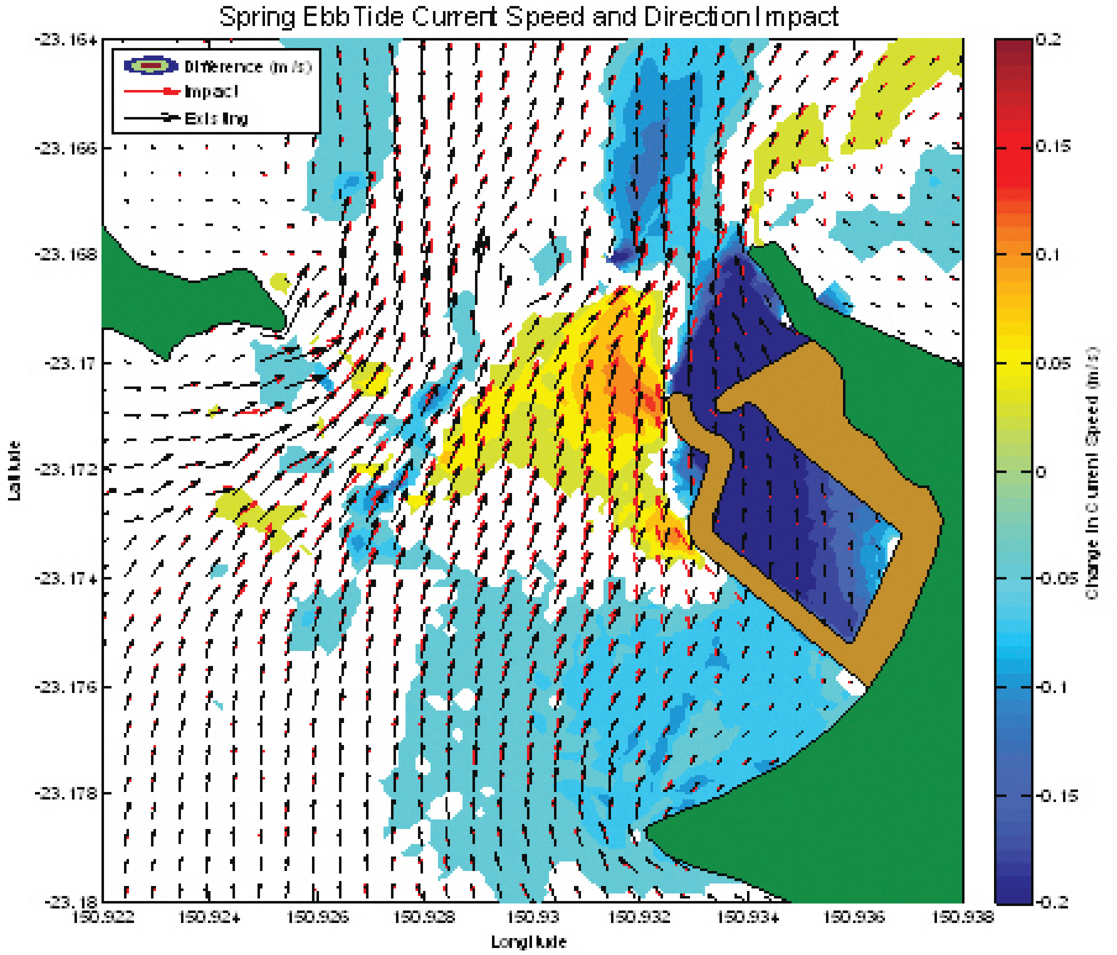
- Ebb tide currents south of the marine facility will be diverted around the western edge of the marine facility resulting in a reduction in peak current speeds of approximately 0.05 – 0.075 metres per second south of the marine facility along Putney Beach.
- Ebb tide current speeds will be accelerated around the western edge of the marine facility with local increases above existing conditions of up to 0.15 metres per second.
- Ebb tide current speeds between the marine facility entrance and Putney Point will be reduced by 0.2 metres per second compared to existing conditions.
- Ebb tide current directions between Passage Rocks and Putney Point will be orientated slightly more east of north than under existing conditions resulting in a minor distribution of current speeds and directions north of Putney Point.
- A negligible impact on water levels and tidal phase is predicted.

Figure 3.66 PREDICTED PEAK SPRING FLOOD TIDE CURRENT VELOCITY IMPACT



Source: 'COASTAL ENVIRONMENT TECHNICAL REPORT' (2011) WATER TECHNOLOGY

Figure 3.67 PREDICTED PEAK SPRING EBB TIDE CURRENT VELOCITY IMPACT



Source: 'COASTAL ENVIRONMENT TECHNICAL REPORT' (2011) WATER TECHNOLOGY

(c) Mitigation Measures

The local and relatively minor changes to current speeds and directions predicted to arise from the construction of the marina are not considered to result in direct environmental impacts requiring mitigation.

3.6.2.2 Sediment Transport and Coastal Processes

Assessment of the potential impacts of the marina development on sediment transport and siltation has considered the impact on sediment transport and siltation due to changes to tidal and wind driven currents and waves from the marina development. The assessment has been undertaken to identify the magnitude of any morphological changes caused by the proposed marina development and to enable the requirements, or otherwise for maintenance dredging of the channel entrance and marina basin to be determined.

The Proponent commits to undertaking any sediment bypassing that may be required during the operational phase. The bypassing will be undertaken in accordance with an Operational EMP. A legal agreement for the Project will be negotiated between the Proponent and the State of Queensland. The agreement will reflect, amongst other things, the Proponents commitment to bypass sand, where necessary, from between the marina entrance and Putney Point to Putney Beach."

3.6.2.3 Sand Transport Potential

To facilitate the assessment of the potential impact of the marina development on net sand transport potentials due to tidal and wind driven currents, a hydrodynamic and sediment transport model was simulated over a month of summer wind and tidal conditions under existing conditions and incorporating the main structural features of the marina to enable the impact on net sediment transport potentials due to tidal and wind driven currents in the area to be quantified. The following impacts on the net sediment transport rates are predicted:

- net sediment transport rates around the western edge of Putney Point are predicted to decrease. Construction of the marina will deflect the ebb and flood tidal currents away from the western edge of Putney Point and create an area between the marina and Putney Point that is relatively sheltered from strong current action and sediment transport;
- construction of the marina will slightly reduce the flood and ebb tide current velocities that sweep past the spit head and therefore the rate at which sediment is mobilised and transported away from the spit head;
- the western breakwater of the marina will cause an acceleration of the currents around the seaward edge of the breakwater. This is predicted to cause a slight increase in the sand transport potentials at these locations and a corresponding reduction in transport potentials immediately adjacent to the breakwater where current velocities are lower; and
- the predicted increases in flood tide velocities across the sandy shoal to the south west of Passage Rocks is predicted to increase the rate of southward sediment transport in this area.

3.6.2.4 Putney and Fisherman's Beach Coastal Processes

Potential impacts to incident wave energy and directions and subsequent sediment transport potential along Putney Beach associated with the proposed marine facility have been assessed. The wave hindcast or wind/wave modeling results have been compared to the wave hindcast results simulated under existing conditions over the same hindcast period. The simulated results show the following impacts:

- under northerly wave conditions and with the proposed marine facility, northerly waves will defract around the western edge of the marine facility breakwater and approach Putney Beach with directions almost shore normal. Under existing conditions, northerly waves will defract around Putney Point and approach Putney Beach with small oblique angles; and
- under northerly wave conditions, wave heights along Putney Beach are predicted to be slightly lower than existing conditions due to the sheltering effect of the marine facility and the reduction in wave heights caused by the diffraction of waves around the western edge of the breakwater.

The following impacts on longshore sediment transport rates on Putney Beach due to changes in the wave climate discussed above are predicted:

- the gross longshore sediment transport potential (sand movement) is predicted to reduce from approximately 1,200 cubic metres to 600 cubic metres per year;
- the net longshore sediment potentials are predicted to reduce from approximately 800 cubic metres per year under existing conditions to close to zero.

3.6.2.5 Siltation

Bed shear stresses less than approximately 0.1 newtons per square metre are conservatively estimated as generally resulting in fine silt deposition. To identify areas within and adjacent to the marina that may not experience bed shear stresses large enough to resuspend fine silts, the hydrodynamic model simulation results over a month of representative summer wind and tide conditions have been processed to calculate the maximum bed shear stresses over this period. The following locations of potential fine silt deposition are predicted:

- the potential extent of the area of fine silt deposition will be largely confined to within the marina basin; and
- a small area immediately adjacent to the breakwater on Putney Beach is also predicted to experience bed shear stresses low enough to allow fine silt deposition. However, wave action on Putney Beach is expected to be significant enough at times to resuspend fine silts in this area such that long-term accretion of fine silts is not expected at this location.

3.6.2.6 Mitigation Measures

The following measures are proposed to mitigate the impact of the marina on the local sediment transport processes and to maintain the operational functionality of the marina over the long-term.

(a) Maintenance Dredging

Maintenance dredging is likely to be required periodically over the course of the marina's operation to maintain the minimum navigable depths required in the entrance channel. As the sediment transport modelling predictions provide only very small rates of sediment transport, maintenance dredging of the entrance channel is only expected to be required occasionally (i.e., approximately greater than five years on average) or following a severe cyclone.

Initially, following construction of the marina, local acceleration of the ebb tidal currents around the outer edge of the marina breakwaters are predicted to result in some localised scour, as the bed morphology immediately adjacent to the toes of the breakwaters adjusts. To accommodate this initial flux of sediment past the entrance following the breakwater construction and to minimise the frequency in which maintenance dredging is required generally, it is proposed that the entrance channel is overdredged and/or a sediment trap is established. The sediment trap would limit the impact of siltation of the entrance channel in the first years of the operation of the marina and to limit the potential impact on navigability of the marina entrance following a severe cyclone.

The relatively low ambient suspended sediment concentrations are such that the rate of siltation of the marina is unlikely to be significant to the marina's operation over the long-term. Fluxes of sediment into the marina basin during large floods in Putney Creek are to be mitigated with sediment traps constructed on the landward side of the marina.

(b) Sediment Bypassing

Construction of the marina will deflect the ebb tidal currents away from Putney Point and sediment transport modelling indicates that the sediment transport potentials in this area will be reduced. The marina will also prevent the onshore migration of sediment towards Putney Beach by wave action. Over time, sediment would be expected to accrete in the sheltered zone that will exist between the marina and Putney Point. To prevent siltation of the entrance channel by this accreting sand and to maintain the long-term sand transport continuity on Putney Beach, periodic bypassing of sand from the area between the marina entrance and Putney Point is proposed.

Initial sediment transport estimates suggest the rate of sand accretion between the marina and Putney Point is likely to be of the order of 1,000-1,500 cubic metres per year. Periodic bypassing of approximately 5,000 – 7,000 cubic metres of sand every five years would maintain the sediment transport continuity to Putney Beach and result in no net sand accretion between the marina and Putney Point. The frequency of sand bypassing operations and the impact of the accreting sand could be minimised by the establishing a dredged sediment trap at this location during the initial capital dredging works.

The Proponent commits to undertaking any sediment bypassing that may be required during the operational phase. The bypassing will be undertaken in accordance with an Operational Environmental Management Plan to be developed in consultation with DEHP. A legal agreement for the Project will be negotiated between the Proponent and the State of Queensland. The agreement will reflect, amongst other things, the Proponents commitment to bypass sand, where necessary, from between the marina entrance and Putney Point to Putney Beach.

(c) Putney Beach

Under existing conditions, the net sediment transport potential along Putney Beach has been estimated at approximately 800 cubic metres per year towards the spit head. This net sediment transport potential is currently transporting sand from Putney Beach to the spit head, resulting in long-term shoreline recession on Putney Beach.

Construction of the marina is expected to reduce the net sediment transport potential along Putney Beach to close to zero, or potentially, a minor reversal in the net transport back towards Putney Point. The impact of the change in the net sediment transport potentials is expected to be a reduction in the rate of shoreline recession along Putney Beach and over the long-term, gradual accretion of sand along Putney Beach and progradation of the Putney Beach shoreline between the spit head and the western breakwater of the marina.

The periodic bypassing of sand from Putney Point to Putney Beach will also serve to increase the beach volumes and widths and improve the amenity of this beach.

Sand will continue to be slowly lost from the spit head by the action of waves and tidal currents sweeping past the spit head. Construction of the marina is however predicted to slightly reduce current velocities and therefore sediment transport potential rates at the spit head. Periodic bypassing of sand from Putney Point to Putney Beach and out to the spit head will be required to maintain the long-term sediment transport continuity of this system and prevent long-term decline in the projection of the spit head or impacts to Fisherman’s Beach

(d) Marina Wave Climate

Protection for vessels moored within the marina from waves generated in Keppel Bay is provided by breakwaters such that waves may only propagate into the marina through the marina entrance. The orientation of the marina entrance to the north results in worst case wave penetration into the marina being associated with wave conditions from the north- east through north-west directions.

The Australian Standards AS 3962-2001 *Guidelines for Design of Marinas* recommends wave heights at berths for one and 50 year ARI design wave conditions. **Table 3.73** summarises these guidelines.

TABLE 3.73 GUIDELINES FOR MARINA WAVE CONDITIONS (AS 3962-2001)

Wave Direction at Berth	1 Year Wave Conditions (m)			50 Year Wave Conditions (m)		
	Excellent	Good	Moderate	Excellent	Good	Moderate
Head-on Seas	<0.225	<0.3	<0.375	<0.45	<0.6	<0.75
Beam-on Seas	<0.125	<0.15	<0.1875	<0.1875	<0.25	<0.3125
Oblique Seas	<0.225	<0.3	<0.375	<0.3	<0.4	<0.5

To assess the marina wave climate and degree of protection afforded by the breakwaters in relation to the Australian Standards, the spectral wave model geometry was modified to represent the main structural features of the marina. The spectral wave model has then been simulated under the one and 50 year ARI design wave conditions previously developed and summarised in **Table 3.73** to predict the resultant wave climate inside the marina basin.

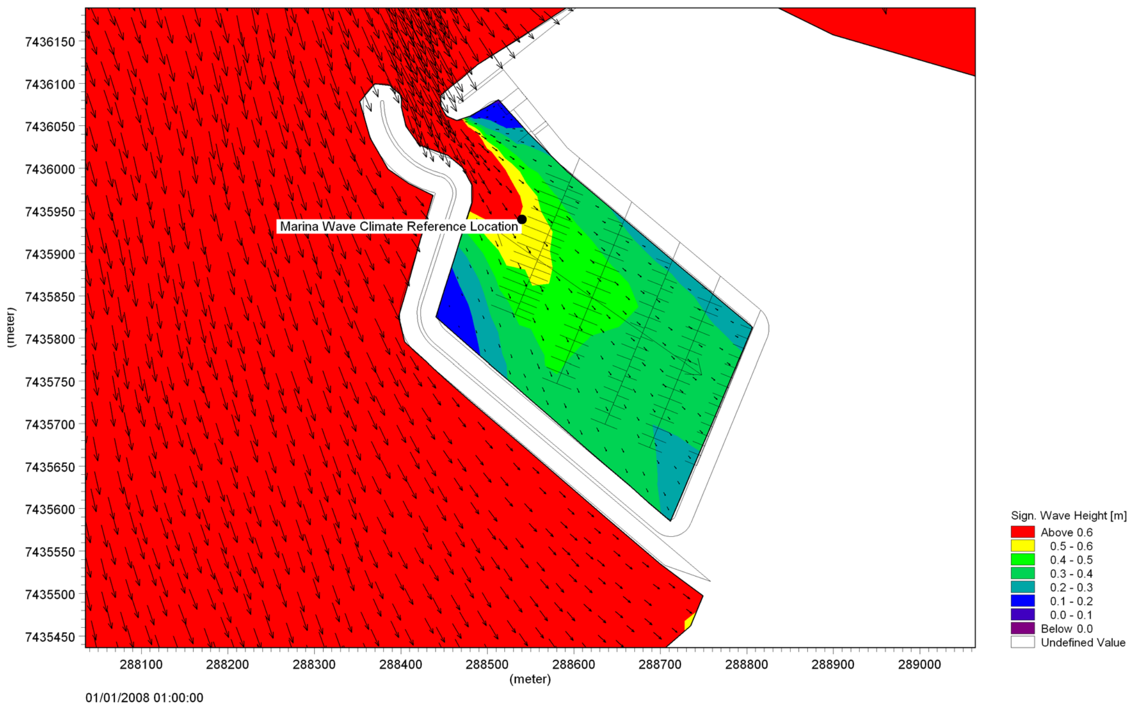
Figure 3.68 displays the spectral wave model layout and predicted wave heights under the worst case 50 year ARI north-westerly wave conditions. From **Figure 3.68** it can be seen that wave heights are significantly attenuated through the marina entrance, even under worst case north-westerly wave conditions.

Table 3.74 summarises the significant wave heights predicted at the most exposed berth location inside the marina basin for all relevant wave directions and recurrence intervals. The following comments are provided in relation to the predicted marina wave climate and the Australian Standards for marina design:

- the design wave conditions developed for the marina wave climate assessment are conservatively high, providing worst case wave climate conditions in the marina;
- the orientation of the berths within the marina is such that incident waves will be close to head-on to the berthed vessels. Wave height guidelines for head-on wave conditions are larger than beam-on conditions;

- for all design wave directions from the south through to west, all berth locations in the marina are predicted to experience an 'excellent' wave climate;
- for worst case design wave conditions from the north to north-west, a relatively small number of berths immediately adjacent to the marina entrance could experience wave heights that would be considered to provide a 'good - moderate' climate. The remainder of the berths would all experience wave heights consistent with 'excellent' conditions; and
- minor optimisation of the entrance alignment and overlap during the detailed design of the marina breakwaters will provide an opportunity to further reduce wave heights in the marina under worst case north to north-westerly design wave conditions.

Figure 3.68 PREDICTED MARINA WAVE HEIGHTS UNDER 50 YEAR ARI NW DESIGN WAVES



Source: 'COASTAL ENVIRONMENT TECHNICAL REPORT' (2011) WATER TECHNOLOGY

TABLE 3.74 SUMMARY OF MARINA WAVE CLIMATE RESULTS AT MOST EXPOSED BERTHS LOCATION

Design Wave Direction	Design Wave ARI (Yrs)	Significant Wave Height (m)
North	1	0.39
	50	0.44
North-West	1	0.40
	50	0.59
West	1	0.2
	50	0.3
South-West	1	0.1
	50	0.08
South	1	0.04
	50	0.08

3.6.3 Climate Change Risk Assessment

3.6.3.1 Background

To assess the potential impact of climate change on the coastal environment and the coastal infrastructure proposed as part of the GKI Revitalisation Plan, a risk assessment methodology has been adopted. For the purposes of the risk assessment process *Risk* is defined as the product of the *Likelihood* of the occurrence of the various *Threats* associated with climate change times the *Consequences* of their occurrence.

To accommodate the likely effects of climate change current best management practice requires an adaptive approach towards planning and design in the coastal zone. In this respect, it is noted that the National Committee of Coastal and Ocean Engineering (Engineers Australia, 2004) discusses three main options for managing the threats of climate change to coasts and coastal infrastructure. These are:

- **Retreat**: allow the coastline to retreat and prevent development in areas near threatened coastlines through conditional approvals and phasing-out of development;

- **Accommodate**: accommodate coastal recession to avoid the worst impacts through advanced planning and modification of land use, building codes, etc; and
- **Protect**: protect the coastline through hard structural options including, dykes, sea walls, revetments and groynes of soft structural options such as beach nourishment, wetland creation and littoral drift make-up.

3.6.3.2 Threats Identification

Increased concentrations of greenhouse gases in the Earth's atmosphere are projected to cause a warming of the atmosphere and oceans which in turn are projected to drive a range of other changes to the Earth's climate and the climates variability. Relevant climate change impacts on the physical processes operating on Putney and Fisherman's Beach are considered the following:

- sea level rise;
- seasonal distribution of wind speeds and directions; and
- Tropical Cyclone Intensity (increase) and Frequency (potential decrease).

(a) Sea Level Rise

Global average sea level rose by approximately 0.17 metres during the 20th Century. The average global rate of sea level rise between 1950 and 2000 was 1.8 ± 0.3 millimetres per year. Rosslyn Bay to the west of the Island is one of the National Tide Centre's array of 16 high accuracy sea level measurement stations. The net relative sea level trend since installation in June 1992 is 2.0 millimetres per year at Rosslyn Bay (NTC, 2010). The Intergovernmental Panel on Climate Change (IPCC) is the authoritative source on projections of future sea-level rise due to climate change. **Table 3.75** displays the sea level rise projections relative to late 20th century mean sea levels for the A1F1 high emission scenario.

TABLE 3.75 IPCC 2007 A1F1 PROJECTED SEA LEVEL RISE

Sea Level Rise Scenario	2030	2070	2100
IPCC 2007 A1F1	0.15 metres	0.47 metres	0.82 metres

The main impacts associated with increase in mean sea level on Putney and Fisherman's Beach are considered:

- shoreline recession; and
- increase in storm tide elevations.

(b) Seasonal Distribution of Wind Speeds and Directions

The south-east trade wind circulations dominate the wind/wave climate of Keppel Bay. Projections of climate change impacts on wind speeds in the Region have been provided by the CSIRO (2007).

While significant variation in the projections between climate models exists, the 50th percentile results suggest a potential increase in wind speeds of between five to 10 percent along the Central Queensland Coast and Keppel Bay by 2070 under high emission scenarios. A strengthening in the prevailing south-east trade winds would result in a corresponding increase in the predominance and magnitude of east to south easterly waves in Keppel Bay. The potential impacts of changes to the seasonal distribution of wind speeds and directions on Putney and Fisherman's Beach are summarised in **Table 3.76**.

TABLE 3.76 IMPACT OF CHANGES TO THE SEASONAL DISTRIBUTION OF WIND SPEEDS AND DIRECTIONS

Process or Parameter affected	Impact	Important Factor
Five to ten percent increase in wind speeds by 2070.	Generation of larger waves in Keppel Bay could change sediment transport rates on Putney and Fisherman's beach and affect spit head alignment.	Prevailing waves are significantly refracted before impacting these beaches. Spit head alignment already variable.

(c) Tropical Cyclone Intensity

Current projections on the impact of climate change on tropical cyclones suggests that a warming atmosphere will produce more intense cyclones as measured by maximum wind speeds and rainfall (Lough 2007). The spatial and seasonal distribution of occurrence is however expected to remain approximately similar to present whilst the frequency of tropical cyclone formation may actually decline under climate change (Lough 2007).

The main impacts associated with increases in tropical cyclone intensity are considered the following:

- higher maximum wind speeds generating larger waves and associated wave set-up on the coastline; and
- higher maximum wind speeds and lower central pressures generating large storm surges.

Predicted annual exceedance probability storm tides by 2100 for Putney and Fisherman's Beach from are summarised relative to existing conditions in **Table 3.77**.

TABLE 3.77 PREDICTED 2100 STORM TIDE AEP FOR PUTNEY AND FISHERMAN'S BEACH

	Yeppoon		Putney Beach		Fisherman's Beach	
	Exs	2100	Exs	2100	Exs	2100
AEP	(m AHD)		(m AHD)		(m AHD)	
2%	2.75	3.74	2.32	3.34	2.37	3.39
1%	2.94	4.33	2.67	3.74	2.74	3.82
0.2%	3.49	4.62	2.75	3.87	2.83	3.97

3.6.3.3 Exposure to Risk

The main components of the coastal environment and the GKI Revitalisation Plan that are exposed to the climate change threats identified previously are considered to belong the following four main categories:

- Putney and Fisherman's Beaches;
- marina breakwaters;
- marina infrastructure and reclamation; and
- foreshore development.

(a) Putney and Fisherman's Beaches

(a) (i) *Threats*

General models of sandy shoreline profile response to increases in mean sea level predict that sandy shoreline profiles could be expected to be translated shoreward and upward to maintain an equilibrium form. This implies the transfer of sand from the upper beach profile offshore to the seaward profile. The ratio of shoreline translation to sea level rise is generally predicted to be within 50 to 100:1. At Putney and Fisherman's Beach this could be expected to result in long-term shoreline recession as the shoreline profiles on these beaches adjust to a new equilibrium with mean sea level. Based on a projected increase in mean sea level of 0.82 metres, approximately 40 – 80 metres of shoreline recession could be observed.

It is noted that inner regions of the continental shelf such as Keppel Bay have experienced a relative sea level fall of approximately one metre since the Holocene sea level maximum approximately 6000 years ago (Smithers *et al* 2007). The relative sea level fall has been caused by minor flexure of the continental shelf in response to the loading of seawater (hydro-isostasy). This has resulted in the upward flexure of the inner margins of the continental shelf such as Keppel Bay and a corresponding relative fall in sea level. This implies that major coastal landforms in Keppel Bay were formed under relatively higher sea level conditions and would suggest that a degree of resilience to projected 21st century sea level rise exists such that large modifications to trailing spit landforms and associated beaches is not to be expected (Smithers *et al.* 2007).

Increases in the intensity of tropical cyclones due to climate change, resulting in higher maximum wind speeds, in combination with increased mean depths due to sea level rise may potentially allow slightly larger waves to impact Putney Beach during the passage of a tropical cyclone. However, the significance of these changes will be mitigated by the limited fetches and shallow depths of water that exist over the applicable fetches to Putney Beach. These factors currently limit the size and period of the waves that can impact Putney Beach during a cyclone.

Reductions to tropical cyclone frequency due to climate change are potentially significant as the greater the period between subsequent tropical cyclone impacts on Putney Beach, the greater the period for natural recovery of the beaches to occur.

(a) (ii) *Consequences*

The consequences of shoreline recession on Putney and Fisherman's Beach would include loss of beach amenity as the eroding shoreline could be expected to result in a low and narrow beach. Beach access can also be impeded as a high and steep dune scarp is likely to exist along these shorelines.

(a) (iii) *Mitigation*

Mitigation of shoreline recession hazards and loss of beach amenity can be mitigated by nourishment of beaches.

(b) Marina Breakwaters

(b) (i) *Threats*

The main threats to the marina breakwaters are:

- increases in mean sea level and storm tide heights and increases in the size of extreme waves could potentially lead to increased rates of overtopping of the breakwaters; and
- increased structural damage of the breakwaters could also occur due to increases in storm tide heights and extreme waves.

(b) (ii) *Consequences*

The consequences of increased overtopping of the breakwaters could lead to increase wave action within the harbour which could ultimately become unacceptable and result in damage to berthed vessels in the marina under design storm conditions.

The consequence of structural damage to the breakwaters is considered to generally relate to increased long-term maintenance costs.

(b) (iii) *Mitigation*

The risks posed by climate change to the marina breakwaters can be accommodated during the detailed design of the breakwaters by the following:

- increasing or adapting breakwater crest heights to limit the extent of wave overtopping under design water level and wave conditions to 2100; and
- increasing the primary armour unit weights during detailed design to limit the potential for structural damage to occur to the breakwaters under design water level and wave conditions to 2100.

(c) Marina Infrastructure and Reclamation

(c) (i) *Threats*

Marina infrastructure and the reclamation area will be protected from wave action by the breakwaters. As a result, the main threats to these components will be associated with inundation due to increases in mean sea level and storm tides.

(c) (ii) *Consequences*

The consequences of inundation to marina infrastructure and reclamation would include water damage costs and inconvenience.

(c) (iii) *Mitigation*

The risk posed by climate change to marina infrastructure and reclamation area can be accommodated by constructing finished surface levels and floor levels above the relevant design storm tide inundation levels to 2100.

(d) Foreshore Development

(d) (i) *Threats*

Development associated with the Project adjacent to or near the existing shoreline of Putney and Fisherman's Beaches could potentially be exposed to threats associated with shoreline recession. The majority of the proposed development is located at a distance greater than 100 metres from the existing shoreline and is therefore not expected to be impacted by shoreline recession by 2100.

The majority of the land proposed to be developed as part of the Project is located at an elevation of approximately four metre AHD or greater and is therefore not expected to be subjected to storm tide inundation to 2100. Some minor areas of the development are however located at an elevation of between 3.5 to four metres AHD and could potentially be subjected to inundation during an extreme storm tide by 2100.

(d) (ii) *Consequences*

Areas of the development located at an elevation of between 3.5 to four metres AHD and could potentially be inundated to depths less than 0.5 metres in an extreme storm tide event by 2100. The consequences of this inundation include water damage costs and inconvenience

Some minor components of the development located within 100 metres of the existing shoreline could potentially be impinged upon by shoreline recession hazards by 2100. The consequences of exposure to this risk include potential exposure to more significant inundation by storm tides and wave action and foundation instability.

(d) (iii) *Mitigation*

The impact on minor areas of the development that could potentially be subjected to relatively shallow storm tide inundation under extreme 2100 storm tide conditions can be mitigated by raising floor levels in these areas and/or landscaping to prevent storm tides penetrating into these areas.

3.6.4 Sediment Quality

3.6.4.1 Marine Sediments – Surface Sediments

(a) Sites Surveyed

Surface sediment sampling was undertaken during the following seasons:

- pre-wet – 15 to 19 November 2010;
- wet – 17 to 21 January 2011; and
- post-wet – 30 March to 2 April 2011, and 1 to 2 May 2011.

Sediment samples were collected at 13 sites around the Island (**Figure 3.69**) and two sites near the mainland (**Figure 3.70**) for laboratory analysis of potential contaminants. Sediment was collected by frc environment from the top 0.3 metres of seabed using a stainless steel trowel, and transferred directly into the sampling containers provided by the analytical laboratory.

Replicate sediment samples were collected at one site during the pre-wet and wet season survey, and at two sites during the post-wet season survey to provide an indication of within-site variation. In addition, replicate subsamples of two sediment samples were analysed to provide an estimate of variation due to laboratory analysis.

The Australian and New Zealand Water Quality Guidelines for Fresh and Marine Waters (the national guidelines) (ANZECC & ARMCANZ 2000) interim sediment quality guideline (ISQG) values were used as the guidelines, as regional guidelines have not been set for the Project area. Surface sediment quality data was compared to the ISQG-low trigger value (where available). The ISQG-low trigger value is referenced in the ANZECC & ARMCANZ (2000) guidelines as the most conservative trigger value for comparison.

Figure 3.69 GKI SURFACE SEDIMENT QUALITY SITES

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SOURCE: MODIFIED FROM 'AQUATIC ECOLOGY' (2011) - frc environmental

Figure 3.70 MAINLAND SURFACE SEDIMENT QUALITY SITES

SOURCE: MODIFIED FROM 'AQUATIC ECOLOGY' (2011) - frc environmental

3.6.4.2 Sediments of the Marina Footprint

Sediment sampling was undertaken in the proposed marina and channel footprint at Putney Beach from 15 to 18 June 2011 (**Figure 3.71**). This sediment sampling and analysis plan (SAP) for dredging was designed in accordance with the *National Assessment Guidelines for Dredging* (NAGD) (DEWHA 2009), the *Guidelines for Sampling and Analysis Procedure for Lowland Acid Sulphate Soils (ASS) in Queensland 1998* (the ASS guidelines) (Ahern *et al*. 1998) and the *State Planning Policy 2/02 Guideline: Acid Sulphate Soils*.

(a) Sites Surveyed

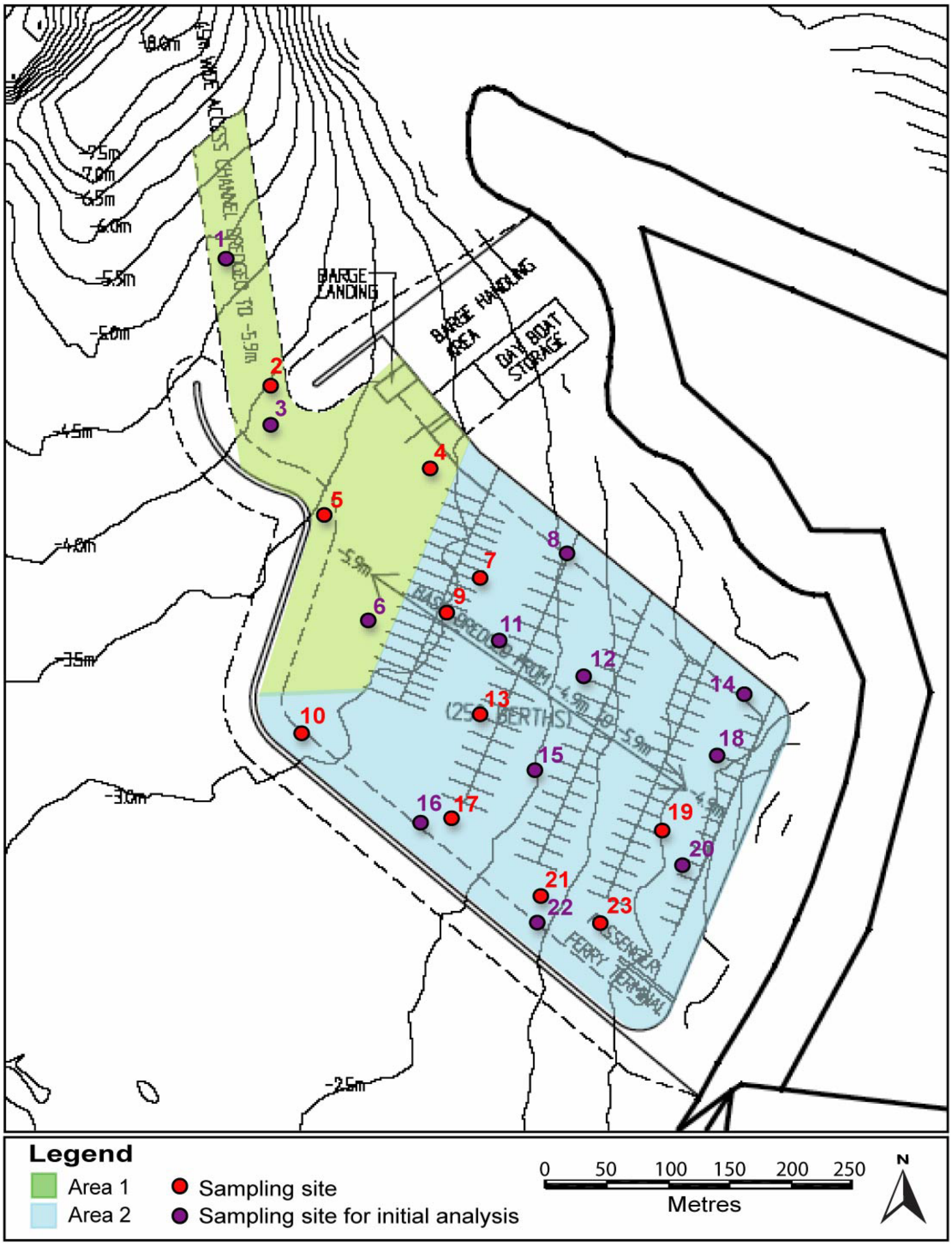
Samples were collected by frc environmental from 23 sites in accordance with Appendix A of the NAGD: sites 1 to 6 were located in the proposed entrance channel (Area 1), and the remaining sites were in the proposed marina basin (Area 2).

Approximately half of these sites (12) were assessed, as preliminary surface sediment sampling indicated that sediments were 'probably clean'. The 12 sites initially analysed represent the spatial extent of the dredge area and the range of sediment depths to be dredged.

The assessment of sediment quality in the marine footprint followed the approach outlined in Section 4.2 of the NAGD.

Any results less than the practical quantification limit (PQL) were entered as half the PQL, for statistical and analytical purposes (DEWHA 2009). The concentration of detected organic compounds was normalised to total organic carbon (TOC) content, as outlined in Section 4.2.3 of the NAGD.

Figure 3.71 SEDIMENT SAMPLING SITES WITHIN THE MARINA FOOTPRINT (NAGD)



Source: International Marina Consultants

SOURCE: MODIFIED FROM 'AQUATIC ECOLOGY' (2011) - frc environmental

3.6.4.3 Freshwater Sediments

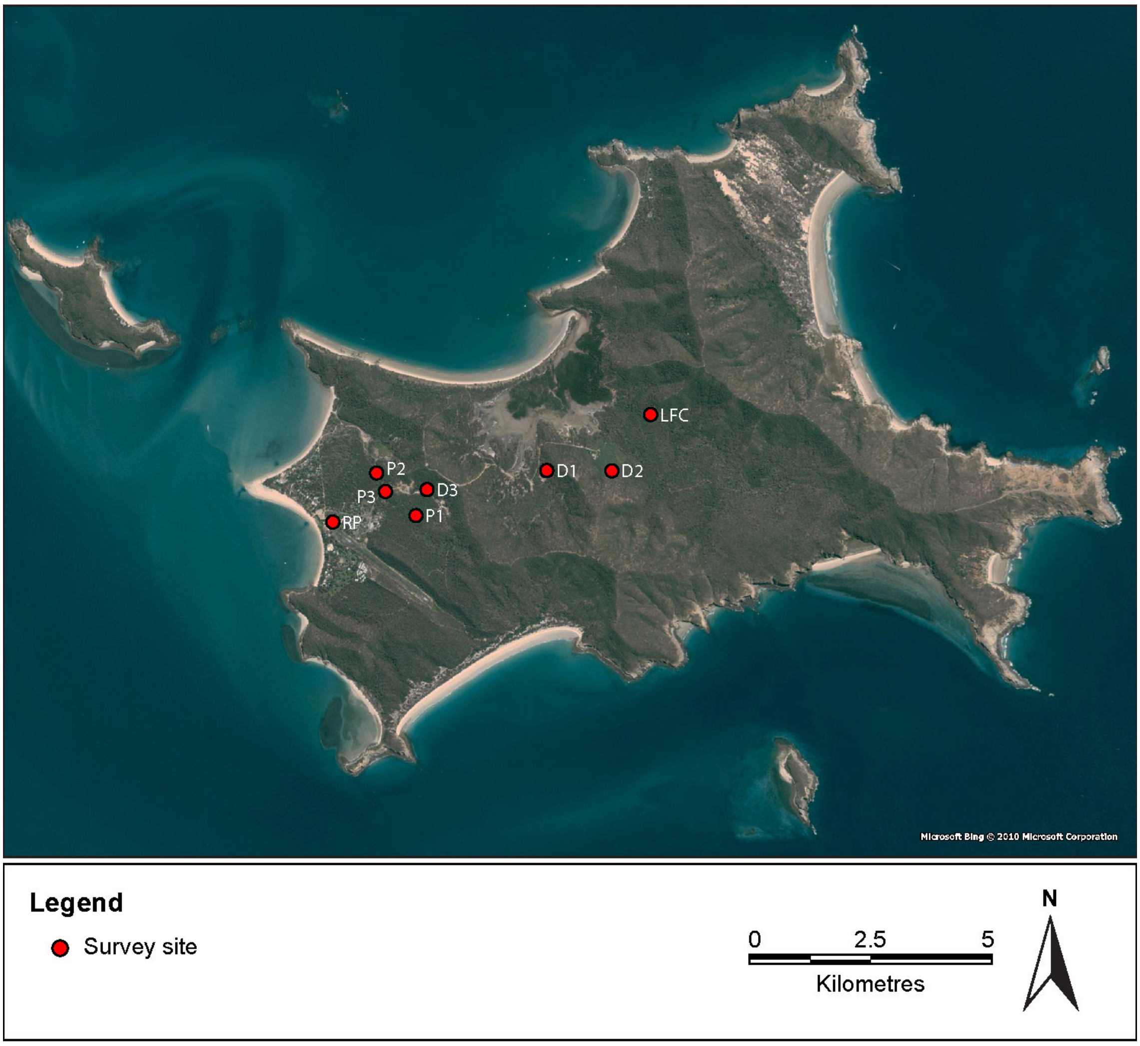
Eight freshwater sites on the Island were surveyed in the post-wet season (on 2 April 2011, 3 May 2011 and on 18 June 2011) (**Figure 3.72**):

- Large Dam (D1);
- Homestead Dam (D2);
- Resort Dam (D3);
- Putney Creek (P1, P2 and P3);
- Leeke's Creek (LFC); and
- Resort Creek (RP).

Sediment samples were collected from the wet channel bed at each site and from accreting banks for laboratory analysis of potential contaminants.

Data from each site was compared to laboratory detection limits and ANZECC & ARMCANZ (2000) trigger values for sediment (Interim Sediment Quality Guideline (ISQG) low trigger value).

Figure 3.72 FRESHWATER SITES



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3.6.4.4 Results

(a) Marine Sediments

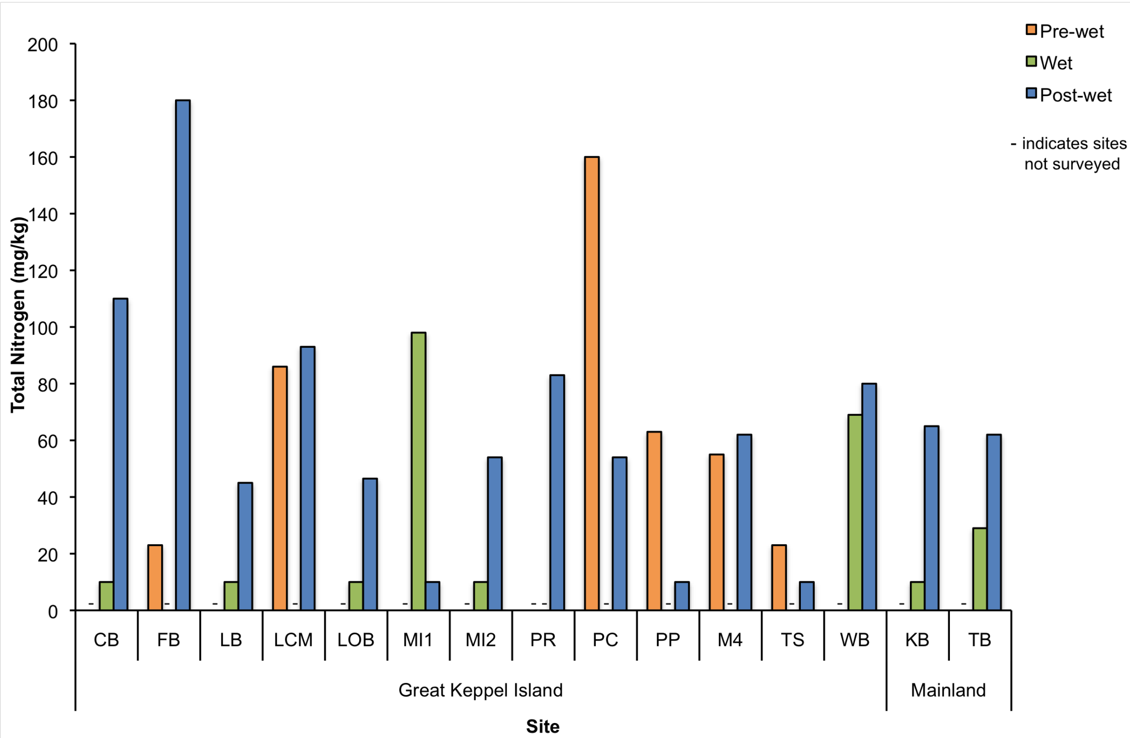
(a) (i) *Surface Sediments*

Surface sediments collected were largely found to be composed of sands.

The concentration of total nitrogen was variable between sites and surveys. The highest concentration of total nitrogen was in Putney Creek during the pre-wet survey and at Fisherman's Beach during in the post-wet survey (**Figure 3.73**).

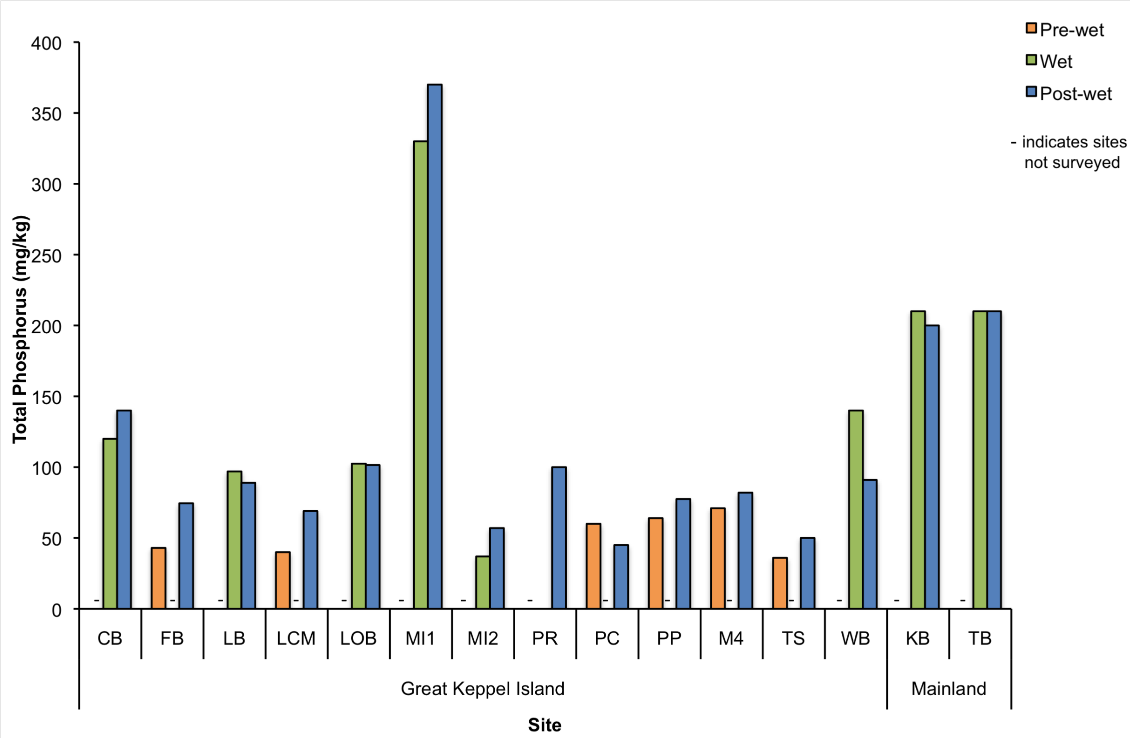
The concentration of total phosphorus was highest at Middle Island during both surveys, and also relatively high at the mainland sites during both wet and post-wet surveys; the concentration of total phosphorus was generally similar at each site during each survey (**Figure 3.74**).

Figure 3.73 TOTAL NITROGEN CONCENTRATION IN SURFACE SEDIMENT AT EACH SITE IN EACH SURVEY



SOURCE: 'AQUATIC ECOLOGY' (2011) - frc environmental

Figure 3.74 TOTAL PHOSPHORUS CONCENTRATION IN SURFACE SEDIMENT AT EACH SITE IN EACH SURVEY

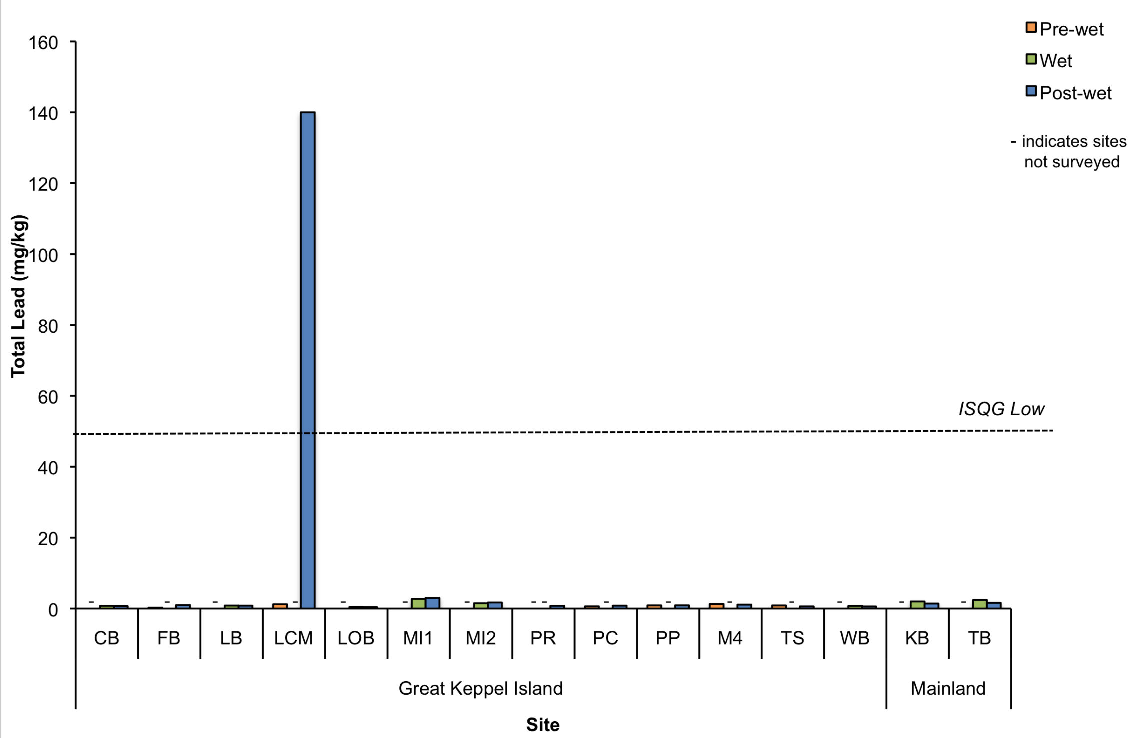


SOURCE: 'AQUATIC ECOLOGY' (2011) - frc environmental (Refer to **Figures 3.69** and **3.70** for sites).

The concentration of total arsenic, chromium, copper, mercury and zinc was below the ISQG-low trigger value at all sites during all surveys. The concentration of total lead at the Leeke's Creek mouth exceeded the ISQG-low trigger value during the post-wet survey; all other sites were substantially lower than the trigger value in all surveys (**Figure 3.75**).

Overall, concentrations of metals and metalloids were higher at Leeke's Creek mouth, near the underwater observatory on Middle Island and at the mainland sites. Relatively high levels could be related to the (decommissioned) underwater observatory, boating activity in Leeke's Creek and terrestrial run-off (e.g., fertilisers and mining activities) at the mainland sites.

Figure 3.75 TOTAL LEAD CONCENTRATION IN SURFACE SEDIMENT AT EACH SITE IN EACH SURVEY



SOURCE: 'AQUATIC ECOLOGY' (2011) - frc environmental (Refer to **Figures 3.69** and **3.70** for sites).

(a) (ii) *Sediments of the Marina Footprint*

Sediments of the marina footprint were largely composed of sands. The concentration of nutrients in the sediments was substantially lower than other locations in Queensland. The concentrations of all contaminants were below the laboratory LORs and NAGD screening levels (where available). The sediments are therefore considered to be uncontaminated.

No treatment of acid sulfate soils is likely to be required during dredging activities, as net acidity (including acid neutralising capacity) was low and mostly below the laboratory limits of reporting.

The results of quality assurance / quality control analyses were generally acceptable, with the exception of the laboratory replicates of silver and field replicates of phosphate, nitrate and copper. Given that there are no screening levels for phosphate and nitrate, and that concentrations of copper in all samples were below the screening level, this does not affect the interpretation of the results.

(a) (iii) *Regional Context*

Keppel Bay has been shaped through macrotidal currents, and wind and wave regimes, with continental islands, relict seabed morphology, and sediment input from terrestrial and marine sources. Terrestrial sediment from the Fitzroy Basin mostly accumulates in the mouth of the Fitzroy River estuary, with river sediment reaching the offshore reefs of the Keppel Islands during major flood events.

Agricultural and mining activities throughout the Fitzroy Basin introduce contaminants to waterways and ultimately to the offshore areas during flood events. Contaminants include fertilisers which can contain nutrients and metals as phosphate salts (particularly cadmium), 'cattle dips' which can contain arsenic compounds and DDT for parasite control, and mining activities which can introduce heavy metals. .

Metal contamination in the sediment of the Region appears to be low. The data, for the concentration of metal in sediment, indicates that the concentration of most metals in the Fitzroy River estuary is consistent with the concentration of metals in other Queensland estuaries that are not so heavily impacted by agricultural and mining activities. However elevated concentrations have been recorded for nickel, chromium, arsenic, copper and antimony, which are likely to reflect the geology of the Central Queensland Region rather than anthropogenic influences (particularly for nickel, arsenic and chromium). High nickel and mercury concentrations have been reported throughout the estuary, suggesting possible diffuse anthropogenic sources. High antimony and gold concentrations have been reported in Keppel Bay, suggesting some historical accumulation of these metals.

The Fitzroy River estuary and inshore coastal waters of the Region contain weathered sediments that are naturally nutrient-rich. Dissolved and particulate nutrients reach Keppel Bay via the Fitzroy River plume during flood events, or during the dry season by tidal flows when fine sediments and water are exchanged within the Fitzroy River estuary.

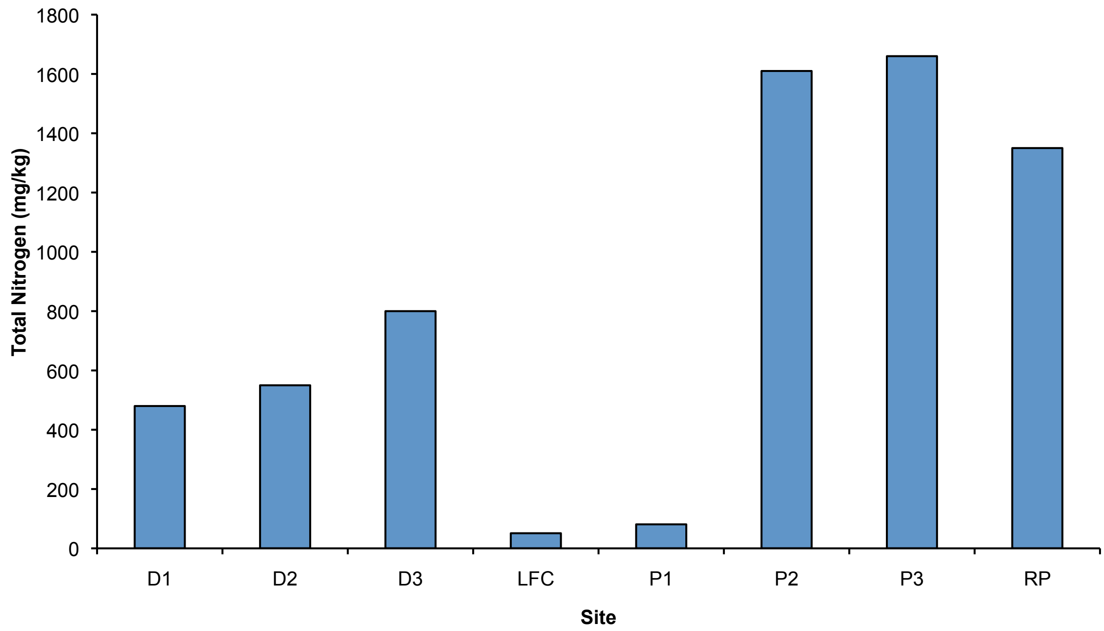
(b) Freshwater Sediments

(b) (i) *Surface Sediments*

The concentration of total nitrogen in the sediment was highest at sites P2 (downstream Putney Creek), P3 (mid Putney Creek) and RP (Resort Creek) (**Figure 3.76**). The concentration of total phosphorus in the sediment was highest at sites P3 (mid Putney Creek) and RP (Resort Creek) (**Figure 3.77**). This is likely to be due to seepage from septic tanks and possibly landfill.

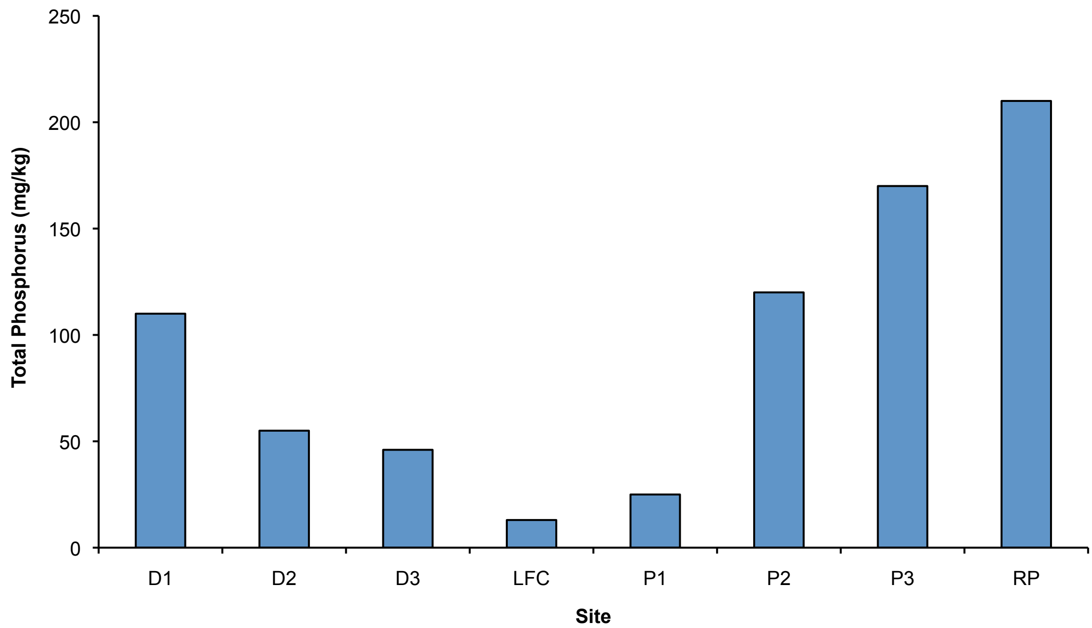
The concentrations of arsenic, cadmium, chromium, copper, lead, mercury, nickel and zinc in the sediment were below the ISQG-low trigger value at all sites. Concentrations were relatively high at some sites, which is likely to be related to seepage from landfill, livestock grazing activities and / or local geology.

Figure 3.76 CONCENTRATION OF TOTAL NITROGEN IN THE WHOLE FRACTION OF SEDIMENT AT EACH FRESHWATER SITE



SOURCE: 'AQUATIC ECOLOGY' (2011) - frc environmental (Refer to **Figure 3.72** for sites).

Figure 3.77 CONCENTRATION OF TOTAL PHOSPHORUS IN THE WHOLE FRACTION OF SEDIMENT AT EACH FRESHWATER SITE



SOURCE: 'AQUATIC ECOLOGY' (2011) - frc environmental (Refer to **Figure 3.72** for sites).

(b) (ii) *Regional Context*

Information is not readily available regarding sediment quality of freshwater streams on continental islands or in the lower Fitzroy Basin.

3.6.5 Water Quality

3.6.5.1 Water Quality Objectives

(a) Marine

Water quality objectives (WQOs) have been defined based on published guidelines including the *Water Quality Guidelines for the Great Barrier Reef Marine Park* (GBRMPA 2009) and the *Queensland Water Quality Guidelines* (QWQG) for coastal / inshore waters in the central Queensland region ((QWQG; DERM 2009). For parameters not specified in these guidelines, the WQOs have been based on the *Australian and New Zealand Water Quality Guidelines for Fresh and Marine Waters* (the national guidelines) (ANZECC & ARMCANZ 2000) for tropical Australia.

These published guidelines are considered sufficient to protect the described environmental values of the proposed development area, with the exception of visual recreation and cultural heritage, to which the following guidelines apply:

- visual recreation – water should be free of: floating debris; oil and grease; substances that produce undesirable colour, odour, taste or foaming; and undesirable aquatic life such as algae or dense growth of attached plants or insects, and
- cultural heritage – protect or restore Indigenous and non-Indigenous cultural heritage, consistent with relevant policies and plans.

(b) Freshwater

Freshwater results were compared with the *Queensland Water Quality Guidelines* (QWQG) low and high trigger values for lowland streams in the Central Coast Region (DERM 2009) where available. Concentrations of metals and metalloids, aromatic and petroleum hydrocarbons and organochlorine pesticides were compared with the ANZECC & ARMCANZ (2000) trigger values for toxicants in slightly to moderately disturbed systems.

3.6.5.2 Methods

(a) Marine

Surveys were undertaken during the following seasons:

- pre-wet – 15 to 19 November 2010;
- wet – 17 to 21 January 2011; and
- post-wet – 30 March to 2 April 2011, and 1 to 2 May 2011.

Water quality assessments included *in situ* physicochemical measurements at 31 sites around the Island (**Figure 3.78**):

- Putney Point to Putney Beach (WQ1–8) (near the proposed marina);
- the Leeke's Creek area (WQ 9–13) (downstream of the proposed golf course); and
- offshore[2] (WQ14–30) (around the entire island, approximately 500 metres from the shore).

Water samples were collected at 11 sites surrounding the Island (**Figure 3.79**) and two sites near the mainland (**Figure 3.80**) for laboratory analysis of potential contaminants.

A combination fluorometer and turbidity logger was placed offshore of The Spit (site TS; located between Putney and Fisherman's Beaches) by Water Technology from 11 February to 13 March 2011 to measure chlorophyll-aconcentration and turbidity (**Figure 3.78**).

2. *Only offshore sites were surveyed during the wet season due to time-constraints.*

Figure 3.78 GKI PHYSICOCHEMICAL WATER QUALITY SITES

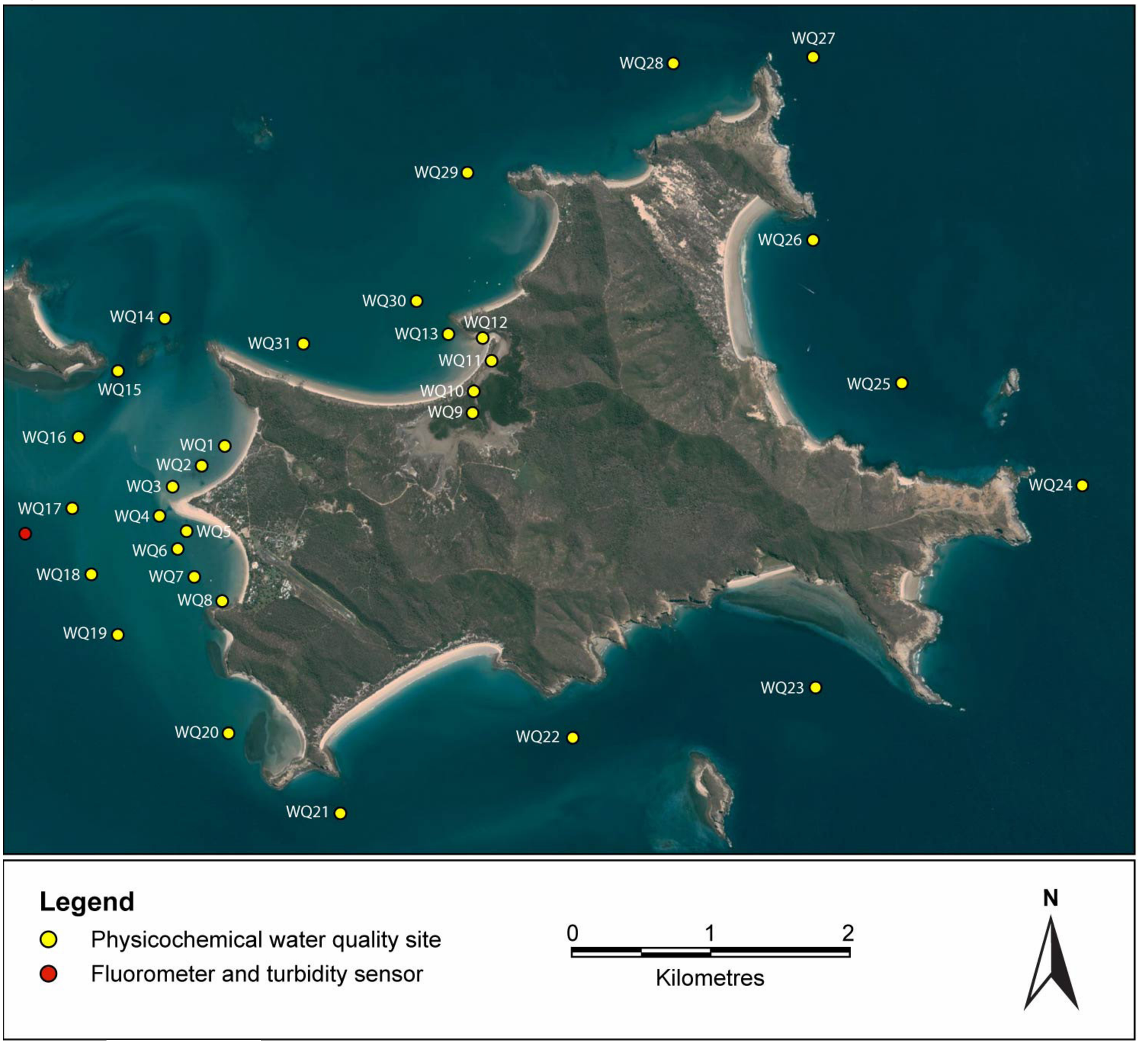


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Figure 3.79 GKI WATER QUALITY SITES FOR LABORATORY ANALYSIS OF CONTAMINANTS

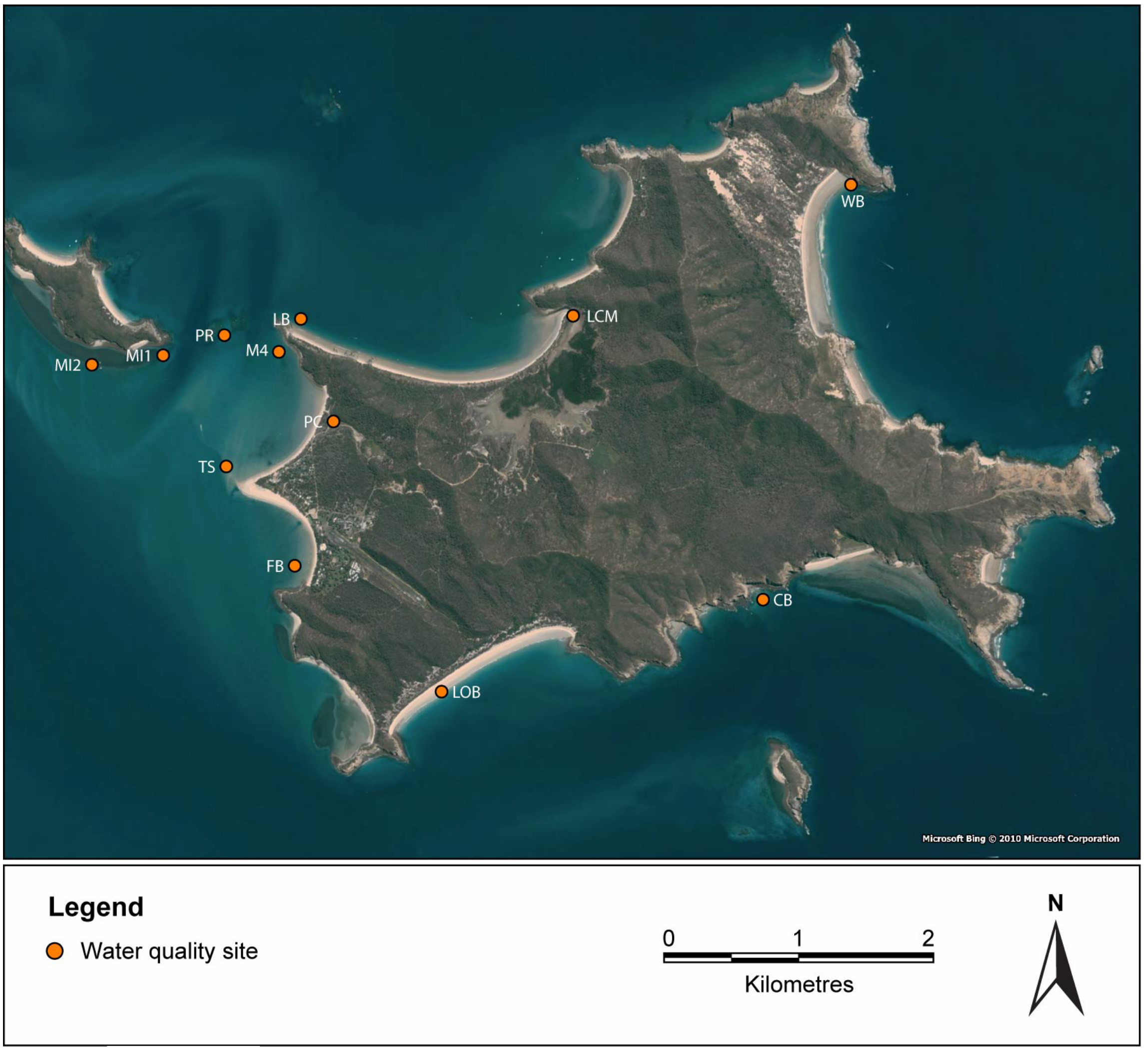

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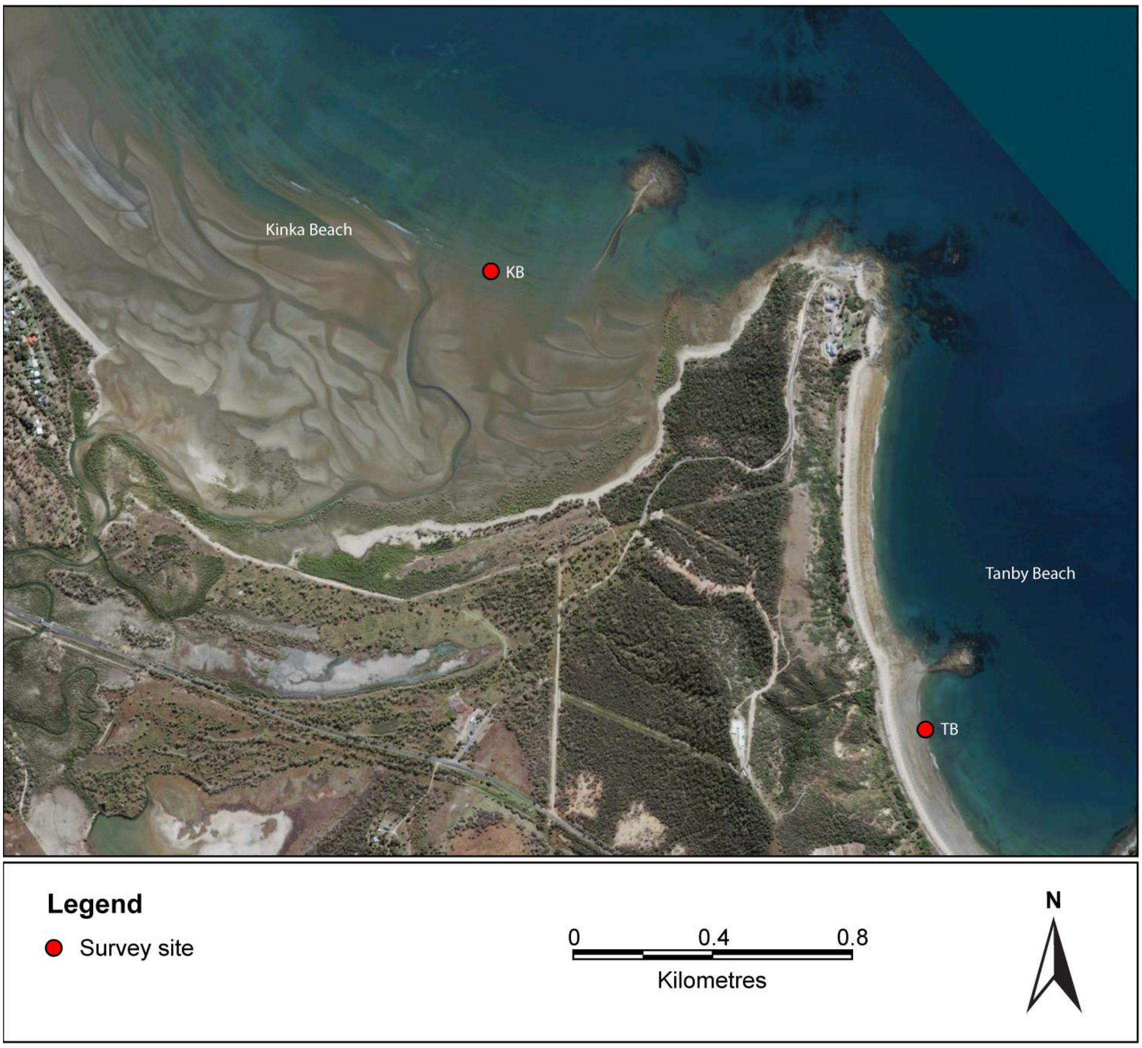
Figure 3.80 MAINLAND WATER QUALITY SITES FOR LABORATORY ANALYSIS OF CONTAMINANTS



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SOURCE: MODIFIED FROM 'AQUATIC ECOLOGY' (2011) - frc environmental

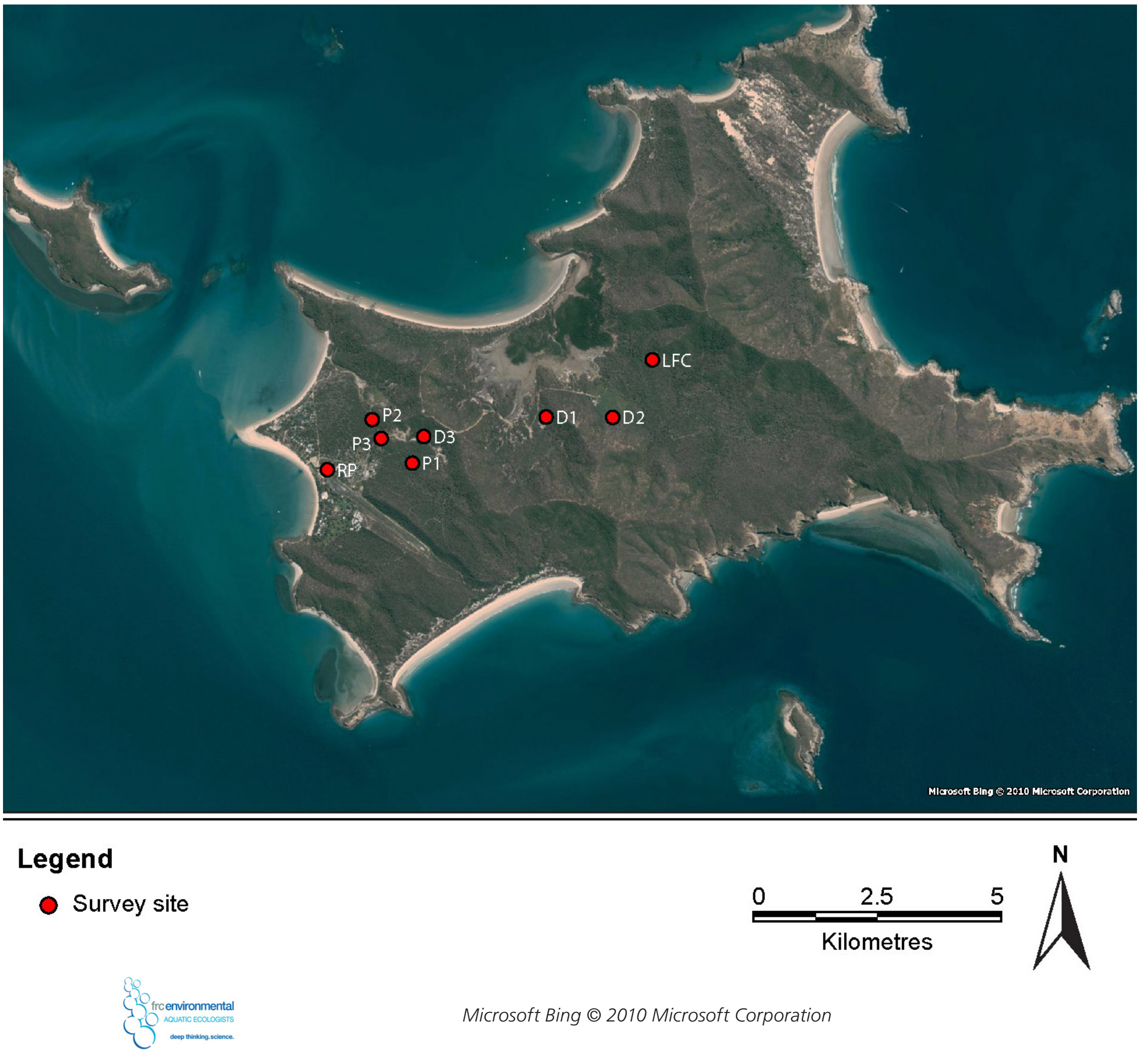
(b) Freshwater

Eight freshwater sites on the Island were surveyed in the post-wet season (on 2 April 2011, 3 May 2011 and on 18 June 2011) (**Figure 3.81**):

- Large Dam (D1);
- Homestead Dam (D2);
- Resort Dam (D3);
- Putney Creek (P1, P2 and P3);
- Leeke's Creek (LFC); and
- Resort Creek (RP).

Water quality assessments included *in situ* physicochemical measurements and laboratory analysis of potential contaminants.

Figure 3.81 FRESHWATER SITES



SOURCE: MODIFIED FROM 'AQUATIC ECOLOGY' (2011) - frc environmental

3.6.5.3 Results

(a) Marine

(a) (i) *Physicochemical*

Salinity within the survey area observed during the EIS was typical of inshore waters. During the post-wet survey, salinity was typically lower near the surface than at depth. During the wet survey, salinity was lower on an outgoing tide than on an incoming tide. This is likely to reflect tidal movement of freshwater run-off (floodwaters) and stratification of fresh and marine waters.

Dissolved oxygen concentrations were typically higher near the surface than at depth, and were highest during the wet survey. Concentrations near the surface were often above the relevant QWQG trigger value range whereas concentrations at depth were often below the relevant range. Leeke's Creek tended to have lower dissolved oxygen concentrations than other sites. These patterns are likely to reflect wind- and wave-driven water movement that mixes the water column with oxygen in the atmosphere (strong winds and large waves characterised the wet survey); together with primary production and microbial activity.

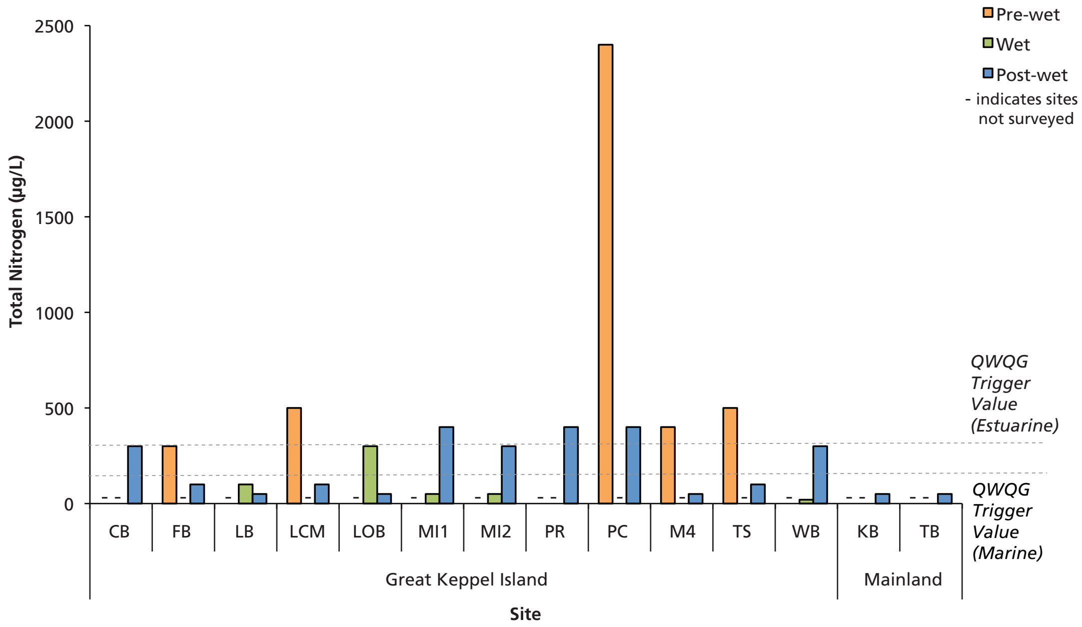
Turbidity was typically higher during the post-wet survey than other surveys, and higher at depth than near the surface. Turbidity at several sites exceeded the relevant QWQG trigger value during the wet and post-wet survey; turbidity tended to be highest in Leeke's Creek but was also relatively high near Passage Rocks and Putney Point. Turbidity offshore of The Spit (collected by the *in situ* logger) also exceeded the QWQG trigger value on several occasions and often for an extended duration (more than five days). High turbidity reflects sediment-laden run-off associated with rainfall and / or disturbance of the substrate due to wind, wave and tidal action; all of which introduce suspended particles into the water column.

The concentration of total suspended solids exceeded the relevant QWQG trigger value in Leeke's and Putney Creeks and at both mainland sites. Concentrations were generally highest in the post-wet survey.

(a) (ii) *Laboratory Analyses*

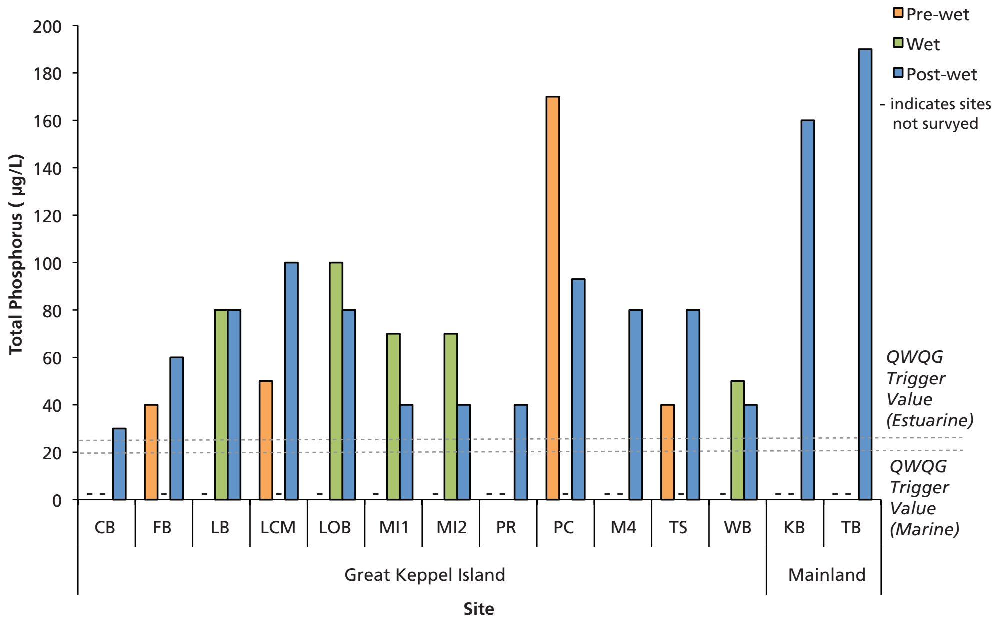
The concentrations of total nitrogen and total phosphorus exceeded the relevant QWQG trigger values at most sites, and were particularly high in Putney Creek during the pre-wet survey (**Figure 3.82**). The concentration of total phosphorus was relatively high at the mainland sites (**Figure 3.83**). The concentration of chlorophyll-a offshore of The Spit was above the QWQG upper trigger value for much of the fluorometer logging duration (**Figure 3.84**). This is likely to be related to the concentration of nitrogen in nearby waters exceeding the QWQG upper trigger value prior to the survey, and the concentration of phosphorus exceeding the QWQG upper trigger value both before and after the survey.

Figure 3.82 TOTAL NITROGEN CONCENTRATION IN SURFACE WATERS AT EACH SITE IN EACH SURVEY



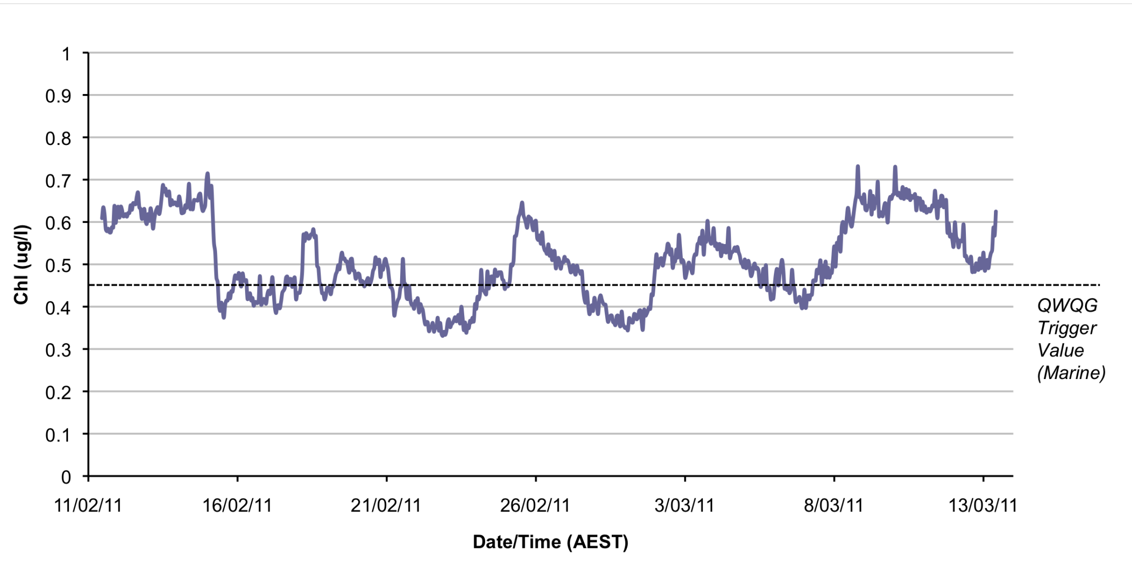
SOURCE: 'AQUATIC ECOLOGY' (2011) - frc environmental (Refer to Figure **3.81** for sites).

Figure 3.83 TOTAL PHOSPHORUS CONCENTRATION IN SURFACE WATERS AT EACH SITE IN EACH SURVEY



SOURCE: 'AQUATIC ECOLOGY' (2011) - frc environmental (Refer to Figure **3.81** for sites).

Figure 3.84 CONCENTRATION OF CHLOROPHYLL-A IN WATERS OFFSHORE OF THE SPIT FROM 11 FEBRUARY 2011 TO 13 MARCH 2011



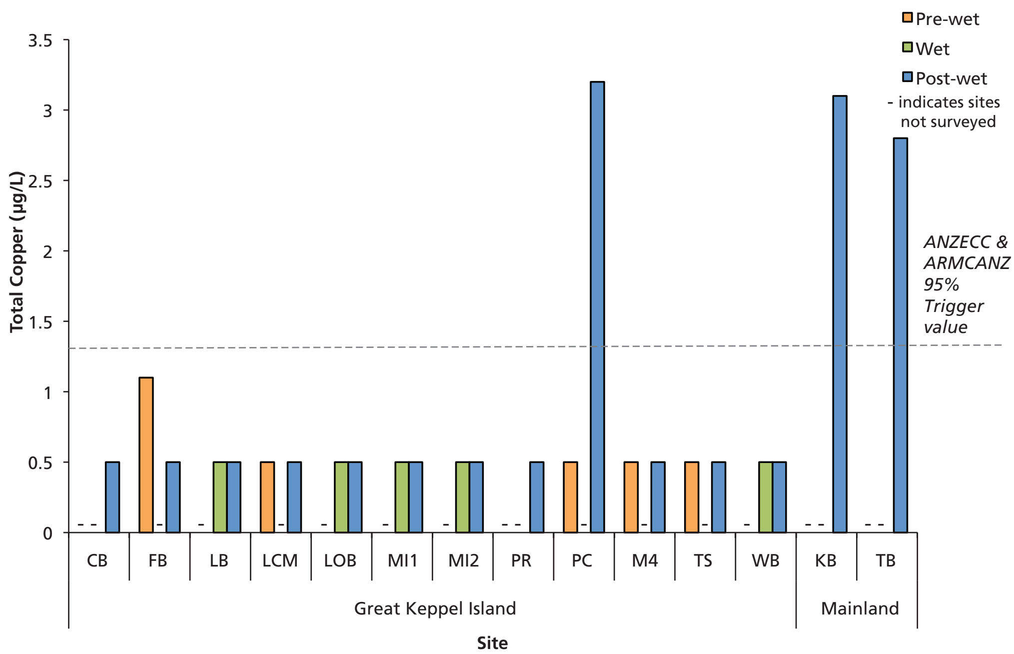
SOURCE: 'AQUATIC ECOLOGY' (2011) - frc environmental

The concentration of total arsenic was below the laboratory detection limit at all sites during all surveys, except in Putney Creek during the pre-wet survey. There are no trigger values for arsenic in estuarine or marine waters.

The concentration of total copper exceeded the relevant ANZECC & ARMCANZ trigger value in Putney Creek and at the mainland sites in the post-wet survey (**Figure 3.85**).

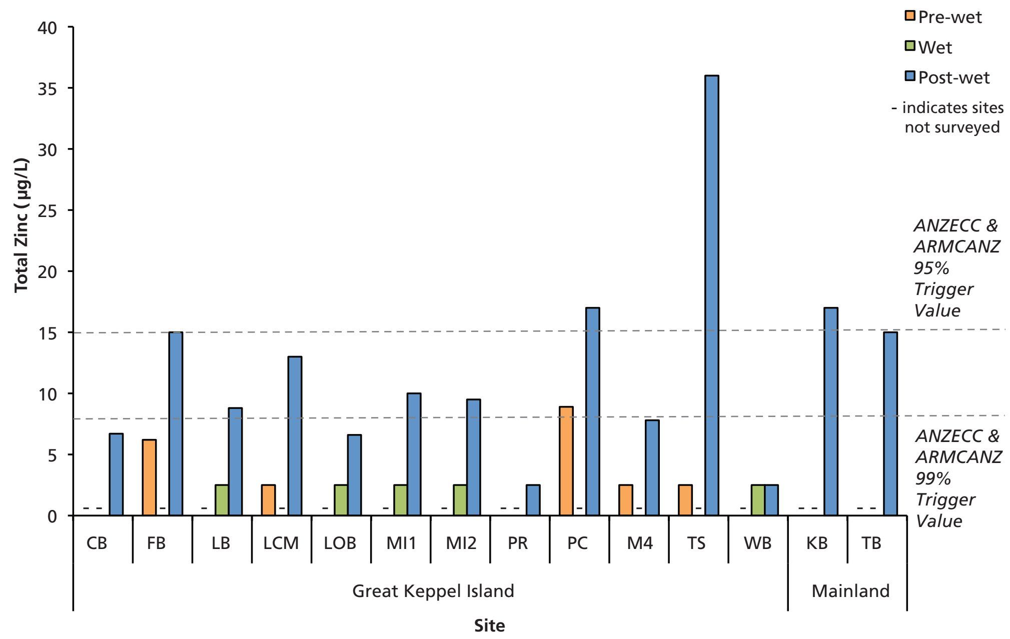
The concentration of total zinc exceeded the relevant ANZECC & ARMCANZ trigger value at most sites in the post-wet survey, and was particularly high near The Spit and to a lesser extent in Putney Creek and at Kinka Beach (**Figure 3.86**).

Figure 3.85 TOTAL COPPER CONCENTRATION IN SURFACE WATERS AT EACH SITE IN EACH SURVEY



SOURCE: 'AQUATIC ECOLOGY' (2011) - frc environmental

Figure 3.86 TOTAL ZINC CONCENTRATION IN SURFACE WATERS AT EACH SITE IN EACH SURVEY



SOURCE: 'AQUATIC ECOLOGY' (2011) - frc environmental

The concentration of other metals and metalloids (cadmium, chromium, nickel, lead and mercury), total petroleum hydrocarbons, aromatic hydrocarbons and organochloride pesticides were below laboratory detection limits and / or relevant trigger values at all sites in all surveys.

(a) (iii) *Regional Context*

Concern regarding the trend of decline in water quality in the water draining to the GBR, as well as its lagoon, is well documented. Located approximately 40 kilometres off the mouth of the Fitzroy River, the waters surrounding the Island have a seasonal input of fresh and turbid waters that can result in episodes of poor water quality. Land use in the Fitzroy Basin is dominated by grazing and agriculture, together with mining and forestry.

The main sources of nutrients in the Project area are derived from river and land run-off, particularly during floods. Nutrients (nitrogen and phosphorous) are mostly derived from diffuse sources, however point sources are locally significant in the upper estuary during extended periods of very low flow (as nutrients remain for a long time). There is little evidence to indicate that nutrient loads from the Fitzroy Basin are having a major impact on the ecology of the Fitzroy River estuary and offshore waters.

There are significant concentrations of several herbicides (atrazine, tebuthiuron and diuron) and lower concentrations of additional herbicides entering the Fitzroy River estuary in summer flows, with the potential to flow into coastal waters.

Coastal water quality of the Region and of the Island in particular, is highly variable, responding to flood discharge from the Fitzroy River and less frequently cyclonic conditions. It is these event-based 'drivers' of coastal water quality that have the greatest ecological significance (and within which the potential impacts of the proposed marina should be viewed).

(b) Freshwater

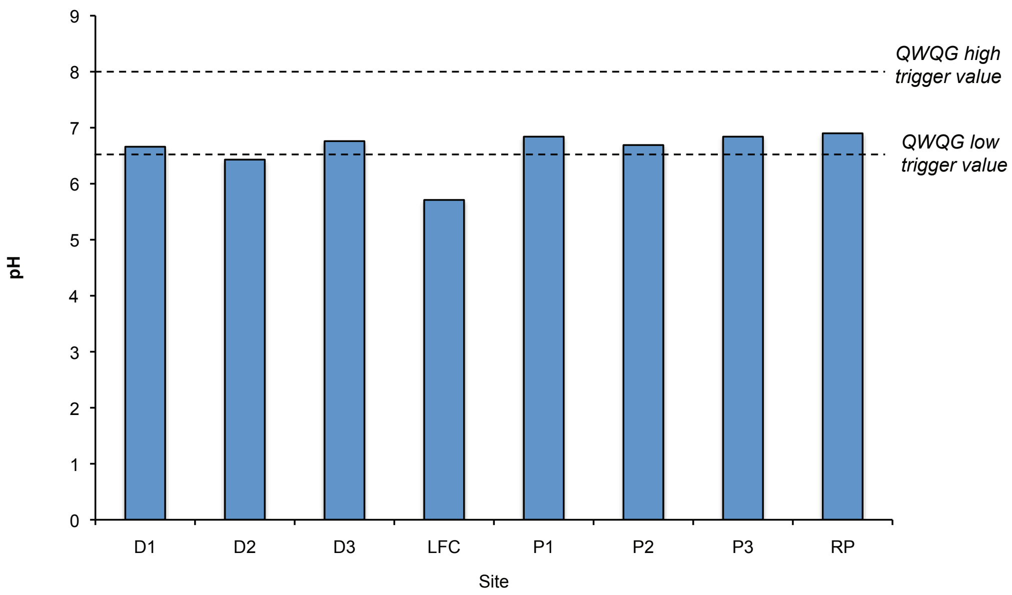
(b) (i) *Physicochemical*

The pH was within the QWQG trigger value range at most sites and it was below the range at sites D2 (Homestead Dam) and LFC (Leeke's Creek) (**Figure 3.87**). The reason for this is not clear, but may be related to local geology.

Electrical conductivity was above the QWQG upper trigger value at most sites, particularly at site P1 (upstream Putney Creek); the dams (D1 to D3) were below the trigger value (**Figure 3.88**). This is likely to be related to evaporation at most sites and the groundwater waters source at site RP (Resort Creek).

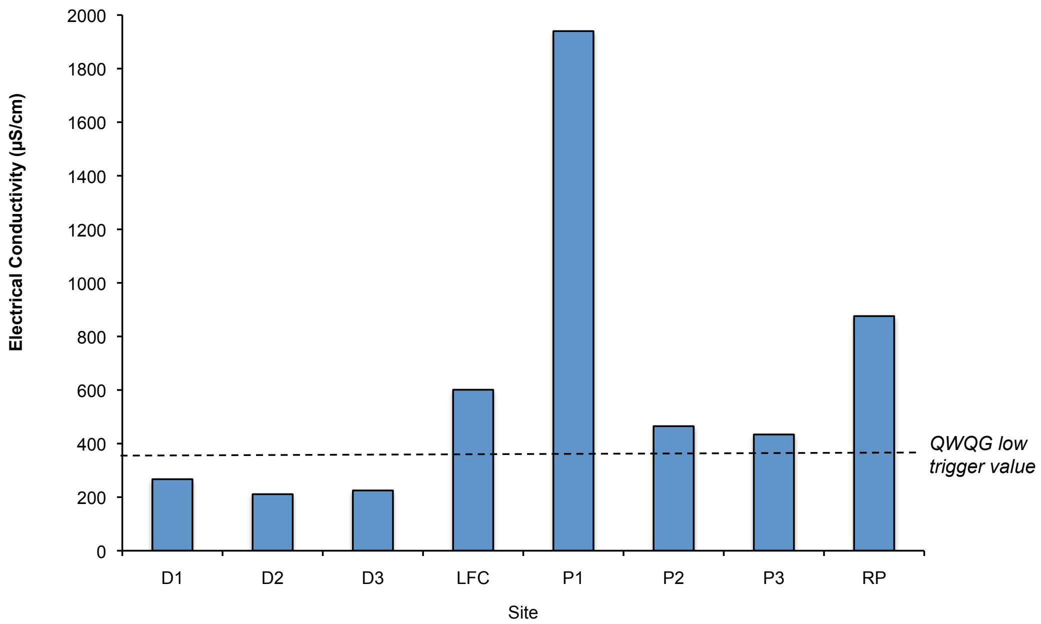
The total suspended solid concentration was highest at sites P2 (downstream Putney Creek), P3 (mid Putney Creek) and LFC (Leeke's Creek) and relatively low at sites D3 (Resort Dam) and site RP (Resort Creek) (**Figure 3.89**).

Figure 3.87 THE PH AT EACH FRESHWATER SITE, AND THE QWQG TRIGGER VALUE RANGE



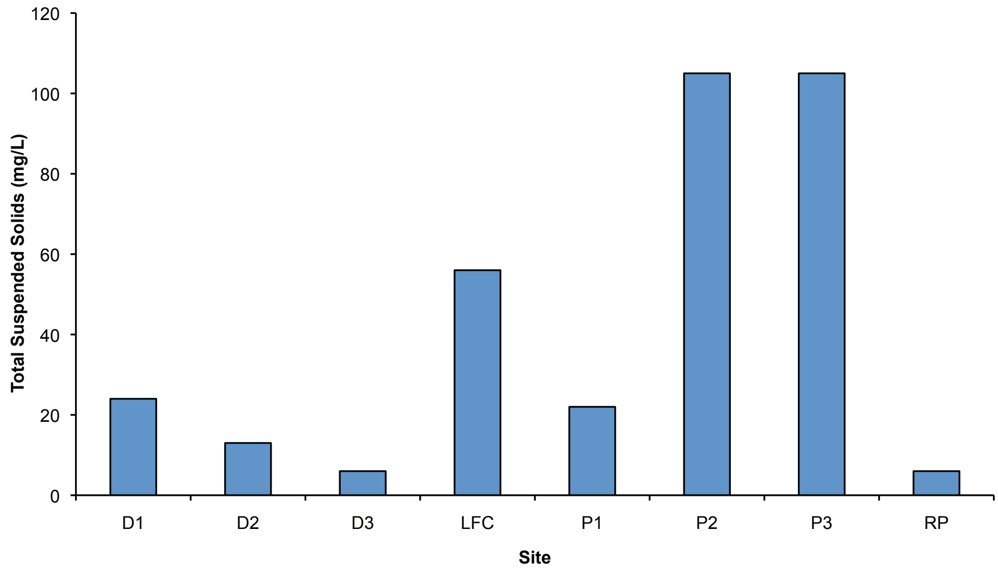
SOURCE: 'AQUATIC ECOLOGY' (2011) - frc environmental (Refer to **Figure 3.81** for sites).

Figure 3.88 ELECTRICAL CONDUCTIVITY AT EACH FRESHWATER SITE, AND THE QWQG TRIGGER VALUE



SOURCE: 'AQUATIC ECOLOGY' (2011) - frc environmental (Refer to **Figure 3.81** for sites).

Figure 3.89 CONCENTRATION OF TOTAL SUSPENDED SOLIDS AT EACH FRESHWATER SITE

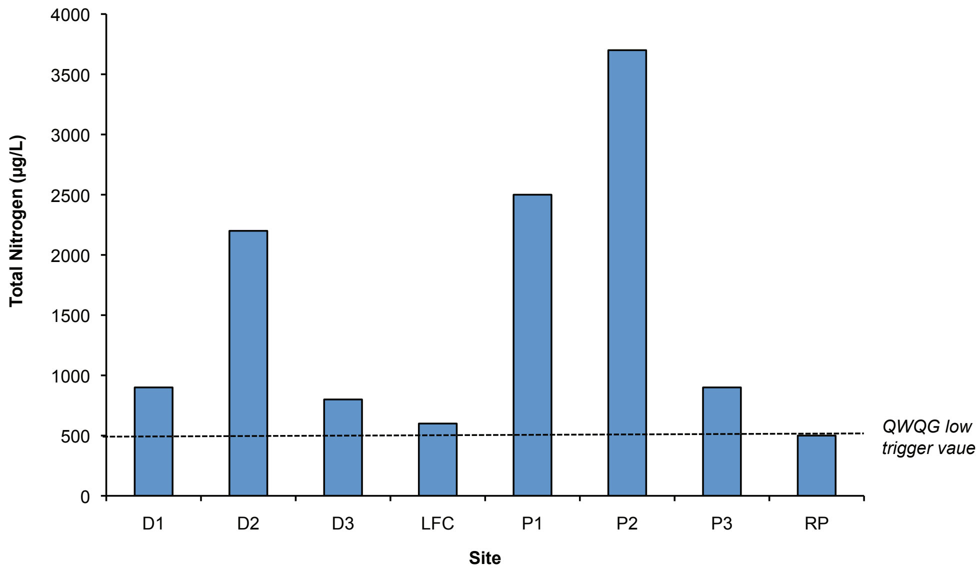


SOURCE: 'AQUATIC ECOLOGY' (2011) - frc environmental (Refer to **Figure 3.81** for sites).

(b) (ii) *Laboratory Analyses*

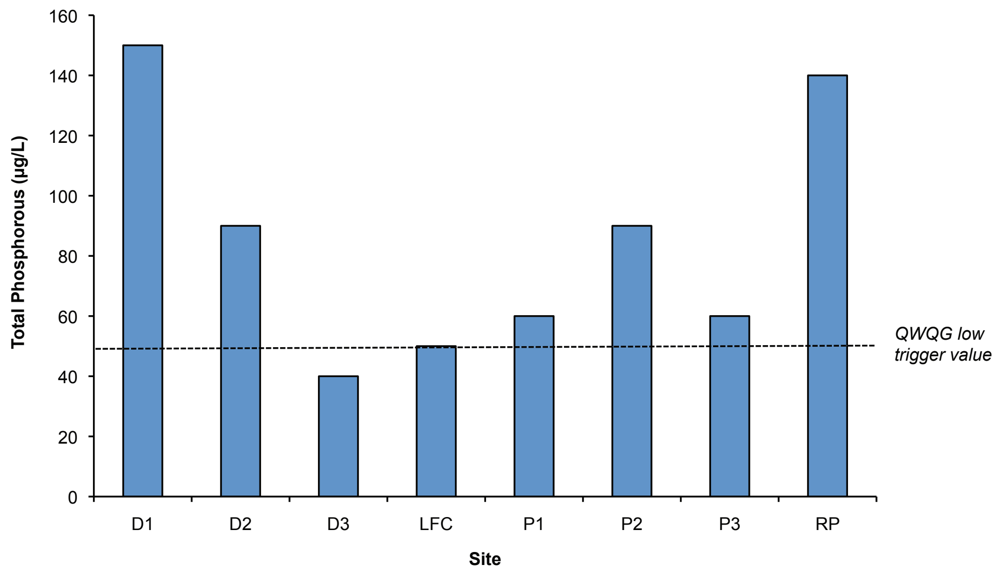
The concentration of total nitrogen was above the QWQG lower trigger value at all sites (**Figure 3.90**). The concentration of total phosphorous was above the QWQG lower trigger value at all sites, except site D3 (Resort Dam) (**Figure 3.91**). This could be related to seepage from residential septic systems and possibly the old landfill site.

Figure 3.90 CONCENTRATION OF TOTAL NITROGEN AT EACH FRESHWATER SITE, AND THE QWQG TRIGGER VALUE



SOURCE: 'AQUATIC ECOLOGY' (2011) - frc environmental (Refer to **Figure 3.81** for sites).

Figure 3.91 CONCENTRATION OF TOTAL PHOSPHORUS AT EACH SITE, AND THE QWQG TRIGGER VALUE



SOURCE: 'AQUATIC ECOLOGY' (2011) - frc environmental (Refer to **Figure 3.81** for sites).

Concentrations of total arsenic, cadmium, mercury and nickel were below laboratory detection limits and / or the relevant ANZECC & ARMCANZ trigger values at all sites. Total chromium, copper, lead and zinc concentrations were above laboratory detection limits and / or trigger values at some sites, which is likely to be related to seepage from the former landfill, historical livestock grazing activities and / or local geology. The concentration of total chromium was above the trigger value at site P1 (upstream Putney Creek). The concentration of total copper was above the trigger value at sites D1 (Large Dam), D2 (Homestead Dam) and in Putney Creek (P1 to P3). The concentration of total lead was above the trigger value at sites D3 (Resort Dam) and LCF (Leeke's Creek). The concentration of total zinc was above the trigger values at most sites; it was below the trigger value at sites D2 (Homestead Dam), D3 (Resort Dam) and LFC (Leeke's Creek).

The concentration of the total petroleum hydrocarbon C15 to C28 fraction was relatively high at site D1 (Large Dam); this site may have been exposed to diesel. The total concentration of the C29 to C36 fraction was relatively high at sites D1 (Large Dam), D2 (Homestead Dam) and P2 (downstream Putney Creek); these sites may have been exposed to mineral-based oils and lubricants.

(b) (iii) *Regional Context*

The Fitzroy Basin has a large number of mines and is heavily grazed and farmed. Coupled with the soil types in the Region the waterways tend to have high turbidity, and high concentrations of suspended solids and nutrients. A recent survey by Australian Pacific (2009) reported electrical conductivity above trigger value and dissolved oxygen concentrations and turbidity levels within trigger value ranges (APLNG 2010).

3.6.5.4 Marina Residence Times

The marina basin volume at mean sea level will be approximately 500,000 cubic metres. The volume change in the marina between MLSW and MHWS is over 330,000 cubic metres. Therefore, greater than 50 percent of the average marina volume will be exchanged over a single spring tidal cycle. Practical measures of residence times such as the e-folding time are therefore likely to no greater than one to two days for all locations within the marina basin.

(a) Antifouling

Copper concentrations in the waters of the marina are likely to be elevated due to the presence of copper in antifouling paints. The concentration of copper in the marina will be dependent on a number of factors including:

- leaching rate from vessel hull;
- number of vessels;
- hydraulic flushing; and
- background concentration.

The marina will have berthing facilities for up to 250 vessels with an average length of around 17.5 metres, providing an estimated typical wet hull area of approximately 27 square metres per vessel. Significant variations in leech rates in the marina will occur depending on the anti-fouling maintenance regime of the vessels within the marina. For the purposes of this assessment, an appropriately conservative average copper leach rate of 4 $\mu g/cm^2/day$ has been adopted.

Hydrodynamic model simulations have been undertaken to determine the resulting concentrations and fate of the copper leached from antifouling paint for a fully berthed marina. A conservative numerical tracer was released evenly over the berth area of the marina at a rate equivalent to the leaching of 263 grams per day of copper. The hydrodynamic model was simulated over a one month period of typical summer wind and astronomical tidal conditions and the fate and transport of the numerical tracer was tracked over the simulation period. The copper concentration in the model relates to the total amount of copper released from the antifouling paints rather than the bio-available copper and is therefore conservative. Studies have found that if only total copper is determined, the toxicity will be overestimated by a factor of four on average (Dürr, Simone, 2010).

The highest protection trigger level (99 percent) for copper in high conservation value marine aquatic ecosystems is provided by the ANZECC (2000) guidelines as 0.3 ug/L, this level is considered for outside of the marine. For within the marina, this environment is representative of a slightly to moderately disturbed system, the trigger level of copper in a slightly –moderately disturbed system is provided by ANZECC (2000) guidelines as 1.3 ug/L.

The model simulation results show slightly elevated copper concentrations are generally confined to the marina basin, however these levels are considered to slightly exceed the ANZECC (2000) guidelines of 1.3 ug/L for slightly to moderately disturbed systems. The results also show that the concentration of copper rapidly decrease directly outside of the marina, these levels are seen to be below the ANZECC (2000) guidelines of 0.3 ug/L for pristine environments.

(a) (i) *Mitigation Measures*

No mitigation measures are proposed as the predicted copper concentrations are considered to only slightly exceed the specified thresholds as outlined in the ANZECC (2000) guidelines. There are also considered to be no practical options for mitigating the rate of antifouling leachate.

3.6.5.5 Sediment Quality and Dredging

(a) Overview

During construction, dredging will be required to create the marine facility basin, approach channel and to provide material for reclamation and breakwater construction. The volume of material to be dredged including an allowance for over-dredging has been determined as approximately 300,000 cubic metres, the depth of dredging required is generally of the order 2.5 to three metres.

(b) Dredge Sediment Characteristics

Seismic refraction survey was undertaken over the area encompassing the marina footprint. The survey was undertaken to map the depth of unconsolidated material and identify any bedrock surfaces within the dredge footprint to assess marina construction and dredging feasibility. The geophysical survey identified a continuous reflector across the marina footprint at a minimum depth of 10 metres that was interpreted as a bedrock surface. Sediment cores were also undertaken from 23 locations within the dredge area footprint. The dredge sediment is overwhelming comprised of sand sized of greater fractions. Only approximately five percent of the material to be dredged has particle sizes in the silt or clay fraction. **Table 3.78** displays the median characteristics of the sediments to be dredged.

TABLE 3.78 SUMMARY OF DREDGE SEDIMENT CHARACTERISTICS

Fraction	Grain Size (mm)	Median Percentage (%)	Settling Velocity (m/s)
Gravel	+2.0	2	1.2
Sand	2.0 - 0.06	93	0.02
Silt/Clay	>0.06	5	0.001

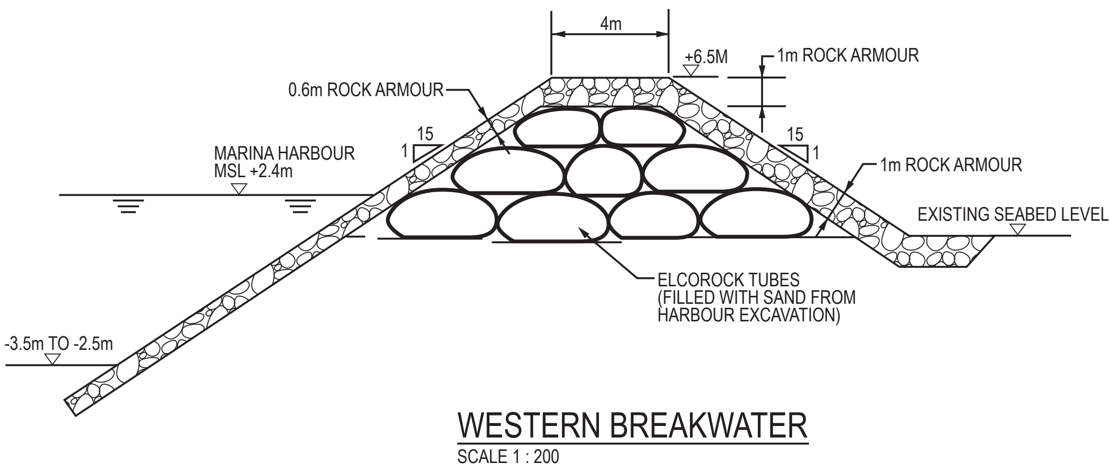
(c) Marina Construction Methodology

The proposed construction method for the marine facility has been developed in consideration of the following:

- limited access to major local sources of quarry material on the Island to enable the construction of traditional rubble mound breakwaters or to provide material for land reclamation; and
- the desire to prevent the need for sea disposal of dredge material as part of the construction of the marina.

To overcome the above, it has been proposed that all the material from the marina basin dredging be utilised to form the core of the breakwaters and to provide the majority of the material required for land reclamation. The proposed construction method therefore requires the breakwater cores to be constructed of a number of large geotextile tubes filled with sediment excavated from the marina basin. **Figure 3.92** displays a conceptual illustration of the breakwater design incorporating the use of sand filled geotextile tubes to form the core of the breakwater. This type of technology has been used in a number of marinas in Australia as outlined in Water Technology's Report (refer **Appendix Y**).

Figure 3.92 CONCEPTUAL ILLUSTRATION OF WESTERN BREAKWATER CROSS SECTION (IMC, 2011)



Source: 'COASTAL ENVIRONMENT TECHNICAL REPORT' (2011) WATER TECHNOLOGY

Construction the marine facility is proposed to be undertaken in four main stages and the details of each stage are discussed below:

Stage 1 - Western Breakwater Construction and Basin Dredging

Construction of the western breakwater in Stage 1 will eliminate the majority of the current and wave action from the marine facility basin and minimise weather related downtime and risks for the remainder of the marine facility construction. Construction of the western breakwater first will also help to contain the extent of any turbid plumes, generated during construction, within the marine facility footprint.

Stage 1 will require approximately 57,000 cubic metres of sediment to be dredged from the marina basin to fill the geotextile tubes to create the core of the western breakwater. It is expected that a small cutter suction dredge (CSD) will be able to achieve a dredging rate of 120 cubic metres per hour, enabling a 20 metre long by 16 metre circumference tube to be filled within approximately three hours. Assuming four tubes a day can be filled at this rate for seven days a week and including some contingency, it is estimated that the western breakwater core construction can be completed in 12 weeks with this method.

(c) (i) *Stage 2 – Marina Basin Revetment and Basin Dredging*

Stage 2 will involve the construction of the marina basin revetments. Stage 2 will require a total of approximately 40,000 cubic metres of sediment to be dredged from the marina basin to fill the geotextile tubes to create the marina revetments. Based on a similar dredging and geotextile tube fill rates as adopted for the western breakwater core construction, a total twelve weeks is expected to be required to construct the marina revetments.

(c) (ii) *Stage 3 – Northern Reclamation*

Stage 3 will require the remainder of the marina basin excavation and approach channel dredging to be completed. The total remaining volume of material to be dredged in Stage 3 has been determined as approximately 185,000 cubic metres. It expected that a medium sized cutter dredge, achieving a dredge rate of approximately 500 cubic metres per hour and operating eight hours a day, seven days a week could complete the dredging within eight weeks.

Dredge material will be pumped directly into the reclamation area to the north of the marina basin. The reclamation area will be designed with a number of settling basins to allow fines to settle out of suspension before the decant overflow is allowed to return to the marina basin.

(c) (iii) *Stage 4 – Placement of Breakwater Armour and Marina Basin Rip Rap*

Following completion of the geotextile core, armour rock will be placed over the breakwaters and marina revetments. The placement of the armour rock is likely to be undertaken from a barge mounted excavator, with the armour rock barged from sources on the mainland.

(d) Suspended Solids Generation Rates and Loadings

Construction and associated dredging of the marine facility will generate turbid plumes. The following potential sources of suspended sediment have been identified during construction of the marine facility:

- at the head of the cutter suction dredge (CSD);
- discharges from the overflow ports on the geotextile tubes during filling; and
- decant discharges from the reclamation.

The mechanism of turbidity production and rates of turbidity generation for the identified turbidity sources are discussed below.

(d) (i) *Cutter Suction Dredge*

Suspended sediment generation rates at the dredge head vary considerably depending on the proportion of fines in the bed material, the size and type of dredge plant and skill and experience of the dredge plant operator. A very conservative approach is to assume approximately five percent of excavated material goes into suspension. Assuming a small CSD with a 120 cubic metre per hour capacity, this corresponds to a suspended sediment generation rate of approximately three kilograms per second. Of this suspended sediment, the overwhelming majority will be sand sized fractions which will settle out all most instantly around the dredge head. The remaining five percent of fines will however remain is suspension producing a suspended sediment generation rate of 0.1 kilograms per second or 4.4 kilograms per cubic metre.

(d) (ii) *Geotextile Tube Overflow Discharges*

The filling of the geotextile tubes with dredged material will result in the generation of some suspended sediment. To enable water component of the slurry pumped into the geotextile bags during filling to exit the tubes, the tubes are designed with a number of ports where water is able to escape out of the tube as it is pumped full of sediment.

The water flowing from the geotextile ports is likely to contain a high proportion of fine material which has not settled within the tube and will go into suspension once it is discharged from the geotextile tube ports. It has been assumed very conservatively that 100 percent of the fine faction in the dredged sediment will be discharged through the geotextile ports. This is considered to be a conservative assumption as in practice a proportion of the fines will be captured within the geotextile tubes as they are filled.

Assuming a 250 millimetre pipe and 100 litre per second pumping rate, turbidity generated at the overflow ports during the geotextile tube filling was estimated at 2.9 kilograms per second or 88.3 kilograms per cubic metre.

(d) (iii) *Decant Discharges from Reclamation*

Use of the dredged material for fill in the reclamation area will require dewatering to be carried out. The reclamation area will be arranged to ensure settling time is optimised to reduce the concentration of fines in the decant outfall. Conservative estimates of suspended sediment loads from the decant outfall from the reclamation area have been adopted considering a 100 litres per second outfall and suspended sediment load of 0.004 kilograms per second.

A summary of the total suspended solids (TSS) generation rates and total loads used for the dredge plume impact assessment are provided in **Table 3.79**.

TABLE 3.79 SUMMARY OF TSS LOADINGS DURING CONSTRUCTION OF THE MARINE FACILITY

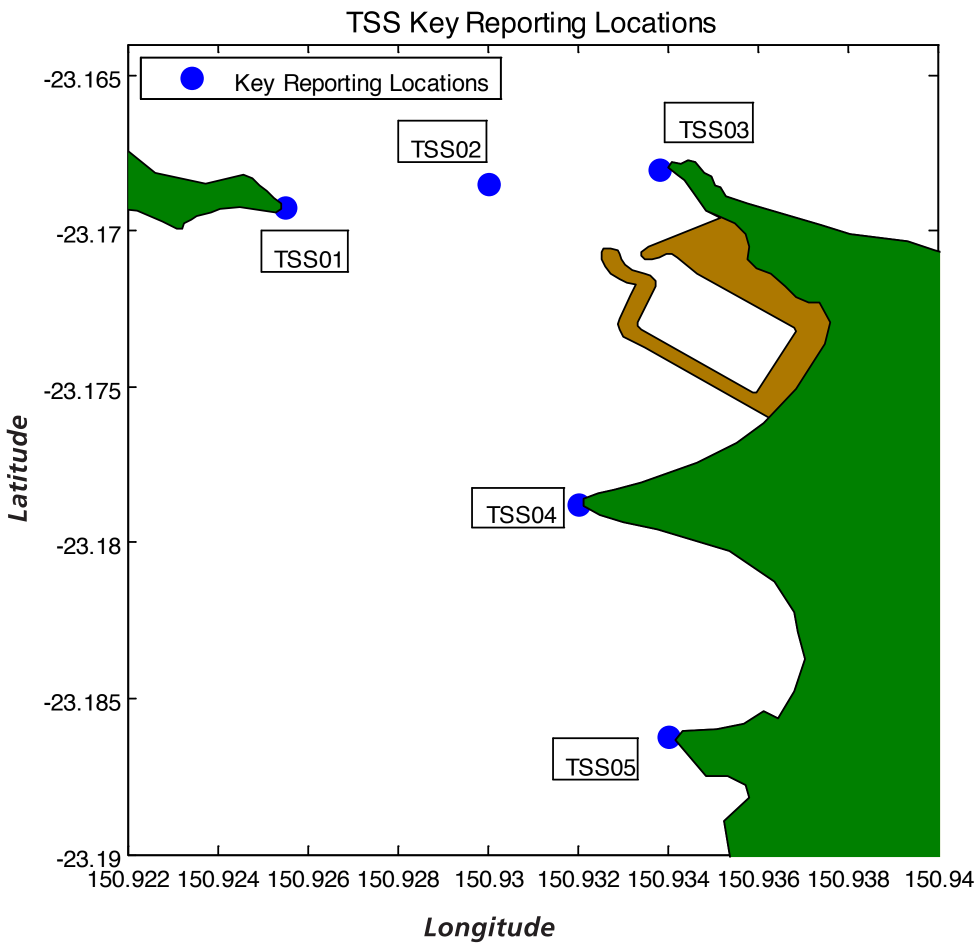
Stage	Dredge Volume (m3)	Source Description	Operation	TSS Generation Rate (kg/s)	Total TSS Load (× 103 kg)
1	58,000	Small CSD dredging marina basin	9 hrs/d, 7 days a week, 8 weeks	0.15	270
		Geotextile overflow port discharge		1.92	3500
2	40,000	Small CSD dredging marina basin	9 hrs/d, 7 days a week, 6 weeks	0.15	205
		Geotextile overflow port discharge		1.92	2600
3	185,000	Medium CSD dredging marina basin and approach channel	10 hrs, 7 days a week, 6 weeks	0.4	830
		Decant overflow from reclamation		0.004	6

(e) Suspended Sediment Plume Impact Assessment

To assess the likely magnitude and extent of suspended sediment plumes generated during construction of the marine facility, the hydrodynamic model was coupled with a suspended sediment transport model. The suspended sediment transport model enables the simulation of suspended sediment sources and their transport, deposition and erosion under the action of currents and/or waves.

Suspended sediment plume impacts during construction have been assessed separately for each construction stage. Time series results of the suspended sediment plume simulations have been summarised at the five key locations displayed in **Figure 3.93**. Spatial plots of the 10 percentile exceedance TSS results are also provided from the modelling results for each construction stage.

Figure 3.93 TSS KEY REPORTING LOCATION



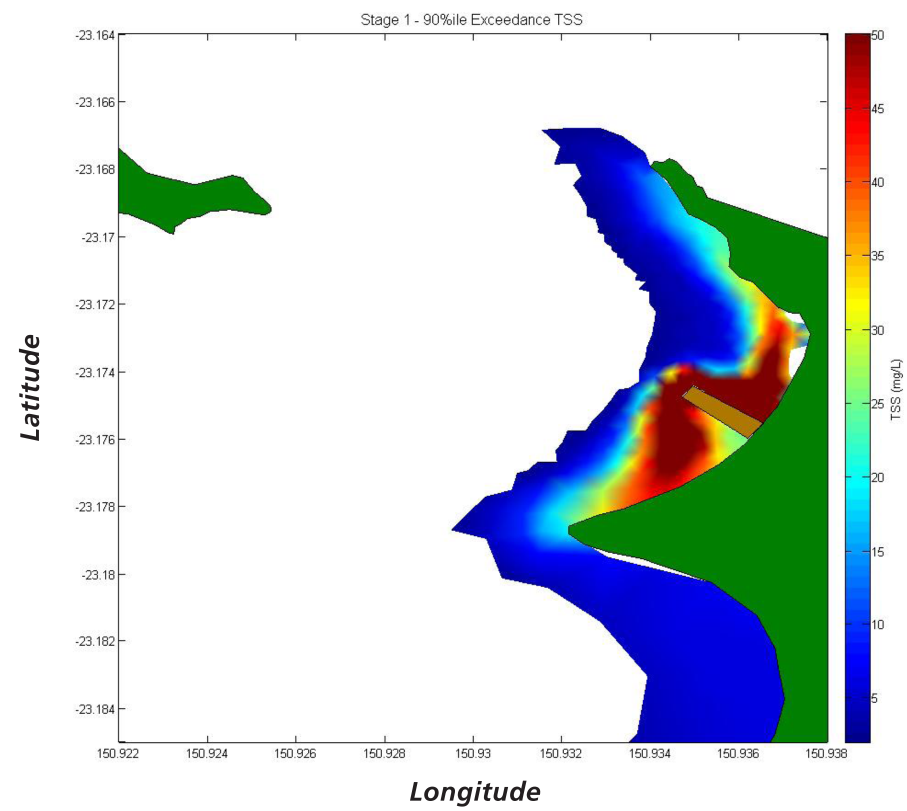
Source: 'COASTAL ENVIRONMENT TECHNICAL REPORT' (2011) WATER TECHNOLOGY

(e) (i) *Stage 1*

Stage 1 has been represented by a partially constructed western breakwater. The hydrodynamic model has been simulated over the eight week construction period with the suspended sediment generation rates and loads summarised in **Figure 3.94**. The impacts from the analysis of the dredge plume simulations for Stage 1 construction are considered as follows (Refer also **Figure 3.95**):

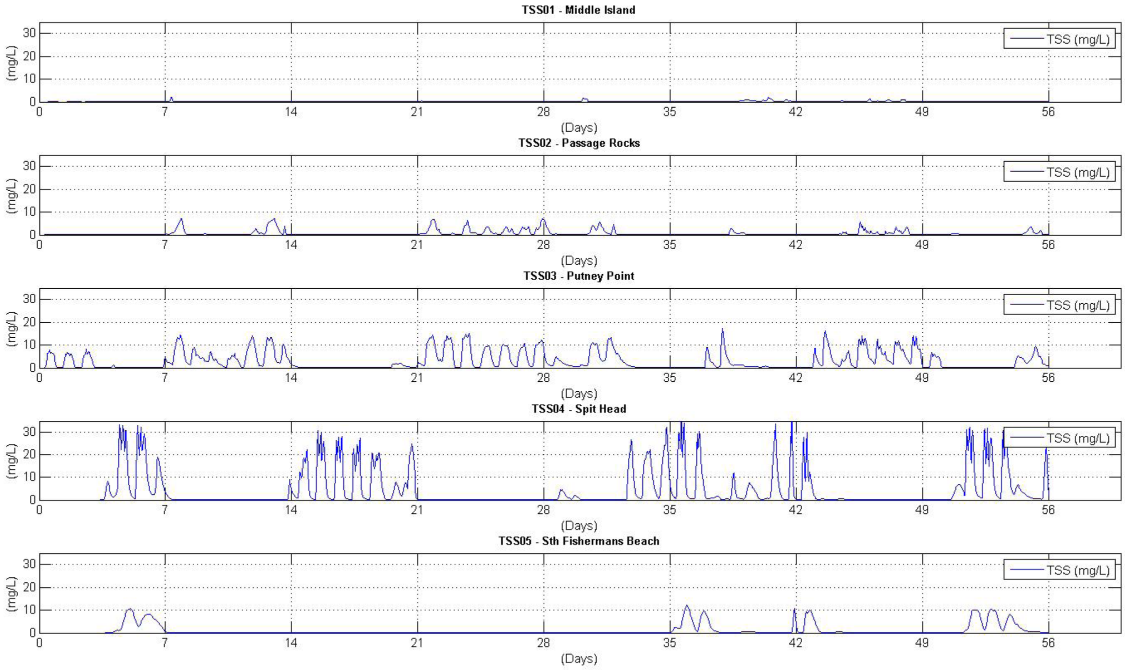
- median TSS above five milligrams per litre will be restricted to the immediate dredging and geotextile filling area. Median TSS less than five milligrams per litre may occur within a relatively localised area around the dredging and construction operations;
- sediment plumes with concentration above 30 milligrams per litre may briefly extend to Spithead to the south and Putney Point to the north as tidal currents sweep along Putney Beach;
- all other TSS reporting locations are predicted to experience only infrequent increases in TSS of less than 10 milligrams per litre; and
- localised suspended sediment deposition of up to 0.1 metre is predicted adjacent to the western breakwater and within the marina basin as is the western breakwater is being constructed.

Figure 3.94 STAGE 1- 90 PERCENTILE EXCEEDANCE TSS



Source: 'COASTAL ENVIRONMENT TECHNICAL REPORT' (2011) WATER TECHNOLOGY

Figure 3.95 STAGE 1 – TSS TIMESERIES AT KEY REPORTING LOCATIONS



Source: 'COASTAL ENVIRONMENT TECHNICAL REPORT' (2011) WATER TECHNOLOGY

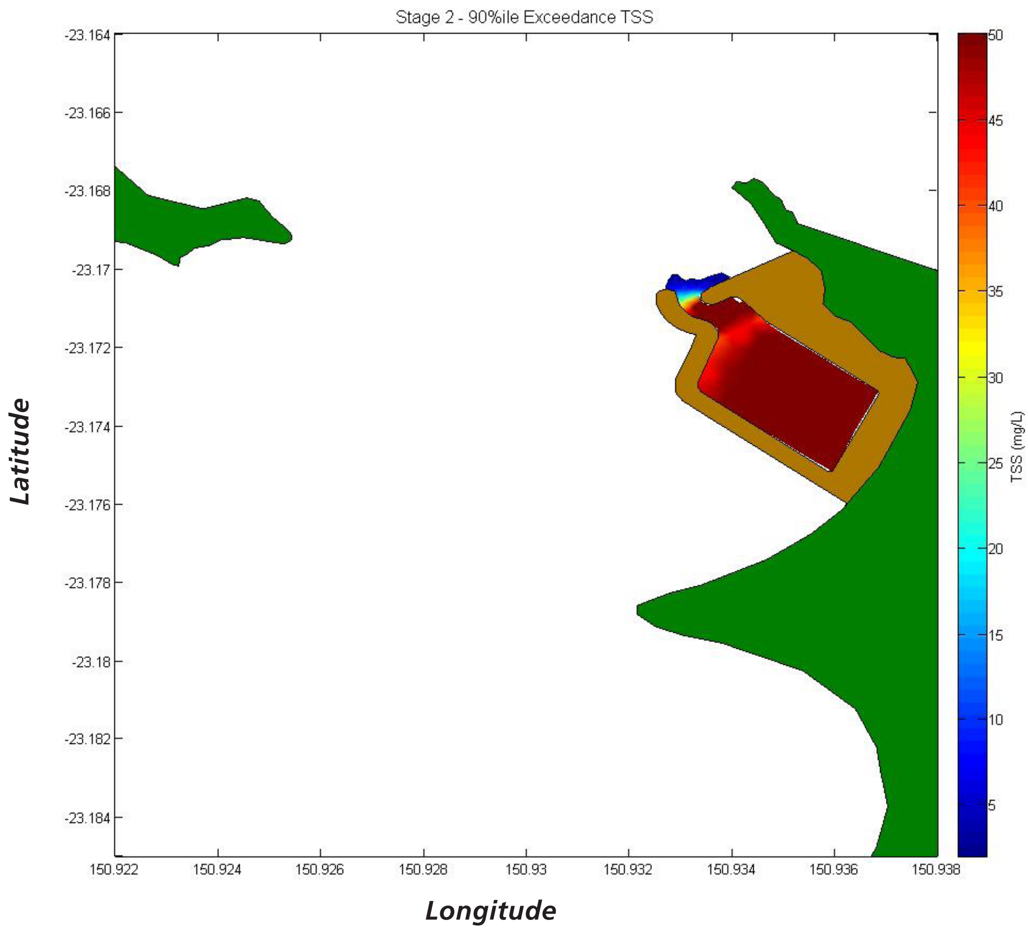
(e) (ii) *Stage 2*

Following the construction of the western breakwater, Stage 2 involves the construction of the marina basin revetments. The hydrodynamic model has been simulated over the six week Stage 2 construction period with the suspended sediment generation rates and loads summarised in **Figure 3.96**.

The impacts from the analysis of the dredge plume simulations for Stage 2 construction are considered as follows:

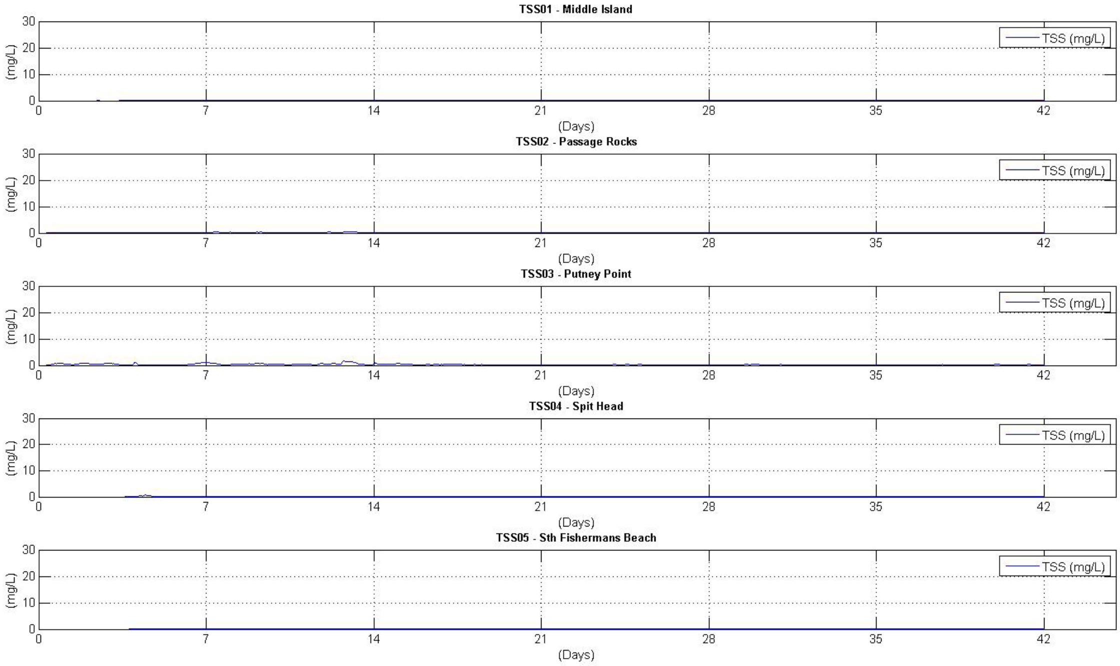
- suspended sediment plumes are predicted to be largely contained within the marina basin;
- sediment plumes outside of the dredging area will be minimal with concentrations less than five milligrams per litre modelled at Putney Point (TSS03); and
- suspended sediment deposition is predicted to be essentially confined to within the marina basin.

Figure 3.96 STAGE 2- 90 PERCENTILE EXCEEDANCE TSS



Source: 'COASTAL ENVIRONMENT TECHNICAL REPORT' (2011) WATER TECHNOLOGY

Figure 3.97 STAGE 2 – TSS TIMESERIES AT KEY REPORTING LOCATIONS



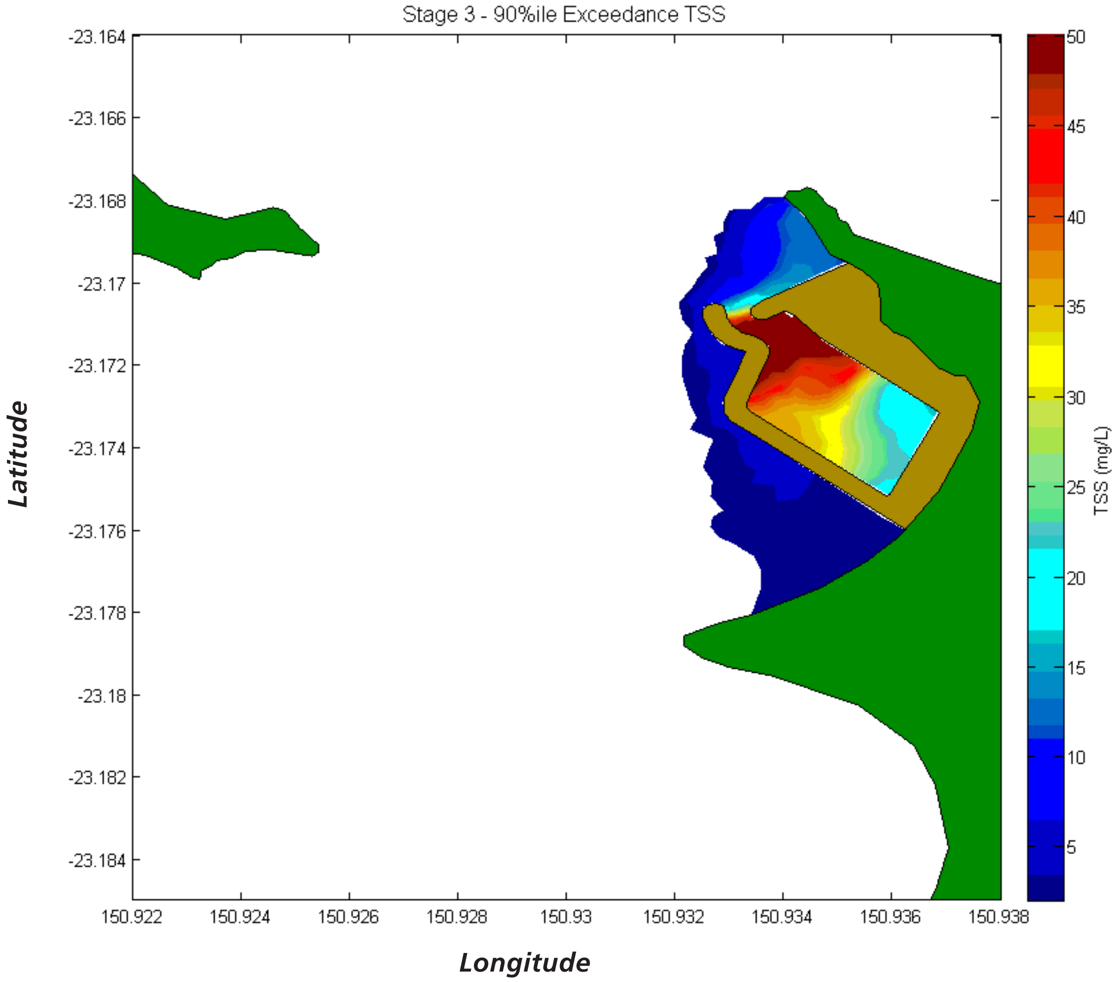
Source: 'COASTAL ENVIRONMENT TECHNICAL REPORT' (2011) WATER TECHNOLOGY

(e) (iii) *Stage 3*

Stage 3 involves dredging of the remainder of the marina basin and approach channel and reclamation. The hydrodynamic model has been simulated over the six week Stage 3 construction period (**Appendix Y**). The impacts from the analysis of the dredge plume simulations for Stage 3 construction are considered as follows:

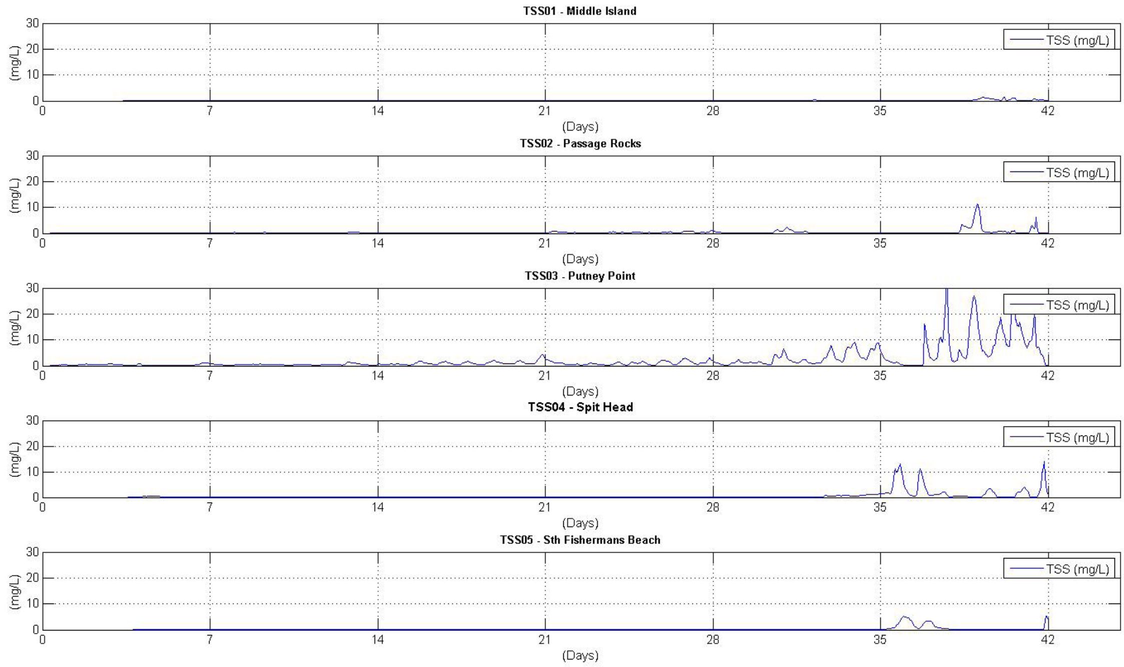
- suspended sediment plumes are predicted to be largely contained within the marina basin with the exception of the final stages of the approach channel dredging outside the marina breakwater;
- elevated levels of suspended sediment are predicted to occur during the dredging of the approach channel with levels up to 30 milligrams per litre briefly occurring at Putney Point (TS003); and
- suspended sediment deposition is predicted to be essentially confined to the marina basin and in the vicinity of the decant overflow from the reclamation.

Figure 3.98 STAGE 3 – 90 PERCENTILE EXCEEDANCE TSS



Source: 'COASTAL ENVIRONMENT TECHNICAL REPORT' (2011) WATER TECHNOLOGY

Figure 3.99 STAGE 3 – TSS TIMESERIES AT KEY REPORTING LOCATIONS



Source: 'COASTAL ENVIRONMENT TECHNICAL REPORT' (2011) WATER TECHNOLOGY

(e) (iv) *Mitigation Measures*

The proposed construction and dredge methodology are considered to constitute significant mitigation measures in their own right, as they have been specifically designed to limit the magnitude and extent of the turbid plumes generated during construction of the marina. The following key features of the construction and dredge methodology are considered to significantly mitigate the potential magnitude and extent of the turbid plumes generated during construction:

- the use of small to medium CSD will limit the amount of suspended sediment generation during excavation in relation to other dredge plant options;
- the use of the dredge material to fill geotextile bags to provide the core of the breakwater and marina revetments will prevent the need for ocean disposal of the material and assist in filtering and settling out a significant amount of the fines that would have otherwise gone into suspension during sea disposal of the material; and
- construction of the western breakwater in Stage 1 will assist in eliminating the majority of the current and wave action from the marine facility basin and significantly assist to contain the extent of the turbid plumes generated during construction to within the marine facility footprint.

The following additional measures are proposed to be developed to mitigate the impact of the dredge plumes predicted to occur during construction:

- investigation into the potential application of silt screens at the entrance to the marina, following the construction of the western breakwater in Stage 1 will be undertaken. The presence of silt screens across the entrance will potentially further reduce the extent that the turbid plumes may impact areas outside the marina basin;
- the reclamation area will be designed with multiple cells to maximise the length of time over which fine sediments may settle out of suspension before the decant flows back to the marina basin; and
- a Dredge Management Plan will be developed incorporating real time turbidity monitoring at key locations and trigger levels for instigating mitigation measures, including reducing the rate, or even cessation of dredging.

(f) Wet Weather Wastewater Outfall

An assessment of the potential impact of discharges via the wet weather wastewater outfall on the water quality of the receiving environment has been undertaken.

As discussed in **Section 3.5.3.2** Surface Water, the vast majority of the wastewater from the development is to be reused on the Island. The wastewater is to be treated to be equivalent to Class A+ standards and will comply with the nutrient levels specified by GBRMPA (Opus Pty Ltd, 2011).

A 37 to 44 megalitres wet weather storage facility is to be constructed to store treated effluent during periods of wet weather. It is anticipated that the capacity of this storage facility may be exceeded during extreme wet weather events and that, under these circumstances, discharge via the ocean outfall will be required. Modelling using the last 53 years of rainfall data indicates that the wet weather storage would have reached capacity and discharge via ocean outfall would have occurred on approximately five to six occasions (each event may have been one or more consecutive days) (Opus, 2011).

The worst case discharge scenario has been assessed corresponding to three consecutive wet weather days resulting in a total discharge via the outfall of 5.1 megalitres at a rate of 23.6 litres per second for 20 hours per day. The wastewater discharges would contain approximately 20 milligrams per litre Total Nitrogen and seven milligrams per litre Total Phosphorus.

(f) (i) *Initial Dilution*

The wastewater outfall diffuser is proposed to be located at a mean water depth of approximately 11.0 metres. This would provide a minimum water depth above the diffuser at LAT of 8.6 metres. Wastewater discharges from the outfall would exit the outfall via a tee shaped diffuser comprising two ports approximately 75 millimetres in diameter. This would result in port exit velocities of approximately 2.7 metres per second at a discharge rate of 23.6 litres per second. High port exit velocities will increase the initial dilution of the wastewater discharges.

The application of empirically derived relationships (e.g., Cederwall, 1966, or Fan and Brooks, 1969) for the dilution of buoyant plumes under quiescent current conditions from this diffuser port configuration has provided estimated minimum dilutions by the time the buoyant plume reaches the surface of in excess of 70:1 and 100:1 at mean low water and mean high water, respectively. This would correspond to Total Nitrogen and Total Phosphorus concentrations of 0.20-0.28 milligrams per litre and 0.07-0.10 milligrams per litre respectively at the surface.

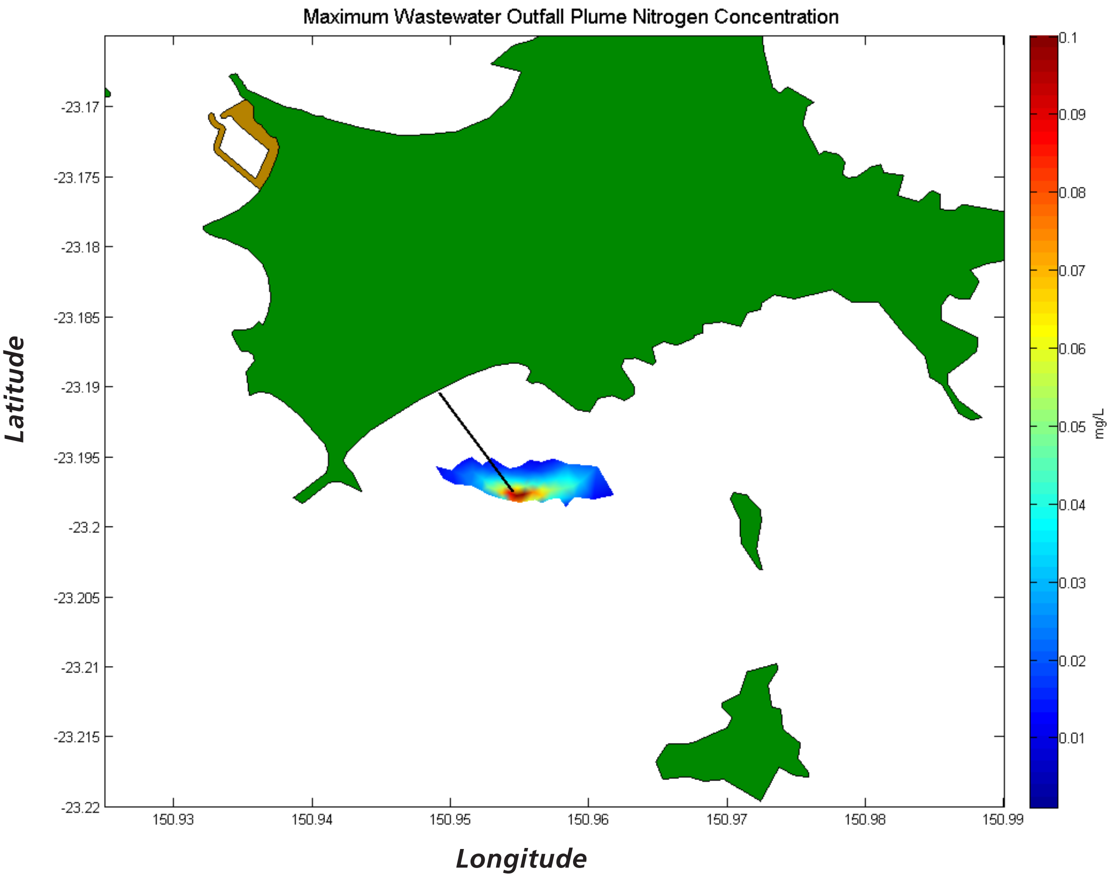
The assumption of quiescent conditions is considered to be conservative, as current action is relatively strong and slack water conditions only occur briefly at the top and bottom of the tide at the outfall location. Mixing of the wastewater discharges would significantly increase in the presence of cross currents and an initial dilution well in excess of 100:1 would be expected on average.

(f) (ii) *Far Field Mixing*

Far field modelling of the wastewater outfall discharges has been undertaken in the hydrodynamic model. The modelling has adopted low dispersion coefficients to provide a conservative (worst case) wastewater constituent concentrations around the outfall. Turbulent dispersion associated with wind induced overturning and wave mixing has not been included and would result in wastewater constituent concentrations below those identified in the modelling.

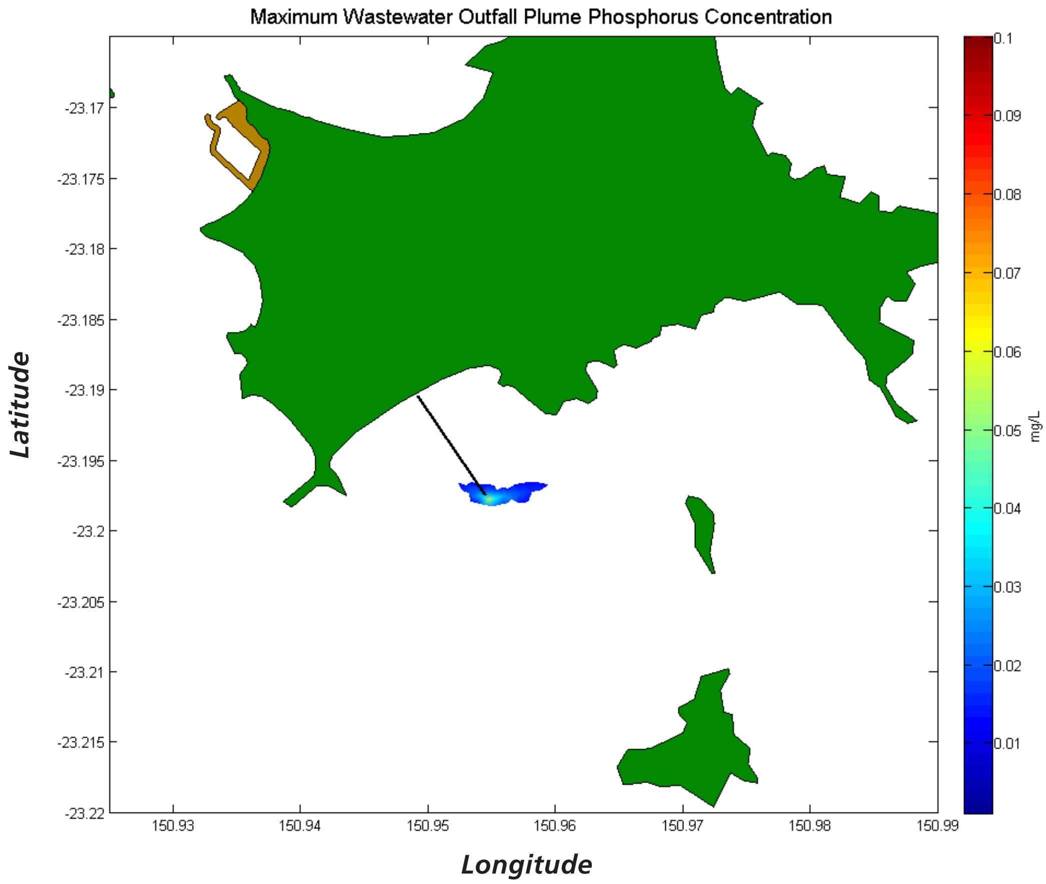
A conservative numerical tracer has been used to assess the advection and dispersion characteristics of the wastewater discharges from the outfall. The numerical tracer has been applied to the model at the location of the wastewater outfall at a constant concentration of 1,000 units per cubic metre and rate of 23.6 litres per second for 20 hours over a total of three days. The hydrodynamic model has been simulated over a representative period of tide and wind driven current conditions over this period. The advection and dispersion of the initial tracer concentration from the outfall has been used to calculate the relative concentrations of Total Nitrogen and Total Phosphorus in the receiving environment around the outfall. **Figure 3.100** and **Figure 3.101** display the predicted maximum instantaneous Total Nitrogen and Total Phosphorus concentrations respectively above background over the worst case three day wet weather outfall scenario.

Figure 3.100 PREDICTED MAXIMUM TOTAL NITROGEN CONCENTRATIONS FROM WASTEWATER OUTFALL



Source: 'COASTAL ENVIRONMENT TECHNICAL REPORT' (2011) WATER TECHNOLOGY

Figure 3.101 PREDICTED MAXIMUM TOTAL PHOSPHORUS CONCENTRATIONS FROM WASTEWATER OUTFALL



SOURCE: 'COASTAL ENVIRONMENT TECHNICAL REPORT' (2011) WATER TECHNOLOGY

3.6.6 Risk Evaluation

A risk assessment of potential environmental impacts associated with coastal process aspects of the GKI Revitalisation Plan has been undertaken and is described in the following section, along with proposed mitigation measures to address each identified risk. A standard risk assessment matrix as presented in **Table 3.1** has been used for the purpose of assessing risks associated with coastal processes.

A summary of potential coastal processes impacts and mitigation strategies for the Project are provided in **Table 3.80**.

TABLE 3.80 COASTAL PROCESSES RISK ASSESSMENT

Coastal Process Description	Potential Impacts	Mitigation Measures	Risk Level (unmitigated)	Risk Level (mitigated)
Tidal Flows and Hydrodynamics	• Minor changes to ebb and flood tide currently around the marina, along Putney Beach and between Putney Point and Passage Rocks. • A negligible impact on water levels and tidal phase is predicted.	• The tidal flow and hydrodynamic impacts are considered negligible.	**(1,3) Low**	**(1,3) Low**
Tidal and Wind Driven Current Sediment Transport Potential	• Net sediment transport rates around the western edge of Putney Point are predicted to decrease. • Rate at which sediment is mobilised and transported away from the spit head will be reduced. • Small increase in sand transport potentials at the seaward edge of the western breakwater. • Flood tide velocities across the sandy shoal to the south west of Passage Rocks is predicted to increase the rate of southward sediment transport in this area.	• Maintenance dredging of the entrance channel expected to be required every five years on average.	**(3,3) Medium**	**(2,2) Low**
Putney and Fisherman's Beach Coastal Processes	• The gross longshore sediment transport potential is likely to reduce from approximately 1,200m³/yr to 600m³/yr • The net longshore sediment transport potential is likely to be reduced to close to zero and potentially result in a small reversal towards the north.	• The periodic bypassing of sand from Putney Point to Putney Beach will be required to maintain the long-term sediment continuity along Putney Beach.	**(3,3) Medium**	**(2,2) Low**
Siltation	• The potential extent of the area of fine silt deposition is largely confined to within the marina basin. • A small area immediately adjacent to the breakwater on Putney Beach is predicted to experience bed shear stresses low enough to allow fine silt deposition. Wave action on Putney Beach is expected to be significant enough at times to resuspend fine silts in this area such that long-term accretion of fine silts is not expected. • Flood flows from Putney Creek may transport sediment into the marina.	• The rate of siltation is in general expected to be very low. • A sediment trap will be constructed to prevent sediment from Putney Creek being transported into the marina basin during flood flows.	**(3,3) Medium**	**(2,2) Low**

TABLE 3.80 COASTAL PROCESSES RISK ASSESSMENT (CONTINUED)

Coastal Process Description	Potential Impacts	Mitigation Measures	Risk Level (unmitigated)	Risk Level (mitigated)
Marine Wave Climate	• All berth locations in the marina are predicted to experience a 'good' to 'excellent' wave climate under worst case design wave conditions.	• No additional mitigation measures are considered necessary.	**(2,2) Low**	**(2,2) Low**
Climate Change – Shoreline Recession	• At Putney and Fisherman's Beach approximately 40 – 80 metres of shoreline recession could be observed, resulting in a loss of beach amenity and beach access.	• Infrastructure will be located a sufficient buffer distance from existing shorelines.	**(3,3) Medium**	**(2,2) Low**
Climate Change - Increase in Storm Tide Elevations	• Increased overtopping of the breakwaters resulting in increased wave action within the marina, resulting in damage to berthed vessels under design storm conditions.	• Increasing/adapting breakwater crest heights to limit the extent of wave overtopping under design water level and wave conditions to 2100. • Increasing the primary armour unit weights during detailed design to limit the potential for structural damage to occur to the breakwaters under design water level and wave conditions to 2100.	**(3,3) Medium**	**(2,2) Low**
Climate Change – Coastal Inundation	• Inundation to marina infrastructure and reclamation would include water damage costs and inconvenience.	• Constructing finished surface levels and floor levels above the relevant design storm tide inundation levels to 2100	**(3,3) Medium**	**(2,2) Low**
Marine Water Quality – Marine Residence Times	• Practical measures of residence times are likely to be no greater than 1 – 2 days for all locations within the marina basin.	• No additional mitigation measures are considered necessary.	**(1,1) Low**	**(1,1) Low**
Marine Water Quality – Antifouling	• Copper concentrations from antifouling leachate are predicted to slightly exceed relevant guidelines within the marina basin.	• There is not considered any practical mitigation measures available for this impact.	**(3,3) Medium**	**(3,3) Medium**

TABLE 3.80 COASTAL PROCESSES RISK ASSESSMENT (CONTINUED)

Coastal Process Description	Potential Impacts	Mitigation Measures	Risk Level (unmitigated)	Risk Level (mitigated)
Sediment Quality and Dredging –Stage 1 Suspended Sediment Plume	***Stage 1 -*** Localised suspended sediment deposition of up to 0.1 metres is predicted adjacent to the western breakwater, within the marina basin, as it is being constructed.	• The use of small to medium CSD will limit the amount of suspended sediment generation during excavation. • The use of the dredge material to fill geotextile bags to provide the core of the breakwater and marina revetments will prevent the need for ocean disposal of the material and assist in filtering and settling out a significant amount of the fines that would have otherwise gone into suspension during sea disposal of the material. • A Dredge Management Plan will be developed incorporating real time turbidity monitoring at key locations and trigger levels for cessation of dredging.	**(3,3) Medium**	**(2,2) Low**
Sediment Quality and Dredging –Stage 2 Suspended Sediment Plume	***Stage 2 -*** Suspended sediment plumes are predicted to be largely contained within the marina basin. • Putney Point will be occasionally exposed to brief periods of elevated TSS of up to approximately 30mg/L on ebb tides. • The Spit Head is predicted to experience occasional spikes in TSS of less than 10mg/L. • Suspended sediment deposition is predicted to be essentially confined to the marina basin.	• Construction of the western breakwater in Stage 1 will significantly assist to contain the extent of the turbid plumes generated within the marine facility. • Investigation into the potential application of silt screens at the entrance to the marina, following Stage 1 will be undertaken. • A Dredge Management Plan will be developed incorporating real time turbidity monitoring at key locations and trigger levels for cessation of dredging.	**(3,3) Medium**	**(2,2)Low**

TABLE 3.80 COASTAL PROCESSES RISK ASSESSMENT (CONTINUED)

Coastal Process Description	Potential Impacts	Mitigation Measures	Risk Level (unmitigated)	Risk Level (mitigated)
Sediment Quality and Dredging –Stage 3 Suspended Sediment Plume	***Stage 3 -*** Suspended sediment plumes are predicted to be largely contained within the marina basin. • Putney Point will be occasionally exposed to brief periods of elevated TSS of less than approximately 10mg/L, particularly while the approach channel dredging is occurring. • Suspended sediment deposition is predicted to be essentially confined to the marina basin and in the vicinity of the decant overflow from the reclamation.	• The reclamation area will be designed with multiple cells to maximise the length of time over which fine sediments may settle out of suspension before the decant flows back to the marina basin. • A Dredge Management Plan will be developed incorporating real time turbidity monitoring at key locations and trigger levels for cessation of dredging.	**(3,3) Medium**	**(2,2)Low**