Australia Pacific LNG Project
Supplemental information to the EIS

Marine Ecology

LNG Facility

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Executive Summary

This marine ecology report was prepared to support the Environmental Impact Statement (EIS) for the Australian Pacific LNG Project (the Project). An assessment of the potential impacts of the revised liquefied natural gas (LNG) facility layout, including associated facilities, on the western side of Curtis Island and examination of the potential impacts of the brine discharge and treated wastewater outfalls in Port Curtis have been undertaken.

Dredging has been proposed as part of construction of the associated facilities on the northwest side of Curtis Island and a supplementary assessment has been undertaken of this area, in addition to the dredge areas previously assessed as part of the Port of Gladstone Western Basin Dredging and Disposal Project (WBDDP) (GPC 2009).

Construction of the proposed offshore associated facilities (wharf, berth pocket, MOF) and associated dredge footprint on the south-western side of Curtis Island, immediately south of Laird Point, will have a direct impact where the construction / dredging causes a loss of existing habitat. The ocean outfall also has the potential for direct impacts on the marine environment in areas immediately adjacent to the outfall. Two habitat types have been identified as being affected by the proposed offshore construction activities and ocean outfall, namely seagrass meadows and intertidal mangroves present within the subtidal and intertidal habitats in The Narrows.

The proposed associated facilities will require direct removal of around 12.07 ha of seagrass adjacent to the south-western shore of Curtis Island (not including seagrass directly removed through the WBDDP), which represents around 0.3% of the 4000 ha or so, of seagrass previously documented throughout Port Curtis. It is expected this will have a proportionally small flow-on impact to related secondary productivity in the disturbed area for associated benthic flora and fauna, including invertebrates, fish and mammals. However, the availability of similar seagrass habitats in adjacent areas not subject to dredging, will limit the extent of project impacts to seagrass-related communities. These adjacent areas should therefore be managed and maintained during construction and operational activities.

In addition to the loss of seagrass habitat, the area to be dredged (approximately 1.5 Mm^3) is covered by mostly fine, muddy substrates, which characteristically have a low abundance and species diversity of benthic assemblages, compared with coarser sandy substrate areas. Dredging of non-vegetated, muddy substrate areas will likely have limited impacts to benthic marine communities compared with those that might result from dredging of other, coarser substrate areas.

Dredging activities will also resuspend sediments, which will increase turbidity and can result in indirect impacts to benthic primary producers over a broader area, such as seagrass beds, through increased light attenuation and possible smothering. In order to minimise the potential for indirect, turbidity-related impacts to local seagrass beds where practical, dredging activities will be conducted during cooler months, when seagrass meadows are less productive, and over short durations (less than three weeks) in areas adjacent to vulnerable seagrass habitat, to limit detrimental impacts from increased light attenuation.

Available information on naturally occurring turbidity levels within Port Curtis, combined with modelling results for likely turbidity characteristics and distribution from proposed dredging activities, indicates the potential for light-related impacts to marine communities in the immediate vicinity of the area to be dredged (surrounding the APLNG Dock, from dredging of Construction Docks and the MOF

Construction Access areas). However, beyond this immediate zone of expected turbidity-related impact, modelled turbidity levels indicate rapid amelioration to levels comparable with the Queensland Water Quality Guideline TSS trigger values and background TSS concentrations. This indicates a limited likelihood of appreciable impacts from increased turbidity over a broader area.

The potential for settlement of suspended material to smother seagrass beds adjacent to APLNG dredging activities will likely be limited to a reasonably small area surrounding the APLNG Dock, adjacent to the western shore of Curtis Island. In isolation this represents a potentially small indirect impact to local seagrass communities. In the event that APLNG dredging is conducted at the same time as the proposed GPC WBDDP, without appropriate mitigation, likely indirect impacts to local seagrass communities are expected to be more severe and extend over a much broader area, including the western reaches of Point Curtis.

During operation of the desalination plant there are unlikely to be any appreciable impacts on the receiving environment, beyond the mixing zone (1:50 dilution achieved at 12.8 m or less), from discharges of residual oxidants, or any other residual contaminants present in the discharged brine waste stream. Furthermore, based on the assessment of treated wastewater streams there are also unlikely to be any acute impacts on the receiving environment from residual oils, chlorine and nutrients beyond the near field mixing zone (beyond 50 m from the diffuser discharge).

To avoid chronic effects beyond the edge of the mixing zone from the residual oil present in the treated wastewater / brine composite, the residual oil shall be treated prior to discharge into the receiving environment, using a dissolved air floatation unit and a tertiary filter and the wastewater tested prior to discharge. To reduce uncertainty regarding actual, as opposed to predicted, risks to the marine environment from proposed marine discharges, WET testing will be undertaken during pre-commissioning, post-commissioning and then annually during operational activities.

Ameliorative measures, such as collecting waste material from screens and reverse osmosis filters will be adopted, and re-directed to landfill, wherever possible, to reduce suspended solids concentrations in the brine stream. A baseline water quality monitoring program prior to plant commissioning will be implemented, to develop an understanding of site specific water quality conditions and an operational water quality monitoring program will be implemented post-commissioning, to manage future potential water quality and ecological impacts.

Contents

1. Introduction 1
2. Project Description 3
2.1 LNG Facility – Associated Facilities 3
2.2 Desalination Plant Brine Discharge 3
2.2.1 Treated Wastewater Discharges 6
3. Existing Conditions 8
3.1 Water Quality 8
3.1.1 Water Quality Objectives 9
3.1.2 Existing Conditions 10
3.1.3 Port Curtis Integrated Monitoring Program 11
3.2 Marine Flora and Fauna 17
3.2.1 Seagrass 17
3.2.2 Mangrove and Saltmarsh 17
3.2.3 Rocky Intertidal 18
3.2.4 Subtidal 18
3.2.5 Plankton 19
3.2.6 Fish and Invertebrate Communities 19
3.2.7 Commercial and Recreational Fishing 20
3.2.8 Invasive Marine Pest Species 23
3.2.9 EPBC Listed Species 24
4. Assessment of Impacts 25
4.1 Direct Impacts 25
4.1.1 Dredging and Construction of the MOF 25
4.1.2 Pest Species 29
4.2 Indirect Impacts 29
4.2.1 Water Quality Impacts from Dredging and Construction Activities 29
4.2.2 Impacts to the local fisheries 46
4.3 Desalination Plant Ocean Outfall 47
4.3.1 Salinity 49
4.3.2 BOD 50

4.3.3 Suspended solids 50
4.3.4 Sodium hypochlorite 50
4.3.5 Polyelectrolytes (Polymers) 51
4.3.6 Sodium bisulphite 51
4.3.7 Sulphuric acid 52
4.3.8 Anti-scalant (phosphinocarboxylic acid) 52
4.3.9 Citric acid 52
4.3.10 Summary of impacts 52
4.4 Impact Assessment – Treated Wastewater Discharges 53
4.4.1 Treated Process and Contaminated Stormwater 53
4.4.2 Treated Sewage 54
4.4.3 Summary of Impacts 55
5. Conclusions 56
6. References 60

Figures

Figure 1-1 Location of the proposed dredge areas for the offshore associated facilities (including GPC WBDDP proposed dredge area). 2

Figure 3-1 Map of the 30 minute grids for recording commercial fishing catch and effort in the Port Curtis region. Grid S30 contains the proposed development location 22

Figure 3-2 The annual catch weight and value of the commercial net and crab fishing catch between 1988 and 2005 in Queensland commercial fishing grid S30 22

Figure 4-1 Seagrass areas impacted by the proposed dredging of the APLNG associated facilities and the WBDDP 28

Figure 4-2 Construction Docks dredge - statistical maximum TSS concentration above background (referenced from WorleyParsons Coastal Environment Supplementary Report, LNG Facility 2010). 31

Figure 4-3 Construction Docks dredge - statistical mean TSS concentration above background (referenced from WorleyParsons Coastal Environment Supplementary Report, LNG Facility 2010). 31

Figure 4-4 Construction Docks dredge - TSS concentration time-series (a) Graham Ck N and (b) Graham Ck S 34

Figure 4-5 Construction Docks dredge - TSS concentration time-series (a) APLNG Dock and (b) Main Channel 35

Figure 4-6 Construction Docks dredge - TSS concentration time-series (a) Tidal Flats and (b) The Narrows 36

Figure 4-7 Embarkation Dock TSS concentration time-series (a) Embarkation Dock and (b) Tidal Flats 37

Figure 4-8 Construction Docks dredge plume snapshot. 39

Figure 4-9 Construction Docks with GPC dredging plume snapshot. 40

Figure 4-10 Construction Docks with GPC dredge - statistical maximum TSS concentration above background. 41

Figure 4-11 Construction Docks with GPC dredge - statistical mean TSS concentration above background. 41

Figure 4-12 Construction Docks with GPC dredge TSS concentration time-series (a) Tidal Flats and (b) The Narrows 43

Figure 4-13 Construction Docks with GPC dredge TSS concentration time-series (a) APLNG Dock and (b) Main Channel 44

Figure 4-14 Construction Docks with GPC dredge TSS concentration time-series (a) Graham Ck N (b) Graham Ck S 45

Figure 4-15 Comparison Site: Dilution Curves for a Range of Flow Rates at Low Water Slack (referenced from WorleyParsons Coastal Environment Supplementary Report, LNG Facility 2010).54

Tables

Table 2-1 Likely end-of-pipe concentrations of brine stream constituents from the proposed Australia Pacific LNG desalination plant at Port Curtis. 4

Table 2-2 Chemical additives frequently used in the RO desalination process. 5

Table 2-3 Likely concentrations of RO discharge components at end-of-pipe and following a dilution of 1:50. 6

Table 2-4 Likely end-of-pipe concentrations of treated process contaminated stormwater from the proposed Australia Pacific LNG facility. 7

Table 2-5 Likely end-of-pipe concentrations of treated sewage from the proposed Australia Pacific LNG facility. 7

Table 3-1 Water Quality Objectives 9

Table 3-2 Physico-chemical WQ Parameters (EPA data 1996-2006). 10

Table 3-3 Concentrations of trace metals in Port Curtis and nearby marine waters (Apte *et al.* 2005).11

Table 3-4 Ecosystem Health guidelines (EH) and Worst Case Scenario (WCS) trigger values for Port Curtis 13

Table 3-5 Ecosystem Health Rating Grades. 14

Table 3-6 Water quality standardised scores and average Ecological Health grades for each zone in Port Curtis. 16

Table 4-1 Current and historical areas of seagrass impacted by dredging associated with the LNG facility on Curtis Island..... 27

Table 4-2 Time Series recording locations..... 33

Table 4-3 Ecotoxicology literature review for chemical additives identified in the desalination plant waste stream. 48

1. Introduction

This marine ecology report has been provided to support the Environmental Impact Statement (EIS) for the Australian Pacific LNG Project (the Project) (APLNG 2009). An assessment of the potential impacts of the revised liquefied natural gas (LNG) facility layout, including associated facilities, on the western side of Curtis Island and examination of the potential impacts of the brine discharge and treated wastewater outfalls in Port Curtis have been undertaken.

Dredging has been proposed as part of construction of the associated facilities on the northwest side of Curtis Island. Figure 1-1 shows the location of proposed dredge areas in relation to these facilities and also the dredge area which is proposed for the Port of Gladstone Western Basin Dredging and Disposal Project (GPC WBDDP) (GPC 2009). Mitigation measures associated with managing dredging works however, are discussed within the GPC WBDDP EIS (GPC 2009).

A number of activities on Curtis Island associated with the LNG facility will generate wastewater, which will be treated and discharged into Port Curtis via outfalls (two outfalls are proposed - one for construction and one for operations). Water demand for the Australia Pacific LNG facility during operations is primarily driven by the continuous demand for demineralised water required for the Acid Gas Removal Unit (AGRU). Potable water during construction and operation is also required. This water will be supplied through the collection of stormwater, reuse onsite of treated effluents and the operation of a seawater desalination plant, which will use the reverse osmosis (RO) process with seawater sourced in Port Curtis, directly offshore of the LNG facility.

Desalination plants produce a hyper-saline brine (highly concentrated salty water) waste stream which will be discharged through an outfall offshore from Curtis Island. This waste stream contains seawater constituents at approximately double their normal concentrations. In addition to this, the brine waste stream contains small amounts of additives used for treatment and cleaning during the desalination process such as sodium hypochlorite, sodium bisulphite, sulphuric acid, citric acid and anti-scalant.

In addition to brine, treated wastewater from the LNG facility is proposed to be discharged into Port Curtis. Treated wastewater comprises treated stormwater (from process areas of the LNG facility) and treated sewage effluent. Treated wastewater may be mixed with brine prior to discharge into Port Curtis.

The assessment of the pipeline crossing of the intertidal wetlands on the mainland and crossing of The Narrows is addressed in a separate report.

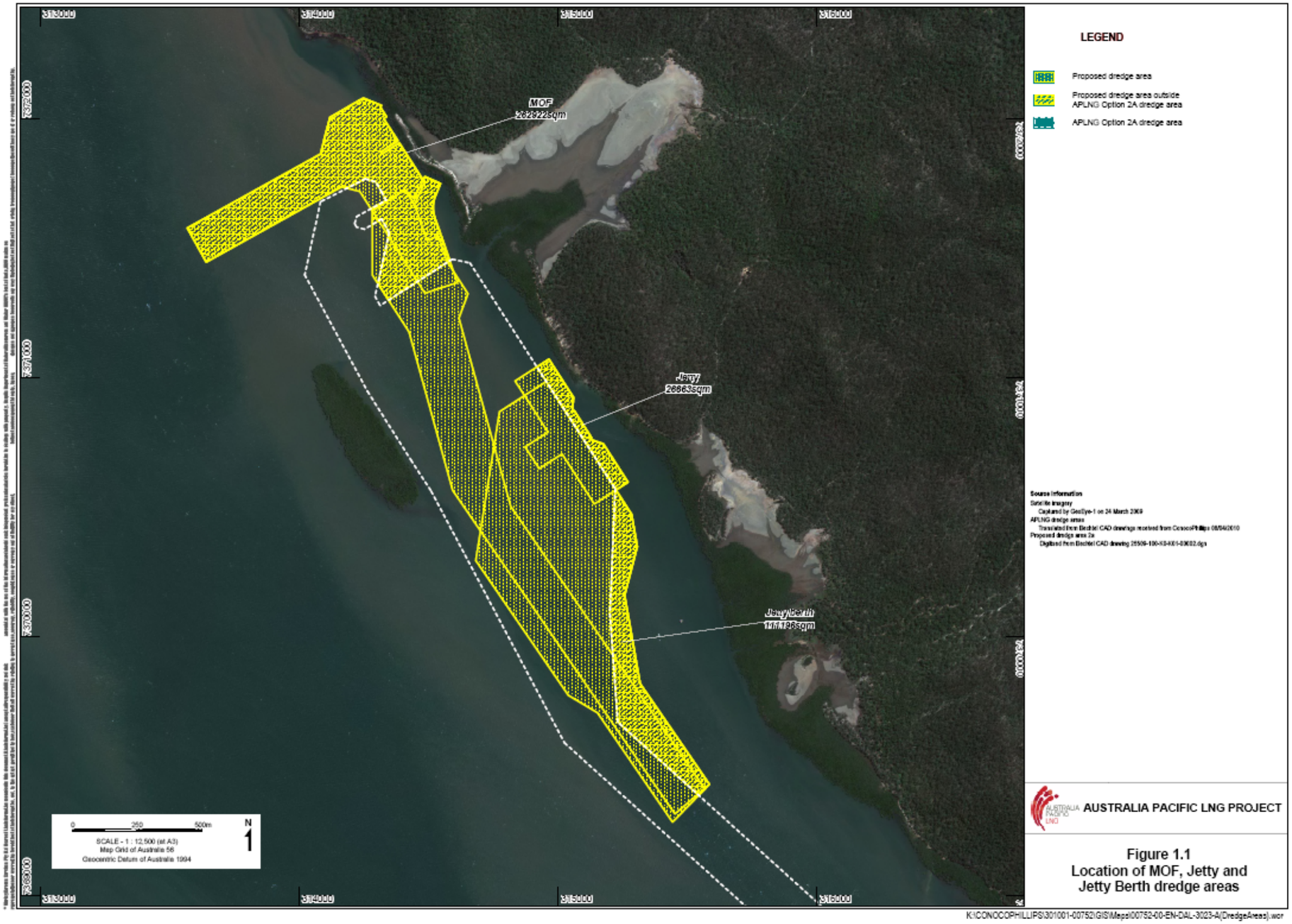

Figure 1-1 Location of the proposed dredge areas for the offshore associated facilities (including GPC WBDDP proposed dredge area).

2. Project Description

The layout of the LNG facility and associated facilities on the northwest end of Curtis Island has been reconfigured and is described below. Properties of the discharge effluent for the desalination plant and the wastewater treatment plant have been refined and the wastewater streams remodelled as described below.

2.1 LNG Facility – Associated Facilities

Associated facilities to support the LNG facility on Curtis Island will include a Materials Offloading Facility (MOF) (for the transfer of building materials, heavy equipment and people), loading berths (to transfer product to tankers for shipping to market) and temporary workforce accommodation facilities. The capital dredging (berth pockets, swing basins, channels and MOF) required for shipping access to the Curtis Island LNG facilities and the subsequent management of dredged material will be provided under the approvals sought by the Gladstone Port Corporation as part of the GPC WBDDP.

Early dredging works are proposed at six locations, as follows:

- Dredge Area 1 – Embarkation Dock (28,200 m^3)
- Dredge Area 2 – Construction Docks (937,000 m^3)
- Dredge Area 3 – Materials Offloading Facility (MOF) Construction Access (493,000 m^3)
- Dredge Area 4 – MOF Channel (1,800,000 m^3)
- Dredge Area 5 – Jetty Construction Access (935,000 m^3)
- Dredge Area 6 – Jetty Berth Dredging Limit (5,500,000 m^3)

Dredging at the first three locations is part of the scope of the APLNG EIS and is assessed in this report. The remaining locations are assessed as part of the GPC WBDDP EIS. The footprints of the proposed dredge areas for the APLNG EIS (see proposed dredge area outside APLNG Option 2A) and GPC WBDDP EIS (see APLNG Option 2A) are shown in Figure 1-1.

Dredge Area 1 is required to service the roll-on roll-off dock and passenger ferry dock at Fisherman's Landing Northern Expansion. Dredge Area 2 is required to construct and access the temporary rock dock, roll-on roll-off dock and construction ferry dock on Curtis Island.

2.2 Desalination Plant Brine Discharge

The freshwater used on site will be supplied through operation of a RO seawater desalination plant with seawater sourced directly offshore of the LNG facility. The desalination process creates a brine discharge which contains seawater constituents at roughly double their normal concentrations and small amounts of additives used for treatment and cleaning during the desalination process, typically sodium hypochlorite, sodium bisulphate, sulphuric acid, citric acid and anti-scalant.

The APLNG desalination plant will produce brine at a rate of up to 130 m^3/hr to be discharged into Port Curtis. The likely discharge concentrations of brine stream constituents are provided in Table 2-1.

Table 2-1 Likely end-of-pipe concentrations of brine stream constituents from the proposed Australia Pacific LNG desalination plant at Port Curtis.

Characteristic	Estimated discharge value
pH	6.0 – 8.0
TSS (mg/L)	20 – 30 (40 maximum)
Calcium (Ca) (mg/L)*	600 – 750
Magnesium (Mg) (mg/L)*	2,000 – 2,500
Potassium (K) (mg/L)*	600 – 750
Sodium (Na) (mg/L)*	19,000 – 22,000
Chloride (Cl) (mg/L)*	30,000 – 33,000
Flouride (F) (mg/L)	1.5 – 3
Sulfate (as SO_4) (mg/L)*	4,000 – 6,000
Strontium (Sr) (mg/L)*	15 – 25
Chlorine (Cl) (mg/L)	<1
Anti-scalant (mg/L)	8
Flocculent (mg/L)	5
Polymer (mg/L)	1
Silicon Dioxide (mg/L)	1 – 2
BOD_5 (mg/L)	5 – 10

* Natural irons present in seawater – refer to http://www.seafriends.org.nz/oceano/seawater.htm and http://www.answers.com/topic/ocean-water, as is chloride.

As a consequence of its characteristically high salinity compared with that of the receiving environment, the brine discharge tends to be negatively buoyant and will tend to sink to the seabed under calm conditions. The APLNG desalination plant will use a variety of chemicals for cleaning and fouling management, coagulation of solids from wastewater, potabilisation of the drinking water and for control of microbiological fouling of membranes. Some residuals of these chemicals, or chemical by-products derived from the chemicals used, will be discharged with the brine. A summary of likely chemical additives proposed for use in the APLNG desalination plant are shown in Table 2-2.

Seawater will be drawn into the desalination plant through an open intake to the intake pipeline and then to the seawater intake pump station. The intake system is normally subject to fouling by marine organisms which have the potential to restrict the intake flow rate. In order to control the level of fouling within the intake system, sodium hypochlorite solution will be intermittently dosed into the intake structure during desalination plant operation. The dosing period is usually in the order of 60 minutes which results in a residual chlorine concentration within the intake pipeline of between 4 and 10 mg/L. It is envisaged that this dosing operation will be performed at weekly intervals. The sodium hypochlorite will be neutralised by the addition of sodium bisulphite solution upstream of the reverse osmosis system. The chlorination and subsequent neutralisation processes will marginally increase the sodium, chloride and sulphate ions concentration in the seawater feed to the desalination plant. The process incorporates a very comprehensive control and monitoring system to ensure that no chlorine is present at the RO membranes.

The RO system requires continuous addition of an anti-scalant. The anti-scalant is likely to be either phosphonic or carboxylic-rich polymers.

Similarly, a polymer will also be used as a flocculation aid. For the APLNG desalination plant, it is expected that a polymer will be added to the wastewater clarifier. The polymer is likely to be a high molecular weight flocculant. Polymers are soluble in water and quickly and irreversibly bind to naturally occurring dissolved organic carbon and particulate material.

The polymer will be rejected by the RO membrane and will be discharged in the brine stream to the ocean. The RO membranes will require periodic chemical cleaning at a rate of about twice per year. The cleaning solution will likely be an alkaline detergent that typically contains 500 mg/L of sodium hydroxide and between 250 mg/L and 500 mg/L of detergent.

Lime, carbon dioxide, chlorine (gas) and fluorosilicic acid are traditionally used in the potabilisation process. None of these chemical additions however, are usually discharged with the brine. Considering the end of pipe concentrations highlighted in Table 2-3 presents the likely concentrations of RO discharge components present in the receiving environment, following a dilution of 1:50, at a distance of 12.8 m from the diffuser arrangement (WorleyParsons 2010).

Table 2-2 Chemical additives frequently used in the RO desalination process.

Stage	Additive	Process	Purpose	Treatment method
Intake	Sodium hypochlorite (4-10 mg/L)	Intermittent chlorination for shock dosing at the intake	Prevent marine growth in pipelines.	Total residual oxidant concentration [(1)] increased by 4-10 mg/L during intermittent shock chlorination periods at the intake; reduced to zero prior to discharge to ocean by the addition of sodium bisulphite.
Prior to Pre-treatment	Sodium bisulphite typically dosed at 200% of stoichiometric demand	Dechlorination	Remove chlorine prior to RO membranes	The bisulphite will chemically reduce the sodium hypochlorite. Excess bisulphite will remove some oxygen from the seawater.
Pre-treatment	Polymer (Polyelectrolyte Pre-treatment)	Pre-treatment of the RO feedwater	Removal of particulate matter	Polyelectrolytes are soluble in water and quickly and irreversibly bind to naturally occurring dissolved organic carbon and particulate material.
	Sulphuric acid and Citric acid	Chemical cleaning of RO membranes	To clean membranes and restore filtration performance	Sulphuric and citric acid are used to remove calcium carbonate and iron deposits from the RO membranes during periodic cleaning sequences.
Reverse Osmosis	Anti-scalant	Anti-scaling dosing of RO feed	Prevents formation of membrane scaling	Anti-scalant is added to the feedwater after pre-treatment and prior to entering the RO process.

[(1)] Total residual oxidant refers to Cl_2, HOCl, HOBr, hypochlorite ion (OCl^-) and hypobromite ion (OBr^-) in equilibrium.

Table 2-3 Likely concentrations of RO discharge components at end-of-pipe and following a dilution of 1:50.

Characteristic	Estimated End-Of-Pipe Discharge Values	Likely concentrations at 1:50 Dilution
pH	6.0 – 8.0	7.0 – 8.0
TSS (mg/L)	20 – 30	0.4 – 0.6
Calcium (Ca) (mg/L)*	600 – 750	12 – 15
Magnesium (Mg) (mg/L)*	2000 – 2500	40 – 50
Potassium (K) (mg/L)*	600 – 800	12 – 16
Sodium (Na) (mg/L)*	19000 – 22000	380 – 440
Chloride (Cl) (mg/L)*	30,000 – 33,000	600-660
Fluoride (F) (mg/L)	1.5 – 3	0.03 – 0.06
Sulfate (as SO_4) (mg/L)*	4000 – 6000	80 – 120
Strontium (Sr) (mg/L)*	15 – 25	0.3 – 0.5
Chlorine (Cl^-) (mg/L)	<1	0.02
Anti-scalant (mg/L)	8	0.16
Flocculent (mg/L)	5	0.1
Polymer (mg/L)	1	0.02
Silicon Dioxide (mg/L)	1 – 2	0.02 – 0.04
BOD_5 (mg/L)	5 – 10	N.D [(2)]

* Natural irons present in seawater – refer to http://www.seafriends.org.nz/oceano/seawater.htm and http://www.answers.com/topic/ocean-water,

[(1)] Actual discharge concentrations are dependent on the relative dilution of treated wastewater with brine.

[(2)] N.D. No data

2.2.1 Treated Wastewater Discharges

In addition to the brine discharge, treated wastewater may be discharged into Port Curtis via the offshore outfalls (one used for construction and one for operations):

- Sewage produced from the various buildings will be transported by gravity through underground lines to sanitary sumps before being pumped into the sewage treatment plant. The sewage will be treated in an extended aeration type activated sludge plant. Treated wastewater will be further processed in tertiary filters and stored before being pumped to the irrigation system, or alternatively may be mixed with brine and discharged to Port Curtis
- Low to moderate volumes of process wastewater and contaminated stormwater runoff from the plant process areas will be routed for treatment to the CPI separator via a process area spill containment sump and various stormwater lift stations. CPI effluent will be further treated in a dissolved air floatation unit and a tertiary filter and then routed to the irrigation system, or alternatively may be mixed with brine and discharged to Port Curtis

Treated wastewater discharges to the marine environment have been modelled in complement with the brine discharge, and so the impact assessment undertaken for the residual contaminants present in the treated wastewater discharges is based on a quantitative assessment of the fate of the various contaminants present. The residual contaminants and their likely in-pipe concentrations are listed in Table 2-4 and Table 2-5.

Table 2-4 Likely end-of-pipe concentrations of treated process contaminated stormwater from the proposed Australia Pacific LNG facility.

Characteristic	Estimated discharge value (1)
pH	6.0 – 7.0
TSS (mg/L)	5 – 10
TDS (mg/L)	250
BOD_5 (mg/L)	10 – 20
Oil (mg/L)	5 – 15

(1) Actual discharge concentrations are dependent on the relative dilution of the treated wastewater discharge with brine.

Table 2-5 Likely end-of-pipe concentrations of treated sewage from the proposed Australia Pacific LNG facility.

Characteristic	Estimated discharge value (1)
pH	6.5 – 7.5
BOD_5 (mg/L)	10 – 20
TDS (mg/L)	250
Oil (mg/L)	5 – 10
Chlorine (Cl) (mg/L)	1 – 2
Total Nitrogen (mg/L)	<5
Total Kjeldahl Nitrogen (mg/L)	1 – 5
Total Phosphorus (mg/L)	1
Ammonia nitrogen (mg/L)	1 – 5

(1) Actual discharge concentrations are dependent on the relative dilution of treated sewage effluent with brine.

3. Existing Conditions

Port Curtis is a natural deepwater embayment with water depths to 12 m. The Port is protected from the open ocean by Curtis and Facing Islands. Port Curtis has areas which are largely unaffected by human activity as well as areas that have been highly modified by port developments and various industries. Water quality in Port Curtis is generally good but is strongly influenced by tidal state. Existing water quality conditions in the estuary have been examined via a number of studies (see Section 3.1.1) and through the Port Curtis Integrated Monitoring Program (PCIMP) which is detailed in Section 3.1.2.

The proposed location for the LNG facility is just south of Laird Point on the south-western side of Curtis Island, which is within the Gladstone Port Limits. Laird Point is located at the start of the Narrows, a 20,903 ha tidal passage separating Curtis Island from the mainland. The Narrows is zoned as a habitat protection zone. In addition, all Port waters below the mean low water mark lie within the Great Barrier Reef World Heritage Area (GBRWHA). Therefore, all proposed offshore facilities associated with the LNG facility are located within the GBRWHA.

The Port Curtis region contains extensive wetland habitats including saltmarsh, saltpan and mangroves with extensive seagrass beds. Habitat types within the coastal and offshore footprint of the LNG facility and associated facilities include intertidal mud flats, seagrass beds and sandy seabed. Ramsar wetlands are not located within or adjacent to the proposed development site. The closest Ramsar wetlands are Corio Bay and Shoalwater Bay, which are approximately 150 km north of the site. Laird Point lies within the Curtis Island Nationally Important Wetland (QLD021). The nearest declared fish habitat areas are the Fitzroy River, which includes large parts of northern and north-western Curtis Island (FHA-072), Colosseum Inlet (FHA-037) and Rodds Harbour (FHA-036). These are approximately 23 km, 35 km and 50 km respectively, from the proposed LNG facility.

These aquatic habitats support a number of species of conservation significance including dugong and marine turtles, as well as fisheries production. The Port Curtis region, including the proposed location of the LNG facility, is also within a Dugong protection area. Seagrass and bare sedimentary habitats are used by various species of marine turtle, while the endemic flatback turtle nests on the eastern beaches of Curtis Island in the vicinity of the South End township.

3.1 Water Quality

Water quality in the study area was addressed in the EIS by investigating the environmental values in and around Port Curtis, the applicable water quality guidelines and the existing water quality conditions described in the literature and the PCIMP. For the purposes of this supplementary assessment however, a selected summary of physico-chemical conditions and contaminants has been provided to allow the reader to examine potential impacts against existing water quality conditions.

3.1.1 Water Quality Objectives

Under the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (Australian and New Zealand Environment and Conservation Council (ANZECC) and Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ) 2000), Port Curtis can be considered as a 'slightly to moderately' disturbed ecosystem. ANZECC/ ARMCANZ (2000) guidelines for toxicants in aquatic ecosystems apply a 95% protection level to ecosystems which are classed as moderately disturbed. In addition to the national guidelines, the Queensland Department of Environment and Resource Management (DERM) (formerly the Environmental Protection Agency (EPA)) provide statewide *Queensland Water Quality Guidelines* (QWQG) (DERM 2009).

As no site specific water quality objectives have been derived for Port Curtis, other than for turbidity and TSS as part of the GPC WBDDP EIS (GPC 2009), the QWQG (DERM 2009) and appropriate ANZECC/ ARMCANZ (2000) trigger values were used during the present study to examine potential impacts to the receiving environment from discharge of various contaminants in the brine and wastewater discharges. Table 3-1 provides the QWQG objectives for enclosed coastal waters in the Central Coast Queensland Region (DERM 2009) and the ANZECC/ ARMCANZ (2000) default trigger values for slightly disturbed ecosystems in inshore marine waters of tropical Australia.

Table 3-1 Water Quality Objectives

Parameter	Queensland Water Quality Guidelines (DERM 2009)	ANZECC/ ARMCANZ (2000) Guidelines *
Ammonia N (µg/L)	8	1-10
Oxidised N (µg/L)	3	2-8
Organic N (µg/L)	180	ND
Total N (µg/L)	200	100
Filterable P (µg/L)	6	5
Total P (µg/L)	20	15
Chlorophyll-a (µg/L)	2.0	0.7-1.4
DO (% saturation) Upper	100	ND
DO (% saturation) Lower	90	90
Turbidity (NTU)	6	1-20
Secchi (m)	1.5	ND
Suspended solids (mg/L)	15	ND
pH Upper	8.4	8.4
pH Lower	8.0	8.0
Conductivity	n/a	ND

* default trigger value for 95% species protection

ND = no data

3.1.2 Existing Conditions

3.1.2.1 Physico-chemical data

Port Curtis is a well mixed estuary, which can be attributed to its large tidal range (4 – 5 m) (Storey *et al.* 2007). Past investigations have shown that water quality in Port Curtis is generally high, but is strongly influenced by tidal state, with poorer water quality occurring at low tide (BMT WBM 2009).

Table 3-2 displays a number of physio-chemical water quality parameters for Port Curtis from EPA data collected from 1996-2006. Temperature, conductivity and salinity values are generally within the range expected for inshore marine waters. Minimum salinity values reflect freshwater inputs from adjacent estuaries such as the Calliope and Fitzroy Rivers.

Table 3-2 Physico-chemical WQ Parameters (EPA data 1996-2006).

	Gladstone Harbour water quality parameters				
	Minimum	20th percentile	Median	80th percentile	Maximum
Temperature °C	17.7	22.5	26.2	29.2	33.9
Conductivity mS/cm	29.9	52.7	55.0	56.6	60.5
Salinity[1] ppt	18.5	34.7	36.5	37.6	40.6

[1] Derived from Temperature and Conductivity (note Conductivity @ 25ºC). Parts per thousand (ppt).

Port Curtis waters typically have a pH around 8 (range pH 7 to pH 8.5) (GPC 2009) which is indicative of inshore marine waters. Lower pH values are also likely to reflect freshwater/ estuarine inputs. Concentrations of total suspended solids (TSS) and nutrients were much more variable and on occasionally exceed QWQG (DERM 2009) and ANZECC/ ARMCANZ (2000) guidelines (GPC 2009).

The water column of the Port Curtis estuary generally exhibits uniform water temperature and pH levels throughout (BMT WBM 2009), although elevated temperatures with a maximum differential of 8.2 ^{0}C occur in the vicinity of the cooling water discharge of the Gladstone Power Station which discharges into the Calliope River (Saenger *et al.* 1982). Monthly water quality measurements taken for the GPC WBDDP EIS confirm this finding, with mostly homogeneous water temperature and pH conditions throughout the Port Curtis water column (GPC 2009). Some evidence of temperature stratification (thermocline) was detected in May 2009 with a 0.5 °C difference between deeper waters and overlying mid and upper water levels (GPC 2009).

Fixed-site turbidity monitoring of deep waters during baseline studies for the GPC WBDDP EIS measured median turbidity between 3 to 9 NTU during the dry season, with 95th percentiles from 11 to 35 NTU (GPC 2009). Median turbidity levels at shallow water sites during the dry season were around 9 NTU with 95th percentiles of 30 to 90 NTU. Median turbidity at shallow water sites during the wet season ranged between 10 and 23 NTU and were considerably higher than those measured during dry season monitoring.

3.1.2.2 Contaminants

Various contaminants, such as heavy metals, fluoride, cyanide and tributylin (TBT), have been previously measured in the estuary. Although most metal concentrations are below ANZECC/ ARMACANZ (2000) guideline levels, some metals (e.g. copper, nickel, lead and zinc) occur at concentrations greater than those of pristine coastal water sites (Apte *et al.* 2005, Jones *et al.* 2005)

(see Table 3-3). The distribution of elevated concentrations of copper and nickel in The Narrows are believed to probably reflect naturally occurring concentrations (Apte *et al.* 2005), whereas elevated concentrations of lead and zinc in Port Curtis are most likely a consequence of anthropogenic inputs (Apte *et al.* 2005). Under certain conditions, water from the Fitzroy River, which is a source of dissolved metals to the region and which contains elevated levels of nickel and copper, may flow into The Narrows and influence the levels of these metals locally (Apte *et al.* 2005). TBT concentrations in Port Curtis are greater than ANZECC/ ARMCANZ (2000) trigger levels, especially around Fisherman's Landing and the mid and southern Harbour areas (Jones *et al.* 2005). Although levels are much lower than in other Australian ports (Anderson 2004), TBT has bio-accumulated in oysters, mud whelks and mud crabs in Port Curtis. As the use of TBT as an anti-foulant on ships is phased out, the concentrations of TBT in the Port Curtis estuary are expected to decline.

The dispersion of contaminants in Port Curtis is largely dependent on flushing time. A hydrodynamic model developed for the Harbour has found that flushing and retention time is greater than was previously thought (Herzfeld *et al.* 2004). Although particles within the Harbour water are well mixed it takes a long time for particles to leave the estuary, approximately 19 days for the total mass of material to decrease to one-third of its original mass (Apte *et al.* 2006). Over time, this limited estuarine flushing may have significant implications for water quality in the estuary. For example, although levels of heavy metal contaminants in the estuary have been recorded to be below regulation guidelines, a number of marine organisms show evidence of bioaccumulation of these contaminants when compared to those in pristine environments (Andersen *et al.* 2005, Apte *et al.* 2005, Jones *et al.* 2005). This bioaccumulation has been attributed to the reduced flushing time of the estuary (Andersen *et al.* 2005).

Table 3-3 Concentrations of trace metals in Port Curtis and nearby marine waters (Apte *et al.* 2005).

	Metal concentration (ng/L)				
Location	**Cadmium (Cd)**	**Copper (Cu)**	**Nickel (Ni)**	**Lead (Pb)**	**Zinc (Zn)**
Port Curtis (average)	6	496	407	76	163
The Narrows (average)	7	512	536	21	124
Central QLD Coastal waters (average)	1	42	147	13	34
Lower Fitzroy River (saline)	8	672	1030	21	118
NSW Coast	2.4	31	180	9	< 22

3.1.3 Port Curtis Integrated Monitoring Program

The PCIMP is a collaborative, holistic monitoring program for Port Curtis. Established in 2001 as a consortium of members from 16 bodies representing industry, government (both local and state), research institutions and other stakeholders, the cooperative monitoring program was developed and implemented to assess the ecosystem health of the Port Curtis estuary. The water quality monitoring program commenced in 2005 and has generally found that water conditions in the estuary, including metal concentrations, have met Australian Water Quality Guidelines (Storey *et al*. 2007).

3.1.3.1 Sampling Sites and Methods

The PCIMP divides the Harbour into nine zones which include a full cross section of inner Harbour regions of high activity, reference zones of lesser impact in the outer Harbour (estuarine) and oceanic areas. Oysters and passive sampling devices (diffuse gradients in thin films (DGT)) are used to measure the level of contaminants in the Harbour whilst measurement of physicochemical parameters and concentrations of nutrient and metals in the water at each site provide information on the water quality of the Harbour. Collated results from the monitoring program provide an overall Ecosystem Health (EH) rating / standardised score which is displayed in a Report Card format. The nine zones monitored in Port Curtis are as follows:

- The Narrows
- Inner Harbour – Fisherman's
- Inner Harbour – Calliope
- Auckland Creek
- Mid Harbour
- Inner Harbour – South Trees
- Boyne Tannum
- Reference – Estuarine (Colosseum Inlet)
- Reference – Oceanic

The Narrows and Inner Harbour – Fisherman's are both located in the vicinity of the proposed LNG facility.

3.1.3.2 Water Quality Parameters Measured

The physical water quality parameters measured in the PCIMP include pH, dissolved oxygen (DO), temperature, oxidation reduction potential (ORP), specific conductivity, turbidity, light attenuation, fluoride and nutrients (total phosphorous (TP), orthophosphate, ammonia, nitrate, nitrite, total nitrogen (TN) and total Kjeldahl nitrogen (TKN)). Metals have been monitored using passive samplers (DGT) for aluminium, cadmium, chromium, cobalt, copper, iron, lead, manganese, nickel and zinc and bioaccumulation in oysters for aluminium, arsenic, cadmium, chromium, cobalt, copper, gallium, iron, lead, manganese, mercury, molybdenum, nickel, selenium, silver, vanadium and zinc. Fluoride has been monitored using oyster shells.

Of the various parameters measured, only those which are predictable indicators of disturbance, those which are known toxicants identified by the ANZECC/ARMCANZ water quality guidelines (ANZECC/ARMCANZ 2000) and those which are sensitive to ecological disturbance or identify issues of local importance are used as indicators to derive standardised scores for the report cards. These parameters are as follows:

- Physical parameters - pH, DO, turbidity, total nitrogen, total phosphorous
- DGT – aluminium, cadmium, chromium, cobalt, copper, lead, manganese, nickel
- Oyster bioaccumulation – aluminium, cobalt, copper, manganese, nickel, selenium, zinc

3.1.3.3 PCIMP Ecosystem Health Guidelines

Ecosystem Health (EH) is broadly defined as the ability of an environment / ecosystem to cope with stress from both human and non-human impacts. Data for each indicator is measured against appropriate Australian Water (or sediment) Quality Guidelines or background reference zone data, and a standardised score from 0 to 1 produced. The closer the result is to a score of 1, the healthier the ecosystem. The indicators are grouped into performance categories (such as water chemistry, DGT metals, sediment metals etc.) and these are averaged to develop a final health rating grade from A+ to F for that zone. A rating below a D+ represents an environmental condition that would be highlighted for action, while a rating close to reference zone ratings (A+) indicates a relatively un-impacted ecosystem.

EH ratings for most water chemistry and DGT indicators were assigned using ANZECC/ ARMCANZ (2000) water quality trigger values for estuarine ecosystems of tropical Australia for the protection of 99% of species. The 99% guideline for cobalt is regarded as exceedingly conservative, so the 95th percentile value of all local reference data (oceanic and estuarine) was the EH value assigned for this metal. This method was also used for those parameters for which no trigger value was available. For metals in oysters, the 95th percentile value of rate of uptake of each metal based on historic reference data (oceanic and estuarine) was used. The EH guidelines and Worst Case Scenario (WCS) trigger values for Port Curtis are shown in Table 3-4 and the ratings criteria for assessing a particular body of water are provided in Table 3-5.

Table 3-4 Ecosystem Health guidelines (EH) and Worst Case Scenario (WCS) trigger values for Port Curtis

Indicator	Ecosystem Health (EH) Guideline	Worst Case Scenario (WCS) Trigger Value
Water Chemistry		
* pH	7.0 – 8.5	< 6 and > 9.5
* DO (%)	80	60
* Turbidity (NTU)	20	200
* Total nitrogen (TN) (µg/L)	250	2500
* Total phosphorous (TP) (µg/L)	20	200
Contaminants in Oysters		
Aluminium (mg/kg)	1.9	19
Cobalt (mg/kg)	0.006	0.06
Copper (mg/kg)	0.2	2.1
Manganese (mg/kg)	0.16	1.6
Nickel (mg/kg)	0.005	0.05
Selenium (mg/kg)	0.03	0.3
Zinc (mg/kg)	2.8	28
Contaminants in DGTs		
Aluminium (µg/L)	1.5	15
* Cadmium (µg/L)	0.7	14

Indicator	Ecosystem Health (EH) Guideline	Worst Case Scenario (WCS) Trigger Value
* Chromium III (µg/L)	7.7	49
Cobalt (µg/L)	0.07	0.71
* Copper (µg/L)	0.3	3
* Lead (µg/L)	2.2	6.6
Manganese (µg/L)	2.9	29
* Nickel (µg/L)	7.0	200

* represents parameters for which ANZECC/ ARMCANZ (2000) guidelines were applied.

Table 3-5 Ecosystem Health Rating Grades.

Standardised Score	Zone Rating Grade	Condition
> 0.95 – 1.00	A+	Equals Reference
> 0.90 – 0.95	A	Mild departure from reference
> 0.85 – 0.90	A-	
> 0.80 – 0.85	B+	
> 0.75 – 0.80	B	Moderately impacted
> 0.70 – 0.75	B-	
> 0.65 – 0.70	C+	
> 0.60 – 0.65	C	
> 0.55 – 0.60	C-	
> 0.50 – 0.55	D+	Severely impacted
> 0.45 – 0.50	D	
> 0.40 – 0.45	D-	
> 0.35 – 0.40	E+	
> 0.30 – 0.35	E	
> 0.25 – 0.30	E-	
> 0.20 – 0.25	F+	
> 0.15 – 0.20	F	
0.10 – 0.15	F-	
< 0.00 - < 0.11	Fail	Degraded

3.1.3.4 PCIMP Water Quality Results - Summary

Physicochemical data

Physicochemical water quality characteristics for inner Harbour zones of Port Curtis were similar to those of reference zones, although more estuarine sites tended to have lower pH and elevated turbidity levels, especially the upper estuarine sites. Transient elevations in turbidity were expected for shallow, mangrove-lined estuaries. Most parameters were below the ANZECC/ ARMCANZ (2000) water quality guideline levels for protection of 95% of species and any concentrations exceeding the guidelines were isolated events (Storey *et al.* 2007).

The average and lowest concentrations of total phosphorous (TP) exceeded the ANZECC/ ARMCANZ (2000) guidelines on some occasions. Values of TP were up to 2.8 times greater than the guidelines. However, only a small proportion of the TP was biologically available with concentrations of filterable reactive phosphorous at all zones approximating the laboratory limit of detection. Concentrations of total nitrogen were within ANZECC/ ARMCANZ (2000) guidelines in all zones (Storey *et al.* 2007).

DGT-labile Metals

Mean concentrations of DGT-labile metals from each zone were below their respective ANZECC/ ARMCANZ (2000) water quality guideline values for the protection of 95% of species in a slightly to moderately disturbed ecosystem. Inner Harbour zones tended to have the highest concentrations of DGT-labile metals, while outer zones and reference sites generally had the lowest concentrations of DGT-labile metals, especially for copper, aluminium, iron, lead and zinc. Slightly elevated concentrations of manganese, cobalt and nickel in the estuarine reference zone and The Narrows zone showed a similar trend of estuarine influence evident at inner Harbour estuaries, suggesting that elevated concentrations of these parameters may be a consequence of natural influences. However, elevated metal concentrations from the Inner Harbour and South Trees zones reflect increased anthropogenic influences in these areas (Storey *et al.* 2007).

Metals in Oysters

Inner Harbour zones generally had greater metal concentrations in oysters than outer Harbour or reference zones. The spatial distribution of metals in oysters was generally a reflection of anthropogenic influences. Low metal concentrations were evident in oysters from The Narrows (Storey *et al.* 2007).

3.1.3.5 PCIMP Water Quality Results – By Location

PCIMP Harbour zones all achieved an EH rating of B+ or above. This indicates that all Harbour zones within Port Curtis have water quality conditions either equal to or slightly less than those of reference locations. A summary of EH findings for each zone is provided in Table 3-6, followed by a brief description of the zones occurring in the vicinity of the LNG facility (The Narrows and Inner Harbour – Fisherman's) and the estuarine reference zone.

Table 3-6 Water quality standardised scores and average Ecological Health grades for each zone in Port Curtis.

Zone	Water Chemistry	DGT-Labile Metals	Oyster-Labile Metals	EH Grade *
The Narrows	0.96	0.99	0.97	A
Inner Harbour – Fisherman's	0.96	0.90	0.87	B+
Inner Harbour – Calliope	0.96	0.96	0.87	A
Auckland Creek	0.97	1.00	0.79	A
Mid Harbour	0.96	0.99	0.94	A-
Inner Harbour – South Trees	0.95	0.95	0.93	B+
Boyne Tannum	0.95	0.98	0.99	A+
Reference - Estuarine	0.98	1.00	1.00	A+
Reference - Oceanic	0.98	1.00	1.00	A+

(* average grading incorporates sediment ratings not shown).

The Narrows – Ecological Health Grade of A

The Narrows is a narrow estuarine passage separating Curtis Island from the mainland. It is one of only five narrow tidal passages separating large continental islands from mainland Australia. This PCIMP estuarine zone encompasses Graham Creek near the southern end of Curtis Island. The Narrows is located within the GBRWHA and marine parks. The Narrows is in a near pristine state and is listed on the Australian Heritage Commission Register of National Estate (QEPA 2003). Due to its estuarine influence, the Narrows has lower pH and higher turbidity than other PCIMP zones in Port Curtis. Total phosphorus is elevated in The Narrows, as it is within all other zones in the Harbour. Cobalt and manganese concentrations in DGT are also elevated in this zone, however this is common to upper estuaries in Port Curtis. Elevated aluminium concentrations in DGT are attributed to a couple of high anomalous readings. Bioaccumulation of copper and zinc in oysters is higher in The Narrows than in reference zones, but lower than Inner Harbour zones (Storey *et al.* 2007).

Inner Harbour Fisherman's - Ecological Health Grade of B+

This area extends from the southern reaches of The Narrows to just north of Wiggins Island seagrass beds and includes the small estuary of Boat Creek. A number of industries are located in the adjacent catchment area and there are two licensed discharge points associated with the Fisherman's Landing wharf. The upper estuarine areas of Boat Creek tend to have a lower pH, higher turbidity and lower DO than in the lower estuary. Total phosphorus is moderately elevated in this zone, as is evident for other zones in Port Curtis. Elevated concentrations of aluminium, copper, cobalt and manganese in this zone are attributed to the conditions in Boat Creek. Uptake of copper, nickel and zinc in oysters is noted across the whole zone (Storey *et al.* 2007).

Reference Estuarine – Ecological Health Grade of A+

The reference estuarine zone is located to the south of Port Curtis, incorporating the Colosseum Inlet. This zone includes a Great Barrier Reef World Heritage site, a marine park, fish habitats and the Rodds Bay Dugong Protection Area (QEPA 2003). Water chemistry in this zone is of a high standard. Some low DO readings were evident in the upper estuary. Slightly elevated concentrations of total phosphorus were also found. Low accumulation of metals in oysters and DGT were also evident (Storey *et al.* 2007).

3.2 Marine Flora and Fauna

A general description of the marine flora and fauna of Port Curtis is provided in the following sections. Further information was provided in the EIS. Seagrass meadows and mangrove communities are the primary flora environmental features of interest in the vicinity of the proposed marine infrastructure on Curtis Island and outfalls. These vegetated habitats contribute to the high primary productivity of the local estuarine environment. These structurally complex habitats maximise food availability and minimise predation for fish, prawns and crabs (Halliday and Young 1996; Thomas and Connolly 2001; Heck *et al.* 2003). Rocky intertidal and shallow subtidal environments in the general area are important foraging areas for various fish species, while man-made structures such as jetties and seawalls provide additional hard substrata within the Port Curtis region. Extensive un-vegetated intertidal banks around Laird Point and Friend Point also provide foraging opportunities for fish at high tide and shorebirds (including migratory shorebirds) at low tide.

3.2.1 Seagrass

The seagrass beds of the Port Curtis region have been extensively investigated and mapped by Rasheed *et al*. (2003), Taylor *et al.* (2007) and more recently by Chartrand *et al.* (2009). Around 20% of the intertidal (7,246 ha) and subtidal (6,332 ha) seabed of Port Curtis is covered by seagrass, although this is considered an overestimate due to the high seasonal variation observed at this location (Connolly *et al*. 2006). The areal extent of seagrass and its biomass peaks in late spring and summer and is lowest over winter (McKenzie 1994; Lanyon and Marsh 1995). Subtidal seagrass beds in Port Curtis show more temporal variability in seagrass cover compared with intertidal seagrass beds (Chartrand *et al*. 2009). This temporal and spatial variability in seagrass cover has been largely attributed to local and regional climate conditions (Rasheed *et al.* 2008).

Seagrass around Laird Point and North Passage Island, which are closest to the proposed LNG facility, generally consist of aggregated and isolated patches of *Zostera capricorni* with a light cover of *Halophila ovalis*, *Halophila decipiens* and *Halophila spinulosa*. Overall biomass and cover is generally low and varies between 2 – 3 g/dw/m^2 (Rasheed *et al*. 2008).

3.2.2 Mangrove and Saltmarsh

Extensive mangroves occur along the coastline from the Gladstone city precinct to The Narrows and associated tributaries (Danaher *et al*. 2005). Recent estimates of the extent of mangroves in the Gladstone region suggest there are 3,875 patches of mangroves with a combined area of 203 km^2 and a total perimeter of 4,855 km (Manson *et al.* 2005). However, Duke *et al*. (2003) reported a regional loss of almost 40% of mangrove area in Port Curtis between 1941 and 1999.

The proposed LNG facility and associated facilities will result in some disturbance of intertidal areas in the vicinity of Laird Point, on Curtis Island just south of Graham Creek. The location for the LNG facility at Laird Point is largely comprised of saltpan which is inundated on spring tides. The development location surrounds a large stand of mangroves that extends between 120 m and 200 m from a small tidal creek that drains into Port Curtis. This stand of mangroves contains red mangrove, yellow mangrove, grey mangrove and blind-your-eye mangrove. The LNG facility has been designed such that this area of mangrove will be retained. While the saltpan is largely unvegetated, isolated plants of various saltmarsh species are present as are a number of small isolated mangrove trees. The area of the proposed pipeline landing on Curtis Island consists of a sandy beach with isolated mangrove trees that extends into an area of saltpan. The latter contains saltmarsh plants including salt couch, common samphire and seablite.

The seaward edge of the proposed development site (Port Curtis) consists of an upper area of sandy beach extending into a predominantly rocky shore which transitions to mud flat in the lower part of the shore. Taylor *et al.* (2007) previously identified that a small area of seagrass (principally *Z. capricorni*) occurs on these mudflats.

3.2.3 Rocky Intertidal

Intertidal rocky shores occur at a number of locations in the Port Curtis region including in the vicinity of the proposed LNG facility and associated facilities. These rocky shores are best described as a "rubble field" with significant oyster cover, and other macro-invertebrates that associate with oyster cover, in particular the oyster borer (*Morula marginalba*).

The main area of intertidal rocky habitat present in the vicinity of the proposed LNG facility is approximately 0.5 km south of Laird Point. A moderate sloping rocky shoreline with oyster encrusted rocks between the mid to low tide levels occurs at this location (URS 2009). Species diversity on these hard substrates was low as a consequence of the high silt content on the rocks.

Rasheed *et al*. (2003) also identified rubble reef areas in the deep channel area from the vicinity of Graham Creek to Fishermen's Landing, which contained medium density cover (>15% of the area surveyed) of bivalves, ascidians, bryozoans and hard corals. Other such areas of reef habitat are located in the vicinity of Hamilton Point.

3.2.4 Subtidal

Surveys of the subtidal habitat in the vicinity of the proposed LNG facility were undertaken for the Santos GLNG Project EIS (URS 2009). The subtidal area in the vicinity of the proposed LNG facility was found to be principally bare substrate consisting mostly of unconsolidated shell and rubble material (URS 2009). At some locations macroalgae was found attached to shell and rubble. Evidence of bioturbation was largely absent. No hard coral was present and there was no reef structure that afforded any vertical relief, although isolated epifauna individuals (e.g. gorgonians) were present (URS 2009).

Much of the existing knowledge of infaunal assemblages of Port Curtis is based on the work of Currie and Small (2005, 2006). Additionally, Alquezar (2008) provided further information for the area of interest for the proposed project. These surveys show local assemblages are dominated by filter feeders, the most abundant of which is the bivalve mollusc *Carditella torresi.* Other common species were the ascidian, *Ascidia sydneiensis,* and additional bivalve species (*Corbula tunicata*,

Mimachlamys gloriosa, *Leionuculana superba*, *Mactra abbreviata* and *Placamen tiara*), the ascidian (*Ascidiacea* sp.), the polychaete worm (*Eunice vittata*) and the caridean shrimp (*Alpheus* sp.)

In terms of spatial variability of the macrobenthic infaunal assemblage, species richness and abundance were lowest on fine muddy substrates in intertidal areas and highest on coarse sandy sediments that were mostly present in the deeper channels of the estuary. The pattern of freshwater flow was identified as the principal source of temporal variation in the assemblage with regional rainfall and freshwater inflow positively correlated with macrobenthic infaunal abundance.

Some information presented by Currie and Small (2006) can be disaggregated into a smaller spatial scale of relevance to the proposed development location. Sampling stations closest to Laird Point were comprised of low density macrobenthic infaunal assemblages that were numerically dominated by the deposit feeding bivalve *Leionuculana superba* and the predatory polychaetes *Eunice* species 1, *Nephtys* species 1 and *Leanira* sp 1.

3.2.5 Plankton

Phytoplankton concentrations are measured by assessing the concentration of chlorophyll A in the water column. Chlorophyll A is the phytoplankton's principal photosynthetic pigment. Prediction of chlorophyll A winter levels in the Port of Gladstone range from 0.6 to 3.2 µg/L and are generally between 2.0 µg/L and 2.3 µg/L in waters adjacent to Curtis Island. Very little is known about plankton assemblages in Port Curtis in common with the limited information that exists generally for Queensland waters.

3.2.6 Fish and Invertebrate Communities

All sub-tropical inshore fish assemblages are temporally and spatially variable at many different scales. Components of this fish assemblage in the Port Curtis region support regionally important commercial and recreational fisheries.

Currie and Connolly (2006) identified the fish assemblages from intertidal and shallow, nearshore sedimentary parts of Port Curtis area. They found a diverse assemblage consisting of 88 species of which two small schooling species, common ponyfish (*Leiognathus equulus*) and southern herring (*Herklotsichthys castelnaui*), comprised around half of the total fish abundance. The structure of the sub-tidal fish assemblage in the vicinity of Laird Point was similar to most other inshore sites surveyed in Port Curtis. The most abundant species present were common ponyfish (*L. equulus*), finny scad (*Megalapsis cordyla*), southern herring (*H. castelnaui*), estuary perchlet (*Ambassis marianus*), happy moments (*Siganus rivulatus*), large-scaled grinner (*Saurida undosquamis*), striped cardinalfish (*Apogon fasciatus*), yellow-fin tripod fish (*Tripodichthys angustifrons*), large-toothed flounder (*Pseudorhombus arsius*) and winter whiting (*Sillago maculata maculata*). All of these species are common, widely distributed and typical of inshore habitats in sub-tropical Australia.

Saltmarsh and saltpan habitats tend to have lower species richness than other inshore habitats such as mangroves and seagrass (Sheaves *et al*. 2007), but nonetheless provide important fish habitat for some species of recreational and commercial significance. Although fish utilisation of saltmarsh habitats in the Gladstone region is not well studied, Sheaves *et al*. (2007) presented information on the saltmarsh fish assemblages of Munduran Creek which drains into The Narrows approximately 15 km from the proposed development location. The numerically dominant species recorded were mullet (unspecified), ponyfish (*L. equulus*) and silverbiddies (*Gerres subfasciatus*). These species may also be abundant at the proposed location of the LNG facility and associated facilities.

Fish utilisation of mangrove habitats in the Port Curtis area has not been studied, however Halliday and Young (1996) examined density, biomass and species composition of fish inhabiting mangrove forests further south at Tin Can Bay. Similar to the mangroves in Port Curtis, the mangroves examined by Halliday and Young (1996) were dominated by the red mangrove *Rhizophora stylosa*. They recorded 42 fish species from the mangrove forests with economically important fish species representing 76% by number and 74% by weight of the total catch. The numerically dominant species included yellowfin bream, goldenline whiting, silver mullet, sand whiting and the common silverbiddy. Although specific information is lacking, the rocky reef habitat within Port Curtis is likely to be utilised by a range of adult and juvenile fish species including yellowfin bream, sweetlip, estuary cod and blubber-lip bream.

In terms of fish species of conservation significance, the whale shark (*Rhincodon typus*), listed as Vulnerable and Migratory under the *Environment Protection and Biodiversity Conservation* (EPBC) Act, occurs in oceanic waters east of Facing and Curtis islands and as such is unlikely to occur in an estuarine environment such as Port Curtis. The grey nurse shark (*Carcharius taurius*) is listed as Endangered under the Queensland *Nature Conservation Act* 1992, is associated with offshore rocky reefs in southern to central Queensland and is unlikely to inhabit nearshore estuarine waters of Port Curtis. The green sawfish (*Pristis zijsron*) has been recorded from shallow inshore coastal environments including estuaries, although detailed records of the occurrence of the species from 1912 to 2004 identify no individuals of the species in the Gladstone region during that period (Stevens *et al*. 2005). The estuary stingray (*Dasyatis fluviorum*) is ranked as a high priority species by the DERM Back on Track species prioritisation framework, which prioritises Queensland's native species to guide conservation, management and species recovery. The estuary stingray utilises a range of shallow inshore habitats and is likely to occur frequently within the area of the proposed development.

Nektobenthic invertebrates are larger, more mobile benthic invertebrates such as crabs, prawns and lobsters which are typically absent or significantly underestimated in standard benthic sampling gear such as grabs or sleds. Nektobenthic invertebrates are often important fisheries components. Although a comprehensive analysis of locally-occurring nektobenthic invertebrate fauna is not currently available, the Port Curtis area provides habitat for various portunid crabs (including the blue swimmer crab), juvenile prawns (including tiger prawns, eastern king prawns and banana prawns) and mud crabs (Walker 1997).

3.2.7 Commercial and Recreational Fishing

The following provides a description of commercial and recreational fishing activities in the Port Curtis region. This information has been presented, as it provides background information for informing the impact assessment, to follow later in Section 4.

3.2.7.1 Commercial Fisheries

Gladstone supports a significant commercial fishing industry. The commercial fishing fleet out of Gladstone Harbour includes line fishers, net / crab fishers, trawl fishers and seasonal prawn fishers (GPC 2009). Commercial operators use various locations in and around Gladstone Harbour, Port Curtis and offshore areas (GPC 2009). Net and mud crab fisheries are the principal commercial fisheries in the Port Curtis area, although beam trawling also permitted for relevant endorsement holders. Net and crab fishers operating in Port Curtis are also permitted to operate anywhere on Queensland's east coast in areas where these fishing activities are permitted. Commercial fishers with endorsements to beam trawl in the Port Curtis area are only permitted use of such equipment in Port

Curtis, The Narrows, mouth of the Fitzroy River and Keppel Bay. Commercial fisheries in Queensland are monitored through a compulsory logbook program administered by the Queensland Primary Industries and Fisheries (QPI&F). Data collated from the logbook program is available via the coastal habitat and resource inventory system (CHRISweb) database[1] which is also administered by the QPI&F. A key consideration when interpreting information from the database is the spatial resolution is very coarse. Commercial net and crab fishers record spatial information on catch and effort in 30 minute (i.e. nautical mile) grid squares. In the current area of interest this scale includes all of the Gladstone Port Area and The Narrows area as well as significant areas in offshore waters east of Curtis Island (Figure 3-1).

Both the catch weight and value of the local net and crab fishery has increased over time with a more rapid increase since 2003, particularly for the net fishery. No data is currently publicly available for years after 2005. The crab fishery in the region is almost solely focused on the mud crab (*Scylla serrata*). Most of the commercial mud crab fishery is concentrated in The Narrows and the associated tributary creeks (for example Graham Creek, D.McPhee pers. obs). By catch weight and value, the key target species in the net fishery include various species of shark, blue threadfin salmon, mullet, barramundi and grey mackerel. Additionally a small net fishery for bait fish targets garfish and mullet using ring nets. The beam trawl fishery targets various species of prawns with banana prawns, school prawns and greasyback prawns comprising most of the catch. The beam trawl fishery within the Port Curtis / Fitzroy River / Keppel Bay area contributes around 15% of the total Queensland beam trawl catch. However, while the Port Curtis region is within the area and can be accessed by the fishery, available logbook information demonstrates the Port Curtis area is rarely fished in practice.

Consultation undertaken as part of the GPC WBDDP EIS (GPC 2009) found that mud crabbing was conducted along the mainland coast north and south of Fisherman's Landing, commercial fish netting occurs at various locations off the mainland coast and specific sites are generally selected based on their ability to intercept coastal tidal flows on particular tide changes. Friend Point is a particularly productive site. Trawlers also use the Port of Gladstone as a thoroughfare to access the ocean, The Narrows and northern Curtis Island (GPC 2009).

[1] http://chrisweb.dpi.qld.gov.au/chris/

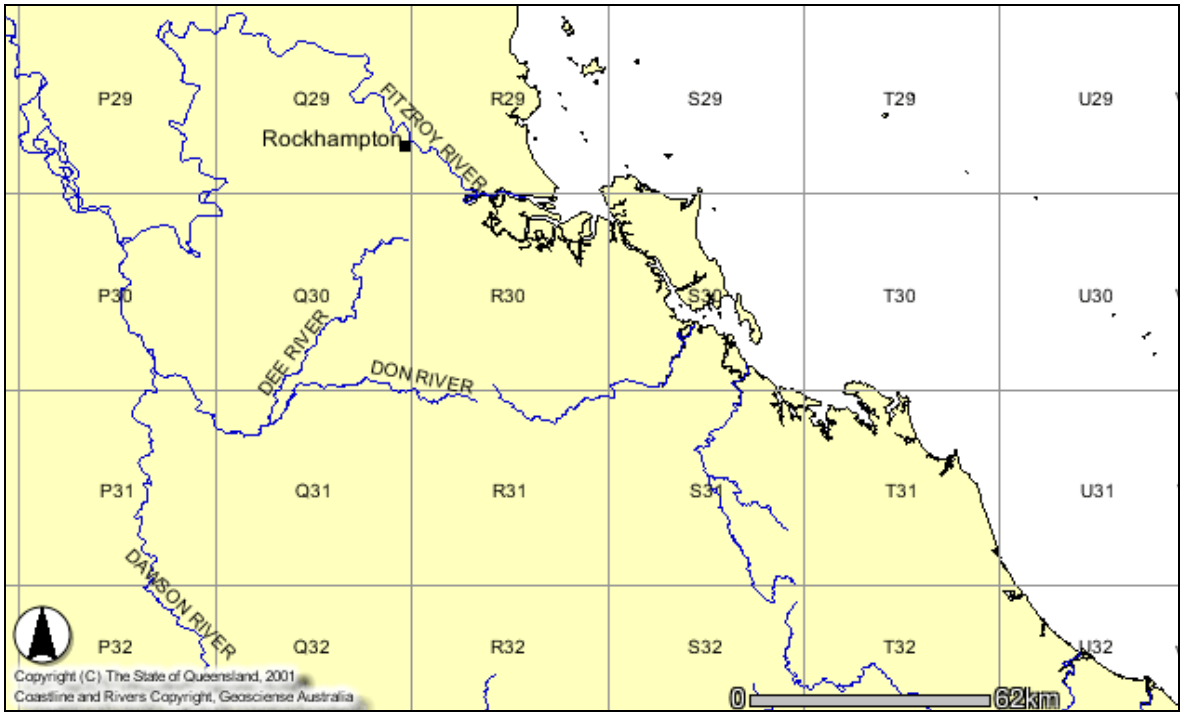

Figure 3-1 Map of the 30 minute grids for recording commercial fishing catch and effort in the Port Curtis region. Grid S30 contains the proposed development location

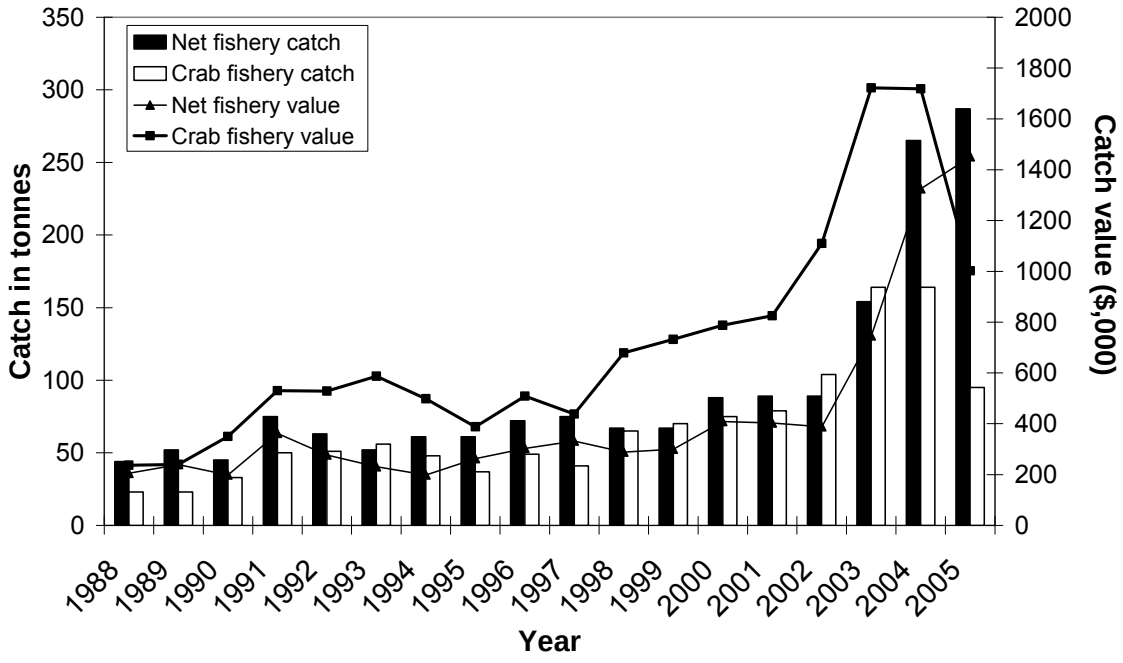

Figure 3-2 The annual catch weight and value of the commercial net and crab fishing catch between 1988 and 2005 in Queensland commercial fishing grid S30

3.2.7.2 Recreational Fisheries

Fishing is a major recreational activity throughout the Gladstone region, with Gladstone city having one of the highest rates of boat ownership of any community in Australia (GAPLD 2008). Recreational fishing activity predominately includes line fishing, pawning and crabbing (GPC 2009). Like commercial fishing activity, information on recreational fishing can be accessed through CHRISweb. State-wide recreational fishing surveys were undertaken in 1997, 1999, 2002 and 2005. These surveys reported catch and effort information at a broad spatial scale, specifically the statistical division (region) a fisher resides in. In the current instance, the relevant statistical division is the Fitzroy region. Approximately 45% of the Fitzroy statistical division undertake recreational fishing activities at least once a year (Henry and Lyle 2003). In addition, with the influx of employees to the region for the APLNG Project, the number of potential recreational anglers is likely to increase (APLNG 2009).

Recreational line fishing is mainly conducted off privately owned boats, with activity and catch, dictated by season. Barramundi is captured more frequently in warmer months and yellowfin bream, blue threadfin, salmon and sand whiting are caught more frequently in winter (Platten *et al.* 2008). Mud crabs are harvested from rivers and estuaries during the summer months (potting is the only legal method of crab fishing) and prawns are fished offshore (Travel Australia 2008).

Platten *et al*. (2007) provided information on the levels of boat-based fishing effort through Central Queensland, including Gladstone. From 1985 to 2005, boat registrations in the Gladstone region increased 110% from 2,171 to 4,581, with most of these boats used for recreational fishing. Boat ramps are available at Gladstone Harbour, Boyne Island, Tannum Sands, Calliope River and The Narrows (GPC 2009). It was estimated, between the period June 2005 and May 2007, around 16,395 boating trips commenced from the Gladstone boat ramp (adjacent to Gladstone Volunteer Marine Rescue) which is the main public boat ramp in the region (Platten *et al*. 2007). While the number of vessels utilising the Laird Point and Graham Creek area was unknown, the Graham Creek area was recognised as a very important anchorage area for recreational vessels and an important area for recreational fishing, particularly mud crabbing.

Graham Creek is also utilised as a safe anchorage for yachts (Platten *et al*. 2007). More recently, Alquezar (2009) undertook a study of maritime harbour movements (recreational and commercial) over a 10 day period (from October to November 2009) in Port Curtis. Data was collected from three locations; Auckland Creek, Calliope River and The Narrows. Significantly higher numbers of recreational vehicles were recorded at all sites during weekends, compared to weekdays and tinnies made up the highest proportion of boating movements at each site (Alquezar 2009).

3.2.8 Invasive Marine Pest Species

The following provides a brief description of invasive marine pest species in the Port Curtis region, as reported in the APLNG EIS (GPC 2009). No new data is contained in this section. This information has been presented, as it provides background information for informing the impact assessment, in Section 4.

The Port of Gladstone is one of 18 ports in Australia targeted for ongoing monitoring for marine pests as it is recognised there is an ongoing high risk of introductions and translocations to the area. However, the monitoring program is yet to commence in Port Curtis.

Previously, Lewis *et al*. (2001) studied the distribution, abundance and risk of exotic marine species in Port Curtis and identified the presence of nine exotic marine species, none of which are classified as marine pest species. Marine pest species are those introduced species capable of significantly impacting on marine industries, the marine environment, coastal communities and the economy. The nine exotic marine species present in Port Curtis consist of four bryozoans (*Amathia distans*, *Bugula neritina*, *Cryptosula pallasiana*, and *Watersporia subtoraquata*), two ascidians (*Botrylloides leachi* and *Styela plicata*), one isopod crustacean (*Paracerceis sculpta*), one hydrozoan (*Obelia longissima*) and one dinoflagellate (*Alexandrium* sp.). These species have successfully colonised ports within Australia and worldwide and are unlikely to have significant impact on native assemblages.

3.2.9 EPBC Listed Species

The following provides a brief summary of the species of conservation concern listed under the EPBC Act 1999 in the Port Curtis region as reported in the APLNG EIS (GPC 2009). No new data is contained in this section. This information has been presented, as it provides background information for informing the impact assessment, to follow later in Section 4.

Cetaceans

The EPBC database has identified ten cetacean species in the Port Curtis region of which the Indo-Pacific Humpback dolphin, the Australian snubfin dolphin and the bottlenose dolphin are known to occur within the Project area (GPC 2009). Snubfin dolphins and Indo-Pacific humpback dolphins are considered to be periodic visitors in the Gladstone region rather than permanent residents (GPC 2009). Dugongs are a listed migratory and marine EPBC species that are present within the project area and are managed within Port Curtis and Gladstone Harbour under The Port of Gladstone - Rodds Bay Dugong Protection Area. Dugong's present within Port Curtis are associated with the seagrass meadows, most commonly within areas around Rodds Bay and near Wiggins Island. The following species of whale are unlikely to occur within the project area as they are principally oceanic species – minke whale, humpback whale, Bryde's whale, Risso's dolphin, spotted dolphin, common dolphin and the killer whale (GPC 2009).

Marine Turtles

Of the six species of marine turtle present in Queensland Waters, green, loggerhead, hawksbill and flatback have internationally significant populations in Queensland. The Port Curtis / Gladstone region represents a medium density nesting site for flatback turtles and a low density nesting habitat for green turtles. Within this region, south-east Curtis Island, the seaward coastline of Facing Island and the coastal beaches of Tannum Sands are considered important nesting habitat (GPC 2009).

Sea Snakes

The EPBC protected matters database identified 12 species of sea snake that may occur in the Project area. Three species, namely the elegant seasnake, spine bellied seasnake and small headed seasnake, are most likely to occur within the Project area based on habitat preference (GPC 2009).

Pipefish and Seahorses

The EPBC protected matters database identified 33 species of sygnathids that may occur in the study area (GPC 2009).

4. Assessment of Impacts

Significant changes to the LNG facility layout, construction activities (including dredging) and ongoing operational activities since the EIS was completed have been assessed in terms of their potential impacts to the marine environment. As discussed, mitigation measures associated with managing dredging works however, are discussed within the GPC WBDDP EIS (GPC 2009).

4.1 Direct Impacts

Construction of the proposed offshore associated facilities (wharf, berth pocket, MOF) and associated dredge footprint on the south-western side of Curtis Island, immediately south of Laird Point, will have a direct impact where the construction / dredging causes a loss of existing habitat. The ocean outfall also has the potential for direct impacts on the marine environment in areas immediately adjacent to the outfall.

Two habitat types have been identified as being affected by the proposed offshore construction activities and ocean outfall, namely seagrass meadows (see Figure 4-1) and intertidal mangroves present within the subtidal habitat in The Narrows.

4.1.1 Dredging and Construction of the MOF

Construction (and associated dredging) of the proposed associated facilities (i.e. the proposed wharf, berth pocket and MOF), necessary to support the LNG facility, will have direct impacts on subtidal seagrass and intertidal mangrove communities on the western side of Curtis Island just south of Laird Point. The proposed dredge footprints associated with APLNG and WBDDP, and the seagrass occurring in these areas is illustrated in Figure 4-1. Dredging activities associated with the LNG facility on Curtis Island (including dredging associated with the GPC WBDDP) will cause the direct removal of 20.28 ha of seagrass. The area of seagrass which is proposed to be removed from this area via dredging associated with the APLNG project alone (not including areas addressed under the WBDDP EIS) is 12.07 ha. This represents approximately 0.3% of the total seagrass mapped in the estuary (~ 4066 ha). **Error! Reference source not found.** indicates the amount of current and historically mapped seagrass which will be directly impacted by dredging associated with the APLNG associated facilities and the WBDDP EIS. It also outlines the area of seagrass which will be impacted by the separate infrastructure components.

As previously mentioned, studies have shown that the seagrass communities in this area are comprised of aggregated and isolated patches of the species *Z. capricorni*, with some *H. ovalis*, *H. decipiens* and *H. spinulosa*. Extensive mapping of seagrass in Port Curtis estuary has found that approximately 20% of Port Curtis is covered by seagrass meadows (Rasheed *et al.* 2003, Taylor *et al.* 2007, Chartrand *et al.* 2009). Seagrass distribution and abundance in Port Curtis is highly temporally variable, as mentioned. Seasonal variability and the ephemeral nature of these seagrass meadows therefore, have implications for construction impacts, with construction activities during winter months likely to have reduced impacts, compared with those conducted during summer months.

Seagrasses provide a significant contribution to primary productivity within estuarine environments. Although the area of seagrass directly impacted by the proposed marine infrastructure is small relative to the total amount in the estuary, any localised reduction in the abundance of this primary producer, will likely lead to a localised reduction in the primary productivity available for higher trophic levels. In

addition, seagrass habitats provide important refuge / shelter, nursery and feeding grounds for a wide variety of marine fauna, including benthic, sessile and nektobenthic marine invertebrates, fish and marine mammals such as dugongs (e.g. Halliday and Young 1996, Thomas and Connolly 2001, Heck *et al.* 2003).

Dredging will result in the direct disturbance / removal of subtidal habitat and the benthic infauna living within the sandy / silty substrates present directly offshore. Macrobenthic infaunal assemblages in Port Curtis are dominated by filter feeders and have a relatively low species richness compared with higher latitude embayment's in Australia (Currie and Small 2005, 2006). In addition, species richness and abundance of benthic infauna were lowest on fine muddy substrates, which dominate the intertidal and shallow subtidal areas of Port Curtis, compared to higher species diversity and abundance characteristic of coarser sandy sediment areas found in the deeper channels of the estuary (Currie and Small 2005, 2006). As construction and dredging of the associated facilities will take place in these intertidal and shallow subtidal edge areas the impact on marine benthic infauna would be considered to be insignificant in comparison to if construction was undertaken in deeper areas of the channel.

It is also possible that a number of nektobenthic marine invertebrates such as portunid crabs and various prawn species residing in these seagrass areas will be impacted directly by construction activities (including dredging) and associated habitat loss in the immediate area (Walker 1997). A study of fish assemblages in Port Curtis by Currie and Connolly (2006) indicates the presence of a wide variety of finfish species in this area, some of which may be potentially impacted directly by the loss of seagrass habitat. However, all fish species recorded in the area are quite common, are capable of relocation and are widely distributed across available inshore habitats of sub-tropical Australia. Accordingly, areas of seagrass nearby and elsewhere in Point Curtis are expected to provide alternative habitat opportunities for these mobile finfish and nektobenthic invertebrate species. Therefore, the localised loss of seagrass habitat from installation of the APLNG MOF is unlikely to appreciably impact fish resources in the broader context of Port Curtis.

Mud crabs are known to be fished commercially and recreationally in The Narrows and associated tributaries such as Grahams Creek. Maintenance of mangrove stands adjacent to the northern reaches of the proposed APLNG footprint will retain important productive habitat used by mud crabs and other nektobenthic fishery resources in this area. Similarly, maintenance of most existing inter- and subtidal habitats in the vicinity of the southern reaches of The Narrows will limit the potential for impacts to existing fish species and fisheries resources in these areas traditionally used by commercial and recreational fishers (Platten *et al.* 2007).

The regionally small loss of seagrass meadows adjacent to the south-western shoreline of Curtis Island may have some impact on several species of conservation importance known to utilise shallow, inshore habitats and seagrass beds in the area of the proposed development. These include 33 species of sygnathids, the elegant sea snake, the small headed sea snake, the Indo-Pacific Humpback dolphin, the Australian snub fin dolphin, the bottlenose dolphin, the estuary stingray and the dugong (GPC 2009). These species are generally susceptible to disturbances and removal of habitat and the subsequent recovery of such affected populations may be very slow.

Table 4-1 Current and historical areas of seagrass impacted by dredging associated with the LNG facility on Curtis Island

Area	Current seagrass impacted (ha)	Historical Seagrass impacted (ha)
Combined Dredging Areas (APLNG and WBDDP)	20.20	12.99
APLNG dredging (in excess of WBDDP project)	12.07	8.75
MOF Construction Access	4.87	2.28
Jetty Construction Access	1.82	1.08
Construction Docks	5.44	6.02
MOF Channel	3.87	0.93
Jetty Berth Dredging Limit	2.68	0.50

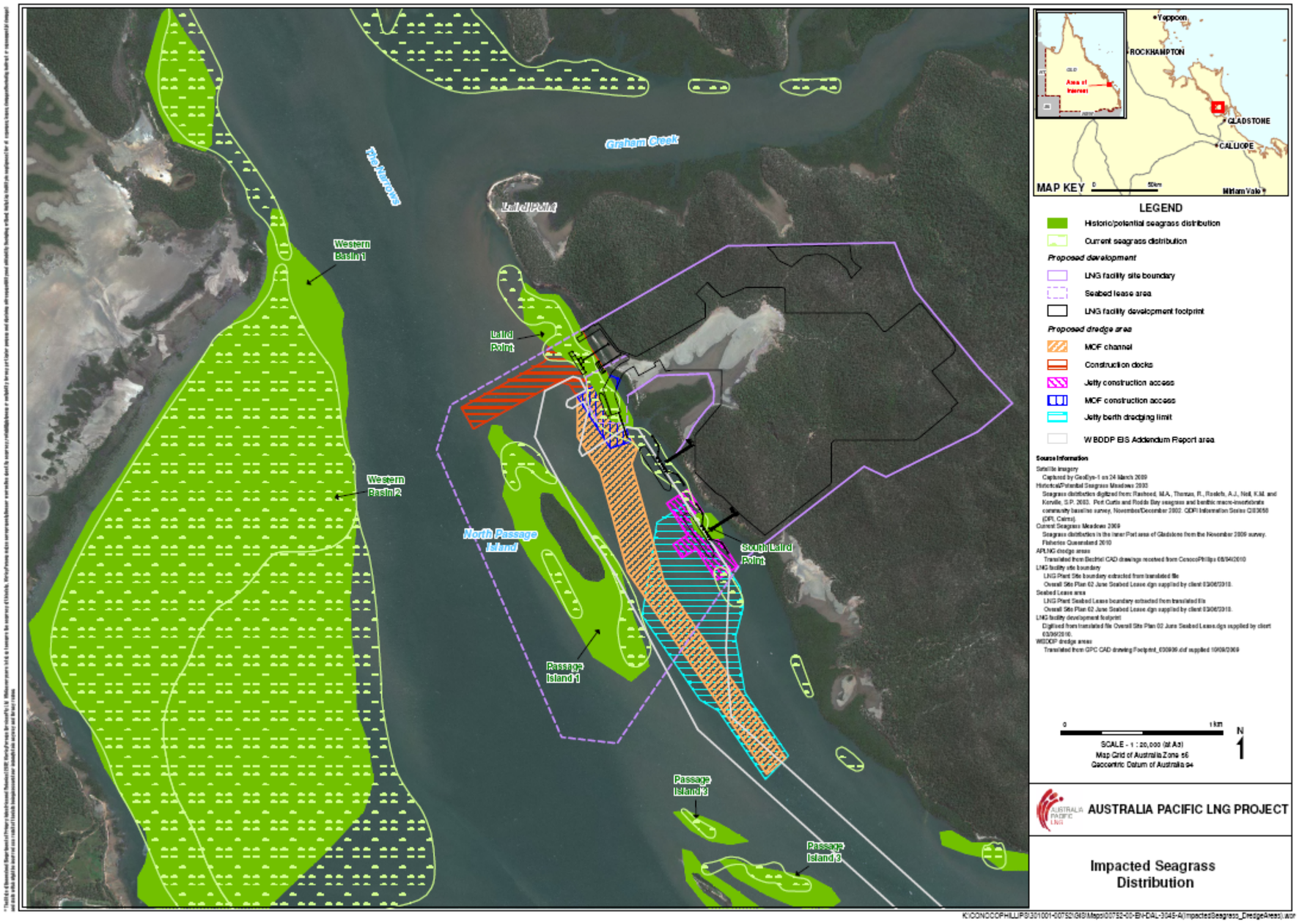

Figure 4-1 Seagrass areas impacted by the proposed dredging of the APLNG associated facilities and the WBDDP

4.1.2 Pest Species

Potential impacts associated with marine pests include potential transport of these species from Port Curtis to the broader marine environment. The main activity which has the potential to impact on transport of pest species out of Gladstone Harbour and Port Curtis is from shipping and dredging activities. As dredging and disposal activities are largely contained within Port Curtis, associated impacts outside of Port Curtis are unlikely.

There are existing protocols in place to minimise the risk of marine pest incursions and the early detection of an incursion if one occurs. A national system for the prevention and management of marine pest incursions is in place, which includes three major components being (1) prevention, (2) emergency response and (3) ongoing control and management. Requirements which have been in place since 2001 for the management of internationally sourced ballast water apply to all ships arriving from overseas. These are implemented through the *Quarantine Act 1908* and administered by the Seaports Program within the Australian Quarantine Inspection Service (AQIS). All ships are also required to comply with the International Convention of Pollution from Ships (MARPOL) which specifically addresses issues such as bilge pumping, sewage and garbage.

As per the GPC WBDDP EIS, all vessels must adhere to Commonwealth and State biofouling and ballast water management requirements. All vessels, particularly dredgers, are to be of low risk of introducing marine pests to the area via construction activities. This may require pre-entry inspections.

4.2 Indirect Impacts

Indirect impacts may occur to subtidal communities (i.e. seagrass) as a result of elevated turbidity and reduced water quality conditions caused by dredging activities and brine and wastewater discharges through the ocean outfalls.

4.2.1 Water Quality Impacts from Dredging and Construction Activities

Construction of the associated facilities on the south-western side of Curtis Island will involve dredging and excavation of both intertidal and subtidal areas. By comparison with other dredging activities proposed for the Western Basin, to the dredging assessed in this report is relatively small. It is proposed that 1,458,200 m^3 of material will be removed as part of the APLNG EIS (see Section 2.1 for individual volumes) while approximately 36,000,000 m^3 of material will be removed for the entire GPC WBDDP (GPC 2009).

Resuspension of sediments from dredging and excavation operations have the potential to increase turbidities in both the immediate waterways and surrounding areas through transport of suspended sediments with tides and currents. Turbid plumes can decrease ambient light levels and thereby affect photosynthesis by benthic aquatic flora such as seagrasses. Smothering of seagrass communities can also occur as the sediment settles on the seabed. The environmental impacts of dredging on seagrasses has been reviewed by Erftemeijer and Lewis (2006), who identified critical thresholds of light availability for a range of seagrass species around the world. Variations between species in terms of tolerance and recovery from periods of reduced light were found to relate to differing morphology and physiology.

Larger, slow-growing seagrass species such as *Z. capricorni*, which are abundant seagrass components around the proposed marine infrastructure development, survive reasonably long periods of reduced light owing to their characteristically high levels of stored reserves (Erftemeijer and Lewis 2006). These larger species are reasonably resistant to short to medium term reduced light impacts. By comparison, smaller, short-lived seagrass species such as Halophila (which is present at the site in small abundances) were found to be less tolerant to changes in light conditions outside of their environmental tolerance levels. However, these species were found to recolonise relatively quickly following an impact (Erftemeijer and Lewis 2006). If the duration of high turbidity from dredging persists to a point where seagrasses have exhausted stored reserves, seagrasses will generally die and recover either slowly or not at all following resumption of suitable light conditions.

Under natural conditions, seagrass within Port Curtis are exposed to naturally elevated turbidity levels and high rates of sediment deposition for extended periods of time. Turbidity levels of 20 NTU (56 mg/L) have been reported in the deep water channels (see Chapter 7 of the GPC WBDDP EIS; GPC 2009). Elevated turbidity levels and TSS concentrations have been shown to persist for up to 7 days at a time (GPC 2009).

The maximum TSS concentration reported from model results of dredging of the Construction Docks was greater than 500 mg/L (0.5 kg/m^3) over a limited area (Figure 4-5) whilst mean TSS concentration values ranged from 0 to more than 2.5 mg/L (0.0025 kg/m^3) over a broader area (Figure 4-3). It is therefore likely that there will be zero light on the seabed within the seagrass meadows located near the southwest margin of Curtis Island, adjacent to Laird Point and North Passage Island for reasonably short durations (i.e. remaining for up to a day or two following dredging) (see Figure 4-2 and Figure 4-3). In order to minimise the potential for indirect, turbidity-related impacts to local seagrass beds where practical, dredging activities will be conducted during cooler months, when seagrass meadows are less productive, and over short durations (less than three weeks) in areas adjacent to vulnerable seagrass habitat in order to limit detrimental impacts from increased light attenuation.

To reduce the potential indirect impact on nearby seagrass communities, in the case that cutter suction dredging (CSD) is used, the GPC WBDDP (GPC 2009) suggests that the Dredge Management Plan (DMP) should be followed. In the case that trailer suction hopper dredges (TSHD) are used the DMP should be followed in addition to the following:

- Monitor turbidity levels against site specific objectives within relevant sensitive ecosystem receptors and adjacent habitats and respond as required by DMP
- Activity alteration may include reducing duration of dredging at particular locations during spring tide, relocating dredge to different areas in accordance with dredge program, and planned increase in period between dredging activity at any one location
- The use of a CSD has been nominated for areas closest to The Narrows and Grahams Creek
- Program dredge to avoid the use of TSHD in dump mode in the northern extent of the Western Basin during flood phase of large spring tides

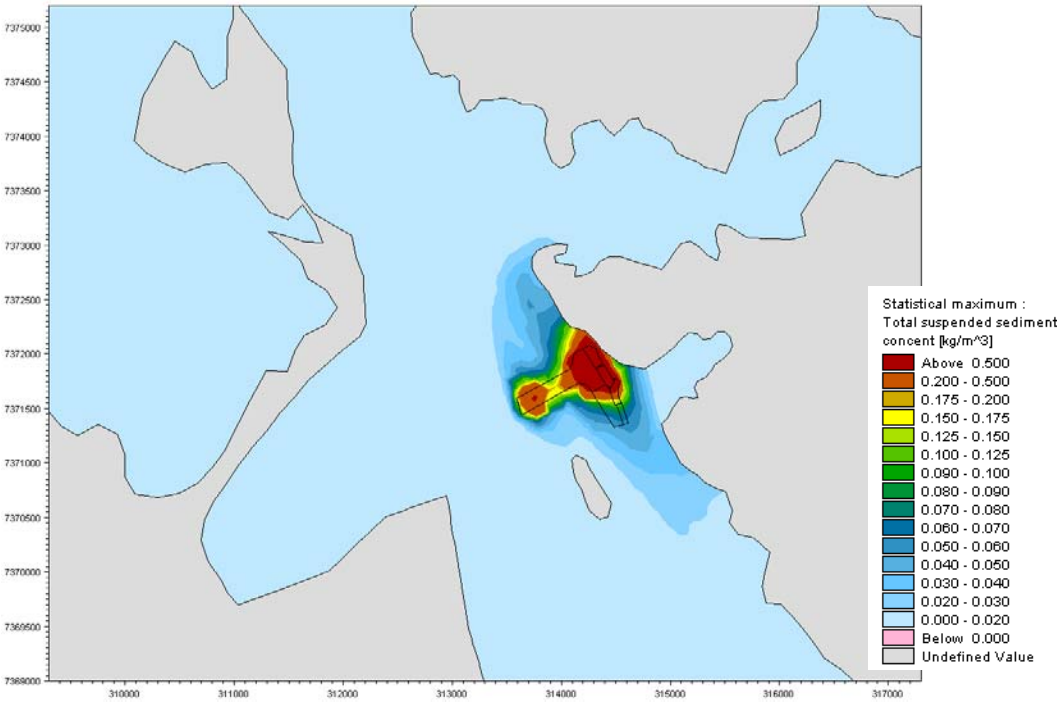

Figure 4-2 Construction Docks dredge - statistical maximum TSS concentration above background (referenced from WorleyParsons Coastal Environment Supplementary Report, LNG Facility 2010).

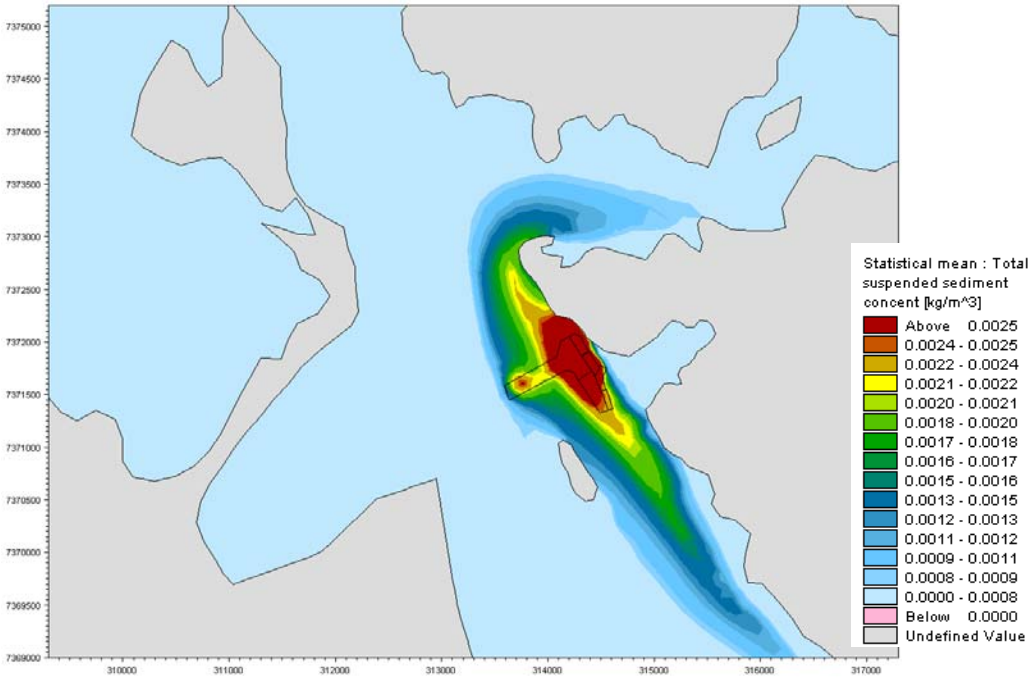

Figure 4-3 Construction Docks dredge - statistical mean TSS concentration above background (referenced from WorleyParsons Coastal Environment Supplementary Report, LNG Facility 2010).

Further afield, TSS concentrations are predicted to be less than 20 mg/L. At the Graham Creek, immediately north of the proposed offshore infrastructure, the highest peaks of between 6 mg/L and 13 mg/L occur over two periods for about 1.5 weeks at a time, with a period of lower peaks in between. The peak value shown by the simulation was 12.8 mg/L, while a value of less than 7.2 mg/L was recorded for 99% of the duration and less than 3.7 mg/L for 90% of the duration. This peak value is less than the Queensland Water Quality Guidelines TSS trigger value (DERM 2009) of 15 mg/L and so, is unlikely to have a measurable impact to the marine environment, given the TSS concentrations proposed and short duration of high turbidity.

The light tolerances of the seagrass species which occur within the project area are fundamental to understanding impacts from increased TSS concentrations. Seagrass around Laird Point and North Passage Island, which are closest to the proposed LNG facility, generally consist of aggregated and isolated patches of *Z. capricorni* with a light cover of *H. ovalis*, *H. decipiens* and *H. spinulosa*. Overall biomass and cover is generally low and varies between 2 – 3 g/dw/m^2 (Rasheed *et al*. 2008). A large percentage (70% of the biomass) of the seagrass beds in the project area are intertidal and therefore, any increase in light attenuation and reduction in incident light levels on the seabed, are applicable to all seagrass beds at high tide and also those seagrass beds which occur subtidally, at low tide.

Zostera capricorni can tolerate 5% surface irradiance for one month and *H. ovalis* can tolerate 0% surface irradiance for one month (Erftemeijer and Lewis 2006). Therefore, considering the baseline data and the threshold tolerances of the seagrass species of interest, if turbidity remains elevated for greater than three weeks, then this will cause persistent reduction of light levels on the seabed and therefore, may impact on seagrass meadows within the vicinity of the dredge plumes. This is unlikely however for the broader project area, given that the modelling undertaken suggests that turbid plumes are only likely to persist for a few days. Time series locations modelled are presented in Table 4-2. These locations are shown in Figure 4-8 and Figure 4-9. A TSS concentration of up to 3,200 mg/L occurred for a few days at the Construction Docks; a TSS concentration of 4 mg/L for up to 2 days was reported within the Main Channel; TSS of 0.5 mg/L and 0.8 mg/L in the Tidal Flats an in The Narrows for short-term peak (1 - 2 days); and a maximum TSS concentration of 257 mg/L occurred in the Embarkation Dock dredging area as a short-term peak for less than a day (see Figure 4-4 to Figure 4-7).

Due to the similarities in the location of the Construction Docks and MOF Construction Access, plumes simulated by the model for dredging of the MOF Construction Access were similar to that described for the Construction Docks. Due to the smaller dredge volume however, and the spatial extent of the dredge area, the TSS concentrations over the duration of dredging were considerably lower, compared to dredging of Construction Docks. Considering the TSS time series plots, there may be some impact immediately surrounding the Construction Docks; however (see Figure 4-5), from dredging of Construction Docks and the MOF Construction Assess areas, given that some prolonged turbidity (up to three and a half weeks) of up to 100 mg/L, is likely surrounding the APLNG Dock.

Table 4-2 Time Series recording locations.

Marker	Locations	Easting	Northing
t1	Graham Ck N	313635	7373880
t2	APLNG Dock	314293	7371802
t3	Main Channel	313271	7372124
t4	Tidal Flats	311866	7371522
t5	Graham Ck S	314154	7373103
t6	The Narrows	311791	7373622

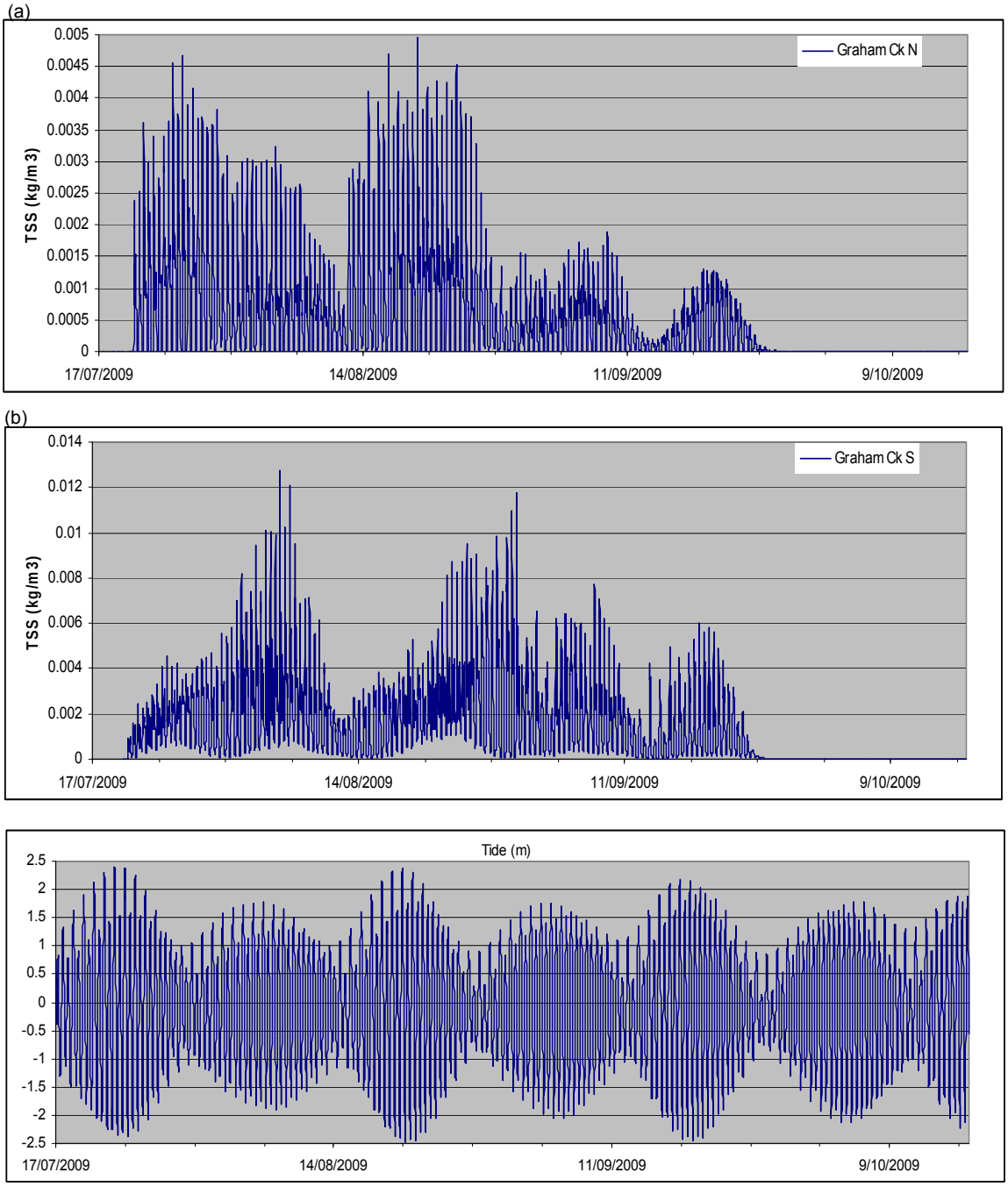

Figure 4-4 Construction Docks dredge - TSS concentration time-series (a) Graham Ck N and (b) Graham Ck S

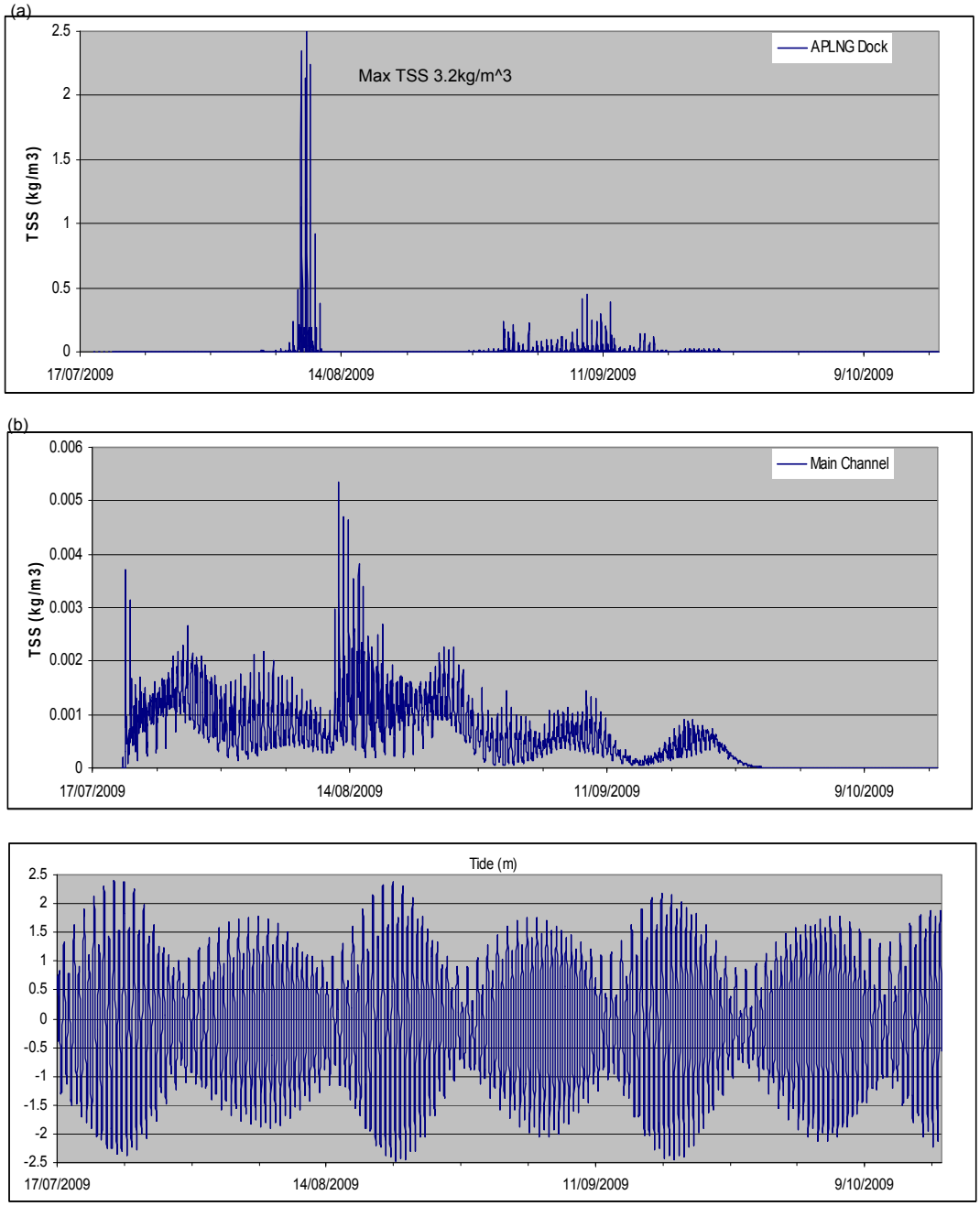

Figure 4-5 Construction Docks dredge - TSS concentration time-series (a) APLNG Dock and (b) Main Channel

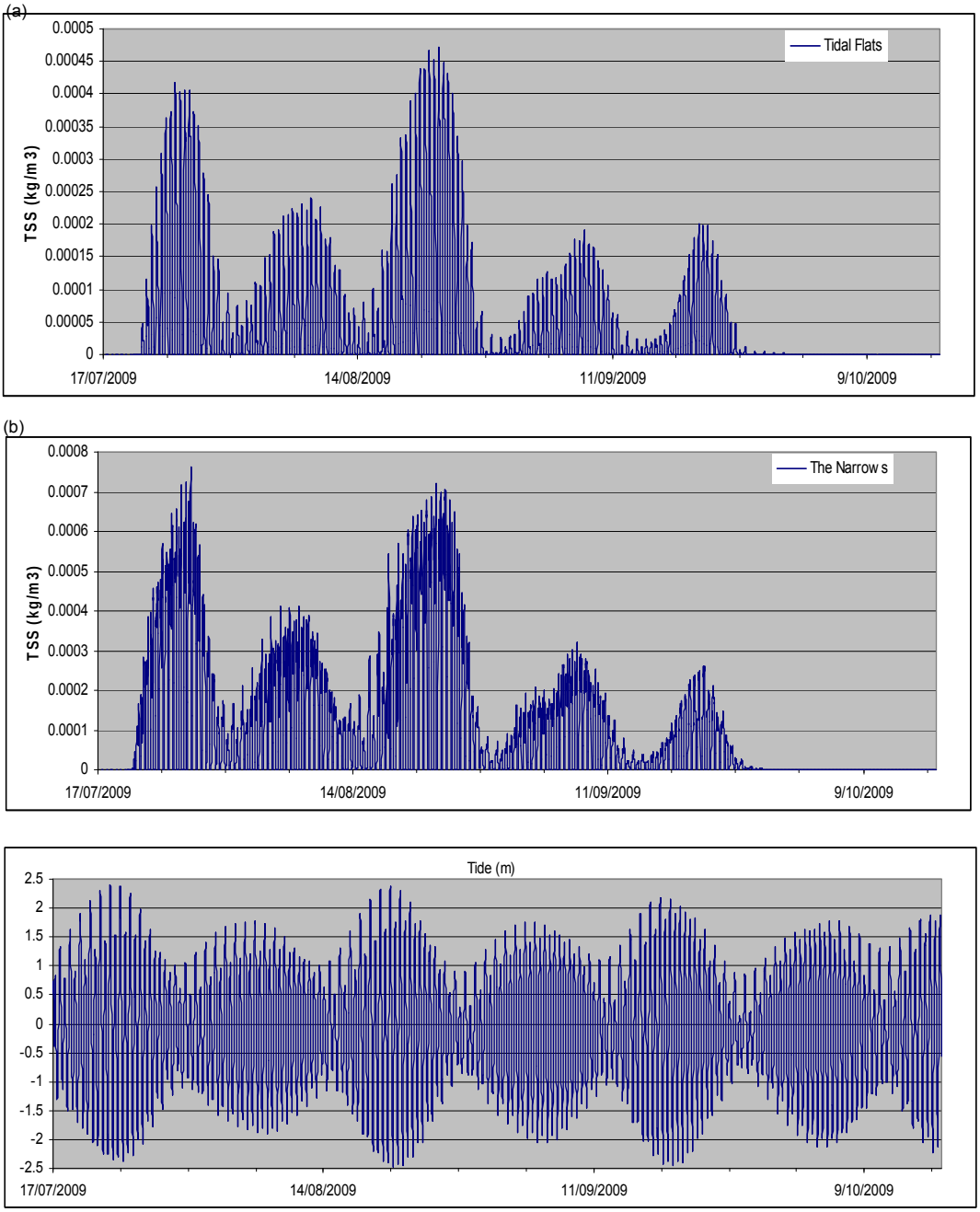

Figure 4-6 Construction Docks dredge - TSS concentration time-series (a) Tidal Flats and (b) The Narrows

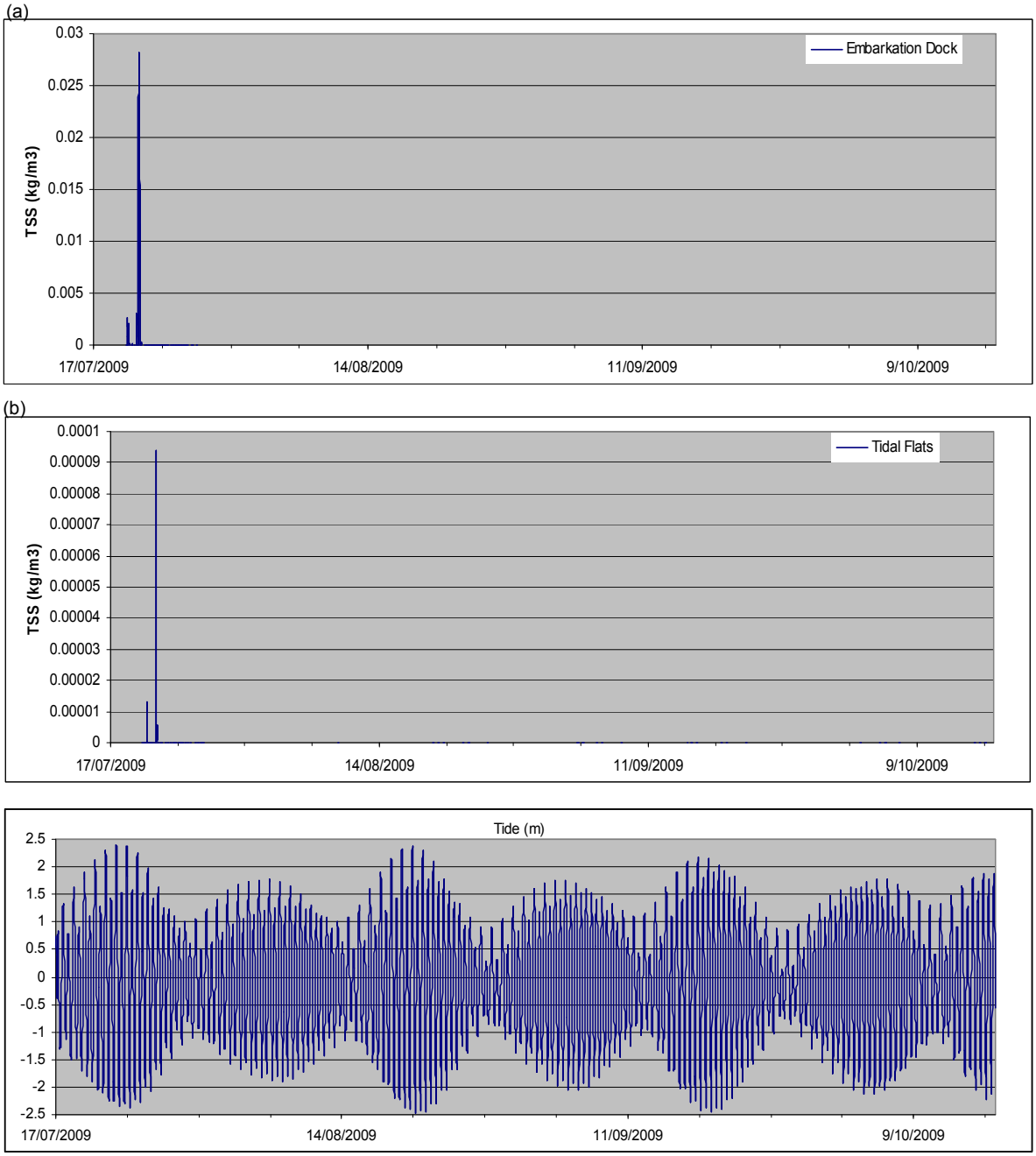

Figure 4-7 Embarkation Dock TSS concentration time-series (a) Embarkation Dock and (b) Tidal Flats

Sedimentation rates during dredging should be considered in terms of also managing impacts of smothering on seagrass beds. Maximum sedimentation rates predicted during dredging for the proposed GPC WBDDP vary from 0.022 to 0.4 mm/day in calm and low velocity conditions (GPC 2009). *Zostera spp*. and *H. ovalis* were reported to tolerate approximately 2 cm of sedimentation per year (Erftemeijer and Lewis 2006), which is in between sedimentation rates observed during baseline studies, where sediment accumulation was reported from 0.43 to 15 cm per year (see GPC WBDDP EIS; GPC 2009). Therefore, maximum sedimentation rates would need to occur for greater than 10 days, for impacts from smothering to occur. The greatest likelihood from smothering will occur from dredging of the Construction Docks and the MOF Construction Access areas, which will result in extended periods of dredging.

It is noteworthy that the duration of dredging, volume of dredge material, TSS concentrations and dredge plume durations associated with dredging of Construction Docks and the MOF Construction Access is considerable smaller than the proposed 12 to18 month dredging of 36,000,000 m^3 of material proposed for the Western Basin Dredging and Disposal Project (GPC 2009) and therefore any contribution from dredging associated with the APLNG LNG facility and associated facilities will be insignificant, compared to the impacts from the GPC WBDDP dredging campaign (see Figure 4-8 and Figure 4-9).

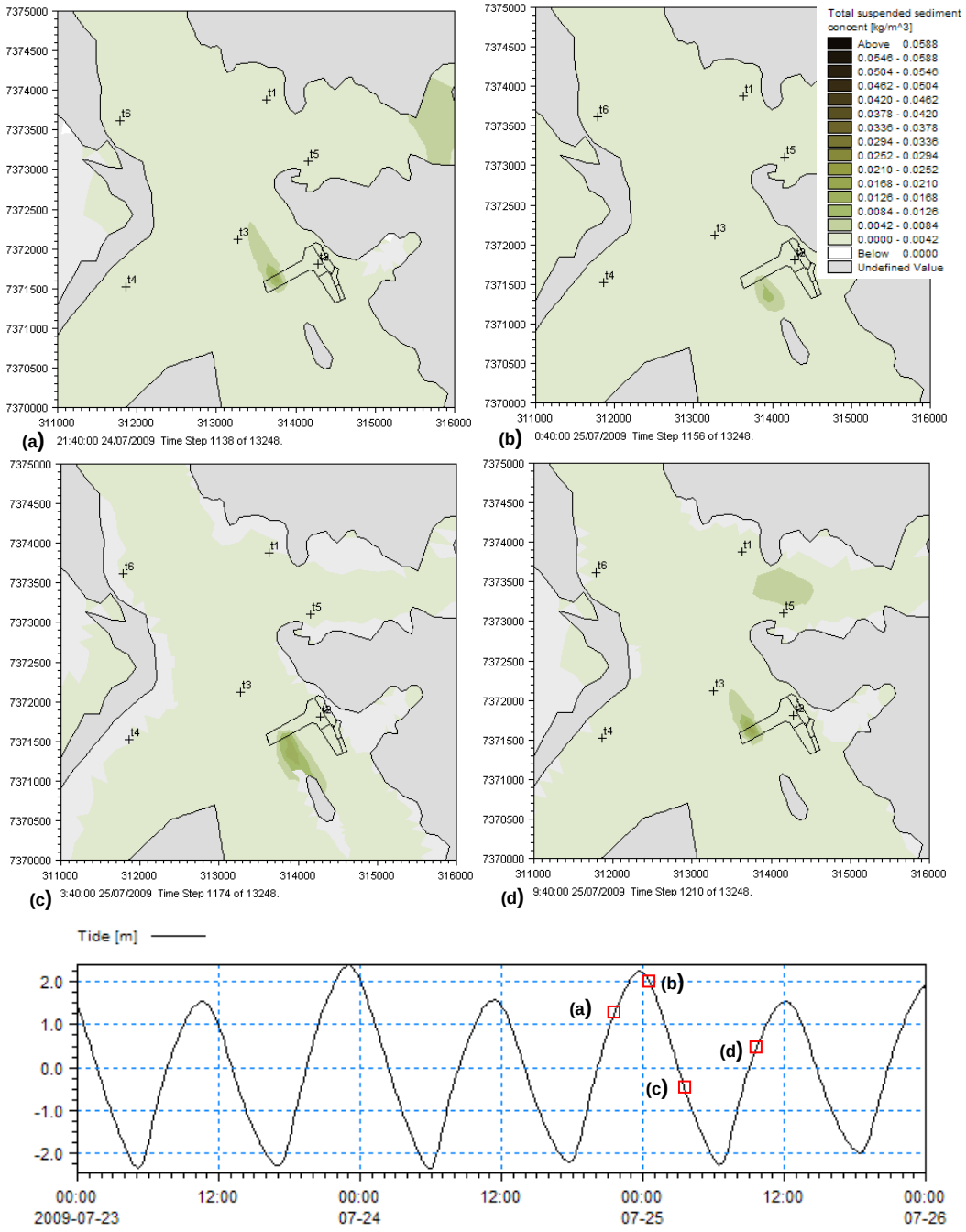

Figure 4-8 Construction Docks dredge plume snapshot.

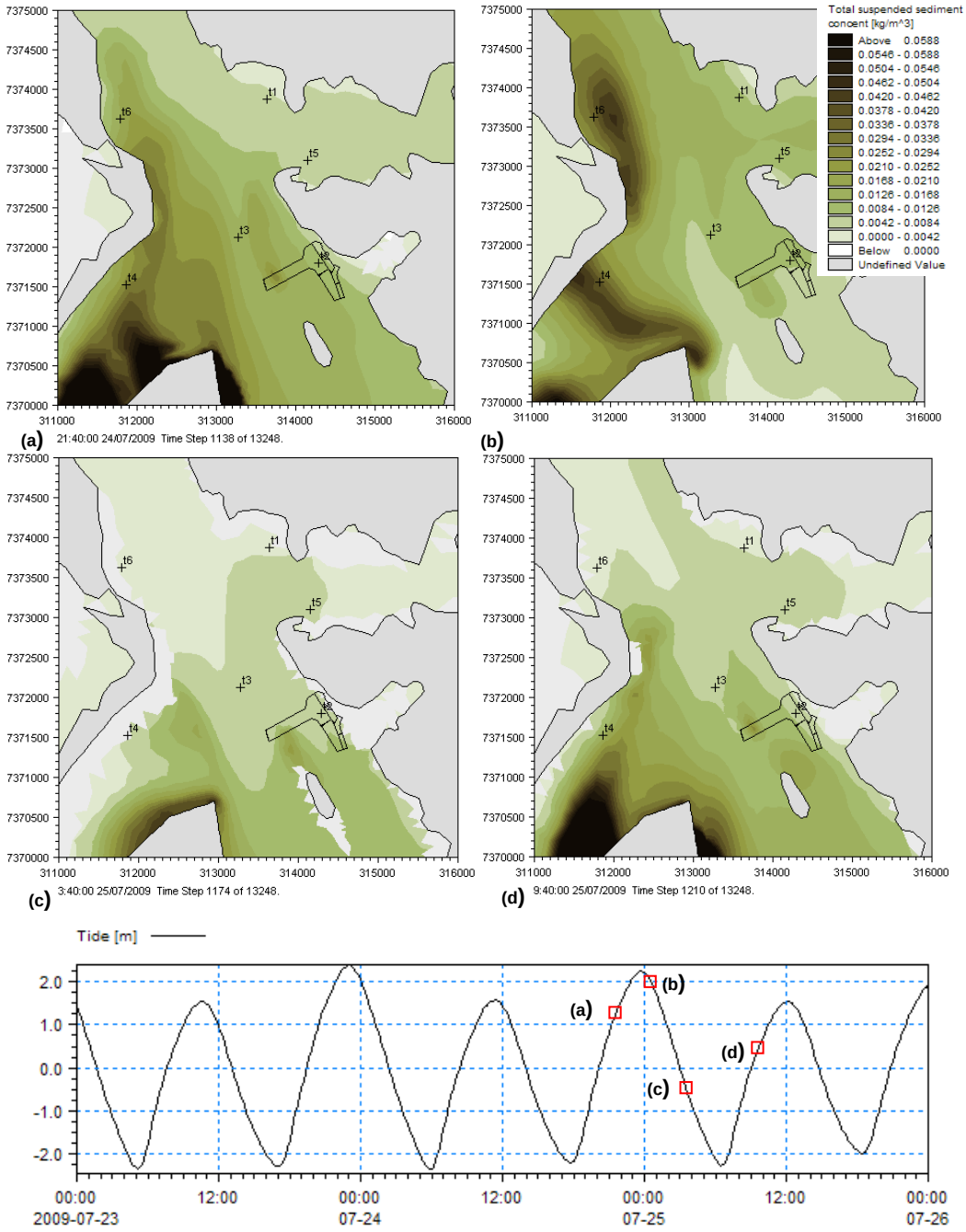

Figure 4-9 Construction Docks with GPC dredging plume snapshot.

Should the proposed dredging of Construction Docks and the MOF Construction Access area be undertaken at the same time as the GPC WBDDP, then the cumulative affect of the dredge plumes and increased turbidity in the water quality from both programs is likely to have an impact on seagrass communities within Port Curtis. The TSS maximum and average concentrations modelled for the dredge plumes generated from both programs undertaken at the same time are illustrated in Figure 4-10 and Figure 4-11.

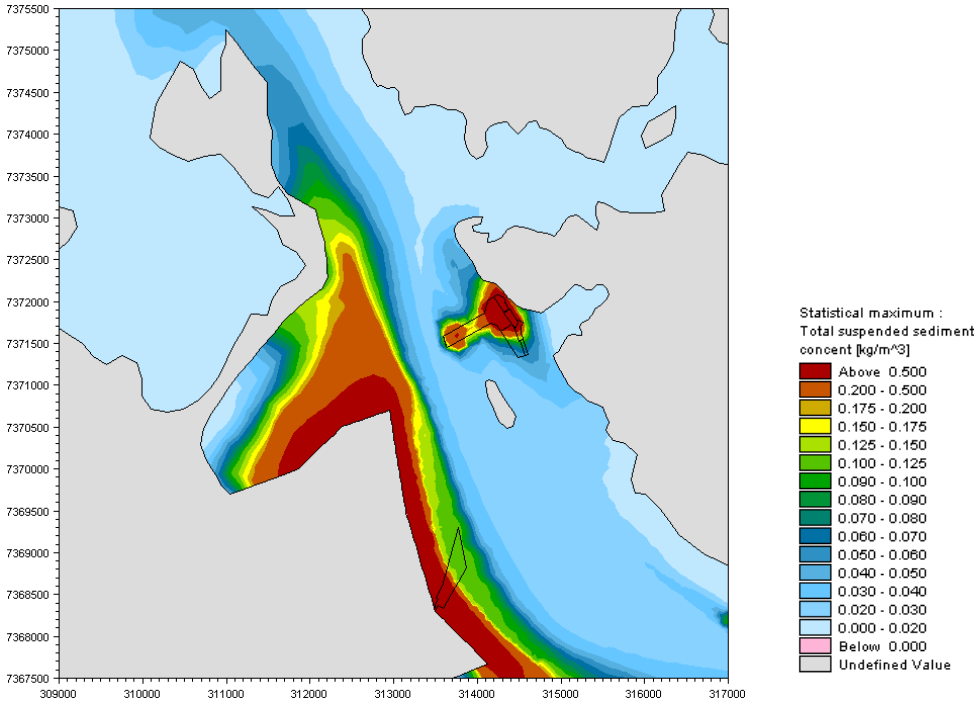

Figure 4-10 Construction Docks with GPC dredge - statistical maximum TSS concentration above background.

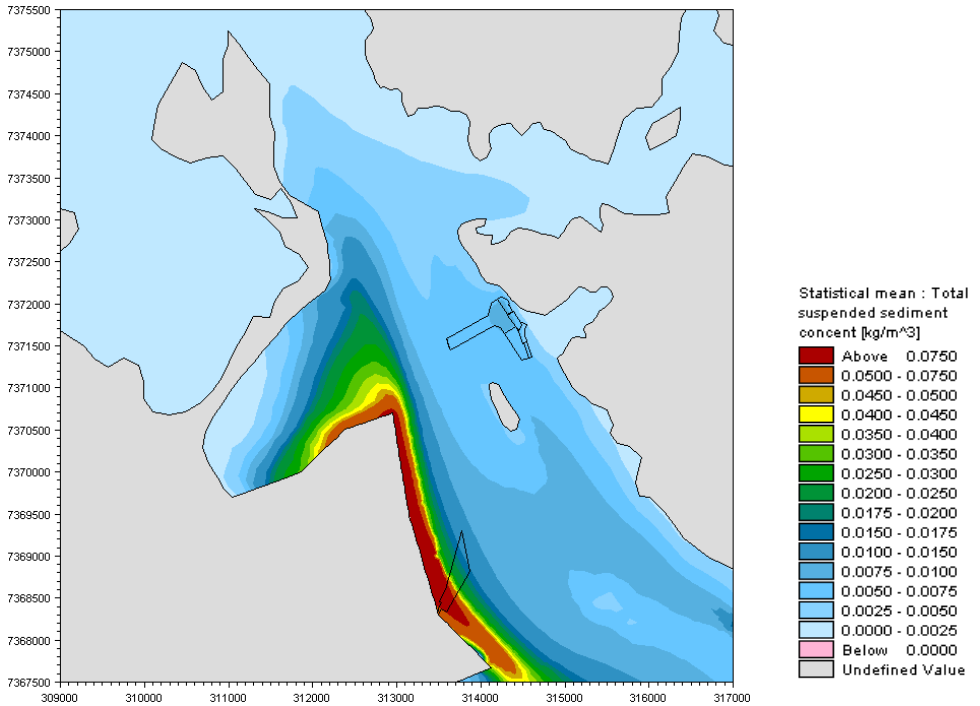

Figure 4-11 Construction Docks with GPC dredge - statistical mean TSS concentration above background.

Considering the threshold light tolerances previously mentioned for the seagrass species present within Port Curtis and the concentrations and durations of the plumes (see Figure 4-12 and Figure 4-13), without appropriate mitigation there is a high likelihood of seagrass meadows within the Western Basin (Tidal Flats), adjacent to The Narrows, within intertidal areas and south of the Main Channel (around North Passage Island) being significantly impacted by high TSS concentrations for extended durations. High TSS concentrations for extended durations around the reclamation area will also without appropriate mitigation impact on seagrass beds by causing smothering of these communities.

The seagrass meadows within Graham Creek are unlikely to be impacted given the short duration of elevated turbidity (above the QWQG TSS guideline value of 15 mg/L), based on the modelling results presented (Figure 4-14). As previously stated, in addition to implementation of a DMP, the GPC WBDDP EIS (GPC 2009) suggests that turbidity levels should be monitored against site specific objectives within relevant sensitive ecosystem receptors and adjacent habitats. As part of this monitoring it is suggested that monitoring of turbidity within Graham Creek occur, to determine that the turbid plumes do not persist in these areas for greater than three weeks.

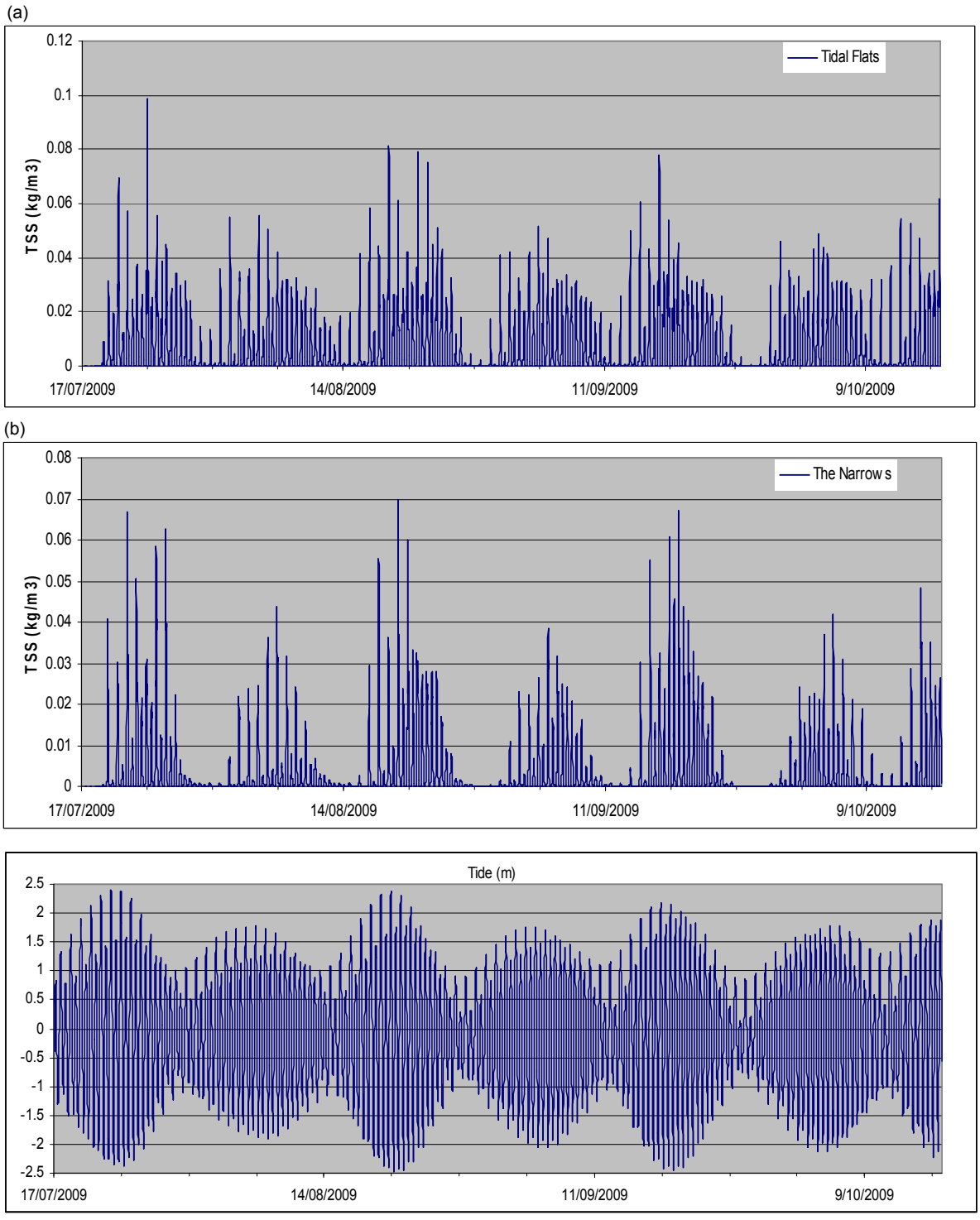

Figure 4-12 Construction Docks with GPC dredge TSS concentration time-series (a) Tidal Flats and (b) The Narrows

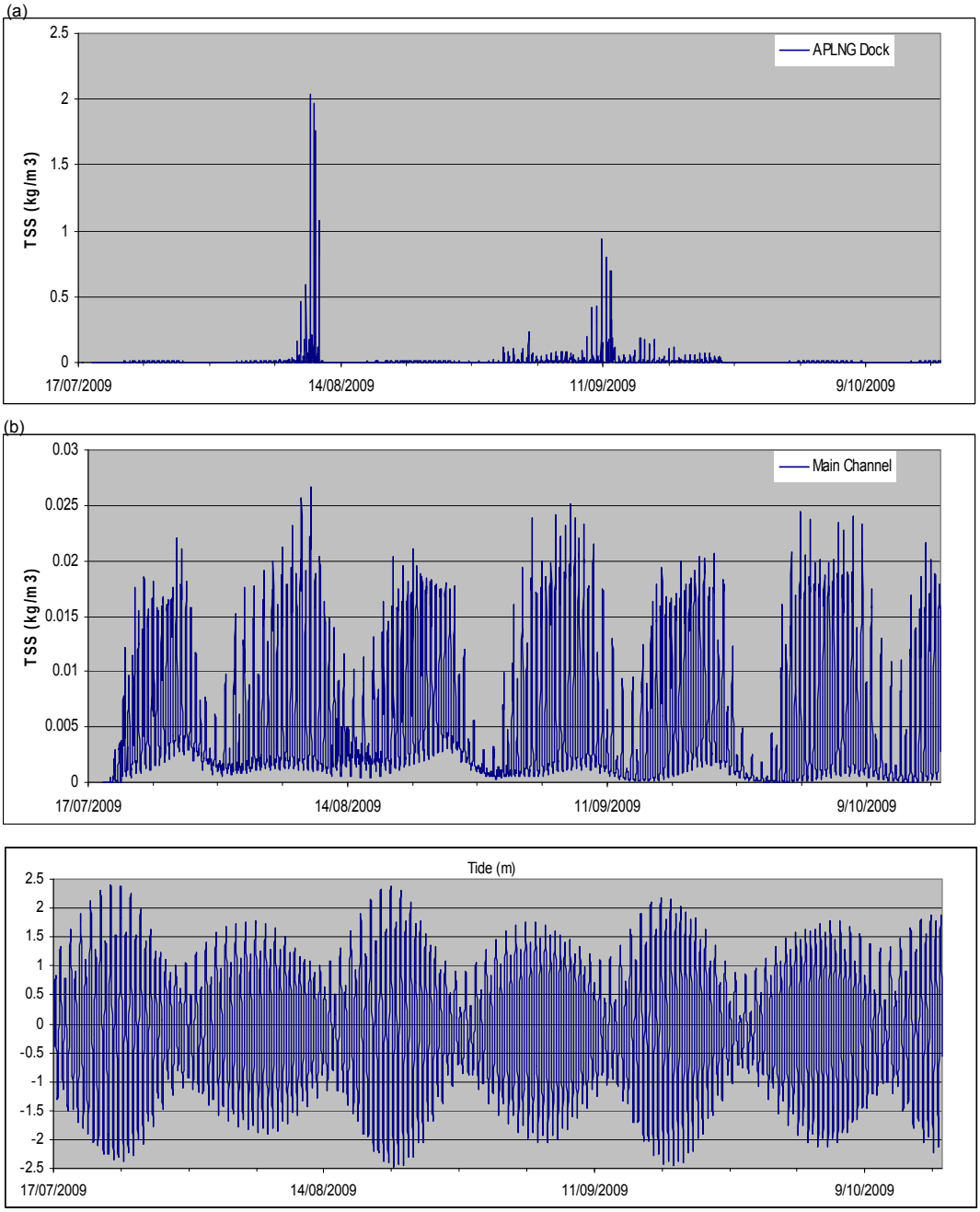

Figure 4-13 Construction Docks with GPC dredge TSS concentration time-series (a) APLNG Dock and (b) Main Channel

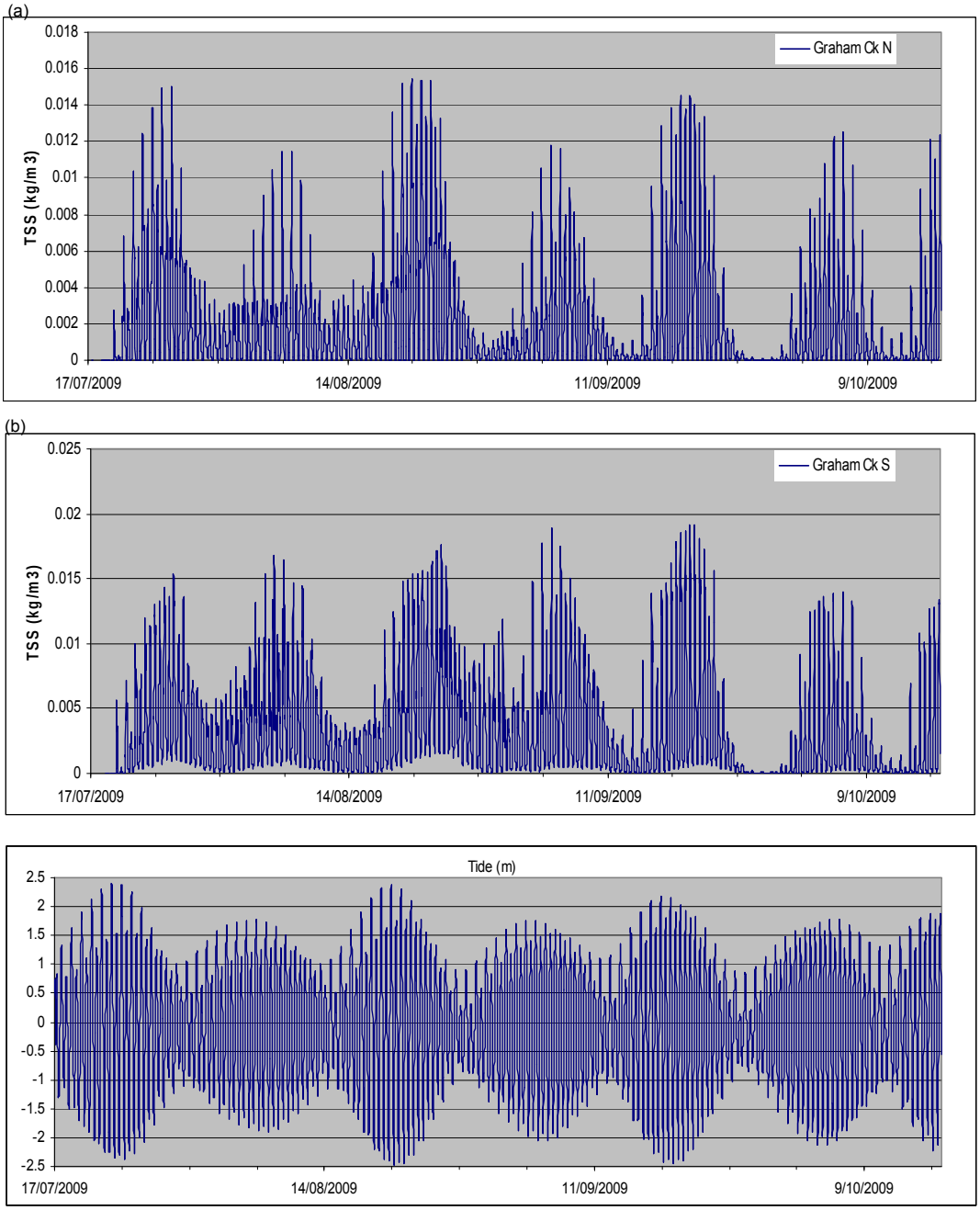

Figure 4-14 Construction Docks with GPC dredge TSS concentration time-series (a) Graham Ck N (b) Graham Ck S

4.2.1.1 Sediment Quality

If contaminated, resuspension of sediments poses a serious risk to the marine environment through water quality impacts and impacts on marine flora and fauna. However, sediment analysis has confirmed that the level of contaminants in all sediments to be removed from the proposed construction footprint are below the NAGD screening levels (DEWHA 2009) and EL and HIL-A of the Draft Guidelines for the Assessment and Management of Contaminated Land in QLD (DOE 1998). As such, these sediments are not considered to be contaminated and any resuspension of these sediments would not pose any threat associated with the spread of contaminated sediments. However, there is the potential for water quality impacts associated with the excavation, oxidisation and subsequent generation of acidic leachate from potential acid sulphate soils which are known to be present in the area. Acidic leachate has the potential to enter the estuary through groundwater migration if not appropriately stored and treated.

4.2.2 Impacts to the local fisheries

The marine footprint of the proposed LNG facility covers an area of 60 ha or so over a distance of 2.5 km along and adjacent to the south-western shore of Curtis Island. The development will result in the direct loss of between 8.75 ha (based on the 2000 seagrass data) and 12.07 ha (based on 2009 seagrass data) of seagrass beds and around 45 to 50 ha of bare substrate from the eastern reaches of the Inner Harbour – Fisherman's and southern Narrows areas. The combined area of Inner Harbour – Fisherman' s and southern-most reaches of The Narrows is around 3,500 ha, so the marine footprint of the proposed facility represents a relatively small (2%) loss of locally available fishing habitat for commercial and recreational fishing activities and a much smaller (0.3 to 0.6%) loss of seagrass area from Port Curtis (see Figure 4-1).

Related issues relevant to local commercial and recreational fishing in the area include loss of access to fishing grounds and the loss of productive fishing habitats.

Available information on local fisheries (see Section 3.2.7) indicates the main commercial fisheries in Port Curtis target mud-crabs in The Narrows and associated tributary creeks and some net fishing for finfish is likely throughout the area, although the areas actual areas fished and fishing intensities are not known. The GPC WBDDP EIS (GPC 2009) documents the potential for impacts on commercial fishers caused by construction of the LNG facility on Curtis Island. Most direct impacts on commercial fishing would result from the implementation of exclusion zones around the LNG facilities and around an increased number of industrial ships accessing the area (GPC 2009). However, commercial fishing entitlements for the mud crab and net fisheries entitle licence holders to fish anywhere on Queensland east coast, so the loss of access to areas contained by the marine footprint is extremely small and potentially inconvenient rather than prohibitive for any affected fishers. Beam trawling is allowed but rarely practiced in Port Curtis and so the proposed facility will not negatively influence the productivity of the local beam trawl fishery.

Recreational fishing is undertaken throughout the Port Curtis zones, Inner Harbour – Fisherman's and The Narrows. The GPC WBDDP EIS reports that many residents of Gladstone value the proximity and access to the sea for recreational fishing and boating activities. There are concerns that proposed developments will limit access to key quality recreational areas (GPC 2009). It is difficult to quantify specific recreational usage of the dredging and reclamation sites, however, data indicates that the Western Basin of Gladstone Harbour is a relatively frequented destination for fishing trips and is often

used as a thoroughfare for fishing destinations in Grahams Creek and The Narrows (Sawknock 2009). Available information indicates that Graham Creek is a reasonably protected and productive area for recreational fishing, particularly for mud crabbing. Loss of access to 60 ha or so of marine habitat adjacent to the western shore of Curtis Island is unlikely to significantly impair fishing opportunities and the availability of fish resources for local recreational fishers. On the basis of existing information, it is unlikely the proposed facility will appreciably impact the extent and success of local fishing operations, both commercial and recreational, nor the availability of fish resources, on which both operations are based.

4.3 Desalination Plant Ocean Outfall

As part of the EIS, an impact assessment was carried out on the individual chemical additives, or their degradation products formed during the desalination process, that are likely to be in the brine waste stream discharged to the receiving environment. The effect of salinity, which is usually the main constituent of brine discharge was examined, however salinity is defined as a physico-chemical characteristic and not a toxicant in the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC/ ARMCANZ 2000).

An assessment of the potential biological effects on the receiving environment from discharge of brine was developed from the findings of an ecotoxicology literature review and relevant material safety data sheets (MSDS). Ecotoxicology data are generally not available for organisms indigenous to waters surrounding the proposed diffuser outlet at Port Curtis. Therefore, data from the international literature, on both marine and (to a lesser extent) freshwater species were examined, as well as some data on native Australian species. For the purpose of this assessment, the anti-scalant assessed was a phosphonic polymer, which is the most widely used anti-scalant in desalination plants around Australia. The toxicity information reported in Table 4-3 relates to the parent chemical unless otherwise stated.

Table 4-3 Ecotoxicology literature review for chemical additives identified in the desalination plant waste stream.

Chemical additive	Degradation product	Toxicity	Use/environmental fate
Sodium hypochlorite	Total Residual Oxidant	Marine fish: 2 spp, 48−96 h LC50 128−250 µg/L (2−8 h/day intermittent to continuous dosing). Chronic NOEC (7 d growth), *Menidia beryllina*, 87−186 µg/L.(1) Marine crustacean: 1 sp, *Mysidiopsis bahia*, 96-h LC50, 73−268 µg/L (2−8 h/day intermittent to continuous dosing). Chronic NOEC (7 d reproduction), *M. bahia*, 20−87 µg/L.(1) Freshwater crustacean: Freshwater crustaceans: 3 species of cladocerans, 24−48 h LC50, 12−160 µg/L. Two 48-h LC50 values were 5 and 6 µg/L, measured under continuous flow of test solution. Chronic NOEC, 10 d immobilisation *Ceriodaphnia dubia*, 48 µg/L (same as acute figures). (1)	Marine growth control. Total residual oxidant refers to Cl_2, HOCl, HOBr, hypochlorite ion OCl^- and hypobromite (OBr^-) in equilibrium. The relative amounts of the different forms in equilibrium are governed by pH, temperature and ionic strength(1)
Polymer flocculants	Remains as polymer (polyquaternary amines)	Flocculants appear to act mainly by acute toxicity, probably by physical blocking and mucous production of gill tissue and adsorption by small invertebrates. (1) Toxicity results range between 100 and 1,000,000 µg/L for fish. As acute effects are reported as low as 10 µg/L, polymer concentrations greater than 1 µg/L may cause environmental harm. (2)	Binds to naturally occurring particulate material in seawater. Polyectrolyte polymer typically used consist of 9-20% N (by weight) and are usually not toxic. May contribute a small additional nitrogen load to the receiving environment. The form of N in these types of polymer are not biologically available as it is chemically inert and bound to flocs (8)
Sulphuric acid	Dissociates into hydronium and sulphate ions	48 h LC50 Flounder 100 to 330 mg/L; 48 h LC50 Shrimp 80 to 90 mg/L; 48 h LC50 Prawn 42.5 ppm. This material may be toxic to aquatic life. (2)	Used for cleaning MF membranes and neutralisation of alkaline waste solutions.
Sodium bisulphite	Sodium and sulphate ions	For sodium sulphate, a range of toxicity data exists. A selection of the lowest effects concentrations includes: Algae were shown to be the most sensitive to sodium sulfate; EC50 120h = 1,900 mg/L. For invertebrates (*Daphnia magna*) the EC50 48h = 4,580 mg/L; and fish appeared to be the least sensitive with a LC50 96h = 7,960 mg/L for *Pimephales promelas* (3). Sea squirt, *Ascidiella scabra*, 24 h LC50 6,400 mg/L (5)	Used for dechlorination i.e. removal of oxidant residual by reducing oxidants. Residual free chlorine in the feedwater will be removed prior to the RO system by dosing with sodium bisulphite. This neutralisation process ultimately produces sodium, chloride and sulphate ions which are common in seawater.
Anti-scalant (phosphinocarboxlic acid)	Carbon dioxide and phosphorus oxides	Phosphinocarboxylic acid: zebrafish: 96 hr LC50 >1000 mg/L. (5) Toxicity of anti-scalants is relatively low. In seawater, the complexing properties of anti-scalants, which are important for inhibiting scale formation, could interfere with natural element cycles. Metal complexes are generally less available for marine organisms than dissolved metal ions, so that uptake of essential nutrients (e.g. iron) or toxic heavy metals (e.g. copper) could be reduced. (6)	Prevent scale formation on membranes. Usually polymeric substances: either polyphosphates, phosphonates, polymaleic acids or polyacrylic acids(6) Some eutrophication related issues have been identified with use of polyphosphates. Toxicity of anti-scalants is relatively low with slow biodegradation rates(6)
Citric acid	Citrate	The product itself and its products of degradation are not toxic. (7)	Organic acid used for membrane cleaning. Hazardous short-term degradation products are not likely. However, long-term degradation products may arise. (7)

(1) Referenced from ANZECC/ ARMCANZ (2000). (2) Material Safety Data Sheet (MSDS) referenced from J.T.Baker. (3) UNEP Publications.http://www.inchem.org/documents/sids/sids/7757826.pdf; (1973). (4) Robinson and Perkins (1977). (5) http://www.gulfengineering.com/msds/wm_msds/g103%20msds.pdf. (7) MSDS referenced from Science Lab. (8) Accepta 2058 MSDS. PolyDADMAC Water and Wastewater Treatment. www.accepta.com. (9) Accepta 2058 MSDS. Pulp and Paper. www.accepta.com. (10) Material Safety Data Sheets. Ciba Specialty Chemicals PLC, 1998.

4.3.1 Salinity

The brine to be discharged is calculated to have a salinity of up to 60 ppt (ppt = g/kg) at the point of discharge. This salinity is approximately 1.9 times the concentration in background seawater, which is normally between 35 to 37ppt. A minimum dilution of 1:50 at a distance of 12.8 m from the diffuser arrangement will be achieved under all conditions (WorleyParsons 2010). The dilution of a combined brine / wastewater discharge would meet the criteria of 1 ppt above ambient salinity, within 12 m under the worst case, and for the majority of the time, 1ppt above background would be achieved less than 2 m from the outfall. Similarly, the major irons, such as sodium, sulphate, magnesium, calcium, chloride will all be present at concentrations below background conditions within 12.8 m from the diffuser arrangement. Modelling results and details of the diffuser location and design are provided in WorleyParsons (2010) (see Australia Pacific LNG Project – Coastal Environment Report).

An extensive literature review was conducted to understand impacts of a brine discharge on the marine environment. The primary concern regarding salinity impacts to organisms relates to physiological changes resulting from osmotic effects. Water will generally pass through membranes from a less concentrated environment to a more concentrated environment, and in the context of marine organisms exposed to hypersaline waters could affect their health by dehydration and associated impairment.

Salinity outside (either higher or lower) of the tolerance range of organisms causes osmoregulatory stress. However, salinity can also be a modifier of toxicity. It generally decreases the toxicity of other toxicants (Chapman *et al.* 2001), such as some metals and organics, by decreasing their solubility (i.e. the 'salting out effect').

Most of the existing literature investigating salinity toxicity is focused on rising salinity in freshwater environments (e.g. Kefford *et al.* 2003; 2004) and changes in osmoregulatory ability under exposure to high heavy metal concentrations (Jones 1975). Salinity tolerances for a range of marine fauna are described in the literature, however much of this relates to tolerance of reduced salinities rather than increased salinities, or hypersaline conditions. Salinity tolerances reported for a range of Australian marine species include the scallop, *Pecten fumatus* (25 to 40 g/L), the pipi, *Plebidonax deltoides*, the flat oyster, *Ostrea angasi* (20 to 45g/L), the blue mussel *Mytilus edulis planulatus* and the Sydney cockle *Anadara trapezia* (15 to 45g/L) (Nell and Gibbs 1986). It is apparent from this that some marine species can tolerate a wide range of salinity changes. Further, the upper threshold concentrations are all greater than the 38 g/L maximum concentration predicted at up to 12.8 m from the diffuser arrangement. As previously mentioned, the negative buoyancy of the plume will cause the brine to sink to the seabed under calm conditions, however, hypersaline conditions will be non–existent within 12.8 m, under these low velocity conditions. It is therefore expected that salinity will not cause unacceptable changes to environmental values beyond a distance of 12.8 m from the point of discharge.

4.3.2 BOD

When large amounts of biomass are degraded by bacteria, the biological oxygen demand (BOD) of the bacteria can deplete the oxygen concentration in the water leading to severe events like fish kills (ANZECC/ ARMCANZ 2000). Low DO concentrations can also result in adverse effects on many aquatic organisms (e.g. fish, invertebrates and microorganisms) which depend upon oxygen for their efficient functioning. The lower limit for DO in the receiving environment is 60% saturation (ANZECC/ ARMCANZ 2000).

Given that the receiving environment within Port Curtis is a well flushed tidal environment, and considering the efficiency of the proposed diffuser arrangement, it is highly unlikely that any far field impacts will be experienced from the BOD loads discharged within the brine. Dissolved oxygen levels are expected to be at saturation levels within 12.8 m from the diffuser arrangement.

4.3.3 Suspended solids

The expected end-of-pipe concentrations of 20 to 40 mg/L of suspended solids are greater than the QWQG threshold of 15 mg/L (DERM 2009). It is expected that other processes such as naturally-occurring flocculation will further reduce the likely concentration of discharged suspended solids with distance from the discharge point. The discharge concentrations are comparable to upper turbidity levels measured in deep waters during the dry season (95th percentiles from 11 to 35 NTU (GPC 2009) and median turbidity's measured in shallow water sites during the wet season, ranging between 10 and 23 NTU (GPC 2009).

Suspended solids will be monitored within the vicinity of the diffuser during operation of the brine outfall, to manage potential smothering and the affects of increased light attenuation in the water column on sensitive marine receptors. To mitigate impacts from high suspended solids loads on the marine environment, any waste materials collected off screens and RO filters will be directed to land fill, rather than into the brine stream discharged into the marine environment.

4.3.4 Sodium hypochlorite

Chlorine in the form of sodium hypochlorite will be dosed intermittently in the intake to prevent marine growth on the internal wall of the intake pipe. Sodium hypochlorite is expected to be dosed at between 4 mg/L and 10 mg/L (reported as chlorine) at the intake structure as is the common practice in other Australian desalination plants. Cleaning solutions with chlorine concentrations up to 500 mg/L may also be used in the pre-treatment process to chemically clean the membranes.

In seawater, the reaction of chlorine with bromine results in the formation of chloride ion and hypobromous acid (HOBr) (ANZECC/ ARMCANZ, 2000). Chlorine degradation products are often referred to as total residual oxidants (TRO), which consist of Cl_2, HOCl, hypochlorite ion (OCl^-) and HOBr, hypobromite (OBr-) in equilibrium, where the relative amounts of the different forms in equilibrium are governed by pH, temperature, salinity and ionic strength.

Sodium hypochlorite (from shock dosing of the intake structures) is normally neutralised with sodium bisulphite before entering the RO process. Similarly, spent hypochlorite cleaning solutions in such circumstances are dosed with sodium bisulphate solution to reduce the oxidant to below detection levels.

Residual oxidant concentrations have been predicted at 0.02 mg/L, at 12.8 m from the diffuser arrangement. This concentration at the edge of the mixing zone is predicted to be above the value of 3 µg Cl/L set by ANZECC/ ARMCANZ (2000) as a low reliability marine trigger for total residual chlorine in the marine environment. ANZECC/ ARMCANZ (2000) notes however, that this value should only be used as an indicative interim working level. The minimum concentration reported to influence toxicity was reported in the marine crustacean *Mysidiopsis bahia*, with a NOEC of 20 µg/L. The concentration predicted at the edge of the mixing zone is comparable to the NOEC levels reported in Table 4-3.

Residual chlorine will be treated to ensure there is zero discharge of any disinfection agents discharged into the surrounding marine environment. This process of dechlorination will also reduce the likelihood that chlorination by-products are formed. By dechlorinating water to control marine growth prior to discharge, there are unlikely to be any significant impacts on the receiving environment from discharge of residual oxidants present in the brine waste stream.

4.3.5 Polyelectrolytes (Polymers)

For the APLNG desalination plant, it is expected that a polymer will be added to the wastewater clarifier. The polymer is likely to be a high molecular weight flocculant. Polymers are soluble in water and quickly and irreversibly bind to naturally occurring dissolved organic carbon and particulate material. Acute toxicity (LC50 values) reported for polymers ranges between 100 µg/L and 1,000,000 µg/L for marine fish (ANZECC/ ARMCANZ 2000). For the APLNG desalination plant, the residual concentration for these compounds is expected to be around 1 mg/L. Likely concentrations at a distance of 12.8 m from the diffusers were calculated to be no greater than 20 µg/L, which is below the lowest reported acute toxicity value of 100 µg/L. The risk of these additives resulting in unacceptable changes to environmental values beyond 12.8 m from the diffuser arrangement is considered negligible.

4.3.6 Sodium bisulphite

The derivatives from sodium bisulphite reaction with chlorination associated with the intake system will increase the salinity of the brine stream by up to 40 mg/L for a short duration every week. The salinity increase is due to increased concentration of sodium, chloride and sulphate ions. Sodium bisulphite is added in excess of the stoichiometric demand and the excess chemical will remove approximately 2 mg/L of oxygen from the brine steam before it is introduced into the ocean.

Sodium bisulphite is also commonly used to neutralise chlorine in the spent chemical cleaning streams associated with the membrane filter. The end products of this reaction are sodium, chloride and sulphate ions contained in a background sodium chloride solution. When this solution is dosed into the brine stream it has the effect of lowering the ion concentration in the brine before it is introduced into the ocean. Considering the comparatively low concentrations of sodium bisulphite derivatives discharged into the receiving environment, it is unlikely that these derivatives will result in any impacts on the receiving marine environment surrounding the diffuser outlet.

4.3.7 Sulphuric acid

Sulphuric acid is used for RO membrane cleaning and to adjust the pH of alkaline waste. The end product associated with the use of sulphuric acid is the sulphate ion at a neutral pH. The pH corrected cleaning solutions are pumped into the brine stream and this has the effect of reducing the concentration of the sulphate ion discharged into the ocean. All end products resulting from the addition of sulphuric acid are benign and present no adverse environmental impact.

4.3.8 Anti-scalant (phosphinocarboxylic acid)

Anti-scalants are added to feedwater after pre-treatment to reduce scaling on the RO membranes. The anti-scalant likely to be used at the APLNG desalination plant is a phosphonate–based compound. The expected maximum anti-scalant concentration in the brine stream is 8 mg/L. Likely maximum concentrations of anti-scalant at 12.8 m from the diffuser arrangement will be up to 160 µg/L for the 1:50 dilution.

The predicted concentrations in the receiving environment are considerably lower than the 96 h LC50 value reported for the zebrafish of >1000 mg/L (see Table 4-2). Toxicity of anti-scalant is considered to be relatively low. The risk from residual phosphonate-based anti-scalant to the receiving environment is considered low.

4.3.9 Citric acid

Citric acid is used in periodic cleaning sequences to remove calcium carbonate and iron deposits from the membranes. The product itself, and its products of degradation, are not considered toxic. The concentrations of the cleaning solutions will be significantly diluted and all wastewater will be neutralised before entering the brine outflow, hence no resulting impacts to the marine receiving environment are anticipated from the use of citric acid.

4.3.10 Summary of impacts

The brine impact assessment has identified the toxicological risks posed by all known compounds in the desalination effluent from the APLNG desalination plant that could be considered as contaminants to the receiving marine environment in the vicinity of the discharge location. The assessment was based on a review of existing information and a limited number of assumptions regarding operational performance of the desalination plant.

Residual oxidant concentrations (chlorine and disinfection by-products) have been predicted to be comparable to the chronic NOEC values, and ANZECC/ ARMCANZ (2000) low reliability trigger value, respectively, at the edge of the mixing zone. All of the residual chlorine will be treated to minimise discharge of disinfection agents into the surrounding marine environment. This process of dechlorination will also reduce the likelihood that chlorination by-products are formed. By dechlorinating water to control marine growth prior to discharge, there are unlikely to be any significant impacts on the receiving environment beyond the edges of the mixing zone (1:50 dilution at 12.8 m), from discharge of residual oxidants or any other residual contaminants present in the brine waste stream.

A register of all chemicals added to the desalination process and likely to be discharged to the receiving environment will be maintained. This register will include the dose rate and load of the addition and a copy of the MSDS for the additive. Assessment should be made of the likely loss and / or removal of any additive during the desalination process and the resulting concentration in the discharge. Environmental toxicity will be assessed if chemicals are changed.

4.4 Impact Assessment – Treated Wastewater Discharges

A semi-quantitative impact assessment was initially conducted as part of the EIS, considering the various chemical additives present within the treated wastewater. Modelling of the near field and far field mixing zones has since been completed, together with the brine discharge and a more detailed quantitative toxicity risk assessment undertaken.

4.4.1 Treated Process and Contaminated Stormwater

The pH of this treated wastewater stream will be slightly more acidic compared to the surrounding seawater. Once this treated wastewater stream mixes with the brine discharge and is then discharged into the marine environment of Port Curtis, any acidity will be quickly buffered from the surrounding seawater environment.

The TSS concentrations of 5 to 10 mg/L, predicted in the treated process and stormwater, are similar to the background TSS concentrations measured in the receiving environment during the dry season. Fixed site turbidity monitoring undertaken during baseline studies for the GPC WBDPP EIS reported median turbidity in deep waters during the dry season ranging from 3 to 9 NTU (GPC 2009).

The TDS concentrations predicted, when mixed with the high ion concentrations present in the brine stream, will markedly increase, prior to discharge. It is likely that once mixed with the brine, the discharge will not be as positively buoyant and most likely will have a greater affinity to readily mix with the surrounding seawater.

The main risk to the marine environment, from the treated process and contaminated stormwater would be from the oily residue present. Oil concentrations were predicted to be 5 to 15 mg/L. It is currently unknown what percentage of this oily discharge is made up of aliphatic and/ or aromatic hydrocarbons and metals, which are traditionally associated with petroleum hydrocarbons.

Oil is less dense than water and is biodegradable. As it floats on the surface of water, a major effect of oil on the environment results from shoreline smothering, unless it is first physically or chemically dispersed (ANZECC/ ARMCANZ 2000). When oil is spilt at sea, the rate of weathering depends on the nature of the oil, water temperature, wave action and use of dispersants. Initial weathering processes depend on spreading of the oil, evaporation, dispersion, formation of emulsions, dissolving of oil and oxidation (ANZECC/ ARMCANZ 2000).

The LC50 values previously reported by Gilbert (1996) reported toxicity of 14 crude and refined oils to fish and invertebrates between 1 and 100 mg/L (48 to 96 h LC50). The lowest LC50 figure to crustaceans was 0.2 mg/L, to the crab *Ocypode quadrata* (ANZECC/ ARMCANZ 2000). There is no trigger value available for oil or total petroleum hydrocarbons. Given however, the lowest LC50 value reported was 0.2 mg/L, a 100 fold dilution would be required, to ensure with some degree of certainty, no acute effects are exhibited beyond the near field mixing zone, which would result in a maximum concentration of 0.15 mg/L at 50 m from the diffuser discharge. Chronic effects to marine organisms beyond the edges of the diffuser (beyond the edges of the mixing zone) however, are considered

likely. Based on the modelling performed, a 1:100 dilution is achieved within 50 m from the outfall, at the maximum flow rate (see **Figure 4.15**). Therefore, no acute impacts from oily residue are expected beyond 50 m from the diffuser discharge. To avoid chronic affects beyond the edge of the mixing zone from the residual oil present in the treated wastewater / brine composite, the residual oil shall be treated prior to discharge into the receiving environment using a dissolved air floatation unit and a tertiary filter and tested prior to discharge.

It should also be noted that dilutions of between 1:4 and 1:2 are expected in-stream from combining of the treated wastewater and brine waste streams. Accordingly, the concentrations predicted at the edge of the mixing zone are likely to be less than the residual concentrations described above.

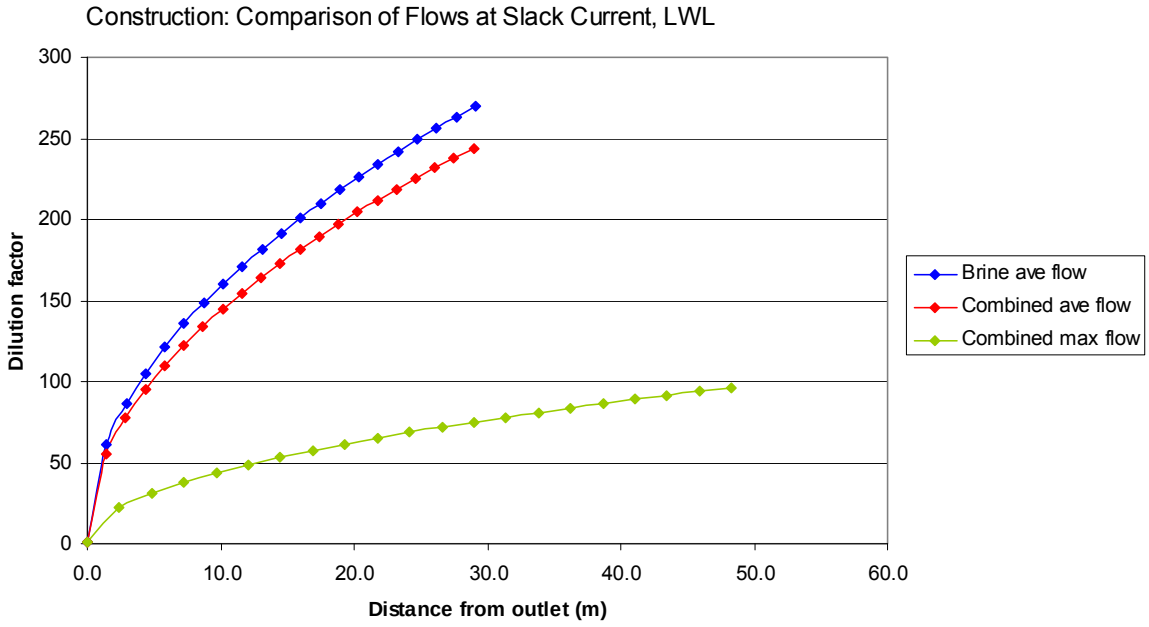

Figure 4-15 Comparison Site: Dilution Curves for a Range of Flow Rates at Low Water Slack (referenced from WorleyParsons Coastal Environment Supplementary Report, LNG Facility 2010).

4.4.2 Treated Sewage

The risk to the marine environment from discharge of treated sewage wastewater is primarily from residual oil, chlorine, nutrient loads and ammonia-N. The risks associated with residual oil are the same as previously mentioned for the treated stormwater, in Section 4.4.1 whereby, a 1:100 dilution is required to ensure that any impacts are localised to as small an area, within the near field mixing zone, as possible. The residual chlorine concentrations of 1 to 2 mg/L predicted in the sewage wastewater are up to two orders of magnitude higher than the lowest reported NOEC data in Table 4-3. Therefore, to limit any impacts to the receiving environment from residual chlorine and the disinfection by-products (i.e. residual oxidants), the composite waste stream will be treated with chemicals such as sodium sulphate prior to discharge.

The ammonia-N concentrations predicted in the treated sewage (1 to 5 mg/L) are considered low enough to ensure the ANZECC/ ARMCANZ (2000) trigger value for ammonia-N of 910 μg/L is satisfied within a few metres from the diffuser array. The lowest NOEC figure reported in the literature is a NOEC (20 d) for sea bream *Sparus auratus* of 3640 μg/L (growth), which suggests that it is unlikely there will be any impacts from residual ammonia-N discharged in treated sewage.

Total nitrogen and phosphorus concentrations of 5 mg/L and 1 mg/L are anticipated within the treated sewage. In combination, there is the potential for increased aquatic plant growth within areas affected by a concentrated discharge plume. It should also be noted that dilutions of between 1:4 and 1:2 are expected in-stream from combining of the treated wastewater and brine waste streams. Accordingly, the concentrations predicted at the edge of the mixing zone are likely to be less than the residual concentrations described above.

4.4.3 Summary of Impacts

Based on the assessment undertaken here, there are unlikely to be any acute impacts on the receiving environment from residual oil, chlorine and nutrients present in the treated wastewater streams beyond the near field mixing zone (beyond 50 m from the diffuser discharge). To mitigate impacts from residual chlorine, as mentioned for the brine discharge, the composite waste stream will be treated with chemicals such as sodium sulphate prior to discharge.

5. Conclusions

The proposed APLNG facility, to be established towards the south-west of Curtis Island near Laird Point, will influence marine ecology locally in two primary ways. Dredging of intertidal and subtidal habitats for construction of the associated facilities will result in the direct clearance of some nearshore communities including areas of saltpan, seagrass and other benthic habitats, and potentially affect marine communities nearby as a consequence of tidal drift and settlement of sediments suspended by dredging operations. Additionally, discharge of concentrated brine and various treated wastewater streams to Port Curtis during desalination plant operation, without appropriate mitigation, may also impact marine communities in the immediate vicinity of the discharge diffuser.

The proposed associated facilities are located within the GBRWHA. Habitat types within the coastal and offshore infrastructure footprint of the LNG facility include intertidal mud flats and rocky shores, mangrove and saltmarsh areas, inter- and subtidal seagrass and sandy seabed areas and also subtidal reef habitats. Benthic communities across Port Curtis vary with substrate characteristics however, macrobenthos in the vicinity of Laird Point consists primarily of deposit feeding bivalves and predatory polychaetes.

Seagrass areas adjacent to the south-western shoreline of Curtis Island and in the area of the proposed desalination plant footprint consist of patches of *Z. capricorni* amongst a light cover of three species of *Halophila*. Intertidal rocky shores with significant oyster cover are also located in the area of the proposed desalination plant footprint. The proposed LNG facility has been designed to avoid a large stand of mangroves on Curtis Island, but will be built over a largely unvegetated saltpan area. The seagrass and mangrove / saltpan habitats contribute nutrients for coastal living resources, which include a diverse and productive fish community in Port Curtis. In spite of the diversity of local finfish resources, mud-crabs appear to provide the mainstay of commercial and recreational fishing activities near Laird Point.

Water quality conditions within Port Curtis are generally good, but can be influenced by tidal state. Temperature, conductivity and salinity values were generally within the range expected for inshore marine waters (as reported from EPA data 1996-2006). Contaminant concentrations in the water column, whilst mostly within ANZECC/ ARMCANZ (2000) guidelines, are elevated compared to those characteristic of pristine coastal waters. Mean concentrations of DGT-labile metals in all zones were at acceptable limits and metal concentrations in oysters were highest in areas subject to anthropogenic influences. Results from integrated monitoring of Inner Harbour Fishermans, in which the proposed associated facilities will be located, indicated a mild departure from reference condition in standardised environmental health ratings.

The proposed associated facilities will require direct removal of around 12.07 ha of seagrass adjacent to the south-western shore of Curtis Island, which represents around 0.3% of the 4000 ha or so of seagrass normally present throughout Port Curtis. It is expected this will have a proportionally small flow-on impact to related secondary productivity in the disturbed area for associated benthic flora and fauna including invertebrates, fish and mammals. However, the availability of similar seagrass habitats in adjacent areas not subject to dredging, will limit the extent of project impacts to seagrass-related communities. These adjacent areas should therefore be managed and maintained during construction and operational activities.

In addition to the loss of seagrass habitat, the area to be dredged (approximately 1.5 Mm^3) is covered by mostly fine, muddy substrates which characteristically have a low abundance and species diversity of benthic assemblages compared with coarser sandy substrate areas. Dredging of non-vegetated, muddy substrate areas will likely have limited impacts to benthic marine communities compared with those that might result from dredging of other, coarser substrate areas.

Dredging activities will also resuspend some dredged sediments which will increase turbidity and which can result in indirect impacts over a broader area to benthic primary producers, such as seagrass beds, through increased light attenuation and possibly by smothering. In order to minimise the potential for indirect, turbidity-related impacts to local seagrass beds where practical dredging activities will be conducted during cooler months, when seagrass meadows are less productive, and over short durations (less than three weeks) in areas adjacent to vulnerable seagrass habitat in order to limit detrimental impacts from increased light attenuation.

Available information on naturally occurring turbidity levels within Port Curtis, combined with modelling results for likely turbidity characteristics and distribution from proposed dredging activities, indicates the potential for light-related impacts to marine communities in the immediate vicinity of the area to be dredged (surrounding the APLNG Dock, from dredging of Construction Docks and the MOF Construction Access areas). However, beyond this immediate zone of expected turbidity-related impact, modelled turbidity levels indicate rapid amelioration to levels comparable with the QWQG (DERM 2009) TSS trigger values and background TSS concentrations. This indicates a limited likelihood of appreciable impacts from increased turbidity over a broader area.

The potential for settlement of suspended material to smother seagrass beds adjacent to APLNG dredging activities will likely be limited to a reasonably small area surrounding the APLNG Dock, adjacent to the western shore of Curtis Island. In isolation this represents a potentially small indirect impact to local seagrass communities. In the event that APLNG dredging is conducted contemporaneously with the proposed GPC WBDDP without appropriate mitigation likely indirect impacts to local seagrass communities are expected to be more severe and extend over a much broader area, including the western reaches of Point Curtis.

Chemical analyses of sediments from areas to be dredged for APLNG MOF installation indicates contaminant levels below NAGD screening levels. Accordingly, there is limited or no potential for contaminant-related impacts to local marine communities from the resuspension and redistribution of dredged sediments. However, potential acid sulphate soils exist in the area and there remains the potential for water quality impacts from the excavation, oxidization and subsequent generation of acid leachate from such soils.

Local fisheries in Port Curtis generally, and specifically towards the southern reaches of The Narrows, are comprised of recreational and commercial activities. Available information indicates the loss of access to the proposed associated facilities area is unlikely to have appreciable consequences for either form of fishing. Additionally, the locally important commercial and recreational use of mud crab resources from The Narrows and Graham Creek are unlikely to be affected by APLNG associated activities owing to maintenance of preferred habitat for mud crabs such as mangrove and sedimentary seabed areas. Similarly, the availability of other locally-popular fish resources are unlikely to be appreciably impacted by installation of the proposed APLNG MOF.

During desalination plant operation, there are unlikely to be any appreciable impacts on the receiving environment, beyond the mixing zone (1:50 dilution achieved at 12.8 m or less), from discharges of residual oxidants or any other residual contaminants present in the discharged brine waste stream.

Furthermore, based on the assessment of treated wastewater streams there are also unlikely to be any acute impacts on the receiving environment from residual oils, chlorine and nutrients beyond the near field mixing zone (beyond 50 m from the diffuser discharge). To avoid chronic affects beyond the edge of the mixing zone from the residual oil present in the treated wastewater / brine composite, the residual oil shall be treated prior to discharge into the receiving environment using a dissolved air floatation unit and a tertiary filter and the wastewater tested prior to discharge To reduce uncertainty regarding actual, as opposed to predicted, risks to the marine environment from proposed marine discharges, WET testing will be undertaken during pre-commissioning, post-commissioning and then annually during operational activities.

Ameliorative measures, such as ensuring freshwater is used efficiently throughout the desalination plant, reduces freshwater demand and hence the volumes of brine and treated wastewater to be discharged. The waste material collected from screens and RO filters should, wherever possible, be re-directed to landfill in order to reduce suspended solids concentrations in the brine stream.

A baseline water quality monitoring program prior to plant commissioning will be implemented to develop an understanding of site specific water quality conditions. Results from such a program will enable site specific water quality objectives to be developed for those water quality parameters that may exceed QWQG WQO's and ANZECC/ ARMCANZ (2000) trigger values, thereby enabling locally appropriate water quality objectives to be applied post-commissioning. This might be appropriate for nutrient parameters, given that nutrient concentrations greater than QWQG objectives and ANZECC trigger values have been previously reported in Port Curtis (GPC 2009). An operational water quality monitoring program will be implemented post-commissioning which includes the following:

- A plume validation study, to validate the results of near-field and far-field modelling exercises
- Conduct routine in-pipe testing for those contaminants and physico-chemical properties addressed within this marine impact assessment and in accordance with any DERM permit requirements
- In the event that concentrations greater than DERM permit discharge limits are reported in-pipe, the fate of those chemicals / physical properties in the receiving environment should be investigated through a relevant approach such as follows:

    1. Investigate the predicted concentrations in the receiving environment using the diffuser modelling and plume validation study. When a predicted concentration at the boundary of the approved toxicity zone exceeds the EPA (2007a) WQO's or relevant ANZECC/ ARMCANZ (2000) trigger values, proceed to step 2
    2. Measure actual concentrations of the contaminant/s of concern in the receiving environment, at or near the approved mixing zone boundary. Water column profiling of salinity should also be conducted to examine actual dilution of the brine and thereby assist in assessing likely residual contaminant concentrations prior to receipt of laboratory test results. If the measured concentrations exceed their respective WQO's or trigger limits, proceed to step 3
    3. Compare measured concentrations with background concentrations at key reference sites. If the measured concentrations exceed background concentrations at or beyond the boundary of the approved mixing zone, proceed to step 4

4. Conduct Direct Toxicity Assessments (DTA) for elevated toxicants. The DTA uses in-pipe brine to determine the likely extent of any toxicity effects beyond the approved mixing zone boundary. If toxicity is considered likely beyond the approved toxicity zone and there is uncertainty regarding the contaminant/s causing the observed toxicity, proceed to step 5
5. Implement a Toxicity Identification Evaluation to determine the contaminant/s likely to be causing toxicity beyond the approved mixing zone boundary. Other studies, such as sediment and biota (infauna) investigations may be necessary to examine whether the potential toxicity is impacting on the Port Curtis marine environment

As part of the receiving environment monitoring program, increases in light attenuation in the water column and potential for smothering will be monitored within the vicinity of any marine environmental receptors. Seagrass has recently been documented adjacent to the southwest reaches of Curtis Island and around North Passage Island (Rasheed *et.al.* 2008), and therefore, seagrass meadows present beyond the near-field mixing zone should be managed accordingly.

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