Gladstone Ports Corporation

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Chapter 7 – Coastal Environment

GHD

7. Coastal Environment

Overview

This chapter provides information on marine water and sediment quality, coastal processes and Matters of National Environmental Significance for the immediate Project Area and surrounds in accordance with Section 3.5 Coastal Environment of the ToR (refer Appendix A). Matters of National Environmental Significance (Section 3.5.3 of the ToR) are addressed in Chapter 9 (Nature Conservation) as they are mainly related to terrestrial and marine ecology, which are discussed in Chapter 9.

Baseline information on water and sediment quality within the Project Area has been summarised. These data have been sourced from previous studies in the area as well as specific studies undertaken for this EIS. The detailed water and sediment quality reports are provided in Appendix K and Appendix L respectively. A detailed coastal processes report is provided in Appendix M.

Hydrodynamic and water quality modelling was undertaken to inform the discussion of potential impacts of dredging and reclamation on water quality and coastal processes in the Project Area (Appendix J). An assessment of the subsequent potential impacts on seagrass, mangrove and benthic habitats is provided in Chapter 9. Monitoring and mitigation measures for the construction and operational phases of the project are recommended based on the assessment of potential impacts.

Legislation

Environmental values are described for the potentially impacted area in accordance with environmental legislation and associated statutory instruments, including the requirements of the State Coastal Plan and Curtis Coast Regional Coastal Management Plan (EPA 2003), the *Coastal Protection and Management Act* 1995, and the *Environment and Protection and Biodiversity Conservation Act, 1999*.

7.1 Marine Water Quality

A detailed Water Quality report is provided in Appendix K. The Water Quality report also includes a summary of available water quality data for the Project Area and surrounding areas. This section of the EIS focuses on addressing Section 3.5.1 of the ToR as it relates to the water quality within the Project Area (Appendix A). The water quality impact assessment has informed the discussion of potential impacts of this project on the nature conservation values of the Project Area, which are further discussed in Chapter 9. This section focuses on marine water quality, with surface waters and groundwater being discussed in Chapter 8.

7.1.1 Description of Environmental Values

Water Quality Environmental Values

The environmental values of an area are determined by the existing beneficial uses of that area including conservation values and significance, human uses and spiritual and cultural significance. To determine the water quality parameters that are relevant to an area it is important to establish the existing condition and use of the area. Various water types within the Project Area have been identified on the basis of the classification system in the Queensland Water Quality Guidelines 2006 (QWQG 2006), Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC

2000), and by information in both the State Coastal Plan – Queensland's Coastal Policy (State Coastal Plan) and the Curtis Coast Regional Coastal Management Plan (Curtis Coastal Plan, EPA 2003) for coastal resource types. The Project Area is located within the Central Coast region and the relevant water type is inshore marine waters (QWQG 2006). The coastal resources (as listed in the Coastal Plans) that require consideration for the project include coastal wetlands, soft-bottom (benthic) systems, mid-water column (pelagic) systems, coastal and estuarine waters, indigenous traditional owner cultural resources, and cultural sites. Whilst not all the coastal resources listed are necessarily water types, many align with the water types listed in the QWQG (2006) and therefore, are assessed with those parameters.

The Environmental Protection Act 1994, Section 9, defines 'environmental value' (EV) as:

> *(a) a quality or physical characteristic of the environment that is conducive to ecological health or public amenity or safety; or*
>
> *(b) another quality of the environment identified and declared to be an environmental value under an environmental protection policy or regulation.*

Environmental values have been extracted from the Environmental Protection (Water) Policy 1997 (EPP (Water)), the State Coastal Plan and Curtis Coastal Plan for this project and are discussed in the following sections and summarised in Table 7-1.

Environmental Protection (Water) Policy 1997

The *Environmental Protection (Water) Policy 1997* (EPP (Water)) is subordinate legislation to the Environmental Protection Act 1994 and applies to all Queensland waters. As stated in the EPP (Water), section 6:

The purpose of this policy is to be achieved by providing a framework for—

> *(a) identifying environmental values for Queensland waters; and*
>
> *(b) deciding and stating water quality guidelines and objectives to enhance or protect the environmental values; and*
>
> *(c) making consistent and equitable decisions about Queensland waters that promote efficient use of resources and best practice environmental management; and*
>
> *(d) involving the community through consultation and education, and promoting community responsibility.*

Part 3, section 7 of the policy states:

(1) The ***environmental values*** *of waters to be enhanced or protected under this policy are:*

> *(a) for a water in schedule 1, column 1—the environmental values stated in the document opposite the water in schedule 1, column 2; or*
>
> *(b) for another water—the qualities in subsection (2).*

(2) For subsection (1)(b), the qualities are—

> *(a) for high ecological value waters—the biological integrity of an aquatic ecosystem that is effectively unmodified or highly valued; and*

(b) for slightly to moderately disturbed waters—the biological integrity of an aquatic ecosystem that is affected adversely to a relatively small but measurable degree by human activity; and

(c) for highly disturbed waters—the biological integrity of an aquatic ecosystem that is measurably degraded and of lower ecological value than waters mentioned in paragraph (a) or (b); and

(d) suitability for—

(i) primary recreational use; or

(ii) secondary recreational use; or

(iii) visual recreational use; and

(e) suitability for minimal treatment before supply as drinking water; and

Note—

For guidelines that apply to water after it has been treated or is to be used for drinking, see—

(a) the guidelines about drinking water published by Queensland Health; or

(b) the document called 'Australian drinking water guidelines 2004', developed by the National Health and Medical Research Council and the Natural Resource Management Ministerial Council.

(f) suitability for agricultural use; and

(g) suitability for aquacultural use; and

(h) suitability for producing aquatic food for human consumption; and

(i) suitability for industrial use; and

(j) the cultural and spiritual values of the water.

(3) However, if a natural property of the water precludes enhancement or protection of a particular environmental value, subsection (1)(b) does not apply to the value.

(4) For subsection (1)(a), a document is taken to state environmental values for a water if it states one or more values (however described) that are equivalent to a quality or qualities in subsection (2)

(5) In this section—

***cultural and spiritual values**, of a water, means places, objects, or uses, in or near the water, that have anthropological, archaeological, historic, sacred or scientific significance or value.*

***primary recreational use**, of a water, means full body contact with the water, including, for example, diving, swimming, surfing, waterskiing and windsurfing.*

***secondary recreational use**, of a water, means contact other than full body contact with the water, including, for example, boating and fishing.*

***visual recreational use**, of a water, means viewing the water without contact with it.*

Marine waters in the Port Curtis area are not included in schedule 1 of the EPP (Water), therefore, environmental values and water quality objectives need to be derived in accordance with the Queensland Water Quality Guidelines (QWQG) (2006).

In accordance with the QWQG (2006), the aquatic ecosystem condition is assessed as a Level 2 - Slightly to moderately disturbed ecosystem where the ecosystem has previously been "…adversely affected to a relatively small but measurable degree by human activity" and is "…immediately adjacent to metropolitan areas". Water quality trigger values are therefore, those that are defined for Level 2 waters.

State Coastal Management Plan

The State Coastal Management Plan — Queensland's Coastal Policy describes management requirements for the Queensland coastal zone and has statutory effect under the *Coastal Protection and Management Act 1995* (Coastal Act 1995). The Coastal Act defines 'Coastal Zone' in section 15 as:

> *(a) coastal waters; or*
>
> *(b) all areas to the landward side of coastal waters in which there are physical features, ecological or natural processes or human activities that affect, or potentially affect, the coast or coastal resources.*

Major values and pressures for Queensland's coastal resources are tabulated in the State Coastal Plan and these 'values' could also be categorised as 'environmental values' in accordance with the definition provided in the *Environmental Protection Act 1994*, section 9(a), as they have "a quality or physical characteristic of the environment that is conducive to ecological health, public amenity or safety". Consequently, 'values' potentially relevant to this project have been extracted from the State Coastal Plan for a range of coastal resources such as for coastal wetlands, soft-bottom (benthic) systems, mid-water column (pelagic) systems, coastal and estuarine waters, indigenous traditional owner cultural resources, and cultural sites.

Curtis Coast Regional Coastal Management Plan

Like the State Coastal Plan, the Curtis Coastal Plan is also a statutory instrument under the Coastal Act 1995. The Curtis Coastal Plan identifies the coastal management district for the Curtis Coast region, addresses matters of international, national, state or regional importance within the region, and provides direction on future development and land management decisions in the coastal zone. As previously stated for the State Coastal Plan, the values tabulated in the Curtis Coastal Plan can be considered environmental values as defined in the *Environmental Protection Act 1994*. Environmental values associated with water quality, extracted from the Curtis Coastal Plan, are also provided in Table 7-1 for coastal resources such as coastal wetlands, mid-water column (pelagic) systems, coastal and estuarine waters, indigenous traditional owner cultural resources, and cultural sites. The coastal resource "*soft-bottom (benthic) systems*" is not included in the Curtis Coastal Plan, however, there are potential impacts on benthic marine biota that may occur as a result of the project and as such, consideration is given to this environmental value.

Summary of Environmental Values

A summary of environmental values, as determined from information contained in the QWQG (2006), State Coastal Plan, Curtis Coastal Plan and from existing data, is presented in Table 7-1. The QWQG (2006) recommends default guidelines for use when no Queensland guidelines are available for a range of environmental values. Where the levels of water quality indicators differ for the protection of the different environmental values, the most stringent indicator should be applied to protect identified environmental values.

Table 7-1 Environmental Values and Applicable Water Quality Guidelines for Coastal Waters within the Project Area

Environmental Values	Information Source	Management Goal	Applicable Water Quality Guidelines
Modified aquatic ecosystem	EPP (Water)	Maintain biological integrity of system where the water quality is not pristine (EPP(Water)) and it is a Level 2-slightly to moderately disturbed ecosystem (QWQG 2006).	QWQG (2006)[a] ANZECC (2000)[b], Ch 3 – Aquatic ecosystems Toxicants in water, sediment and biota as per ANZECC (2000) (QWQG 2006) Release of sewage from vessels to be controlled in accordance with requirements of the *Transport Operations (Marine Pollution) Act and Regulations 1995* (QWQG 2006) Comply with Code of Practice for Antifouling and in-water Hull Cleaning and Maintenance, ANZECC (2000) (QWQG 2006)
Recreational uses Also as scenic and recreational amenity in coastal plans	EPP (Water) State Coastal Plan Curtis Coastal Plan	Meet guideline values for primary contact, secondary contact and visual use recreational activities	Guidelines for Managing Risks in Recreational Water (2008)[c] ANZECC (2000), Ch 5 – Guidelines for recreational water quality and aesthetics
Industrial uses	EPP (Water)	Water quality requirements for industry vary and the ANZECC (2000) do not provide guidelines to protect industrial water use and these are assessed on a case-by-case basis. In any case, the industrial use of marine water shall not compromise marine environment water quality such that existing aquatic ecosystem environmental values shall be protected.	Code of Practice for antifouling and In-water Hull Cleaning and maintenance *Transport Operations (Marine Pollution) Act and Regulations 1995*

Environmental Values	Information Source	Management Goal	Applicable Water Quality Guidelines
Human consumer	Local knowledge	Food grown and or caught in the environment meets human consumption guidelines as provided in the FDFA Guidelines.	ANZECC (2000)[d] Guidelines as per ANZECC (2000) and Food Standards Code, Australia New Zealand Food Authority 1996 and updates (QWQG 2006)
Wetland[e]	Directory of Important Wetlands	Meet guidelines where possible or not lead to a deterioration of water quality values.	ANZECC (2000), Protection of slightly disturbed aquatic ecosystems. TVs for physical and chemical stressors, salinity and turbidity in Tropical Australia (Table 3.3.4 and 3.3.5 in ANZECC)
Indigenous traditional owner cultural resources and values[f]	State Coastal Plan Curtis Coastal Plan	Protect or restore Indigenous and non-Indigenous cultural heritage consistent with relevant policies and plans (QWQG 2006).	
Habitat for native and migratory animals	State Coastal Plan Curtis Coastal Plan	Protect habitat for native and migratory animals. Meet guidelines were possible or not lead to a deterioration of water quality values.	ANZECC (2000), Protection of slightly disturbed aquatic ecosystems.
Habitat for native plants	State Coastal Plan Curtis Coastal Plan	Protect habitat for native plants. Meet guidelines were possible or not lead to a deterioration of water quality values.	ANZECC (2000), Protection of slightly disturbed aquatic ecosystems.
Nursery habitat	State Coastal Plan Curtis Coastal Plan	Protect habitat for fish nursery purposes. Meet guidelines were possible or not lead to a deterioration of water quality values.	ANZECC (2000), Protection of slightly disturbed aquatic ecosystems.
Fishing	State Coastal Plan Curtis Coastal Plan	Protect environment for fishing purposes. Meet guidelines were possible or not lead to a deterioration of water quality values.	ANZECC (2000), Protection of slightly disturbed aquatic ecosystems.
Localities for maritime infrastructure	State Coastal Plan Curtis Coastal Plan	Localities be utilised for maritime infrastructure requirements as and where appropriate.	No applicable guidelines

a. Queensland Water Quality Guidelines (2006) prepared by the Environmental Protection Agency, Queensland Government.

b. Australian and New Zealand Guidelines for Fresh and Marine Water Quality (2000) prepared by the Australian and New Zealand Environmental and Conservation Council (ANZECC) and the Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ).

c. Guidelines for Managing Risks in Recreational Water (2008) prepared by NHMRC, Australian Government.

d. Australia New Zealand Food Standards Code (2000).

e. The Port Curtis Wetland (QLD019) is listed on the Directory of Important Wetlands and includes all tidal areas in the vicinity of Gladstone, from a line between Laird Point and Friend Point (southern end of The Narrows), to a line between Gatcombe Head and Canoe Point, including the seaward side of facing Island and Sable Chief Rocks, and southern Curtis Island west of a line between North Point an Connor Bluff (DEWHA 2008a)

f. Indigenous traditional owner cultural resource values - (significant animals, fishing practices, spiritual significance, cultural significance, economic significance, self determination, knowledge systems)

Water Quality Guidelines

An overview of the applicable water quality guidelines in QWQG (2006) and ANZECC (2000) for the protection of identified environmental values is provided in this section.

The QWQG (2006) provides information on guideline development with the concept of an acceptable departure from a natural or reference condition. With this approach, criteria from a reference site are used as indicators of physico-chemical, biological and habitat characteristics. However, this monitoring method is unsuitable for this project because adjacent sites for which there is data available do not comply with reference site criteria, namely:

- No significant point-source wastewater discharge within the estuary or within 20 km upstream; and
- No major urban area (>5000 population) within 20 km upstream.

The QWQG (2006) regional guideline values for physico-chemical indicators in the Central Coast region and water types identified in the Project Area are summarised in Table 7-2.

The ANZECC (2000) guidelines are also provided in Table 7-2 where the QWQG (2006) indicate that they must be followed. The ANZECC (2000) guidelines do not have specific values for Central Queensland, but rather present guidelines for south east Australia and tropical Australia. Central Queensland is geographically positioned between these two regions, but for the purposes of this EIS the Tropical Australian guidelines are adopted because of the sub-tropical (versus temperate) character of the coastal waters. Where the ANZECC (2000) guidelines are used, they are referenced with the system of guideline 'trigger values'. 'Trigger values' are defined in ANZECC (2000) as:

"…concentrations that if exceeded, would indicate a potential environmental problem, and so 'trigger' a management response, e.g. further investigation and subsequent refinement of the guidelines according to local conditions".

'Trigger values' are default guideline values to provide an appropriate level of low-risk protection against chronic exposures. As these data are not based on objective biological criteria or specificity, *"…default trigger values should only be used until site or ecosystem-specific values can be generated"* (ANZECC 2000).

'Trigger values' for metals and metalloids in marine water for slightly-moderately disturbed systems are provided in Table 7-3 for the recommended level of protection for aquatic ecosystems, in accordance with requirements set out in Table 3.4.1 of ANZECC (2000). For metals and metalloids that have the potential to bioaccumulate or where 95% protection levels provide inadequate protection, a 99% protection level is recommended in ANZECC (2000). For some metals and metalloids, there are insufficient data available for a trigger value to be derived. No trigger values are available for Aluminium, Antimony, Arsenic, Beryllium or Iron.

Indigenous traditional owner cultural resources and cultural sites were identified as environmental values in the State and Curtis Coastal Plans, however there are no water quality guidelines for the protection of these values. Instead, Indigenous interests are recognised and managed through native title and cultural heritage legislation.

Table 7-2 Guidelines for Physico-chemical Indicators in Central Queensland Waters

Central Region Water Type	Enclosed coastal (QWQG 2006)	Marine Inshore Waters (Tropical Australia) (ANZECC 2000)
pH	8.0 – 8.4	8.0 – 8.4
Turbidity (NTU)	6	1 – 20
Secchi depth (m)	1.5	-
Suspended Solids (SS) (mg/L)	15	-
Dissolved Oxygen (DO) (% sat)	90 – 100	90 – no data
Ammonia as N (µg N/L)	8	1 – 10
Oxidised Nitrogen as N (µg N/L)	3	-
Organic Nitrogen (µg N/L)	180	-
Total Nitrogen as N (µg N/L)	200	100
Filterable Reactive Phosphate as P (µg P/L)	8	5
Total Phosphorus as P (µg P/L)	25	15
Chlorophyll-a (µg/L)	4	0.7 – 1.4

Table 7-3 Trigger Values for Metals and Metalloids in Marine Water for Slightly to Moderately Disturbed Systems (ANZECC 2000)

Metals and Metalloids	TV for Marine Water (µg/L)	Level of Protection (% species)
Ammonia	910	95
Cadmium	0.7	99
Chromium (Cr III)	27.4	95
Chromium (Cr VI)	4.4	95
Cobalt	1	95
Copper	1.3	95
Lead	4.4	95
Mercury (inorganic)	0.1	99
Nickel	7	99
Silver	1.4	95
Tributyltin (as Sn)	0.006	95
Vanadium	100	95
Zinc	15	95

Previous Studies of Water Quality of Port Curtis

A detailed review of previous water quality studies in the vicinity of the Project Area between 1995 and 2009 is provided in Appendix K. A summary of this review is provided in Table 7-4 with turbidity and light attenuation discussed in greater detail in the following sections.

In the proposed Project Area, pH generally complies with guidelines ranging from pH 7.0 to pH 8.5. However, total suspended solids and nutrient levels are variable and frequently exceed ANZECC (2000) and QWQG (2006) guidelines. Metals, although frequently monitored in recent studies, have often not been analysed to the required detection levels below guideline values to allow assessment, and therefore results are inconclusive. However, some studies have shown that metals in the area have exceeded guidelines for the protection of aquatic ecosystems, in particular cadmium, nickel, cobalt, chromium, copper, silver and zinc.

Table 7-4 Summary of Water Quality Results Extracted from Previous Studies

Parameter	General Findings
pH	pH measurements for waters in the vicinity of the proposed project were: ◗ Mostly within range of pH 7.0 and pH 8.5 and generally, around pH 8 ◗ Fisherman's Landing adjacent to dredge head (pre-dredging): pH 7.7 – 8.2 ◗ Fisherman's Landing on northern seagrass meadow (pre-dredging): pH 7.6 – 8.1
Total Suspended Solids (TSS)	Generally, tidal movements affected TSS and higher levels were found in shallower areas due to resuspension of bottom sediments. Results for total suspended solids in the vicinity of the proposed project included: ◗ Intertidal areas adjacent to Wiggins Island and Mud Island: TSS – 30.5 and 55 mg/L for May and September periods respectively ◗ Flying Fox Creek: TSS 57 mg/L during dry season ◗ Sandfly Creek: TSS 44 mg/L during dry season ◗ Fisherman's Landing reclamation site: TSS averaged 29 mg/L
Nutrients	Nutrients previously measured in the vicinity of the proposed project include total phosphorus and total nitrogen. Values from past studies include: ◗ Shipping channels near Tide Island and South Passage respectively: TP 0.02 and 0.01 mg/L; TN <0.2 and 0.6 mg/L ◗ Fisherman's Landing reclamation site 2008: TN and TP substantially exceeded guidelines for 13 sites sampled; FRP exceeded guideline for 11 out of 13 sites sampled

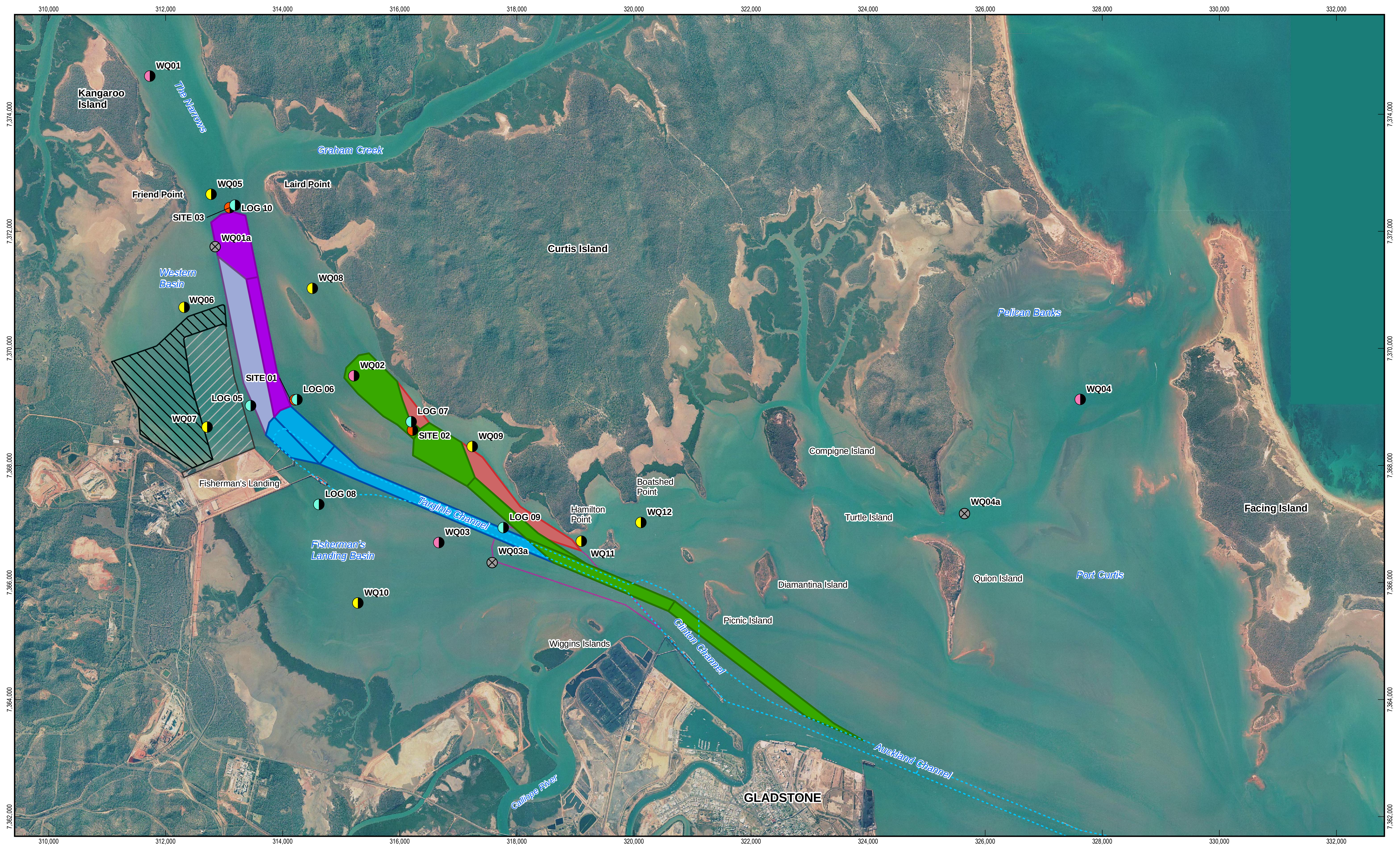
Parameter	General Findings
Metals	The following results were recorded for nickel, cobalt, silver, chromium, copper and zinc at various sites: ◗ Nickel levels were greater than the TV at many sites of past studies inclusive of the shipping channel near South Passage Island, Fisherman's Landing (NE edge of ship turning circle), Targinie Creek (middle reaches and at mouth), Boat Creek, Flying Fox Creek, Nutmeg Creek and Calliope River ◗ Cobalt, chromium and copper levels were measured as greater than the TV in the creeks in the vicinity including Boat Creek, Flying Fox Creek and Nutmeg Creek ◗ Silver exceeded the TV in Boat Creek and Flying Fox Creek ◗ Zinc exceeded the TV at Flying Fox Creek and Nutmeg Creek and was compliant to the 95% protection guidelines for the ANZECC (2000) at the Fisherman's Landing sites monitored

Baseline Water Quality Methods

A baseline water quality monitoring program was undertaken in Gladstone Harbour as part of the Western Basin EIS. The program will involve six months of data collection (of which four months of monitoring have been undertaken) from the following two sources with spatial locations provided in Figure 7-1:

- Fixed water quality loggers at 10 locations provided by James Cook University (JCU); and
- Monthly vessel-based monitoring of *in situ* water quality measurements and collection of samples for laboratory analysis of water quality parameters at 12 locations.

The monitoring program also included a survey of elutriate water quality in the proposed water quality sampling areas collected by QGC and provided by GPC for use in this EIS in raw excel format. In the next section the methodology for the baseline water quality monitoring program is described.



1:60,000 (at A3)

0 0.5 1 1.5 2

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Grid: Map Grid of Australia 1994, Zone 56

N

LEGEND

- ADCP Site
- Sample Location
- WQ Logger and Sample Location
- WQ Logger
- WQ Logger - Temp Site
- Western Basin Reclamation Area
- Fisherman's Landing Northern Expansion
- Existing Channels, Swing Basins and Berths
- Wiggins Island Coal Terminal (Approved)
- Stage 1A - North China Bay LNG
- Stage 1B - Fisherman's Landing LNG
- Stage 2 - Laird Point LNG
- Stage 3 - Fisherman's Landing
- Stage 4 - Hamilton Point

GHD GPC

Port of Gladstone
Western Basin Dredging and Disposal Project

Location of Fixed Water Quality Loggers and Vessel-based Water Quality Stations

Job Number	42-15386
Revision	A
Date	1 Sep 2009

Figure 7-1

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Level 4 201 Charlotte Street Brisbane QLD 4000 Australia T +61 7 3316 3000 F +61 7 3316 3333 E bnemail@ghd.com W www.ghd.com

Water Quality Loggers

Reference should be made to Section 4.2 in Appendix K for more detail on the methodology used in relation to the water quality loggers.

Locations

At the onset of the monitoring program, fixed *in situ* water quality loggers were deployed on the seabed at four locations as shown in Figure 7-1. Vessel-based water quality monitoring with a multi-parameter probe and water sample collection for subsequent laboratory analysis, was carried out at twelve locations (i.e. sites WQ01 to WQ12) of which the first four corresponded with the fixed logger deployments (Figure 7-1).

Six additional water quality loggers (i.e. locations Logger05 to Logger10) and three ADCPs were deployed for approximately 2 months to aid in calibration of the hydrodynamic model. Further, monitoring of the turbidity plume generated by dredging from the Wombat cutter suction dredge was also carried out over this EIS data collection period by WBM and GHD. Turbidity data from both these monitoring programs has been incorporated into the current EIS (Appendix K).

Vessel-Based Water Quality Monitoring

Overview, Dates and Locations

Vessel-based monitoring and water sample collection was conducted to coincide with the maintenance and data download regime for the fixed loggers. Two forms of data were collected during vessel-based monitoring, namely *in situ* physico-chemical parameters and water samples for laboratory analysis. Samples were collected from the twelve water quality monitoring sites throughout the Project Area (Figure 7-1). On the first sampling date (20 April 2009) only four stations were sampled, but subsequent monthly sampling required two days to complete the monitoring program of twelve stations (Table 7-5 and Figure 7-1).

Table 7-5 Vessel-based Water Quality Monitoring Dates and Site Locations (Figure 7-1)

Sampling Event	Date	Sampling Locations
1	20 April 2009	WQ01, WQ02, WQ03, WQ04
2	21 May 2009	WQ01, WQ04, WQ05, WQ08, WQ10, WQ11, WQ12
3	26 May 2009	WQ02, WQ03, WQ06, WQ07, WQ09
4	23 June 2009	WQ02, WQ03, WQ04, WQ08, WQ10, WQ11, WQ12
5	24 June 2009	WQ01, WQ05, WQ06, WQ07, WQ09
6	27 July 2009	WQ02, WQ03, WQ04, WQ08, WQ10, WQ11, WQ12
7	28 July 2009	WQ01, WQ05, WQ06, WQ07, WQ09
8	17 August 2009	WQ0,1 WQ02, WQ05, WQ08, WQ09, WQ10, WQ11, WQ12
9	18 August 2009	WQ04, WQ06, WQ07
10	19 August 2009	WQ03

Water Quality Grab Samples

Water quality sampling was undertaken in accordance with the appropriate guidelines and standards (Appendix K). Water samples were collected in laboratory supplied containers at each monitoring station and two sites were randomly sampled to provide quality assurance samples from approximately 0.2 m below the water surface.

The following water quality parameters were recorded on a monthly basis:

- Dissolved metals and metalloids (Aluminium, Antimony, Arsenic, Barium, Beryllium, Cadmium, Chromium, Cobalt, Copper, Iron, Lead, Manganese, Mercury, Nickel, Silver, and Vanadium);
- Nutrients (Ammonia, Nitrate, Nitrite, Total Oxidised Nitrogen, Total Kjeldahl Nitrogen, Total Nitrogen, Reactive Phosphorus, Total Phosphorus);
- Total Dissolved Solids (TDS);
- Chlorophyll-*a*;
- Total Suspended Solids (TSS);
- pH; and
- Electrical Conductivity.

The following water quality parameters were monitored during the initial round of sampling, and on an ongoing basis if concentrations were found to be above the limits of reporting:

- BTEX(Benzene, Toluene, Ethylbenzene, and Xylenes (3));
- Fungicide (one species);
- Herbicides (nine species);
- Organochlorine pesticides (twenty-six species);
- Organophosphorus pesticides (twenty species);
- Trybutyltin,
- Polycyclic aromatic hydrocarbons (PAHs) and Phenols (twenty-nine species);
- Phenoxy acid herbicides (fourteen species);
- Phenoxyacetic acid herbicides (two species);
- Cyanide;
- Total petroleum hydrocarbons (TPHs) (five species); and
- Volatile organic compounds (VOCs) (three species).

Elutriate Water Quality Monitoring

When dredge material is released into the natural environment, pollutants present in the pore water can be released into the water column. Elutriate water quality testing is used to estimate the water quality impacts of the release of dredge spoil. The elutriate water quality testing was undertaken by QGC, with a full description of the methodology described in the Queensland Curtis Pre-Dredging Assessment Plan (Sampling and Analysis Plan) (2009).

Samples were analysed for the following categories of water quality:

- Ammonia;
- Seventeen metals and metalloids;
- Hexachlorobenzene;
- Organochlorine pesticides (twenty-five species);
- Organophosphorus pesticides (nineteen species);
- PAHs and Phenols (eighteen species);
- Polychlorinated Biphenyls (eight species); and
- Semi-VOCs (6 species).

Baseline Water Quality Results

Rainfall

Figure 7-2 shows the rainfall recorded at Gladstone Airport during 2009. Little rainfall was recorded during the baseline data collection period though 74.4 mm was recorded on 5 April approximately two weeks prior to the initial field sampling event and deployment of loggers.

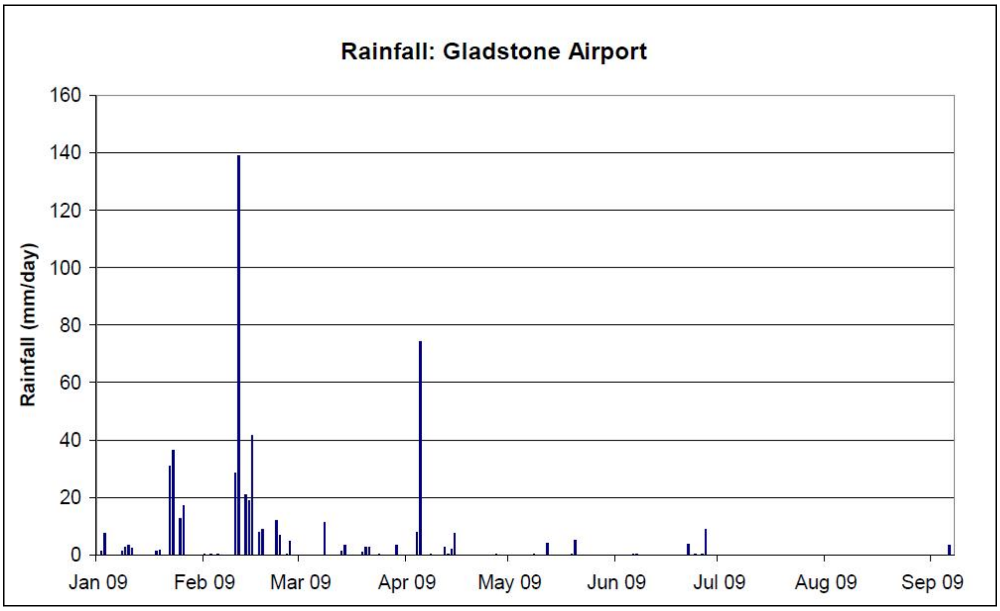


Figure 7-2 Rainfall Recorded at Gladstone Airport in 2009

In Situ Physico-Chemical Profiling

The following sections provide an overview of the spatial and temporal trends of *in situ* physico-chemical water quality recorded as part of the monthly vessel-based water quality monitoring program.

Temperature

There are no applicable temperature guidelines in QWQG (2006) or ANZECC (2000). Median values of multiple measurements at each of three depths (near-surface, mid-depth, near-bottom) at each of the twelve sampling sites over the four (WQ05-WQ12) to five (WQ01-WQ04) months had the following patterns:

- Temperatures were almost always homogeneous through the water column at each station. There were several exceptions, where for example, during May 2009 at WQ01 and WQ05 the bottom waters were 0.2-0.5˚C cooler than the mid- and near surface waters; and
- Generally, temperatures were cooling over the 4 months from 26˚C in April to 19-20˚C in July, with the initiation of heating of water in September.

Electrical Conductivity

There are no applicable electrical conductivity (or salinity) guidelines in the QWQG (2006) or ANZECC (2000). Medians at three depths (near-surface, mid-depth, near-bottom) at each of the twelve sampling sites over the four (WQ05-WQ12) to five (WQ01-WQ04) months had the following patterns:

- Electrical conductivity was almost always homogeneous through the water column at each station. There are several exceptions, where for example, during May 2009 at WQ01 and WQ03 the bottom waters were 1 mS/cm more saline than the mid- and/or near surface waters; and
- Generally, electrical conductivity increased across the Western Basin over the 4 months from 53-54 mS/cm in May to 55-56 mS/cm in August. Presumably, this is simply a function of reduced freshwater inputs relative to the wet season, thereby nearing typical ocean values as well regional evapo-concentration over the course of the dry season.

pH

The QWQG (2006) guideline for pH in a Central Coast Region for an enclosed coastal area has a lower limit of 8.0 and an upper limit of 8.4. Medians at three depths (near-surface, mid-depth, near-bottom) at each of the twelve sampling sites over the four (WQ05-WQ12) to five (WQ01-WQ04) months indicate the following:

- For the most part, pH was homogeneous through the water column at each station. There are several exceptions, where for example, during May 2009 at WQ03 and WQ04 where the pH of the near-bottom measurements were lower than at the surface;
- Generally, pH followed similar temporal patterns across all of the stations with elevated pH during May and August and lower pH during June and July; and
- Over the four sampling events, only during the August sampling event were all sites and depths within the lower and upper guidelines. The four stations sampled during the May event were nearly within the guidelines, but the June and July events were well below the lower guideline value of 8.0 (ca. <7.5).

Dissolved Oxygen

The QWQG (2006) guideline range for DO saturation consists of upper and lower guideline values of 90% and 100%, respectively. Medians of multiple measurements at three depths (near-surface, mid-depth, near-bottom) at each of the twelve sampling stations over the four (WQ05-WQ12) to five (WQ01-WQ04) months are summarised as follows:

- DO saturation was generally in the range of 80 – 100%, and generally highest at the surface;
- Deviations below and above the 90%–100% guideline were common, but generally in 75-110% range; and

- Where differences were observed in DO saturation levels between the surface, middle and bottom of the water column, measurements at the surface were generally higher than middle, which was in turn greater than the bottom.

Turbidity

The QWQG (2006) turbidity guideline for an enclosed coastal area of the Central Coast Region is 6 NTU, while the ANZECC (2000) turbidity guideline range for tropical Australian estuarine and marine waters is 1–20 NTU. The *in situ* turbidity data can be summarised as follows:

- The *in situ* dry season turbidity ranged approximately up to 30 NTU. Generally, turbidity at the surface was lower than or near to levels at the bottom of the water column;
- It is not possible to make conclusions about the temporal turbidity dynamics of the area with this dataset because turbidity varies over short time-scales, and this data has a monthly frequency;
- No significant rainfall events occurred within several weeks of these monthly turbidity measurements;
- With the exception of station WQ04, turbidity generally exceeded the QWQG (2006) guideline level of 6 NTU. WQ04 is a suitable reference site some distance from the Project Area near the confluence with the coastal ocean, and as such, generally had considerably lower turbidity; and
- The records across the sites were generally below the upper ANZECC (2000) guideline level of 20 NTU, except at WQ02 and WQO3, which exceeded this upper limit in May 2009.

Oxidation-Reduction Potential

ORP at each site and monitoring date was nearly equivalent throughout the water column with values at all sites and dates throughout the water column consistent with a generally well oxygenated water column.

Summary of Field Multi-probe Measurements

In summary, the *in situ* physico-chemical profiles indicate the following:

- Generally, all measured parameters (temperature, electrical conductivity, pH, DO, turbidity, ORP) were homogeneously distributed throughout the water column, indicative of vertically well-mixed conditions;
- Seasonal signals included decreasing water temperatures, increasing electrical conductivity, increasing ORP, increasing pH and decreasing turbidity, all of which are indicative of less influence of freshwater inputs and reduced primary productivity from lower winter insolation; and
- pH tended to be lower than the QWQG (2006) guideline range, as did turbidity. However, turbidity tended to be near the upper limit of the ANZECC (2000) guideline range. DO saturation tended to be within the QWQG (2006) guideline range of 90-100%, with occasional measurements above or below this range.

Vessel-Based Water Quality

Water samples collected from stations WQ01 to WQ12 were analysed for a broad range of chemical and physical properties, which are summarised next.

Undetected Contaminants

For the following groups of contaminants, one sample was taken at each of the 12 water quality monitoring stations on the 21 May 2009 or 26 May 2009 and did not exceed the limits of reporting:

- Benzene, Toluene, Ethylbenzene, and Xylenes (BTEX);
- Propiconazole, a triazole fungicide;
- Tributyltin;
- A suite of 27 Polycyclic Aromatic Hydrocarbons (PAHs) and phenols;
- A suite of 14 phenoxy acid herbicides;
- Two species of phenoxyacetic acid herbicides;
- A suite of 5 species of TPHs;
- A suite of 3 species of VOCs;
- A suite of 26 organochlorine pesticides; and
- Cyanide.

No samples exceeded the limits of reporting, so these measurements were not included as part of the suite of measurements during subsequent field monitoring dates.

Organophosphorus Pesticides

One sample was taken at each of the 12 water quality monitoring stations and analysed for a suite of twenty organophosphorus pesticides on the 21 May 2009 and/or 26 May 2009. With the exception of chlorpyrifos, all species tested were below the limit of reporting. Chlorpyrifos was detected at several locations, and as such, was measured again during the June monthly monitoring, along with diazinon and malathion. Diazinon and malathion measurements did not exceed the limits of reporting on either occasion at any site. Six of the 36 measurements were above the limit of reporting (<0.005 ug/L) ranging from 0.008-0.024 ug/L.

Herbicides

Samples from the 12 water quality monitoring stations during May, June and/or August 2009 were analysed for the nine herbicide species. With the exception of metolachlor (i.e. a chloroacetanilide herbicide), all samples were below the limit of reporting. Seven of the 35 measurements were above the limit of reporting (<0.005 ug/L) ranging from 0.009-0.271 ug/L.

Metals and Metalloids

Samples at each of the twelve water quality monitoring stations were analysed for the 16 metal and metalloid species in May, June, July and August 2009. All results for antimony, beryllium, cobalt, lead and mercury were below the limits of reporting. A summary of results for the remaining species are shown in Table 7-6. This table also includes a comparison of data to the trigger values included in the ANZECC (2000) guidelines. Except for cadmium all metals species with trigger values listed in the ANZECC (2000) were below the relevant trigger values. Cadmium exceeded its trigger value during the May sampling event at stations WQ06 and WQ09.

Nutrients

Nutrient species were measured at all 12 water quality monitoring locations each month (May, June, July, and August 2009) as shown in the summary in Table 7-7. Ammonia concentrations exceeded the QWQG (2006) guideline level ten times, and the ANZECC (2000) guideline level six times. Total oxidised nitrogen exceeded the QWQG (2006) guideline level 26 times out of a total of 48 measurements with the median value (0.004 mg/L) greater than the guideline level (0.003 mg/L). Total kjeldahl nitrogen exceeded the QWQG (2006) level twice from 48 samples. Reactive phosphorus did not exceed the QWQG (2006) guideline level, however it did exceed the ANZECC (2000) guideline level on 6 occasions. Total phosphorus did not exceed the QWQG (2006) guideline level or the ANZECC (2000) guideline level during the monitoring period.

Other Laboratory Measurements of Physico-chemical and Chemical Species

A number of additional measurements of physico-chemical and chemical properties were carried out in the laboratory on water samples from the 12 stations on a monthly basis inclusive of chlorophyll a, pH, electrical conductivity, TDS and TSS (summary in Table 7-8).

Chlorophyll *a* exceeded the limits or reporting on several occasions, reaching a maximum of 5 µg/L. The QWQG guideline for Chlorophyll *a* is 2.0 µg/L or mg/m^3.

The QWQG (2006) guideline for pH in a enclosed coastal area of the Central Coast Region has a lower limit of 8.0 and an upper limit of 8.4. Laboratory pH was generally at the lower end of this range, or below the lower limit of 8.0, in agreement with the *in situ* measurements.

Some variability in electrical conductivity and TDS was observed as expected from mixing between different water types in the Project Area (e.g. mixing between fresh water inputs and sea water) and because of evapo-concentration over the monitoring period that coincided with the dry season.

The majority of the TSS measurements exceeded the QWQG (2006) guideline for an enclosed coastal area of the Central Coast Region (15 mg/L) with only one measurement below the limit of reporting (5 mg/L).

In summary, the water quality of the Project Area generally met the relevant adopted guidelines.

Table 7-6 Metals and Metalloids above Limits of Reporting from Vessel-based Water Quality Monitoring

	Total Number of Samples	Number Above LoR	Maximum Value	Median Value (inc. results < LoR)	ANZECC (2000) Guideline Level	Number Above ANZECC Guideline
Aluminium (µg/L)	48	9	210	<10	-	-
Arsenic (µg/L)	48	48	1.9	1	-	-
Barium (µg/L)	48	48	13	8	-	-
Cadmium (µg/L)	48	3	2.7	<0.2	0.7	2
Chromium (III+VI) (µg/L)	48	1	2.9	<0.5	27.4 / 4.4 *	0
Copper (µg/L)	48	7	1	<1	1.3	0
Iron (µg/L)	48	7	12	<5	-	-
Manganese (µg/L)	48	41	11	2.15	-	-
Nickel (µg/L)	48	18	1.2	<0.5	7	0
Silver (µg/L)	48	1	0.1	<0.1	1.4	0
Vanadium (µg/L)	48	44	3.6	1.3	100	0

Table 7-7 Nutrient Data in Gladstone Harbour from Vessel-based Water Quality Monitoring

	Total Number of Samples	Number Above LoR	Maximum Value	Median Value (inc. results < LoR)	QWQG (2006) Guideline Level	Number Above QWQG	ANZECC (2000) Guideline Level	Number Above ANZECC Guideline
Ammonia (mg/L)	48	29	0.019	0.006	0.008	10	0.01	6
Nitrate (as N) (mg/L)	48	40	0.014	0.004	-	-	-	-
Nitrite (as N) (mg/L)	48	1	0.002	<0.002	-	-	-	-
Nitrogen (Total Oxidised) (mg/L)	43	36	0.014	0.004	0.003	28	-	-
TKN (as N) (mg/L)	48	44	1.88	0.13	0.18	2	-	-
Nitrogen (Total) (mg/L)	48	44	1.88	0.135	0.2	2	0.1	37
Reactive Phosphorus as P (mg/L)	48	37	0.008	0.002	0.008	0	0.005	6
Total Phosphorus (mg/L)	48	18	0.014	<0.005	0.025	0	0.015	0

Table 7-8 Other Laboratory Physico-chemical and Chemical Data

	Total Number of Samples	Number Above LoR	Maximum Value	Median Value (inc. results < LoR)	QWQG (2006) Guideline Level	Number Above QWQG	ANZECC (2000) Guideline Level	Number Above ANZECC Guideline
Chlorophyll *a*	48	23	6	<1	4	8	1.4	13
Electrical conductivity (us/cm)	48	48	72400	51000	-	-	-	-
pH	48	48	8.27	8.045	8.0 8.4	12	8.0-8.4	12
TDS (mg/L)	48	48	49400	42250	-	-	-	-
TSS (mg/L)	48	47	110	18	15	28	-	-

Summary of Grab Water Quality Measurements

The majority of chemical species analysed from the water quality grab samples were below the limit of reporting across all sites. Chlorpyrifos (pesticide) and metolachlor (herbicide) exceeded the limit of reporting for 15-20% of the measurements.

In regards to dissolved metals, all measurement of antimony, beryllium, cobalt, lead and mercury were below the limits of reporting throughout the monitoring period. The remaining metals species of aluminium, arsenic, barium, cadmium, chromium (III+VI), copper, iron, manganese, nickel, silver and vanadium included measurements above their respective limit or recording. Of these, only cadmium exceeded the ANZECC (2000) trigger value on two occasions during the period of monitoring.

All nitrogen nutrient species exceeded the QWQG (2006) and/or ANZECC (2000) guidelines on at least one occasion over the monitoring period. The most regularly exceeded guideline levels were:

- Total oxidised nitrogen with a median of 0.004 mg/L above the QWQG (2006) guideline level of 0.003 mg/L; and
- Total nitrogen with a median of 0.135 mg/L exceeded the ANZECC (2000) guideline level of 0.1 mg/L on thirty seven occasions.

Both reactive and total phosphorus were always lower than the QWQG (2006) guideline levels. Reactive phosphorus exceeded the ANZECC (2000) guideline level of 0.005 mg/L on six occasions.

Chlorophyll *a* exceeded both the QWQG (2006) and ANZECC (2000) guideline levels on eight and thirteen occasions, respectively, out of a total of forty-eight samples over the monitoring period.

Generally, pH was below the lower guideline limit of both QWQG (2006) and ANZECC (2000).

TSS exceeded the QWQG (2006) guideline level of 15 mg/L on twenty-eight occasions out of the forty-eight measurements with a median TSS of 18 mg/L.

Elutriate Water Quality

Of the 121 elutriate samples across the four proposed dredge areas, most water quality parameters were analysed for a subset of 100 of these samples. Filtered arsenic was measured on a subset of 10 samples, while ammonia was analysed for a subset of 71 samples.

Samples were collected across the following proposed dredge areas:

- Area 1A: 32 samples;
- Area 1B: 22 samples;
- Area 2: 24 samples.
- Area 3: 14 samples; and
- Area 4: eight samples.

Figure 7-1 illustrates the various dredge areas.

Undetected Contaminants

For the following groups of contaminants one sample was taken at each of the 12 water quality monitoring stations on the 21st May 2009 or 26th May 2009 and did not exceed the limits of reporting:

- Hexachlorobenzene;

- A suite of 25 organochlorine pesticides;
- A suite of 19 organochlorine pesticides; and
- A suite of eight polychlorinated biphenyls (PCBs).

No samples exceeded the limits of reporting, so these measurements were not included as part of the suite of measurements during subsequent field monitoring dates.

Semi-Volatile Organic Compounds

One hundred of the 121 elutriate samples were analysed for a suite of six semi-VOCs species. All measurements were below their respective limits or reporting, apart from Site 1A-063 at which 7,12-dimethylbenz(a) anthracene was measured at 0.2 µg/L.

Polycyclic Aromatic Hydrocarbons (PAHs) and Phenols

One hundred of the 121 elutriate samples were analysed for a suite of 18 organochlorine pesticides species. None of these samples exceeded their respective limits of reporting, apart from at Site 1A-063 in dredge area 1A. At Site 1A-063, acenaphthene, acenaphthylene, anthracene, benz(a)anthracene, chrysene, fluoranthene, fluorene, phenanthrene and pyrene were all at 0.1 µg/L concentration, and Naphthalene was 0.2 µg/L concentration.

Ammonia

Ammonia elutriate measurements at 33 sites had a median of 783 ug/L, well in excess of the QWQG (2006) guideline level of 8 ug/L and the ANZECC (2000) guideline upper limit of 10 ug/L, but compliant to the ANZECC (2000) toxicant guideline of 910 ug/L. The largest ammonia concentration recorded was 8,680 ug/L.

Metals

One hundred of the 121 elutriate samples were analysed for the 16 metal and metalloid species, except for filtered arsenic, which had only 10 samples analysed. Levels of lead and mercury were below the limit of reporting in all samples.

Table 7-9 summarises all of the metals elutriate measurements that exceeded the limits of reporting. Cobalt and copper exceeded the ANZECC (2000) marine environment trigger values on several occasions. These same results are broken down based on the different proposed dredging areas in Table 5.8 in Appendix K.

Table 7-9 Overall Statistical Summary of Elutriate Metals and Metalloids

Species	Number of Samples	Number of Samples Above LoR	Median Value (ug/L)	95th Percentile Value (ug/L)	Maximum Value (ug/L)	ANZECC (2000) Guideline (ug/L)	Number of Samples over ANZECC Guideline
Aluminium	100	12	<10	30	190	-	-
Antimony	100	69	4.2	10.2	12.2	-	-
Arsenic	100	99	4.85	18.9	29.6	-	-
Cadmium	100	3	<0.2	<0.2	0.4	0.7	0
Chromium (III+VI)	100	5	<0.5	<0.5	1.7	27.4 / 4.4	0
Cobalt	100	49	<0.2	4	22.9	1	22
Copper	100	11	<1	2	2	1.3	6
Iron	100	69	8	140	201	-	-
Manganese	100	99	399	984	3030	-	-
Nickel	100	80	0.9	3	6.7	7	0
Selenium	100	1	<2	<2	5	-	-
Silver	100	5	<0.1	<0.1	0.8	1.4	0
Vanadium	100	99	8.45	34.1	89.8	100	0
Zinc	100	21	<5	9	12	15	0

A comparison between median elutriate metal and metalloid concentrations with median water column concentrations is presented in Table 7-10. The median water column values are based on four months of monthly sampling conducted between May and August 2009. Not all species were recorded in both sets of data (NR indicates that a species was not recorded). Results from the elutriate testing are higher than those measured in the water column, or below the limit of reporting.

Table 7-10 Comparison of Metals and Metalloids in Elutriate and the Water Column

Species	Median Water Column Concentration (ug/L)	Median Elutriate Concentration (ug/L)
Aluminium	<10	<10
Antimony	<0.5	4.2
Arsenic	1	4.85
Barium	8	NR

Species	Median Water Column Concentration (ug/L)	Median Elutriate Concentration (ug/L)
Cadmium	<0.2	<0.2
Chromium (III+VI)	<0.5	<0.5
Cobalt	<0.2	<0.2
Copper	<1	<1
Iron	<5	8
Manganese	2.15	399
Nickel	<0.5	0.9
Selenium	NR	<2
Silver	<0.1	<0.1
Vanadium	1.3	8.45
Zinc	NR	<5

Summary of Elutriate Water Quality Measurements

Concentrations of organochlorine pesticides, organophosphorus pesticides, PAHs, phenols, PCBs and semi-VOCs were below the limits or reporting apart for one site in dredge area 1A that had some PAHs and phenols above the limit or reporting.

Concentrations of metals, metalloids and ammonia were generally much higher that those levels recorded in the water column, with ammonia compliant to the ANZECC (2000) toxicant guideline, but exceeding the QWQG (2006).

Water Quality Loggers

The water quality loggers deployed in this study measured turbidity, light intensity, sediment accumulation, water depth and wave height. However, not all parameters were recorded at every station during every deployment (Table 7-11). The process of redeploying the instruments took several days and as such, the deployment dates overlap on occasion. The dates specified in the table cover the time from when the first logger was activated, to when the last logger was retrieved.

Table 7-11 Logger Configuration for Deployments

	Deployment 1	Deployment 2	Deployment 3	Deployment 4
Deployment Dates	20 Apr – 19 May	19 May – 25 Jun	23 Jun – 28 Jul	27 Jul – 19 Aug
Logger 1	T, L, A			T, L, A, D, W
Logger 2	T, L, A, D, W		T, L, A, D, W	T, L, A, D, W
Logger 3	T, A	T, L, A	T, L, A, D, W	T, L, A, D, W
Logger 4	T, L, A, D, W	T, L, A, D, W	T, L, A	T, L, A, D, W

	Deployment 1	Deployment 2	Deployment 3	Deployment 4
Logger 5		T	T	
Logger 6			T	
Logger 7		T	T	
Logger 8		T	T, L	
Logger 9		T	T, L, A, D, W	
Logger 10			T	

T = Turbidity, L = Light, A = Aggregated Suspended Solids Deposition, D = Depth, W = Wave Height

Turbidity Logger Data

The logger turbidity data over the first four deployments is summarised with simple statistics in Table 7-12. Whilst all loggers were located in relatively deep water (depth greater than 4m), a comparison of the median turbidity indicates differences between sites still exist. Higher values were seen in those channel areas that were slightly deeper (i.e. loggers 2, 3, 6 and 9). However, according to the equipment supplier, the turbidity data collected with Logger 5 showed indications of bio-fouling and has been excluded from this analysis.

Separation of turbidity measurements during neap and spring tide conditions shows a strong relationship between tidal conditions and turbidity (Table 7-12). At all locations, median turbidity under spring tide conditions is substantially greater than during neap tide conditions. Across all of the logger locations, the turbidity exceeded the QWQG (2006) guideline level of 6 NTU around 20 – 50% of the time. In general, turbidity levels were below the ANZECC (2000) upper guideline of 20 NTU limit for 80 to 99% of the time.

Table 7-12 Summary of Logger Turbidity Data (units NTU)

Logger (or subset of logger data)	95th Percentile Turbidity
Logger 01	**11.39**
Spring Tide Subset	**12.87**
Neap Tide Subset	**9.67**
Logger 02	**27.98**
Spring Tide Subset	**30.32**
Neap Tide Subset	**23.49**
Logger 03	**15.77**
Spring Tide Subset	**17.54**
Neap Tide Subset	**9.69**
Logger 04	**11.31**
Spring Tide Subset	**12.43**
Neap Tide Subset	**9.83**
Logger 06	**25.41**
Spring Tide Subset	**30.11**
Neap Tide Subset	**15.17**
Logger 07	**13.81**
Spring Tide Subset	**16.54**
Neap Tide Subset	**4.9**
Logger 08	**20.17**
Spring Tide Subset	**27.13**
Neap Tide Subset	**13.63**
Logger 09	**27.85**
Spring Tide Subset	**31.73**
Neap Tide Subset	**17.22**
Logger 10	**16.08**
Spring Tide Subset	**22.52**
Neap Tide Subset	**14.12**

Incorporation of Other Recent Turbidity Data

With the primary impact on water quality from the Project likely to be attributable to the effects of the capital dredging and reclamation decant effluent on turbidity within the Project Area, recent *in situ* turbidity logger and profiling data have been incorporated into the analysis. This section therefore provides a complete data set from which to determine appropriate interim turbidity trigger values for this Project.

Turbidity as an Indicator of Water Quality

Turbidity is used as an indirect indicator of the amount of suspended material in suspension. Different sediment types have different light scattering properties and as such, the relationship between turbidity and suspended solid concentration is site specific.

Variability in Turbidity in the Project Area

All continuous turbidity measurements made to date for the Project as part of the baseline data set have been collected during the dry season with minimal influence from rainfall events and associated catchment inputs. It is expected, on the basis of previous experience, that turbidity will vary between wet and dry seasons owing to sediment laden catchment inputs into the Project Area.

Sources of Continuous Turbidity Data

Sources of continuous turbidity data relevant to the Project Area are summarised in Table 7-13. Some of the continuous turbidity data from past studies coincided with the wet season, which has not yet been covered by the monitoring program for this Project. Therefore, data from other sources was made available for this project to allow estimates of characteristic turbidity ranges during the wet season.

Table 7-13 Sources of Continuous Turbidity Data

Date	Reference
Feb – Apr 2005 *(Wet Season)*	*Capital Dredging of the Fourth Berth at RG Tanna Coal Terminal, Protection of the Marine Environment During Dredging and Dewatering. (GHD Gladstone 2005)*
2008-2009 *(Wet and Dry Seasons)*	*Port Curtis Seagrass Water Quality* (Wilson *et al.* 2008)
2008 *(Dry Season)*	*WBM Turbidity Data from Fisherman's Landing)(WBM 2008)*
2009	*Fisherman's Landing Baseline Turbidity Report* (Wilson and Andersen 2009)
2009 *(Dry Season)*	*GHD Baseline Study for the Western Basin EIS.*

Much of the data previously collected has been made available as raw data. Hence, all data sets presented here have been analysed in a similar manner as summarised in the following section.

Summary Turbidity Statistics

The preferred method for presenting statistical summaries of turbidity data sets is the application of ‘percentage exceedance’ or ‘percentile’ calculations. This allows the data to be summarised in terms of ambient (or background) behaviour with the median (50th percentile) and extreme behaviour with a higher percentile value (e.g. 95th percentile).

Table 5-29 in Appendix K presents a statistical summary of the all available recent logger data that has been collated in the Project Area. From the combined data sets (Table 7-14), the following conclusions can be drawn:

- Median dry season turbidity in deep water logger deployment locations (GHD logger deployments for this EIS, Berth 5 Fisherman’s Landing June-October 2008) varies from around 3 to 9 NTU with the 95th percentile ranging from 11-35 NTU;
- Median dry season turbidity in shallow logger deployment locations of 9 NTU and a 95th percentile range from 30-90 NTU; (refer Fisherman’s Landing shallow water samples from August-September 2008, Seagrass bed 8 north of Fisherman’s Landing May to November 2008, and seagrass bed 5 west of Wiggins Island May to November 2008)
- Median wet season turbidity in shallow logger deployment locations (Fisherman’s Landing shallow water January-April 2008 and December 2008-April 2009, Bed 8 north of Fisherman’s Landing January-April 2008 and December 2008-April 2009) of 10 and 23 NTU, and the 95th percentile of 127 and 176 NTU; and
- During the dry season the turbidity during spring tide conditions is 2-4 times those in neap tide conditions.

Though the available data indicates that the turbidity is substantially higher during the wet season, much less data has been collected over this period relative to the dry season (approximately 15% of all data). As such, it is likely that the wet season statistics are heavily biased towards individual events during the wet season as the record is not sufficiently long to ascertain otherwise. However, it could reasonably be expected that turbidity will be higher in the wet season due to impacts of higher catchment run-off.

Relation of TSS versus Turbidity

As previously discussed, turbidity is an optical property and can only be considered an indicator of the TSS concentration. The relationship between turbidity and TSS is site specific and must be determined on a case by case basis with simultaneous measurements of turbidity and TSS.

Several turbidity and TSS datasets are available. These include data collected under normal conditions, periods of dredging and data collected through the process of calibrating nephelometer sensors. In order to establish a common relation between turbidity and suspended solids, these datasets have been combined and a simple relation derived for application in this EIS.

Table 7-14 Summary Available Turbidity and TSS Datasets

Dataset Title	Recorded By	Comments
Non-dredging Data	WBM	Past measurements by WBM under non-dredging conditions in the Project Area.
Dredge Monitoring Data	WBM	Data collected by WBM during dredging operations, Fisherman's Landing Berth 1, June/July 2009.
Dredge Monitoring Data, Round 1	GHD	Data collected by GHD during dredging operations, Fisherman's Landing Berth 1, June/July 2009.
Dredge Monitoring Data, Round 2	GHD	Data collected by GHD during dredging operations, Fisherman's Landing Berth 1, June/July 2009.
Baseline Data	GHD	Data collected during the baseline monitoring for this EIS across the Project Area.

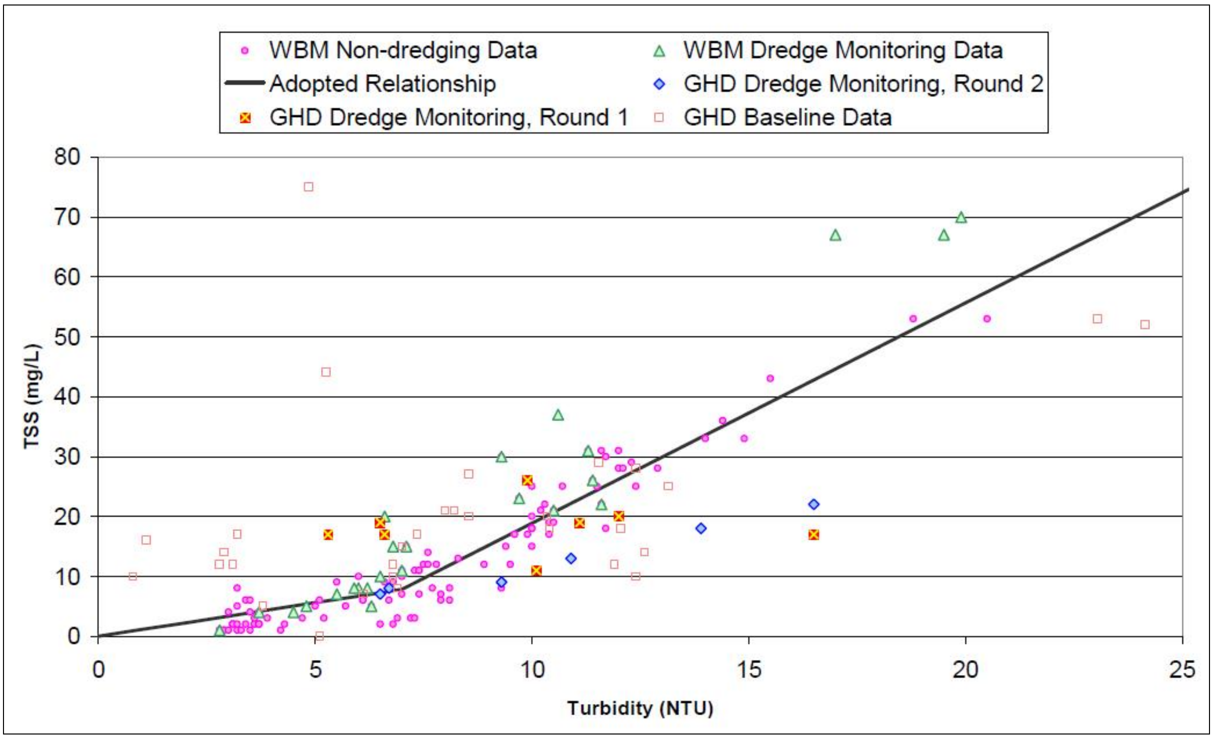


Figure 7-3 Relation of TSS versus Turbidity

The adopted relation between turbidity and TSS in Figure 7-3 is a piece-wise linear function, based on the largest and most consistent dataset available (WBM Non-dredging Data), and is defined as follows:

- TSS = 1.12 x [turbidity] where [turbidity] is between 0 and 7 NTU; and
- TSS = 3.68 x [turbidity] – 17.92 where [turbidity] is greater than 7 NTU.

The relation reflects the current data-set and may therefore change to some degree as additional data is collected. There is considerable scatter above and below the adopted relation. This is not unexpected as naturally occurring resuspended material, suspended material bought into the estuary by freshwater inputs, and suspended material generated by dredging are likely to have different physical and optical characteristics.

Given the degree of scatter, it is suggested that turbidity be used rather than TSS, as the primary indicator and point of comparison of water clarity, as it is a direct measure.

Photosynthetically Available Radiation (PAR)

Photosynthetically available radiation (PAR) is used to measure the amount of visible light available for photosynthetic processes for the benthic primary producer communities (e.g. seagrass communities). PAR measurements exhibit a strong diurnal fluctuation associated with the natural variability between day and night, as well as variation from day to day.

Differences in peak daily light intensity between sites are primarily a function of deployment depth. The closer the sensor is to the surface, the more PAR will reach the sensor and the higher the recorded measurement. A typical daylight light intensity at the surface is approximately 1,800 uE/m^2s^{-1}.

Because of the large range of the depth of deployments of the PAR sensors, the primary influence on the underwater light intensity data was water depth with turbidity (or TSS) levels a secondary influence.

Accumulated Suspended Solids Deposition (ASSD)

Accumulated suspended sediment deposition (ASSD) was recorded over the four deployment periods, but owing to the high variability between and within deployments, ASSD is not considered quantitatively reliable; rather a qualitative measure of when high deposition events occur. For example, based on the net sedimentation measurements the duration to accumulate 30 cm of sediment ranges from 2 (i.e. Location 4, Period 3) to 70 (Location 3, Period 2) years.

Summary of Baseline Water Quality in the Project Area

A summary of the water quality data from the baseline monitoring data for this EIS and other available recent turbidity logger data within the Project Area follows.

Turbidity

Turbidity and suspended solids data confirm that the Project Area is a naturally turbid system. The continuous logger data indicates that turbidity is regularly elevated above the QWQG (2006) and ANZECC (2000) guidelines. Turbidity logger data indicates the following characterisation of the Project Area:

- The median and 95th percentile turbidity ranges during the dry season in deep waters (approximately >2 m LAT) of the Project Area are 3-9 NTU and 11-35 NTU, respectively;
- The median and 95th percentile turbidity ranges during the dry season in shallow waters (approximately <2 m LAT) of the Project Area are 9 NTU and 30-90 NTU, respectively;

- The median and 95th percentile turbidity ranges during the wet season in shallow waters of the Project Area are 10-23 NTU and 127-176 NTU, respectively; and
- During the dry season the turbidity during spring tide conditions is 2-4 times those in neap tide conditions.

Two environmental variables appear to influence sediment concentrations in the water column in the Project Area; tidal state current speeds that induce resuspension of bottom sediments and wet season inflows from the catchment, both of which are natural events.

Water Quality

The majority of water quality parameters analysed from the vessel-based monitoring program were below the limit of reporting except for:

- One herbicide, metolachlor, exceeded the limit of reporting on six out of 36 recordings;
- One organophosphorus pesticide, chlorpyrifos, exceeded the limit of reporting on six out of 36 recordings;
- Of the dissolved metals, aluminium, arsenic, barium, cadmium, chromium (III+VI), copper, iron, manganese, nickel, silver and vanadium had some measurements above their respective limit or recording. Only cadmium exceeded the ANZECC (2000) trigger value on two occasions;
- All nitrogen nutrient species exceeded the QWQG (2006) and/or ANZECC (2000) guidelines on at least one occasion over the monitoring period. The most regularly exceeded guideline levels were:
  - Total oxidised nitrogen with a median of 0.004 mg/L above the QWQG (2006) guideline level of 0.003 mg/L;
  - Total nitrogen with a median of 0.135 mg/L exceeded the ANZECC (2000) guideline level of 0.1 mg/L on 37 occasions;
- Both reactive and total phosphorus were always lower than the QWQG (2006) guideline levels. Reactive phosphorus exceeded the ANZECC (2000) guideline level of 0.005 mg/L on six occasions;
- Chlorophyll *a* exceeded both the QWQG (2006) and ANZECC (2000) guideline levels on eight and 13 occasions, respectively, out of a total of 48 samples over the monitoring period;
- Laboratory and *in situ* pH tended to be below the lower limit specified in both the QWQG (2006) and ANZECC (2000) guidelines, but not above the upper limit;
- TSS exceeded the QWQG (2006) guideline level of 15 mg/L on 28 occasions out of the 48 measurements with a median TSS of 18 mg/L;
- *In situ* turbidity tended to be near the upper limit of the ANZECC (2000) guideline range of 20 NTU and above the QWQG (2006) guideline of 6 NTU; and
- *In situ* DO saturation tended to be within the QWQG (2006) guideline range of 90-100% with occasional measurements above or below this range.

The results indicate that anthropogenic contaminant inputs are minor (one herbicide, one pesticide, one metal) and that nitrogen regularly exceeds the adopted guidelines. This may indicate anthropogenic input of nitrogen from urban and agricultural sources (e.g. sewage effluent and fertilisers), but this may also result from naturally high levels in the Project Area.

Elutriate Water Quality

Concentrations of metals, metalloids and ammonia were generally much higher that those levels recorded in the water column or the relevant ecosystem water quality guidelines, so mobilisation of these water quality parameters need to be assessed with regards to potential impacts during dredging works on the Project Area.

Site Specific Turbidity Objectives and Simulation TSS Thresholds

The ANZECC (2000) guidelines favour the development of site specific water quality objectives, based on natural conditions and known tolerances of key sensitive species and habitats. Background turbidity in the Project Area regularly exceeds the QWGQ (2006) and ANZECC (2000) guidelines. Therefore, it is appropriate to develop site specific guideline values for turbidity.

Next, site specific turbidity objectives were developed for the decant discharge, decant receiving environment, shallow water Berth 5 Fisherman's Landing, northern Western Basin seagrass bed (Bed 8), west Wiggins Island seagrass bed (Bed 5) and deeper waters potentially impacted by the Project. The development of these turbidity objectives is largely based on Table 5-29 in Appendix K.

McArthur *et al.* (2004) indicate that the 95th percentile turbidity represents a suitable tolerance threshold for a marine community in the absence of direct physiological response data because of adaptation to frequent intensities and durations of elevated turbidity and accompanying regimes of light attenuation and sediment deposition. The methodology used here in the development of site specific turbidity objectives was to:

- Utilise the dry season turbidity data to establish the water quality objectives. Available recent continuous turbidity data is heavily biased towards dry season measurements. Elevated turbidity during the wet season from catchment loads is highly variable depending on frequency and intensity of rainfall events. An adaptive water quality objective for the wet season that is dependent on interannual variability of wet season turbidity may be appropriate;
- Utilise median turbidity to represent the background concentration levels; and
- Utilise the 95th percentile turbidity to represent the site specific water quality objectives.

For this EIS, turbidity loggers were deployed over the 'dry' season in numerous 'deep' water locations (>3 m LAT). The purpose of these deployments was to develop turbidity objectives in regions throughout the Project Area in which dredging and/or decant potential impacts may occur. A summary of medians and 95th percentiles at each of the deep water logger locations is summarised in Table 7-15. An average of these values was adopted as the turbidity objective for the dry season, namely 5 NTU for the median and 20 NTU for 95th percentile, representative of background and impact threshold levels.

Table 7-15 Summary of Median and 95th Percentile Turbidity for Dry Season Deployments in Channels throughout the Project Area for this EIS

Logger	Median (NTU)	95th Percentile (NTU)
1	3	11.4
2	5.3	28
3	5	15.8
4[1]	3.2	11.3
6	4.5	25.4
7	2.9	13.8
8	4.1	20.2
9	8.6	27.9
10	3.1	16.1
FL Berth	9	35
Average	**4.9**	**20.5**

Table 7-16 summarises site (i.e. 3 shallow and 1 deep water objectives) specific turbidity objectives (i.e. the 95th percentile values), the background levels (i.e. medians), conversion to TSS with the adopted relation from turbidity, and the simulation TSS threshold (i.e. 95th percentile minus median) for analysis of plume simulations. To reiterate, the plume simulations only model the dredge plume material, and not the ambient TSS levels. Hence, the simulation TSS threshold was used to evaluate the modelled plume scenarios.

Justification for each of these site specific turbidity objectives includes:

- Decant receiving environment:
  - Median turbidity of 9 NTU was the same at all shallow water locations and higher than the deep water locations, presumably because of greater re-suspension (i.e. shallower depths) and greater proportion of fine particles relative to deeper waters with higher tidal current speeds; and
  - The 95th percentile of 30 NTU was the lowest of all shallow water locations because it was not in proximity to either extensive salt pans (source of turbidity) or any rivers (another source of turbidity); and
  - As outlined in the Review of Previous Water Quality Studies Report (Appendix K), GPC has previously undertaken a number of capital and maintenance dredging programs in accordance with approved Dredge Management Plans. GPC successfully complied with the requirements of the Dredge Management Plans, however, the water quality guidelines applied to turbidity at the final reclamation cell in the Development Approvals for both the RG Tanna Coal Terminal Berth 4

[1] Not used to derive turbidity objective because of proximity to coastal ocean. Logger location 5 was not used because of unreliable data.

and Fisherman's Landing Berth 1 dredging projects were quite low in comparison to the turbidity objectives determined here. These previous water quality guidelines were 20 NTU in winter (May – September) and 40 NTU in summer (October – April).

- Northern Western Basin seagrass beds:
  - The median turbidity of 9 NTU is in agreement with all of the other dry season values in shallow waters; and
  - The elevated 95th percentile turbidity of 55 NTU relative to 30 NTU near the existing Fisherman's Landing reclamation is likely from a combination of shallower depths and proximity to the salt pan to the north. Nonetheless, it is indicative of the substantially greater turbidity levels that the seagrass meadows in this region are adapted to.
- Wiggins Island and South Fisherman's Landing seagrass beds:
  - The median turbidity of 9 NTU is in agreement with all of the other dry season values; and
  - The elevated 95th percentile turbidity of 91 NTU relative to 55 NTU for the northern Western Basin seagrass beds is likely from the combined effect of the salt pans to the west as well as the Calliope River (i.e. two sources of turbidity in addition to re-suspension of fine material).This is indicative of the substantially greater turbidity levels that the seagrass meadows in this region are adapted to.
- Deep channel waters:
  - The median turbidity of 4.5 NTU is approximately half of the dry season levels for the shallow sites as expected for a range of factors (greater dilution, less re-suspension, larger particle size classes); and
  - The 95th percentile value of 20 NTU is substantially lower than the dry season levels for the shallow sites (33-91 NTU) as expected for the same range of factors as the lower median values at deeper sites.

Table 7-16 Summary of Median and 95th Percentile Turbidity, TSS and Modelled Plume for Dry Season for Shallow Water and Deep Water Deployments in Western Basin Area

		Turbidity (NTU)		TSS (mg/L)		Dredge Plume TSS (mg/L)
Data Source	Applicability	Median	95th Percentile	Median	95th Percentile	Threshold
FL Shallow Water (Aug-Sep 2008) WBM	Decant receiving environment	9	30	15	92	77
Bed 8, North of FL (May-Nov 2008)	Western Basin seagrass beds	9	55	15	184	169
Bed 5, West of Wiggins Island (May-Nov 2008)	Wiggins Island, South FL seagrass beds	9	91	15	317	302
GHD May-Aug 2009 at 8 sites	Deep channel waters	4.5	20	5	56	51

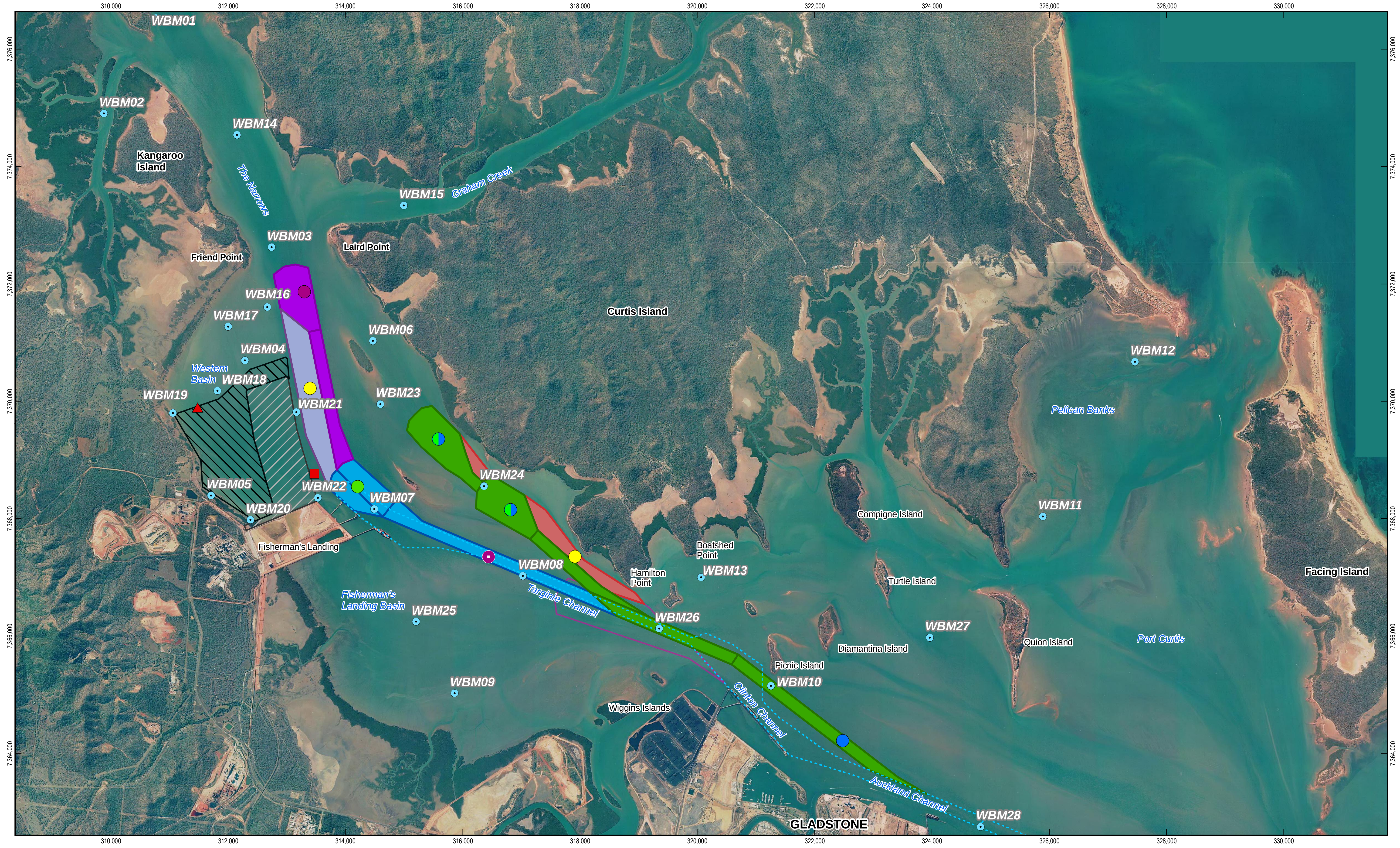
7.1.2 Potential Impacts and Mitigation Measures

Project Activities

Dredging activities for the channels are expected to occur in three phases. These are identified on Figure 7-4. Stages 1A and part of stage 1B (Stage 1) are expected to be dredged from 2010 to 2011 (over a period of two years). The remainder of Stage 1B and Stage 2 are expected to commence in 2012 and require a period of 12 months to complete. Stages 3 and 4 could commence in 2013, as required, and will be undertaken to meet market demand. It is expected that large cutter suction dredgers (CSD) will be used for the majority of works with a large trailer suction hopper dredger (TSHD) required for some works in Stage 1A in the Clinton Bypass Channel area and Stage 1B.

For the purposes of this water quality impact assessment, the following activities were considered to fall within the construction phase of the proposed development:

- Construction of the bund wall;
- Dredging, rehandling and placement of material within the bund; and
- Decant of tailwaters from placement of dredged material within the bund.



1:60,000 (at A3)

0 0.5 1 1.5 2 Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Grid: Map Grid of Australia 1994, Zone 56

N

LEGEND

- Decant Outfall
- TSHD Dumping/ CSD Rehandling
- TSHD Scenario 1a
- CSD Scenario 1b
- CSD Scenario 1a, 1b
- CSD Scenario 2
- TSHD Scenario 2
- CSD Scenario 3
- Model Output Location
- Stage 1A - North China Bay LNG
- Stage 1B - Fisherman's Landing LNG
- Stage 2 - Laird Point LNG
- Stage 3 - Fisherman's Landing
- Stage 4 - Hamilton Point
- Western Basin Reclamation Area
- Fisherman's Landing Northern Expansion
- Existing Channels, Swing Basins and Berths
- Wiggins Island Coal Terminal (Approved)

GHD

Port of Gladstone
Western Basin Dredging and Disposal Project
Project Area with outlines of each Stage of Dredging Works, the Developed Reclamation and the Locations of Model Output Time Series

Job Number 42-15386
Revision A
Date 30 Aug 2009

Figure 7-4

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Level 4 201 Charlotte Street Brisbane QLD 4000 Australia T +61 7 3316 3000 F +61 7 3316 3333 E bnemail@ghd.com W www.ghd.com

Modelling Overview

Methodology for Hydrodynamic and Flushing Simulations

The predicted changes to hydrodynamics and flushing efficiency from the Project, which in turn can impact water quality, were assessed with a numerical hydrodynamic model (Appendix J). Four scenarios were simulated, namely:

- Base case – Existing conditions including approved dredge works in the Wiggins Island area (already approved);
- Scenario 1 – Base case with Western Basin reclamation bund and Stage 1A and Stage 1B (Stage 1) dredging;
- Scenario 2 – As for Scenario 1 along with Stage 1B (Full) and Stage 2 dredging; and
- Scenario 3 – As for Scenario 2 along with Stages 3 and 4.

These scenarios are described in Table 7-17. Each hydrodynamic modelling scenario was simulated assuming the existence of the fully developed Reclamation Area and completion of dredging works. This allows impact assessment of the hydrodynamics/flushing after the completion of dredging scheduled for each scenario.

Table 7-17 Overview of the Four Hydrodynamic Modelling Scenarios

Scenario	Stages	Details
Base		Existing Reclamation - Existing Fisherman's Landing reclamation Dredging - Existing Channels - Present Fisherman's Landing Berth 1 - Ultimate Wiggins Island Coal Terminal
Scenario 1	Reclamation Western Basin Reclamation Area fully constructed Dredging of: • Stage 1A • Stage 1B (Stage 1)	Developed Reclamation - Area to north of existing Fisherman's Landing reclamation Stage 1A - Clinton Bypass channel 200m wide at -13m LAT - Spur channel to China Bay 200m wide at -13m LAT - China Bay Swing Basins (2) 600m wide at -13m LAT Stage 1B (Stage 1) - Targinie Channel 180m wide at -10.6m LAT - Fisherman's Landing Bulk Liquids Wharf Swing Basin 550m wide at -10.6m LAT - Fisherman's Landing Bulk Liquids Wharf Swing Berth to 430m long at -12.5m LAT

Scenario	Stages	Details
Scenario 2	Scenario 1 completed Dredging of: ◗ Stage 1B (fully developed) ◗ Stage 2	Stage 1B (Fully Developed) - Targinie Channel 180m wide at -13.0m LAT - Fisherman's Landing Swing Basin 650m wide at -13.0m LAT - Fisherman's Landing Bulk Liquids Wharf Swing Berth to 430m long at -13.0m LAT Stage 2 Dredging - Channel extension to Laird Point 200m wide at -13m LAT - Laird Point Swing Basin approx 650m wide at -13m LAT
Scenario 3	Scenario 1 completed Scenario 2 completed Dredging of: ◗ Stage 3 ◗ Stage 4	Stage 3 Dredging - Berth and Swing Basins to Laird Point 450m wide (total 650m) at -13m LAT Stage 4 Dredging - China Bay and Hamilton Point additional Swing Basins and Departure Areas at -13m LAT

Modelling assessments indicate that the effects on the hydrodynamics within the Project Area are not consistent across sites or tides and will include changes to water velocity, water levels, bed shear stresses and tidal flows. Details are provided in Appendix J.

Methodology for Dredge Plume Simulations

Turbidity (or TSS) plumes generated from the dredging operations were assumed to occur from:

- Dredge head source during dredging by Trailer Suction Hopper Dredge (TSHD) and Cutter Suction Dredge (CSD);
- TSHD hopper overflowing during dredging;
- TSHD hopper dumping at a rehandling site in the vicinity of Fisherman's Landing berth and swing basin; and
- Decant discharge from the reclamation.

Simulations only modelled the "dredge plume material", which is the TSS in the water generated from dredging above natural background levels after settling of coarser material (i.e. cobbles, gravel, large sand particles, clay clumps). The increased TSS/turbidity from the dredge plume and the additional sediment deposition are two of the primary potential environmental impacts arising from the Project. Dredging is proposed to occur progressively over a number of stages with combinations of:

- Large CSDs with dredge slurry pumped to the reclamation and eventually discharging via the decant outlet (after sufficient residence time to allow substantive TSS settling);
- A large TSHD at locations not practical for the CSD pumped slurry operation; and
- A medium CSD for rehandling dredged material at the TSHD rehandling location.

These stages have been grouped into four dredge plume scenarios as outlined in Table 7-18, along with estimates of TSS loading rates from each source. All dredge plume loads were simulated as stationary sources with TSS inputs into a single model “cell”, which assumed:

- Continuous operation for the CSDs and decant sources; and
- A continuous TSHD cycle of 3 hours with 1 hour of hopper filling (and overflow) during dredging and a 10 minute period of dumping.

These are deemed to be conservative plume modelling assumptions as not all dredgers can maintain continuous operation. Further, all plume modelling assumed the bathymetry for each scenario was at the initiation of dredging, which may be considered as a conservative measure, as less volumetric dilution is simulated.

Table 7-18 Overview of the Four Dredge Plume Scenarios and Associated TSS Loadings

Scenario	Stage	Description	Loading
1a	1A	Western Basin Middle with Large CSD	4 kg/s continuous
		Western Basin North with Large CSD	4 kg/s continuous
		Decant from Piped Slurry from Western Basin Middle & North Direct to Reclamation	100 mg/L TSS @ 5 m^3/s
		Clinton Wedge & Bypass, Western Basin South with Large TSHD	75 kg/s for 1 hour every 3 hours
		Dumping at Fisherman’s Landing Dumping Ground with Large TSHD	340 kg/s for 10 min every 3 hours
		Rehandle at Fisherman’s Landing with Medium CSD	4 kg/s continuous
		Decant from Piped Slurry from Fisherman’s Landing Rehandling Site Direct to Reclamation	100 mg/L TSS @ 1.25 m^3/s
1b	1A	Western Basin Middle with Large CSD	4 kg/s continuous
		Western Basin North with Large CSD	4 kg/s continuous
		Decant from Piped Slurry from Western Basin Middle & North Direct to Reclamation	100 mg/L TSS @ 5 m^3/s
	1B Stage 1	Fisherman’s Landing Swing Basin with Large TSHD	75 kg/s for 1 hour every 3 hours
		Dumping at Fisherman’s Landing Dumping Ground with Large TSHD	340 kg/s for 10 min every 3 hours
		Rehandle at Fisherman’s Landing with Medium CSD	4 kg/s continuous
		Decant from Piped Slurry from Fisherman’s Landing Rehandling Site Direct to Reclamation	100 mg/L TSS @ 1.25 m^3/s

Scenario	Stage	Description	Loading
2	2	Laird Point with Large CSD	4 kg/s continuous
		Decant from Piped Slurry from Laird Point to Reclamation	100 mg/L TSS @ 2.5 m^3/s
	1B Full	Targinie Channel with Large TSHD	75 kg/s for 1 hour every 3 hours
		Dumping at Fisherman's Landing Dumping Ground with Large TSHD	340 kg/s for 10 min every 3 hours
		Rehandle at Fisherman's Landing with Medium CSD	4 kg/s continuous
		Decant from Piped Slurry from Fisherman's Landing Rehandling Site Direct to Reclamation	100 mg/L TSS @ 1.25 m^3/s
3	3	Fisherman's Landing North with Large CSD	4 kg/s continuous
	4	Hamilton Point with Large CSD	4 kg/s continuous
	3 & 4	Decant from Piped Slurry from Fisherman's Landing North and Hamilton Point Direct to Reclamation	100 mg/L TSS @ 5 m^3/s

It is noted that the model simulations of plumes utilise TSS as the model state variable. Hence, the TSS versus turbidity relation is used to convert TSS simulation output to turbidity when needed.

Construction of the Reclamation

Potential Impacts

Construction of the bund will involve placement of core material and rock armour by trucks. It is not proposed to remove the soft surface sediments before placement of the rock as this is not necessary to achieve the agreed design criteria for geotechnical stability of the bund wall. Therefore, as the rock is dumped onto the seabed during the construction of the bund wall, soft sediments will be remobilised into the water column and will also be pushed out the front and sides of the bund wall. This is likely to result in the generation of a small yet visible turbid plume. While a turbid plume will reduce light penetration over nearby seagrass beds, these meadows experience elevated turbidity on a regular basis through natural tidal re-suspension of the soft seabed sediments. It is likely that any sediments disturbed by the construction of the bund wall that deposit over the seagrass beds will be remobilised and transported away from the tidal flats again during tidal movements and elevated wave conditions.

The disturbance of the soft seabed sediments will be limited to the first layer of rocks, after which any additional rock for that section will be placed on rock and not the soft seabed sediments. Therefore, the generation of plumes through the placement of rock is likely to be transient. Also, migration of turbid plumes will be somewhat minimised by the presence of the rock on the seabed, which will act to reduce water movement in the immediate vicinity of the bund construction as the height of the rock increases.

There will be an increased risk of remobilisation of the mud wave during elevated wind and wave conditions, or during spring tides. The potential for waves to erode core material during storm (cyclone) conditions may arise over the course of construction, although armouring of the core should be close behind the rate of core construction.

There is the potential for spillage (either minor, through drips or major through a leak/accident) of oils and fuels from construction equipment to impact on marine water quality.

Mitigation

Generation of turbid plumes by the placement of rock during bund construction can be limited through control of the material being used. The fine material (<20 mm) will be scalped from the core material for the bund wall, removing this potential source of turbid plume generation during construction. The erosion of core material by waves during potential storm conditions will be managed by placement of armour material to the exposed face of the core material closely behind the core work face. A small stockpile of armour material will be held at the quarry, sufficient to cover any exposed core if a cyclone were to approach. Contingency planning for a storm may require the placement of the stockpiled armour material to cover exposed faces of the core material. A maximum unarmoured length of 50 m will be maintained during construction.

Monitoring and management of any material that is displaced above LAT or its current elevation will be undertaken in accordance with an Acid Sulphate Soil Management Plan (ASSMP).

No planned refuelling or maintenance of construction equipment will occur on the site, nor will equipment be parked at the site for a significant time, reducing the potential for significant spills of oils and fuels to occur. All construction equipment will undergo regular maintenance and pre-start inspections will be undertaken on a daily basis to identify any leaks. Spill kits for land and water based spills will be kept at the site and personnel trained in their use. Emergency response procedures will be established.

Filling of the Bund

Potential Impacts

The bund design includes the placement of geotextile fabric on the inner face of the bund before commencement of filling operations. This will act to minimise the migration of fines through the bund wall and into the surrounding waters from the differential pressures created on either side of the wall by the rise and fall of the tide. Once a significant amount of dredged material is beached against the inner wall, this will also act as a filter layer to assist in preventing the migration of fine material through the bund wall into the receiving environment. Therefore, minimal direct impacts to water quality are expected from the filling of the bund with dredged material. The potential impacts of decant waters are discussed in below in the section “Impacts of Decant Outfall on Turbidity”.

Mitigation Measures

No further mitigation measures are recommended for construction of the reclamation as minimal impacts to water quality are expected.

Hydrodynamics

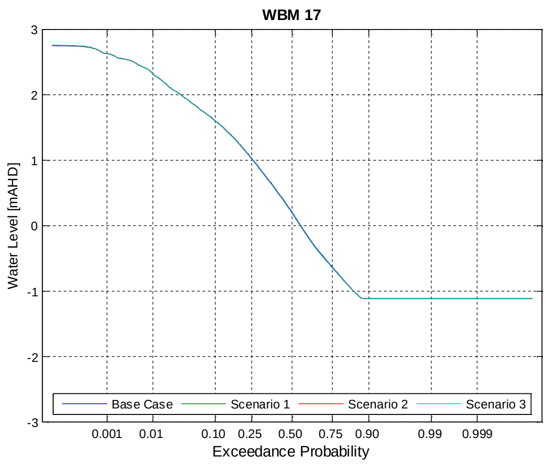
Potential Impacts Affecting Turbidity

Changes to hydrodynamics (water level and current speed) can affect turbidity via the process of re-suspension. Predicted impacts on water levels at two shallow locations in the northern Western Basin inter-tidal area (refer WBM04 and WBM17 sites in Figure 7-4) are considered here owing to their proximity to the developed Reclamation Area and seagrass beds. Results are presented in the form of exceedance plots in Figure 7-5. These show no change at WBM17, and only a minor change at WBM04.

Water level differences (time of low tide) are predicted to be more substantive in the 40 m tidal channel (refer sites WBM20 and WBM05) and the immediate vicinity of the northern perimeter of the reclamation wall (refer sites WBM19 and WBM18).

Water level variations in other regions of the Project Area are more subtle as detailed in Section 7.3 and Appendix J.

Site WBM17 – Northern Western Basin



Site WBM04 – North of Reclamation

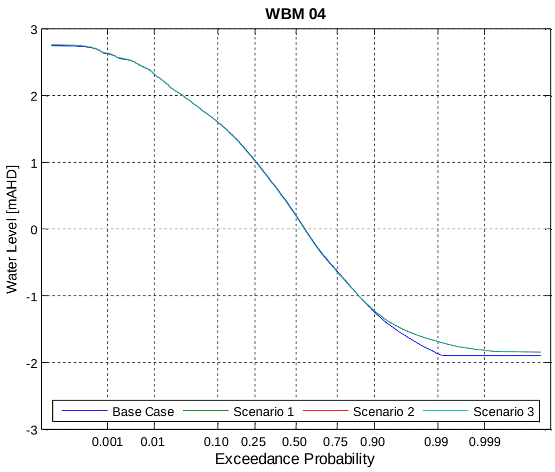
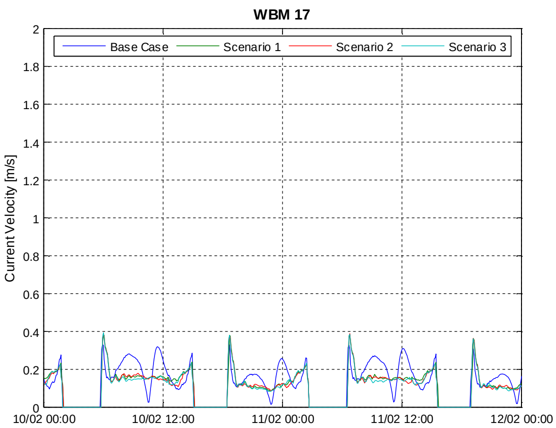


Figure 7-5 Probability Exceedance Plots of Water Level at Two Locations in the Western Basin Inter-tidal Area

Predicted current velocity impacts during spring tides (10-12 February 2009) at the same two locations (WBM17 and WBM04) again illustrate that the effect of the Reclamation Area (difference between Base Case and Scenario 1) is greater than expansion of dredged areas (differences between Scenarios 1, 2 and 3) (Figure 7-6).

At WBM04, as with other locations around the perimeter of the developed Reclamation Area, current velocities are generally predicted to increase. In contrast, at the northern Western Basin location at WBM17, current velocities are predicted to become more consistent. In short, the impacts to current speeds in the inter-tidal and sub-tidal areas decreases with distance north from the Reclamation Area and proximity to the deeper channels, with little predicted impact to ongoing turbidity generation.

Site WBM17 – Northern Western Basin



Site WBM04 – North of Reclamation

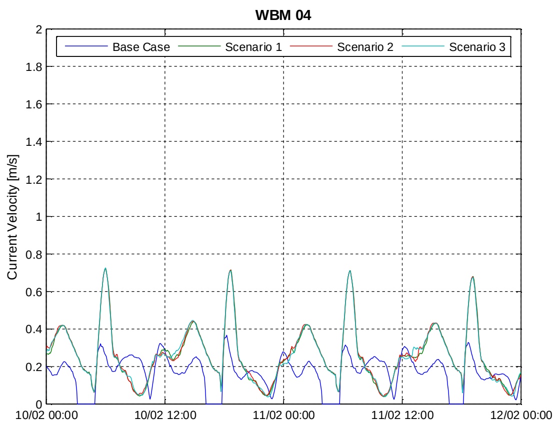
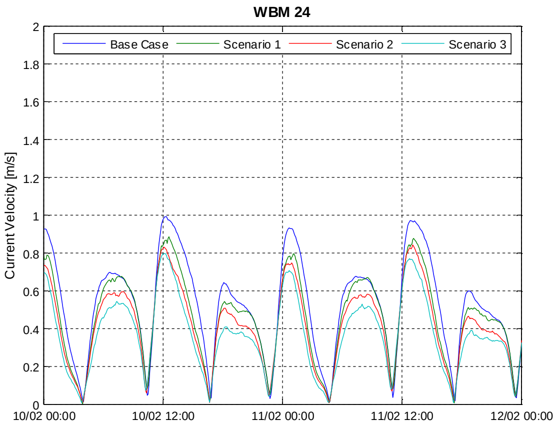


Figure 7-6 Time Series of Spring Tide Current Speeds at Two Locations in the Western Basin Inter-tidal Area

Predicted current velocity impacts at two locations within a newly dredged area (WBM24) and upstream of a newly dredged channel (WBM06) are illustrated in Table 7-7. The impact on spring tide current speeds at WBM24 is a decrease with each successive scenario that deepens the channel. In contrast, the impact on spring tide current speeds at the upstream location (WBM 06) are smaller in scale.

Site WBM24 – China Bay Swing Basin



Site WBM06 – Curtis Channel

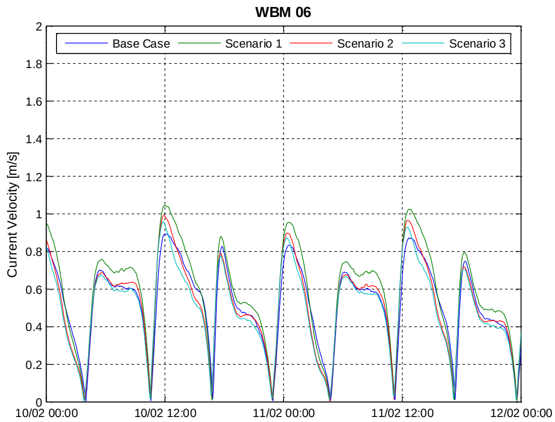
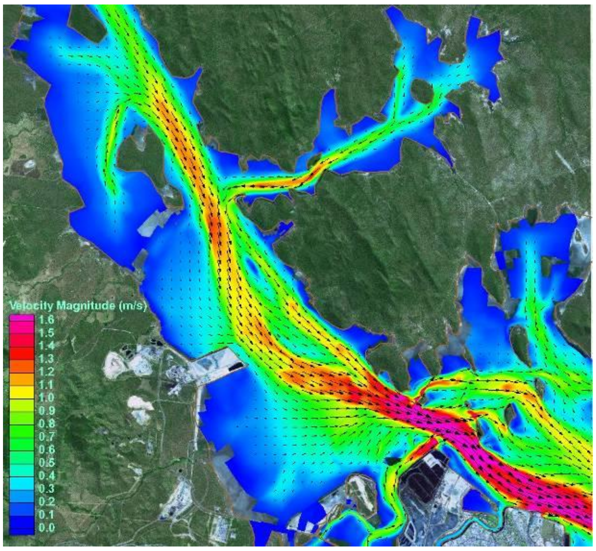


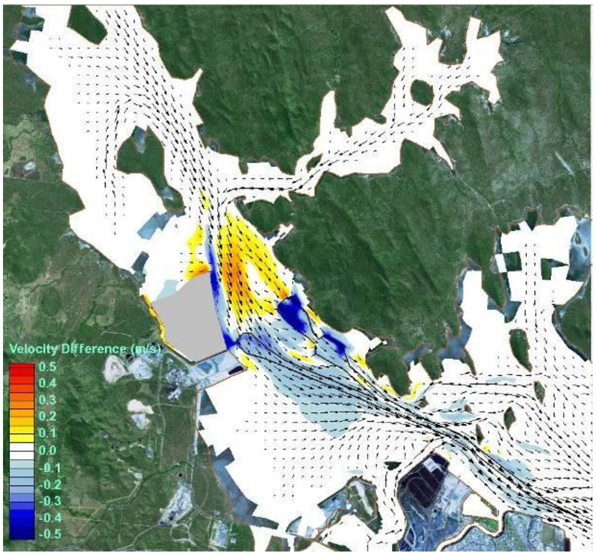
Figure 7-7 Time Series of Spring Tide Current Speeds at Two Locations in or near Newly Dredged Areas

Predicted spatial water velocity impacts between the base case and the three scenarios during spring ebb tides (simulation date and time: 10 February 2009 at 12:30) generally exhibit lower peak velocities in dredged areas and higher peak velocities in the upstream regions of completed dredging channels during each stage (Figure 7-8). This snap shot (results at a given instant) indicates that the model predicts increased velocities upstream of dredged areas, at the northeastern corner of the Reclamation Area and in the narrow tidal channel bounded by the Reclamation Area and shoreline. Decreased velocities are predicted in the dredged areas as well as along the eastern margin of the Reclamation Area. Similar patterns occur during flood tide cycles, though the high velocities along the north-eastern corner are not predicted.

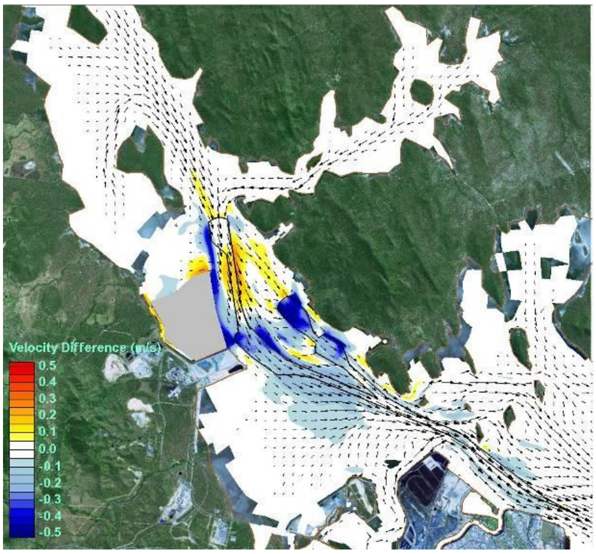
Base Case Ebb Spring Tide



Scenario 1 – Base Case (Ebb Spring Tide)



Scenario 2 – Base Case (Ebb Spring Tide)



Scenario 3 – Base Case (Ebb Spring Tide)

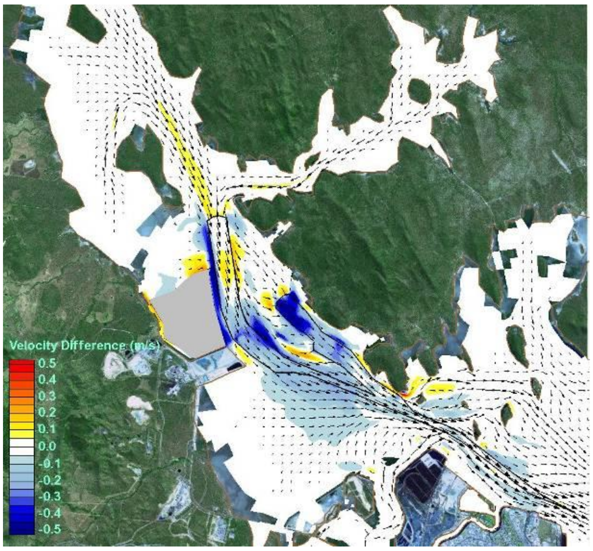


Figure 7-8 Peak Spring Ebb Tide Current Speeds for Base Case and Velocity Impacts of each Scenario

The Numerical Modelling report (Appendix J) has identified the following hydrodynamic impacts arising from the proposed Reclamation Area and dredging works:

- The proposed Reclamation Area reduces the inter-tidal storage area of the Western Basin region sufficiently to subtly alter the tidal propagation dynamics (i.e. water levels and currents) generally.
- Predicted water levels indicate that the Reclamation Area works have negligible impact (<1 cm) on high tide levels in the Project Area, but can increase low tide levels by 1-5 cm with some tidal slight phase changes.
- The relative impact of the Reclamation Area and associated loss of inter-tidal storage on the Project Area hydrodynamics is greater than the dredging works.
- Generally, current velocities tend to decrease in dredged areas as well as those laterally adjacent. Increased velocity typically occurs to adjacent areas upstream and downstream of the newly dredged areas.
- Tide flows are expected to increase between Mud Island and Hamilton Point, not change at the Narrows, and to decrease at Targinie Channel. This is predicted presumably, as a consequence of the loss of tidal storage volume from the reclamation.

Mitigation Measures

There are no mitigation measures proposed in response to the minor predicted changes in hydrodynamics arising from the construction of the Western Basin Reclamation Area and dredging works.

Flushing

Potential Impacts

Changes to flushing efficiency can modify water quality because of differences with coastal oceanic exchange. Spatial impacts on flushing efficiency were assessed by tracking a uniform initial conservative tracer concentration of 100 units throughout the model domain and determining the e-folding time for each grid cell in the domain for each scenario, where e-folding time denotes the time for the tracer to reduce from 100 units to l/e (i.e. 36.8% or 36.8 units). Details of the methodology are provided in Appendix J.

A comparison of tracer results between the Base Case and the three scenarios (during slack water at high tide near the end of the 2 month simulations) show higher tracer in response to the developed Reclamation Area and dredging works (Figure 7-9). Generally, the tracer levels increase with each successive scenario except for Scenario 2. This indicates that the effect of the dredging works on broad scale circulation patterns also influences flushing. After the 2 month simulation duration there is an approximate increase of 1-2% of tracer for the scenarios in the model domain relative to the Base Case.

Impacts to flushing were characterised with spatial representations of e-folding times between the Base Case and three Scenarios (Figure 7-10). Generally, a 1-2 day increase in the e-folding flushing time was predicted in response to the Project. The remnant 40 m tidal waterway bounded by the developed reclamation and shoreline has the greatest reduction in flushing efficiency of up to 7 days, though model predictions in this region are not considered robust because of coarse grid resolution of this tidal channel.

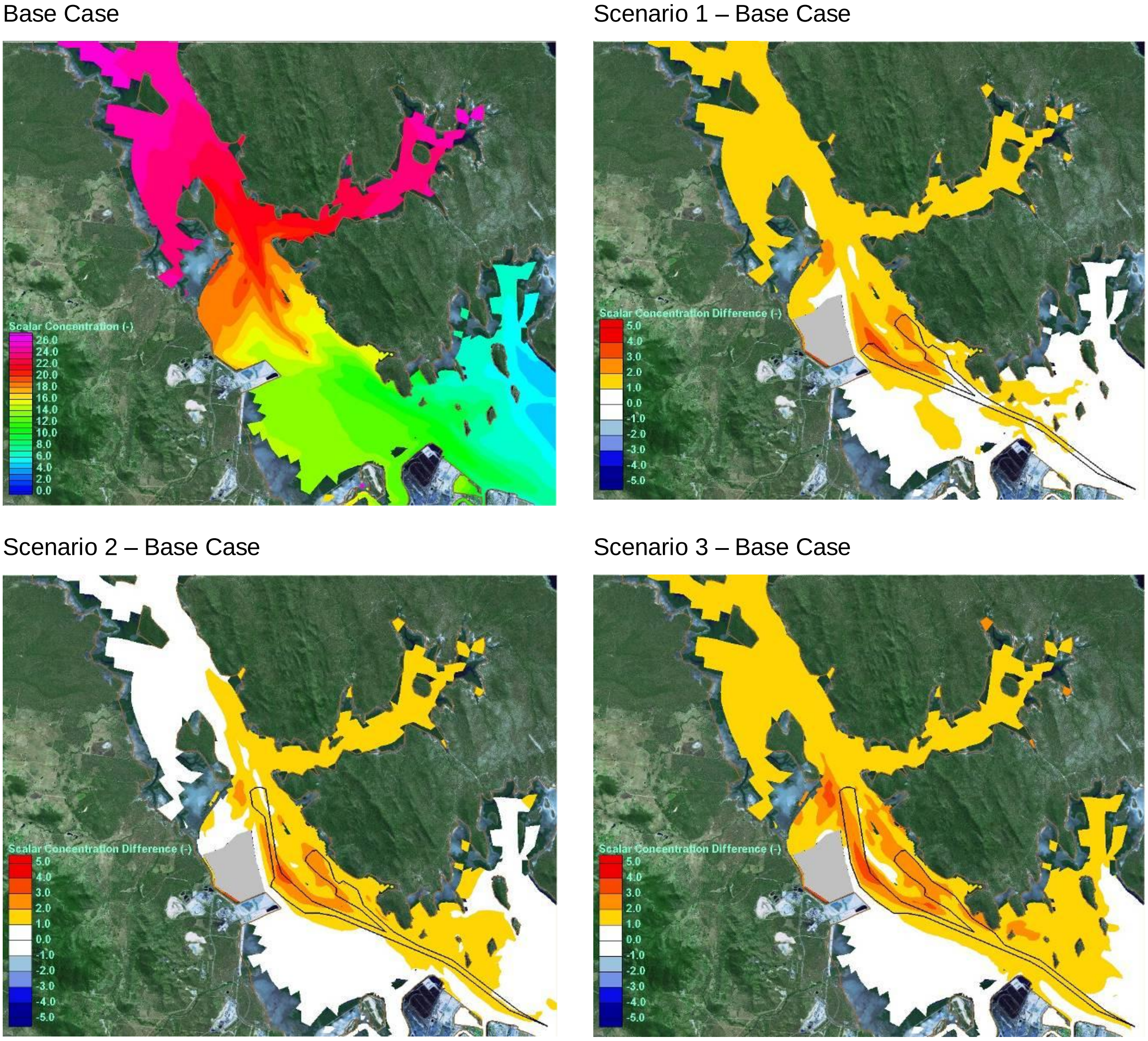


Figure 7-9 Tracer Distribution during Spring Tide for the Base Case and impact (difference) associated with each Scenario

The base case e-folding time is approximately 30 – 40 days, so a reduction of 1 – 2 days yields a 3 – 5% reduction in terms of impacts to flushing. There will also be slight reductions in flushing efficiency of areas surrounding the Passage Islands and the western shoreline of Curtis Island.

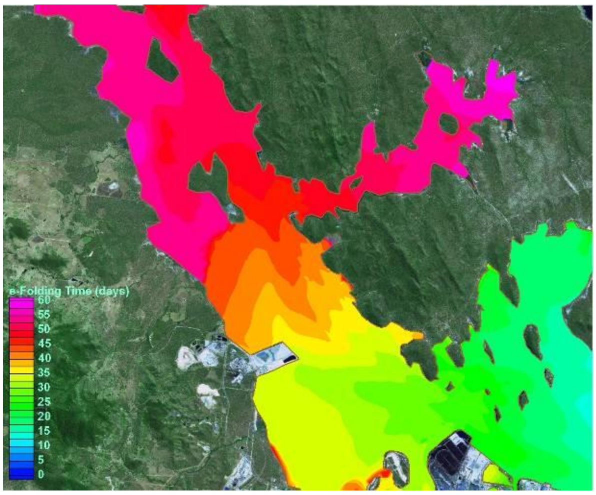
Further to the above, flushing has the potential to affect the fate of various pollutants within the water column. This relates to nitrogen species (TKN, TN, NH_X, TON, FRP[2]), chlorophyll[3], pH[3], the organo-phosphorus pesticide chlorpyrifos, the herbicide metolachlor and cadmium, all of which were indicated at levels above or nearing guideline values (refer Section 7.1.1). Hence, any potential increases from

[2] Regularly above ANZECC (2000) only, but not QWQG (2006).

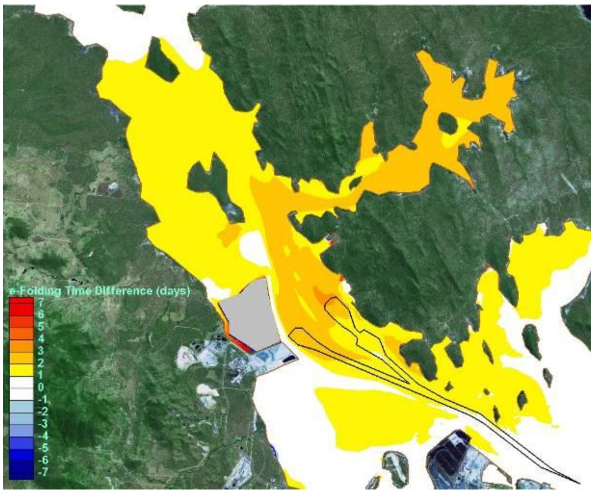
[3] Regularly above ANZECC (2000) and QWQG (2006).

reduced flushing to the levels of these constituents may need to be captured in monitoring programs of the Project Area.

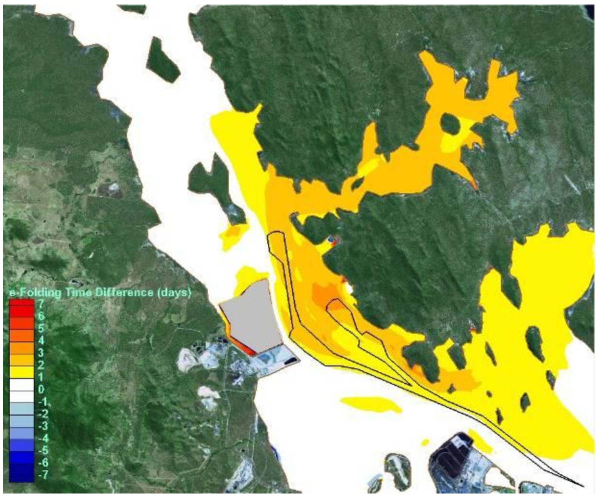
Base Case



Scenario 1 – Base Case



Scenario 2 – Base Case



Scenario 3 – Base Case

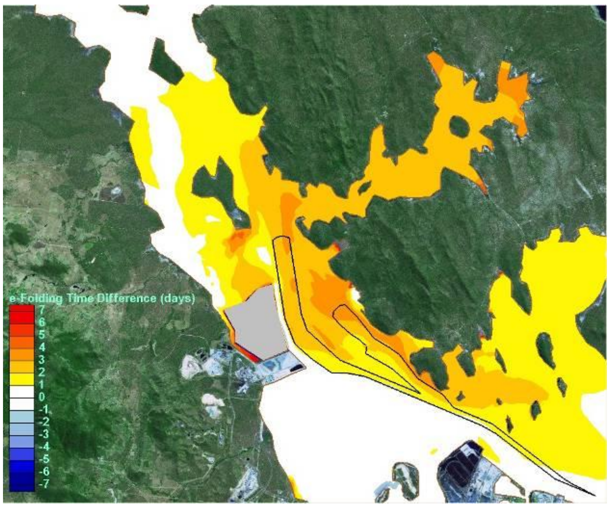


Figure 7-10 Spatial Estimates of Fitted e-folding times during Spring Tide for Base Case and Changes (Differences) for each Scenario

At most a 3 – 5% increase in these levels would be expected if they behaved in a conservative manner (i.e. the predicted decrease in flushing from the Project). However, all of these substances are likely to undergo a variety of natural processes (e.g. decomposition, mineralisation, adsorption to particles and burial) so that any increases from flushing will be substantially lower. Hence, it is unlikely that changes to concentrations of these substances from reduced flushing will be detected.

Mitigation Measures

There are no practical mitigation measures to address the minor predicted changes in flushing regime as a result of the construction of the Western Basin Reclamation Area and dredging works.

Impacts of Decant Outfall on Turbidity

Potential Impacts

The recommended turbidity objectives for the decant outfall are:

- 100 NTU in the final reclamation cell prior to discharge into the receiving environment, which is equivalent to 350 mg/L TSS; and
- 30 NTU in the receiving environment adjacent to the decant outfall, which is equivalent to 92 mg/L TSS. With the indicative background TSS value at this location of 15 mg/L TSS, the corresponding threshold to compare with the plume simulations is 77 mg/L (i.e. 92 mg/L minus 15 mg/L) (Table 7-16).

In order to assess the potential impact and extent of the decant plume, reference is made to the results of Scenario 3. Scenario 3 involves the simultaneous operations of two CSDs that pump dredge material slurry to the reclamation with decant discharge from the north-eastern corner after sufficient residence time to meet the turbidity objective of 100 NTU (350 mg/L TSS). These CSDs do not generate a large dredge plume (refer Table 7-18 for loading rates used). Hence, Scenario 3 was used to evaluate the likely plume impacts from the decant discharge on the Western Basin inter-tidal and sub-tidal TSS (or turbidity) climate.

Spatial TSS representations of the maximum level and 10% exceedance levels for Scenario 3 over the two month simulations are illustrated in Figure 7-11. The simulations show that the decant discharge into the receiving environment does not reach the adopted decant plume TSS objective of 77 mg/L.

Scenario 3 – Maximum TSS | Scenario 3 – 10% Exceedance

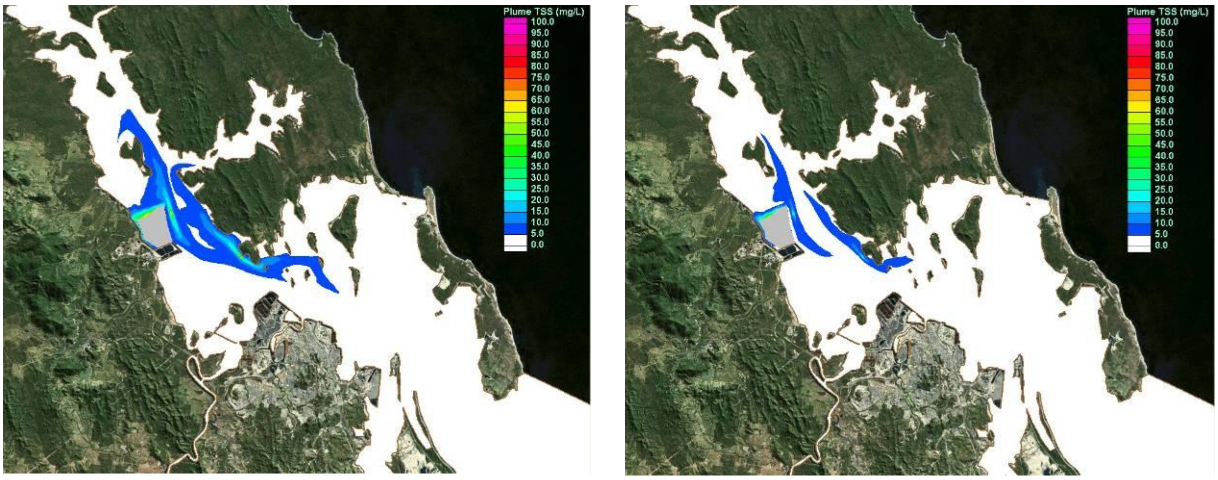
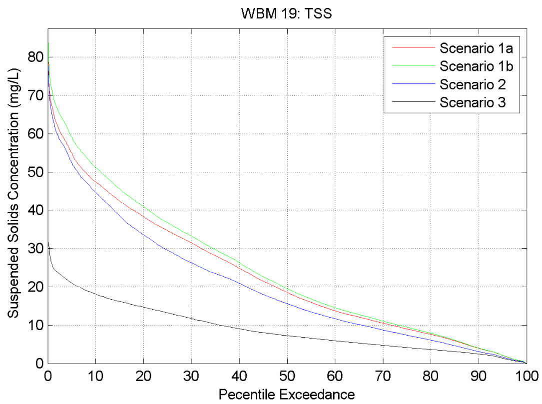


Figure 7-11 Spatial Representation of Maximum and 10% Exceedance TSS for Scenario 3

Inspection of the time series location at WBM19, adjacent to the decant discharge, illustrates that the decant TSS objective of 77 mg/L is not exceeded for Scenario 3 (Figure 7-12), with the 95th percentile being of the order of only 20 mg/L TSS. In the simulations the decant discharge was input as 100 mg/L TSS.

Scenario 3 – TSS Exceedance Probability at WBM19



Scenario 3 – Time Series of TSS for different particle types at WBM19

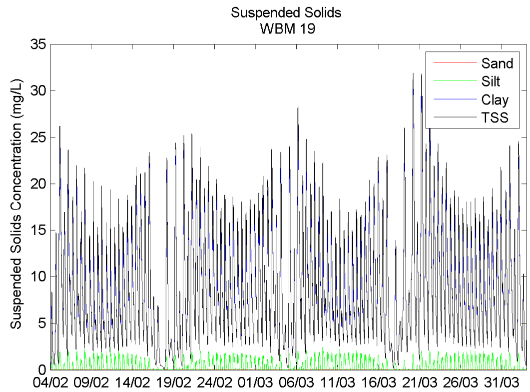


Figure 7-12 Total Suspended Solids at the Decant Discharge Location (WBM19)

The conclusions from analysis of the plume modelling of Scenario 3 with respect to the decant are:

- The predicted increase in TSS (and turbidity) is within the natural range and variability that has been measured within the Western Basin inter-tidal and sub-tidal regions of the Project Area;
- The spatial extent of TSS introduced by the reclamation decant outfall cannot be clearly separated because Scenario 3 also modelled two CSDs that generated a modest dredge plume that interacted with the decant plume. Nonetheless, the combined areal extent of the decant outfall and the two CSDs was predicted to have elevated TSS levels restricted to the northern boundary of the Reclamation Area; and
- Therefore, impacts from the decant on seagrass beds are expected to be focused along the northern boundary of the developed Reclamation Area.

Mitigation Measures

To achieve water quality objectives, multiple cells will be established within the Reclamation Area to allow the finer materials to settle out of suspension. These cells will be connected via weir boxes with adjustable gates, allowing water to be retained for longer periods when more time is required for fine materials to settle out of suspension. The final weir box at the outfall will be able to be completely closed to allow retention of decant waters should the water quality objective value in the receiving environment be exceeded. Floating booms will also be available on site and will be deployed into the reclamation cells should wind conditions result in waves stirring up deposited sediments within the reclamation cells.

Detailed calculations will be undertaken prior to each dredging program once the dredger, volume, production rate and time frame of the particular program is known, to ensure that the nominated turbidity objective can be maintained over the course of the decant. These calculations will also allow design of the number of reclamation cells and the area required to achieve the water quality objectives.

A Dredge Management Plan will be developed employing a similar monitoring program as undertaken for the recent Berth 1 dredging at Fisherman's Landing, including daily monitoring of sites adjacent to the dredge, within the final reclamation cell, at the outfall and at the northern Western Basin seagrass bed.

Monitoring will commence a minimum of two weeks prior to dredging and will continue during decant discharge. The control measures will be re-assessed if the turbidity exceeds 100 NTU in the final reclamation cell or 30 NTU in the receiving environment adjacent to the outfall or if the visible plume extends beyond the spatial extent predicted by the modelling.

Impacts on Turbidity and Light Climate

Potential Impacts

This section presents a discussion of the potential impacts with respect to turbidity and the light climate at representative seagrass locations. It supports the assessment of impact on sensitive habitats in the Project Area, namely seagrass communities, which is evaluated in the Marine Ecology Report (Appendix Q) and summarised in Chapter 9 of this EIS.

Potential Spatial Impacts from Cutter Suction Dredgers on Turbidity

Previous dredging programs have indicated that the spatial extent of the visible plume from a cutter suction dredger is typically not large, most recently evidenced with the recent Wombat CSD capital dredging at Fisherman's Landing Berth 1 (GHD 2009c). Monitoring of this campaign indicated that elevated turbidity levels near the dredger were less than 45 NTU during daily measurements.

Hence, the effect of the CSD dredge plumes from capital dredging operations at the North and Middle Western Basin, Laird Point, Fisherman's Landing North and Hamilton Point are likely to be localised to a relatively small area surrounding the dredger with a visible plume likely to extend along the channel in the direction of tidal current flow. Model predictions of the generation of dredge plumes by CSD supports the suggestion that limited impact on the turbidity climate will result, as illustrated in Figure 7-11.

Potential Spatial Impacts from Trailer Suction Hopper Dredges on Turbidity

In contrast to CSDs, TSHDs will have a greater impact on the turbidity environment of the Project Area. This is clearly evident through inspection of Table 7-18 where large TSS source rates have been estimated during overflow while dredging (i.e. 75 kg/s for 1 hour because of overflow) and rapid release of the dredged material at the dumping ground (i.e. 340 kg/s for 10 minutes).

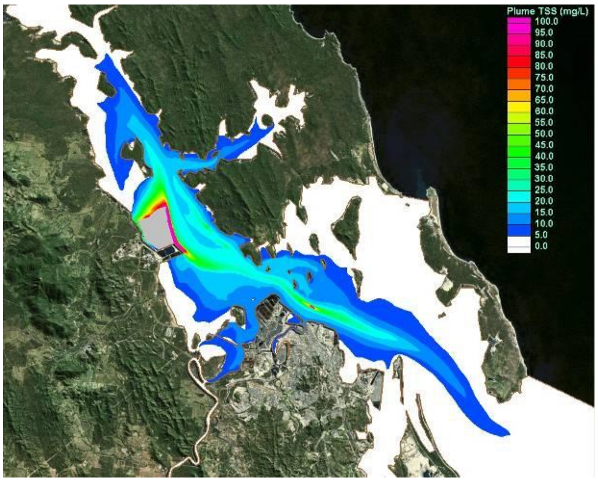
Spatial representations of plumes for Scenarios 1a, 1b and 2 are plotted as 10% exceedance TSS levels over the 2 month simulations. These are utilised in a comparative analysis in order to provide a more robust measure of elevated turbidity levels that sensitive habitats are likely to experience (Figure 7-13).

For Scenarios (1a, 1b, 2) where combinations of CSD and TSHD dredges operating simultaneously have been simulated, several key insights into spatial dredge plume patterns are obtained. These can then be used to inform potential impacts to sensitive environments and potential operational mitigation measures. The following patterns are described with respect to the adopted deep water (channel) TSS objective of 50 mg/L (Table 7-16):

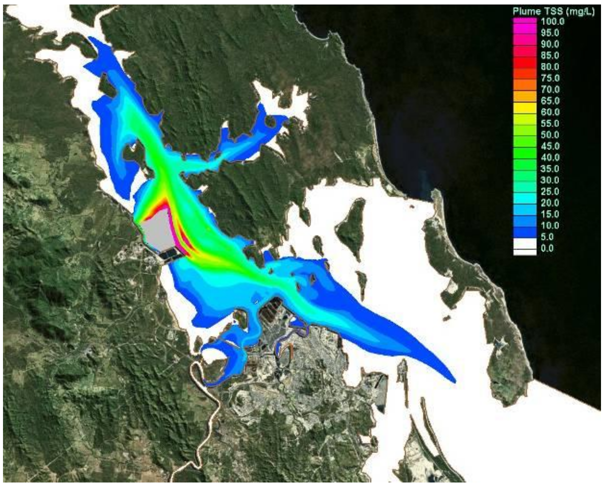
- All three Scenarios included one large TSHD dredger dumping in the vicinity of the north-eastern corner of the current Fisherman's Landing reclamation. Inspection of animations of the simulated dredge plume clearly show that when TSHD dumping occurs coincidentally with a flood tide, much of the dredged material is transported into the shallow waters of the northern part of the Western Basin, with a strong tendency to accumulate along the northern margin of the developed Reclamation Area. Similarly, the dumping of dredged material during flood tides will lead to higher TSS concentrations in The Narrows and Grahams Creek;

- In contrast, TSHD dumping during ebb tides offers a reduced impact on the seagrass beds in the shallow waters between Fisherman's Landing and Wiggins Island as the majority of the dredge plume material is transported along and within the adjacent dredged channels. This difference between flood and ebb tides provides a potential operational measure to reduce impacts to the northern Western Basin and The Narrows seagrass beds on the basis of the programming of TSHD dumping events;
- TSHD operations locales were predicted to experience elevated TSS levels in response to hopper overflows of 1 hour duration. Hence, the proximity of the TSHD dredging location to the dumping location has a substantive effect on the areal extent of plume. For example, for Scenario 1a with TSHD dredging of the Clinton Channel, distinct elevations of TSS are predicted at the dredge and dumping locations. However, for Scenario 1b with the TSHD operating in close proximity to the dumping ground, the areal extent that exceeds the TSS objective of 50 mg/L increases dramatically. The areal extent of dredge plume exceedance for Scenario 2 is somewhat reduced relative to Scenario 1b, because of the greater separation distance between the overflow and dumping dredge plume sources.

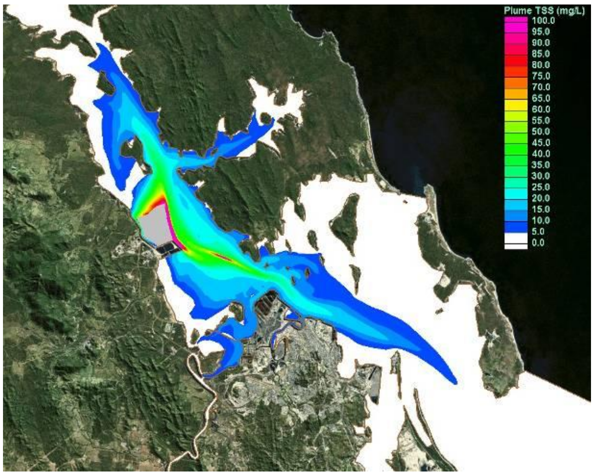
Scenario 1a



Scenario 1b



Scenario 2



Scenario 3

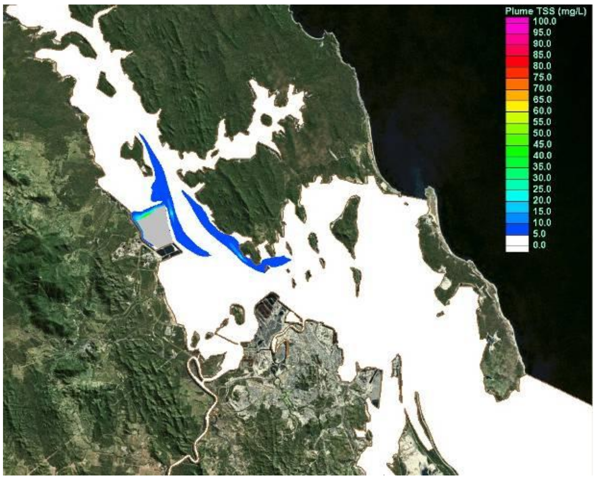


Figure 7-13 Spatial Representation of 10% TSS Exceedance for all Scenarios

Potential Impacts of Dredge Plumes to TSS Climate of Seagrass Beds

Potential light climate impacts from the predicted dredge plumes for the four scenarios have been evaluated at representative locations of environmental sensitivity (i.e. seagrass beds). These include the following model time series points, the locations of which were illustrated in Figure 7-4:

- WBM17 - Northern Western Basin seagrass beds;
- WBM04 - Middle Western Basin seagrass beds;
- WBM02 - Narrows seagrass beds; and
- WBM09 - Wiggins Island seagrass beds.

Probability exceedance plots of TSS at each of these locations (Figure 7-14) indicate the following:

- Scenario 3, with dredging only by cutter suction dredgers, generates substantially lower dredge plume TSS concentrations than the other three scenarios;
- The middle Western Basin (WBM04) dredge plume (as defined by the extent of elevated TSS levels) is substantially greater (by a factor of two) for Scenarios 1a, 1b and 2 over the northern Western Basin (WBM17) with potential impacts to The Narrows (WBM02) and Wiggins Island (WBM09) seagrass beds substantially reduced; and
- Scenario 1a generates lower dredge plume TSS concentrations than the other two TSHD scenarios whilst Scenario 1b has the highest TSS concentrations.

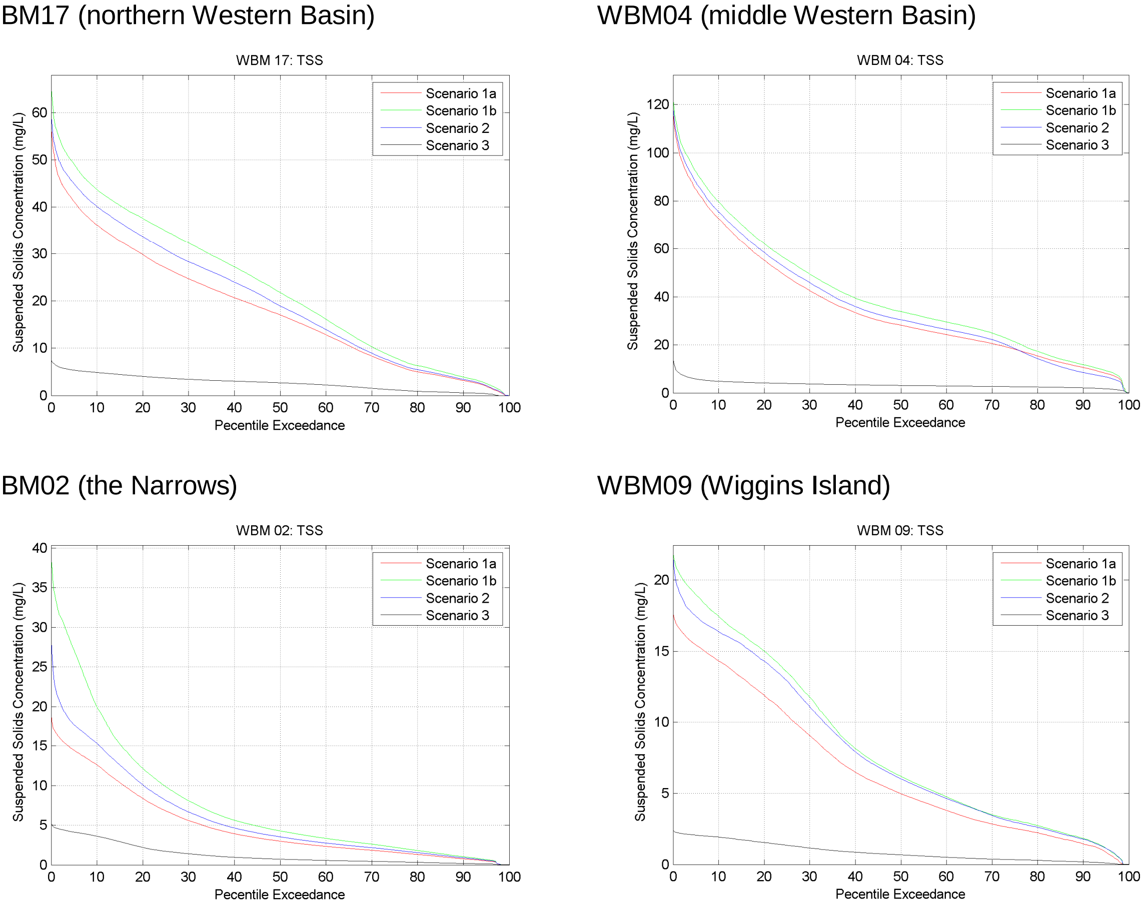


Figure 7-14 Probability Exceedance Plots of TSS at four key Seagrass Bed Locations

A tabular comparison of the 50th, 20th, 10th and 5th probability exceedance TSS concentrations at four representative locations relative to the turbidity/TSS objectives is summarised in Table 7-19. Of these, Scenario 3 experiences dredge plume TSS concentrations at all locations well below the TSS objective. Concentrations are higher for Scenarios 1a, 1b and 2, with the following conclusions offered:

- Seagrass beds at Wiggins Island (WBM09) are predicted to be subjected to turbidity levels well below a TSS objective based on either the 95th or 80th percentile of data;

- Seagrass beds at The Narrows (WBM02) and the northern Western Basin (WBM17) are predicted to be subjected to turbidity levels below a TSS objective based on the 95th percentile of data, and would still meet the objective if an 80th percentile criteria was adopted; and
- Seagrass beds in the middle Western Basin (WBM04) are predicted to be impacted, including a strong influence from elevated dredge plumes generated by TSHD dumping at the rehandling site coincident with flood tides.
- All results need to be considered in terms of the duration for which they occur, and must recognise the significant natural variability that occurs in these waters.

Table 7-19 Comparison of Simulated Dredge Plume TSS versus the TSS Objective

Scenario	Data Derived		Simulations			
Scenario	TSS Objective (95th Percentile) (mg/L)	Alternate TSS Objective (80th Percentile) (mg/L)	Median	20th%ile	10th%ile	5%ile
Location: WBM04 (Middle Western Basin)						
Scenario 1a	77	29	28	55	73	85
Scenario 1b	77	29	33	63	80	93
Scenario 2	77	29	30	58	76	89
Scenario 3	77	29	4	4.5	5	6
Location: WBM17 (North Western Basin)						
Scenario 1a	169	55	17	30	36	41
Scenario 1b	169	55	22	37	44	49
Scenario 2	169	55	19	34	40	45
Scenario 3	169	55	3	4	5	6
Location: WBM02 (The Narrows - Objective as WBM04)						
Scenario 1a	77	29	3	8	12	14
Scenario 1b	77	29	4	12	20	27
Scenario 2	77	29	3.5	10	15	18
Scenario 3	77	29	1	2	3	4
Location: WBM09 (Wiggins Island)						
Scenario 1a	302	59	5	12	14	16
Scenario 1b	302	59	6.5	15	17.5	18.5
Scenario 2	302	59	6	14	16.5	17.5
Scenario 3	302	59	1	2	2.5	2.5

Note: Grey shading denotes where suggested trigger value is exceeded (e.g. 5% exceedance is higher than 95% occurrence). Trigger value based on difference between median and nominated threshold.

Potential Impacts of Dredge Plumes to Light Climate of Seagrass Beds

A dry season analysis of potential impacts of dredging works on the light climate is detailed in Appendix K, with an overview provided in this section.

The specific attenuation coefficient of TSS was estimated through comparisons with measured PAR near the seabed by the loggers at locations 1, 2 and 4 with a background turbidity of 5 NTU (5.6 mg TSS L^{-1}). These values yield a specific attenuation coefficient of roughly 0.15 m^{-1} (mg TSS $L^{-1})^{-1}$ over the range of water levels in Figure 7-15. Estimates here also assumed a median chlorophyll a level of 1 ug chla L^{-1} (Table 7-8) with a specific attenuation coefficient of 0.02 m^{-1} (mg chla L^{-1}).

The relative percentage of incident PAR at the seabed was estimated with the following assumptions:

- Characteristic or 'representative' tidal cycles for the Project Area can be estimated as the 5th, 25th, 50th, 75th and 95th percentile tide predictions over a 12 hour cycle;
- A specific attenuation coefficient of roughly 0.15 m^{-1} (mg TSS $L^{-1})^{-1}$;
- Seagrass beds at -1, -1.5 and -2 m relative to mean sea level; and
- A background turbidity of 9 NTU (15.6 mg TSS L^{-1}) for shallow waters.

An average of the median TSS for Scenarios 1a, 1b and 2 (Table 7-19) was added to the background TSS to assess light climate impacts at each of the four locations with the following values:

- Wiggins Island seagrass beds: 5.8 mg L^{-1} above background TSS;
- Narrows seagrass beds: 3.5 mg L^{-1} above background TSS;
- North Western Basin seagrass beds: 19.3 mg L^{-1} above background TSS; and
- Middle Western Basin seagrass beds: 30.3 mg L^{-1} above background TSS.

An example of the relative percentage of incident PAR at the seabed for the representative 95th percentile tidal cycle (i.e. spring tide) is illustrated in Figure 7-16. The highest percentage occurs at tidal cycle hour 6 when the water level is at a minimum (i.e. 10 cm). The impact of the dredge plume at Wiggins Island (WBM09) and upper Narrows (WBM02) is minimal, but substantially greater at the two Western Basin locations (WBM17 and WBM04), in terms of both light intensity and the duration of light exposure on the seabed.

Figure 7-17 shows that a large neap tide (25th percentile tidal range) results in a substantial decrease for all cases of the relative percentage of incident PAR. This is attributable to the greater minimum water during the tidal cycle. Further, the relative impacts are also much greater because of the non-linear relation between light absorption through the turbid water column and depth. A decrease in the seabed depth to 1.0 m below mean sea level yields substantial exposure of seagrass to incident light for the 50th percentile tidal range with periods of 100% light exposure at the seabed (Figure 7-18).

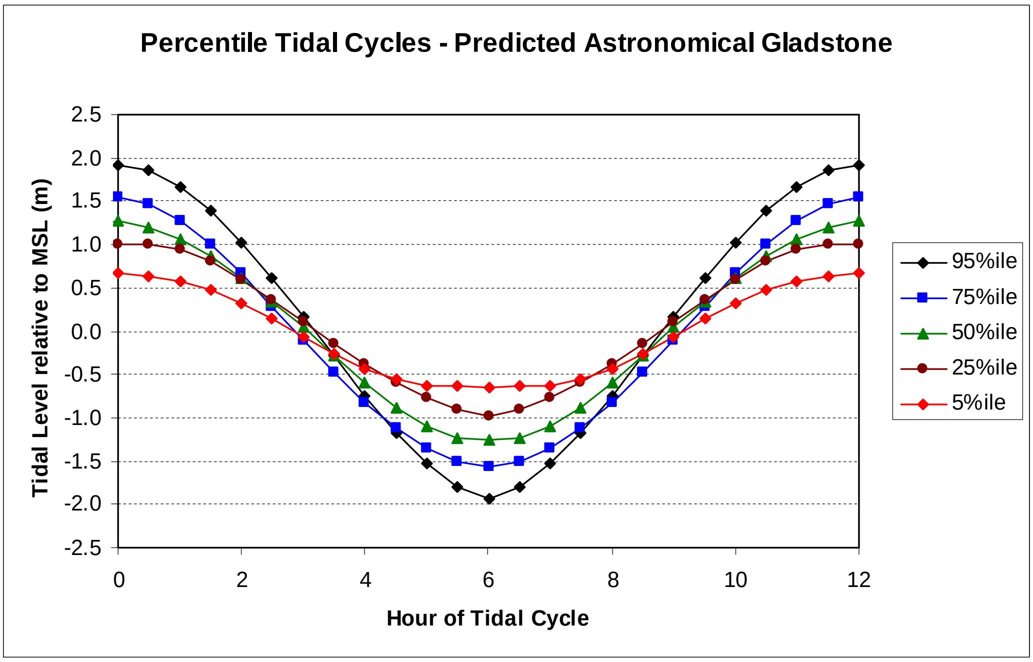


Figure 7-15 Percentile (95th, 75th, 50th, 25th and 5th) Predicted Astronomical Semi-Diurnal Tides

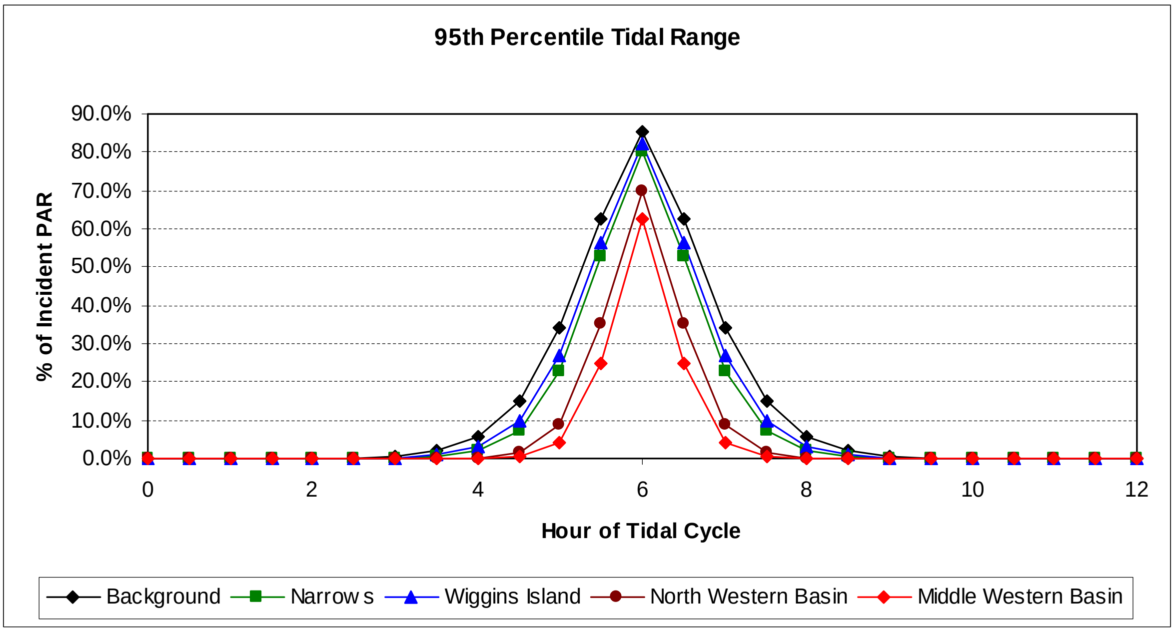


Figure 7-16 Percent of Incident PAR at the Seabed for 95th Percentile Tidal Range (Spring Tide) in 2 m of Depth relative to MSL for Background and Dredge Plume Scenarios

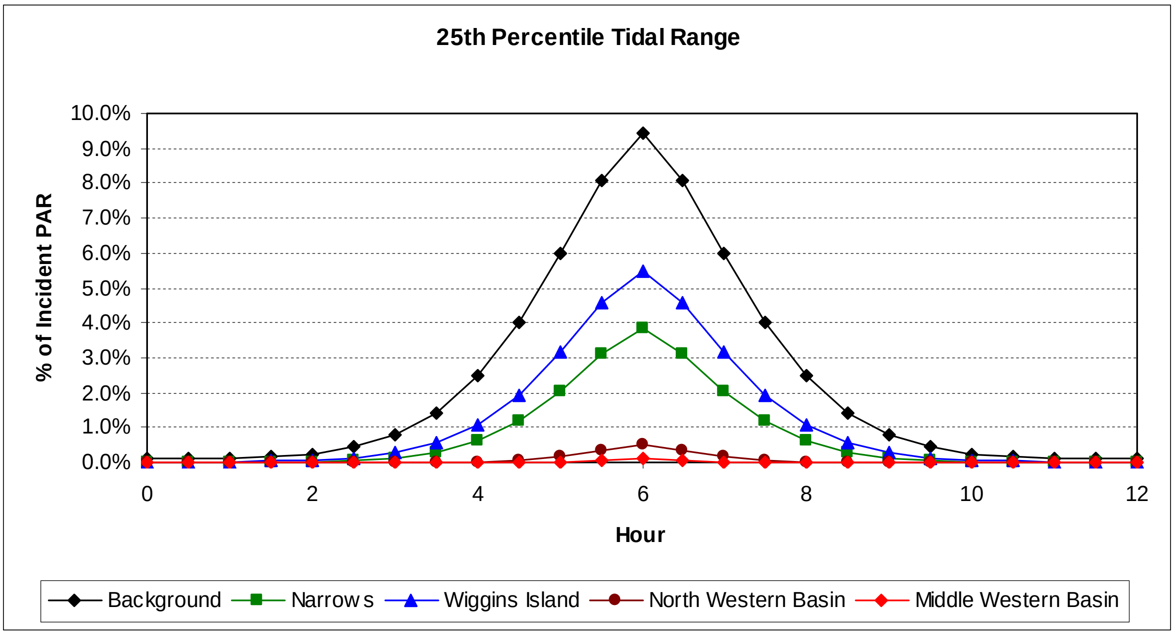


Figure 7-17 Percent of Incident PAR at the Seabed for 25th Percentile Tidal Range (Large Neap Tide) in 2 m of Depth relative to MSL for Background and Dredge Plume Scenarios

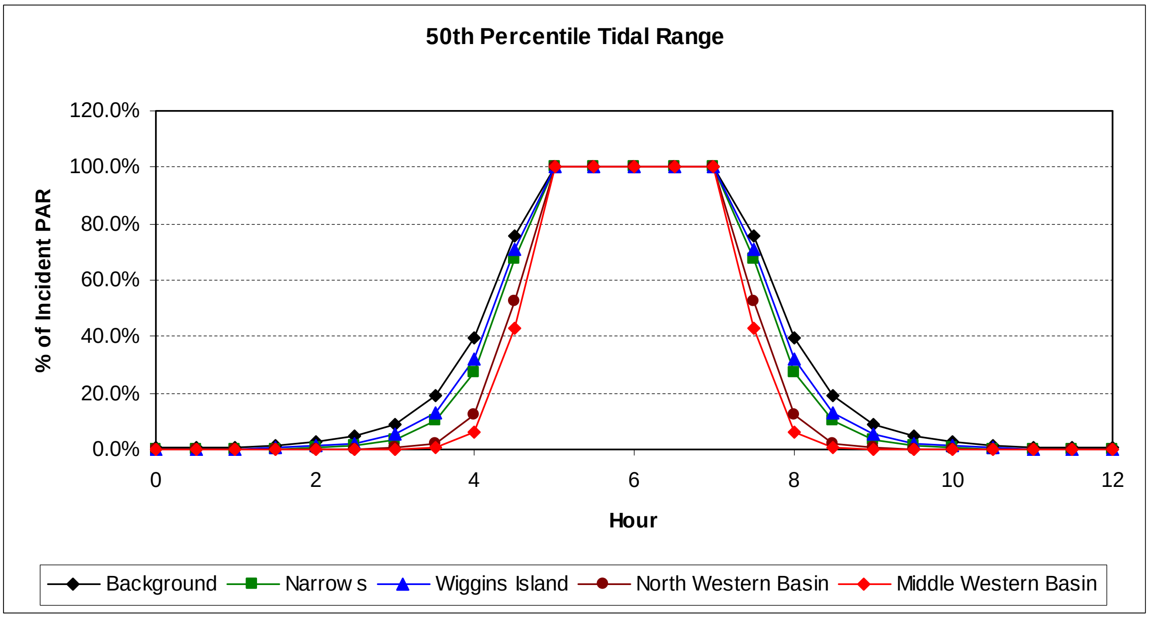


Figure 7-18 Percent of Incident PAR at the Seabed for 50th Percentile Tidal Range (Transition Tide) in 1.0 m of Depth relative to MSL for Background and Dredge Plume Scenarios

With the dredging period expected to occur over several years, the following assumptions were made in order to provide an integrated light climate impact assessment over this time scale:

- The range of tidal cycles and water depths are evenly distributed across dredging years in terms of high insolation periods (e.g. several hours either side on solar noon);
- No account made for any differences in variable background TSS between spring and neap tides;
- Assume that the median dredge plume TSS is a reasonable representation of the long-term particle climate that is added to the background levels for impact assessment over yearly time scales.

An annual light climate impact assessment on the basis of representative astronomical tides, high incident PAR of 1800 uE/m^2/s and mean water depths of 1, 1.5 and 2 m (Table 7-20) can be summarised as:

- For a 1 m water depth, relative percentage of incident PAR ranges from 20% (Western Basin) to 30% (Background). The relative decrease in PAR is approximately 10% at Wiggins Island and the Narrows and 30% at the Western Basin site;
- For a 1.5 m water depth, relative percentage of incident PAR ranges from 7% (Western Basin) to 15% (Background). The relative decrease in PAR is approximately 20% at Wiggins Island and the Narrows and 50% in Western Basin; and
- For a 2 m water depth, relative percentage of incident PAR ranges from 1% (Western Basin) to 5% (Background). The relative decrease in PAR is approximately 30-40% at Wiggins Island and the Narrows and 80-90% in Western Basin.

Table 7-20 Light Climate Impact Assessment

Depth (m)	Background	Narrows	Wiggins Island	North Western Basin	Middle Western Basin
% of Incident PAR at Seabed					
1	30.0%	26.2%	27.5%	22.1%	20.4%
1.5	15.2%	11.7%	12.8%	8.3%	7.1%
2	5.3%	2.9%	3.7%	1.1%	0.7%
% Change of Incident PAR relative to Background					
1		13%	9%	27%	32%
1.5		23%	16%	46%	53%
2		45%	31%	79%	88%

Mitigation Measures

A Dredge Management Plan will be developed for the Western Basin capital dredging, employing a similar monitoring program to that undertaken for the recent Berth 1 dredging at Fisherman's Landing, including daily monitoring of sites adjacent to the dredger, within the final reclamation cell, at the outfall and at the Fisherman's Landing and Wiggins Island seagrass beds.

Several operational considerations for the period of capital dredging have been identified as a means to potentially reduce dredge plume impacts to sensitive habitats. It is noted that:

- The effect on the Narrows and northern portion of the Western Basin is greater during the flood phase of large spring tides as tidal transport of dredge material to this region is predicted to be substantial. Hence, TSHD dumping during daytime flood tides should be minimised through programming wherever possible (with emphasis on periods of large spring tides); and
- The same constraints are not present during ebb tides as most of the dumped dredge material is predicted to be constrained to the deeper channels and does not greatly elevate TSS levels at the Wiggins Island seagrass beds.

Operationally, utilisation of the option to pump from TSHDs directly into the reclamation during the periods identified above should be considered. As TSHD bottom dumping events are predicted to produce elevated TSS levels for relatively short durations, this approach may also provide benefit to the seagrass beds during dredging works.

Improved characterisation of the light environment of the seagrass beds is also recommended, as the light climate is not well characterised to date. Deployment of a PAR logger array in the Wiggins Island and Northern Western Basin seagrass beds is recommended for consideration to achieve this outcome.

As specified previously, the turbidity objectives derived for this EIS are based predominately on dry season continuous logger measurements. With wet season turbidity likely to exhibit strong inter-annual variability as a function of rainfall and resultant catchment loadings, it is recommended that wet season logger deployments in both deep and shallow waters be implemented to allow for the further development of wet season turbidity objectives.

Dredging programs will need to be undertaken in accordance with Dredge Management Plans approved under the *Coastal Management and Protection Act 1995* and *Environmental Protection Act 1994*.

Impacts of Dredging and Decant on Sedimentation

Potential Impacts

Potential Impacts of Sand-Sized and Fine Material Dredge Plume Sedimentation on Deeper Waters

Potential impacts to bed shear stresses, and sand-sized and silt-sized sedimentation in the deeper waters (>2 m LAT) are reported in Appendix J and Section 7.3.2. The purpose of this assessment was to provide sedimentation estimates to inform maintenance dredging frequency, which indicates the following:

- Bed shear stresses during spring tides in channels are large enough so that fine sediments will not be stable deposits in the long term, which is consistent with observations of limited fine material in the main channel. The shallower areas with lower velocities have smaller bed shear stresses, which is consistent with the natural deposition of fine material in these areas. The predicted Project impact is a reduction in bed shear stresses in the dredged areas where depths are greater and velocities lower as well as laterally adjacent areas where velocities are reduced;
- Additional sand-sized sedimentation is predicted to occur in the Project Area for all of the scenarios relative to the base case because of the expanded dredge footprint. It is noted that sand-sized sedimentation for areas less than -2 m LAT were not estimated because of likely over-prediction due to lack of incorporation of resuspension dynamics that are likely an important mobilisation process; and
- The substantial (17-fold) increase in fine material siltation of dredged areas is due to the much larger dredged area footprint in the developed cases, this dredge footprint occurs largely in a region of

lower tidal flow energy than the existing port channels, and the further decrease in tidal velocities due to the dredging associated with the developed cases. Sedimentation rates of up to 0.08 m/year occur at siltation hotspots within the dredged areas. Therefore, a 0.3 m over-dredging allowance should accommodate 3+ years of sedimentation between maintenance dredging campaigns.

These sedimentation predictions focused on the dredged areas to determine maintenance dredging requirements and utilised currents and bed shear stresses from the hydrodynamic/flushing simulations.

Predicted Spatial Impacts from Dredge Plume Sedimentation

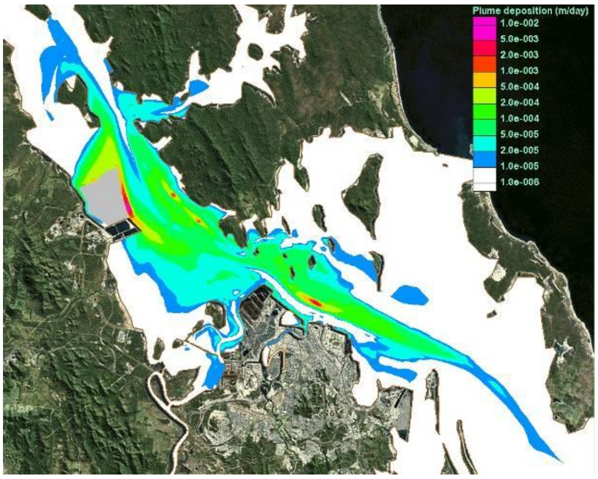
An output from the dredge plume simulations was the average sedimentation rate of the dredge plume material over the 2 month simulation period (Figure 7-19). The assumptions in the modelling included:

- No provision for re-suspension of already deposited plume material as it will generally become mixed with and hence, indistinguishable from the re-suspension of the natural bed material; and
- Settling will occur in areas when currents and waves (and hence bed shear stresses) are sufficiently low.

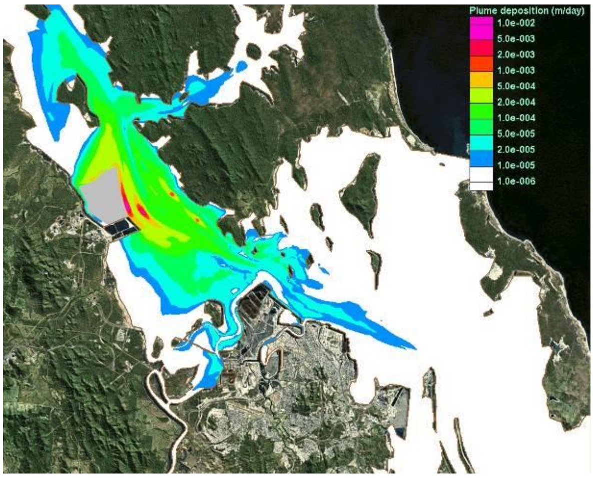
Given these assumptions, spatial representations of the sedimentation predictions are shown in Figure 7-19, which have the following patterns:

- Elevated sedimentation rates are predicted to occur at locations of dredging operations (CSD, TSHD overflow, TSHD dumping) and the decant outfall. Those at the actual dredging location are, of course, artificial estimates, in that they will continue to be removed as part of the dredging process until design depth is achieved;
- Scenario 3 has a relatively small dredge plume sedimentation footprint in comparison with the other scenarios confined primarily to the operating locales of the two CSDs and the decant outfall. Clearly, there is an interaction between the CSD operating in Fisherman's Landing North and the decant outfall that enlarges the sedimentation footprint;
- The other three scenarios (1a, 1b, and 2) all have similarly sized plume deposition patterns with differences in sedimentation hot spots coincident with CSD and TSHD overflow locations. The deposition footprint of Scenario 1a extends further south owing to TSHD operations in the Clinton Channel. In contrast, the deposition footprint extends further up The Narrows for Scenario 1b as a consequence of TSHD operations in the Fisherman's Landing swing basin, the northern most extent of simulated TSHD operations; and
- Sedimentation in the Western Basin inter-tidal and sub-tidal areas is predicted to be substantially greater for those scenarios inclusive of TSHD dumping.

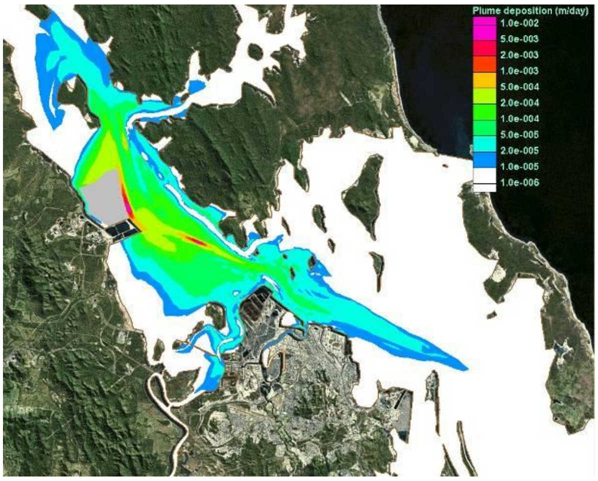
Scenario 1a



Scenario 1b



Scenario 2



Scenario 3

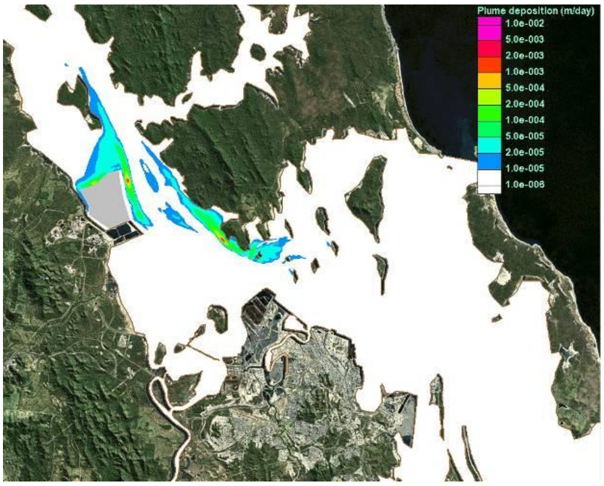


Figure 7-19 Spatial Representation of TSS Plume Deposition

Potential Impacts of Dredge Plume Sedimentation at Representative Seagrass Bed Locations

Potential sedimentation impacts to seagrass beds may result from smothering of existing substrates by settling of dredge plume material during the dredging operations. Smothering of seagrass can weigh down leaves, restrict light penetration and cause stress on the plants. The seagrass communities in the vicinity of the Project Area may experience an increase in sedimentation because of the Project. Potential sedimentation impacts from the predicted dredge plumes are assessed at the same representative locations of environmental sensitivity (i.e. seagrass beds) as for the prior light climate impact analysis, namely (Figure 7-4):

- WBM17 - Northern Western Basin seagrass beds;
- WBM04 - Middle Western Basin seagrass beds;
- WBM02 - Narrows seagrass beds; and
- WBM09 - Wiggins Island seagrass beds.

Daily sedimentation rates of dredge plume material at these four locations are summarised in Table 7-21.

Table 7-21 Daily Sedimentation Rates of Dredge Plume Material (mm/day)

Scenario	Narrows	Wiggins Island	North Western Basin	Middle Western Basin
1a	0.008	0.033	0.167	0.367
1b	0.022	0.047	0.217	0.400
2	0.012	0.043	0.192	0.383
3	0.003	0.003	0.025	0.033

Daily sedimentation rates at the Western Basin seagrass beds are clearly much greater than The Narrows and Wiggins Island sites, particularly for Scenarios 1a, 1b and 2. These estimates should be viewed as qualitative comparisons as the resuspension of natural bed material has not been modelled. Hence, these estimates are more representative of calm and low current conditions when wave and current induced resuspension is minimal.

Mitigation Measures

Operationally, addition of the option to pump directly from TSHDs into the Reclamation Area during the flood phase of large spring tides coincident with daytime could be considered. TSHD bottom dumping events are predicted to produce elevated rates of TSS sedimentation over the Western Basin seagrass beds at these times. Mitigation measures to reduce turbidity from the decant are also applicable for reduction of sedimentation rates.

Potential Impacts on Water Quality of Sediment Quality and Elutriate Release during Dredging

Potential Impacts

Potential Impacts from Dredged Sediments

The Project will encompass a wide range of sediment types with a range of physical (i.e. cobble, gravel, sand, silt and clay relative composition) and quality properties. Nonetheless, the analysis of QGC sediment quality data in the Sediment Quality Report (Appendix L) indicates that sediments are 'clean' with the following overall characteristics:

- The analysis of a large number of sediment samples from each of the dredge stages for an extensive suite of potential contaminants has revealed that the overall quality of the sediments in the Project Area are compliant to the NAGD (2009) and the EPA Draft Guidelines for the Assessment and Management of Contaminated Land in Queensland (1998) – Environmental Investigation Levels; and
- The only exception to the compliance of the sediment quality with the adopted guideline values is the elevated manganese concentrations observed within the Stage 1B area.

Due comprehensive nature of the sediment sampling and analysis program, the findings are considered representative of the sediments to be dredged for the Project. The results of the sediment chemical characteristics are also consistent with a number of other recent capital and maintenance dredging sampling programs within Port Curtis. It is therefore considered that the sediments proposed to be dredged are suitable for placement within the proposed Western Basin Reclamation.

Potential Impacts from Elutriate on Water Quality during Dredging

Median elutriate concentrations of ammonia (783 ug N L^{-1}) and manganese (399 ug Mn L^{-1}) were substantially greater than median values in the water column (NH_4=6 ug N L^{-1}, Mn=2.2 ug Mn L^{-1}) (Section 7.1.1). The QWQG (2006) guideline for indirect effects (i.e. eutrophication) of ammonia/ammonium is 8 ug N L^{-1} and no guideline exists for manganese in marine waters.

The NAGD (2009) defaults to the ANZECC (2000) 95th percentile level of protection for direct toxicity effects from elutriate after 'initial dilution' estimates. Hence, for ammonia elutriate the relevant guideline is 910 ug N L^{-1}, so the median elutriate ammonia level is below the relevant NAGD (2009) guideline for direct toxic effects on the ambient waters of the Project Area during overflow and rehandling operations.

Because of the potential indirect (i.e. eutrophication) impacts from ammonia elutriate during TSHD overflow and rehandling operations, estimates of the near-field (i.e. in close proximity to the TSHD) concentrations of the receiving estuarine waters were derived with the following assumptions:

- TSHD filling discharge rate is 16.7 m^3 s^{-1} (i.e. 10,000 m^3 hopper capacity filling in 10 minutes);
- TSHD overflows for 50 minutes of 60 minutes (10 minutes to fill);
- Concentrations of ammonia elutriate of 783 ug L^{-1} and receiving waters 6 ug L^{-1} ;
- 7.83 kg of ammonia elutriate dredged per 3 hour cycle of TSHD;
- 75% of the ammonia elutriate released during 50 minutes of overflow and remaining 25% during 10 minute dump, which assumes the majority of the ammonia elutriate is discharged during released overflow operations;
- Assumed overflow and rehandling TSS plumes have a cross-current length scale of 100 m (characteristic length scale);
- Assumed a completely mixed water column of 10 m depth (characteristic depth scale); and
- Assumed conservative behaviour (i.e. no oxidation to NO_X, no particle adsorption, no transfers across air-water interface).

These assumptions were used to calculate the near-field ammonia concentrations for representative current speeds of 0.1 m/s (slack), 0.5 m/s (neap) and 1 m/s (spring) as shown in Table 7-22.

Table 7-22 Overall Ammonia Elutriate Impact Assessment for Indirect Impacts

Current (m/s)	Time (s)	Dilution Volume (m^3)	Median NH_X (g/m^3)	Overflow Volume (m^3)	NH_X Elutriate Mass (g)	NH_X Hopper Elutriate (mg/L)	NH_X (mg/L) Near-Field	Ratio Relative to Guideline
Overflow								
0.1	3000	300,000	0.006	50000	5873	0.117	0.022	2.7
0.5	3000	1,500,000	0.006	50000	5873	0.117	0.010	1.2
1	3000	3,000,000	0.006	50000	5873	0.117	0.008	1.0
Rehandling								
0.1	600	60,000	0.006	10000	1958	0.196	0.033	4.1
0.5	600	300,000	0.006	10000	1958	0.196	0.012	1.5
1	600	600,000	0.006	10000	1958	0.196	0.009	1.1

This conservative approach indicates that the QWQG (2006) guideline will be exceeded during rehandling and overflow activities except during elevated currents (i.e. 1 m/s) for both overflow and rehandling operations. In contrast, because of the much smaller dilution volume during low slack tide currents, ammonia levels of 3 – 4 fold over the guideline values are estimated in this situation.

This analysis does not take into account far-field dispersion processes nor non-conservative processes (i.e. adsorption to particles and settling, volatilisation across the air-water interface, oxidation to oxidised inorganic nitrogen or uptake by photosynthetic organisms) and as such should be interpreted as a very conservative measure of potential indirect impacts from increased levels of nitrogen availability to primary producers.

Application of the NAGD (2009) guidelines to estimate 'initial dilution' over a 4 hour period will substantially reduce these estimates as dispersion of the elutriate will be much greater than the conservative approach used here (i.e. elutriate dilution in water volume that moves past during overflow and rehandling activities). Generally, the most likely indirect impact under these circumstances is the stimulation of phytoplankton growth or blooms, which is highly unlikely as the ammonia plume is coincident with a turbid plume, which greatly reduces light availability.

It is noted that the concentration of metals and ammonia in the decant waters from the reclamation were not considered in this analysis as the majority of the pore water fraction would be fluxed out of the sediments during dredging, overflow and rehandling.

Mitigation Measures

There are no mitigation measures proposed for the predicted changes in water quality associated with elutriate inputs or sediment mobilised into the water column as a result of the dredging operations other than to monitor ammonia and manganese periodically in the locale of dredging operations.

Maintenance Dredging

Maintenance dredging will be required on occasion to maintain the channels, swing basins and berths to their declared depths and to maintain shipping safety. Based on current maintenance dredging for Port Curtis, it is likely that dredging will continue to be required annually.

The impacts of maintenance dredging will be much reduced relative to those of capital dredging because the duration will be considerably less than the capital dredging programs. Sediment quality will be analysed prior to any dredging and appropriate disposal locations identified based on the physical and chemical properties of the material to be dredged. GPC will obtain all required permits for maintenance dredging and will implement mitigation measures and monitoring programs to minimise impacts on the receiving environment, in particular water quality.

Overview of Potential Impacts and Mitigation Measures

An overview of the potential impacts and mitigation measures for water quality is summarised in Table 7-23.

Risk Assessment

To assess the risk posed by the Project on water quality, a risk assessment has been undertaken via the risk assessment process outlined in Chapter 3. The assessment of water quality risk for the Project is summarised in Table 7-24.

Table 7-23 Overview of Potential Impacts of the Project on Water Quality

Construction Aspect	Construction Process	Potential Impacts	Potential Mitigation Measures
Construction of Bund Wall	Construction of the bund will involve placement of core material and rock armour into the harbour by trucks.	The disturbance of soft seabed sediments will be limited to the first layer of rocks, after which subsequent any additional rock for that section will be placed on rock and not the soft seabed sediments. There will be an increased risk of remobilisation of the mud wave during elevated wind and wave conditions, or during spring tides. There will also be the potential for waves to erode core material during storm (cyclone) conditions that may arise over the course of construction. There is the potential for spillage (either minor through drips or major through a leak/accident) of oils and fuels from construction equipment to impact on marine water quality. Small reduction in flushing because of loss of inter-tidal storage and small changes to currents, water levels and tide phases.	Generation of turbid plumes during rock placement to be visually monitored and photographed daily during initial construction stages. Difficult to mitigate this plume as the large tidal range and strong tidal currents limit the practicality of silt curtains in this environment. A stockpile of armour material will be held at the quarry, sufficient to cover any exposed core if a cyclone were to approach. Contingency planning for a storm will require the placement of the stockpiled armour material to cover exposed faces of the core material. No refuelling or maintenance of construction equipment will occur on the site, nor will equipment be parked at the site for a significant time, reducing the potential for significant spills of oils and fuels to occur. Spill kits for land and water based spills will be kept at the site and personnel trained in their use. Emergency response procedures will be established. No mitigation measures for flushing and hydrodynamic changes.

Construction Aspect	Construction Process	Potential Impacts	Potential Mitigation Measures
Filling of Bund Wall and Reclamation Decant	Dredged plume material will either be pumped from CSD locations or dumped by a TSHD adjacent to the Reclamation Area and rehandled by a medium-sized CSD into the Reclamation Area.	Placement of geotextile fabric will act to minimise the migration of fines through the bund wall and surrounding waters. Once a significant amount of dredged material is beached against the inner wall, this will also act as a filter layer to assist in preventing the migration of fine material through the bund wall into the receiving environment. TSS (and turbidity) from the decant is expected to be within the natural range and variability that has been measured within the Western Basin inter-tidal and sub-tidal regions of the Project Area with elevated levels primarily along the northern boundary of the Reclamation Area, which is likely to the region of impacts to seagrass beds.	No mitigation required for migration of dredge plume material through the bund. To achieve water quality objectives multiple cells within the Reclamation Area will allow finer materials to settle out of suspension via weir boxes with adjustable gates so that water can be retained for longer periods if needed, and the final weir box at the outfall can be completely closed if water quality objective is exceeded. Floating booms will also be available on site and will be deployed into the reclamation cells should wind conditions result in waves stirring up deposited sediments within the reclamation cells. Prior to each dredging program, once the dredger, volume, production rate and time frame of the particular program is known, calculations will allow design of the number of reclamation cells and the area required to achieve the water quality objectives. Development of a Dredge Management Plan including daily monitoring of sites within the final reclamation cell, at the outfall and at the northern Western Basin seagrass bed that commences two weeks prior to dredging, and continues during decant discharge.

Construction Aspect	Construction Process	Potential Impacts	Potential Mitigation Measures
Channel Dredging	Material removed from seafloor by pumped CSD or TSHD rehandling with placement in Reclamation Area.	Increased turbidity in vicinity of CSD, TSHD overflow and TSHD dumping. Development of turbid plumes that impact seagrass beds in Western Basin (primarily during flood tides because of TSHD dumping), but less so for those in Narrows and Wiggins Island. Decrease in the light climate experienced by seagrass beds in shallow waters. Slight reductions in net circulation patterns and flushing.	Monitoring of water quality during dredging and comparison of results to site specific water quality objectives for turbidity. Sediment sampling undertaken for the EIS determined dredged material is suitable for reclamation material, therefore the risk of contaminants being mobilised into the water column is considered low. Where possible, reduce occurrence of TSHD dumping during selected periods (such as flood phase of large spring tides) through programming, as this is when much of the dredge plume material will be transported into the Western Basin seagrass beds, and to a lesser extent, beyond these beds. No mitigation for changes to circulation patterns and flushing.

Table 7-24 Water Quality Risk Assessment

Activity Description	Potential Impacts and their Consequences	Preliminary Risk Assessment (C, L) Score	Additional Control Strategy	Residual Risk with Control Strategies Adopted (C, L) Score
Construction Phase				
Construction of Bund	Impact upon hydrodynamic regime and slightly reduced flushing of the Project Area with potential for small increases to background water quality levels.	(1,5) Medium	No ability to control impact.	(1,5) Medium
	Impact upon turbidity of the Western Basin inter-tidal and sub-tidal area from the disturbance of soft seabed sediments will be limited to the first layer of rocks after which any additional rock will be dumped on rock and not the soft seabed sediments.	(1, 5) Medium	Little ability to control impact. Silt curtains inappropriate given high flow environment. Minimal impacts expected.	(1, 5) Medium
	Increased risk of remobilisation of disturbed sediments during elevated wind and wave conditions, or during spring tides. There will also be the potential for waves to erode core material during storm (cyclone) conditions that may arise over the course of construction.	(2, 3) Low	Small stockpile of armour material held at the quarry sufficient to cover any exposed core if a cyclone approaches. Construction technique likely to have armour layer only 20 to 30m behind core. Minimise exposed core to 50m.	(2, 2) Low
	There is the potential for spillage (either minor through drips or major through a leak/accident) of oils and fuels from construction equipment to impact on marine water quality.	(3, 5) High	No planned refuelling or maintenance of construction equipment to occur on site, nor equipment to be parked at the site for a significant time. Readily available spill kits for land and water to be kept on site with trained personnel. Emergency response procedures will be established. Adherence to waste management controls identified in the EMP for this Project.	(1, 5) Medium

Activity Description	Potential Impacts and their Consequences	Preliminary Risk Assessment (C, L) Score	Additional Control Strategy	Residual Risk with Control Strategies Adopted (C, L) Score
Filling of the Bund and Dredge Decant	Placement of geotextile fabric will minimise migration of fines through bund wall into surrounding waters. Once substantial amount of dredged material is beached against the inner wall this will act as an additional filter layer to prevent fine material migration through the bund wall into the receiving environment.	(3,4) Medium	No additional mitigation required.	(3,4) Medium
	Predicted TSS (and turbidity) from the decant results primarily in elevated levels along the northern boundary of the Reclamation Area, which is the likely region of impacts to seagrass beds.	(3,5) High	Appropriate design and construction of bund, including lining with geotextile fabric and installing internal bunding, to reduce potential for fines to be moved back into marine environment through the bund wall or via the decant waters. Monitor tailwater decant to meet conditions/objectives within pond and/or within approved mixing zone. Provision to modify internal bund structure or discharge weir arrangement if required.	(3,4) Medium
Remnant Channel to West of Reclaimed Area	Reduction in net circulation and flushing.	(1, 3) Low	Limited ability to control impact.	(1, 3) Low
CSD Dredging	Increased turbidity in vicinity of CSD.	(1, 5) Medium	Limited impact in comparison to TSHD, with DMP to be adopted. No additional measure proposed.	(1, 5) Medium
	Metals concentrations exceed trigger level due to CSD operation including release of sediment due to the activity of the cutter.	(1, 5) Medium	No ability to control impact, but likely extent and persistence minimal.	(1, 5) Medium

Activity Description	Potential Impacts and their Consequences	Preliminary Risk Assessment (C, L) Score	Additional Control Strategy	Residual Risk with Control Strategies Adopted (C, L) Score
TSHD Dredging	Increased turbidity in vicinity of TSHD overflow. Primary impact will be on seagrass bed areas in the Western Basin.	(4,4) High	Monitoring and control of dredge regime to be in accordance with dredge management plan (DMP). Monitor turbidity levels against site specific objective 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, planned increase in period between dredging activity at any one location. Use of a CSD has been nominated for areas closest to The Narrows and Graham Creek.	(4,3) Medium
	Increased turbidity and decreased light on seagrass beds in Western Basin owing to TSHD dumping, with reduced impact on areas such as The Narrows and Grahams Creek.	(4, 5) High	Program dredge activity to avoid, where practicable, use of TSHD in dump mode in northern extents of Western Basin during flood phase of large spring tides. Implement offset program in accordance with conditions.	(3, 5) High
	Increased turbidity and decreased light on seagrass beds other than the Western Basin because of TSHD dumping	(2, 4) Medium	Dumping and rehandling primarily affect remnant part of Western Basin immediately to north of reclamation. Recommendations as above.	(2, 3) Low
	Metals concentrations exceed trigger level due to TSHD operation including release of sediment due to the activity of the cutter	(2, 5) Medium	No ability to control impact, but perhaps relatively large extent and moderate persistence.	(2, 5) Medium

Activity Description	Potential Impacts and their Consequences	Preliminary Risk Assessment (C, L) Score	Additional Control Strategy	Residual Risk with Control Strategies Adopted (C, L) Score
	Potential release of waste materials or pollutants associated with the dredger into the marine environment resulting in reduction in biodiversity.	(4, 3) Medium	Adherence to waste management controls for vessel operations.	(4, 2) Medium
Operational Phase				
Water Quality Impacts	Impacts to marine water quality from alteration of stormwater input, including increased erosion or storm water run-off to adjacent marine environment during storm / flooding events. Potential to mobilise contaminants into the marine environment and reduce biodiversity.	(2, 3) Low	Implement appropriate topside waste and stormwater management system. Design stormwater drainage systems to avoid increased scouring potential at release points in adjacent marine environment or concentration of freshwater inputs at outflow points to reduce impacts at point of introduction.	(2, 2) Low
Maintenance Dredging	Maintenance dredge program will increase in keeping with extended network of channels. Turbidity will be generated accordingly, subject to the type of dredge used. Similar practices to those currently employed for maintenance dredging likely to be employed.	(2, 5) Medium	Sediment quality will be analysed prior to dredging and appropriate disposal locations identified based on the physical and chemical properties of the material to be dredged. GPC will obtain all required permits for maintenance dredging and will implement mitigation measures and monitoring programs to minimise impacts on the receiving environment, in particular water quality. Review and update DMP for maintenance dredging.	(2, 5) Medium

Cumulative Impacts and Mitigation Strategies

Project Context

The Port of Gladstone has experienced ongoing development since the beginning of the twentieth century. Surveys in recent years and those for this EIS have identified good water quality in the Project Area under existing port operational conditions. However, as dredging and reclamation have both direct and indirect impacts on water quality, it follows that the implementation of additional dredging and the reclamation project will have a cumulative impact.

The proposed dredging activities intend to utilise the Western Basin reclamation site for dredged material disposal. An ability to better assess the potential cumulative impacts that could occur from the multiple dredging programs that are proposed for the Gladstone region has been achieved by including and simulating a large number of potential future dredging works under the impact assessment for this EIS. Works proposed for Fisherman's Landing, LNG Limited and Wiggins Island Coal Terminal have not been included in the impact assessment for this project. Wiggins Island Coal Terminal has already achieved approval and the dredging works to be undertaken for Fisherman's Landing and LNG Limited are being assessed under separate EIS processes.

Construction and operational cumulative impacts beyond dredging works have not, however, been addressed under this project. Accordingly, in conjunction with the assessment of impacts from all dredging activities, it is appropriate to also explore potential cumulative impacts that may result from concurrent water based construction projects within the Project Area as these could compound and amplify the impacts identified by this project. With respect to turbidity, these changes are likely to be limited to piling, and construction of marine off-loading facilities (MOFs) (dredging of MOFs is included in this EIS, but MOF construction activities may also generate turbidity).

Approaches to Reduce Cumulative Impact Potential within Gladstone

By locating the Western Basin Dredging and Disposal Project adjacent to the Fisherman's Landing Northern Expansion, the potential impacts of these projects are amalgamated in one area. This amalgamation of impact areas has allowed for the avoidance of multiple regions of degraded water quality in the port.

Expected Cumulative Impacts in Addition to Dredging Activities

Hydrodynamic modelling as well as water and sediment quality studies undertaken to support this EIS have been used to inform what potential impacts may occur as a direct or indirect result of all (cumulative) reclamation and dredging works. This includes scenarios with multiple dredgers operating. A full quantitative assessment of potential impacts from all concurrent projects would require detailed understanding of construction requirements and approaches, which is beyond the scope of this study currently. However, the risk assessment for this project also identified a range of in-water construction impacts, which are likely applicable across all projects and have been considered here for the qualitative assessment.

On this basis, potential cumulative impacts from concurrent projects in the Project Area are expected to result in some degradation of water quality and have been identified to include:

- Declines in water and sediment quality (including increased pollution) associated with construction events such as bund construction, bund filling and capital dredging works (as simulated in the modelling process);

- The flow on effects to benthic habitats and communities, particularly with respect to increased turbidity; and
- Declines in water and sediment quality associated with longer maintenance dredging requirements relative to those currently employed.

Expected Effects on Water Quality from Identified Cumulative Impact Activities

Mitigation strategies against each impact for the Proposed Western Basin Dredging and Disposal Project have been identified previously under Table 7-24. These took into consideration the potential impacts from multiple dredging projects occurring concurrently. These are considered to be the biggest concern with regard to cumulative impact potential relating to the multiple project development that may occur within the Project Area. Degradation of water quality is only expected to be temporary, coincident with active dredging operations as the flushing time scale is approximately 30-40 days. Accordingly, impacted areas are not expected to be permanently impacted from declines in water quality or altered hydrodynamic regimes, as assessed by this Project.

Offsets and Mitigation of Potential Cumulative Impacts

The major cumulative impact of approved and proposed projects on water quality is likely to lead to reductions to the extent of seagrass beds and suitable habitat for other marine communities in the Project Area. This is addressed further under the Marine Ecology Report (Appendix Q), which should be referred to for a discussion of all potential cumulative impacts to marine ecology.

Conclusion

Water quality monitoring for this EIS, coupled with the use of past data relevant to the Project Area has characterised the locality as a turbid environment with relatively good water quality. Most of the physico-chemical and chemical parameters were within adopted guidelines.

As the Project involves reclamation of approximately 235 ha of seabed, there is a minor impact on tidal currents, water levels and flushing efficiency with diminishing effects with distance from the Reclamation Area. The hydrodynamic and flushing impacts of the proposed capital dredging areas are less than those associated with the loss of the tidal volume from the Reclamation Area.

The main potential construction impacts, including potential cumulative impacts, which may result during the reclamation and channel dredging works are, therefore:

- Decant discharge during filling of the Reclamation Area is predicted to generate elevated turbidity in the region of the outfall and particularly along the northern bund wall. However, the effects of the decant discharge on the northern Western Basin inter-tidal and sub-tidal regions are greatly diminished relative to the northern bund wall area. Representative locations of sensitive seagrass beds (i.e. Wiggins Island and the Narrows) are not significantly impacted by elevating the decant discharge;
- CSD plants are predicted to have a low impact on turbidity and water quality, as most of the dredged material will be pumped directly to the Reclamation Area;
- TSHD plants are predicted to have greater impacts in terms of areal extent during dredging works. Regions of persistent elevated turbidity are predicted as a consequence of overflows during active dredging and emptying of the hopper adjacent to the eastern bund wall with subsequent rehandling by a dedicated CSD plant with dredge material pumped into the Reclamation Area. In particular, hopper dumping coincident with flood tides will have an impact on the turbidity climate of the Western

Basin and to a lesser degree on the Narrows. Increased turbidity reduces the light intensity at the seabed, thereby impacting seagrass beds. Seagrass beds in the vicinity of Wiggins Island are not greatly impacted during ebb tides as the dredge material plumes are primarily confined to the deep water channels with elevated velocities; and

- The sediments of the Project Area are predominately of good quality, hence other than increases in turbidity, persistent degradation to other physico-chemical and chemical parameters is not anticipated. However, elutriate analyses indicate manganese and ammonia that can be readily released from the sediments and/or are contained within the pore waters, however ammonia concentrations are compliant to the ANZECC (2000) toxicant guidelines. For TSHD overflow and rehandling activities, elevated levels of ammonia were conservatively estimated to range from a 3-4 fold increase over QWQG (2006) guidelines during low slack tide. However, the impact is likely to be substantially less when a number of physical, chemical and biological processes that would decrease ammonia values in the water column are taken into account and the NAGD (2009) initial dilution over a 4 hour period is applied.

All of these potential impacts on water quality are temporary, and water quality should therefore return to levels similar to the current status in between various capital dredging works stages and at the end of the project. Small changes to the overall water quality may occur because of minor changes to flushing efficiency of certain regions in the Project Area.

In addressing the potential risks to the marine system from the Project proposed mitigation measures were examined, where opportunities to mitigate impacts are available. These were detailed above and, in brief, include:

- Development and implementation of a reactive dredge management plan to mitigate against impacts on water quality from dredging activities;
- Implementation of waste management plans;
- Appropriate design of the Reclamation Area facility to reduce water quality impacts from leaching of material through the bund wall, decant waters and storm-water run-off; and
- Practicable scheduling of TSHD hopper dumps to not occur during some flood tide periods to reduce turbidity and light climate impacts to Western Basin shallow waters.

A number of direct impacts are not able to be mitigated such as modifications to hydrodynamics and flushing efficiency.

7.2 Marine Sediment Quality

This section of the EIS has been prepared in accordance with Section 3.5.1 of the ToR for the Project. A detailed report on the Sediment Sampling and Analysis Program implemented for this EIS is provided in Appendix L.

The guidelines of relevance to sediment quality for this project are:

- The National Assessment Guidelines for Dredging (NAGD; Australian Government 2009):
  - The NAGD (2009) are the regulatory framework which are applied to ensure the impacts of dredged material loading and disposal are adequately assessed and, when ocean disposal is permitted, that impacts are managed responsibly and effectively (Australian Government, 2009) under the Commonwealth *Environment Protection (Sea Dumping) Act* (1981). While the NAGD are designed for assessing offshore disposal of sediments, sediment quality in the Project Area has been compared to the NAGD (2009) as these are the most stringent guidelines under the National framework for marine sediments. The NAGD (2009) represent a revision of the National Ocean Disposal Guidelines for Dredged Material (NODGDM, Environment Australia 2002).
- The EPA Draft Guidelines for the Assessment and Management of Contaminated Land in Queensland (1998):
  - The QEPA Draft Guidelines will also be applied as the material will be disposed of in a Reclamation Area, eventually forming a land mass. The EPA guidelines were developed to provide best practice for managing land contamination through planning and development control processes. The Environmental Investigation Levels (EILs) contained in these guidelines have been adopted against which to compare sediment concentrations. The sediment contaminant concentrations have been assessed against these guidelines to inform any future placement in the proposed Western Basin Reclamation Area.

7.2.1 Description of Environmental Values

Sediment Quality Guidelines

The adopted guidelines for sediment quality are:

- National Assessment Guidelines for Dredging (2009):
  - Interim Sediment Quality Guidelines - Maximum level (ISQG – High);
  - Interim Sediment Quality Guidelines - Screening level (ISQG – Trigger Value); and
- EPA Draft Guidelines for the Assessment and Management of Contaminated Land in Queensland 1998 - Environmental Investigation Levels (EIL).

The guideline values are provided in Table 7-25.

Table 7-25 Sediment Quality Guidelines adopted for Western Basin Dredging and Disposal

Parameter	Draft Contaminated Land Qld (1998) – EILs	NAGD (2009) – Screening Level	NAGD (2009) – SQG-high
Metals and Metalloids (mg/kg)			
Arsenic	20	20	70
Antimony	20	2	25
Cadmium	3	1.5	10
Chromium (III +IV)		80	370
Copper	60	65	270
Lead	300	50	220
Manganese	500		
Mercury	1	0.15	1
Nickel	60	21	52
Silver		1	3.7
Zinc	200	200	410
Total Petroleum Hydrocarbons (mg/kg) (TPHs)			
C 6 – C9 Fraction	100		
C 10 – C14 Fraction	100		
C 15 – C28 Fraction	1,000		
C 29 – C36 Fraction	1,000		
Total TPHs		550	
Polycyclic Aromatic Hydrocarbons (µg/kg) (PAHs)			
Benz(a)pyrene			
PAHs (Sum of total)		10,000	50,000
Polychlorinated Biphenyls (µg/kg) (PCBs)			
PCBs (sum of total)	1,000	23	
Organochlorine Pesticides (µg/kg) (OCPs)			
4,4-DDE		2.2	27
Aldrin + Dieldrin	200		
Chlordane		0.5	6.0
DDD		2.0	20

Parameter	Draft Contaminated Land Qld (1998) – EILs	NAGD (2009) – Screening Level	NAGD (2009) – SQG-high
DDT		1.6	46
DDT+DDE+DDD	200		
Dieldrin		280	270 / 620
Endrin		10	120 / 220
g-BHC (Lindane)		0.32	1.0
Organotins (µg Sn/kg)			
Tributyltin (TBT)		9 µg Sn/kg	70 µg Sn/kg

Potential Pollution Sources

The Gladstone region contains the city of Gladstone and a variety of coastal and hinterland townships including Boyne Island/Tannum Sands, Yarwun, Targinie, Miriam Vale and Calliope. Industries within the catchment include pastoral, agricultural and processing and manufacturing. Major processing and manufacturing industries located within the Gladstone Region are summarised in Table 7-26. Major imports and exports handled within the port on behalf of local industries and industries located within the Central Queensland hinterland are provided in Table 7-27.

Based on catchment activities and industries, imports and exports, potential pollutant sources in the Port of Gladstone are summarised in Table 7-28.

Table 7-26 Major Industries in the Gladstone Region

Industry Name	Industry Type
BSL - Boyne Smelters Limited	Aluminium smelter
QAL - Queensland Alumina Ltd	Alumina refinery
NRG - NRG Gladstone Operating Services Pty Ltd	Coal fired power plant
Orica Australia Pty Ltd	Sodium cyanide, ammonium nitrate and chlorine plant
Rio Tinto Aluminium Yarwun	Alumina refinery
QER - Queensland Energy Resources Pty Ltd *	Oil shale miner and medium shale oil and naphtha plant
Cement Australia	Cement and clinker plant

* Ceased operations in 2003

Source: CQPA (2006)

Table 7-27 Major Imports and Exports of Port of Gladstone

Imports	Exports
Bauxite	Alumina
Bunker oil	Aluminium
Caustic soda	Calcite
Cement gypsum	Cement
Containers	Cement Clinker
General cargo	Coal
Liquid pitch	Containers
LP gas	Fly ash
Petroleum coke	General cargo
Petroleum products	Sorghum
	Wheat

Source: CQPA (2006)

Table 7-28 Potential Pollutant Sources in the Port of Gladstone

Source	Potential Contaminants
Shipping	Hydrocarbons (fuels and oils) Polycyclic Aromatic Hydrocarbons (PAHs) Tributyl tin (TBT) Spillage of product during import and export (bauxite, coal, clinker, alumina)
Natural geology	Metals (especially arsenic and nickel) and PAHs
Industrial discharges	Metals, organics
Landfills	Metals and other leachates – few likely in Gladstone as only small, inactive landfills present close to the coast
Agriculture and horticulture	Herbicides and pesticides – horticulture reduced in recent years
Urban stormwater discharges	PAHs, metals, hydrocarbons
Sewage treatment plants	Secondary treated water re-used at local industrial sites

Previous Sediment Quality Assessments

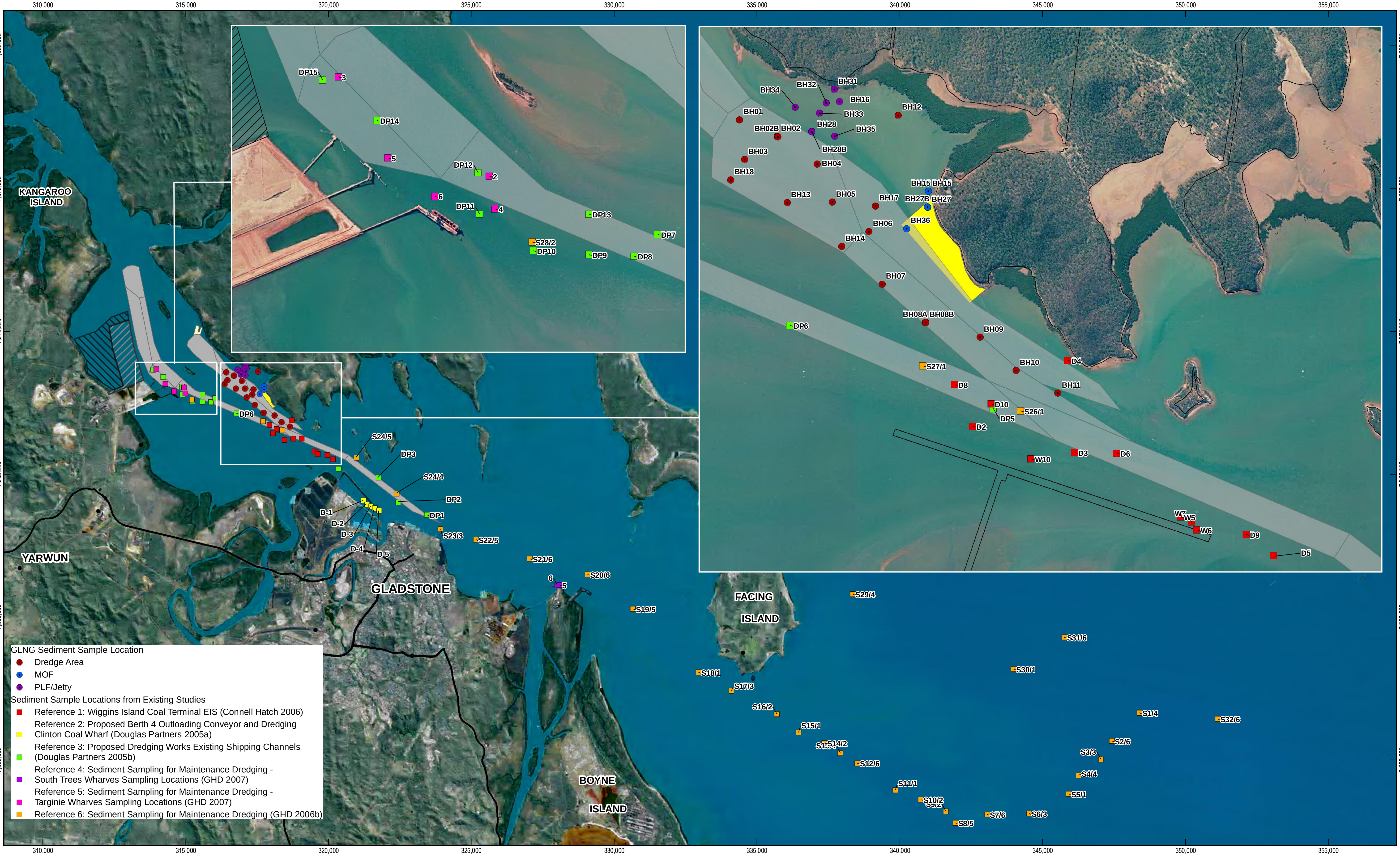
There is a long history of dredging and dredged material disposal in both onshore and offshore locations at the Port of Gladstone. All material to be dredged in recent years has undergone sampling and analysis prior to dredging and all material has been assessed as suitable for its intended disposal location. A comprehensive review of previous sediment quality studies for capital and maintenance dredging projects in the Port of Gladstone is contained in Appendix L. The sampling sites for these previous studies, which correspond to the areas that were dredged in those projects, are shown in Figure 7-20, along with the areas that are proposed to be dredged for this Project. This overlay indicates that a number of the previous studies have been undertaken in the vicinity of the proposed dredging for the Western Basin Dredging and Disposal Project.

The data summarised from the studies noted above is considered good quality data, with much of it collected within the last 5 years. The main contaminants of concern that have been identified in the Port of Gladstone from previous studies include metals (arsenic and nickel), PAHs and TBT. No new land based sources of contamination have been introduced into the catchment of the Port of Gladstone since the most recent capital and maintenance dredging sampling have been conducted that would indicate additional contaminants of concern should be considered in future sampling programs.

The NAGD (2009) define contaminants of concern as those compounds that are known or suspected to be present at concentrations greater than one tenth of the screening levels in Table 2 of the NAGD (2009). Other potential contaminants in the Port of Gladstone, including some that are not listed in Table 2, have been analysed for in previous studies, but have not been identified at concentrations exceeding the laboratory limits of reporting. Therefore, based on previous studies and in accordance with the NADG (2009), the contaminants of concern that have been present in previous sampling programs at concentrations exceeding one tenth of the screening levels in Table 2 of the NAGD (2009) are:

- Metals and metalloids;
- Polycyclic Aromatic Hydrocarbons (PAHs); and
- Organotin compounds (TBT, DBT, MBT).

Acid sulphate soils are also of concern given disposal of the dredged material into a Reclamation Area is proposed, where the material could potentially be exposed to oxygen as the dredging tailwaters are decanted and the height of the material rises above HAT in the Reclamation Area. A separate Acid Sulphate Soils Assessment was undertaken and the results are provided in Appendix I.



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0 1 2 3 4 5

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Grid: Map Grid of Australia 1994, Zone 56

N

LEGEND

- Western Basin Reclamation Area
- Fisherman's Landing Northern Expansion
- Cadastre
- Proposed Dredge Footprint
- GLNG Proposed Marine Offload Facility
- QGC Proposed Marine Offload Facility

Port of Gladstone
Western Basin Dredging and Disposal Project

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Location of Sampling Sites for Previous Studies in the Port of Gladstone

Figure 7-20

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Data Source

There are currently a number of proponents undertaking investigations into proposed developments within the Western Basin. Queensland Gas Corporation Ltd (QGC), a BG Group Company, implemented a sediment Sampling and Analysis Plan (SAP) (ERM 2009) and conducted a marine sediments study for all of the proposed dredging areas covered by the Western Basin Dredging and Disposal Project. The QGC draft SAP was prepared in accordance to the NAGD (2009).

GHD prepared a SAP on behalf of GPC for submission to DEWHA and DERM (GHD 2009h). The GPC SAP was based on the QGC draft SAP and the requirements of the NAGD (2009). Comments on the GPC SAP were received from DEWHA and DERM following the completion of sampling and these comments were addressed in the full Sediment Quality Report (Appendix L).

The raw results from the QGC marine sediments study have been made available to GPC to assist with the preparation of the Port of Gladstone Western Basin Dredging and Disposal Project EIS.

Methods

A full description of the methods employed in the sediment sampling and analysis program is provided in Appendix L.

Number of Samples

The volume of *potentially contaminated* dredge material was calculated by multiplying the respective areas within each of the five distinct planned dredge stages by the value of 1.12 m depth. The full number of sampling locations for each area to be dredged was determined using the volume of *potentially contaminated* material (Table 7-29). The volume of clean material was then calculated by subtracting the volume of *potentially contaminated* sediments from the total estimated volume of dredged material (Table 7-29).

Previous testing of sediment from the maintenance and capital dredging campaigns in Port Curtis found that the sediment was compliant to the NAGD (2009) sediment quality guidelines. Therefore, it is considered that the volume of *potentially contaminated* material for this capital dredging project can be considered to be ‘probably clean’. According to the NAGD (2009), this would allow the number of sampling locations from Table 7-29 to be halved. Table 7-29 presents the full number of sampling locations that would normally be required, as well as 50% of the sampling locations based on the low contamination status of Port Curtis.

The GPC SAP had proposed a pilot study consisting of 20% of the full number of sampling locations (GHD 2009h). The actual number of sampling locations provided to GPC by QGC represents a higher percentage of the full number of sampling locations for all of the proposed dredge stages, with all bar Stage 4 greater than 50% (Table 7-29).

It is noted that QGC gave Stages 3 and 4 a 50% weighting as it was considered that they were unlikely to be dredged in the next 5 years, after which sediment quality data is not considered current (ERM 2009). This was taken into account when calculating the percentage of the full number of sampling locations that have been sampled for these stages, with the full number of sampling locations used (Stage 3 – 41; Stage 4 – 36).

Table 7-29 Dredge Area, Dredge Volumes and Number of Sampling Locations for Proposed Dredge Areas

Area to be Dredged	Total Volume to be Dredged (m^3)	Area (m^2)	Volume of 'potentially contaminated' material*	Full Number of Sampling Locations	Half Number of Sampling Locations	Actual Number of Sampling Locations (% of full number)**
Stage 1A	16 million	3.6 million	4.03 million m^3	116	58	76 (66%)
Stage 1B	6.1 million	2.0 million	2.24 million m^3	72	36	41 (57%)
Stage 2	4.5 million	1.6 million	1.79 million m^3	60	30	38 (63%)
Stage 3	5.5 million	1.0 million	1.12 million m^3	22[#]	11	24 (59%)[#]
Stage 4	3.9 million	0.8 million	0.9 million m^3	20[#]	10	10 (28%)[#]
Total	**36.0 million**	**9 million**	**10.8 million m^3**	**290**	**145**	**189**

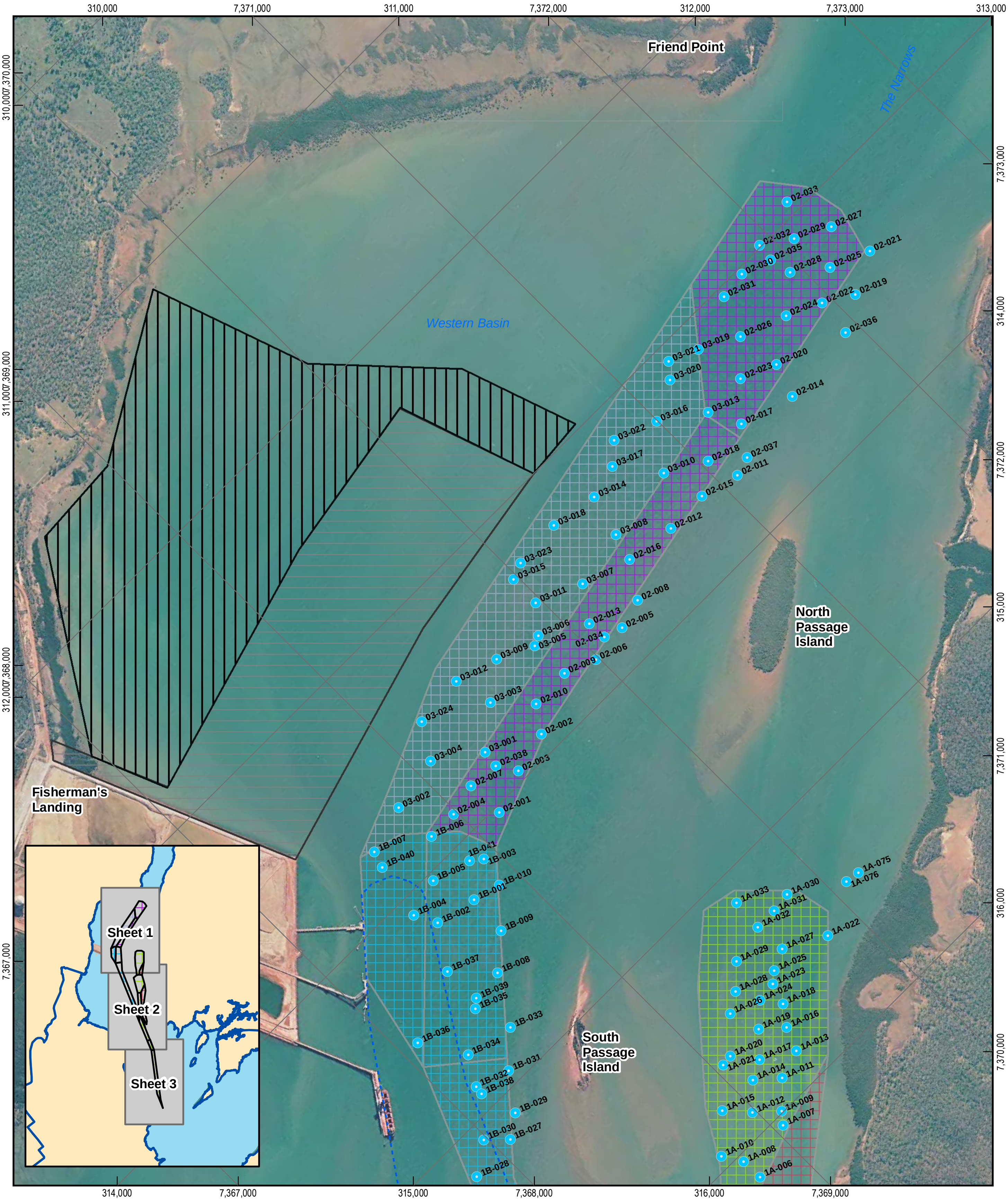
*based on a depth of 1.12 m of potentially contaminated material overlying natural geological material

** data provided by QGC

[#] Stages 3 and 4 were given a 50% weighting by QGC as they were considered unlikely to be dredged in the next 3 – 5 years. Therefore these numbers already represent half the full number of sampling locations required by the NAGD (2009). The actual full number of sampling locations is 41 and 36 and these are the numbers the percentages have been calculated against.

Sampling Locations

The sampling sites were generally randomly chosen in accordance with the method outlined in the NAGD (2009). Where there were non-depositional zones identified or areas that are already deeper than the required depth of dredging, fewer samples were collected in these areas (ERM 2009). The sampling locations are shown in Figure 7-21. Due to the technical constraints associated with sampling at greater than 6 m below seabed, 20% of the cores were drilled to the maximum depth of dredging where this exceeded 6 m.



LEGEND

- Sediment Sample Location
- Western Basin Reclamation Area
- Fisherman's Landing Northern Expansion
- Existing Channels, Swing Basins and Berths
- Wiggins Island Coal Termina (Approved)

Proposed Dredge Stages

- Stage 1A - North China Bay LNG Precinct
- Stage 1B - Fisherman's Landing LNG
- Stage 2 - Laird Point LNG
- Stage 3 - Fisherman's Landing
- Stage 4 - Hamilton Point

1:25,000 (at A4)

0 0.2 0.4 0.6 0.8 1

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

Port of Gladstone
Western Basin Dredging and Disposal Project

Sediment Sample Locations and Proposed Dredge Stages (Sheet 1 of 3)

Job Number	42-15386
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Date	01 Sept 2009

Figure 7-21a

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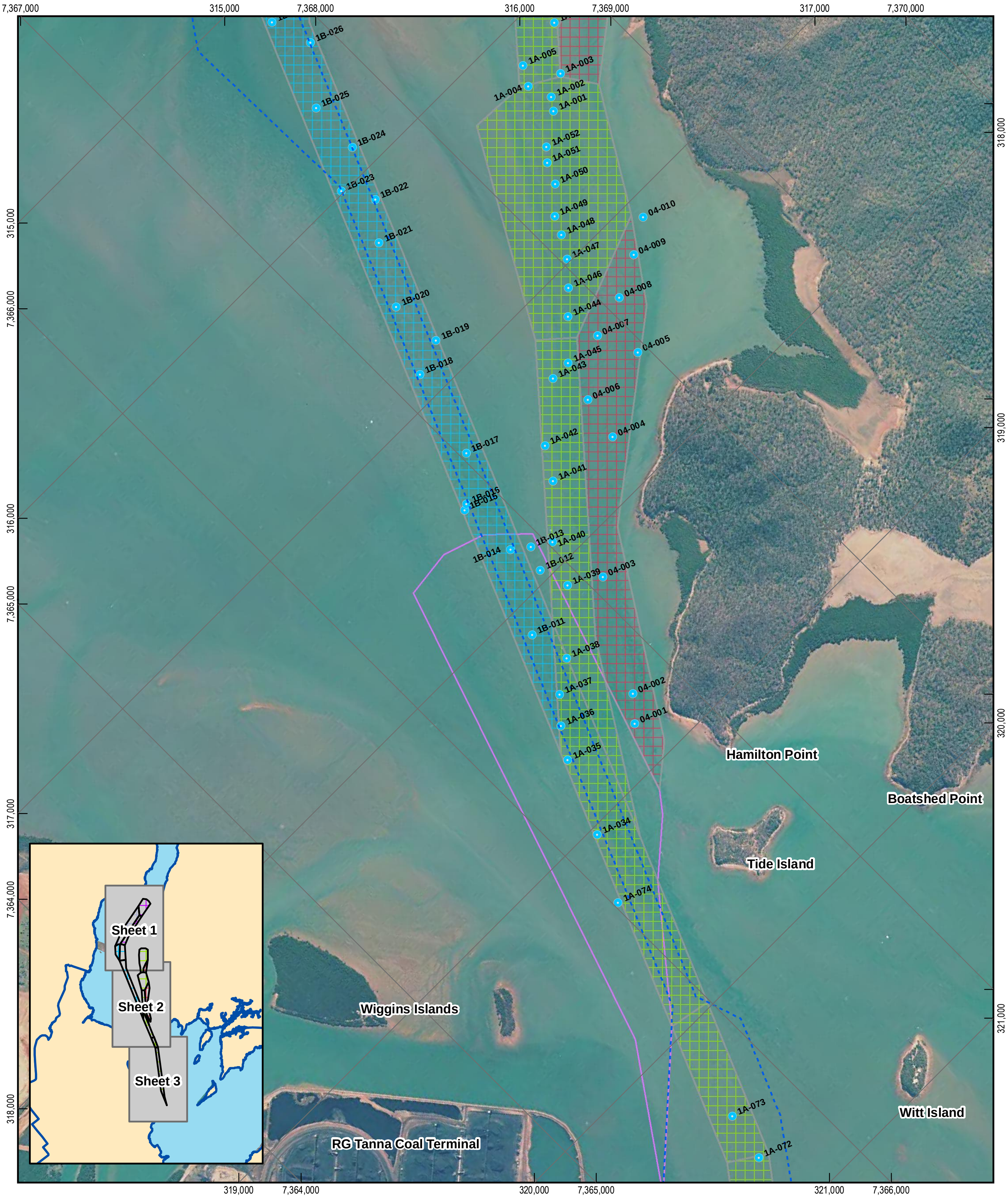

LEGEND

- Sediment Sample Location
- Existing Channels, Swing Basins and Berths
- Wiggins Island Coal Termina (Approved)

Proposed Dredge Stages

- Stage 1A - North China Bay LNG Precinct
- Stage 1B - Fisherman's Landing LNG
- Stage 2 - Laird Point LNG
- Stage 3 - Fisherman's Landing
- Stage 4 - Hamilton Point

1:25,000 (at A4)

0 0.2 0.4 0.6 0.8 1

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

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Port of Gladstone
Western Basin Dredging and Disposal Project

Sediment Sample Locations and
Proposed Dredge Stages (Sheet 2 of 3)

Job Number	42-15386
Revision	B
Date	01 Sept 2009

Figure 7-21b

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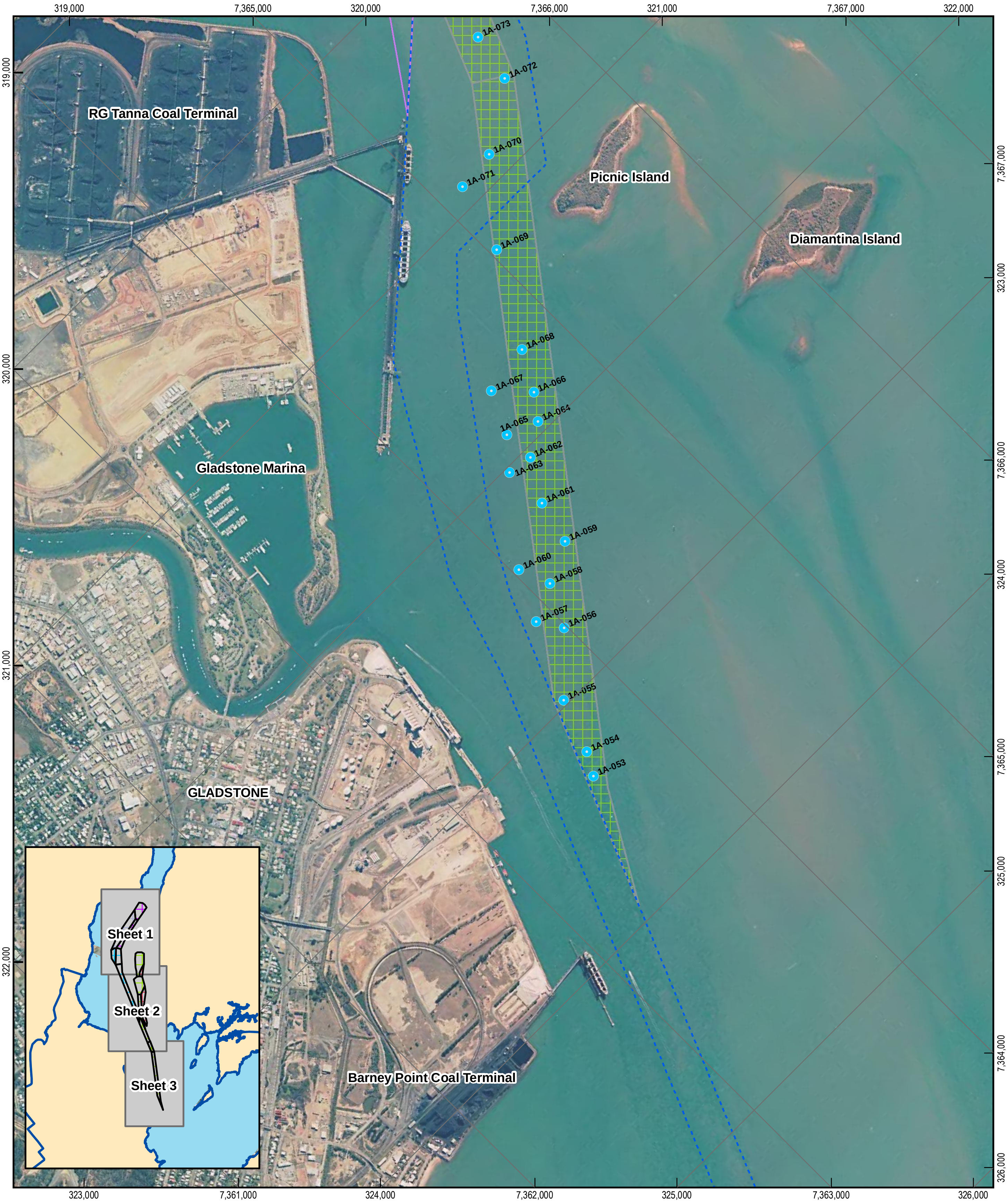

LEGEND

- Sediment Sample Location
- Existing Channels, Swing Basins and Berths
- Wiggins Island Coal Termina (Approved)

Proposed Dredge Stages

- Stage 1A - North China Bay LNG Precinct
- Stage 1B - Fisherman's Landing LNG
- Stage 2 - Laird Point LNG
- Stage 3 - Fisherman's Landing
- Stage 4 - Hamilton Point

1:25,000 (at A4)

0 0.2 0.4 0.6 0.8 1

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

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Port of Gladstone
Western Basin Dredging and Disposal Project

Sediment Sample Locations and Proposed Dredge Stages (Sheet 3 of 3)

Job Number 42-15386
Revision B
Date 01 Sept 2009

Figure 7-21c

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Depth of Sampling

The majority of the areas to be dredged will need to be deepened to a design/declared depth of –13.0 m LAT to accommodate the proposed shipping traffic. This includes channels, swing basins and berth pockets. A few areas will potentially require deepening to a design/declared depth of –16.0 m LAT. Table 7-30 summarises the estimated seabed range, and the range and average depth of boreholes sampled within each of the proposed dredging stages.

Table 7-30 Estimated Seabed and Borehole Depths for the Proposed Dredge Stages

Stage	Estimated Seabed Range (mLAT)	Borehole Depth (mLAT)		
		Maximum	Minimum	Average
Stage 1A	-3.0 to -17.0	-22.4	-5.3	-10.78
Stage 1B	-6.0 to -15.0	-18.3	-7.9	-12.74
Stage 2	-5.0 to -12.0	-17.3	-8.6	-13.36
Stage 3	-5.0 to -12.0	-17.4	-6.5	-11.70
Stage 4	-5.0 to -13.0	-16.7	-6.1	-11.66

Sample Collection Methods

Samples were collected using a combination of continuous coring, conventional coring and standard penetration testing (SPT) to ensure the full sediment depth profile was sampled and characterised. The coring vessels were operated by MIPEC and GeoCoastal Operations Pty Ltd (ERM 2009).

Samples were taken from the following depths in the first half of the core:

- 0 – 0.5 m;
- 0.5 – 1.0 m;
- 1.0 m – 1.5m; and
- 1.5 – 2.0m.

Below 2.0m depth intervals were collected at 0.5 m length where sediment was sandy, or 1.0 m length to the end of the core for other sediment types (i.e. clay, silty clay) (ERM 2009). For instances where the interval crossed a sediment type boundary, the depth interval was adjusted to one side of the boundary (ERM 2009).

Sample Analysis

The suite of analytical parameters tested were determined based on the review of previous studies completed in the area and in accordance with NAGD (2009) requirements. Sediment cores were sub-sampled in three on-site laboratories for a range of parameters including whole sediment analyses (Phase II testing, NAGD 2009) plus elutriate and bioavailability analyses (Phase III). It is noted that the elutriate data are discussed within the Western Basin Dredging and Disposal Project Water Quality Report (Appendix K).

Sediment samples from each of the proposed dredge areas were analysed for a basic and additional suite of parameters. Appendix L identifies the number of boreholes within each of the proposed dredge stage areas, as well as the number of samples analysed for the various parameters included within the basic and additional suites.

Data Analysis

As required in Appendix A of the NAGD (2009), the upper 95% confidence limit (95% UCL) of the mean was calculated for the contaminants of concern to determine overall compliance of the sediment to be dredged with the Screening Levels and SQG-High specified in Table 2 and Table 4 of the NAGD (2009).

Quality Assurance and Quality Control

A full description of the QA/QC procedures employed in this sampling program is provided in Appendix L.

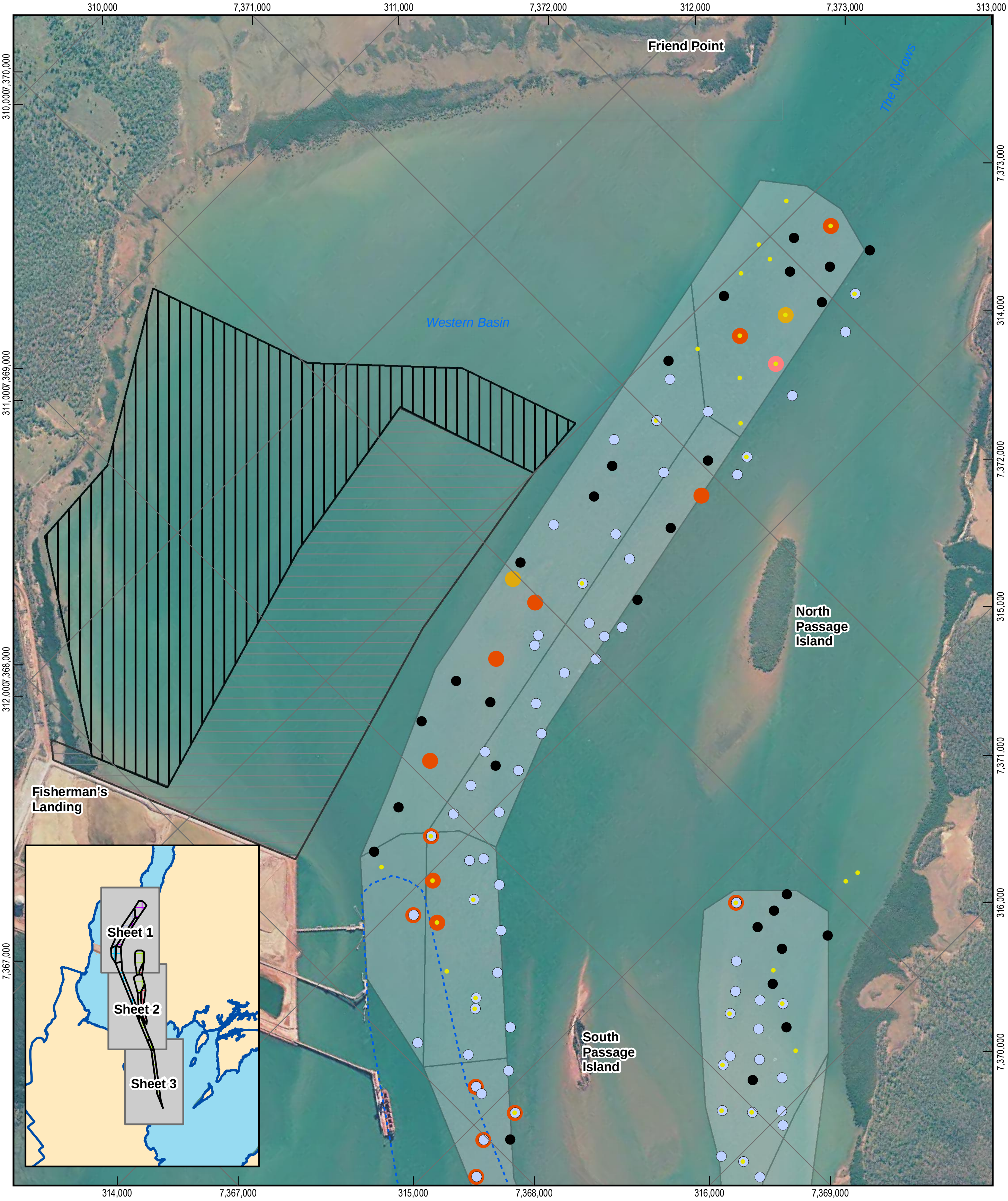
Sediment Quality Results

Metals and Metalloids

A summary of exceedances of the guidelines for metals and metalloids in individual samples is provided in Figure 7-22. In summary:

- Manganese exceeded the QEPA EIL guideline value of 500 mg/kg in individual sediment samples collected from each of the proposed dredging areas. The 95% UCL of the mean manganese concentration (614.7 mg/kg) within the Stage 1B area was above the QEPA EIL guideline of 500 mg/kg;
- The 95% UCL of the mean manganese concentration (479.8 mg/kg) within all dredging stages combined was compliant to the QEPA EIL guideline of 500 mg/kg;
- Arsenic exceeded the NAGD Screening Level and the QEPA EIL guideline value of 20 mg/kg in some samples from the Stage 1A, Stage 1B, Stage 2 and Stage 3 areas;
- Nickel was recorded in concentrations above the NAGD Screening Level of 21 mg/kg in individual samples from the Stage 1A, Stage 1B, Stage 2 and Stage 3 areas;
- A single sample collected from the Stage 1B area recorded a cadmium concentration marginally above the NAGD Screening Level of 1.5 mg/kg, while a further single sample from the Stage 2 area exceeded the NAGD Screening Level for mercury (0.15 mg/kg);
- Copper was recorded in concentrations above the NAGD Screening Level (65 mg/kg) and the QEPA EIL (60 mg/kg) guideline values in a single sample from each of Stage 2 (74.3 mg/kg) and Stage 3 (171 mg/kg); and
- The 95% UCL of mean concentrations of all metals and metalloids, excluding manganese in Stage 1B, were below the relevant Screening Level nominated in NAGD (where guidelines are available) and the QEPA EIL (where available).

A detailed summary of the results for metals and metalloids in each of the dredging stages is provided in Appendix L.



LEGEND

- Sample with No Exceedences
- Arsenic: Exceeds QEPA EIL (20 mg/kg)
- Manganeese: Exceeds QEPA EIL (500 mg/kg)
- Nickel: Exceeds NAGD Screening Level (21 mg/kg)
- Mercury: Exceeds NAGD Screening Level (0.15 mg/kg)
- Copper: Exceeds NAGD Screening Level (65 mg/kg)
- Cadmium: Exceeds NAGD Screening Level (1.5 mg/kg)
- Existing Channels, Swing Basins and Berths
- Proposed Dredge Stages
- Wiggins Island Coal Termina (Approved)
- Western Basin Reclamation Area
- Fisherman's Landing Northern Expansion

1:25,000 (at A4)

0 0.2 0.4 0.6 0.8 1

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

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Port of Gladstone
Western Basin Dredging and Disposal Project

Summary Figure of Metal and Metalloid Results (Sheet 1 of 3)

Job Number	42-15386
Revision	A
Date	01 Sept 2009

Figure 7-22a

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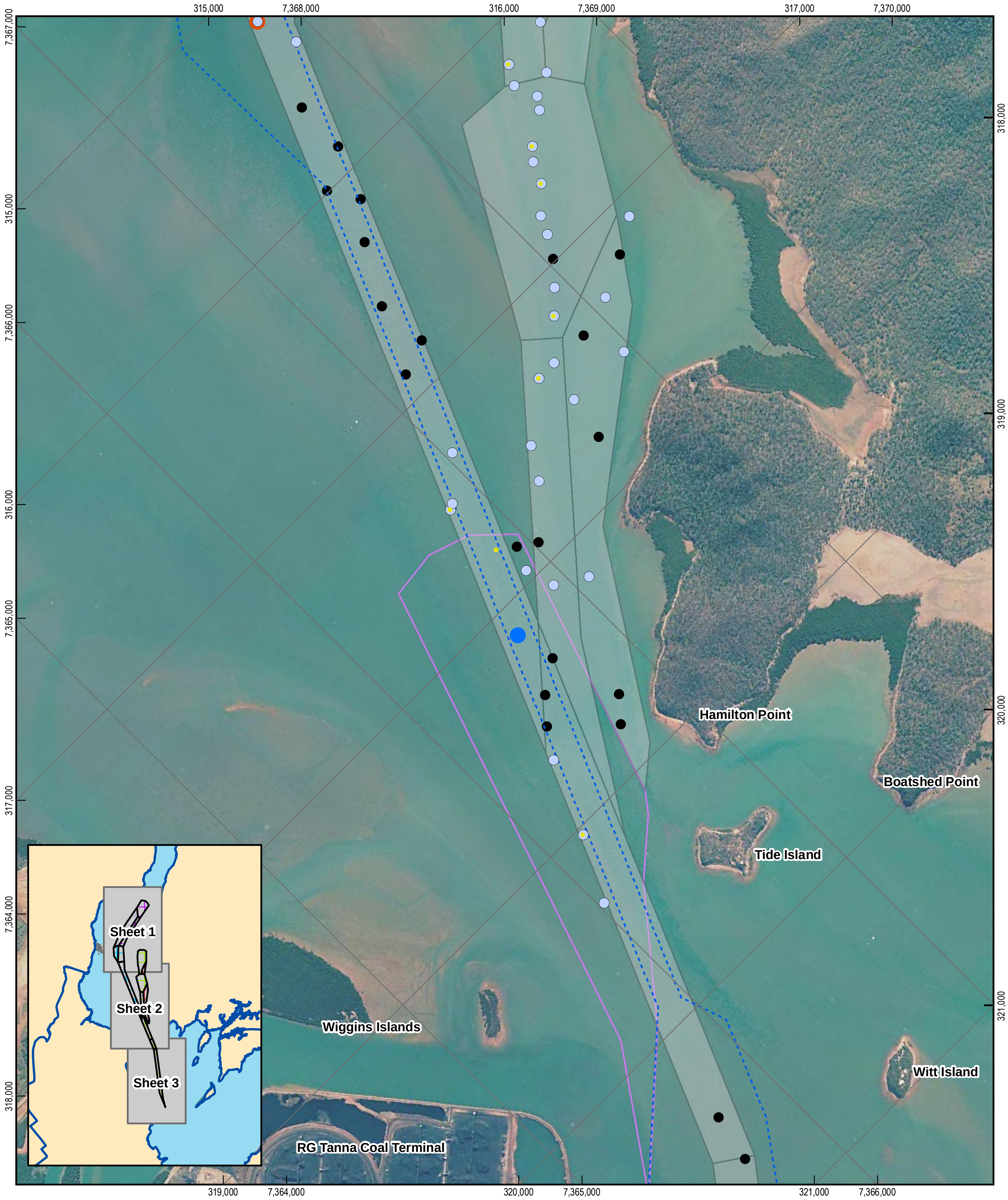

LEGEND

- Sample with No Exceedences
- Arsenic: Exceeds QEPA EIL (20 mg/kg)
- Manganeese: Exceeds QEPA EIL (500 mg/kg)
- Nickel: Exceeds NAGD Screening Level (21 mg/kg)
- Mercury: Exceeds NAGD Screening Level (0.15 mg/kg)
- Copper: Exceeds NAGD Screening Level (65 mg/kg)
- Cadmium: Exceeds NAGD Screening Level (1.5 mg/kg)
- Existing Channels, Swing Basins and Berths
- Proposed Dredge Stages
- Wiggins Island Coal Termina (Approved)
- Western Basin Reclamation Area
- Fisherman's Landing Northern Expansion

1:25,000 (at A4)

0 0.2 0.4 0.6 0.8 1

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

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Port of Gladstone
Western Basin Dredging and Disposal Project

Summary Figure of Metal and Metalloid Results (Sheet 2 of 3)

Job Number	42-15386
Revision	A
Date	01 Sept 2009

Figure 7-22b

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Level 4 201 Charlotte Street Brisbane QLD 4000 Australia T +61 7 3316 3000 F +61 7 3316 3333 E bnemail@ghd.com W www.ghd.com

LEGEND

- Sample with No Exceedences
- Arsenic: Exceeds QEPA EIL (20 mg/kg)
- Manganeese: Exceeds QEPA EIL (500 mg/kg)
- Nickel: Exceeds NAGD Screening Level (21 mg/kg)
- Mercury: Exceeds NAGD Screening Level (0.15 mg/kg)
- Copper: Exceeds NAGD Screening Level (65 mg/kg)
- Cadmium: Exceeds NAGD Screening Level (1.5 mg/kg)
- Existing Channels, Swing Basins and Berths
- Proposed Dredge Stages
- Wiggins Island Coal Termina (Approved)
- Western Basin Reclamation Area
- Fisherman's Landing Northern Expansion

1:25,000 (at A4)

0 0.2 0.4 0.6 0.8 1

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

GHD GPC

Port of Gladstone
Western Basin Dredging and Disposal Project

Summary Figure of Metal and Metalloid Results (Sheet 3 of 3)

Job Number	42-15386
Revision	A
Date	01 Sept 2009

Figure 7-22c

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Nutrients

Total Kjeldahl Nitrogen (TKN) accounted for all Total Nitrogen measured in all samples. Maximum TKN concentrations for the proposed dredge areas ranged between 760 mg/kg (Stage 1B) and 4,240 mg/kg (Stage 4), with average concentrations of between 195 mg/kg (Stage 1A) and 371 mg/kg (Stage 4). The maximum Total Phosphorus (TP) concentration for the proposed dredge areas ranged between 767 mg/kg (Stage 3) and 4,290 mg/kg (Stage 4). The maximum recorded TP concentration was reported for a sediment sample collected at an approximate depth of 1.25 mBSB in Stage 4, and did not coincide with the maximum TKN concentration, also reported from Stage 4.

Oxidised Nitrogen (NO_x) was below the limit of reporting (LOR) in over half of the samples from each of the proposed dredging stages.

Radionuclides

Radionuclides were analysed in a limited number of samples collected in the Stage 1A (8 samples), Stage 1B (6 samples) and Stage 2 areas (6 samples). Three samples recorded above the LOR for alpha radiation from the Stage 1B area. All samples analysed recorded a concentration above the LOR for beta radiation, however the concentrations were well below the NAGD Screening Level of 35,000 mBq/g.

Organic Compounds

- TBT was detected above LOR in a single sample collected from each of the Stage 1A, Stage 1B and Stage 3 areas. Within the Stage 1A and Stage 3 areas the concentrations were low and were recorded within the upper 0.25 m of the sediment profile. The sample from Stage 1B was present at trace levels deep within the sediment profile (6.0 mBSB). The normalised concentrations of the three samples were compliant to the NAGD Screening Level;
- Low concentrations of individual BTEX compounds were recorded within the proposed Stage 2 and Stage 3 dredge areas. No samples recorded concentrations above the LOR for the BTEX suite in the Stage 1A, Stage 1B or Stage 4 areas;
- Low concentrations of TPH compounds were recorded within the proposed dredge areas. Between 64% (Stage 2) and 88% (Stage 3) of samples analysed exceeded the LOR for the TPH (+C10 – C36) (sum of total) fraction. All BTEX and TPH samples were below the QEPA EIL and NAGD Screening Levels;
- No PCBs were detected within the Stage 1A, Stage 3 and Stage 4 areas;
- Low concentrations of various individual PAHs were present in a number of samples within the proposed dredge areas, excluding the Stage 4 area where all samples were below LOR;
- The concentrations of PCBs and PAHs were below the QEPA EIL and NAGD Screening Levels;
- The concentrations of OC/OP pesticides in all samples at all depth intervals were below the laboratory LOR within all of the proposed dredge areas;
- Herbicides and insecticides were analysed in a limited number of samples within each of the proposed dredge areas and all samples analysed were below the LOR; and
- A single chlorinated hydrocarbon compound (Hexachlorobenzene) was analysed for a number of samples within all proposed dredging areas, with no samples exceeding the LOR. Within the Stage 1B area a further 3 samples were analysed for the full range of other chlorinated hydrocarbons, halogenated hydrocarbons and explosives, with no samples exceeding the LOR.

7.2.2 Potential Impacts and Mitigation Measures

Discussion of Sediment Quality

This section discusses the results of the sampling program and considers overall compliance of the material to be dredged to the sediment quality guidelines provided in the NAGD (2009) and the QEPA Draft Guidelines for the Assessment and Management of Contaminated Land (1998) - Environmental Investigation Levels (EIL). These conclusions are based on raw data provided by QGC to GPC.

Metals and Metalloids

The 95% UCL of mean concentrations of all metals and metalloids, excluding manganese in Stage 1B, were below the relevant Screening Level nominated in NAGD (2009) (where guidelines are available) and the QEPA EIL (1998). The 95% UCL of the mean manganese concentration (614.7 mg/kg) within the Stage 1B area was above the QEPA EIL guideline of 500 mg/kg. The 95% UCL of the mean manganese concentration (479.8 mg/kg) within all of the dredging stages combined was compliant to the QEPA EIL guideline of 500 mg/kg.

Other than the occurrence of manganese within the Stage 1B area, there is no apparent trend in the location or depth of the occurrence of metals in the sediment. This lack of an apparent trend indicates that the presence of the metals may be naturally occurring, as only the top 1.12 m of sediments were considered potentially contaminated with anthropogenic contaminants based on past studies and the rate of sedimentation in Port Curtis.

The occurrence of the three highest manganese concentrations within the Stage 1B area within sediment depths less than 1 mBSB indicates that there may be a localised source of manganese contamination within this region.

The average manganese concentration reported for the individual stages for the Western Basin Dredging and Disposal Project ranged between 306 mg/kg with a standard deviation of 222 mg/kg (Stage 3) and 447 mg/kg with a standard deviation of 502 mg/kg (Stage 1A), which is similar to the average values reported by GeoCoastal (2008) for the Santos GLNG dredge areas (323 ± 229 mg/kg).

Manganese is noted to be widely occurring within marine sediments, and has also been mined within the Gladstone region (URS 2009). Given there is no guideline for manganese in the NAGD (2009), the concentrations reported are not considered to be of concern during dredging and rehandling. The Water Quality Report (Appendix K) discusses the results of elutriate analysis for manganese and concludes that while the background concentration may be exceeded during dredging, the only specific mitigation measure required is periodic monitoring of manganese during dredging.

As the final Reclamation Area is to be used for industrial purposes, the manganese concentrations are not considered to pose a restriction to the future use of the Reclamation Area. The Reclamation Area will be lined with geotextile fabric and will be capped once filled. Given the 95% UCL manganese concentration of all the dredging stages combined is below the QEPA EIL, and the likelihood that sediments will therefore be mixed within the Reclamation Area, it is not considered that manganese is of significant concern in the concentrations recorded in this monitoring program.

The URS (2009) marine sediment investigation of the GLNG dredge areas (Stage 1A) also recorded arsenic in concentrations above the relevant guideline values in proposed dredge areas. The maximum recorded concentration for the URS (2009) study of 37 mg/kg is of the same magnitude as the concentrations recorded during this program.

Nutrients

There are no screening or investigation levels for nutrients in sediments in the guidelines adopted for this program. Maximum Total Kjeldahl Nitrogen (TKN) concentration for the proposed dredge areas ranged between 760 mg/kg (Stage 1b) and 4,240 mg/kg (Stage 4). The maximum concentration of 4,240 mg/kg was recorded within Stage 4 for a sediment sample collected at an approximate depth of 4.5 mBSB. The next highest sample from the Stage 4 area of 1,140 mg/kg is similar in value to the maximum value recorded for the Stage 1A area, and within the range of the TKN maximum recorded by URS (2009) of 920 mg/kg for the Santos GLNG project. The maximum Total Phosphorus (TP) concentration for the proposed dredge areas ranged between 767 mg/kg (Stage 3) and 4,290 mg/kg (Stage 4).

Radionuclides

Radionuclides were analysed in a limited number of samples with three samples reporting a concentration above the LOR for alpha radiation from the Stage 1B area. All samples analysed recorded a concentration above the LOR for beta radiation, however the concentrations were well below the NAGD (2009) Screening Level.

Organotins

Tributyltin (TBT) was detected above LOR in a single sample collected from each of the Stage 1A, Stage 1B and Stage 3 areas. Within the Stage 1A and Stage 3 areas the concentrations were low and were recorded within the upper 0.25 m of the sediment profile. The sample from Stage 1B was present at trace levels deep within the sediment profile. The normalised concentrations of the three samples were compliant to the NAGD (2009) Screening Level.

TBT is an anthropogenic compound, which has been widely used in marine paints as an effective means of preventing or retarding the growth of fouling organisms such as barnacles and mussels on the hulls of boats and ships (EPA 1996). The main potential source of organotins to the sediments within Port Curtis would be the marine vessels using the port. TBT leaches from anti-fouling paints into the surrounding water column and rapidly binds to sediment and organic particles and settles out of the water column. It is likely that the ships are coming into close contact with the bottom of the berth pockets when fully loaded, putting the sediments in close proximity with the source of TBT. Some sediments may then migrate out of the existing berths into adjacent areas through disturbance by tug and ship propellers and natural long shore drift. Friction with the berthing dolphins and tugs may also result in the removal of paint from the ship hulls.

Given the very low presence of TBT within the capital dredging material, this compound is not considered of concern for the proposed dredging and disposal project.

Hydrocarbons

Low concentrations of individual Benzene, Toluene, Ethylbenzene and Xylene (BTEX) compounds were recorded within the proposed Stage 2 (benzene and ethylbenzene) and Stage 3 (benzene, ethylbenzene and toluene) dredge areas. Within the Stage Stage 1A, Stage 1B and Stage 4 areas the concentrations of BTEX compounds were below the LOR in all samples. Low concentrations of Total Petroleum Hydrocarbons (TPHs) compounds were recorded within the proposed dredge areas.

These compounds are likely to be sourced form oils and fuels on both recreational and commercial ships utilising the harbour.

All BTEX and TPH samples were below the QEPA EIL (where available) and NAGD (2009) Screening Levels (where available).

PAHs and PCBs

No Polychlorinated Biphenyls (PCBs) were detected within the Stage 1A, Stage 3 and Stage 4 areas. Caution needs to be applied in interpreting the laboratory results for PCBs within the Stage 1B and Stage 2 areas due to a discrepancy in the data resulting in samples some samples reported with a LOR concentration of <1,000 µg/kg which is equal to the NAGD Screening Level. This is likely to be due to matrix interference during the analytical process. The laboratory QA/QC certificates would contain information regarding this.

Low concentrations of various individual Polycyclic Aromatic Hydrocarbons (PAHs) were present in a number of samples within the proposed dredge areas, excluding the Stage 4 area where the concentrations in all samples were below the LOR.

Natural sources of PAHs include exhaust fumes, wood fires, charcoal, shale oil and coal tars and tend to form from incomplete combustion, commonly when materials burn at low temperatures (Wisconsin Dept of Health and Family Services 2004 and DEWHA 2004). PAHs are often found in areas of high shipping activity as a result of the incomplete combustion of motor fuels (DEFRA, 2000). The long term presence of ships at the port provides a potential source of PAHs to the sediments. The presence of shale minerals has also been identified as a potential natural source of PAHs in Port Curtis.

All PCBs and PAHs samples were below the QEPA EIL and NAGD (2009) Screening Levels.

Summary of Sediment Quality

A comprehensive sediment sampling undertaken for the Western Basin Dredging and Disposal Project has demonstrated the presence of minor concentrations of anthropogenic contaminants and naturally occurring compounds in individual samples across the areas to be dredged. Individual results that were above either the NAGD (2009) and/or the EPA Draft Guidelines for the Assessment and Management of Contaminated Land in Queensland (1998) – Environmental Investigation Levels included arsenic, cadmium, copper and manganese. Individual samples recorded concentrations of BTEX, TPHs and individual PAHs above the limits of reporting, but below the relevant guidelines.

The analysis of a large number of sediment samples from each of the dredge stages for an extensive suite of potential contaminants has revealed that the overall quality of the sediments in the Project Area are compliant to the NAGD (2009) and the QEPA EILs. The only exception to the compliance of the sediment quality with the adopted guideline values are the elevated manganese concentrations observed within the Stage 1B area. The occurrence of the three highest manganese concentrations within the Stage 1B area was within the upper 1 mBSB of sediment. However, across all the sediments to be dredged, the manganese concentration is compliant to the QEPA EIL.

Due to the comprehensive nature of the sediment sampling and analysis program, which analysed the required number of sampling locations (50%) based on the classification of the top 1.12 m of material as potentially contaminated, the results are considered representative of the sediments to be dredged for the proposed Western Basin Dredging and Disposal Project. The exception is Stage 4, which had a slightly lower frequency of sampling, but which did not record any contaminants of concern above the relevant guidelines. The results of the sediment chemical characteristics are also consistent with a number of other recently approved capital and maintenance dredging sampling programs within Port Curtis. It is therefore considered that the sediments proposed to be dredged are suitable for placement within the proposed Western Basin Reclamation Area, without the requirement for further sampling and analysis and no significant impacts relating to sediment quality are anticipated for the proposed dredging. The exception would be any dredging stages not dredged within the next 5 years, which is the maximum time samples can be treated as current, or the introduction of a new contaminant source into the Harbour in the vicinity of the areas to be dredged.

Potential Impacts and Mitigation Measures

This section discusses the potential impacts on sediment quality that may occur during the construction and operation of the Western Basin Reclamation area, proposes measures to mitigate and monitor the impacts, and identifies the key risks associated with the Project. This section does not discuss the potential risks associated with acid sulphate soils, water quality or the direct impacts of dredging the materials on the marine habitat and fauna. These are addressed in complementary reports as part of the Western Basin Dredging and Disposal Project (Appendix I, K, Q and R, respectively).

For the purposes of this impact assessment, the following activities were considered to have potential impact from a sediment quality perspective during construction and operation phases:

- Construction:
  - Construction of the rock revetment bund wall;
  - Dredging of materials from the proposed dredge areas;
  - Deposition of material (bottom dumping) and rehandling of dredge material within a Material Discharge Area; and
  - Placement of dredged material within the Reclamation Area.
- Operation:
  - Capping of the Reclamation Area once it is fully filled with dredged material.

Construction of the Revetment Bund

Potential Impacts

To facilitate construction of the Reclamation Area a rock revetment bund will be established. Construction of the bund will involve placement of core material and rock armour into the Reclamation Area. As the rock is placed onto the seabed during the construction of the bund wall there is potential for soft sediment resuspension and subsequent contaminant resuspension and/or desorption and re-entry into the water column. The quality of the sediment material underlying the proposed Western Basin Reclamation Area have previously been assessed for the adjacent Fisherman's Landing Northern Expansion EIS (GHD 2009d).

Surface sediment quality monitoring within the Fisherman's Landing Northern Expansion Reclamation Area was undertaken at fourteen locations in September 2008. Results of the sampling and analysis indicate that the concentrations of contaminants in the sediments underlying the proposed Fisherman's Landing Northern Expansion Reclamation Area are compliant to the QEPA EILs and the NAGD (Screening Levels). Therefore, it is not expected that mobilisation of these sediments into the water column during the construction of the bund wall will result in the introduction of contaminants into the water column. These results are considered representative of the sediments, and there is no reason to suspect significant additional contamination of sediments could have occurred since the sampling was undertaken.

Mitigation Measures

As results of previous sampling and analysis indicate that the concentration of contaminants in the sediments underlying the proposed Reclamation Area are compliant to the NAGD (2009) and QEPA EILs (1998), no mitigation measures to manage sediment quality during the construction of the revetment wall are proposed.

Bottom Dumping and Rehandling of Dredge Material

Potential Impacts

A Trailer Suction Hopper Dredge (TSHD) will be required for some works in Stage 1A in the Clinton Bypass channel area and Stage 1B. Use of the TSHD will require that a suitable Material Discharge Area be developed adjacent to the proposed Reclamation Area. The Material Discharge Area will be utilised for the bottom dumping of dredge material associated with the use of a TSHD, with rehandling of the material for placement within the Reclamation Area by a small Cutter Suction Dredge (CSD).

The potential impacts of sediment quality from the bottom dumping and rehandling of dredge material within the Material Discharge Area include the potential for sediment resuspension and subsequent contaminant resuspension and/or desorption and re-entry into the water column. Despite the likelihood of the metals being naturally occurring, the activities of dredging, bottom dumping and rehandling may mobilise sorbed metals.

Mitigation Measures

Based on the results of the comprehensive sediment sampling program conducted within the proposed dredge stages of the Western Basin Dredging and Disposal Project it is considered likely that all sediments to be dredged will be suitable for placement in the proposed Western Basin Reclamation Area.

Management intervention in dredging activities should be undertaken if trigger levels relevant to background water quality levels within Port Curtis are exceeded (Water Quality Report, Appendix K). Intervention measures may include alteration of dredging activities (frequency, duration, intervals, timing with respect to tidal run) to enable water quality levels to return to background conditions.

Placement of Dredged Material within Reclamation Area

Potential Impacts

The placement of the dredged material within the Reclamation Area, either directly or through rehandling of dredged material deposited in the Material Discharge Area, has the potential to result in resuspension or desorption of the contaminants from the material into the water column, and consequently affect the quality of the decant water from the Reclamation Area.

The placement of dredged material that contains potential contaminants may also result in the Reclamation Area becoming a contaminated site.

Mitigation Measures

Sediments used for filling of the Reclamation Area must be of an appropriate quality to avoid potential land and water contamination issues. The EPA Draft Guidelines for the Assessment and Management of Contaminated Land in Queensland (1998) – Environmental Investigation Levels have been applied to the material proposed for disposal into the Western Basin Reclamation Area. These guidelines were developed to provide best practice for managing land contamination through planning and development control processes.

With the exception of manganese concentrations in sediment from the Stage 1B area, the dredge material within the proposed dredge stages was found to comply with the QEPA EIL. As discussed previously, manganese is noted to be widely occurring within marine sediments, and has also been mined within the Gladstone region (URS 2009). The high concentrations encountered within Stage 1B may be naturally occurring or may be a localised source of contamination. As the final Reclamation Area is to be used for industrial purposes, the manganese concentrations are not considered to pose a restriction to the future use of the Reclamation Area. Also, it is important to note that Stage 1B is likely to be dredged concurrently with Stage 1A and that these sediments will therefore be mixed within the Reclamation Area. Therefore, the 95% UCL of the Reclamation Area may be compliant to the QEPA EIL for manganese. The quality of the sediments is therefore deemed suitable for the purposes of reclamation.

The bund will be lined with geofabric material to reduce the potential for leaching of fine sediments back into the marine environment through the bund wall during reclamation and dewatering works.

Capping of the Reclamation Area

Potential Impacts

Following completion of infilling of the Reclamation Area, the final surface will be capped and revegetated with grasses to prevent any of the soil from being entrained in runoff occurring from overland flow as a result from rainfall. To ensure that the revegetation of the Reclamation Area is successful, the dredge material used for fill needs to be of a suitable quality.

Mitigation Measures

Results of sampling and analysis indicate that the concentrations of contaminants in the dredge material, with the exception of manganese in Stage 1B area, are compliant to the QEPA EILs and are therefore suitable for placement within the Western Basin Reclamation Area. Given the Reclamation Area will be capped with 0.5 – 1.0 m of quarry overburden from an uncontaminated site, elevated concentrations of manganese in the underlying dredged material are unlikely to prevent the successful revegetation of the site.

Risk Assessment

To assess the risk posed to the marine environment by activities undertaken as part of the proposed project a risk assessment has been undertaken. This risk assessment addresses the construction and operational aspects of the Western Basin Dredging and Disposal Project and, therefore, takes into consideration potential compounded impacts from multiple dredging programs.

The risk assessment procedure followed in this EIS is outlined in Chapter 3. The risk assessment outlined examines the ecological risk associated with the sediment quality of the dredge material during the construction and operation phases of the Project. Water quality impacts on marine ecological values are considered however, the full potential range of impacts (including turbidity and total suspended solids) are described in detail in the Water Quality Report (Appendix K), which should be referred to for completeness. Sediment quality related to the potential for acid sulphate soils is described in detail in the Acid Sulphate Soil Report (Appendix I).

Table 7-31 Sediment Quality Risk Assessment

Activity Description	Potential Impacts and their Consequences	Preliminary Risk Assessment (C, L) Score	Additional Control Strategy	Residual Risk with Control Strategies Adopted (C, L) Score
Construction Phase				
Building of Bund	Sediment resuspension and subsequent contaminant resuspension and/or desorption and re-entry into the water column during placement of core material and rock armour into the reclamation area.	(3, 3) Medium	Disturbance of soft seabed sediments will be limited to first layer of rocks.	(2, 2) Low
Bottom Dumping and Rehandling of Dredged Material	Sediment resuspension and subsequent contaminant resuspension and/or desorption and re-entry into the water column during the deposition and rehandling of the dredged material.	(1, 5) Medium	Monitoring and control of dredge regime to be in accordance with dredge management plan (DMP). Program dredge activity to avoid, where practicable, use of TSHD in northern extents of Western Basin during flood phase of large spring tides. Monitor turbidity levels against site specific objective 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 schedule, planned increase in period between dredging activity at any one location.	(1, 5) Medium
Dredging of Material	Spill from dredger during relocation to disposal area.	(2, 2) Low	Operate within safe weather conditions.	(2, 2) Low

Activity Description	Potential Impacts and their Consequences	Preliminary Risk Assessment (C, L) Score	Additional Control Strategy	Residual Risk with Control Strategies Adopted (C, L) Score
Reclamation of Land	Sediment resuspension and subsequent contaminant resuspension and/or desorption and re-entry into the water column during the placement of material into the reclamation.	(3, 3) Medium	Appropriate design and construction of bund, including lining with geotextile fabric and installing internal bunding, to reduce potential for fines to be moved back into marine environment through the bund wall or via the decant waters. Monitor tailwater decant to meet conditions/objectives within pond and/or within approved mixing zone. Provision to modify internal bund structure or discharge weir arrangement if required.	(3, 2) Low
	Alteration of water quality in habitats arising from run-off from the reclamation area resulting in increased sediment loads and potential desorption and re-entry of contaminants into the water column.	(3, 3) Medium	Potential acid sulphate soils will be treated or managed appropriately. Finished surface of reclamation to be capped. Stormwater management system designed to capture and treat runoff.	(3, 2) Low
	Alteration of sediment quality at the reclamation site by introduction of contaminants or potential acid sulphate soils from dredged marine sediments.	(3, 4) Medium	Sediments to be deposited in the reclamation area have been tested for contamination and were below the relevant Screening Level nominated in NAGD (where guidelines are available). The 95% UCL of the mean manganese concentration (479.8 mg/kg) within all of the dredging stages combined was below the QEPA EIL guideline of 500 mg/kg. The reclamation area to be constructed and managed to reduce/remove potential impacts from any contaminants, including potential acid sulphate soils. This includes development and implementation of an Acid Sulphate Soils Management Plan and lining of the bund with geotextile fabric.	(3, 3) Medium

Activity Description	Potential Impacts and their Consequences	Preliminary Risk Assessment (C, L) Score	Additional Control Strategy	Residual Risk with Control Strategies Adopted (C, L) Score
Operational Phase				
Reclamation of Land	Alteration of water quality in adjacent habitats from land run-off resulting from poor sediment quality. Potential reduction in biodiversity. Discharge from stormwater pond to be in accordance with water quality conditions. Limited impact potential.	(1, 2) Very Low	Sediments to be used for reclamation works have been tested for contamination and reclamation area to be constructed and managed to reduce/remove potential impacts from any contaminants, including potential acid sulphate soils. Appropriate design and construction of bund, including lining bund with geotextile fabric and installing internal bunding, to reduce potential for fines to be moved back into marine environment through the bund wall or via the decant waters. Manage stormwater pond discharge to maintain water quality to stated objectives.	(1, 1) Very Low

7.2.3 Conclusions

The sediment sampling and analysis program reported here was implemented by Queensland Gas Corporation Ltd (QGC), a BG Group Company, within Port Curtis over the period 16th November 2008 to the 17th June 2009. The sediment sampling and analysis program was completed for the Western Basin Strategic Dredging and Disposal Project in accordance with the NAGD (2009).

The concentrations of some metals and metalloids, in particular manganese and arsenic, were above the QEPA EIL (1998) and arsenic also exceeded the NAGD (2009) Screening Levels within individual samples in all of the proposed dredge stages. Other metals (nickel, copper, cadmium and mercury) were observed at concentrations exceeding the adopted guideline values within a limited number of samples from some proposed dredge stages. The 95% UCL of mean concentrations of all metals and metalloids, excluding manganese in Stage 1B, were below the relevant Screening Level nominated in NAGD (2009) (where available) and the QEPA EIL (1998). For all other chemical analyses, some samples exceeded the LOR, however none exceeded the adopted guideline values. Overall, low concentrations of contaminants of concern were present within the proposed dredge stages, however it is considered that the quality of the sediments are suitable for the purposes of reclamation.

As sediment quality does not tend to change rapidly over time and the potential contaminants were generally not present at concentrations exceeding the adopted sediment quality guidelines, it is considered that further sediment sampling is not required prior to approval of each dredging stage if the dredging occurs within the next 5 years and there are no new contaminant sources introduced into the marine environment.

7.3 Coastal Processes

The purpose and scope of this section is drawn from Section 3.5.2 of the ToR - Coastal Processes (Appendix A).

The purpose of this section is to:

- Describe the physical coastal processes operating at the site;
- Describe the changes to the physical coastal processes as a result of the Project;
- Assess the effects of changes to the tidal hydrodynamics on the physical coastal environment;
- Describe the wave climate in the vicinity of the Project area including a description of inter-annual variability and details of predicted extreme wave conditions generated by tropical cyclones or other severe storm events;
- Discuss the impacts on siltation, particularly in terms of maintenance dredging requirements;
- Assess the effects of changes to the propagation of storm surge on the physical coastal environment; and
- Describe any measures that might be considered to mitigate against detrimental effects on coastal resources and processes.

Overview

The assessment methodology involves an investigation of the existing physical coastal processes and hydrodynamics in the vicinity of the proposed Reclamation Area and associated dredging and an examination of the effects of the reclamation and dredging on those processes. For the assessment, extensive use is made of the results from the numerical modelling carried out by WBM (Appendix J). The modelling included the hydrodynamics of Gladstone Harbour, ambient and extreme waves, sedimentation, and flushing. Through this assessment, potential impacts on coastal processes are identified and comments provided on the need for mitigation measures.

7.3.1 Description of Environmental Values

The study of coastal processes is essentially a study of sediment movements in the coastal environment and the forcing mechanisms that drive that movement. Within Gladstone Harbour and at Fisherman's Landing, the principal drivers of sediment movement are tidal currents and locally generated waves. Important but infrequent drivers are extreme events like cyclones which can generate high waves and water levels that can have major effects on the environment and affect areas that would not normally be affected under prevailing conditions.

The environmental values associated with coastal processes can be characterised by a description of the forcing mechanisms and any particular local features that influence them. Forcing mechanisms include wind, waves, currents, and water levels, and local features include the geology, land forms, sediment types, and existing infrastructure.

Existing Physical Processes

The physical processes of the adjacent marine environment are predominantly characterised by tidal flows with effects from locally generated waves and storm events which can cause extreme waves and elevated water levels (storm surge).

Surface sediments range from unconsolidated silts and clays in the shallow tidal flats north and west of the Reclamation Area to coarse sands and gravel in the deeper areas. The processes that transport sediment around the area are dominated by tidal currents driven by the relatively large spring tides, coupled with a mild wave climate that stirs up sediments in the shallower areas at times of low tide.

Tides

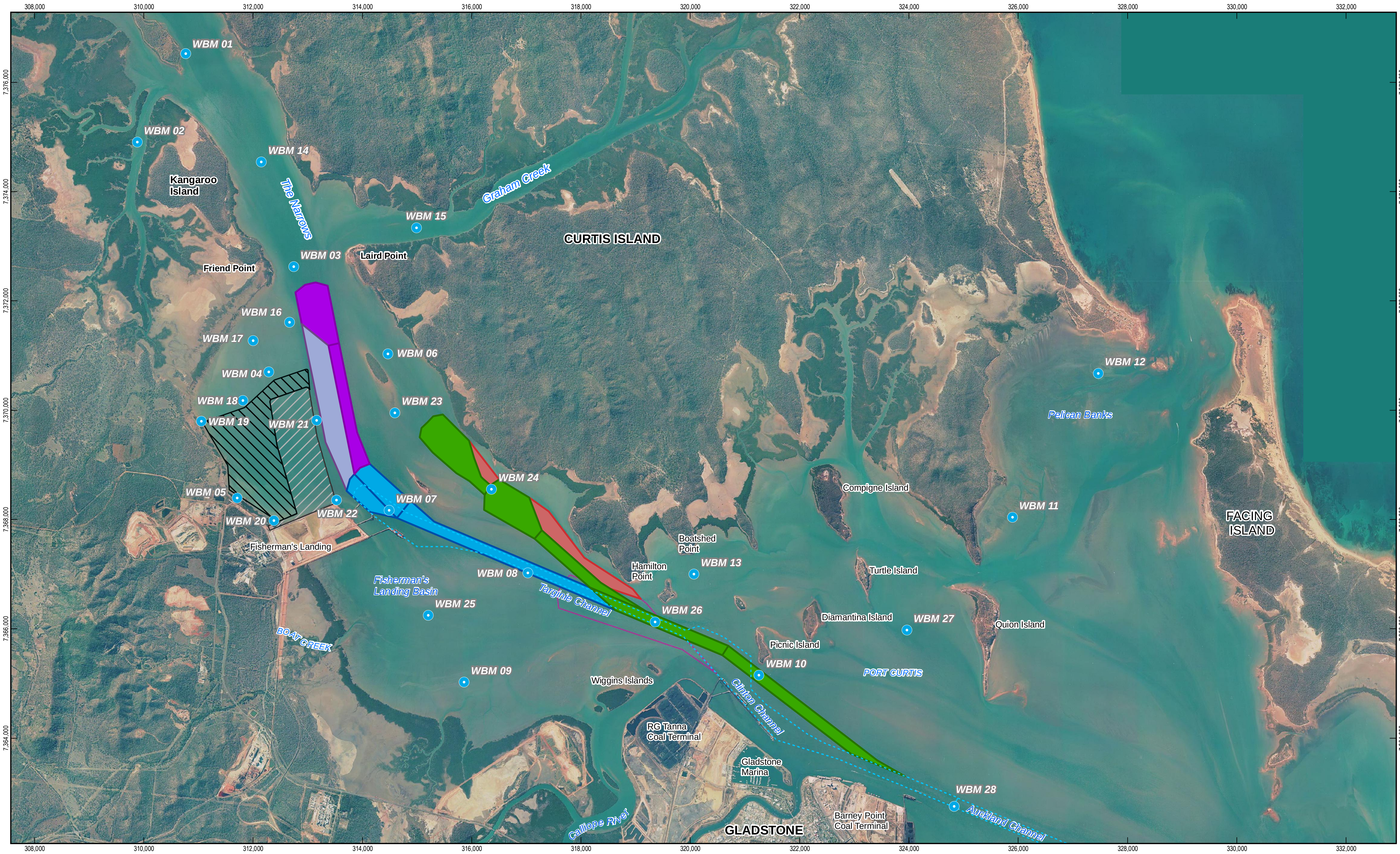
The characteristics of the tides in Gladstone Harbour in terms of the standard tidal planes are described in the Tidal Hydraulics section of the Numerical Modelling Report (Appendix J) and were summarised in Table 6-1. Due to amplification of the tidal wave as it propagates up the estuary, the tidal planes at Fisherman's Landing are higher than at Auckland Point.

The large tides of the region generate strong tidal currents up to 1.5m/s in the main channels and up to 0.35m/s on the shallower areas of the estuary. Tides in this area go through a neap-spring cycle over a period of approximately 14 days, with ranges of around 4m at the spring and 1m during the neap (Connell Hatch 2006). The estuary has extensive intertidal banks, mangrove, and saltpan areas that are inundated to various degrees, depending on the tidal range. The storage volume associated with these areas varies with tide height, meaning that the relationship between tidal velocities, the rate of rise and fall of the water level, and the tide range is non-linear, particularly for tides of large range.

The large tide range and associated high tidal currents means that the estuary waters are well mixed with only minor variation in density of dissolved or suspended material through the water column.

The water level and tidal currents results for locations at Fisherman's Landing Berths for the base case are presented in Figure 7-24. The locations of the points at which the results were extracted are shown on Figure 7-23. The results presented are over a two month period in February / March 2009 and include four spring tides and four neap tides. The modelled period was chosen to coincide with the data acquisition campaign for this EIS.

Tidal currents vary from a maximum of 1.0 m/s at Fisherman's Landing berths, China Bay, and the Entrance to The Narrows, to 0.9 m/s at North Passage Island (all of which are in the tidal stream leading up to The Narrows), to 0.35 m/s in the Western Basin, where it is more sheltered and much shallower. Higher tidal currents up to 1.5m/s occur in the main channels downstream of the Western Basin.



1:65,000 (at A3)

0 0.5 1 1.5 2

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Grid: Map Grid of Australia 1994, Zone 56

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LEGEND

- Output Location
- Stage 1A - North China Bay LNG
- Stage 1B - Fisherman's Landing LNG
- Stage 2 - Laird Point LNG
- Stage 3 - Fisherman's Landing
- Stage 4 - Hamilton Point
- Western Basin Reclamation Area
- Fisherman's Landing Northern Expansion
- Existing Channels, Swing Basins and Berths
- Wiggins Island Coal Terminal (Approved)

GHD GPC

Port of Gladstone
Western Basin Dredging and Disposal Project

Results Extraction Points - Project Area

Job Number	42-15386
Revision	A
Date	30 Aug 2009

Figure 7-23

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Level 4 201 Charlotte Street Brisbane QLD 4000 Australia T +61 7 3316 3000 F +61 7 3316 3333 E bnemail@ghd.com W www.ghd.com

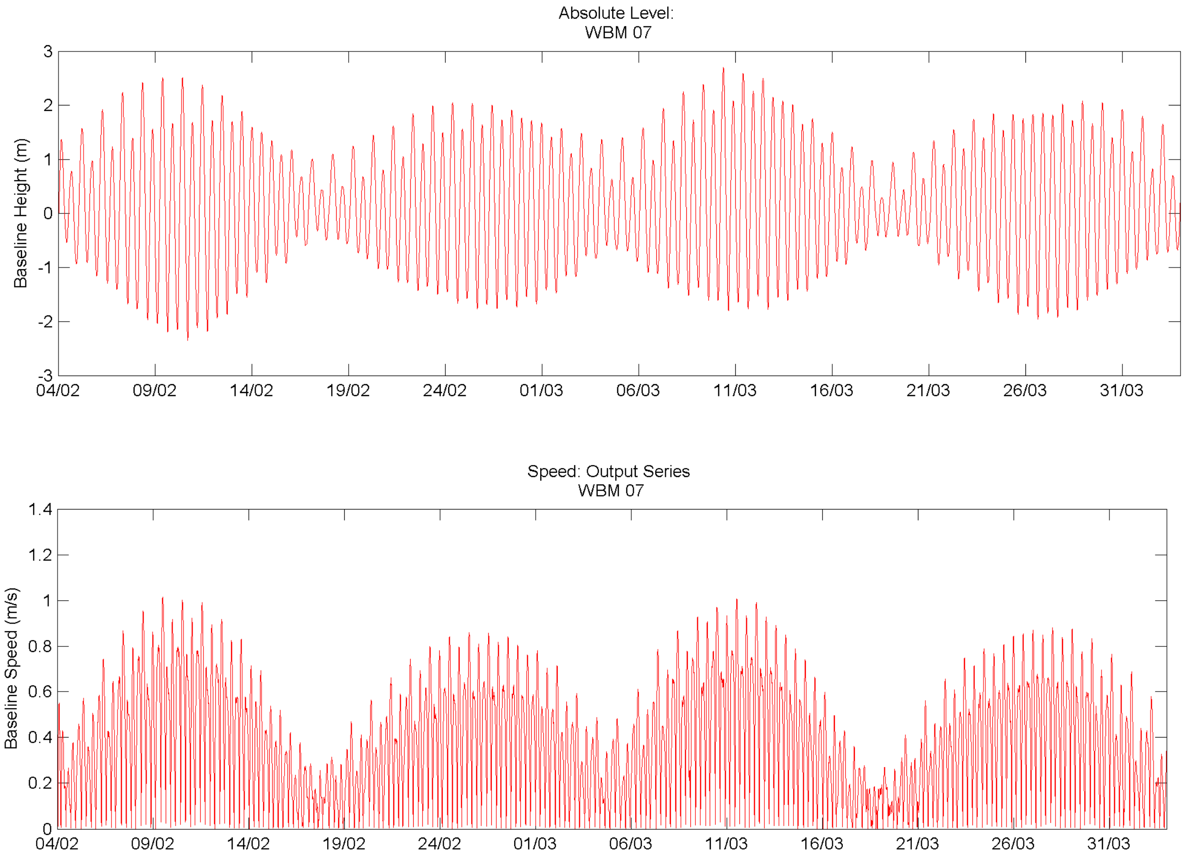


Figure 7-24 Water Level and Tidal Current Plots – Base Case – Fisherman's Landing Berths

Wave Climate

The area is protected from ocean-generated sea and swell waves by Curtis Island and Facing Islands to the east and hence the wave action at the site is relatively mild, although there is a substantial fetch for the generation of waves to the east south-east. The site is subject to locally generated seas waves under the influence of local wind conditions and to higher waves, principally from the east south-east, during cyclonic conditions.

The ambient wave climate is characterised by a predominance of south-easterly wind in the morning, swinging to the east and north-east in the afternoon. Wave height modelling (WBM 2009) for these conditions shows that the maximum wave height would rarely exceed 0.5m from any direction, as illustrated in the wave rose for Fisherman's Landing in Figure 7-25.

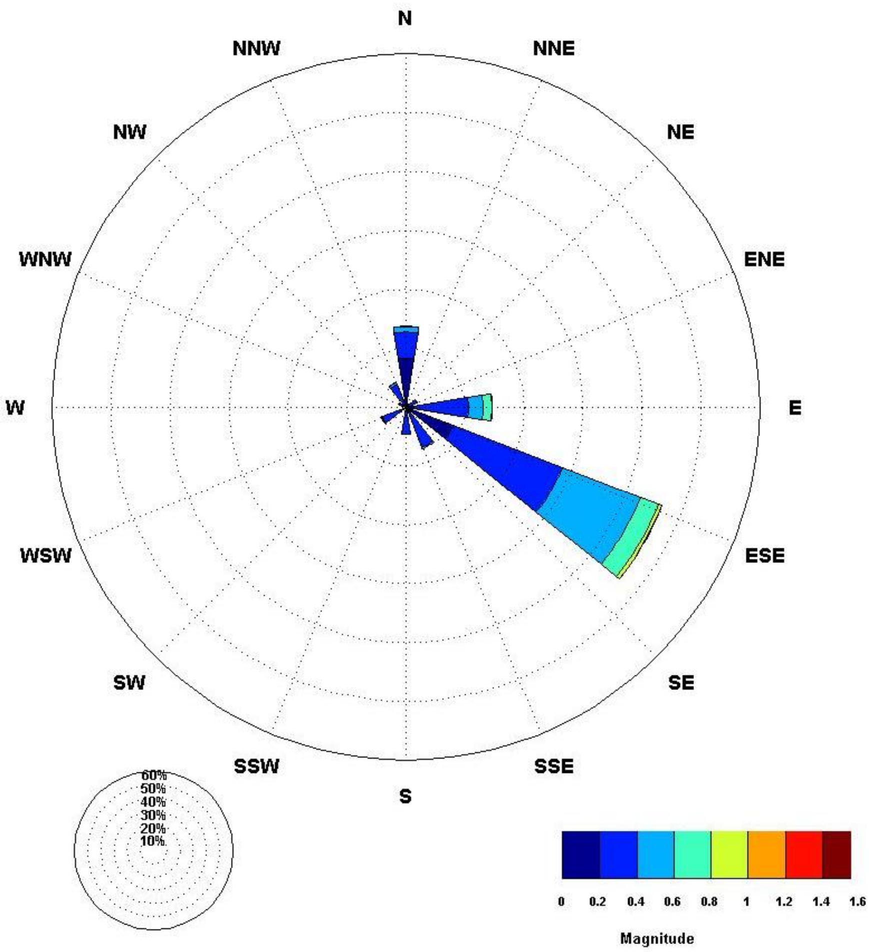


Figure 7-25 Wave Rose - Ambient Conditions – Fisherman's Landing Berths

An analysis of extreme events was carried out by WBM. This revealed that during cyclonic conditions waves up to 2.5m could occur in the dredged channel adjacent to the Fisherman's Landing site and depending on their duration and the time of occurrence in relation to the tide, could cause substantial movement of the sediments in the shallower areas and along the western foreshore (Appendix J).

Figure 7-26 shows the spatial variation of wave height and direction for the base case (existing conditions) and winds from a 1:100 year cyclone. The water level for this simulation was RL 3.53m AHD which included allowances for storm surge and sea level rise. Cyclones are most likely to generate very strong winds from the sector extending from the east to the south and, given that the longest fetch affecting the Western Basin area is aligned approximately east south-east, cyclones could exert a significant effect on the wave climate.

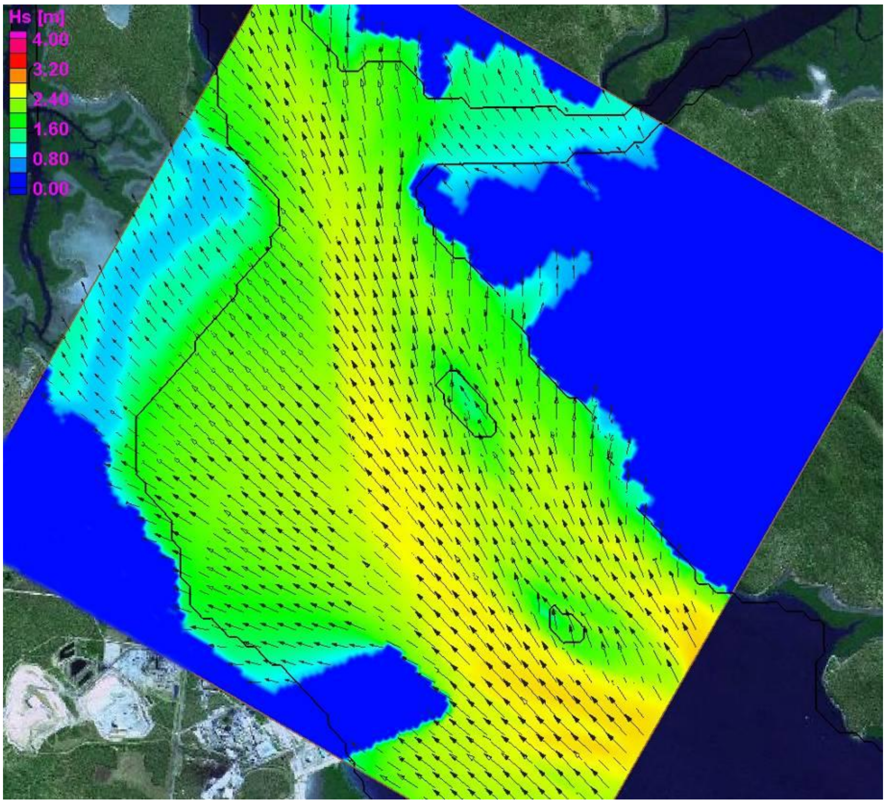


Figure 7-26 Wave Plot for South Easterly Waves generated by a 1:100 year cyclone

South-easterly waves generated by a cyclone are predicted to penetrate to all parts of the Project Area. The highest waves are adjacent to the existing Fisherman's Landing Reclamation and along the channel to the north towards the entrance to The Narrows. In the Western Basin embayment north of Fisherman's Landing, the wave action is reduced due to the shallower water and diffraction around the existing reclamation.

Figure 7-27 shows the variation in wave height and direction against the wind direction at Fisherman's Landing berth for a 1:100 year cyclone. The maximum wave height is 2.54m from the east-south-east and there is a spread of wave heights around 2.5m covering the directions from east to south-south-east as a consequence of the longer fetches from these directions.

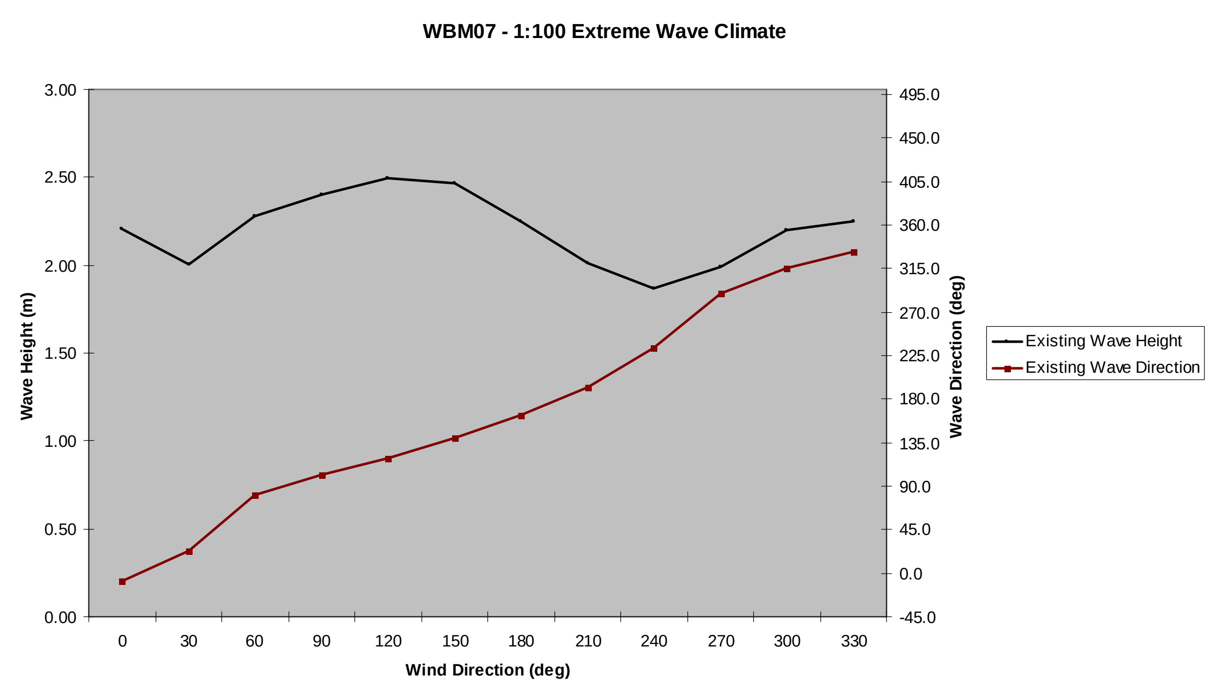


Figure 7-27 Wave Height and Direction at Fisherman's Landing (WBM07) for 1:100 year cyclone

Storm Tides

Storm tides are discussed in detail in Chapter 4. A summary of the storm tide conditions at Fisherman's Landing is presented in this section.

The storm tide level is derived from a combination of the storm surge generated by a cyclone approaching the coast and the astronomical tide level and is presented in terms of the risk of occurrence while considering the independence of the two components. Table 7-32 presents the storm tide level for the 1 in 50, 100, 500, and 1000 year return periods, or, in terms of Annual Exceedance Probabilities (AEP), 2%, 1%, 0.2%, and 0.1% and includes an allowance for sea level rise, and expected changes to cyclonic behaviour (number and intensity). The values are presented for Fisherman's Landing, derived by amplifying the levels for Gladstone at Auckland Point using the amplification of the tide wave as it travels from Auckland Point to Fisherman's Landing as the basis.

Table 7-32 Storm Tide Levels in Gladstone (Hardy *et al*. 2004)

Location	Highest Astronomical Tide (HAT) m AHD	Storm Tide Level (Storm Surge + Tide + 0.3m Sea Level Rise) m AHD			
Return Period (years)		50	100	500	1000
Gladstone (Auckland Point)	2.42	3.05	3.33	4.18	4.51
Fisherman's Landing	2.54	3.33	3.58	4.43	4.78

Sediment Transport

Sediment transport under the action of tidal currents has two principal components – bed load and suspended load. Bed load generally consists of the coarser fractions of the bed material with the finer silts being suspended in the water column by the turbulence from the relatively high tidal velocities.

The transport potential for both types of sediment can be estimated using the results of hydrodynamic modelling. The actual transport that occurs depends on the characteristics of the bed material at each location and on the amount of material that is available for transport.

Sand Transport

The potential for sand transport under tidal current action has been estimated using the hydrodynamic model (Appendix J). This provides an estimate of the sand transport potential assuming a sediment grain size of 1 mm and does not account for the presence of non-erodible areas such as rocky outcrops.

During large spring tides, the strong ebb tide currents generate a high sediment transport potential to the south-east while the flood tide currents, being somewhat weaker, generate less sediment transport potential (Appendix J). The potential for sand transport in the vicinity of the Fisherman's Landing swing basin area is considerably lower than experienced at the Clinton Wharves, further to the south-east, where currents are constricted between Hamilton Point and the Calliope River mouth.

Net sand transport potential was estimated by averaging the results over two consecutive spring-neap tidal cycles. The results for the base case are shown in Figure 7-28. The net sand transport is generally in the ebb tide direction due to the asymmetry in the tidal currents. Potential sand transport is confined to the channels, where current speeds are sufficient to mobilise coarse sand deposits. Within the Western Basin, the net sand transport is generally higher within the Targinie Channel to the west of the Passage Islands than in the "Curtis" channel to the east (Appendix J).

The sand transport potential estimates have been expressed and illustrated as a bulk volumetric flux density; that is the magnitude of the transport potential is the net bulk volume of sand transport per unit width at each computation point averaged over a 12 month period and has units of m^3/year/m (shown in the contour legend as m^2/year).

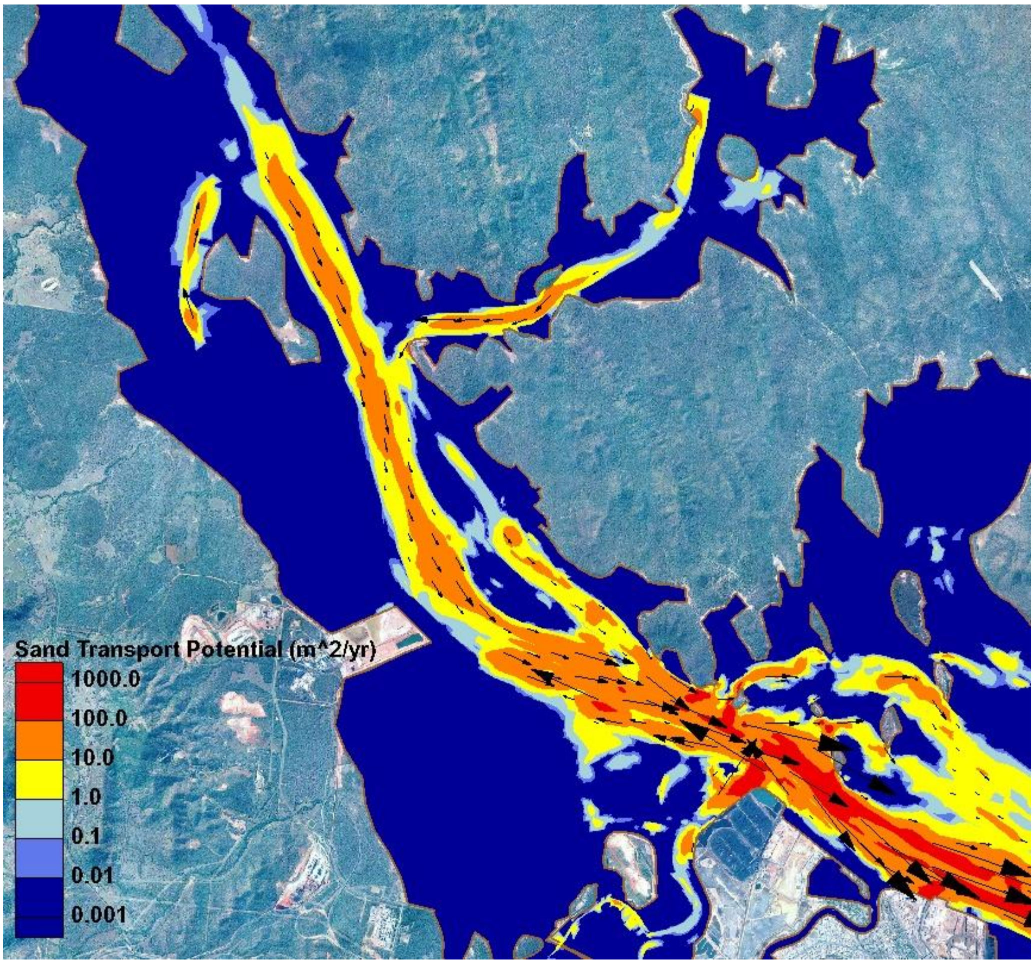


Figure 7-28 Existing Net Sediment Transport Potential

Silt Movement and Deposition

Silt movement and deposition has been assessed through an examination of bed shear stresses that can be derived from the hydrodynamic modelling results. Bed shear stresses less than about $0.2 N/m^2$ will generally result in deposition of fine silts that are in suspension in the water column while higher stresses will re-suspend deposited material and keep it in suspension (Appendix J).

During neap tides, the bed shear stresses in the channel are typically at or below the threshold for deposition. However, during spring tides, the stresses are much greater and as such, the fine sediments will not be stable in the long term (Appendix J). This is consistent with observations of limited fine material in the main channel. In contrast, in the shallower, less dynamic areas where velocities are lower, the bed shear stresses are typically low and this is consistent with the natural deposition of fine material in these areas.

To assess the potential for silt erosion and deposition, bed shear stresses were calculated throughout the hydrodynamic model domain over the full two month simulation period. Maximum bed shear stresses due to tidal currents will correlate inversely with the likelihood of silt deposition. For the base case, the spatial distribution of the 5% exceedance (of the modelled period) bed shear stress is illustrated in Figure 7-29.

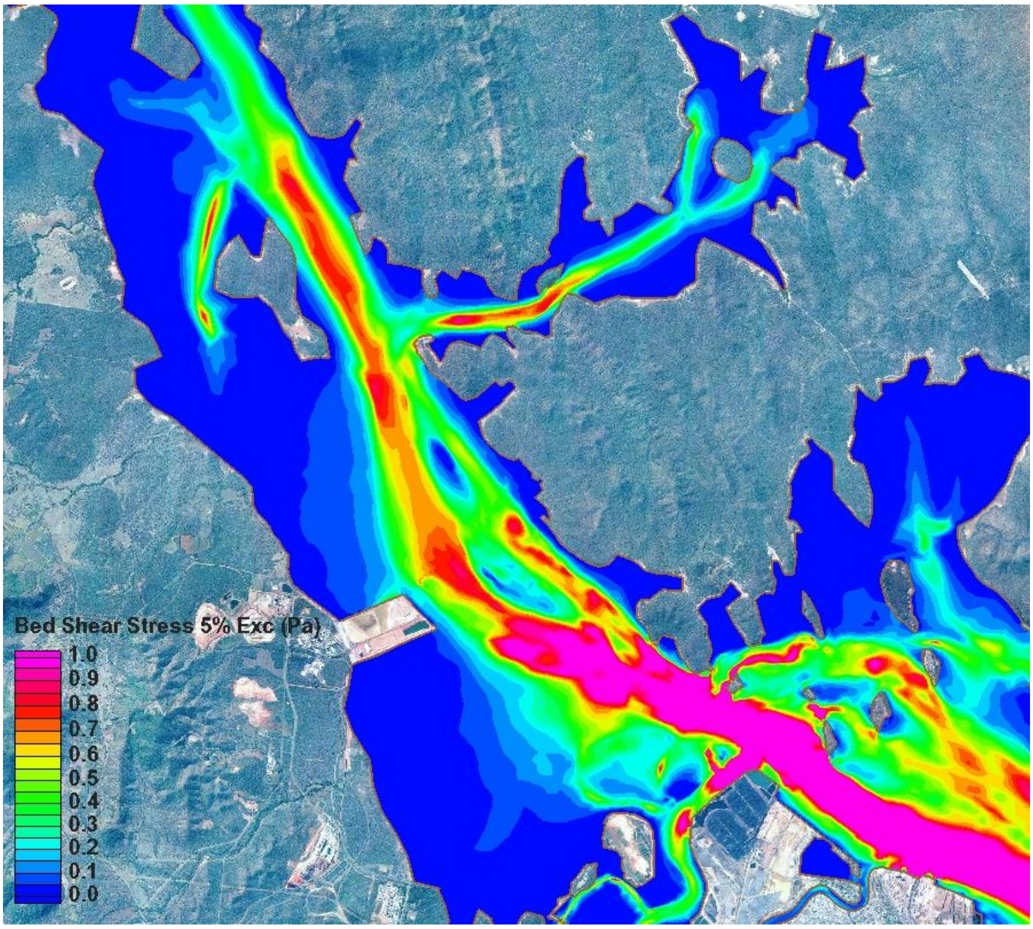


Figure 7-29 Base Case Bed Shear Stresses

Description of Morphology and Integrity of Existing Landforms

The Fisherman's Landing area forms part of a large macro tidal estuary of Port Curtis. This part of the estuary is located between a low lying coastal plain backed by low hills to the west rising to the 500m high Mount Larcom range 8km distant and the southern part of Curtis Island to the east. Fisherman's Landing is on the western side of the estuary that is characterised by a mangrove foreshore, with wide intertidal flats extending into a shallow water environment as far as the edge of the main channel that forms the basis of the access to the existing wharves at Fisherman's Landing. There are no sandy beach / dune formations within the western basin area.

Existing Reclamation

The existing reclamation at Fisherman's Landing was constructed in the early 1980's (Harbours & Marine 1986) and consists of a perimeter bund armoured on the outside with widely graded rock. It is likely that the existing armour layer has been modified from the originally placed material by the prevailing wave conditions that have washed out some of the finer material. Nevertheless, the perimeter bund has formed a stable revetment for the existing reclamation that is 116.5ha in area.

Intertidal Flats

The intertidal flats of Gladstone Harbour have high environmental values, in terms of the individual flora and fauna they support, the ecosystems they represent, and their community values. As a physical feature they are relatively stable unless affected directly by engineering works. The environmental values of the intertidal flats are examined in detail in Chapter 9.

The Narrows

The southern end of The Narrows is located approximately 2 km north of the proposed reclamation at Fisherman's Landing. The Narrows is part of the Great Barrier Reef Coast Marine Park and was listed on the National Estate Register on 26 October 1999. The Narrows was listed as it represents an "uncommon passage landscape", being only one of five narrow tidal passages separating large continental islands from mainland Australia (DEWHA 2009b). The environmental values of The Narrows are discussed in Chapter 9.

Existing Channel and Swing Basin

The closest existing channel to Fisherman's Landing is the Targinie Channel that provides shipping access to the four berths that utilise the existing reclamation. Currently, the Targinie Channel is 120 metres wide and is maintained to a depth of RL10.6m LWD through maintenance dredging (Port of Gladstone 2008). The Numerical Modelling Report (Appendix J) provides information on the historical maintenance dredging quantities between 2000 and 2007 for various locations in the Project Area and is provided in Table 7-33.

Table 7-33 Historical Dredging Quantities (Appendix J)

Location	Dredging Quantities (m^3)						
	2007	2006	2005	2004	2003	2002	2000
Clinton Swing Basin	4,200	4,300	5,300	7,800	400	-	1,000
Targinie Channel	14,600	17,600	12,300	42,500	DEV[1]	DEV[2]	3,600
Targinie Swing Basin	4,400	3,900	1,900	-	-	-	-
Fisherman's Landing Berth	-	1,900	-	-	1,400	6,500	600

Table Notes: Development is extra to maintenance
All volumes are in-situ cubic metres (tons dry/1.3)
Total sedimentation volume is not for whole of Port Curtis.
1) 320,000
2) 95,000

Source: Port of Brisbane Corporation

These are relatively small quantities of maintenance dredging and reflect the minimal siltation regime in the harbour. This in turn, indicates that there is limited sediment transport and/or that the currents/ship movements are sufficient to keep the sediments in suspension, preventing them from settling out in the dredged areas (Connell Hatch 2006). Analysis of historical hydrographic surveys indicates that the general siltation of the channels and swing basins occurs at a rate of around 1 to 5 cm/annum with some areas, such as where the Targinie Channel crosses the Passage Island shoals, the rate is up to 10 cm/annum (Appendix J).

Physical Sediment Properties

The Fisherman's Landing area is located within a coastal plain setting lying to the east of Mount Larcom along the shores of the inlet known as The Narrows. A summary of the characteristics of the geology and the soils of the area relevant to the coastal processes is provided below:

- The local geology at the site comprises estuarine clay overlying marine and residual clays with the estuarine clay varying in thickness from 0.5m to approximately 5.0m across the site. The underlying soil varies from clay, silty clay or residual clay and some areas may contain gravel and/or sand layers, more commonly in the first 10m below seabed.
- The shallow inter tidal areas consist of a mixture of sands and silts with fine soft silts dominating in the lower current and wave energy areas. Sediment density sampling on the inter-tidal flats in the vicinity of the proposed reclamation extension shows that the in-situ material consists of relatively unconsolidated silt material with bulk densities in the range 1200-1500 kg/m^3 in the top 0.5m (WBM 2009a). The thickness of this soft estuarine sediment across the proposed development varies generally between 0.5 and 2m with deeper pockets of up to 5m (Marine & Earth Sciences 2008).
- In the main channel and berthing areas on the eastern side of the proposed Reclamation Area, there is a mixture of gravels, sands, silts and soft clays. High current areas occur in the vicinity of the main channel and typically consist of the coarser fractions as the finer particles have been swept away (Appendix J).

Coastal Process Relationships

Port Curtis is subject to a relatively high tidal range and has a large tidal compartment being the area of waterway into which the tide propagates. This produces tidal currents up to 1.5m/s in the main channels and up to 0.35m/s on some of the shallower areas (Appendix J). These velocities are capable of moving large amounts of sediment depending on the water depth and wave action.

Wave action will not move sediment over long distances except where waves break at an angle on a sandy beach. However, the oscillatory currents under an unbroken wave are capable of mobilising the bottom sediments. The degree to which this occurs depends mainly on the wave height / water depth combination and the wave period. Once mobilised, sediments may then be transported by tidal currents which in themselves may not be strong enough to cause the initial movement of the sediment.

Therefore, in deep areas, tidal currents are the dominant motive force for sediment movement, and in shallower areas, where tidal currents are smaller, it is the combination of wave action and tidal currents that are important. In this chapter, the impact of the proposed Reclamation Area in the Western Basin and the various dredging scenarios on the coastal processes in the harbour and adjacent areas are examined through an assessment of the changes to water levels, tidal currents, ambient and extreme wave climates, and transport of sand and silts as a result of the development.

7.3.2 Potential Impacts and Mitigation Measures

A full description of the development scenarios and the details of the dredging proposed at each stage are provided in Chapter 2 - Description of the Project. The three development scenarios are shown on Figure 7-23, which also shows the data extraction points for the hydrodynamic and wave models.

It is noted that for many of the locations in the model domain, the results for Scenarios 1, 2, and 3 are very similar. In the discussion that follows, reference will be made to the base case (representing the existing conditions) and the developed case, which will use results from Scenario 3 to illustrate changes and impacts. However, particular locations where there are significant differences in the impacts from the three developed scenarios will be noted separately.

Wave Climate

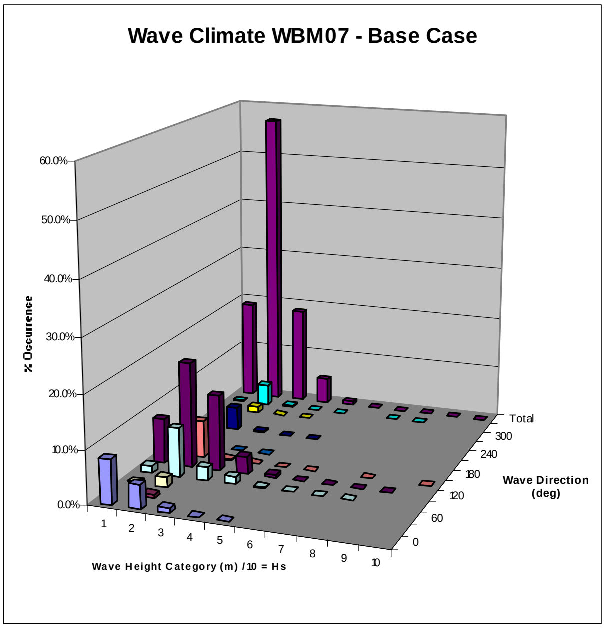
The existing wave climate, in terms of both ambient conditions and extreme events, has been described in Section 3.1.2 in Appendix M. The same modelling package has been used to determine the wave climate for each of the developed cases and by comparing the results at each point of interest, the impact of the development can be assessed.

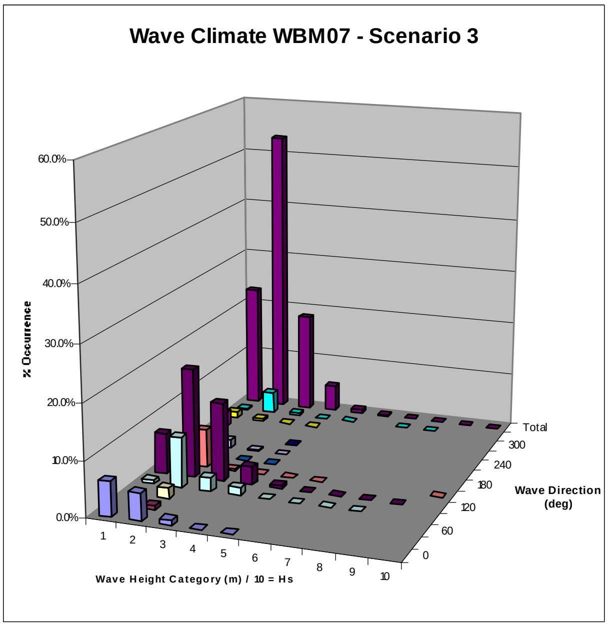
The assessment was carried out using the results from seven points of interest in the Western Basin area and the waterway to Curtis Island.

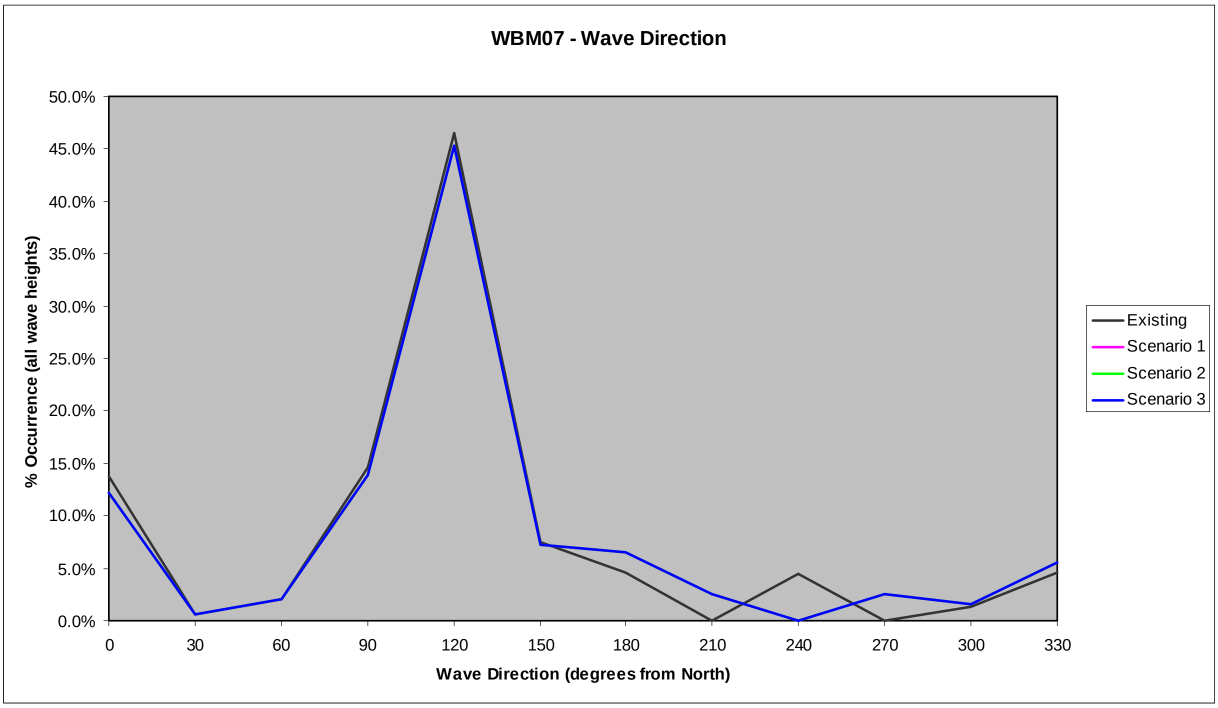
Ambient Wave Climate

The ambient wave climate at each point of interest has been presented as percentage frequency of occurrence of combinations of wave height and wind direction. The development will cause changes in the percentage frequency of occurrence due to the blocking effect of the Reclamation Area and changes in wave refraction patterns caused by the Reclamation Area and the dredging of the navigation channels, swing basins, and berth pockets.

Comparisons of the wave climate for the existing and developed cases have been made using three dimensional plots for the existing case and the developed case (Scenario 3) and separate plots of Wave Direction and Wave Height against percentage occurrence. The plots for Fisherman's Landing are shown in Figure 7-30. Plots for the other six locations are provided in the Coastal Processes Assessment in Appendix M.







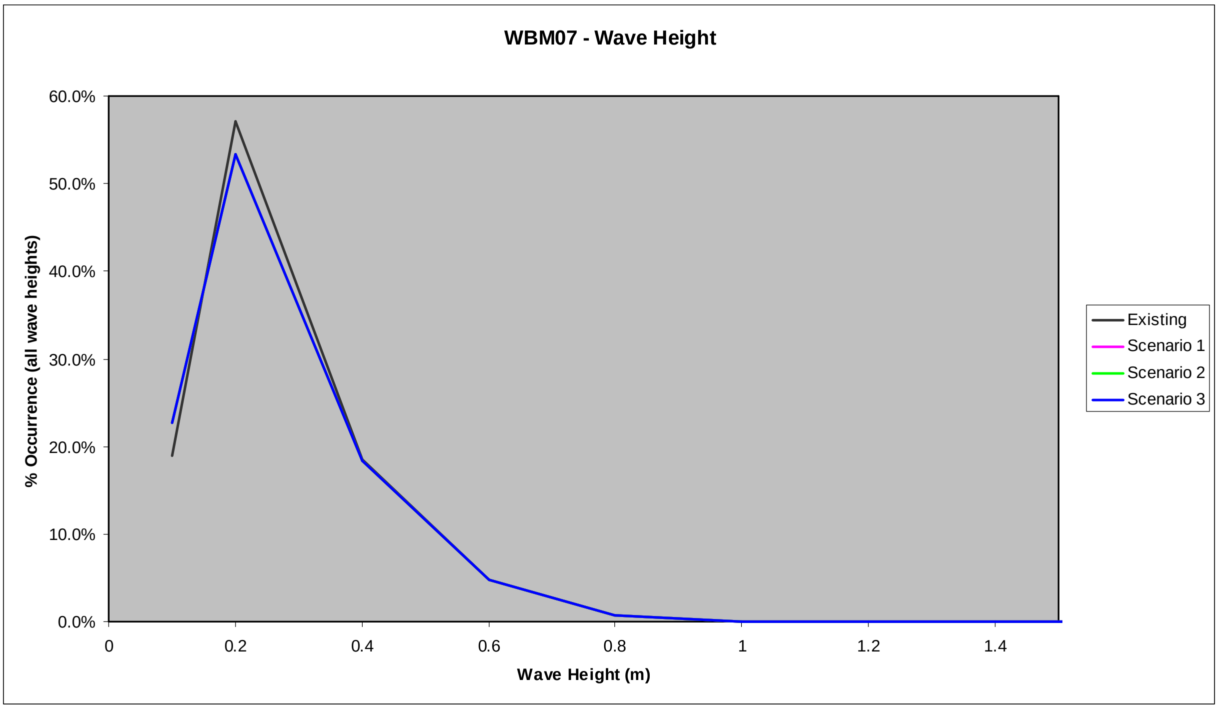


Figure 7-30 Ambient Wave Climate – WBM07 Fisherman's Landing Berths

As expected at this location, the wave directions at the Fisherman's Landing Berths are not affected from the highest occurrence directions from the east to the south-south-east. There are some minor variations in directions from the western sector due to the Reclamation Area but these are not considered significant given their low occurrence.

There is a small reduction in the occurrence of the most common wave height (0.2m) due to the blocking effect of the Reclamation Area on waves from the western sector.

Ambient Wave Climate Summary

The ambient wave height in the Project Area rarely exceeds 0.6m (less than 1% of time) and the predominant direction of the ambient waves is from the south-east with over 50% occurrence from the 120 and 150 degree sectors.

Except for the area immediately north of the Reclamation Area (WBM04), the proposed Reclamation Area and dredging has only minor effects on the wave climate in that part of the harbour between Fisherman's Landing and The Narrows. Given the low wave heights, the changes are not therefore significant in terms of the effects on coastal processes.

North of the Reclamation Area footprint, wave heights will decrease and the predominant wave direction will move from south-east to east. This area will become more quiescent in terms of wave action and will be slightly more prone to increased siltation.

Extreme Wave Climate

The extreme wave climate has been assessed using the numerical spectral wave model SWAN for a 1 in 50 year (AEP 2%) event and a 1 in 100 year (AEP 1%) event (Appendix J). Wind speeds for this analysis were determined from an analysis of tropical cyclones that could affect the Gladstone Region (GHD 2009g) and were coupled with a water level appropriate for the risk level as determined in Chapter 4 - Climate and Climate Change Assessment. The parameters used are summarised in Table 7-34.

Table 7-34 Extreme Wave Climate Parameters

Return Period (AEP)	1:50 (2%)	1:100 (1%)
Wind Speed (m/sec)	31.3	34.5
Water level (m AHD)	3.33	3.53

For each design storm, twelve combinations of wind (direction and speed) and water levels were modelled for the base case and each of the development scenarios and the results are presented in the Wave Climate section of the Numerical Modelling Report (Appendix J) in Appendix J as spatial plots showing the distribution of significant wave heights and directions and as tables detailing the wave height, wave period, and wave direction for each wind direction for each case and design storm.

The spatial plots for waves from the north, east, and south-east are available in Appendix J. The spatial plot for the south-easterly wind direction for the base case is shown in Figure 7-26 in Section 7.3.1. The same plot for the developed case for the 1:100 wind event is provided in Figure 7-31.

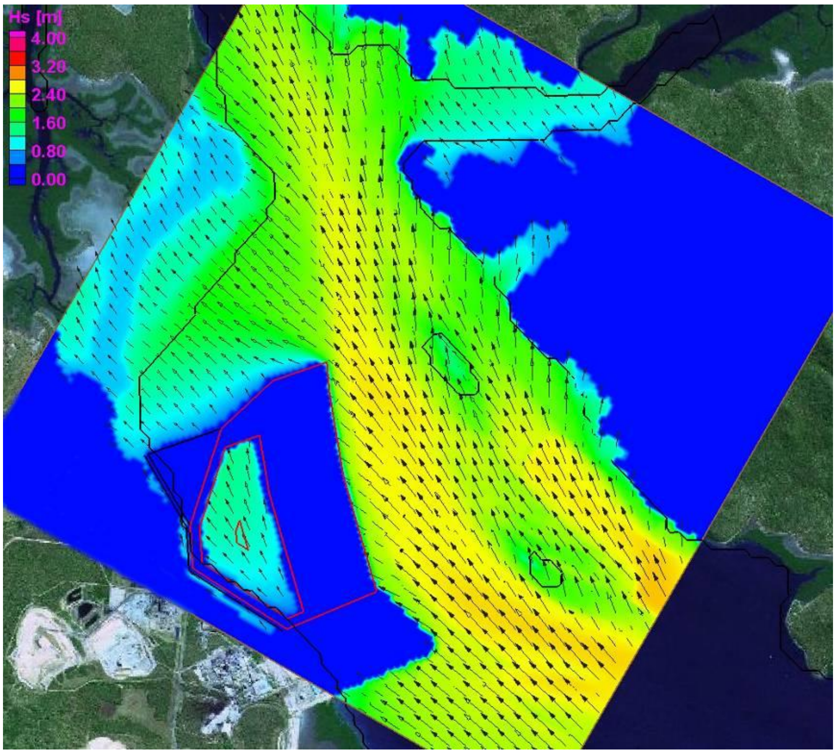


Figure 7-31 Extreme Wave Climate – Modelled Significant Wave Height for South-easterly Wind – Development Scenario 3

The results of the extreme wave climate have been analysed at each point of interest in the Western Basin taking account of the wave height, wave period, and wave direction for each wind direction, for each case and design storm. In order to assess the impact of the development on the extreme wave climate, plots comparing the modelled existing and developed conditions for each point of interest have been compiled and are presented in the Coastal Processes Assessment in Appendix M.

The impact of the three development scenarios on the extreme wave climate at Fisherman's Landing compared to the base case for the 1:100 year design event is presented in Figure 7-32

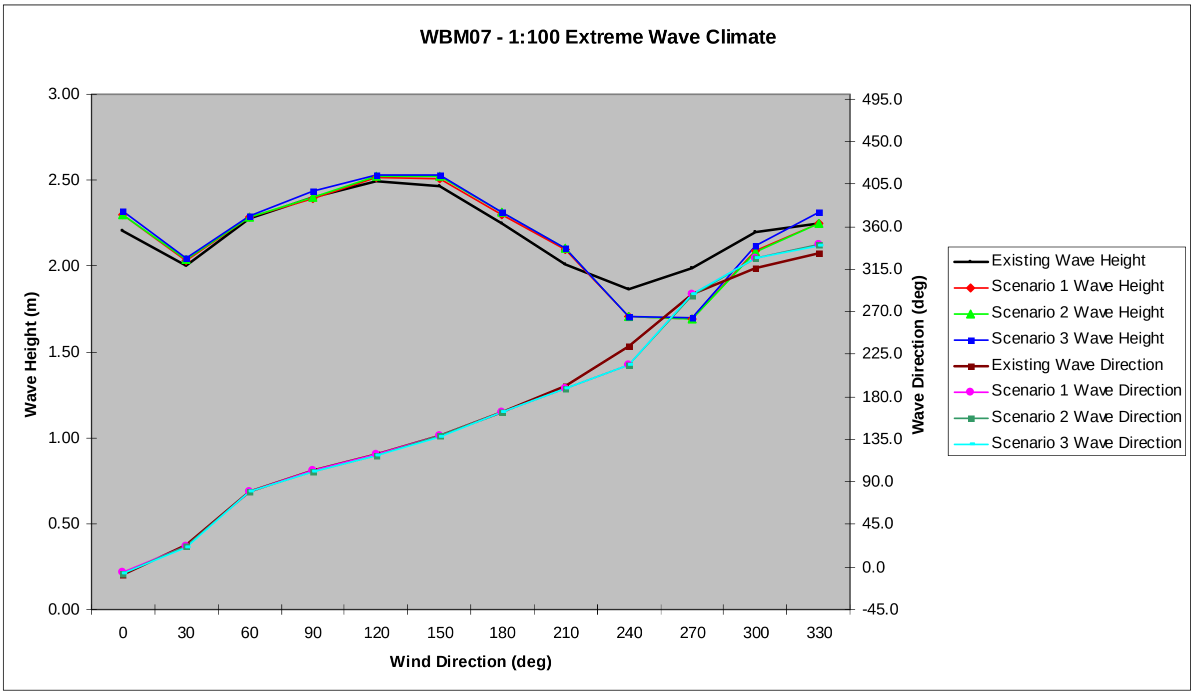


Figure 7-32 Extreme Wave Climate at WBM07 Fisherman's Landing Berths

These results show the following:

- There are marginal increases in wave height from the southerly sector due to the dredged channels;
- There is a marked reduction in wave height from the west due to the blocking effect of the Reclamation Area; and
- There are minor changes in wave direction from the west and north due to the influence of the Reclamation Area.

Extreme Wave Climate Summary

The wave height generated by extreme events (1 in 100 year) in the vicinity of the Western Basin is estimated to be up to a maximum of 2.54 m. The maximum wave height is generated from a few degrees south of east, around to the south-south-east, as a consequence of the fetch lengths in this direction. This is also the most likely wind direction from a cyclone crossing the coast north of Gladstone and therefore, this combination of extreme wave and direction is a realistic component of the overall wave climate for the Western Basin area.

Other than the area immediately north of the Reclamation Area (WBM04) and along the eastern margins of the Reclamation Area (WBM21), the proposed Reclamation Area and dredging are predicted to have only minor effects on the extreme wave climate in the Western Basin area. The most significant impact of the proposed development is a reduction in the extreme wave energy north of the Reclamation Area and hence, in an extreme event, increased siltation may occur in this area. However, this is unlikely to be significant in terms of the overall impacts that such an extreme event would have in other areas in the harbour.

Water Levels

The potential impacts of the proposed works represented in the three development scenarios have been assessed with the calibrated and validated numerical model of Port Curtis. The results from the modelling have been used to assess the impact of the development scenarios and a complete set of results is located in Appendix J.

The dredging and Reclamation Area works introduce various inter-related, additive and sometimes compensating effects to modify water levels and tidal currents. The stage of works also adds to the complexities, with some impacts in early stages being mitigated in certain areas by subsequent works while impacts at other locations increase (Appendix J).

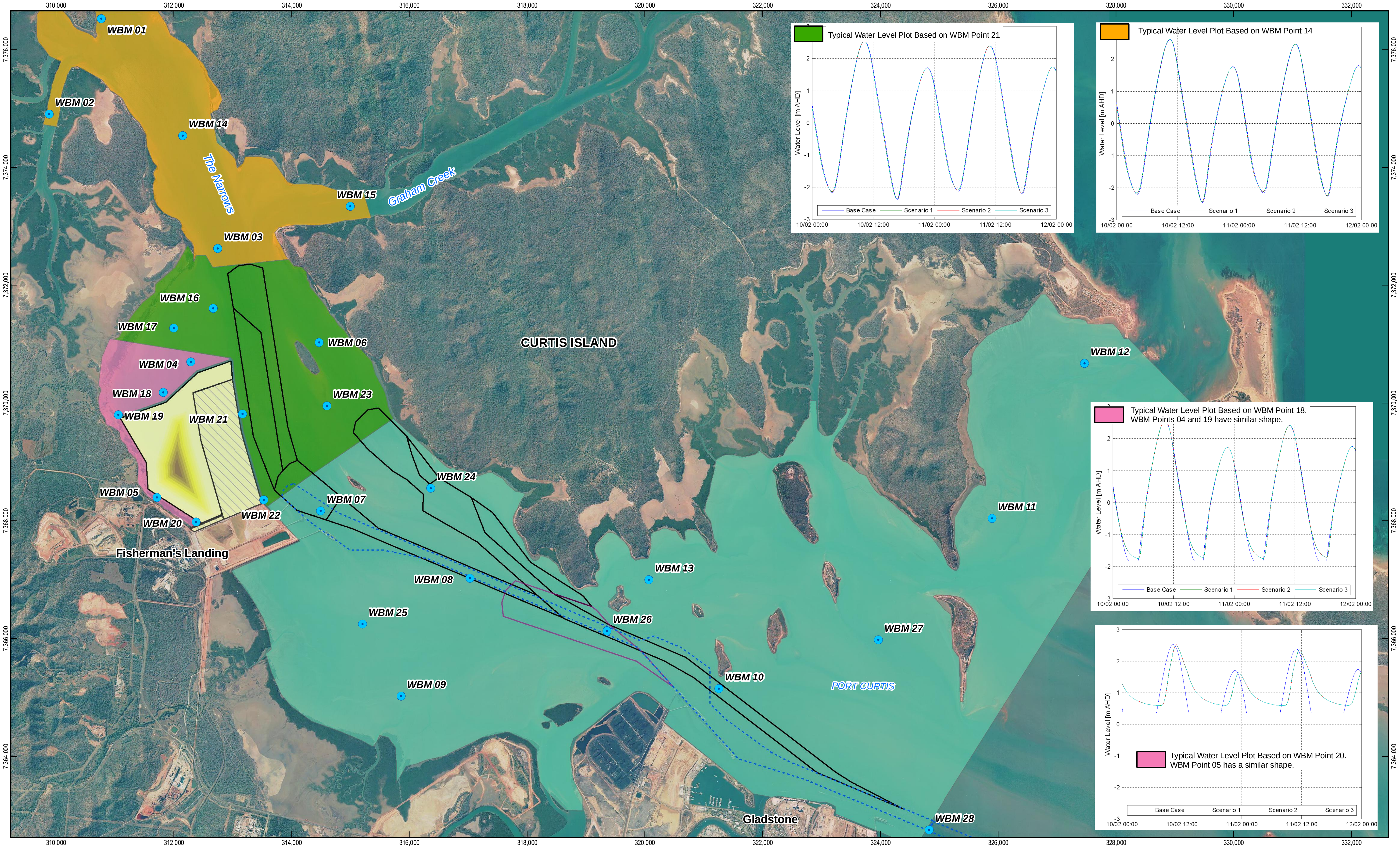
The proposed Reclamation Area reduces the inter-tidal storage area by 408.5ha, which causes a reduction in the tidal prism that subtly alters the tidal propagation dynamics within the system (Appendix J).

Results from Time Series

Time series of water levels for the base case and the three development scenarios were extracted at the 28 locations throughout the model as shown on Figure 7-23. On examination of the results across the model, different impacts are apparent in different parts of the harbour and can generally be characterised by one of the points in those areas. This is illustrated for water level in Figure 7-33. The change categories are described as follows:

1. The area where there is no change (light green) covers all points down-harbour of Fisherman's Landing.
2. Very minor phase changes (dark green) occur at points adjacent to the Reclamation Area in the main harbour i.e. to the east of the Reclamation Area. Typically, the phase change is less than 10 minutes.
3. North of the entrance to The Narrows, a small change to the low water occurs (< 0.05m) in addition to very minor phase changes.
4. The only location where there are noticeable changes in water level is in the immediate vicinity of the Reclamation Area (north and west) (pink). Here it is evident that major changes to low water and phase shifts will occur, resulting in a more gradual drop in the tide to low water and the low water level generally being marginally higher.

The relative impact of the various staged scenarios is much smaller than the impacts relative to the base case, which indicates that the Reclamation Area and the associated loss of inter-tidal storage is a more significant influence on the hydrodynamics of the area than the proposed dredging works.



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Metres

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Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Grid: Map Grid of Australia 1994, Zone 56

LEGEND

- Output Locations
- Western Basin Reclamation
- Fisherman's Landing Northern Expansion
- Proposed Dredging Stages
- Existing Channels, Swing Basins and Berths
- Wiggins Island Coal Terminal (Approved)

Water Level Change

- No Change
- Very Minor Phase Change
- Very Minor Phase Change - Small Change to LW Level
- Major Changes to LW and Phase Shifts

GHD GPC

Port of Gladstone
Western Basin Dredging and Disposal Project

Job Number	42-15386
Revision	A
Date	30 Aug 2009

Predicted Changes in Water Levels

Figure 7-33

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The most noticeable differences in water level occur in the western channel between the proposed Reclamation Area and the western foreshore. At WBM20, the model predicts a shallow depth (<0.3m) of water pondage due to a high spot in the drainage path along the western side of the Reclamation Area. It is noted that this may be an artefact of model bathymetry resolution, and hence the change predicted by the model may be conservatively large in magnitude.

Water Levels Summary

The water level time series results indicate that the Reclamation Area and dredging works will have negligible impacts on high tide levels and relatively minor impacts on low tide levels except potentially in the channel on the western side of the Reclamation Area.

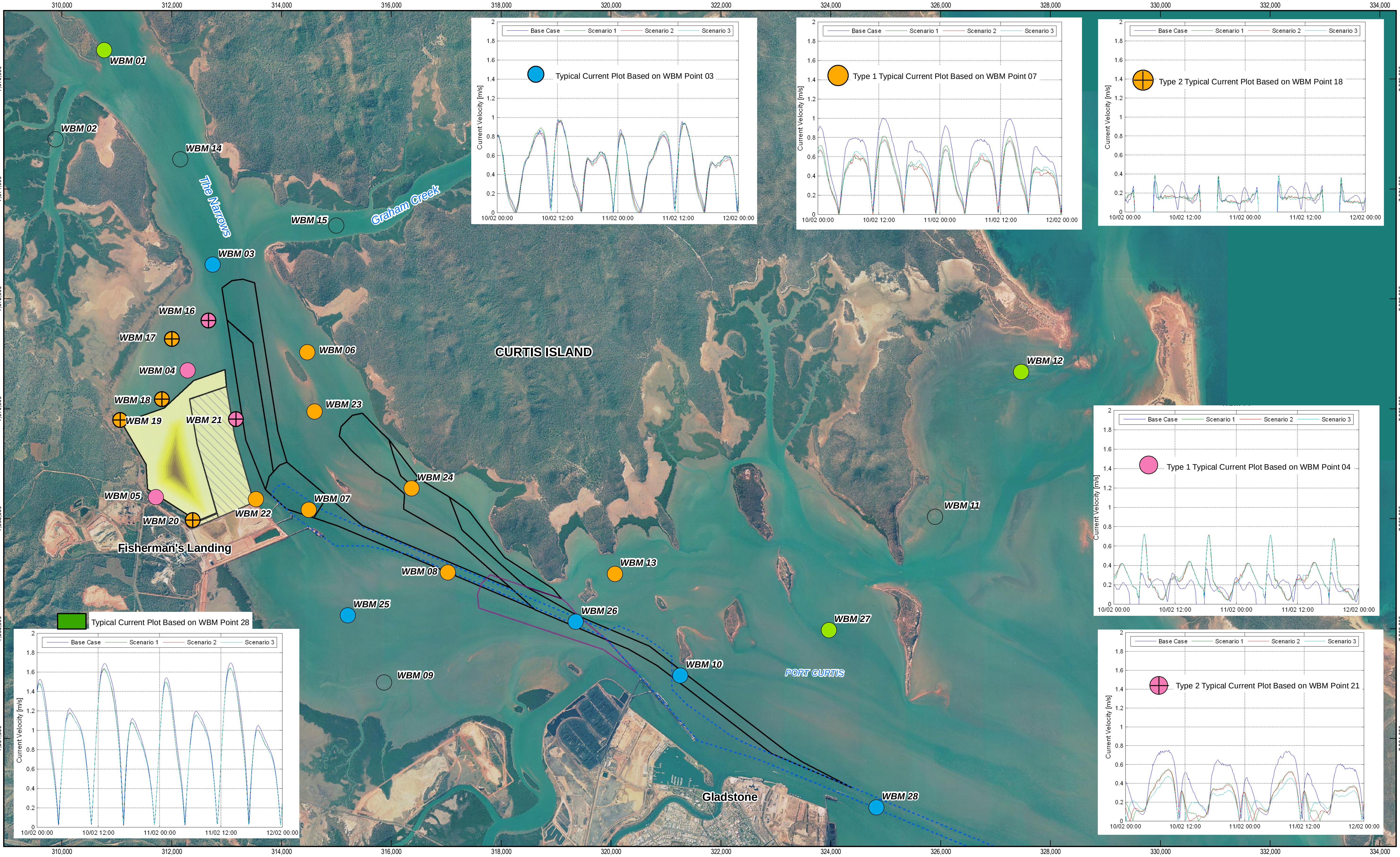
Tidal Currents

As stated previously, the proposed Reclamation Area reduces the inter-tidal storage area by 408.5 ha, which causes a reduction in the tidal prism that subtly alters the tidal propagation dynamics within the system (Appendix J). While these changes do not have significant effects on water levels except in the area immediately adjacent to the Reclamation Area, the reduction in the tidal prism and the changes to flow paths as a result of the reclamation can cause much more significant effects on current velocities.

Results from Time Series

Time series of current velocities for the base case and the three development scenarios were extracted at the 28 locations throughout the model as shown on Figure 7-23. Characterisation of the results into typical responses is more complicated than the same analysis of water levels as there are more significant differences to assess and the there are additional response types. The results are illustrated on Figure 7-34 and are further described as follows:

1. No change (no colour) – at four points only, two upstream in The Narrows, and two downstream in "quiet" areas of the harbour (west of Wiggins Island and east of Compigne Island)
2. Very minor changes (light green) – at three points only, located the furtherest from the Reclamation Area, upstream in The Narrows and downstream in the harbour away from the main channels. Changes are typically evident as a very minor reduction in peak currents.
3. Minor changes (blue) occur upstream and downstream of Fisherman's Landing adjacent to and in the dredged channels and typically consist of a minor change (both up and down) in peak currents and some minor phase changes.
4. In the immediate vicinity of Fisherman's Landing east to Curtis Island and downstream to Hamilton Point, there are substantial differences (orange - Type 1) that show up as changes (both up and down) in peak currents up to 25% and some minor phase (timing) changes. For this group, the current plot for WBM07 is typical.
5. In the area to the west and north of the Reclamation Area, there are also substantial differences (orange - Type 2) of the same general description but the typical plot is quite different (WBM18).
6. Major Changes (pink - Type 1) occur close to the Reclamation Area at points WBM 04 and 05 and involve large velocity increases and decreases and major phase shifts, but on a low velocity base. The plot for WBM04 is typical of this group.
7. Major Changes (pink – Type 2) occur north of the Reclamation Area at WBM16 and along the eastern edge of the Reclamation Area at WBM21. The plot for WBM21 is typical of this group.



1:65,000 (at A3)

0 500 1,000 1,500 2,000

Metres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Grid: Map Grid of Australia 1994, Zone 56

N

LEGEND

- No Change
- Very Minor Changes
- Minor Changes
- Substantial Differences - Type 1
- Substantial Differences - Type 2
- Major Changes - Type 1
- Major Changes - Type 2
- Western Basin Reclamation
- Fisherman's Landing Northern Expansion
- Existing Channels, Swing Basins and Berths
- Wiggins Island Coal Terminal (Approved)

Port of Gladstone
Western Basin Dredging and Disposal Project

Job Number	42-15386
Revision	A
Date	30 Aug 2009

Predicted Changes in Current Velocities

Figure 7-34

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Level 4 201 Charlotte Street Brisbane QLD 4000 Australia T +61 7 3316 3000 F +61 7 3316 3333 E bnemail@ghd.com W www.ghd.com

These observations are consistent with the summary provided in the Numerical Modelling Report (Appendix J) which states that, in general, current velocities tend to decrease in dredged areas as well as those areas laterally adjacent to the dredging (e.g. WBM07, 08, 24, 22, and 13). Increases in velocity are typically evident in adjacent un-dredged areas upstream and downstream of the newly dredged areas (e.g. WBM03, 06, and 23). The Reclamation Area can also act to modify velocities in the immediate adjacent channel and inter-tidal areas by confining and redirecting the flow (e.g. all points in the Western Basin).

Impact Plots

Aerial plots of maximum ebb and flood tide velocities for the base case are shown in Figure 7-35 and Figure 7-37 with the changes to maximum velocities for Scenario 3 shown in Figure 7-36 and Figure 7-38.

Only Scenario 3 is shown here as it generally represents the worst case scenario in terms of impacts outside the new dredged channel areas. For example, the ultimate dredging configuration associated with Scenario 3 causes the footprint of increased velocities to extend further north into The Narrows, and ebb tide velocity increases at Hamilton Point are accentuated and extend through to Boatshed Point. Plots for the other scenarios are available in Appendix J.

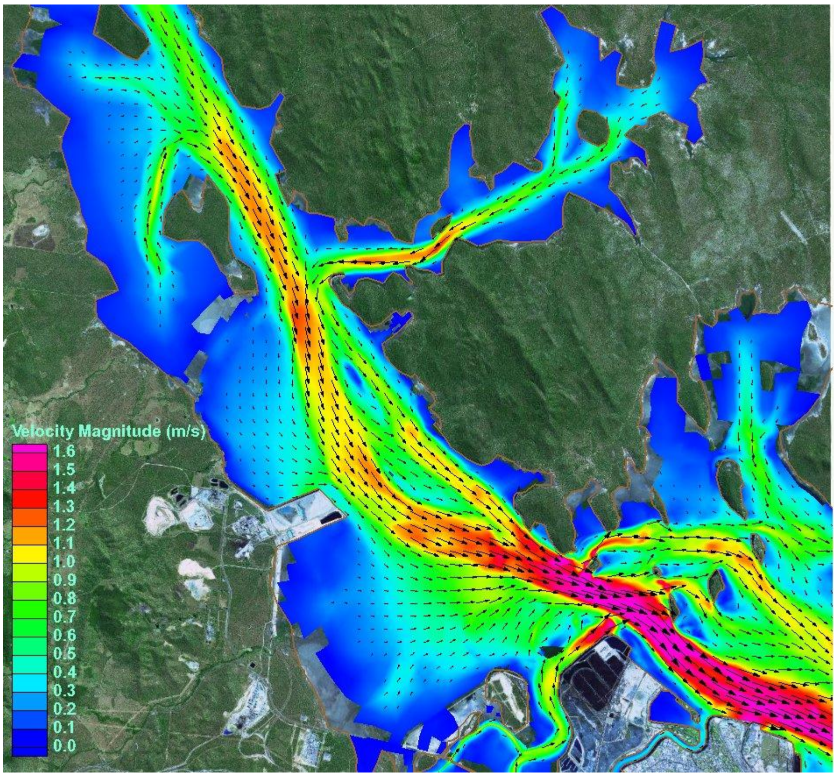

Figure 7-35 Maximum Ebb Currents – Base Case

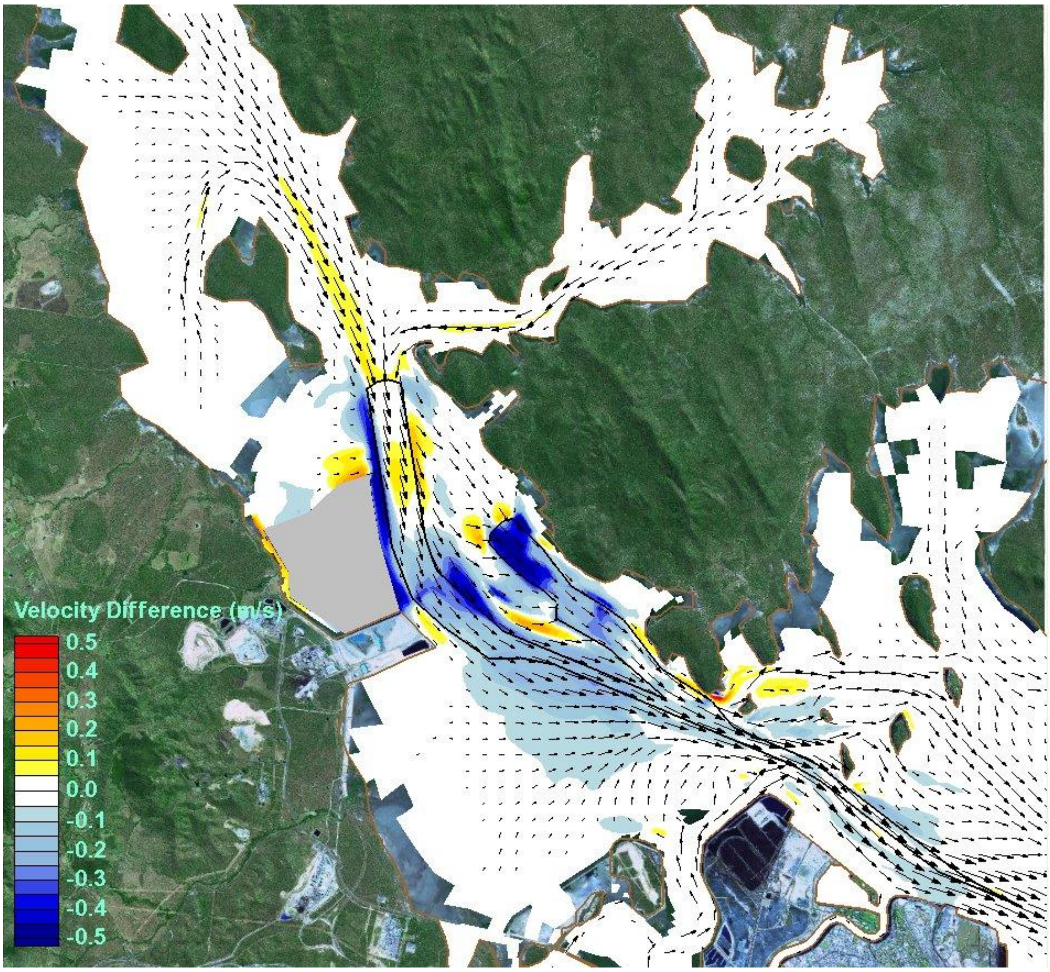

Figure 7-36 Impact of Scenario 3 on Maximum Ebb Currents

The results for the ebb tide case (Figure 7-35 and Figure 7-36) show:

1. There is a small overall reduction in maximum velocity downstream of the western basin due to the presence of the Reclamation Area reducing the tidal prism.
2. Current velocity increases opposite the northern end of the Reclamation Area are evident due to the reduction in the available waterway width.
3. Small area of increased velocities adjacent to Curtis Island (opposite the Reclamation Area) due to "weir effect"[4] as water drops into dredged channel.
4. Around the northern edge of Reclamation Area there is a small area of increased maximum velocities as the tide flows out of the embayment north of the Reclamation Area.
5. Current velocities east of the Reclamation Area reduce progressively from Scenario 1 to Scenario 2 and 3 due to the increasing volume and capacity of the channel.
6. For Scenario 3 there is an area of increased velocities extending up into The Narrows from the Laird Point channel due to the "weir effect" of the final stage of the dredging of the channel parallel to the Reclamation Area.

[4] "weir effect" refers to the analogy of an increase in flow upstream of a broad crested weir as the water approaches the weir crest

7. Erosion of the bed may occur in areas of increased velocity, depending on the bed material. Any eroded material will settle in the bottom of the channel and will need to be removed by maintenance dredging. However, given the low magnitude of the velocity increase, the volume of material is expected to be similar to existing maintenance dredging commitments.
8. Some scour of and redistribution of fine sediments at the northern corner of the Reclamation Area can be expected. Some of this material may also settle in the dredged channel. There is potential for the finer material to form a plume until the fine material in this area is removed or the bed deepens such that the velocities are reduced. The expected scour will also need to be considered in the design of the Reclamation Area bund walls in this area, particularly with respect to the stability of the toe of the wall.

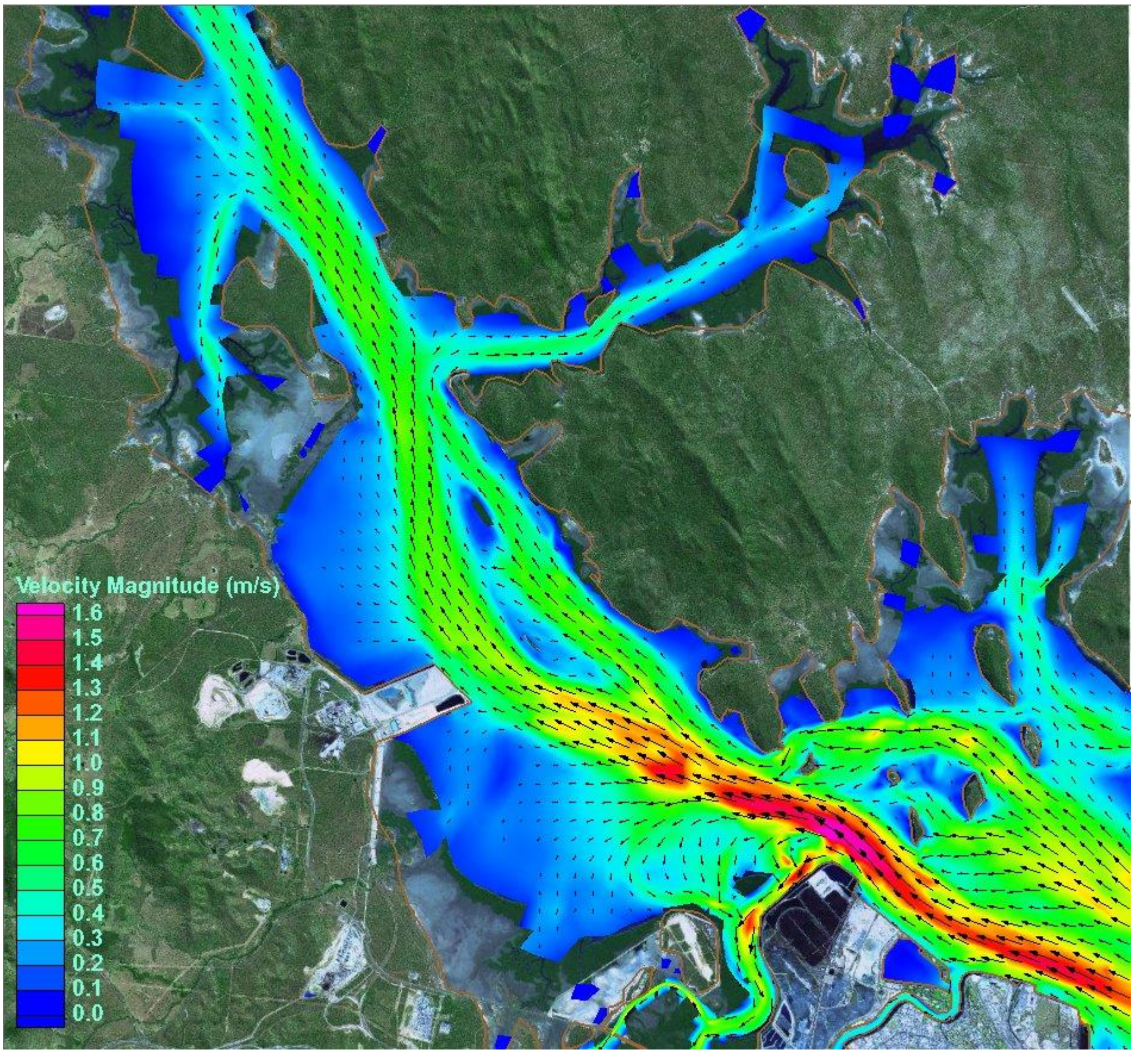

Figure 7-37 Maximum Flood Currents – Base Case

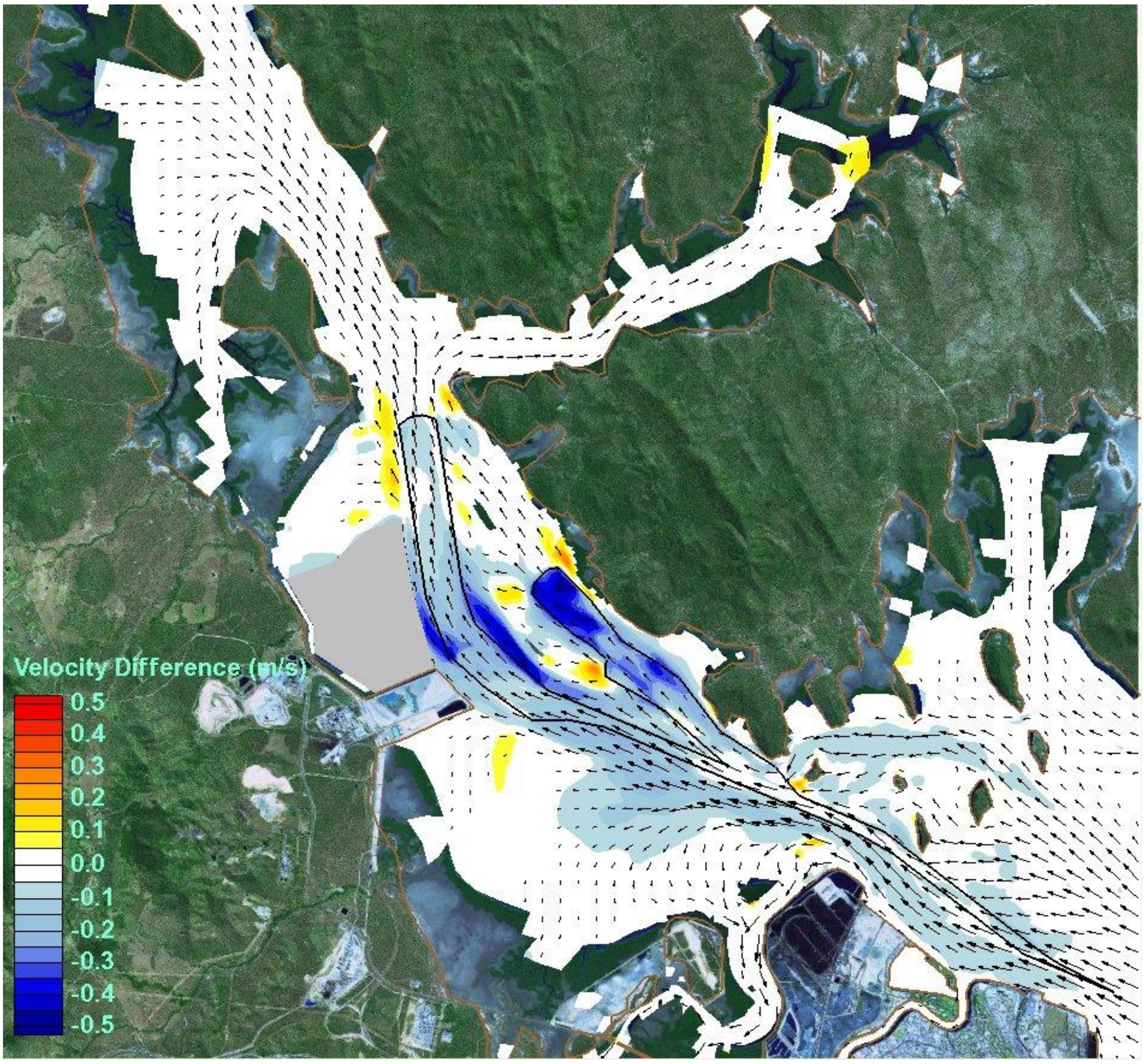

Figure 7-38 Impact of Scenario 3 on Maximum Flood Currents

The results for the flood tide case (Figure 7-37 and Figure 7-38) show:

1. Small increases in maximum currents upstream of dredged channels as flow progresses from the deep dredged channel to shallower un-dredged areas. This phenomenon fades by the time the flow enters The Narrows.
2. General reductions in velocities in the dredged channels due to their larger cross sectional area for similar flows.
3. Increases in currents are generally highest for Scenario 1, reducing for Scenarios 2 and 3 due to the increased capacity provided by the dredged channels.

Integrated Flow Summary

The integrated flow results from the hydrodynamic model indicate a slight reduction in the total flow entering and leaving the Western Basin at the southern (downstream) end between Mud Island and Hamilton Point as a result of the loss of storage volume (tidal prism) associated with the Reclamation Area (Appendix J).

For The Narrows, there are negligible changes to the flood tide flows into this area while ebb tide flows indicate a small increase in flow in line with the small increases in ebb tide velocities in this area (Appendix J).

Sediment Transport

Sediment transport under the action of tidal currents has two principal components – bed load and suspended load. Bed load generally consists of the coarser fractions of the bed material with the finer silts being taken into the water column by the turbulence from the relatively high tidal velocities.

Changes in the sedimentation of the coarser sand fractions are characterised by the impacts on the sand transport potential. Silt movement and deposition is assessed through an examination of bed shear stresses and a semi-quantitative / qualitative assessment of silt deposition.

Sand Sedimentation Impacts

The net sand transport potential for the Base Case is shown in Figure 7-39 with the net sand transport potential impacts relative to the Base Case and Scenario 3 shown in Figure 7-40.

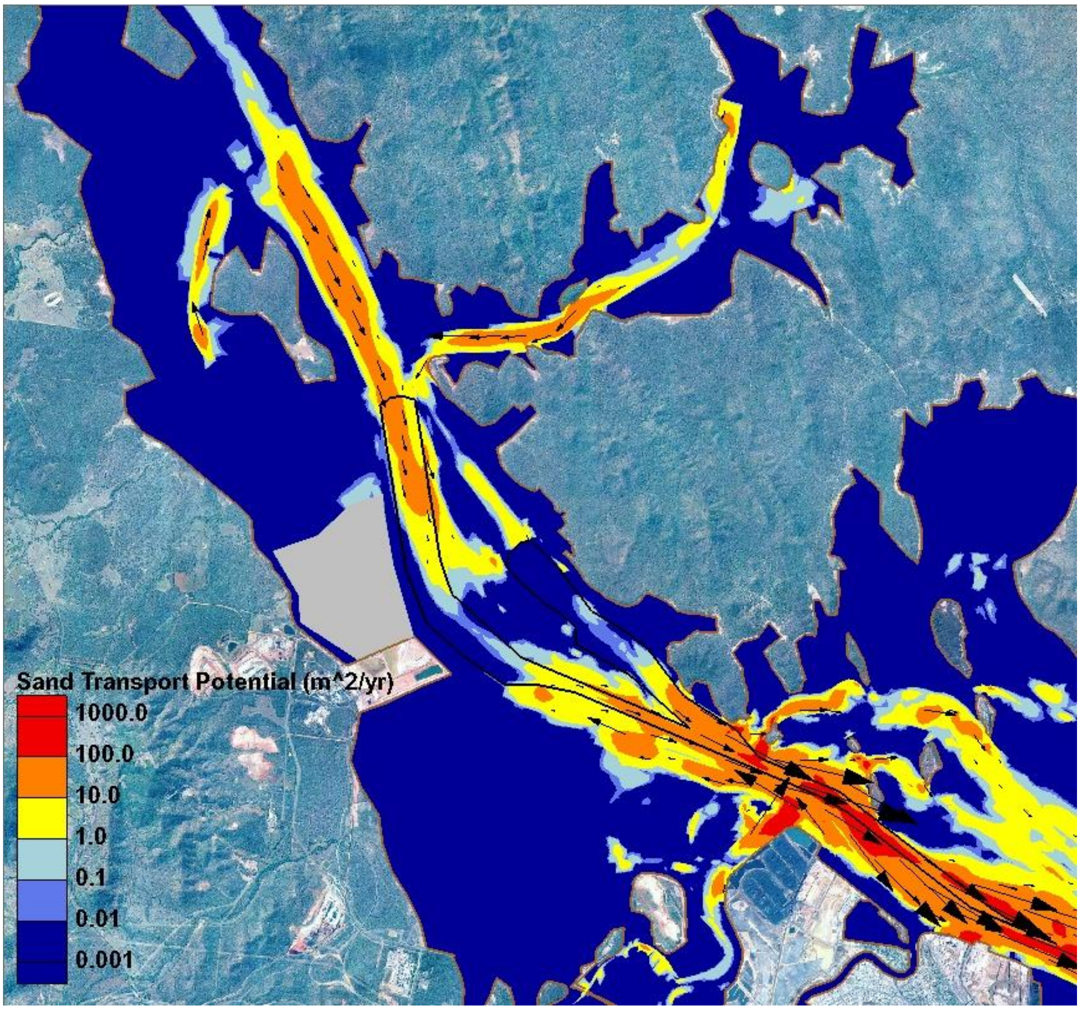

Figure 7-39 Net Sand Transport – Base Case (Existing Conditions)

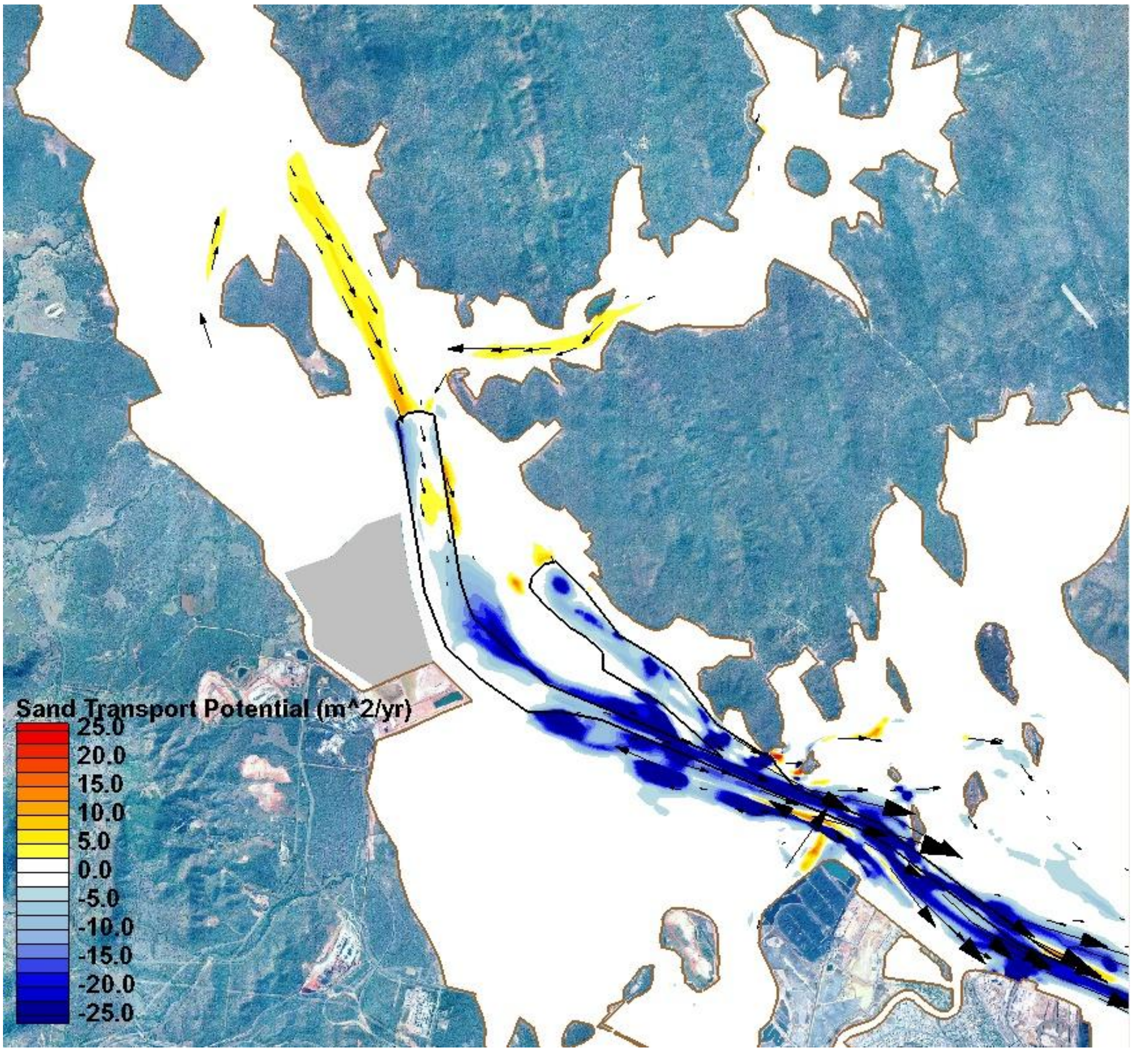

Figure 7-40 Impact of Scenario 3 on Net Sand Transport

The developed scenarios have an impact on net sand transport potential including an increase in the ebb-dominant transport in the channels upstream of the dredging to Fisherman's Landing and a general reduction downstream of Fisherman's Landing because of the reduced current speeds and bed shear stresses caused by the Reclamation Area / dredging development.

While there appear to be some substantial reductions in the net transport potential in the downstream swing basins (Clinton and Wiggins Coal Terminal), it is likely that the transport potential in those areas may be overstated as a result of the assumptions made. Nevertheless, there will be reduction in the transport potential in this area due to the reduction in current speeds and hence, bed shear stresses due to the combined effects of reclamation and dredging on the hydrodynamics. This is most evident in Scenario 1, indicating that the loss of tidal compartment to the reclamation has the most impact.

Relative sedimentation hotspots can be qualitatively identified by inspection of the sand transport potential patterns and include:

- Northern end of Fisherman's Landing swing basin;
- Northern end of both swing basins adjacent to Curtis Island; and

- Northern end of Laird Point swing basin.

At these locations, sand is transported from the shallower upstream areas and is expected to be deposited near the bottom of the dredged batter, under the influence of the net transport in the ebb tide direction. The peak sedimentation rates are expected to be similar to those experienced in current port operation areas, that is 1 to 5cm/annum and up to 10cm/annum at localised "hotspots.

Bed Shear Stress Impacts

Bed shear stresses have been calculated throughout the model domain over a two month simulation period. Spatial plots of 5% exceedance bed shear stresses for the Base Case are shown on Figure 7-41, and the impacts for development Scenario 3 are presented in Figure 7-42.

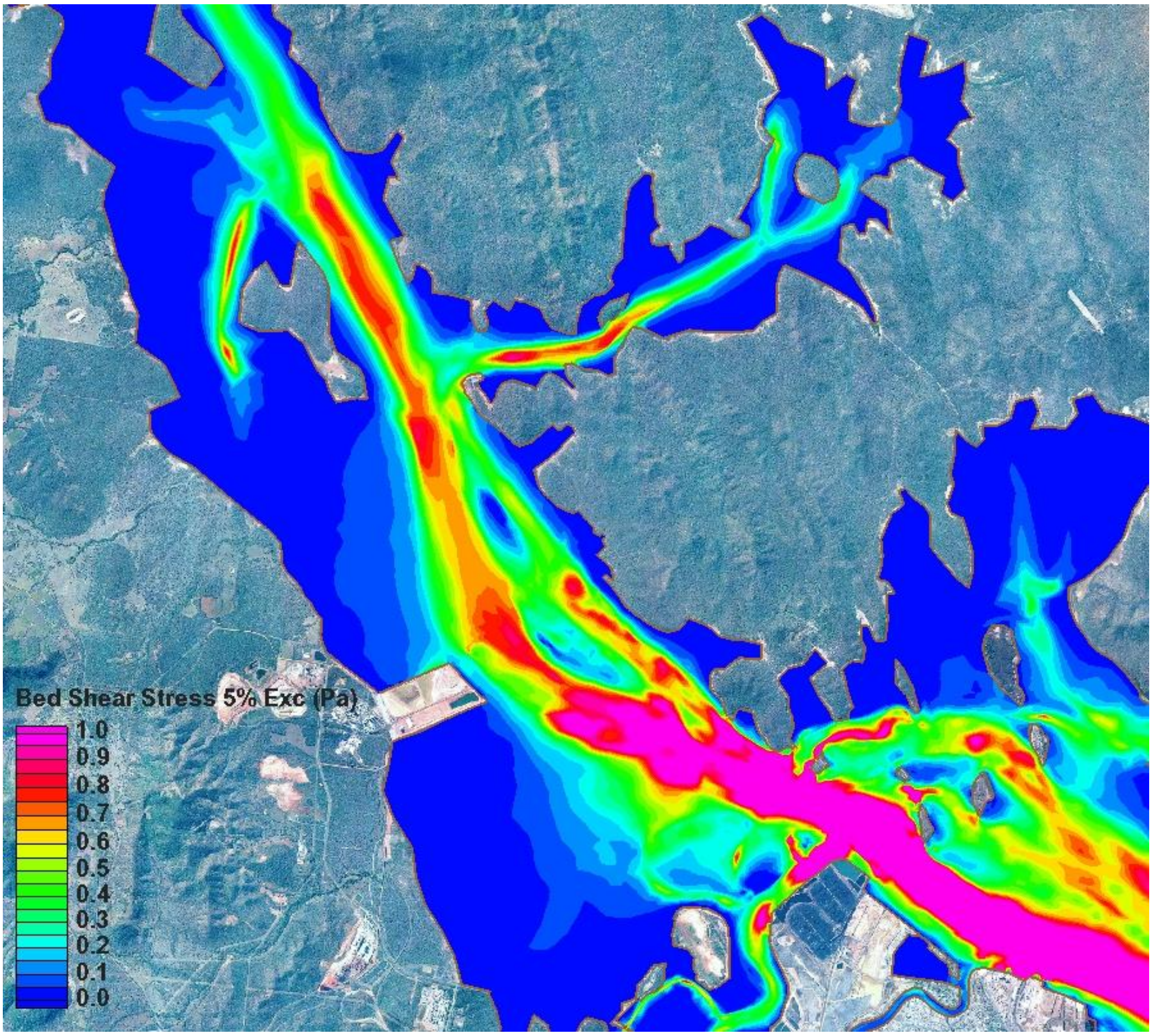

Figure 7-41 Bed Shear Stresses – Base Case (Existing Conditions)

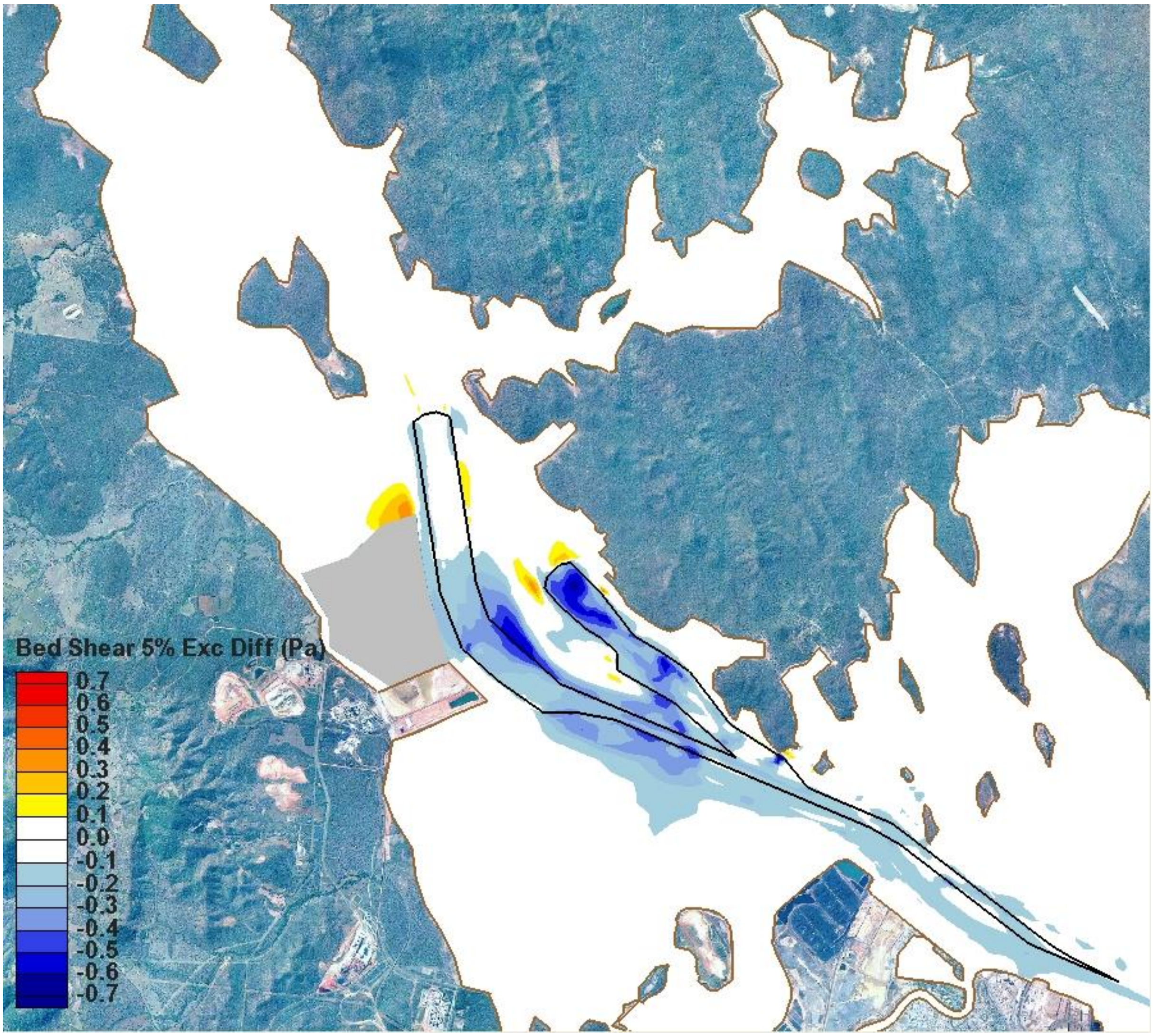

Figure 7-42 Impact of Scenario 3 on Bed Shear Stresses

The dredging in the three developed scenarios reduces the bed shear stresses in the dredged areas and laterally adjacent areas where current velocities are reduced due to the increased flow area provided by the dredging. Increases in the bed shear stresses occur in the undredged channel areas where current velocities are higher upstream of the dredged areas, this being particularly noticeable east of the Reclamation Area and upstream of the eastern dredged channel adjacent to Curtis Island.

In all developed scenarios, there is a zone of increased bed shear stress in the shallow area adjacent to the north eastern edge of the Reclamation Area. The increased bed shear stresses are well above the lower limit at which re-suspension of fine material occurs and hence, as the surface sediments in this area are expected to be fine cohesive material, scouring will occur in this area. This phenomenon is also evident in the vicinity of the north-eastern corner of the existing Fisherman's Landing reclamation (Figure 7-41) where the bed shear stresses are around 0.3Pa compared with 0.4Pa at the north-eastern edge of the developed reclamation.

Silt Deposition

The Numerical Modelling Report (Appendix J) provides an assessment of potential silt deposition based on synthesised variations in turbidity derived from nephelometer measurements and modelled bed shear stresses to calculate the erosion / deposition potential at each point in the model. The report notes that there is a level of uncertainty surrounding the various assumptions made in the assessment, which, along with the absence of appropriate calibration / validation measurements, means that the assessment results should be treated as being qualitative / semi-quantitative.

The patterns of predicted net silt deposition potential for the Base Case are shown in Figure 7-43 and for Scenario 3 in Figure 7-44.

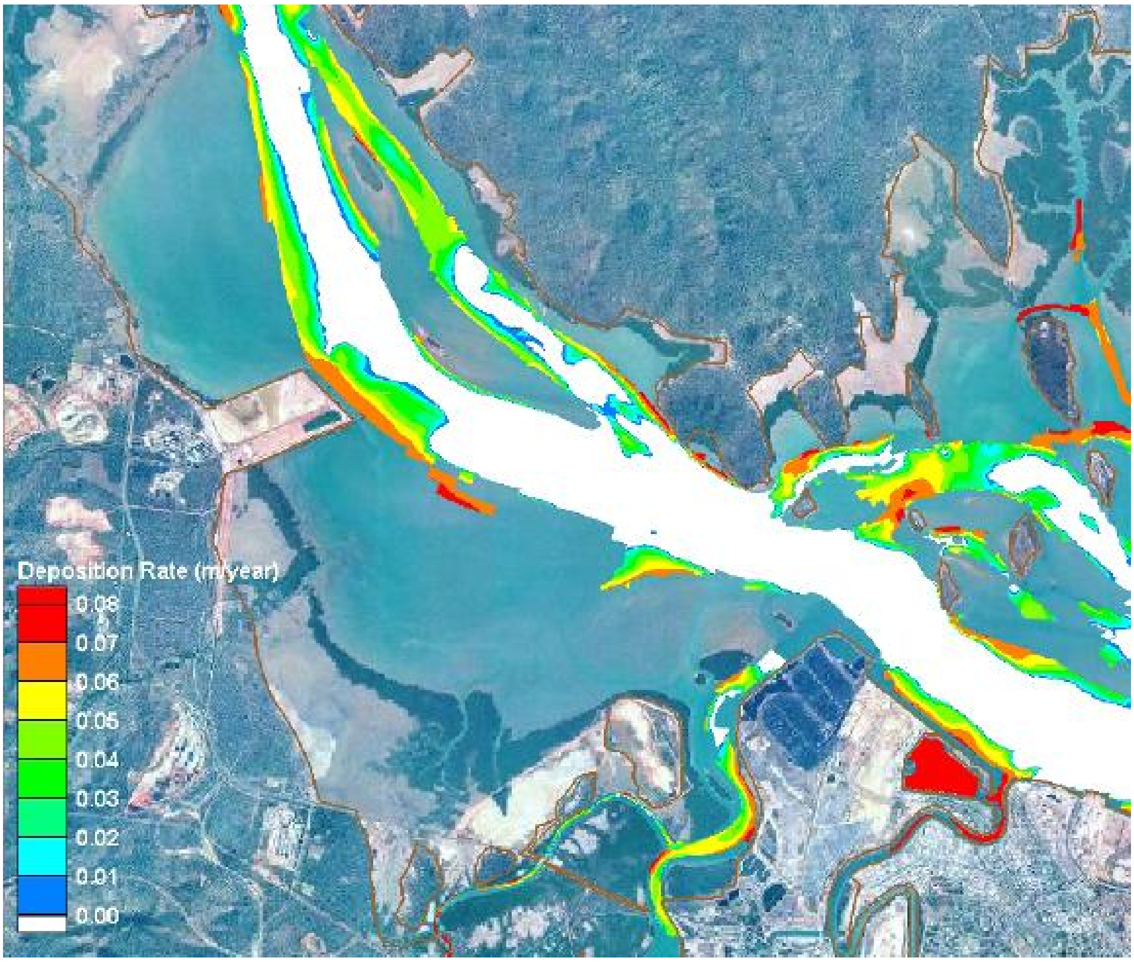

Figure 7-43 Silt Deposition – Base Case (Existing Conditions)

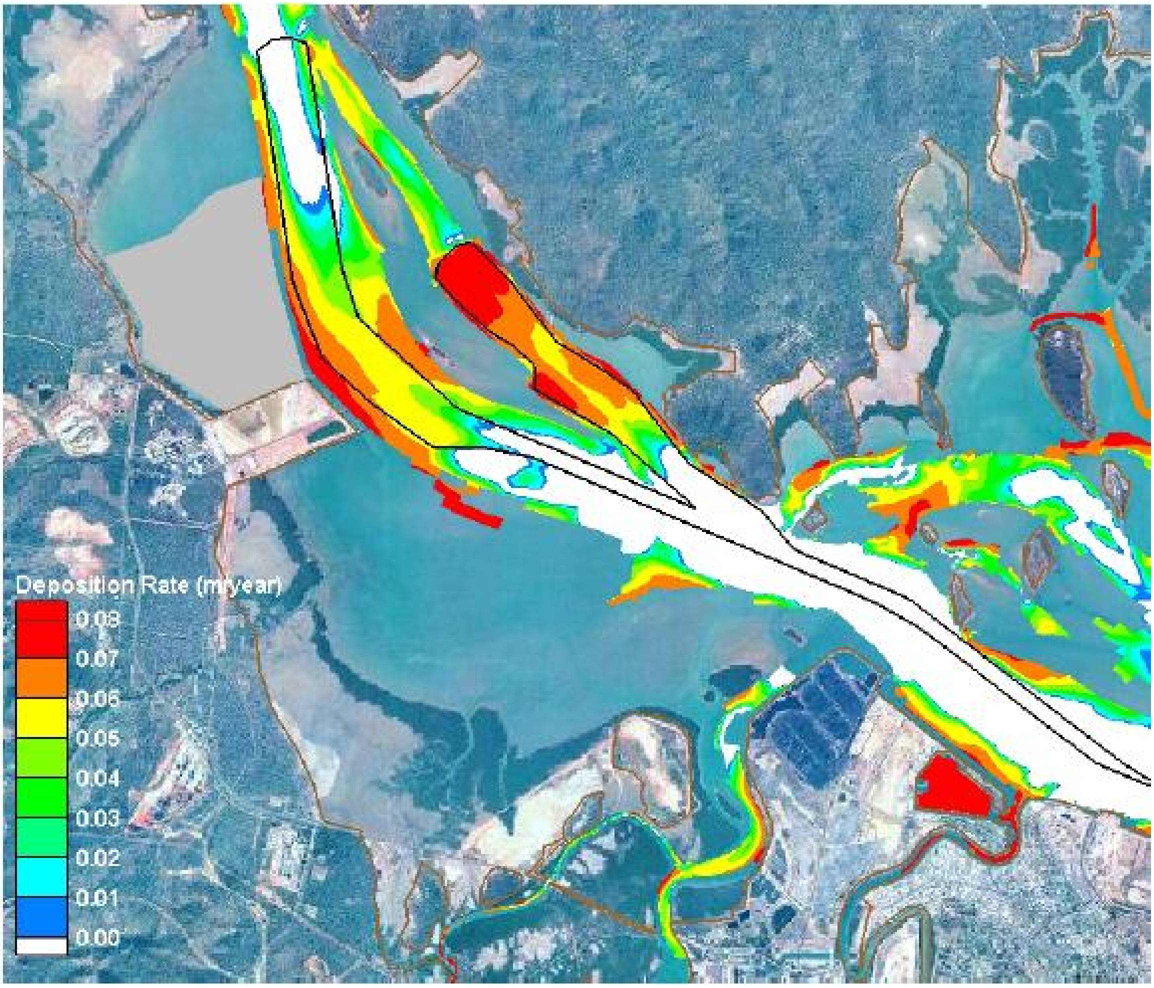

Figure 7-44 Silt Deposition – Scenario 3

The project dredged areas are likely to experience significant silt deposition due to the relatively low-energy hydrodynamic regime that will occur following dredging.

The principal areas where silt deposition is predicted to occur are:

- Western side of Fisherman's Landing swing basin; and
- "Curtis" Island channel upstream of South Passage Island and China Bay (includes the two swing basins adjacent to Curtis Island).

Silt deposition potential into the above areas increases progressively as the extent of dredging increases with each dredging scenario. A fine material siltation rate of 255,000m^3/year in the dredged channels and new swing basins in the Project Area has been predicted for the ultimate dredging scenario.

The significance of this is that silt deposition is not a major source of sedimentation problems in the existing Port Curtis dredged areas (excluding closed harbours) due to high current speeds and associated bed shear stresses (Appendix J).

Impact of Reclamation

The Reclamation Area affects the hydrodynamics of the harbour through a reduction in the tidal prism and, on a local scale, obstructs flows that previously flowed across its footprint area. This leads to a reduction in flows downstream of the Reclamation Area and an increase in flows adjacent to the Reclamation Area from the reduction in the cross sectional area leading up to The Narrows. Most of the impacts of the Reclamation Area are indicated in the results for the developed case Scenario 1 as this scenario has the smallest amount of dredging associated with it. The Reclamation Area also produces quite different flow conditions within its immediate vicinity, particularly in the shallow areas to the north and west.

Impact of Dredged Channels

The dredged channels reduce tidal flows within their footprint due to the increased cross sectional area available for the flow. However, the increased capacity of the dredged channel (albeit at a lower velocity) leads to increased flows in the undredged areas upstream, increasing the sand transport potential into the newly dredged channels / swing basins. The quantity of sand sized material is relatively small and is likely to be concentrated at the northern end of the dredged areas at the toe of the dredged batter, but will nevertheless, need to be removed when it becomes a problem.

The dredged channels will provide increased regions within the Western Basin that are in a relatively low energy hydrodynamic regime and hence, are likely to experience significant silt deposition (255,000 m^3/yr) that will require regular maintenance dredging to maintain the design depth of the channel / swing basin / berth pocket. The expected level of maintenance dredging represents a significant increase compared to the current maintenance dredging commitment.

Impacts on Maintenance Dredging

The impacts of the Reclamation Area and dredged channels on maintenance dredging are determined from the changes to the sedimentation patterns and quantities resulting from the development. The sediment considered includes sand sized sediment transported as bed load and fine silts transported as suspended load.

The highly variable nature of the sediments and the prevailing processes makes quantification of siltation rates and maintenance dredging requirements complex. While quantitative assessments of both sand and silt deposition have been made, the uncertainties associated with the assessments need to be taken into consideration.

Overall, additional sand-sized siltation is predicted to occur within the Western Basin for all developed scenarios owing to the expanded dredge footprint. This additional siltation will cause an elevation of the bed but this likely to be localised to the edges of the swing basins and channels as the sand sized material falls into these deeper areas from upstream. Nevertheless, the material will need to be removed before it affects under keel clearances. However, the expected volume of siltation is relatively small and similar to existing maintenance dredging volumes, and could be removed during programmed maintenance dredging as the need arises.

In terms of fine silt, there will be a substantial increase in the silt deposition in the dredged channels and swing basins in the Western Basin due to the decrease in tidal current velocities (and hence bed shear stresses) caused by the Reclamation Area footprint and the larger cross sections of the channels compared with the existing undredged waterways. The occurrence of silt deposition in the dredged channels in the Western Basin area up to a predicted 255,000m^3/yr represents a maximum of 0.08 m/yr loss of depth. This rate of siltation could be accommodated by an over-dredging allowance to extend the time between maintenance dredging campaigns. For example, over-dredging by 0.3m would provide for 3 + years of sedimentation before the declared depth of the channel / swing basin was affected. Nevertheless, this material will eventually need to be removed so as not to interfere with ship navigation and under-keel clearances and could require a significant increase in the current maintenance dredging commitment should it reach its full potential.

Impacts in Northern Embayment

The embayment immediately to the north of the proposed Western Basin Reclamation Area will be impacted through changes to tidal water levels, tidal current velocities, bed shear stresses, and wave conditions. At this location it was necessary to examine the changes to each of the above parameters in relation to each other in order to better understand the impacts of the development in this area. The area encompasses the western tidal channel that will be formed between the Reclamation Area and the existing western shoreline.

It was concluded that erosion of the bed through increased bed shear stresses is likely to occur in the embayment north of the proposed Western Basin Reclamation Area but will be restricted to the area adjacent to the northern extremity of the Reclamation Area.

It was further concluded that other areas within the embayment and in the western tidal channel are likely to experience additional siltation over time due to the effects of the Reclamation Area on the tidal flows, the deepening of the channels, and the sheltering effects on the ambient wave climate. This tendency for siltation grades from minimal at the entrance to the embayment (WBM16) to significant at the western shoreline and along the western tidal channel.

Summary of Impacts

From a physical coastal processes viewpoint, the potential impacts of the proposed development consisting of a large scale reclamation of part of the tidal waterway and extensive new dredged channels, swing basins, and berths are summarised as follows:

1. The changes in flow and water level conditions adjacent to the Reclamation Area to the north and west, and potentially, the changes to the rate at which the ebb tide level drops, reducing the time that the tidal flats are dry during the lower parts of the tidal cycle;
2. The initial scour of fine silts from the north-eastern corner of the Reclamation Area;
3. An increase in maintenance dredging of sand sized sediment in the new dredged channels and swing basins that is commensurate with the existing maintenance commitment; and
4. Potentially, a large increase in maintenance dredging to remove fine silts from the new channels and swing basins adjacent to the Western Basin Reclamation and in the turning basins adjacent to Curtis Island.

Cumulative Impacts

The cumulative impacts of the proposed Reclamation Area and associated channel dredging have been assessed through a consideration of the impact on a base case representing existing conditions compared to three development scenarios that progress the development from the reclamation and minimal dredging through to the final configuration with deep channels and swing basins to service the future berths in the Western Basin and along the western coastline of Curtis Island opposite Fisherman’s Landing. As such, Scenario 3 represents all proposed future dredging in the Project Area.

The impacts of the development have been described in previous chapters. The majority of the impact on tidal flows and water levels can be attributed to the reclamation. The dredged channels contribute to the impact of the reclamation with further reductions in flows within their own footprints. This, in turn, leads to a lower energy hydrodynamic regime in a number of areas in the Western Basin that provides the conditions for potentially significant fine silt deposition.

Mitigation Strategies

It is not necessary to mitigate the changes to the tidal flows and water levels in themselves as the changes are within the normal bounds of the processes that occur in the natural system (representing the inherent variability of coastal and estuarine environments in a macro tidal area). However, it may be necessary to mitigate against or manage some of the effects that these changes bring about. The effects that appear to have the most impact are:

1. The increased potential for fine silt deposition in the newly dredged channels; and
2. The increased potential for sand sized deposition into the existing channels downstream of the Western Basin.

The need for mitigation of the reduced drying time in the areas near the Reclamation Area will depend on considerations dealt elsewhere in the EIS, such as Chapter 9 (Marine Ecology). The main response would be to allow the ebb tide to drain from this area more efficiently, which should result in increased drying time in those areas that currently experience a substantial drying period around low water.

The most practical management measure for the increased potential for sedimentation in the dredged channels is to monitor the actual deposition rates and devise a maintenance dredging plan to arrange its removal to the reclamation so that there is no interruption to future ship movements. This rate of siltation of fine silts could be accommodated by an over-dredging allowance to extend the time between maintenance dredging campaigns. With an over-dredging allowance of 0.3 m, maintenance dredging of the fine silt material may only be required every 3 to 4 years, should the rate of silt deposition reach its full potential.