8.7 Coastal Environment

8.7.1 Introduction

This section describes the existing coastal environment which may be affected by the proposal in the context of marine water and sediments, and coastal processes. The assessment provides a description of the existing environment, an assessment of potential environmental impacts arising from the proposal and a description of proposed mitigation measures.

The coastal environment study area is shown in Figure 8.7.1. It includes the sites of all relevant project proposed components i.e. LNG facility, product loading facility, materials offloading facility, dredging area, dredge material placement facility, gas transmission pipeline crossing, and potential bridge and road access road.

8.7.2 Methodology

This assessment considered the potential project effects on the marine water quality, hydrodynamics and marine sediments of Port Curtis. The marine ecology effects have been discussed in Section 8.4.5. The effects of the dredge material placement facility are discussed in Section 8.17.

The methodology used to assess the project's effects on the coastal environment included the following tasks:

- Review of existing background data for water quality, hydrodynamics and marine sediments.
- Two separate water quality and hydrodynamic field collection surveys were undertaken in Port Curtis adjacent to the LNG facility site. The data collected included:
  - Tidal water levels;
  - Tidal currents;
  - Echo soundings;
  - Boat mounted acoustic doppler current profiler (ADCP) transects of waterways adjacent to the LNG facility site at varying tidal stages;
  - Hand-held physical water quality profiles; and
  - Water quality grab samples.
- Two separate marine sediment field sampling and analysis programs were undertaken for sediment in the vicinity of the proposed dredging areas for the shipping channel and marine facilities as well as at the potential access bridge location. The data collected and analysed included:
  - Acid sulphate soils;
  - Metals;
  - Nutrients;
  - Organic compounds;
  - Pore water ammonia; and
  - Radionuclides.
- Impact assessment was undertaken using the background and collected baseline data together with mathematical modelling and expert interpretation in order to determine the significance of potential impacts to water quality, hydrodynamics and marine sediments as a result of the construction and operation of the GLNG Project.
- Development of mitigation measures to minimise the potential impacts.

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Client	Project: GLADSTONE LNG PROJECT ENVIRONMENTAL IMPACT STATEMENT	Title: **MARINE STUDY AREA**
URS	Drawn: CA; Approved: JB; Date: 26-02-2009	Figure: **8.7.1** Rev:B
	Job No: **4262 6220**; File No: 42626220-g-982b.wor	A4

8.7.3 Regulatory Framework

Legislation and state planning policies relevant to the management and protection of coastal environments includes:

- *Coastal Protection and Management Act 1995 (Qld)*;
- *Environmental Protection Act 1994 (Qld)*;
- Environmental Protection (Water) Policy 1997 (Qld);
- *Petroleum and Gas (Production and Safety) Act 2004 (Qld)*;
- *Petroleum (Submerged Lands) Act 1982 (Qld)*;
- *Fisheries Act 1994 (Qld)*;
- *Environment Protection (Sea Dumping) Act 1981 (Cth)*; and
- SPP2/02 Planning and Managing Development Involving Acid Sulfate Soils.

8.7.2.1 Coastal Protection and Management Act 1995

The *Coastal Protection and Management Act 1995* (Qld) (Coastal Act) provides for the protection and management of Queensland's coastal zone while allowing for development that improves the total quality of life, now and in the future, in a way that maintains the ecological processes on which life depends.

The Coastal Act sets out licensing and permitting requirements relating to activities within declared coastal management districts, including disposing of marine dredged material or other solid waste material in tidal water and reclamation works on land under tidal water.

8.7.2.2 Environmental Protection Act 1994

The *Environmental Protection Act 1994* (EP Act) aims to protect Queensland's environment while allowing for development that improves the total quality of life, both now and in the future, in a way that maintains the ecological processes on which life depends (being ecologically sustainable development).

Among other things, the EP Act provides for the regulation of environmentally relevant activities (ERAs) which include petroleum activities and other activities that are likely to release contaminants to the environment that may cause environmental harm. Environmental authorities are required under the EP Act to authorise the carrying out of petroleum ERAs. A development approval under the IP Act and a registration certificate under the EP Act are required to authorise the carrying out of all other ERAs.

8.7.2.3 Environmental Protection (Water) Policy 1997

The Environmental Protection (Water) Policy 1997 (EPP (Water)) aims to achieve the object of the EP Act in relation to Queensland waters by providing a framework for identifying environmental values, stating water quality guidelines and objectives to enhance or protect the environmental values, making consistent and equitable decisions about Queensland waters that promote their efficient use and best practice environmental management and providing for community consultation and education. Legislative amendments to the EPP (Water) that took effect on 1 January 2009 were considered during preparation of this EIS.

8.7.2.4 Petroleum and Gas (Production and Safety) Act 2004

The *Petroleum and Gas (Production and Safety) Act 2004* (P&G (PSA) Act) regulates petroleum in Queensland. It aims to facilitate and regulate the carrying out of responsible petroleum activities and the development of a safe, efficient and viable petroleum and fuel gas industry. It aims to achieve this in a way that minimises land use conflicts and encourages responsible land use management (among other measures). The project will require a range of consents and approvals under the P&G (PSA) Act.

8.7.2.5 Petroleum (Submerged Lands) Act 1982

The *Petroleum (Submerged Lands) Act 1982* (PSLA) regulates petroleum and natural gas in Queensland across certain submerged lands adjacent to the coasts of Queensland. The project will require an approval under this Act for the submerged portion of the pipeline.

8.7.2.6 Fisheries Act 1994

The *Fisheries Act 1994* (Fisheries Act) ensures that Queensland fisheries resources are managed and utilised in an ecologically sustainable way, as well as providing for management of fish habitats and ensuring that there is equity in access to the resources by commercial, recreational and Indigenous fishers.

8.7.2.7 Water Act 2000

The *Water Act 2000* (Water Act) provides a framework for the sustainable management of water and related resources. It regulates the taking, use and allocation of water through (among other things) water resource plans and resource operations plans. It sets out permitting and licensing requirements for taking or interfering with water, quarry material and other resources. Development approval under the IP Act is also required in respect of certain Water Act activities (including operational works and removing quarry material from a watercourse).

8.7.2.8 Environment Protection (Sea Dumping Act 1981)

The Environment Protection (Sea Dumping) Act 1981 regulates the loading and dumping of waste at sea. The Act fulfils Australia's international obligations under the London Protocol to prevent marine pollution by dumping of wastes and other matter. The Act protects all waters surrounding Australia's coastlines from wastes and pollution being dumped at sea. It details the disposal activities that require permits, for example, dredging operations, creation of artificial reefs and dumping of vessels, platforms or other man-made structures. The GLNG Project involves the placement of marine dredged material on Curtis Island and it is not intended to dispose of marine dredged material at sea.

8.7.2.9 SPP2/02 Planning and Managing Development Involving Acid Sulfate Soils

The purpose of SPP2/02 is to ensure that development in low-lying coastal areas is planned and managed to avoid the generation of acid sulfate soils (ASS). The policy applies to land below 5 m Australian Height Datum (AHD) where the natural ground level is less than 20 m AHD and development on that land involves the following:

- Filling of land involving more than 500 m^3 or more of material; or
- Excavation of more than 100 m^3 or more of soil and sediment.

8.7.3 Existing Environmental Values

8.7.3.1 Background

Port Curtis falls within the Shoalwater Coast bioregion as defined in the *Integrated Marine and Coastal Regionalisation for Australia* (Commonwealth of Australia 2006). This bioregion includes the coastal and island waters from Mackay south to Baffle Creek. Port Curtis is a natural deepwater embayment that is protected from the open ocean by Curtis Island and Facing Island.

Coastal geomorphology in the study area is characterised by a partially enclosed embayment and shallow estuaries, including small, continental rocky islands, intertidal flats and estuarine islands. Port Curtis estuary is a composite estuarine system that includes the Calliope and Boyne Rivers, The Narrows, Auckland Creek and several smaller creeks and inlets that merge with deeper waters to form a naturally deep harbour protected by southern Curtis Island and Facing Island. Elevated natural turbidity occurs within the shallow marine and estuarine waters with significant input of freshwater and alluvial sediments from the Boyne and Calliope Rivers.

Port Curtis and Curtis Island (above the mean low water mark) are within the Great Barrier Reef World Heritage Area (GBRWHA) but outside of the Commonwealth Great Barrier Reef Marine Park. The Narrows (north of Friend and Laird Points) and the marine areas within approximately three nautical miles of the seaward side of Curtis and Facing Islands lie within the Mackay/Capricorn Management Area of the Queensland Great Barrier Reef Coast Marine Park, including waters around State owned islands. The Narrows is zoned a habitat protection zone under the *Marine Parks (Great Barrier Reef Coast) Zoning Plan 2004*, as are two areas on the seaward sides of Curtis and Facing Islands.

The Curtis Coast Regional Coastal Management Plan (Curtis Coastal Plan), developed under the Coastal Act, provides regional direction for the implementation of the *State Coastal Management Plan – Queensland's Coastal Policy* (State Coastal Plan) in the Curtis Coast Region and describes how the coastal zone of the Curtis Coast Region is to be managed.

The Curtis Coastal Plan applies to the coastal zone defined in Section 11 of the Coastal Act as:

> *"coastal waters and 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."*

Under this plan the Curtis Coast is managed in an ecologically sustainable manner that allows for:

- The region's continued industrial and port development using best practice;
- The protection and maintenance of natural ecosystems while allowing for responsible hunting, fishing and harvesting of resources;
- Recognising and protecting the region's diverse and cultural resources and values;
- Recognising the importance of tourism and recreational facilities to accommodate the increasing population and visitors;
- Maintaining and enhancing lifestyle, liveability and public access to the coast; and
- Strong local indigenous traditional owner community involvement in management and development.

The key challenge for coastal management within the Curtis Coast region is the long term management of further development related to the Port of Gladstone and associated industrial development, and the management of significant impacts on coastal resources. Key initiatives in the Curtis Coastal Plan include the recognition of the Gladstone State Development Area as an area of state and national significance that has been established by the Queensland Government for large-scale industry development.

The Port Curtis area includes over 1,000 km^2 of coastal hinterland, wetlands and estuarine waters with marine and coastal zone wetlands covering an area over 300 km^2 (McKinnon et al. 1995). Mangrove, seagrass, salt marsh, rocky and sandy shoreline, open water and subtidal benthic habitats support varied biological communities within Port Curtis and adjacent marine areas. Much of the estuarine near-shore is lined by dense stands of mangrove, mainly *Avicennia marina* and *Rhizophora stylosa*, while bare soft sediments cover most of the remaining bedforms (Currie & Small 2005).

The geology around the Curtis Island area and just inland of the eastern shoreline of The Narrows comprises Holocene aged estuarine alluvial and residual deposits overlying the Wandilla Formation (mudstone, arenite and chert) as part of the Curtis Island Group of formations from the Early Carboniferous age. The shoreline of The Narrows on the eastern (mainland) side comprises a mixture of Holocene aged estuarine alluvial and residual deposits developing into Holocene age coastal plains moving eastwards into The Narrows, which include tidal flats and comprises lithologies of sands and muds (Department of Mines 1998). While there have been no acid sulfate soil (ASS) risk maps published for the study area by the Queensland Department of Natural Resources and Water (DNRW), the presence of Holocene tidal flats and muds (particularly in existing mangrove swamps or areas where mangrove swamps have been drained and reclaimed), means there is a likelihood that “organic clays” may be either acidic or potentially acidic (refer Appendix R3).

Tides in the area are semi-diurnal and the (spring) tidal range is of the order of 4 m, with significant wetting and drying of mangrove and inter-tidal areas occurring. The study area represents a high energy environment, with strong tidal flows dominating the local hydrodynamics, with typical peak (spring) tidal velocities reach 1.2 to 1.3 m/s. Tidal flows largely follow natural and constructed channels, with these locations consistently experiencing the highest velocities. There is a local asymmetry in the magnitude of the tidal velocities, with ebbing tides being characterised by greater velocities than flooding tides. This is attributed to local bathymetric and geomorphologic features (Appendix R2).

Turbidity increases with depth and tidal velocity, most likely due to bottom sediment re-suspension, while pH and temperature are relatively uniform with depth, with evidence of only slight thermal stratification. Salinity appears to be responsive to rainfall and associated inflow events, although it is not clear whether local or remote inflows (or a combination of both) dominate in this regard. Catchment-derived pollutants may enter the area (either locally or remotely) with freshwater inflows (Appendix R2).

8.7.3.2 Marine Water Quality

Marine Water Quality Objectives

The draft marine water quality objectives (WQOs) that have been adopted for the GLNG Project are listed in Table 8.7.1.

The suspended sediment and nutrient WQOs have been sourced from Table 2.5.2.1 of the EPP (Water) and the Queensland Water Quality Guidelines (QWQG 2006) for slightly to moderately disturbed enclosed coastal systems in the Central Coast Queensland region. Metal WQOs have been sourced from Table 3.4.1 of the ANZECC (2000) guidelines for slightly to moderately disturbed marine environments in South East Australia at the 95% percentile protection level.

The adopted WQOs are subject to review (if needed) and are provided for initial comparative purposes. It is noted that the ANZECC guidelines encourage the use of locally specific data, where available, for defining WQOs. Such locally specific data do exist for Port Curtis, however ownership of this data is unclear, and as such has not been presented or used in detail in this report (Appendix R2).

Table 8.7.1 WQOs Adopted for GLNG Project

Species	WQO
Turbidity[a]	6 NTU
TSS (above background levels)	50 mg/L
TN	200 µg/L
TP	20 µg/L
Ammonia	8 µg/L
Nitrate + Nitrite	3[b] µg/L
FRP	6 µg/L
Aluminium	ID
Arsenic	ID
Cadmium[c]	5.5 µg/L
Copper	1.3 µg/L
Chromium (VI)	4.4 µg/L
Iron	ID

Species	WQO
Lead	4.4 µg/L
Manganese[d]	ID
Mercury[c]	0.4 µg/L
Nickel[c]	70 µg/L
Zinc[c]	15 µg/L

[a] Data from previous sections shows that this guideline value is regularly exceeded due to natural re-suspension of bedload, so this WQO may not be appropriate for this system (NTU = Nephelometric Turbidity Unit)
[b] Combined value for NO_x
[c] May not necessarily protect all species with respect to chronic toxicity
[d] A value of 140 µg/L has been used elsewhere in Port Curtis
ID Insufficient Data

Marine Water Quality Background

A review of previous studies in the Port Curtis region has been undertaken as part of the investigations (Appendix R2). The following data sources were reviewed and relevant data analysed to provide an account of the water quality in Port Curtis:

- Department of Environment and Heritage and the Department of Natural Resources (DEH/DNR) (1999);
- Queensland Environmental Protection Agency (EPA) (2002-2008);
- National Land and Water Resources Audit (NLWRA) condition assessment reports (1998 and 2001);
- Connell Hatch (2006) Wiggins Island Coal Terminal (WICT) Environmental Impact Statement (EIS);
- Geoscience Australia Australian Ports Literature Review (Harris & O'Brien 1998);
- Port Curtis Integrated Monitoring Program (PCIMP) Ecosystem health report card and Biomonitoring (2005, 2006 and 2007);
- URS (2008) Gladstone Nickel Project Environmental Impact Statement Supplement;
- Cooperative Research Centre (CRC) for Coastal Zone, Estuary and Waterway Management studies; and
- BMT WBM studies (1999, 2001).

Between December 1998 and December 2000, WBM undertook routine water quality monitoring in support of studies for a proposed oil shale extraction project. The water quality monitoring program incorporated six water quality sampling sites (Figure 8.7.2) for both the routine and event surveys. A summary of the range of water quality results for all in-situ measurements and the laboratory analysis results from each site is shown in Table 8.7.2 (WBM 2001).

A more recent water quality data set for Port Curtis has been sourced from 10 years of EPA monitoring (1996-2006), Marine Water Quality Program (1998-2001) and monitoring over two seasons in 2006 for the WICT EIS (Connell Hatch, 2006). A summary of these data is given in the Table 8.7.3.

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Scale 1:60 000 (A4)
Datum : GDA94

Marine Water Quality Monitoring Sites
Dredge Material Placement Facility
LNG Facility Site Boundary
Gas Transmission Pipeline

Client	Project	Title
LNG / URS	GLADSTONE LNG PROJECT ENVIRONMENTAL IMPACT STATEMENT	**MARINE WATER QUALITY MONITORING PROGRAMME SAMPLING SITES**
	Drawn: CA | Approved: JB | Date: 18-05-2009	Figure: **8.7.2** | Rev:B
	Job No: **4262 6220** | File No: 42626220-g-1028b.wor	A4

Table 8.7.2 Range of historical water quality values in Port Curtis (December 1998 - December 2000, high water)

Parameter	Unit	1 Boat Creek	2 Fishermans Landing		3 Gully C	4 Targinie Creek	5 Curtis Island (1)	6 Curtis Island (2)	ANZECC Guideline* or Seawater Range
In-situ measurements: (Minimum – Maximum).									
Temperature.	°C	17.8 – 29.0	17.5 – 29.1		17.8 – 28.9	17.0 -29.2	17.4 – 29.3	17.4 – 29.2	<2° increase
Conductivity.	mS/cm	44.3 – 56.8	44.3 – 56.8		41.5 – 57.4	43.6 – 57.9	46.7 – 57.0	47.2 – 57.0	-
Salinity.	g/L	28.6 – 37.8	28.6 – 37.8		26.6 – 38.2	28.3 – 38.7	30.4 – 38.0	30.7 – 37.8	[35.5]
pH.	Units	7.87 -8.35	7.79 – 8.36		7.85 – 8.39	7.68 – 8.28	7.87 – 8.32	7.81- 8.37	[8.1]
Redox.	mV	115 – 420	111 – 437		117 – 426	137 – 605	114 – 430	112 – 435	-
D O.	M g/L	5.03 – 7.93	5.36 – 7.80		5.32 – 8.40	4.45 – 7.77	5.41 – 7.87	5.33 – 7.67	>6.0
DO%.	% Sat	77.0 – 124.4	79.0 – 122.9		80.9 – 130.4	67.8 – 111.5	80.9 – 123.3	81.9 – 120.1	>80
Turbidity.	NTU	2.7 – 31.8	2.5 – 143.0		2.6 – 85.0	2.2 – 55.0	4.4 – 104.0	3.0 – 168.8	<10% change n seasonal mean.
Secchi Depth.	M	0.8 – 1.9	0.6 – 2.1		0.6 – 1.4	0.6 – 2.0	0.3 – 1.7	0.4 – 1.8	As above.
Trace Elements:			2A	2B					
Aluminium.	µg/L	5 – 670	5 – 1,600	7 – 2,700	5 -680	5 – 1,600	5 – 3,700	5 – 2,700	[5]
Arsenic.	µg/L	<1 – 3	<1 – 2	<1 – 2	<1 – 2	<1 – 1	<1 – 1	<1 – 1	50
Barium.	µg/L	<1 – 27	<1 –23	<1 – 21	<1 – 28	<1 – 21	<1 – 37	<1 – 24	-
Boron.	µg/L	3,400 – 5,800	3,700 – 6,000	6,600 – 6,100	3,600 – 5,500	3,400 – 5,700	3,400 – 6,200	3,500 – 5,800	[4,440]
Cadmium.	µg/L	<1	<1	<1	<1	<1	<1	<1	2
Chromium.	µg/L	<1 – 11	<1 – 1	<1 – 23	<1	<1	<1	<1	50
Copper.	µg/L	<1 – 3.6	<1 -2	<1 – 2.3	<1 -4	<1 – 2.5	<1 – 3	<1 – 2	-
Iron.	µg/L	<5 – 400	<5 – 960	<5 – 1,700	<5 – 550	<5 – 1,000	<5 – 2,100	<5 – 1,500	[3]
Lead.	µg/L	<1	<1	<1	<1	<1 – 1	<1	<1	5

Parameter	Unit	1 Boat Creek	2 Fishermans Landing		3 Gully C	4 Targinie Creek	5 Curtis Island (1)	6 Curtis Island (2)	ANZECC Guideline* or Seawater Range
Manganese.	µg/L	<1 – 19	<1 – 24	<1 – 42	<1 – 28	<1 – 51	<1 – 59	<1 – 39	[2]
Mercury.	µg/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.1
Nickel.	µg/L	<1 – 4	<1 – 9	<1 – 15	<1 – 4	<1 – 10	<1 – 20	<1 – 13	15
Zinc.	µg/L	<1 – 9.4	<1 – 11	<1 – 10	<1 – 5.6	<1 – 5	<1 – 9	<1 – 5	50
Fluoride.	µg/L	670 – 3,700	720 – 3,600	840 – 3,600	560 – 3,800	810 – 3,600	830 – 3,900	750 – 4,100	[1,00]
Compounds:									
Cyanide.	µg/L	<5 - 10	<5 - 5	<5 - 5	<5	<5 – 6	<5	<5	5
Nutrients:									
Total Nitrogen.	µg/L	50 – 370	50 – 410	50 – 310	50 – 340	50 – 630	60 – 330	78 – 364	-
Total Kjeldahl Nitrogen.	µg/L	50 – 354	50 – 370	40 – 300	50 – 336	50 – 310	60 – 300	78 – 364	-
Organic Nitrogen.	µg/L	40 – 307	46 – 360	40 – 290	50 – 300	50 – 300	50 – 290	78 – 300	-
Ammonia.	µg/L	<5 - 77	<5 – 72	<5 – 110	<5 – 65	<5 – 93	<5 – 200	<5 – 64	(<5)
Nitrite.	µg/L	<5 - 20	<5 - 20	<5 - 20	<5 - 20	<5 - 420	<5 - 30	<5 - 20	-
Nitrate.	µg/L	<5 – 58	<5 – 41	<5 – 31	<5 – 51	<5 – 61	<5 – 72	<5 – 26	(10 – 100)
Total Phosphorus.	µg/L	<10 - 50	<10 - 50	<10 - 50	<10 - 50	<10 - 50	<10 - 60	<10 - 50	-
Orthophosphorus.	µg/L	<5 - 20	<5 - 20	<5 - 30	<5 – 17	<5 – 20	<5 - 40	<5 - 50	(5 – 15)
Suspended Solids.									
Suspended Solids.	mg/L	8 – 79	5 – 91	9 – 116	7 – 81	3 – 65	2 – 113	9.0 – 116.0	<10% change in seasonal mean

Table 8.7.3 More Recent Water Quality Data for Port Curtis (1996 – 2006)

Parameter	Unit	Minimum	20th %ile	Median	80th %ile	Maximum	n
Turbidity	NTU	1.0	5.0	12.0	27.0	225.0	946
Chlorophyll-*a*	µg/L	0.33	1.07	1.87	4.85	11.36	127
Dissolved Oxygen	%sat	71.5	91.5	94.5	99.7	128.1	1035
pH		4.73	7.88	7.99	8.13	8.60	1032
Suspended Solids	mg/L	2.0	12.0	24.0	48.0	116.0	331
Conductivity	mS/cm	23.6	52.4	54.93	56.6	60.5	1036
Temperature	°C	17.0	22.4	25.85	29.2	35.5	331
Ammonia	µg/L	2.5	7.0	11.0	30.4	200.0	189
Nitrates and Nitrites	µg/L	5.0	5.0	5.0	25.0	422.5	195
Total Nitrogen	µg/L	25.0	140	190	270	2300	194
Filterable Reactive Phosphorous	µg/L	2.5	2.5	2.5	10.0	50.0	192
Total Phosphorous	µg/L	5.0	10.0	25.0	25.0	32.0	194
Aluminium	µg/L	2.5	35.0	73.0	140.0	3,700.0	194
Iron	µg/L	2.5	31.6	90.0	210.0	2,100.0	174
Nickel	µg/L	0.5	0.5	0.5	1.5	20.0	174
Manganese	µg/L	0.5	3.9	7.6	15.0	59.0	194
Zinc	µg/L	0.5	0.5	0.5	3.3	14.0	174

Marine Water Quality Data Collection

Two separate water quality and hydrodynamic field data collection campaigns were undertaken as part of the GLNG Project EIS investigations (refer Appendix R2) comprising:

- Campaign 1: 3 to 7 February 2008; and
- Campaign 2: 4 to 8 June 2008.

The water quality field data collection campaigns included the following measurements:

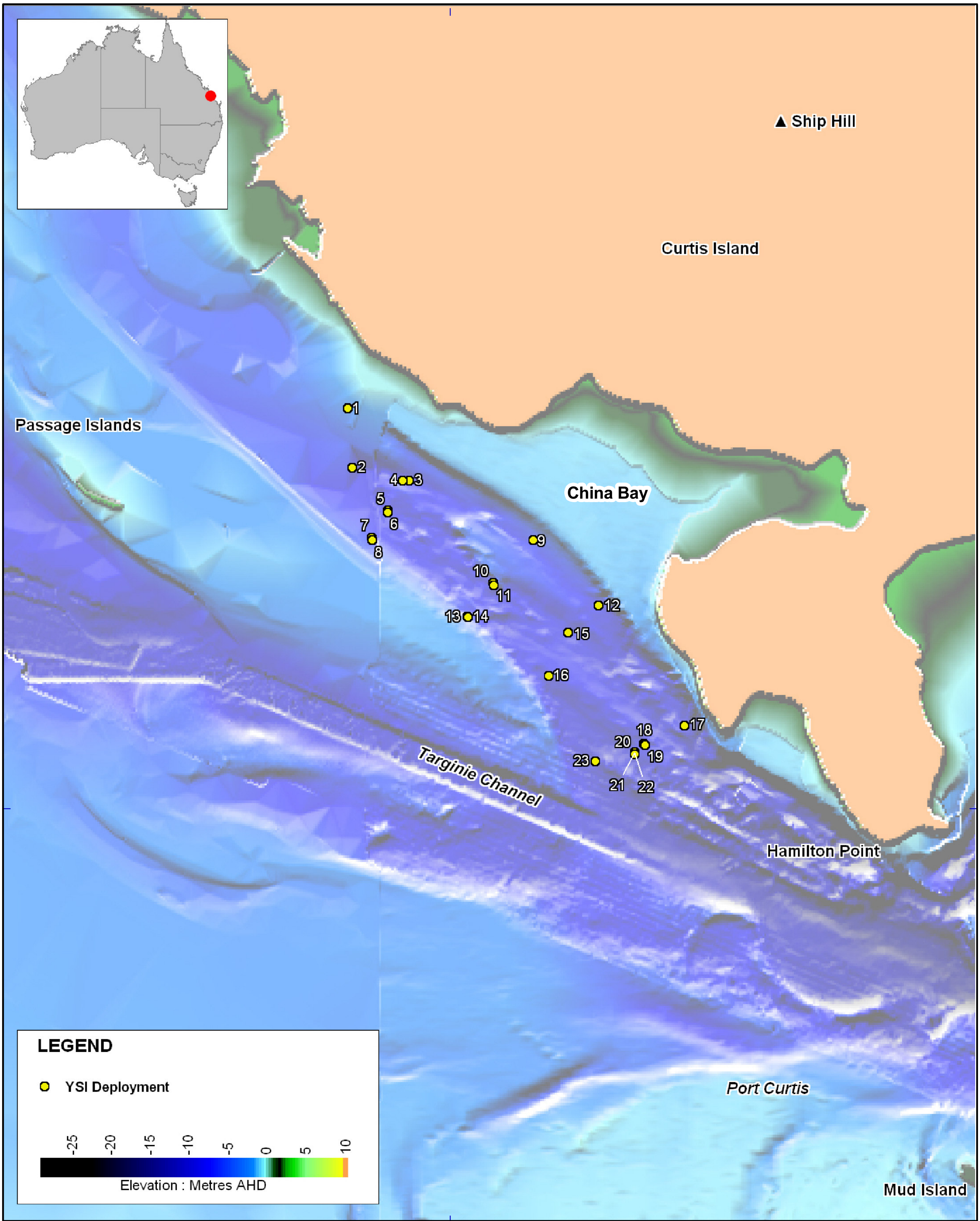
- Hand-held physical water quality profiles; and
- Water quality grab samples (only during Campaign 2).

Details of the methodologies used for the surveys are included in Appendix R2. The locations where sampling equipment was deployed and samples collected are shown in Figures 8.7.3 and 8.7.4.

Hand-held Physical Water Quality

A hand held Model 6600 water quality instrument equipped with a YSI Model 650 MDS data collector instrument was deployed throughout the study area at varying times of the tide.

The YSI was set to log turbidity, pH, temperature and salinity with depth, with each campaign consisting of lowering the instrument over the side of the vessel. Measurements were generally taken at approximately 1 m depth intervals. Given the constraints of other higher priority field measurements, YSI campaigns only took place at low or high water during times of relatively low tidal velocities.



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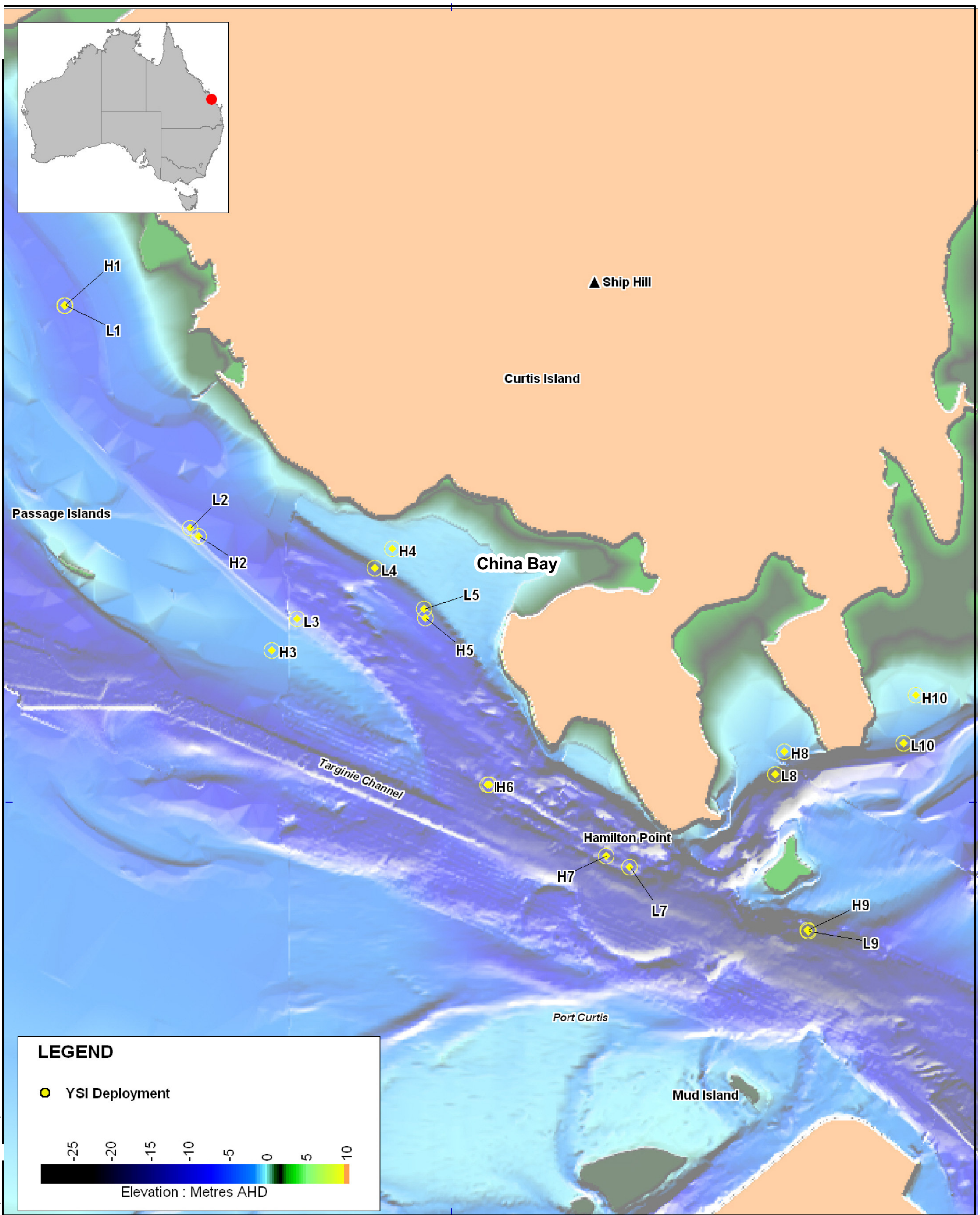
Sourced from BMT WBM Report: Proposed Santos LNG Facility EIS - Marine Water Quality Assessments January 2009.

Client	Project	Title
LNG	GLADSTONE LNG PROJECT ENVIRONMENTAL IMPACT STATEMENT	WATER QUALITY SAMPLE LOCATIONS CAMPAIGN 1
URS	Drawn: MG / Approved: JB / Date: 09-02-2009	Figure: **8.7.3** / Rev. A
	Job No.: **4262 6220** / File No.: 42626220-g-987.mxd	A4



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Sourced from BMT WBM Report: Proposed Santos LNG Facility EIS - Marine Water Quality Assessments January 2009.

Client	Project	Title	
LNG / URS	GLADSTONE LNG PROJECT ENVIRONMENTAL IMPACT STATEMENT	**WATER QUALITY SAMPLE LOCATIONS CAMPAIGN 2**	
	Drawn: MG	Approved: JB	Date: 08-05-2009	Figure: **8.7.4**	Rev. B
	Job No.: **4262 6220**	File No.: 42626220-g-988.mxd		A4

Water Quality Grab Samples

A series of water quality grab samples were collected at ten sites across the area of interest as part of the second campaign (Figure 8.7.4).

Two separate grab sample surveys were undertaken; one at high water and one at low water. In each case, grab samples from the top, middle and bottom of the water column were collected, then composited to form a single, representative sample for each site at each tidal condition. This equated to 20 samples in total. These samples were sent to the Queensland Health Scientific Services laboratory for analysis of the following parameters:

- Total suspended solids (TSS);
- Total nitrogen (TN);
- Total phosphorus (TP);
- Dissolved nitrogen components: ammonia (NH4), nitrate (NO3) and nitrite (NO2);
- Dissolved phosphorus components: free reactive phosphorus (FRP);
- Total metals (aluminium, arsenic, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, zinc); and
- Dissolved metals (aluminium, arsenic, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, zinc).

Details of the analytical results are given in Appendix R2.

Marine Water Quality Data Summary

The salient points from the available water quality data include the following;

- Port Curtis is a well connected estuary which allows dissolved material to be dispersed evenly, however material does not as readily leave the estuary to the offshore environment (Herzfeld et al. 2004). This reduced flushing time is likely to contribute to the anomalous bioaccumulation of some metals in biota of Port Curtis (Anderson et al. 2005).
- Port Curtis is the receiving environment for sewage and diffuse nitrogen sources from a small number of settlements fringing the port as well as nitrogen discharges from industrial sources (Melzer & Johnson 2004).
- However, nutrient, total organic carbon and biochemical oxygen demand concentrations appear generally low and consistent with high quality estuarine water (WBM 1999).
- The character of the estuarine waters within Port Curtis is generally close to seawater. Salinities are often only slightly below that for oceanic seawater (35.5 g/L) and can sometimes be slightly higher (WBM 1999).
- Salinities are higher in the north of Port Curtis than in the surrounding coastal waters. This could reflect evaporation losses in these more sheltered areas where water circulation is restricted. Water column pH was lowest in The Narrows regions and is most likely related to acid inputs from the adjacent mangrove regions (Apte et al. 2006).
- Salinity appears to be responsive to rainfall and associated inflow events, although it is not clear whether local or remote inflows (or a combination of both) dominate in this regard (Appendix R2).
- pH and temperature are relatively uniform with depth, with evidence of only slight thermal stratification (Appendix R2).
- Lower pH and higher turbidities were noted by PCIMP in the shallow mangrove lined upper estuaries.
- A salinity and pH gradient is evident from low tide to high tide and north to south, where salinity and conductivity is highest and pH is lowest at low tide in the northern reaches of Port Curtis. Salinity and conductivity decreases and pH increases further south and as the tide rises (Appendix R2).

- Primary variations in spatial distribution and nature of Coloured Dissolved Matter, Total Suspended Matter and Secchi depth appear to be controlled by tidal stage and stream flow of major rivers flowing into the harbour (Dekker & Phinn 2005).
- Water clarity as defined by Secchi disc visibility is generally poor, being less than 2 m. Similarly, turbidities and suspended solids concentrations are moderate (WBM 1999).
- Turbidity increases with depth and tidal velocity, most likely due to bottom sediment re-suspension (Appendix R2).
- Low chlorophyll a concentrations were noted throughout Port Curtis (Dekker & Phinn, 2005).
- Elevated metal concentrations exist within the harbour. The Narrows region has the highest concentrations of dissolved copper and nickel, which may be attributable to natural geological sources. The Fitzroy River is a source of dissolved metals to the local coastal region. In particular, the Fitzroy River contains elevated dissolved nickel concentrations. Under some flow conditions, the Fitzroy River plume may enter The Narrows region and supply dissolved metals to Port Curtis. Trace metal distributions in Port Curtis are likely to reflect a subtle mixture of metal inputs including industrial and other anthropogenic discharges, inputs from unidentified sources in The Narrows and the Fitzroy River plume. Trace metal inputs to Port Curtis which contribute to dissolved metal concentrations are most likely to be delivered in solution form and not by release of metals from particulates (Apte et al. 2006).
- Aluminium and iron concentrations can be significantly higher than those for oceanic seawater (WBM 1999).
- Concentrations of other major elements (e.g. boron, fluoride, manganese) appear to be consistent with those of oceanic seawater (WBM 1999).
- Trace element, cyanide and phenol concentrations do not appear to be elevated above typical seawater or the ANZECC guideline concentrations (WBM 1999).
- Inner harbour PCIMP sampling sites had significantly higher copper levels than oceanic reference sites (Anderson et al. 2008).
- PCIMP oceanic reference sites had highest cadmium concentrations compared to harbour zones (Anderson et al. 2007).

When compared with relatively stringent water quality objectives, it can be surmised that water quality is generally high, though variable in the area. Water quality appears to be relatively strongly correlated with tidal state and hence bed load re-suspension. In particular, low tides exhibit generally lower water quality than high tides, with the majority of nutrient and metal species at these times being associated with particulate (rather than dissolved) phases.

8.7.3.3 Marine Sediments

Potential Contaminant Sources

The Port of Gladstone includes pastoral, agricultural, chemical and industrial processing as well as manufacturing industries utilising port facilities, or which are located adjacent to the port. Table 8.7.4 lists some of the major industries served by the port and their associated activities which may give rise to potential contaminants of concern. Table 8.7.5 lists the major imports and exports handled by the port and Table 8.7.6 lists some of the chemicals released in water discharges.

Table 8.7.4 Major Industries

Industry Name	Industry type and potential contaminants
BSL – Boyne Smelters Limited	Aluminium smelter
QAL – Queensland Alumina Ltd	Alumina refinery
NRG – NRG Gladstone Operating Services Pty Ltd	Power generator
Orica Australia Pty Ltd	Sodium cyanide, ammonium nitrate and chlorine plant
RTA – Rio Tinto Aluminium (Yarwun)	Alumina refinery
QER – Queensland Energy Resources (ceased operation 2003)	Oil shale miner and medium shale oil and naphtha plant
Cement Australia	Cement and clinker plant
Origin Energy	Gas import, storage and distribution
BP	Petroleum product import, storage and distribution
Caltex	Petroleum product import, storage and distribution
Graincorp	Agricultural product export and import
Queensland Magnesia	Magnesia and magnesite export
Patrick's Corporation	Container/general cargo handling, storage and distribution

Table 8.7.5 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	Agricultural products e.g. grain

Table 8.7.6 Inventory of Chemicals Released in Water Emissions in Port Curtis (Apte et al. 2005)

Industry	Substance	Water Emissions ($kg\ yr^{-1}$)
*BP Oil Aust., terminal[2]	Benzene Cumene Cyclohexane Ethylbenzene n-Hexane Toluene Xylenes	10 30 30 4 30 10 12
*Boyne Smelters Ltd (BSL)[1]	Fluoride (F) compounds	7,500
*Caltex Oil Terminal[2]	Benzene Toluene Xylene	0.3 0.1 0.5
*NRG (Power Station)[2]	Arsenic (As) compounds Chromium (Cr) (VI) Lead (Pb) compounds	147 76 24
*Queensland Alumina Ltd (QAL)[1]	As compounds Cd compounds F compounds Pb compounds Mercury (Hg) compounds Total Nitrogen (TN) Total Phosphorus (TP)	1,050 3 135,720 13 12 30,126 11,400
*Stuart Oil Shale Project Stage One	Pb compounds	0.20
*Ticor Chemicals Co. Pty. Ltd.[1]	Ammonia Cyanide (inorganic)	580 2.8

*Source = National Pollution Inventory, 2000. [1]Reporting period: 01/07/1999-30/06/2000. [2]Reporting period 01/07/1998-30/06/1999.

Previous Investigations

A number of previous studies have investigated sediment properties in the vicinity of the proposed LNG facility, including:

- Douglas Partners (2005) – Proposed Dredging Works Existing Shipping Channels Gladstone; and
- Coastal Cooperative Research Centre (Coastal CRC) (Apte et al. 2005) – Port Curtis Contaminants of Concern.

Details of these studies, along with sampling locations, are provided in Appendix R3. Data from these previous investigations have been used in the overall assessment of sediment quality.

GLNG Project Investigations

Analytical Parameters

As it is proposed to dispose of all dredge material on-shore, the requirements under the *Environment Protection (Sea Dumping) Act 1981* do not apply to this project. As such, consultation with the EPA was conducted to establish what would be required for the project's sediment sampling program. Table 5 of the NODGDM (2002) guidelines was used as the basis for the project's sampling analysis plan (SAP), and the EPA requested that additional testing for the following be undertaken (as a minimum):

- Radionuclides in one core;
- Phenoxyacetic acid herbicides, triazine herbicides and carbamate pesticides in one core; and
- Pore water ammonia data from three cores (boreholes).

These requirements were addressed as follows:

- Radionuclides were analysed in four borehole cores from the dredge area and one from the potential bridge area. Additionally one core in the dredge area was analysed for radionuclides.
- Phenoxyacetic acid herbicides and triazine herbicides were analysed in four boreholes from the dredge area.
- Carbamate pesticides were analysed from the dredge area in one borehole (BH3) at three sample depths.
- Pore water ammonia was analysed in four samples from three boreholes (one sample each from two boreholes and two sample depths from the third).

Sampling Locations

Figure 8.7.5 shows a view of the boreholes located in the proposed dredging area (BH01 – BH14, BH17, BH18) (refer to Appendix R3 for further details). The boreholes were located to ensure representative coverage across the proposed dredge area and into the shallows of China Bay.

The locations of boreholes drilled for the proposed PLF (BH16, BH28, BH31, BH32) and MOF (BH15, BH27) are also shown on Figure 8.7.5. These locations were selected to ensure that there was representative coverage across the entire length of both marine structures. As geotechnical investigations were also undertaken at these boreholes, drilling continued until 5 m of suitable rock was encountered, or to the limits of the drilling rig.

Figure 8.7.5 also shows the alternative locations of the potential bridge crossing of Port Curtis, along with the borehole locations for that area (BH19-BH21, BH24-BH26) used in this investigation. Six borehole locations were drilled; three along a potential northern alignment, and three along a potential southern alignment. Geotechnical investigations were also undertaken at these boreholes to allow for subsequent initial design of the bridge and the pipeline crossing. As such, drilling continued until 5 m of suitable rock was encountered, or to the limits of the drilling rig.

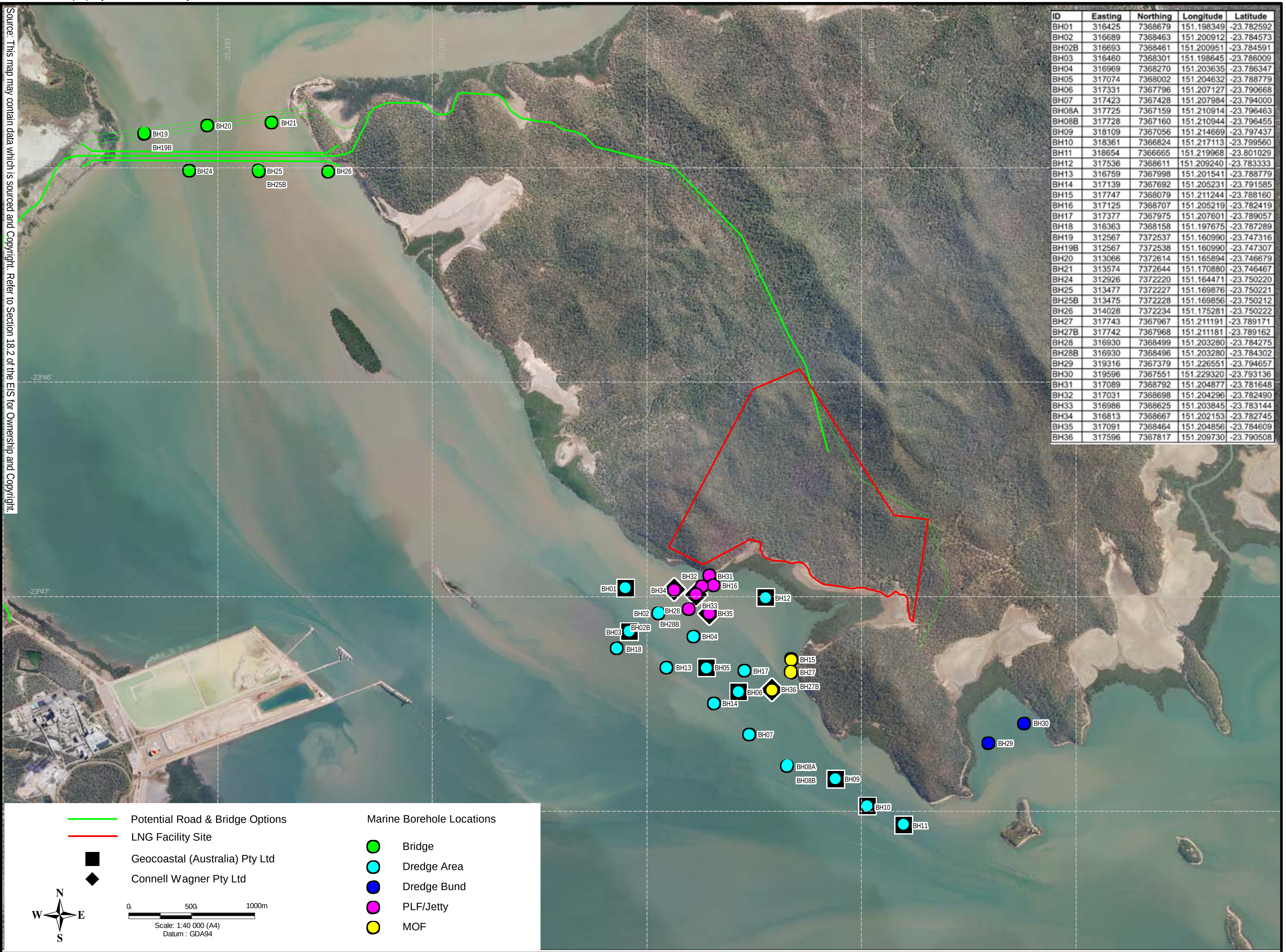
GeoCoastal Survey

Santos commissioned GeoCoastal Pty Ltd to collect sediment cores for environmental and ASS testing from the proposed GLNG dredge area in June 2008.

The locations of the GeoCoastal boreholes are shown in Figure 8.7.5. GeoCoastal drilled eight boreholes; seven in the deeper section of the proposed dredge area and one in the shallower section of China Bay. Depths ranged from 4.2 –mLAT (BH12) to 15.17 –mLAT (BH9 and BH10).

The analytical parameters tested as part of the GeoCoastal investigation were as per the requirements of the National Ocean Disposal Guidelines for Dredged Materials (NODGDM 2002) and the Queensland Environmental Protection Agency (EPA) and are listed below:

- Physical: particle size analysis (PSA);
- Metals: trace elements and metaloids;
- Nutrients: nitrate and nitrite, nitrite, ammonia, nitrate, total kjeldahl nitrogen (TKN), total nitrogen and total phosphorus;
- Organics: total petroleum hydrocarbons (TPH), BTEX (benzene, toluene, ethyl-benzene, m+p xylenes, o-xylene), polycyclic aromatic hydrocarbons (PAHs), and phenolic compounds;



ID	Easting	Northing	Longitude	Latitude
BH01	316425	7368679	151.198349	-23.782592
BH02	316689	7368463	151.200912	-23.784573
BH02B	316693	7368461	151.200951	-23.784591
BH03	316460	7368301	151.198645	-23.786009
BH04	316969	7368270	151.203635	-23.786347
BH05	317074	7368002	151.204632	-23.788779
BH06	317331	7367796	151.207127	-23.790668
BH07	317423	7367428	151.207984	-23.794000
BH08A	317725	7367159	151.210914	-23.796463
BH08B	317728	7367160	151.210944	-23.796455
BH09	318109	7367056	151.214669	-23.797437
BH10	318361	7366824	151.217113	-23.799560
BH11	318654	7366665	151.219968	-23.801029
BH12	317536	7368611	151.209240	-23.783333
BH13	316759	7367998	151.201541	-23.788779
BH14	317139	7367692	151.205231	-23.791585
BH15	317747	7368079	151.211244	-23.788160
BH16	317125	7368707	151.205219	-23.782419
BH17	317377	7367975	151.207601	-23.789057
BH18	316363	7368158	151.197675	-23.787289
BH19	312567	7372537	151.160990	-23.747316
BH19B	312567	7372538	151.160990	-23.747307
BH20	313066	7372614	151.165894	-23.746679
BH21	313574	7372644	151.170880	-23.746467
BH24	312926	7372220	151.164471	-23.750220
BH25	313477	7372227	151.169876	-23.750221
BH25B	313475	7372228	151.169856	-23.750212
BH26	314028	7372234	151.175281	-23.750222
BH27	317743	7367967	151.211191	-23.789171
BH27B	317742	7367968	151.211181	-23.789162
BH28	316930	7368499	151.203280	-23.784275
BH28B	316930	7368496	151.203280	-23.784302
BH29	319316	7367379	151.226551	-23.794657
BH30	319596	7367551	151.229320	-23.793136
BH31	317089	7368792	151.204877	-23.781648
BH32	317031	7368698	151.204296	-23.782490
BH33	316986	7368625	151.203845	-23.783144
BH34	316813	7368667	151.202153	-23.782745
BH35	317091	7368464	151.204856	-23.784609
BH36	317596	7367817	151.209730	-23.790508

Client

Project

GLADSTONE LNG PROJECT
ENVIRONMENTAL IMPACT STATEMENT

Title

MARINE SEDIMENT INVESTIGATION OVERVIEW

Drawn: RG

Approved: JB

Date: 18-05-2009

Job No: **4262 6220**

File No: 42626220-g-1049.wor

Figure: **8.7.5**

Rev: A

A4

- Other Organics: Total organic carbon (TOC), tributyltin (TBT), organochlorine (OC) pesticides, organophosphate (OP) pesticides, polychlorinated biphenyls (PCB), phenoxyacetic acid herbicides, triazine herbicides, carbamate pesticides;
- Acid Sulfate Soils: Indicative field test (phField and pHFox) and chromium suite analysis; and
- Radionuclides.

The results of the sampling and analysis program are detailed in Appendix R3.

URS/Connell Wagner Survey

A second sediment sampling program was undertaken by URS/Connell Wagner between July and November 2008. In total, 26 boreholes were drilled in the vicinity of the LNG facility as well as the potential access bridge location. The borehole locations are shown in Figure 8.7.5. The proposed sampling methodology was as follows:

- Four samples for the first 2 m below seabed (mBSB) every half metre (0.0-0.45 mBSB, 0.5-0.95 mBSB, 1.0 -1.45 m and 1.5-1.95 mBSB); and
- From 2 mBSB to borehole termination (max soil depth, excludes rock coring) samples were taken every change of lithology or every 1 m (whichever was the greater).

The samples were analyses for the same parameters listed above for the GeoCoastal sampling program.

Full details of the sampling and analysis program are given in Appendix R3.

Analytical Results of GLNG Project Investigations

A complete description of the analytical results from the above mentioned sampling programs is presented in Appendix R3. The key findings are presented below.

Metals - Dredging Area

A total of 105 primary samples were analysed from boreholes BH1-BH14, BH17 and BH18 for metals analysis including aluminium, antimony, arsenic, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, silver and zinc. The NODGDM (2002) Screening Level (Effects Range – Low) was exceeded for several metals (antimony, mercury, nickel, arsenic and copper) in some samples. However, antimony at 2.69 mg/kg was the only exceedance when the 95% upper confidence levels (UCLs) were calculated but was well below the Maximum Level (Effects Range – Median) of 25 mg/kg. However, as all the marine dredged material is proposed to be placed onshore, the more appropriate guideline for comparison is the EPA environmental investigation level (EIL) of 20 mg/kg.

Chromium was detected above the EPA EIL in a single sample (BH14 at 7.1-7.4 mBSB) in residual clayey sand. Arsenic was detected marginally above the EPA EIL in three samples collected from BH13 at depths of 1.6-2.3, 11.3-11.4 and 11.9-12.07 mBSB and in BH18 at 30-32 mBSB, in marine sediment sands and gravels. Copper exceeded the EPA EIL in BH17 (at 2.7-3.2 and 3.2-3.5 mBSB).

Manganese exceeded the EPA EILs in 20 of the 105 samples from seven boreholes, ranging in location from the north-western end of the dredge area to the south-eastern end. Exceedances varied from 546 mg/kg to 3,750 mg/kg, with the maximum from BH18 at 11.3-13.25 mBSB.

Metals - Product Loading Facility

A total of 26 primary samples from BH16, BH28, BH31 and BH32 and submitted for metals analysis. None of the calculated 95%UCLs for any metals exceeded the NODGDM (2002) Screening Levels.

Arsenic was detected marginally above the EPA EIL in BH31 in three samples between 0.18 mBSB and 1.0 mBSB (clays tending to clayey gravel). Manganese was detected at concentrations exceeding the EPA EIL in boreholes BH16, BH31 and BH32, between the depths of 0.18 mBSB and 3.2 mBSB. These boreholes are clustered closely around the northern point of China Bay. The maximum concentration for manganese (2,400 mg/kg) was in BH31 at 0.3-0.6 mBSB.

Metals - Materials Offloading Facility

A total of 15 primary samples were collected from BH15 and BH27 and submitted for metals analysis. None of the calculated 95%UCLs for any metals exceeded the NODGDM (2002) Screening Levels.

Arsenic was detected above the EPA EIL in BH15 at 0.0-0.45 mBSB and in BH27 at 0.4-0.8 mBSB. No arsenic was detected in any sample at a seabed depth greater then 0.8 mBSB for the marine sediment profile. Concentrations of chromium, copper and manganese were marginally above EILs. Detection of copper was in QC31 (duplicate of BH15 1.5-2.0 mBSB). Copper was detected in the primary and duplicate sample but at levels below the EIL.

Metals - Potential Northern Bridge Alignment and Pipeline Crossing

A total of 48 samples were collected from BH19, BH20 and BH21 and submitted for metals analysis. None of the calculated 95% UCLs for any metals exceeded the NODGDM (2002) Screening Levels.

Arsenic, copper and manganese were detected above the EPA EILs. Arsenic was detected at a range of depths from 1.1 m through to 18.8 m. Copper was only detected in one shallow sample (2.0 - 2.9 m) and manganese was detected in two samples between 8.5 and 10.0 mBSB.

Metals - Potential Southern Bridge Alignment

A total of 33 samples (including QA/QC) were collected from BH24, BH25, BH25B and BH26 and submitted for metals analysis. None of the calculated 95% UCLs for any metals exceeded the NODGDM (2002) Screening Levels.

Arsenic and manganese were detected above the EPA EILs in BH25 at 2.4-3.0 mBSB, with manganese also being reported above the EPA EILs at 4.4-5.0 mBSB. BH25 comprises sands to a depth of approximately 4.5 mBSB where the lithology transitions into clay. Copper was noted above the EPA EIL in QC16 (a triplicate sample of BH26 3.5-3.9 mBSB).

Nutrients

A complete description of the analytical results is presented in Appendix R3. The key findings are presented below.

- No EILs or NODGDM (2002) Screening Levels were established for nutrients under the guidelines adopted for this investigation.
- Generally, nitrate, nitrite and ammonia results in sediment samples reported concentrations less than the laboratory LOR.
- Within the proposed offshore dredge area, total kjeldahl nitrogen (TKN) was recorded in the range of 30-660 mg/kg. Borehole BH01 was reported to have the highest concentration of TKN and nitrogen, with the maximum TKN value observed at a depth of 0.0-0.5 mBSB (BH01).
- BH12 was located closer to Curtis Island (in the tidal flats of China Bay). Recordable ammonia at the LOR (20 mg/kg) was found at 0.0-0.5 and 0.5-1.0 mBSB. This depth profile also returned maximum TKN value of 920 mg/kg at 0.5-1.0 m BSB. The TKN result exceeds the maximum offshore value and is likely due to an increased organic content of surface seabed sediment on the tidal flats.
- Total phosphorus was detected in the range of 94-506 mg/kg (BH11 at 0.0-0.5 mBSB and BH06 at 4.6-5.6 mBSB respectively).
- Total organic carbon (TOC) was noted to decrease through the marine sediment profile with depth, as the presence of organic material noted in field observations also decreased. The concentration of TOC ranged from 0.02-1.43%, with the highest value observed from BH18 at 2.6-3.0 and 3.0-3.2 mBSB.

Organic Compounds

Sampling and analysis of organic compounds during this investigation was carried out for the following targeted parameters:

- Total petroleum hydrocarbons (TPH);
- Benzene, toluene, ethyl-benzene and xylene (BTEX) compounds;
- Poly aromatic hydrocarbons (PAH);
- Organochlorine (OC) and organophosphate (OP) pesticides;
- Phenolic compounds;
- Tributyltin (TBT);
- Triazine, carbamate and phenoxyacetic acid pesticides; and
- Polychlorinated biphenyls (PCBs).

None of the samples were reported above the NODGDM (2002) screening levels, the EPA EILs or the National Environmental Protection Measure (NEPM) health investigation levels (HILs). Results reported above the LOR include:

- Naphthalene (trace detection) was detected in 8 samples and 2-Methylnaphthalene was detected in 11 samples at concentrations below the NODGDM (2002) screening levels;
- Phenol (trace detection) was reported for seven samples at concentrations below the NEPM HILs; and
- Two OC pesticides (4,4-DDT and endrin) were initially reported above the Interim Sediment Quality Guidelines (ISQG) low screening level at BH11 (12.95-13.45 -mLAT) and BH12 (3.2-4.2 -mLAT). DDT was also detected below the screening level in one other sample. These samples were reanalysed and it was confirmed that these results were false positives and that all samples are below the LOR for DDT and endrin.

Pore Water Ammonia

Analysis for pore water ammonia was carried out on four samples from three boreholes within the proposed dredge area. Results ranged from 2,630 to 5,580 µg/L, which exceeds the ANZECC (2000) 95% level of protection trigger value for marine water (slightly – moderately disturbed systems) of 910 µg/L at a pH of 8.0. No investigation levels are established for this parameter in the EPA EILs or the NEPM HILs. ANZECC (2000) does note that ammonia may occur naturally at elevated levels and its toxicity is greatly affected by pH. A particular source of ammonia is the decomposition of plant material. The locations of the samples for these surveys were generally in shallow silts and clays with a high proportion of decomposing plant material.

The toxicity levels of ammonia (in terms of total ammonia – N) for marine species are listed in Table 8.7.8 (ANZECC 2000). The levels reported in these surveys are below those reported as being potentially toxic.

Table 8.7.8 Toxicology of Ammonia to Marine Species (ANZECC 2000)

Marine Group: Type of Test	Species	Ammonia Level
Fish (3 species): 44 – 68 hrs LC_{50}	*Pagrus major*	8,800 µg/L
	Salmo salar	21,400 µg/L
	Fundulus heteroclitus	44,900 µg/L
Crustaceans (15 species): 24 – 96 hrs LC_{50}	*Penaeus semisulcatus*	18,687 µg/L
	Artemia salina	264,000 µg/L
	11 species	<80,000 µg/L
Molluscs (2 species): 48 – 96 hrs LC_{50}	*Argopecten irradians*	7,720 µg/L
	Anadara granosa	42,800 µg/L
Rotifer: 24 – 96 hrs EC_{50} (population growth)	*Brachionus plicatus*	101,000 µg/L

LC_{50} (Lethal Concentration) concentration that will cause 50% mortality

EC_{50} (Effects Concentration) concentration that will inhibit population growth by 50%

Radionuclides

The specific radionuclide parameters which were analysed during this investigation were Uranium-238 (U-238), Lead-210 (Pb-210), Thorium-232 (Th-232), Radium-224 (RA-224), Radium-226 (Radium-226) and Potassium-40 (K-40). All radionuclide results for the four samples analysed were below the NODGDM (2002) guideline value of 35 becquerels per gram (Bq/g).

Acid Sulfate Soils

The State Planning Policy 2/02 Guideline – Acid Sulfate Soils (SPP 2/02), the “Guidelines for Sampling and Analysis of Lowland Acid Sulfate Soils in Queensland 1988” (Ahern et al. 1998) and the “Soil Management Guidelines – Queensland Acid Sulfate Soils Technical Manual” (Moore et al. 2002), outline the requirements for investigation, treatment and management of acid sulfate soils. Additionally the “Acid Sulfate Soils Laboratory Methods Guidelines” (Ahern et al. 2004) outline the analytical methods for ASS laboratories, as well as having determinations for establishing neutralisation targets (where required). SPP 2/02 applies to all soil and sediment at or below 5 m AHD and becomes applicable for development sites where the natural elevation is less than 20 m AHD, where development involves:

- Excavating or otherwise removing 100 m^3 or more of soil or sediment; or
- Land filling involving 500 m^3 or more of material with an average depth of 0.5 m or greater.

In Queensland, action criteria defined in SPP2/02 indicate when ASS disturbed at a site will need to be managed. Action criteria are based on the sum of actual (existing) plus potential acidity and are shown in Table 8.7.4. The action criteria are differentiated on the basis of soil textural characteristics, depending on the scale of the project. Given the scale of the proposed works and the texture within the marine sediments, the most conservative trigger value has been assumed of 0.03%S Equivalent Sulphur (existing + potential acidity).

Table 8.7.4 Action Criteria Based on ASS Analysis for Three Broad Texture Categories

Type of Material		Action Criteria if 1 to 1,000 tonnes		Action Criteria if more than 1,000 tonnes	
		Existing + Potential Acidity		Existing + Potential Acidity	
Texture Range	**Approximate clay content**	**Equivalent Sulfur (oven-dry basis)**	**Equivalent Acidity (oven-dry basis)**	**Equivalent Sulfur (oven-dry basis)**	**Equivalent Acidity (oven-dry basis)**
Coarse texture sands to loamy sand	≤5 (%)	0.03 (%S)	18 (mol H^+/tonne)	0.03 (%S)	18 (mol H^+/tonne)
Medium texture sandy loams to light clays	5-40 (%)	0.06 (%S)	36 (mol H^+/tonne)	0.03 (%S)	18 (mol H^+/tonne)
Fine texture (medium to heavy clays and silty clays)	≥40 (%)	0.1 (%S)	62 (mol H^+/tonne)	0.03 (%S)	18 (mol H^+/tonne)

The proposed GLNG capital dredge area and a small section of the adjacent materials offloading facility (MOF) are the only sections of the proposed marine works which require removal and exposure of sediment. Along the main dredging transect where capital dredging is proposed, all Holocene-aged sediments provided a negative net acidity, indicating that they have excess buffering capacity. It was concluded that dredging of this sediment will present no acid sulfate soils risk to the environment.

The GeoCoastal ASS investigations identified the area adjacent to the shoreline of China Bay as being a potential acid sulfate soil (PASS) risk. The URS investigation identified that throughout the area of investigation there was no indication of the presence of actual acid sulfate soils (AASS).

The presence of possible horizons of PASS was noted in several areas. In the northern section of the proposed dredge area, where the seabed was at 4.3 m below Lowest Astronomical Tide (-mLAT), some potential acidity in the marine alluvium was noted at an elevation of 16.1 –mLAT (a band 11.8 m thick); effectively the marine sediment profile. As the seabed slopes down toward the southern end of the dredge area (seabed level at 12 –mLAT) the band of potential acidity is approximately 4 m thick (again the marine alluvial sediment).

Acid neutralising capacity (ANC) was recorded in the marine sediments to depths of 3 m. Shell content was noted throughout the marine sediment, decreasing with depth. Surface sediment ANC was likely to be the result of the shell content. ANC was also present at depth, indicating potential microscopic sources of ANC. It should be noted that ANC is indicative of buffering capacity inherent in soils; however the availability of ANC *in-situ* can be overestimated during laboratory analysis. Under natural conditions shell fragments are usually coarse with minimal surface area. Under laboratory conditions shell fragments are finer as they are ground, increasing the surface area to volume ratio for reaction (neutralisation). Additionally, large shell fragments may often be coated in reaction by-products such as gypsum, rendering the bulk of the calcium carbonate ($CaCO_3$) of the shell unavailable for neutralisation. ANC can also be present in the microscopic range (such as foraminiferal content) which provide larger reactive surface area ratios.

The adopted action criteria of 0.03%S for net acidity (Table 8.7.8) was exceeded (when ANC was excluded) in marine sediments collected from the proposed dredge area primarily at depths from seabed to 6 m below sea bed (mBSB). As such, ASS management will be required. With the inclusion of ANC the net acidity found in the dredge area was less than the limit of reporting (LOR) (except for one sample), and below the action criteria.

The overall liming rate (excluding ANC) calculation for the dredge area ranged from 2 to 47 kg $CaCO_3$/tonne. Liming rate is a derived value calculated from the net acidity. A comparison of liming rate (excluding ANC) with depth yields a similar depth to net acidity (excluding ANC). However it is the availability of ANC through the marine sediment which governs the amount of net acidity and subsequently the need for treatment (liming). The inclusion of ANC into the calculation of liming rates, for all samples analysed, reduces the liming rate to <1 kg $CaCO_3$/tonne; except for BH5 at 1.8-2.0 mBSB (3 kg $CaCO_3$/tonne), as for net acidity.

8.7.3.4 Coastal Geology

Three main geological profiles were intersected during this investigation, generally comprising marine sediments (Holocene aged estuarine alluvial) and residual material overlying extremely weathered to fresh bedrock (Wandilla Formation), which ranges from siltstones/sandstones to low grade metamorphosed argillite. The geological profiles were generally not uniform in thickness and were not immediately apparent or distinct. Detailed descriptions and borehole logs are contained in Appendix R3.

Capital Dredging Area

The dredge area comprises marine deposits in the form of soft clays, loose sands and gravels from the seabed surface to a range of depths between 9 and 15 -mLAT. Marine sediments were generally grey or brown in colour and contained shell fragments (of varying prevalence) up to 40 mm in diameter within the first 2 m. The thickest profiles of marine sediment were found in BH13 (11.2 m) and BH18 (10.7 m) which are located on the western edge of the proposed dredge area towards the central channel of the waterway.

Underlying the marine sediment is a residual material generally comprised of orange brown sandy clay, clayey sands, gravelly sands and clays. Occasional rock fabric was noted in several boreholes at depth, suggesting the material was becoming more competent. Residual material was encountered in all boreholes except for those located in the southwest corner of the dredge area, BH08A and BH9-BH11. The residual material was encountered at depths greater than 10 –mLAT, with the thickness increasing in a westerly direction away from Curtis Island.

Bedrock was only encountered in BH4 within the dredge area boreholes. Extremely weathered to distinctly weathered siltstone/sandstone was encountered from 7.15 -mLAT. As bedrock was not encountered in any other borehole within the vicinity, this observation may be an uncharacteristic knoll. From the deeper boreholes drilled in association with the proposed PLF and MOF the depth to rock generally becomes shallower moving east towards Curtis Island.

Particle size analysis (PSA) results for the main dredge area (104 samples) equate with field classifications. Of the 104 samples analysed from the dredge area, approximately 50% had a primary component of clay and silt and were classified as such. The highest clay content observed was 81% from BH14 at 8.2-8.5 mBSB.

Sand was the observed primary fraction in 42 samples, ranging from 38%-89% content. The highest percentage of sand (89%) was recorded in BH13 (11.9-12.07 m BSB) and BH18 (0.7-0.85 m BSB), with BH18 located on a sandbank at the westernmost point of the dredge area.

Gravel was recovered in 11 samples, where gravel percentages ranged from 16% to 73%, with the highest content being from BH2B at 7.8-8.0 mBSB.

Product Loading Facility (PLF) and Materials Offloading Facility (MOF)

The marine sediments in the vicinity of the proposed PLF and MOF were similar to the dredge area and were grey to brown in colour and shell fragments were noted within the upper lithologies. Underlying the marine sediment is a residual material comprised of orange brown sandy clay, clayey sands, gravel sands and clays. Residual material was encountered in all boreholes except BH35 where marine sediments were noted lying directly on weathered siltstone.

Boreholes related to the PLF and MOF were drilled deeper for geotechnical assessment of underlying rock suitability. These boreholes were advanced to depths to encounter bedrock and give a better indication of the underlying bed geology, than boreholes located in other areas of investigation. The general geological composition of the bed rock was extremely weathered to distinctly weathered siltstone and sandstone.

PSA results from samples collected in the proposed PLF area (BH16, BH28, BH31 and BH32) indicate predominant clay and silt lithology between 0.0–5.0 mBSB. The field classification of clay, being the primary lithology for 19 of the 29 samples, appears to equate to the PSA results. All other samples maintained a secondary lithology of clay and silts in the range of 36-58% and 23-52% respectively. Siltstone was also encountered in BH31 at 5.0-5.35 mBSB, BH32 at 8.1-8.4 mBSB and BH32 at 9.3-9.6 mBSB.

Samples from the MOF area indicate that clay and silt (being the primary lithology) were present in the range 24-55% and 19-44% respectively, at a depth profile ranging from 0.0-2.5 mBSB. Sandstone was encountered in BH27 from 2.5 mBSB.

Potential Bridge Alignments and Pipeline Crossing

There is a pronounced deepening of the seabed in the centre of Port Curtis (mid channel) between Friend Point and Laird Point, with a maximum seabed depth of 11.38 -mLAT at BH20. The marine sediments comprise grey to brown clays, loose sands and gravels and range in thickness from 1.9 m to 13.0 m, with the thickest sediments noted in BH25 (located on a sandbar). Shell fragments up to 40 mm in diameter were generally noted in the first 2 m.

Underlying the marine sediment is a residual material comprised of orange brown sandy clay, clayey sands, gravel sands and clays. The residual material was encountered in all boreholes except for BH26 and ranged in thickness from 1.85 m through to the thickest profile located in BH19 (25 m) which is located closest to the western side of the alignment.

Bedrock was intersected at shallower depths closer to Curtis Island. The shallowest instance of bedrock was in BH21 at 18.6 -mLAT while the deepest instance was observed in BH19 at 29.30 -mLAT. Bedrock generally comprised extremely and distinctly weathered siltstones and sandstones. In BH20, conglomerate was noted between 29.98 -mLAT and 46.28 -mLAT. The conglomerate showed a change from being extremely weathered to distinctly weathered with depth, similar to the siltstone and sandstone. Low grade metamorphism (argillite) bedrock was encountered in BH21 at 24.2 -mLAT.

PSA results from samples collected from the potential northern bridge alignment indicate that clay and silt were the main component for samples along this alignment (for marine sediments). There appears to be a slight trend of increased clay and silt content within the clay lithologies with increased depth.

Samples collected from boreholes along the potential southern bridge alignment indicate that:

- Of the 28 samples, 14 were field classified as clay (being the dominant primary lithology from the marine sediment samples analysed) and were collected from a depth of between 0.0-5.0 mBSB. Clay and silt content at this depth range was between 42-63% and 34-42% respectively; and
- Sand was identified as the primary component of some interbedded lithologies and was classified in the field as clayey sands or poorly graded sands. Sand content in these lithologies ranged from 50-81%, with the highest being in BH25 at 2.4-3.0 mBSB.

8.7.3.5 Coastal Processes

Data Collection

A review of existing information on siltation patterns, storm surges and extreme wave conditions was undertaken. Data on geology and lithology, and sediment particle size was extracted from the borehole logs and analytical samples collected as part of the marine sediments investigation.

Physical data on currents and tides were collected in the two sampling campaigns described in Section 8.7.4.2. The hydrodynamic field data collection campaigns included the following suite of measurements:

- Tidal water level measurements (an additional tide gauge was deployed at Graham Creek during Campaign 2);
- Current measurements; and
- Boat mounted acoustic doppler current profiler (ADCP) transects of waterways proximate to the LNG facility site at varying stages of the tide.

Tide and current measurement sampling locations are shown in Figure 8.7.6.

A boat mounted ADCP was used to collect current profile data at a range of locations and tidal times. ADCP measurements were conducted along selected transects (Figure 8.7.7) and the vessel was driven at slow speed (approximately 6 km/h) along each transect, with each transect requiring approximately 10 minutes for completion. A total of 115 ADCP transects were completed over both field campaigns. In addition, 46 supplementary ADCP transects were run over a complete tidal cycle at the location of the potential Curtis Island bridge structure. The ADCP was dynamically linked to the GPS, and position measurements were incorporated into all ADCP measurement files.

Survey details are provided in Appendix R2.

Tidal Regime

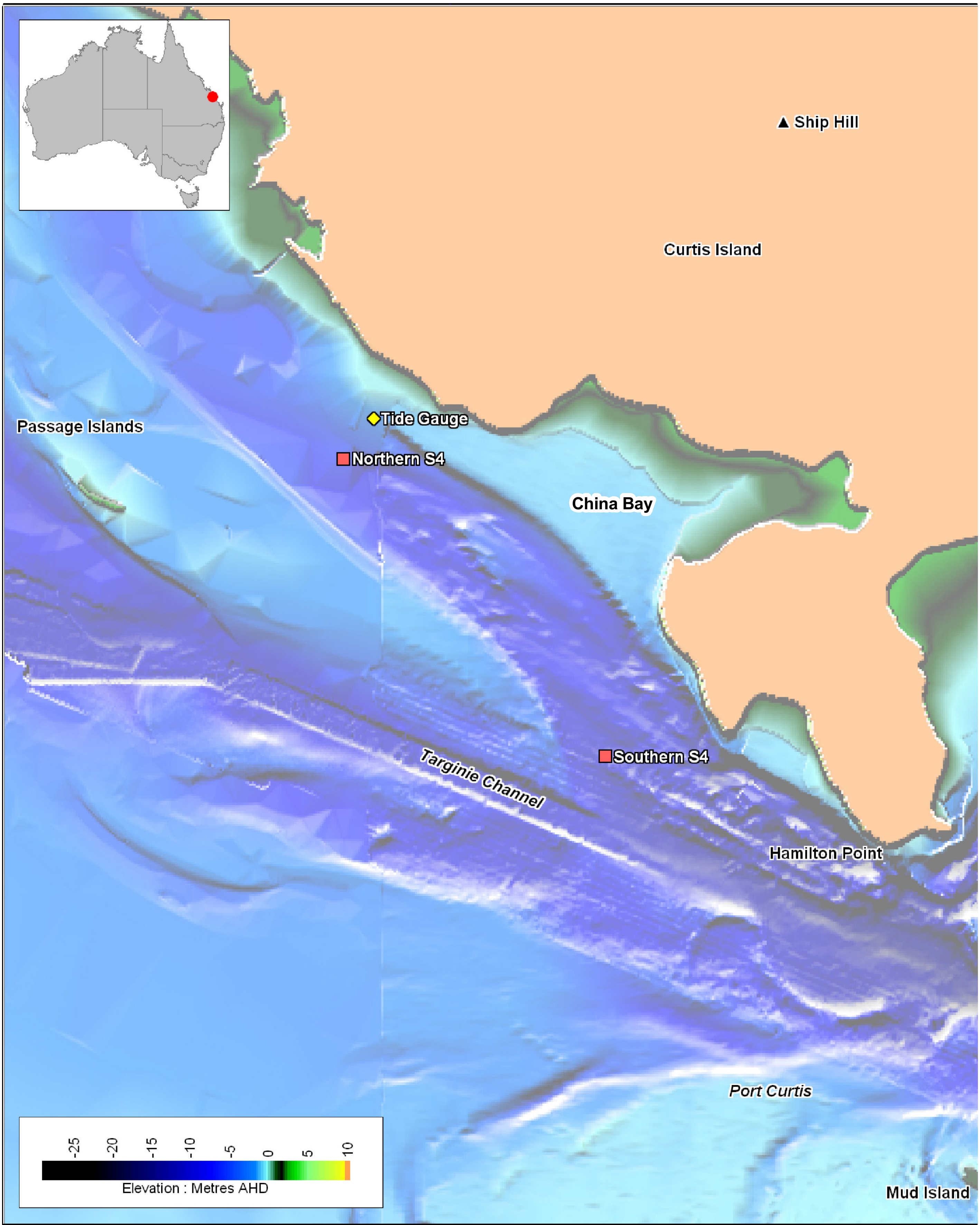
Mean spring tidal range at Gladstone is 3.3 m. Tides are semi-diurnal with a small diurnal inequality. Spring current speeds of 1.75 m/s are evident in the main shipping channel in the port area (GPA 1998).

The area is characterised by semi-diurnal tides and over the study periods maximum tidal ranges were of the order of 3m - 4 m, with some tides exceeding 4 m during the initial stages of the second campaign (refer Appendix R2). In general, the tidal ranges were greater during the second campaign. To provide some contrast, the first study took place over a period of increasing tidal ranges, whereas the second campaign spanned a period characterised by a temporal reduction in tidal amplitudes. The tidal signal at Graham Creek is of similar amplitude to that measured concurrently at the standard tide gauge site, and exhibits a slight phase angle delay.

Currents

Bottom Mounted InterOcean S4 Current Meter

At the broadest level, currents are consistent with the semi-diurnal tidal cycle of the area, with directions alternating twice a day, and remaining relatively constant during both ebb (100 to 150 degrees) and flood (300 to 350 degrees) tides. The tidal measurements showed that peak velocity magnitudes (which typically occur at mid-tide) are generally reflective of a high-energy environment, with peak spring tide velocity magnitudes in the second campaign being initially of the order of 1.0 m/s. Generally, the peak tidal velocities increase with time in the first campaign, with this trend being reversed during the second campaign. This is consistent with the temporal increase and decrease in tidal ranges over the first and second campaign periods, respectively. Further, peak tidal velocities at both sites were generally greater during the second campaign due to the greater tidal ranges experienced over that time.



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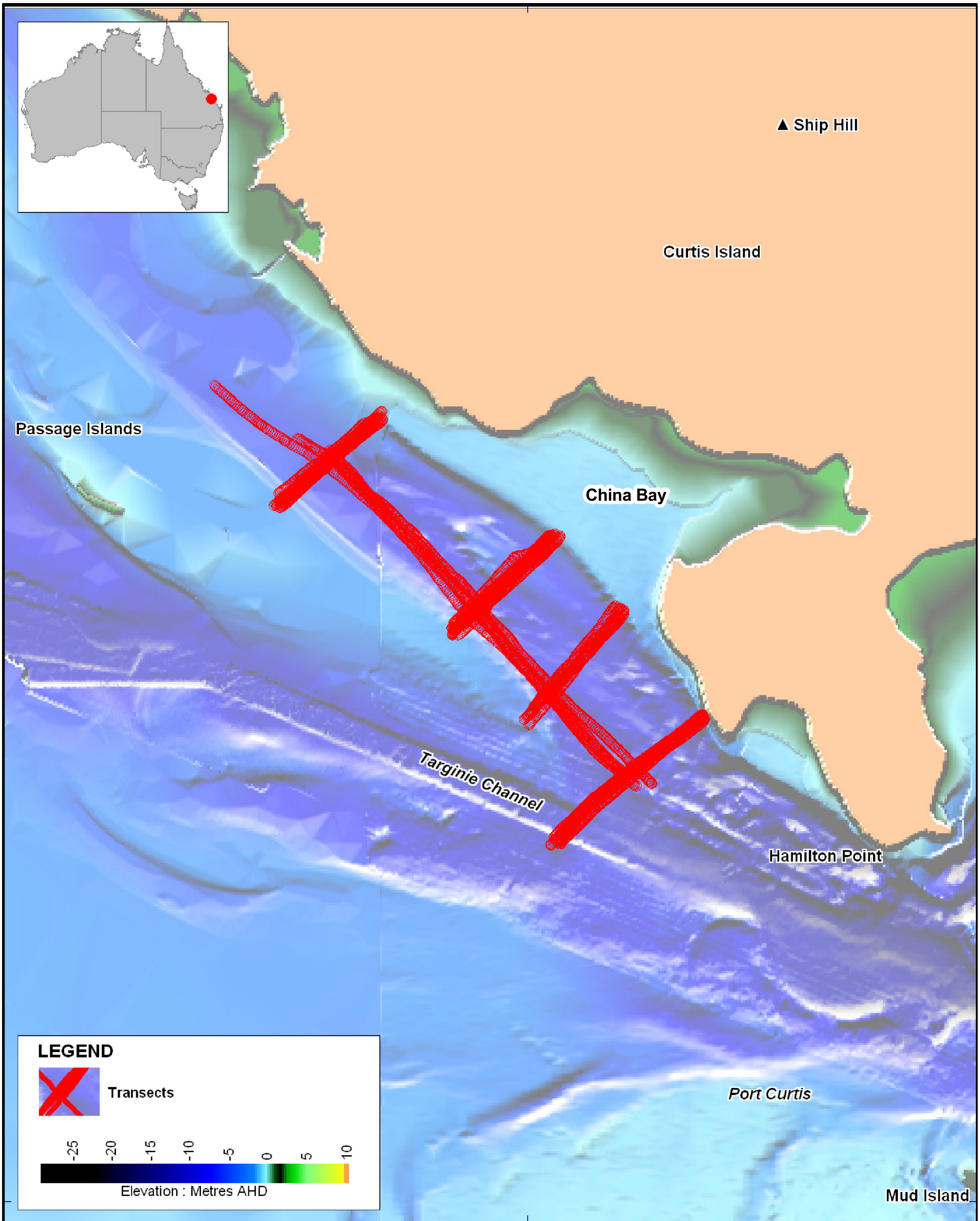
Sourced from BMT WBM Report: Proposed Santos LNG Facility EIS - Marine Water Quality Assessments January 2009.

Client	Project	Title	
LNG	GLADSTONE LNG PROJECT ENVIRONMENTAL IMPACT STATEMENT	**LOCATIONS OF CURRENT METERS AND TIDE GAUGE**	
URS	Drawn: MG · Approved: JB · Date: 09-02-2009	Figure: **8.7.6**	Rev. A
	Job No.: **4262 6220** · File No.: 42626220-g-983.mxd		A4



Source: This map contains data which is sourced and Copyright. Refer to Section 18.2 of the EIS for Ownership and Copyright
Sourced from BMT WBM Report: Proposed Santos LNG Facility EIS - Marine Water Quality Assessments January 2009.

Client	Project	Title	
LNG	GLADSTONE LNG PROJECT ENVIRONMENTAL IMPACT STATEMENT	**ACOUSTIC DOPPLER CURRENT PROFILER (ADCP) TRANSECT LOCATIONS**	
URS	Drawn: MG / Approved: JB / Date: 09-02-2009	Figure: **8.7.7**	Rev. A
	Job No.: **4262 6220** / File No.: 42626220-g-985.mxd		A4

Results from the northern instrument (Figure 8.7.6) are consistent with an asymmetry in tidal velocity magnitude during both campaigns, with ebb tides generally being associated with stronger currents than flooding tides. This is in part related to local topography; water leaving Port Curtis on an ebb tide from regions north of the study site preferentially flows directly adjacent to Curtis Island rather than out into the shipping channel. Conversely, the flooding tide sees inflowing water preferentially follow the shipping channel to Fisherman's Landing, resulting in a relative reduction of tidal velocities through the northern end of the study site at these times.

This asymmetry is not as pronounced at the southern site (Figure 8.7.6) suggesting a more uniformly oscillating hydrodynamic regime. The measurements also demonstrate only a small vertical variation in velocity magnitude and direction at the southern location during the first campaign. Typically the variation in magnitude between top and bottom instruments is within, or close to, the expected instrument error, so is likely to be insignificant. The clearest difference in the two southern instrument measurements is in the direction signals where, at the commencement of two flood tides, surface waters appear to change direction an hour or so earlier than the bottom waters. This creates some vertical shear, albeit short-lived and relatively small in magnitude, given that the bottom velocity magnitudes at these times are typically small. It is noted that this shear is not a consistent feature of the flow, as it does not occur at the onset of every flood tide. It was these findings from the first campaign that motivated the decision to only set one current meter in the southern location during the second campaign.

The observed flow directions at the northern site were relatively consistent between campaigns (approximately 300 and 125 degrees for flooding and ebbing tides, respectively). Some variation in current direction was noted between campaigns at the southern site, with the current direction axis rotating slightly towards the east-west plane during the second campaign. This change is relatively small (less than approximately 20 degrees) and may be related to slight positional changes of the southern current meter between campaigns. Refer to Appendix R2 for further current descriptions of Port Curtis.

ADCP Measurements

In general, the ADCP measurements were consistent with those of the bottom mounted current meters for both campaigns. However the ADCPs provide a more detailed view of the local hydrodynamics and key observations are described below.

All ADCP transects (refer Appendix R2 for details of each transect) show that tidal flows largely follow bathymetric channels, both in the study area and the adjacent shipping channel. Further, peak velocities tend to be in the central reaches of channels, as could be expected. These velocities can be as high as 1.2 m/s.

The data are consistent with minor vertical velocity shear at some locations, but in comparing repeat transects (e.g. Transects 3 and 4 from Campaign 1) the shear appears to be unsteady.

Ebb tides generally display greater velocity magnitudes when compared to corresponding flood tides. This is consistent with the bottom mounted current meters measurements from both campaigns.

The ADCP data show some flood tide current reversals in the lee of geomorphologic features. This is particularly evident in Transect 24 from Campaign 1 and Transects 6 and 7 from Campaign 2, where a transverse eddy structure appears to be shed off the southern point of China Bay.

The ADCP transects carried out at the potential access bridge location have been processed to derive the total flow across each transect. These show a typical asymmetrical flood-ebb tide discharge signal, with peak discharges reaching 4,000 and 8,000 m^3/s on the flood and ebb tides, respectively. These flows have been used in other reports to validate the existing hydrodynamic model in the area, and provide guidance on the likely impacts of potential bridge construction on local flow dynamics, and hence potential water quality impacts.

Sediment Dynamics

Surficial seabed sediments within 10 km of Gladstone are characterised by moderately to poorly sorted sand, high in feldspar and rock fragments. GPC's analysis of dredged material from the harbour revealed that the sediment is <6% mud and <7% gravel (Harris and O'Brien 1998).

Seabed undulations are likely to be common in Curtis Channel due to the strong tidal currents. Dunes 4 to 10 m in height and 250 to 1,200 m in wavelength occur with crestlines trending north-west. Marshall (1977) states that at the northern end of Curtis Channel the dunes are 2 to 20 m in height and most have a wavelength of between 200 and 500 m. Dune asymmetries indicate north-west transport. Marshall (1977) suggests that the dunes are moribund (formed in relation to lower sea levels and are no longer active) based on hydrodynamic evidence and as sediments from the adjacent reefs appear to be prograding over the dune deposits (Harris and O'Brien 1998).

Siltation Patterns

Direct measurements of siltation patterns have not been undertaken within Port Curtis, however, an assessment can be made based on the frequency of maintenance dredging. The WICT EIS (Connell Hatch 2006) reported on maintenance dredging activities undertaken in Port Curtis between 2000 and 2005. Maintenance dredging is typically carried out in the port on an annual basis in different areas as needed by the Gladstone Ports Corporation (GPC). Table 8.7.9 presents details of maintenance (and some capital) dredging as determined from the GPC's dredge logs.

Table 8.7.9 Historical Dredging Quantities (Connell Hatch 2006)

Location	Year – Dredging Quantities (in-situ m^3)				
	2005	2004	2003	2002	2000
Clinton Berths	10,300 (3 berths)	9,700 (3 berths)	3,150 (3 berths)	-	2,000 (2 berths)
Clinton Bypass Channel	800	14,500	320,000[1]	-	46,400[1]
Clinton Swing Basin	5,300	7,800	400	-	1,000
Targinie Channel	14,100	44,500	95,000[2]	380,000[2]	3,600

[1] includes capital and maintenance dredging

[2] capital dredging only

Connell Hatch (2006) concluded that the relatively small quantities of maintenance dredging reflect minimal siltation, which indicates that there is limited sediment transport and/or that the currents/ship movements are sufficient to keep the sediments in suspension. Connell Hatch (2006) also reported that the examination of historical hydrographic surveys confirms that there is minimal siltation.

Maintenance dredging and dredge material disposal within Port Curtis will be conducted following consultation with GPC.

Elevated Water Levels

Water levels at the coast during cyclones may be substantially higher than normal tides due to storm surge effects (increases in water level caused by onshore wind and reduced atmospheric pressure).

The storm tide level is the result of tide plus surge. The surge may peak at any stage of the tidal cycle. Hence abnormally high storm tide levels may result from extreme surge peaks coinciding with moderate to high tides, or moderate surges coinciding with high tides. The probability of an extreme surge peak coinciding with a spring high tide is low.

A comprehensive study of storm tide probabilities in the Yeppoon region was undertaken for the Beach Protection Authority by Blain, Bremner and Williams (1985). The nearest calculation sites for this study were at the Fitzroy River entrance and at Cape Capricorn on Curtis Island. The calculated 100 year average recurrence interval (ARI) storm tide levels (excluding wave set-up) at these sites were 3.5 m AHD and 2.9 m AHD respectively. Any storm surge on the open coast will propagate into Port Curtis and be influenced by local processes as well.

A more recent comprehensive study by the Queensland Government (Hardy et. al. 2004) examines storm tide vulnerability and potential increases in sea level from climate change and more intense cyclonic effects on coastal communities. This study incorporated more detailed modelling on a nearshore grid of approximately 550 m, which extended into Port Curtis. The predicted storm tide levels in the region from the abovementioned study are listed in Table 8.7.10 for various recurrence intervals excluding wave-set up and climate change effects.

Table 8.7.10 Peak Storm Tide Levels (excluding climate change effects)

Location	Storm Tide Level (m AHD)		
	100 year ARI	500 year ARI	1,000 year ARI
Gladstone	2.82	3.51	3.80
Tannum Sands	2.50	3.05	3.31

It can be seen that there is some amplification (increase) in the predicted storm tide level moving into Port Curtis from the south. The resolution of the model is such that not all features will be accurately represented. That is, there is a possibility that slightly greater amplification and hence storm tide levels will occur to the proposed LNG facility site on Curtis Island than have been reported for Gladstone in Table 8.7.10.

The above storm tide levels do not contain provisions for sea level rise due to greenhouse gas (GHG) effects, other climate change influences or wave set-up and run-up. Wave set-up and run-up only occur near or at the shoreline. The additional coastal inundation caused by wave set-up and run-up on top of the storm tide will be assessed for the design of onshore facilities that are within the wave impact zone.

With respect to climate change, there is significant scientific opinion that baseline changes to climate may occur within the design life of much of the coastal and ocean community infrastructure. However, despite the growing body of scientific literature and knowledge, there are still no definitive predictions of its effects or potential impacts.

The Fourth Assessment Report of the IPCC (2007) reports that global sea level rise is projected to be 18–59 cm by year 2100, relative to 1990 levels. These projections do not include a contribution from ice flow rates. If these were to continue to grow linearly with global warming, then the upper ranges of sea level rise will increase by a further 10 to 20 cm (by year 2100 relative to 1990) (IPCC, 2007). There is an acknowledged risk that the contribution of ice sheets to sea level rise this century may be substantially higher than this.

The climate models predict that there will be a not-insignificant regional variation in future sea level rise, predominantly due to spatial variations in the contribution made by ocean thermal expansion. Predictions reported by the CSIRO (2007) indicate that future sea level rise along the eastern Australian coastline may be up to 12 cm greater than the global average by 2100.

In summary the total mean sea level rise along the eastern Australian coastline is estimated to be in the range 28–91 cm by the year 2100. This will occur gradually at first as we continue to accelerate from the historic rate of 1.7 mm per year and then more rapidly as the year 2100 is approached.

Hardy et. al. (2004) examined the potential implications for storm tide statistics of three specific GHG scenarios:

- Combined effect of an increase in maximum potential intensity (MPI) of 10% and a poleward shift in tracks of 1.3°;
- Increase in frequency of tropical cyclones of 10%; and
- Mean Sea Level rise of 0.3 m.

The mean sea level rise component has an almost linear effect on the resultant storm tide levels, while the 10% increase in cyclone frequency has negligible impact. The combined increase in intensity and poleward shift in tracks becomes increasingly significant with large return periods.

The resultant storm tide levels predicted with the predicted climate change effects for a 50 year planning period are presented in Table 8.7.11.

Table 8.7.11 Peak Storm Tide Levels - 50 year Planning Period (including Climate Change Effects)

Location	Storm Tide Level (m AHD)		
	100 year ARI	500 year ARI	1,000 year ARI
Gladstone	3.33	4.18	4.51
Tannum Sands	2.95	3.64	3.94

It should be noted the use of 0.3 m for mean sea level rise is also supported by other Queensland Government Policies, though it should be further noted that this value was derived for a 50-year planning period. For a 100-year planning period a mean sea level rise based on IPCC (2007) of 55 cm (mid-range) to 91 cm (high-range) is considered to be an appropriate allowance. The mid to high range storm tide levels for combined climate change scenarios over a 100 year planning period have been derived and are provided in Table 8.7.12 (Hardy et al. 2004).

Table 8.7.12 Peak Storm Tide Levels – 100 Year Planning Period (including Climate Change Effects)

Location	Storm Tide Level (m AHD)		
	100 year ARI	500 year ARI	1,000 year ARI
Gladstone	3.58/3.94*	4.43/4.79	4.76/5.12
Tannum Sands	3.20/3.56	3.89/4.25	4.19/4.55

*Mid-range/High-range sea level rise by 2100.

The choice of a 50 or 100 year planning period should be based upon an assessment of the component lifetime, risk of failure and options for future adaptation to changing climate conditions. When choosing between mid and high range values, the precautionary principle should be applied in weighing up the risk of failure and options for future adaptation.

Extreme Wave Conditions

Connell Hatch (2006) reports modelling of wave conditions within Port Curtis. Both the penetration of long-period swell and the generation of local wind-waves by cyclonic winds were investigated.

The swell penetration modelling demonstrated that long period ocean swells are generally blocked by Facing Island and the southern boundary of the harbour westwards from South Trees Inlet. Swell does not propagate far enough into the Port of Gladstone to have a significant impact at the location of the proposed LNG facility.

Local wind wave modelling results show that locally generated wind waves have the potential to be larger at the location of the proposed LNG facility than ocean swell waves penetrating to the site. Local wind waves were modelled for a cyclonic 50 m/s wind speed and a variety of wind directions, with a water level of 3.4 m AHD approximately corresponding to a 100 year ARI storm tide. No assessment was made of the annual exceedance probability of these combinations of wind speed, direction and water level.

Significant wave heights at the proposed LNG facility were found to be greatest for winds blowing from the westerly quadrant due to the relatively unconstricted fetch in this direction. In the channel immediately offshore of the proposed LNG facility the channel depth is approximately –12 m AHD. The 50 m/s wind generated significant wave heights (H_s) between 2.5 - 3.0 m, depending on direction. In general the spectral peak period (T_p) of incident waves generated by such a cyclonic wind will be around five seconds.

8.7.4 Potential Impacts and Mitigation Measures

8.7.4.1 Dredging Impacts

As discussed in Section 3.10.1.1, the proposed capital dredging will include the dredging of an approach channel off the existing Targinie Channel, berthing pockets and a swing basin, to a design depth of 14.0 -mLAT. This will allow the safe passage, docking and loading of LNG bulk carriers, with a margin of safety between vessel keel and the seabed. The estimated *in-situ* volume of material to be dredged to lower the seabed to 14 -mLAT is approximately 8,000,000 m^3. Dredging is likely to be undertaken using a conventional cutter suction dredge, with all material pumped as a water/sediment slurry from the dredge, through a floating discharge line to the dredge material placement facility. An additional 100,000 m^3 of material will be dredged at the MOF to a design depth of 8 –mLAT.

CIRIA (2000) reports that for a worst case (i.e. for wholly silty clay and clay sediments) the loss rate of sediments by a cutter suction dredge is of the order of 0.9 kg/s to 1.6 kg/s. Given this range of potential loss rates, a conservative value of 1.5 kg/s has been adopted for this study as the rate at which sediment may be mobilised into the water column by capital dredging works.

In order to quantify the potential impact of this rate of sediment re-suspension on ambient water quality levels, and also to understand the potential spatial extent of sediment plumes which may be generated by such works, sediment transport fate modelling was undertaken for the area of Port Curtis where dredging will occur. This modelling has assumed a source of sediment generated at the above identified rate which is equivalent to the action of a cutter suction dredge. For simplicity, this hypothetical sediment source has been centrally located within the proposed GLNG swing basin. In addition, the existing bathymetry has been (conservatively) assumed in the modelling. In this way the simulation effectively replicates the initial commencement of dredging when depths are at their shallowest and tidal velocities are at their highest. Details of the modelling are given in Appendix R2.

The modelling simulates the deposition and settling of disturbed sediment. In a similar manner to work conducted elsewhere in the region (e.g. background studies for the Wiggins Island Coal Terminal project), a suspended sediment settling rate of 1 m/day was adopted. This is equivalent to the settling rate of finer silty material, which is expected to be the dominant material of concern in this regard.

All modelling assessments were conducted separately for neap and spring tide conditions. In each case, the model was run for a two-day warm-up (with the sediment discharge included), and then through a two-day analysis period (respectively under neap and spring tide conditions). The maximum and average increases in total suspended solids (TSS) levels associated with this two-day period (for both spring and neap tide conditions) are presented in Figures 8.7.8 to 8.7.11.

These results show that there are elevated TSS levels in and around the area of proposed dredging work, with this region occupying an area of approximately 150 m by 500 m during neap tides and approximately 200 m by 150 m during spring tides. These areas are those approximately corresponding to the red/yellow contour regions in the respective maximum contour plots. It should be noted that these plots are not snapshots in time, but rather represent atemporal aggregations of maxima (unchanging maximum sediment load) throughout each selected two day period. As such, the red/yellow areas in the maximum plots do not represent concentrations expected at one time, but rather, the region in which higher TSS concentrations could be expected to occur across each two day period.

Outside this area, the maximum increase in TSS concentrations is in the order of 25 mg/L. When compared with typical background levels in this region of Port Curtis (Table 8.7.2), it is apparent that these TSS levels, while high, are comparable to the existing levels of variability in TSS present in the region. Further afield, additional maximum TSS levels are predicted to be less than 5 mg/L, which will be close to undetectable.

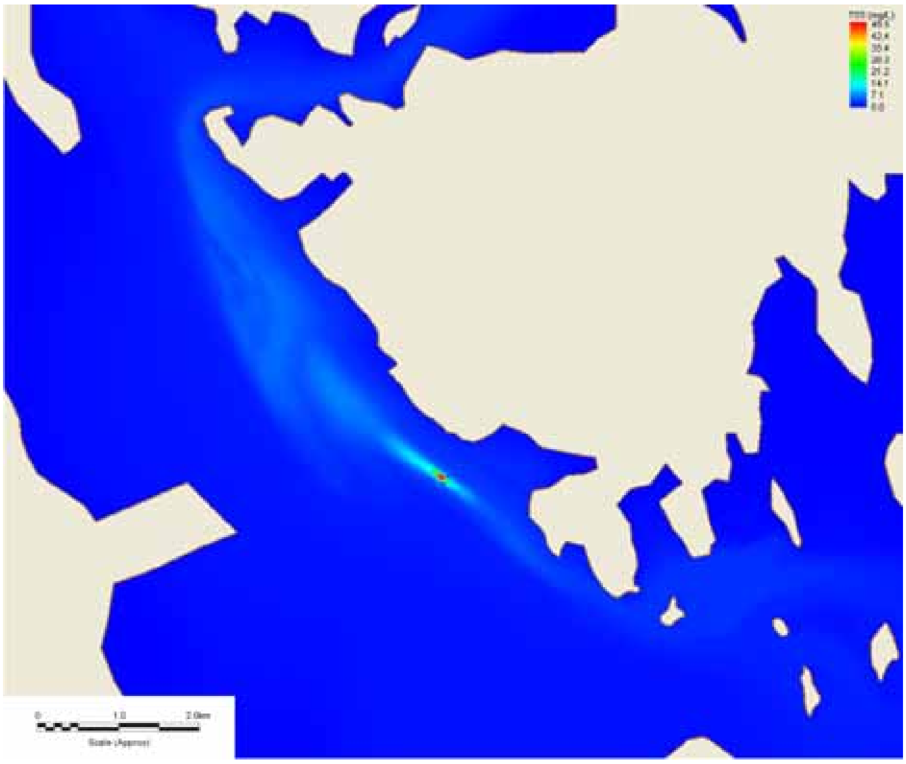


Figure 8.7.8 Maximum TSS Increases, Due to Capital Dredging Works – Spring Tide

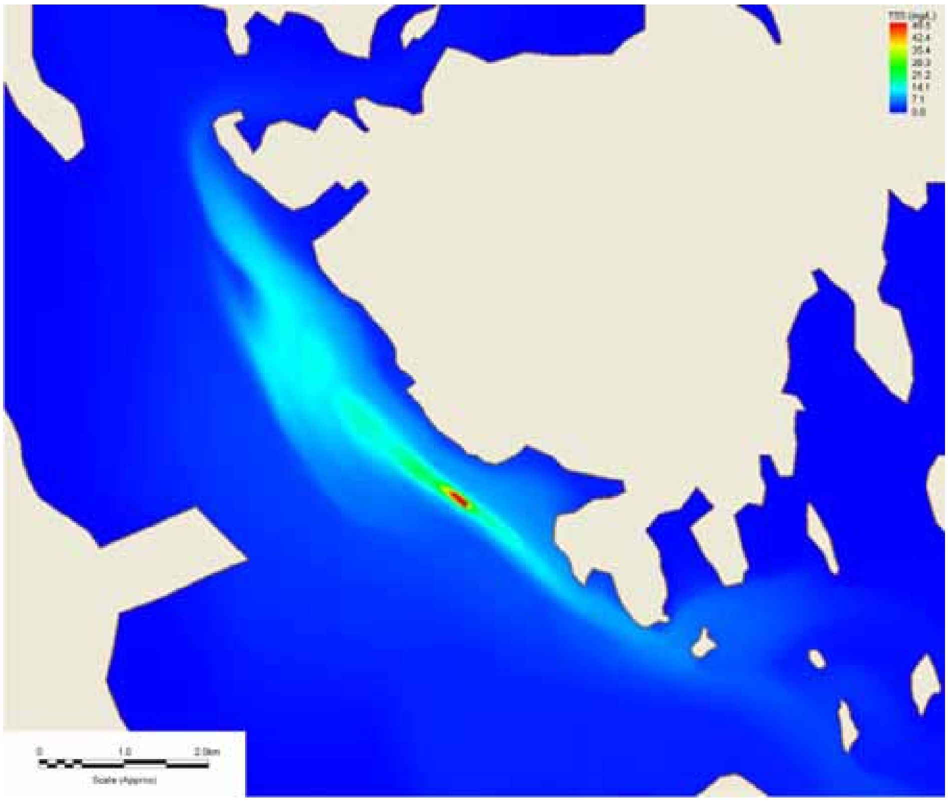


Figure 8.7.9 Maximum TSS Increases, Due to Capital Dredging Works – Neap Tide

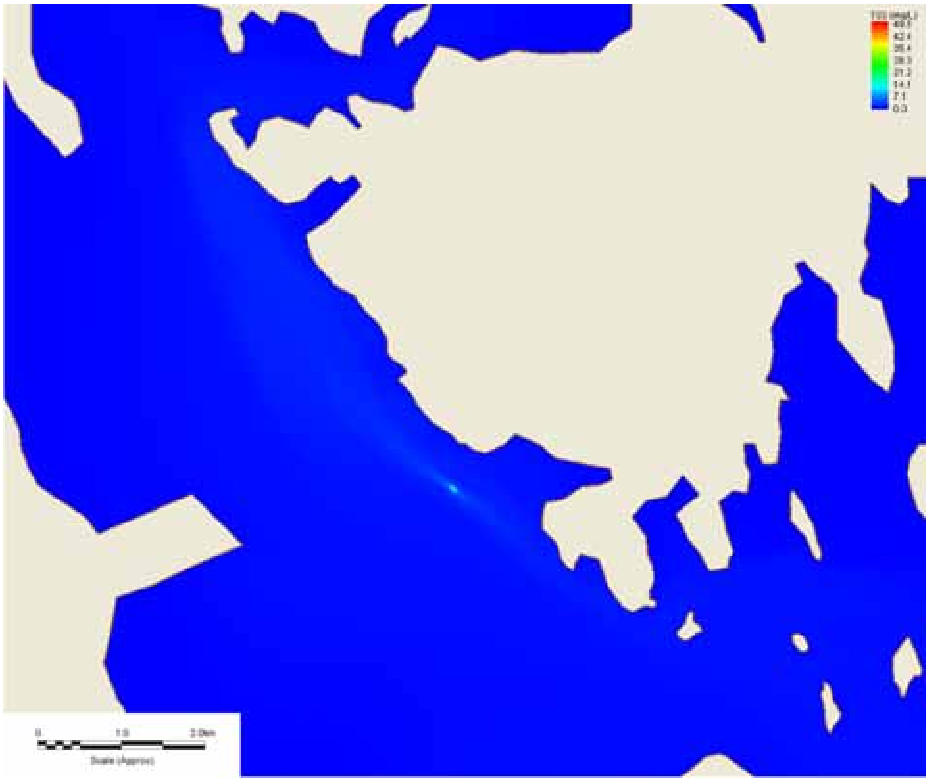


Figure 8.7.10 Average TSS Increases, Due to Capital Dredging Works – Spring Tide

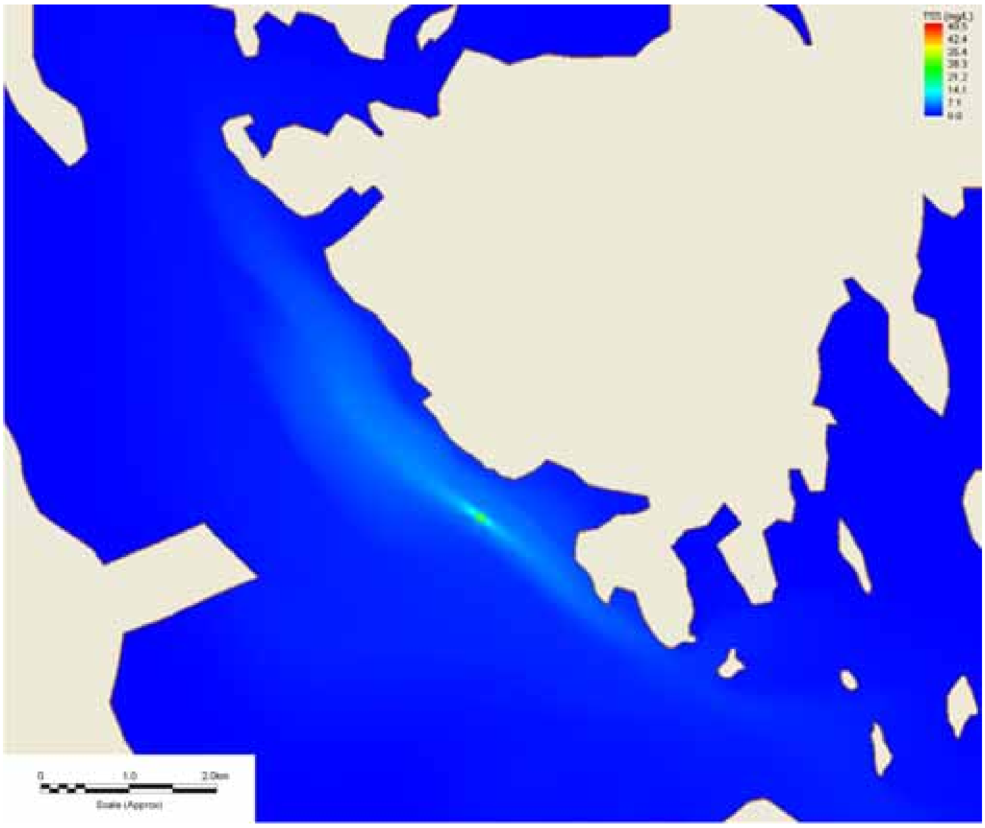


Figure 8.7.11 Average TSS, Due to Capital Dredging Works – Neap Tide

Modelled TSS concentrations for specific locations throughout Port Curtis are shown in Figure 8.7.12. They show that apart from the Santos and BG swing basin sites there are no sites with elevated TSS concentrations greater than 5 mg/L above background. The locations of the selected sites are shown on Figure 8.7.13.

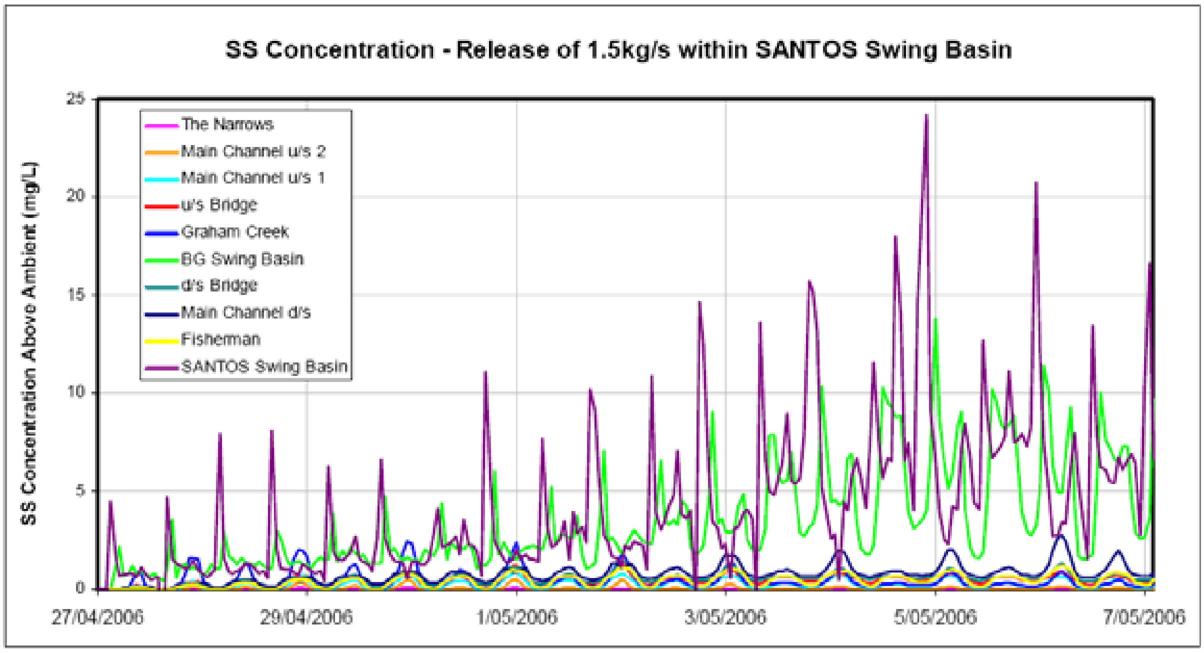


Figure 8.7.12 Far Field Sediment Modelling Results – Capital Dredging Works

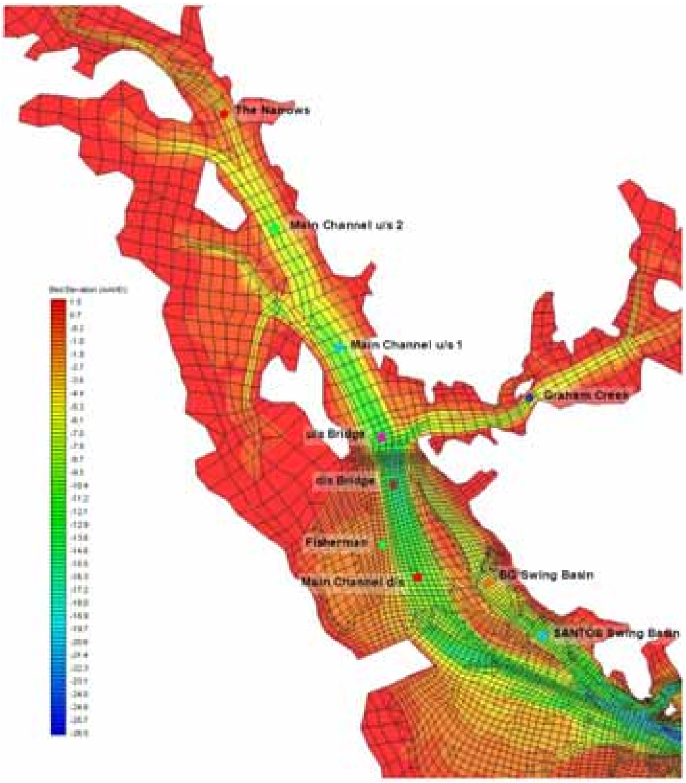


Figure 8.7.13 Sediment Model Result Extraction Locations

As discussed in Section 3.10.2, the dredge material will be disposed of in a dredge material placement facility to be constructed at Laird Point. Details of this facility and its impacts on Port Curtis are discussed in Section 8.17.

8.7.4.2 Gas Transmission Pipeline Construction Impacts

As discussed in Section 3.7.3.20, the gas transmission pipeline is planned to cross Port Curtis between Friend Point and Laird Point, adjacent to the alignment of the potential bridge. The pipeline is proposed to be buried approximately 2 m below the seabed in a 3 m deep trench, with ballast placed on top of the trench to secure the pipeline. The approximate distance from Friend Point to Laird Point is 1500 m. It is estimated that the trench required to lay the pipeline will be approximately 2 m wide, resulting in a total of 9,000 m^3 *in-situ* of disturbed sediments.

The most likely method of trench excavation is by clamshell bucket dredge. The clamshell could operate by crane on a flat topped barge, secured by a temporary mooring system. The barge will assist in placing of the pipe sections, armouring and backfilling activities. The excavated trench will be formed in sections to allow the relevant pipeline sections to be placed. Excavated material from the trench is likely to be stored and placed over completed sections of the pipeline as backfill. Pipe sections will be weighted to provide temporary stability during installation and to prevent uplift during backfill. Pipe sections will be lowered into the excavated trench and mechanically joined to the previous section. Once the pipe section has been installed, backfill and armouring will be placed to stabilise the pipe.

The sediment mobilisation caused by the pipeline's construction has been modelled (Appendix R2). Sediment mobilisation rates used in the model were estimated as discussed below:

- *Trenching* - Sediments will be entrained into the water column during trenching by the release from the clamshell dredge of excess water containing high concentrations of fine sediments. A sediment entrainment rate of 50 kg per bulk m^3 of material excavated was conservatively assumed, based on typical published values for clamshell dredging operations. If it is assumed that industry-standard excavation rates of 1,000 m^3/day for a 15 hour day, then a commensurate sediment entrainment rate of 0.93 kg/s is obtained. The assumed sediment entrainment rate of 50 kg per bulk m^3 is twice the high-end literature values. This introduces some conservatism into the model predictions, given the high current speeds and significant tidal ranges experienced in Port Curtis. That is, the model predictions are expected to be at the high end of likely plume concentrations.
- *Backfilling* - The replacement of excavated material into the dredged trench will also contribute to sediment plume generation. Tavolaro (1984) estimated that between 3% and 7% of dredged material was lost to sediment plumes during disposal. WBM (2007) identified that around 2% of dumped material left the dump site as a suspended sediment plume during detailed monitoring of a marine dredged material disposal event. If a 3% loss of backfill material is assumed (conservative), that the 1,000 m^3 per day of extracted material is also reapplied as backfill, and that the material has a dry bulk density of 1,200 kg/m^3, a further 0.67 kg/s of potential sediment entrainment into the water column can be assumed due to backfilling.

Given the above, the likely worst-case rate of sediment mobilisation due to the combined influence of pipeline trenching and backfilling is some 1.6 kg/s. For simplicity in the modelling, a slightly reduced rate of 1.5 kg/s has been assumed, this being exactly the same as the rate derived for the effect of a cutter suction dredge. Furthermore, the sediment transport fate modelling allowed for the deposition/settling of disturbed sediment at the same rate as that adopted for the capital dredging assessments. This is equivalent to the settling rate of finer silty material which is expected to be the dominant material of concern in this regard.

All modelling assessments were conducted separately for neap and spring tide conditions. In each case, the model was run for a two-day warm-up (with the sediment discharge included) and then through a two-day analysis period (respectively under neap and spring tide conditions). The maximum and average increases in total suspended solids levels associated with this two-day period (for both spring and neap tide conditions) are presented in Figures 8.7.14 – 8.7.17.

These results show that there are elevated TSS levels in and around the area of the proposed trenching work occupying an area of approximately 600 m by 200 m during neap tides and approximately 150 m by 150 m during spring tides. These areas are those approximately corresponding to the red/yellow contour regions in the respective maximum contour plots. It should be noted that these plots are not snapshots in time, but rather represent atemporal aggregations of maxima throughout each selected two day period. As such, the red/yellow areas in the maximum plots do not represent concentrations expected at one time, but rather, the region in which higher TSS concentrations could be expected to occur at any time within each two day period.

Outside these areas, the maximum increase in TSS concentrations will be of the order of 14-16 mg/L. When compared with typical background levels in this region of Port Curtis (Table 8.7.2), it is apparent that these TSS levels, while high, are comparable to the existing levels of variability in TSS present in the region.

Unlike the case of capital dredging, these TSS concentrations extend further afield; both upstream and downstream of the potential bridge, due to the higher water velocities in this region.

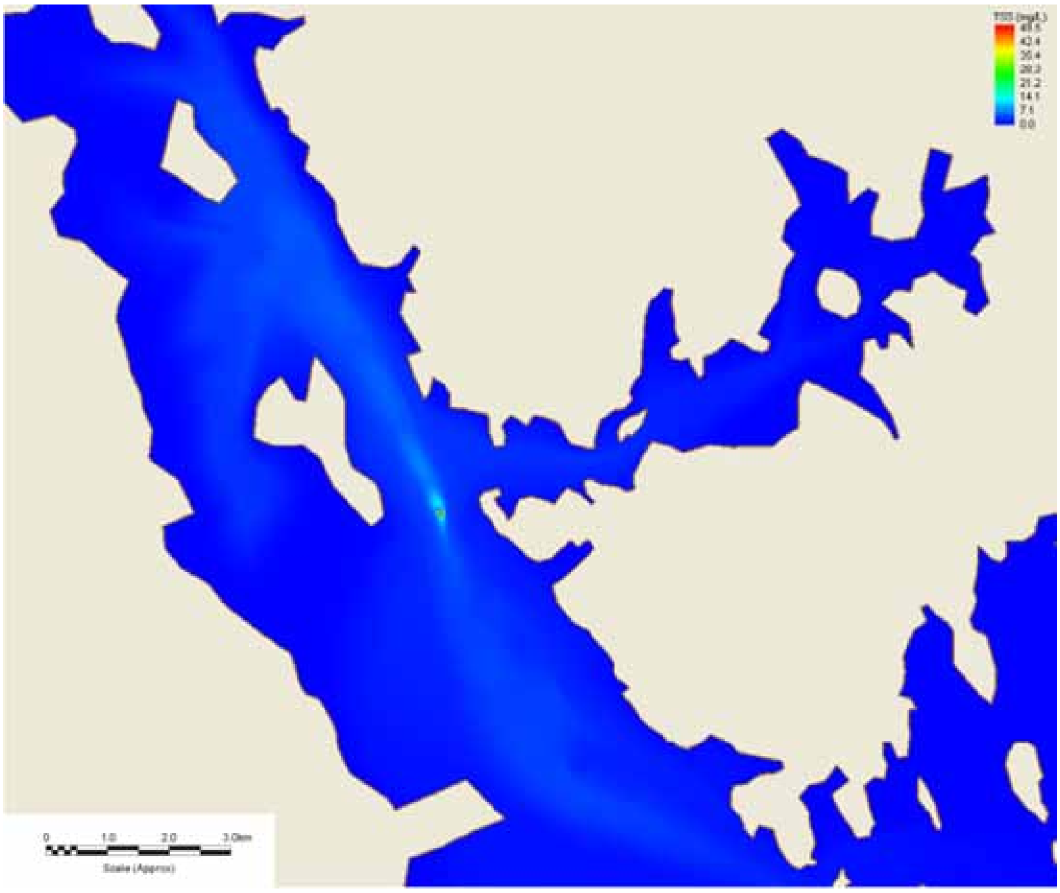


Figure 8.7.14 Maximum TSS Increases, Due to Pipeline Construction – Spring Tide

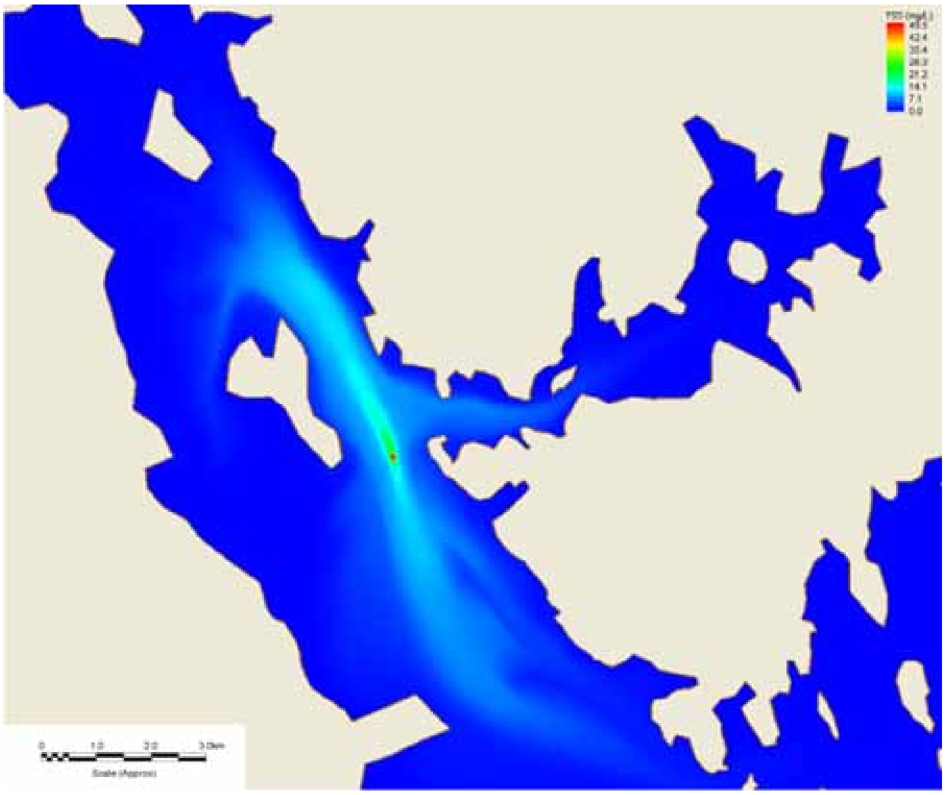


Figure 8.7.15 Maximum TSS Increases, Due to Pipeline Construction – Neap Tide

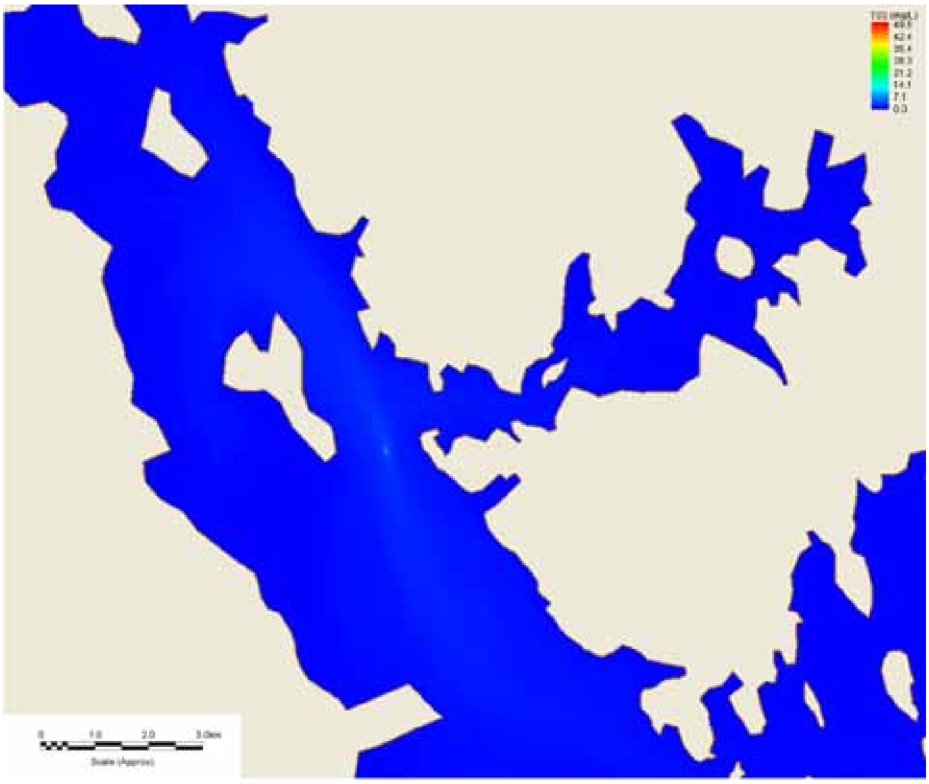


Figure 8.7.16 Average TSS Increases, Due to Pipeline Construction – Spring Tide

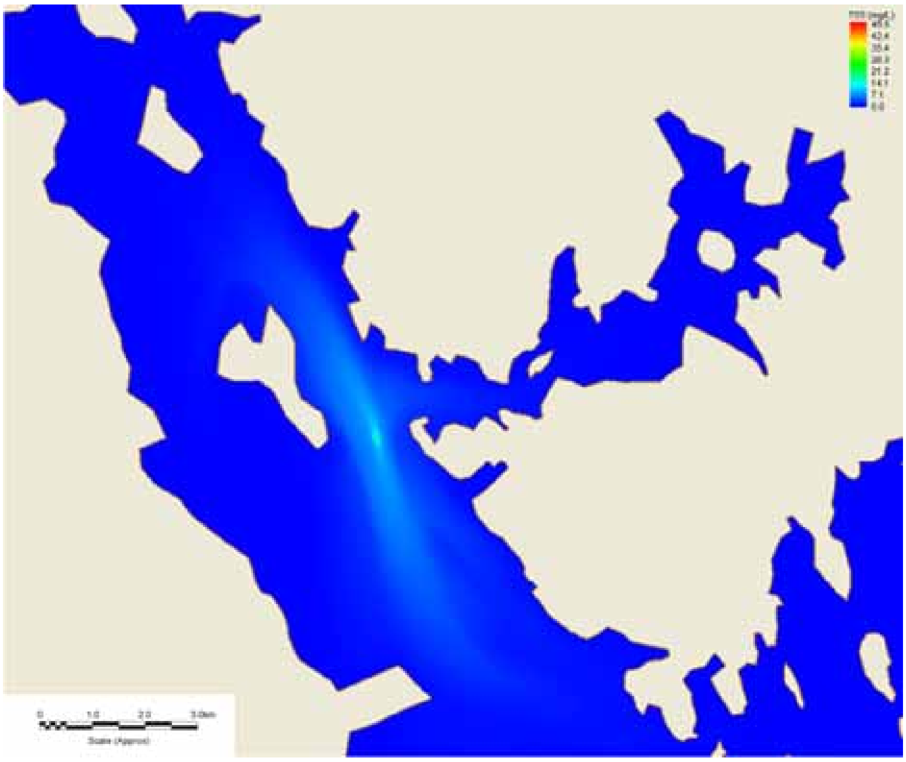


Figure 8.7.17 Average TSS Increases, Due to Pipeline Construction – Neap Tide

Modelled elevated TSS concentrations at specific locations throughout Port Curtis caused by the trenching operation are shown in Figure 8.7.18. The modelled locations are shown on Figure 8.7.13. The results show that there are no sites with elevated TSS concentrations greater than 16 mg/L above background with most less than 10 mg/L above background.

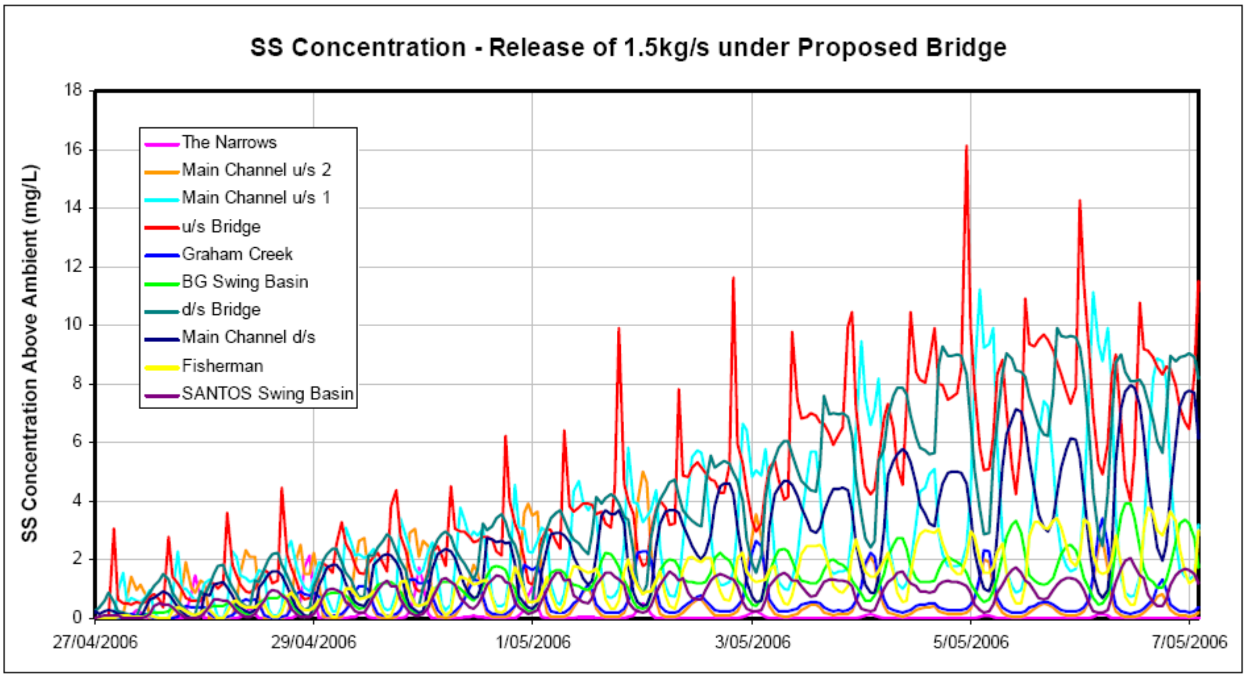


Figure 8.7.18 Far Field Sediment Modelling Results – Pipeline Construction

8.7.4.3 Potential Bridge Pier Piling/Construction Impacts

While it is recognised that there is potential for the generation of sediment plumes during construction of the potential bridge, it is likely that with appropriate management intervention, such plumes would be smaller than those which will be developed by the other sources of potential construction impact already assessed above. Because of this, and the fact that the likely path of the potential bridge is almost concurrent with the gas transmission pipeline crossing (and hence there are likely to be similar spatial areas of impact as assessed for the pipeline crossing), it was not necessary to explicitly model the effects of the bridge piling, but rather to assume that the potential impacts are largely addressed by the other assessments and to implement a high level of management control over such actions during the construction phase.

In summary, no significant water quality impacts are expected from the bridge's construction.

8.7.4.4 Mitigation Measures for Construction Activities

Best practice techniques will be adopted for dredging and pipeline construction activities in order to minimise the extent and duration of sediment plumes which may otherwise be generated during the construction phase of the project. The key measures to reduce construction stage impacts are outlined in Section 8.4 and are primarily related to the implementation of an approved dredge management plan and environmental management plan.

8.7.4.5 Hydrodynamic Impacts

Hydrodynamic Model

The potential hydrodynamic impacts associated with the GLNG Project were assessed using a two-dimensional (2D) hydrodynamic model of Port Curtis. This model has been repeatedly refined with improved calibration and model performance for many years. Figure 8.7.19 shows the extent of the model which extends from the Pacific Ocean boundary of Port Curtis north to beyond The Narrows. Further details of the model are provided in Appendix R2.

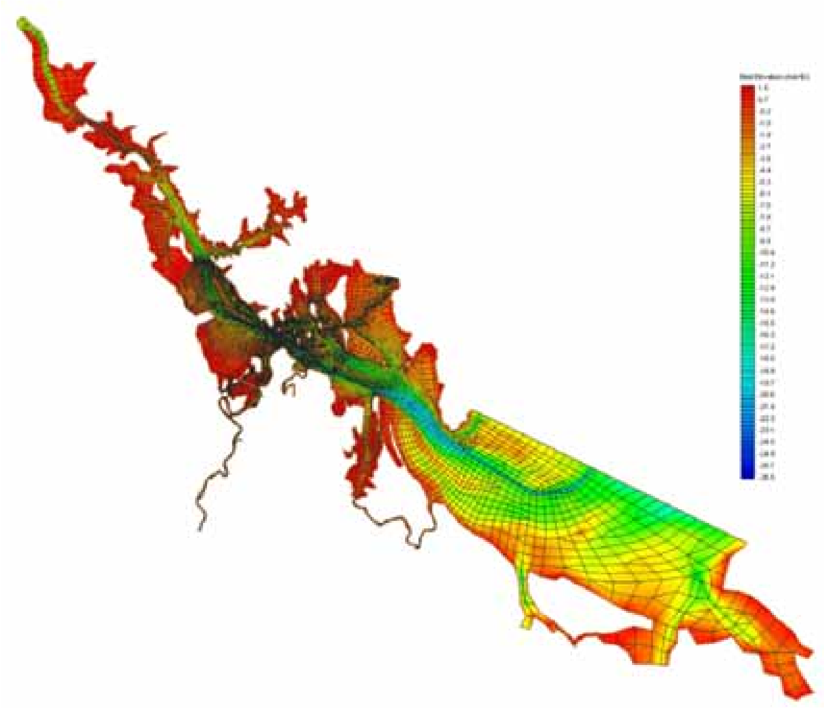


Figure 8.7.19 Port Curtis Hydrodynamic Model Mesh

The Port Curtis hydrodynamic model was used to assess potential impacts associated with the GLNG Project as follows:

- A base case model was run for a mean spring tide boundary condition;
- Modifications were made to the model mesh and model bathymetry to enable the simulation of works associated with the GLNG Project (see below); and
- A post-development scenario was run in the model and subsequent comparisons conducted of predicted 'before' and 'after' hydrodynamic behaviour in Port Curtis and The Narrows.

Modifications made to the Port Curtis model for the GLNG Project as discussed below:

- The model mesh was adjusted to provide more detail in the project area.
- New bathymetry that will exist following dredging works associated with the GLNG Project was added to the model grid. This new bathymetry incorporates the following GLNG Project activities:
  - Dredging for the swing basin;
  - Dredging for access channel to the swing basin (and PLF) from the existing shipping channel (Targinie Channel); and
  - Removal of shoals and other dredging works in and around the Clinton Channel that may be required to enable safe access of LNG carriers in and out of the harbour.
- Adjustments were made to the model to account for the effects associated with the potential bridge across Port Curtis from Friend Point to Laird Point. The bridge will require a number of piled structures to be constructed which will reduce the available flow area at the southern boundary of The Narrows. It was decided that refining the model to simulate the individual piled structures (typically less than 4 m wide) was not practical, and hence an alternative approach was adopted to simulate the flow obstruction effect of the bridge. This alternative approach saw the application of relevant techniques (as outlined in US Department of Transport, 1978) whereby the effective (reduced) conveyance of the bridge channel was derived and then simulated in the hydraulic model of Port Curtis via an increased Manning 'n' value for those refined model mesh elements where the potential bridge will be located.
- Adjustments were made to the model to account for the flow blockage effects associated with the western bridge abutments which will cross intertidal mudflats.
- The potential approach road was included in a limited number of simulations. It is noted that the model bathymetry and calibration status in the area of the potential approach road is highly uncertain, and as such results from the model in this area are treated with caution and should not be relied on for detailed assessments (refer Appendix R2 for further details).

Impacts on Tidal Hydraulics

Following all of the aforementioned changes to the model, relevant 'before' and 'after' simulations were conducted for a 14 day representative neap-spring tidal cycle and the model was interrogated in order to determine relevant impacts of the dredging and potential bridge on tidal hydraulics. These impacts are summarised below:

Tidal water levels:

- Minimum (i.e. spring low tide) water levels at sites upstream and downstream of the potential bridge reduce by no more than 4 mm, with the maximum change predicted immediately upstream (north) of the potential bridge;
- Maximum (i.e. spring high tide) water levels at sites upstream and downstream of the potential bridge also reduce, in this case by no more than 3 mm, with the maximum change predicted immediately upstream (north) of the potential bridge;
- There was no detectable change in tidal phasing; and
- The maximum predicted reduction in tidal range associated with the bridge is 6 mm (0.13%).

Tidal velocities:

- There was no predicted change in minimum velocities, which were all zero at slack water;
- Maximum (i.e. spring tide) velocities at sites upstream and downstream of the bridge also reduced, in this case by no more than 0.003 m/s (or 0.27% of the peak pre-bridge velocity), with the maximum change predicted immediately downstream (south) of the bridge; and
- There was no detectable change in tidal phasing.

Tidal flow rates:

- Predicted changes in tidal flow rates mirrored the above changes in tidal velocities.

Tidal flow distribution:

- There was no detectable change in tidal flow distribution.

A simple analysis of the likely flows across the proposed alignment of the potential approach road was conducted, within the strong model limitations in this area noted above. The predicted tidal flow rates across the alignment for the simulation duration were less than 30 m^3/s. Whilst uncertain, the model predicts that the flows across the proposed alignment are likely to be insignificant in comparison to flows through The Narrows, for example, with the latter reaching up to 8,000 m^3/s.

In summary, the tidal hydraulic impacts of the GLNG Project will be minimal at the selected locations (refer Appendix R2 for further details).

Impacts on Tidal Flushing/Advection Dispersion

The Port Curtis model was also used to assess the project's impacts on tidal flushing and advection/dispersion effects. The model routines have been used for numerous previous studies in Port Curtis. Whilst calibration of such routines can be more difficult to complete than in the case of tidal hydraulics (due to complications associated with collecting robust data sets), dye release testing in Port Curtis conducted several years ago has been used to define relevant model dispersion coefficients. Further details are provided in Appendix R2.

In order to quantify changes in tidal flushing with development of the GLNG Project, the following approach was adopted:

- Pre and post GLNG advection dispersion models were developed, built upon the hydraulic models previously described.
- The domain of both of these models was assumed to have a uniform initial concentration of a conservative tracer, with this concentration being prescribed an arbitrary value of 1 mg/L.
- The boundaries of the models were appropriately configured with a defined concentration of 0 mg/L. That is, when the tide is flooding and oceanic waters are moving 'into' the model domain, inflowing waters have no conservative tracer; whereas when the tide is ebbing, tracer from within the model domain leaves through the model boundaries, and does not return.

For this model paradigm, pre and post GLNG simulations were conducted for a 45 day period and tracer 'flushing times' were calculated at several representative locations within the model. These flushing times were defined by the industry/scientifically accepted technique of 'e-folding' time. This is the time taken for an initial tracer concentration to reduce to 37%, or 1/e, of its initial value.

Based on the above model simulation, tidal flushing times for the pre and post GLNG cases were estimated. In most cases however, even though the model had been run for a 45 day period, the required value of 37% flushing had not been reached and as such definitive flushing times cannot be reported. What can be reported is that there were practically indiscernible differences in flushing behaviour, and (if anything) flushing improved very slightly. As the dredging and potential bridge construction works associated with the GLNG Project will have minimal impact on tidal flushing times, and there are minimal additional pollutant loads associated with the GLNG Project, it can be inferred that there is minimal potential for changes in the existing water quality regime of Port Curtis associated with this project.

8.7.4.6 LNG Facility Discharge Impacts

Stormwater Drainage

As discussed in Section 8.5.5.2, the LNG process is essentially a dry process that produces only minor quantities of wastewater. Figure 8.5.2 summarises the sources and fate of liquid wastes and stormwater runoff from the facility site.

The waste water streams in the LNG facility will be managed to minimise environmental risks and impacts on receiving waters. The following are key management strategies in achieving this objective:

- Treating potentially contaminated water;
- Minimisation of the potential for contaminants to be mobilised in off-site runoff; and
- Directing naturally occurring runoff around the site and away from process or utility areas.

To implement these strategies, the site will be divided into multiple surface water management catchments with each catchment containing uses with varying potential for stormwater contamination. Details of the drainage arrangements in each of these catchments are given in Section 8.5.5.2 and are summarised below:

- Process areas will be built on bunded concrete slabs.
- The bunded areas will each have a sump to collect stormwater.
- Stormwater collected in the bund sumps will pass through a skimmer with the skimmed water/oil being routed to a corrugated plate interceptor (CPI) oil/water separator unit for removal of oil and grease and suspended solids.
- The skimmer underflow will flow to a first flush retention pond with excess runoff above the first flush volume by-passing the initial stormwater storage and discharging directly to the stormwater outlet system.
- Water in the first flush pond will be tested and if suitable will be discharged to the stormwater outlet system. Otherwise (off-spec) it will be sent to the contaminated water tank for transport to an approved off-site treatment and disposal facility.
- Clean stormwater from non-process areas and undisturbed catchments will be discharged via drains to the surrounding natural drainage system.

Implementation of this stormwater management system will ensure that contaminated stormwater will not be discharged from the site and the water quality of Port Curtis will be protected.

Reverse Osmosis Plant Discharge

As discussed in Section 3.8.3.9, water supply for the LNG facility will be provided by the desalination of seawater from Port Curtis. A reverse osmosis (RO) plant will be used for the desalination. The RO plant will have a feed supply rate of 120 m^3/hr and will produce a brine, or reverse osmosis concentrate (ROC), at a rate of approximately 54 m^3/hr (15 L/s) which will be discharged back to Port Curtis. Based on a worst case salinity level in intake waters of 35 g/L, the ROC could have a salinity level of 63.5 g/L. As well as producing ROC, the proposed desalination system will produce wastewater at a small rate (1% of the waste flow) associated with periodic membrane cleaning. This waste stream will be treated on site.

To assess the water quality impact of the ROC discharge, near-field and far-field modelling was conducted (refer Appendix R2). Assumptions made in regard to this discharge were as follows:

- The ROC will be discharged as a constant wastewater stream at the stated flow rate of 15 L/s.
- The discharge will have a constant salinity of 63.5 g/L. In regard to the near-field modelling where receiving water density is important, it has been assumed that ambient water will have a salinity of 35 g/L.

- The ROC temperature will be the same as that of the adjacent receiving waters. For the near-field modelling it has been assumed that this temperature was 24° C.
- There are no 'exotic' pollutants in the brine/ROC stream that would warrant detailed assessment.

Near-Field Impacts

Near-field assessments (assessment in the immediate vicinity of the discharge) were conducted using the CORMIX model which is an accepted industry standard model for such applications. The assumed discharge and diffuser characteristics are as follows:

- Several outfall diffuser configurations were assessed. The proposed configuration comprises a 10 m long diffuser with 0.04 m diameter orifices located every 1 m along the diffuser (i.e. 11 in total) facing in alternate directions. This configuration will have an exit velocity from each outfall port of the order of 1.0 m/s which will encourage maximum initial mixing.
- It was assumed that the diffuser was oriented perpendicular to the prevailing current direction and that the minimum water depth at this site was 6 m.
- Spring–neap tide model duration velocity time series data were extracted from the far-field hydrodynamic model to inform the near-field modelling. For conservativeness, the lower 10th percentile velocity value from this data record (0.03 m/s) was adopted for modelling.

Based on this set of assumptions, the model simulations of near-field mixing were performed and the results are shown on Figures 8.7.20 and 8.7.21. The findings of these simulations were as follows:

- The discharge receives greater than 30:1 dilution within 3 m of the end of the outfall; and
- By the time the discharge plume falls to the seabed, the dilution rates exceed 250:1.

Further CORMIX modelling was also conducted under mean velocity conditions (0.154 m/s) and bottom impact dilutions of more than 840:1 were predicted.

From these assessments it has been concluded that there will no detectable changes in local water quality patterns due to the ROC discharge.

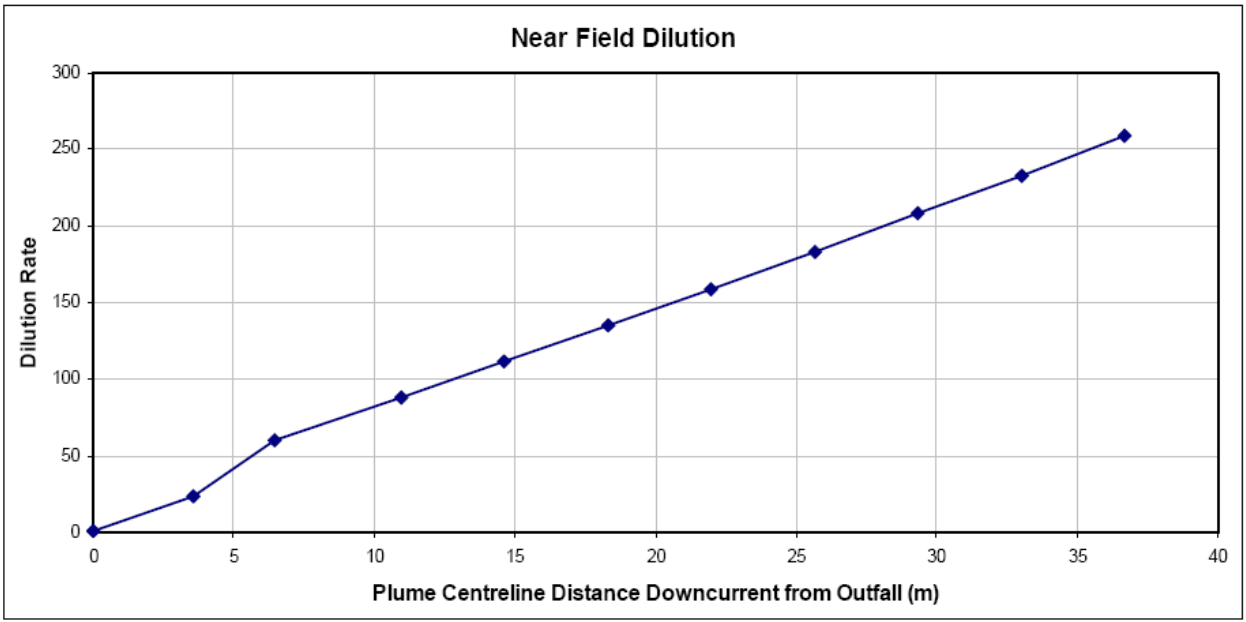


Figure 8.7.20 Near Field Dilution with Distance Down Current from Outfall

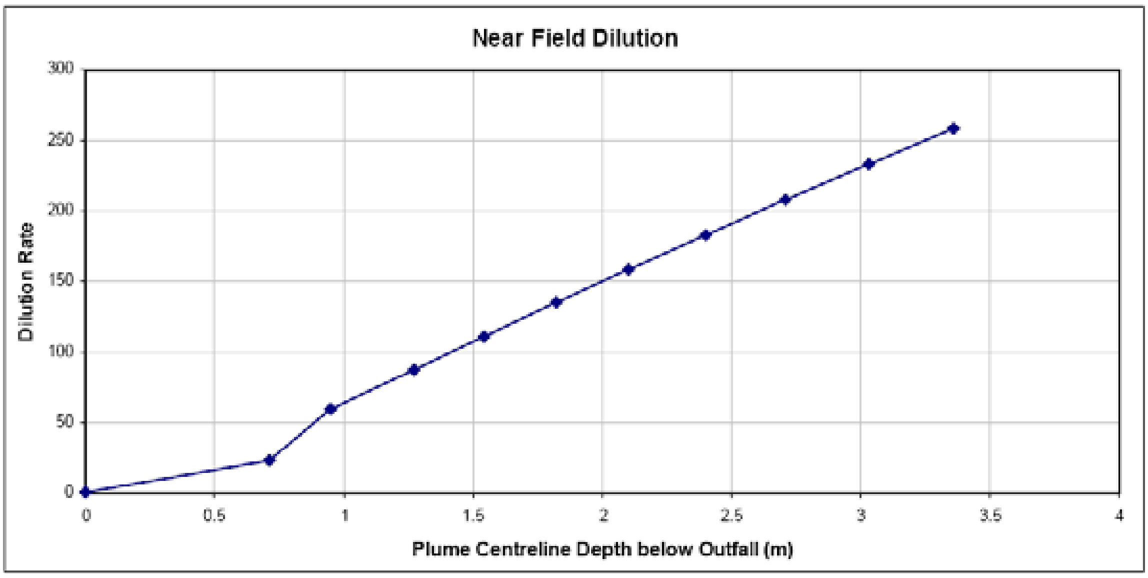


Figure 8.7.21 Near Field Dilution with Depth Below Outfall

Far-Field Assessments

From a far-field perspective (i.e. beyond the immediate vicinity of the discharge and throughout Port Curtis), the impact of the ROC discharge was assessed by simulating a 952 g/s discharge of a conservative tracer (e.g. salt) at the likely location of the outfall. This is equivalent to the 54 m^3/hr ROC discharge at a salinity of 63.5 g/L. The model was run until quasi steady state conditions resulted and results were extracted for the sites shown in Figure 8.7.22. Further details are given in Appendix R2.

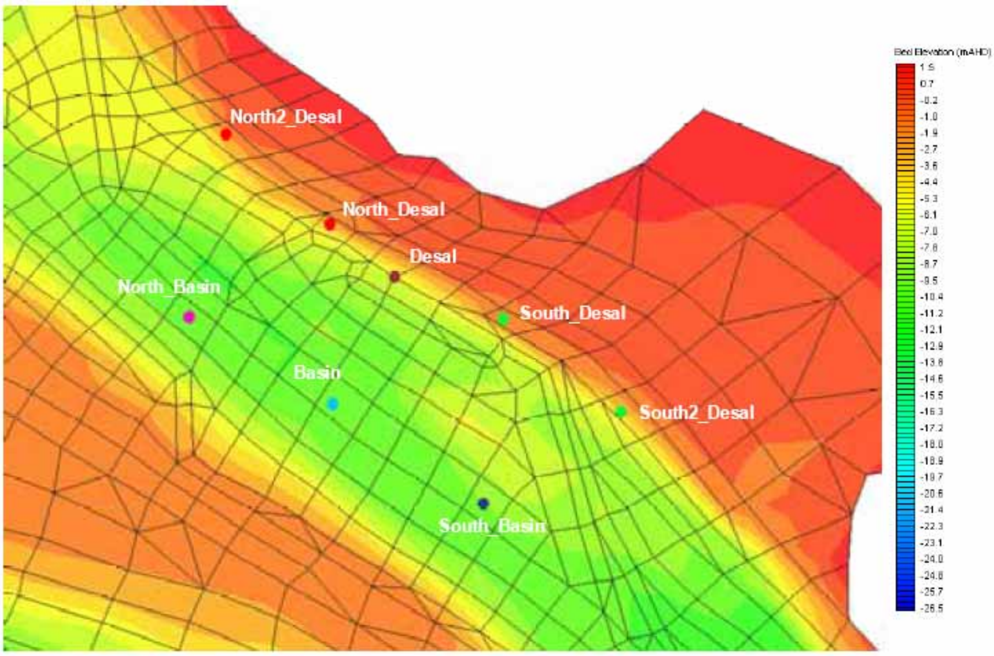


Figure 8.7.22 Salinity Model Result Extraction Locations

The results of these assessments are presented in Figure 8.7.23. These results show a maximum far-field salinity increase of the order of 0.22 g/L, which given background levels of more than 35 g/L at many times of the year and also the natural variable salinity concentrations throughout Port Curtis, will be essentially undetectable.

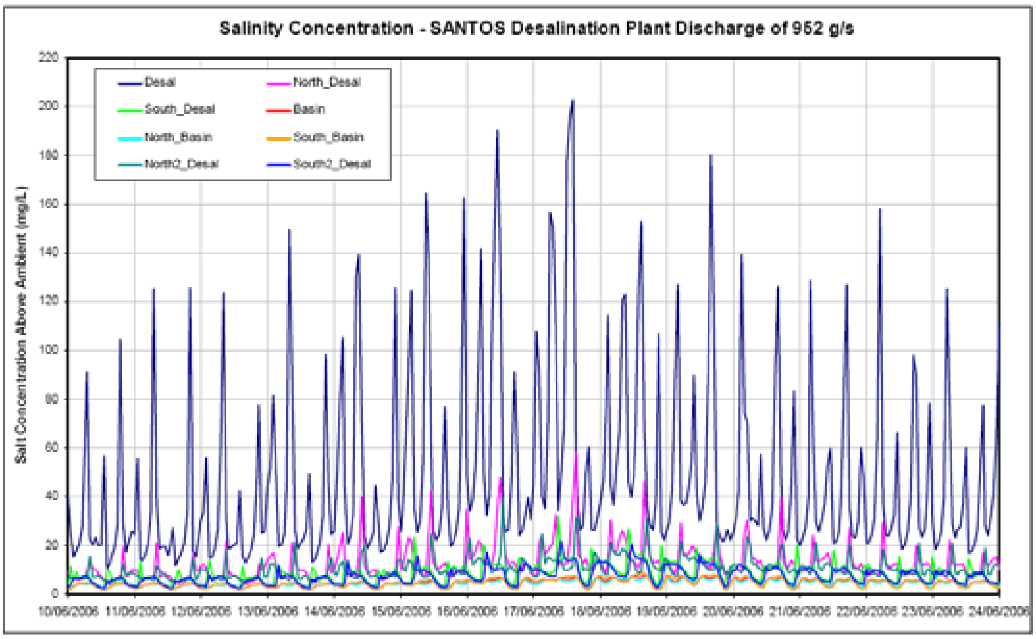


Figure 8.7.23 Far Field Salinity Modelling Results

On this basis it can be shown that the ROC discharge will have no significant water quality effects anywhere in Port Curtis.

8.7.4.7 Cumulative Impacts

At the time of EIS compilation (May 2009) there were two other LNG projects that had been publicly announced for Curtis Island on the Department of Infrastructure and Planning's website. These projects were:

- Queensland Curtis LNG Project proposed to be developed by BG International Ltd and Queensland Gas Company Ltd. This project is for the development 3 gas trains of total capacity up to 12 million tonnes per annum and marine loading facilities.
- Australia Pacific LNG Project proposed to be developed by a joint venture of Origin Energy and ConocoPhillips. This project is for the development of 4 gas trains of total capacity of up to 16 million tonnes per annum and associated marine loading facilities.

The EISs for these projects are still being prepared (and will be released subsequent to submission of the GLNG EIS). Therefore no design information or results of impact assessment studies are publicly available at this point in time. Accordingly, it is not possible to comment on specific impacts. However, Santos understands that these proposals will also require dredging in Port Curtis and will potentially include discharge of treated waters, as per Santos' LNG facility. Therefore, similar types of impacts associated with these activities are likely to occur if these proposals proceed.

The cumulative impacts of multiple dredging programs associated with other planned developments cannot be determined at present as the timing and extent of these other programs is not known. Should they occur concurrently then there may be an opportunity to undertake capital dredging as a single program, although this will need to be undertaken in consultation with GPC and other proponents.

With respect to the potential impacts of multiple dredging projects, the Queensland Government is currently undertaking a master planning exercise to ensure a coordinated approach to the planned development of Port Curtis. This plan considers the dredging and dredge material placement activities that are required to develop the LNG precinct on Curtis Island (including the GLNG Project and other projects) as well as the further development of Fisherman's Landing. In parallel with this process the Gladstone Ports Corporation (GPC) has commenced the planning and environmental assessment process required for a port-wide dredging program. The GPC project proposes a single dredge material placement area of sufficient capacity to accommodate the combined dredged material from all proposed projects. Santos and other relevant stakeholders are liaising with the Queensland Government and GPC with respect to the plan.

A summary of the potential impacts and mitigation measures is shown in Table 8.7.13.

Table 8.7.13 Potential Coastal Impacts and Mitigation Measures Summary

Aspect	Potential Impact	Mitigation Measure	Objective
Construction			
Water Quality.	Dredging/construction impacts on water quality.	Implement approved dredge management plan (DMP) and construction environmental management plan (EMP) before any dredging /construction occurs.	Protect marine environment.
Marine Sediment.	Mobilisation of contaminants during dredging.	Implement approved DMP and construction EMP before any dredging /construction occurs.	Protect marine environment.
Operation			
Water Quality.	Discharges from LNG facility.	Implement standard operational procedures and catchment management/stormwater treatment measures including operational EMP.	Protect marine environment.
Marine Sediment.	Maintenance dredging impacts on water quality.	Implement approved DMP before any dredging occurs.	Protect marine environment.
Marine Sediment.	Mobilisation of contaminants during maintenance dredging.	Implement approved DMP before any dredging occurs.	Protect marine environment.
Decommissioning and Rehabilitation			
Water Quality.	Potential impacts on water quality from decommissioning activities.	Implement approved decommissioning plan before any decommissioning activities occur.	Protect marine environment.
Marine Sediment.	Mobilisation of contaminants during decommissioning activities.	Implement approved decommissioning plan before any decommissioning activities occur.	Protect marine environment.

8.7.5 Summary of Findings

8.7.5.1 Existing Water Quality

When compared with relatively stringent water quality guidelines, it can be surmised that existing water quality in Port Curtis is high, although variable across the area. Water quality levels appear to be relatively strongly correlated with tidal state and hence bed load re-suspension. In particular, low tides exhibit generally a lower water quality than high tides, with the majority of nutrient and metal species at these times being associated with the particulate (rather than dissolved) phase.

8.7.5.2 Existing Sediment Quality

Existing levels of nutrients, organic compounds, and radionuclides in Port Curtis sediments in the vicinity of the GLNG Project site were either below the screening levels of the guidelines adopted for the studies or were below the LOR, or both. Elevated metal levels were suggested by the studies to be naturally occurring. Exceedance of guideline levels were noted for antimony, arsenic, chromium, copper, manganese, mercury and nickel. Iron and aluminium levels were found in notable concentrations, although these metals are generally not considered to be toxic contaminants in marine sediments.

No sediment samples were classified as AASS, but a limited extent of PASS areas was identified. However, sediments were generally found to exhibit an available ANC which was attributed to megascopic carbonate forms such as shells and microscopic foraminiferal components. It is the availability of ANC in the marine sediments which will control the amount of net acidity and subsequently whether treatment (liming) is required.

8.7.5.3 Dredging Impacts

The proposed capital dredging will include the dredging of an approach channel off the existing Targinie Channel, berthing pockets and a swing basin, to a design depth of 14.0 -mLAT. This will allow the safe passage, docking and loading of LNG bulk carriers, with a margin of safety between vessel keel and the seabed. The estimated *in-situ* volume of material to be dredged to lower the seabed to 14 -mLAT is approximately 8,000,000 m^3. Dredging is likely to be undertaken using a conventional cutter suction dredge, with all material pumped as a water/sediment slurry from the dredge through a floating discharge line to the marine dredge material placement facility. An additional 100,000 m^3 of material will be dredged at the MOF to a design depth of 8 –mLAT.

Modelling of the TSS concentrations generated by the proposed dredging shows there will be elevated concentrations (>25 mg/L) in an area of approximately 150 m by 500 m around the dredge during neap tides and approximately 200 m by 150 m during spring tides. Outside this area, maximum levels are in the order of 25 mg/L. When compared with typical background levels in this region of Port Curtis it is apparent that these TSS concentrations, while high, are comparable to the existing levels of variability in TSS present in the region. Further afield, additional maximum TSS concentrations are predicted to be less than 5 mg/L, which will be close to undetectable.

8.7.5.4 Gas Transmission Pipeline Construction Impacts

The gas transmission pipeline is planned to cross Port Curtis between Friend Point and Laird Point, adjacent to the alignment as the potential bridge. The pipeline is proposed to be buried approximately 2 m below the seabed in a 3 m deep trench, with ballast placed on top of the trench to secure the pipeline. The approximate distance from Friend Point to Laird Point is 1500 m. It is estimated that the trench required to lay the pipeline will be approximately 2 m wide, resulting in a total of 9,000 m^3 *in-situ* of disturbed sediments.

Modelling of the TSS concentrations generated by the proposed pipeline construction shows there will be elevated concentrations (>25 mg/L) in an area of approximately 600 m by 200 m during neap tides and approximately 150 m by 150 m during spring tides. Outside these areas, maximum increased concentrations of the order of 14-16 mg/L are predicted. When compared with typical background levels in this region of Port Curtis it is apparent that these TSS concentrations, while high, are comparable to the existing levels of variability in TSS present in the region.

Unlike the case of capital dredging, the TSS concentrations increases from the pipeline construction extend further afield (both upstream and downstream of the potential bridge) due to the higher water velocities in this region.

8.7.5.5 Bridge Construction Impacts

Given the management strategies proposed, no significant water quality impacts are expected from the construction of the potential access bridge to Curtis Island.

8.7.5.6 Hydrodynamic Impacts

Modelling has shown that any hydrodynamic changes to the tidal levels, tidal velocities, tidal flow rates as well as tidal flushing in Port Curtis as a result of the dredging and bridge and pipeline construction will not be significant.

8.7.5.7 LNG Facility Discharges

The LNG process is essentially a dry process that produces only minor quantities of wastewater. All waste water streams will be managed to minimise environmental risks and impacts on receiving waters. Implementation of the proposed stormwater management system will ensure that contaminated stormwater will not be discharged from the site and the water quality of Port Curtis will be protected.

The reverse osmosis plant to be used to provide freshwater to the LNG facility will produce a brine, or reverse osmosis concentrate (ROC), at a rate of approximately 54 m^3/hr (15 L/s) which will be discharged back to Port Curtis. Modelling of this discharge has shown that:

- The discharge receives greater than 30:1 dilution within 3 m of the end of the outfall;
- By the time the discharge plume falls to the seabed, dilution rates exceed 250:1;
- Under mean velocity conditions (0.154 m/s) bottom impact dilutions of more than 840:1 were predicted; and
- The maximum far-field salinity increase caused by the discharge will be of the order of 0.22 g/L, which given background levels of more than 35 g/L at many times of the year and also the natural variable salinity concentrations throughout Port Curtis, will be essentially undetectable.

From these assessments it has been concluded that there will no detectable changes in water quality in Port Curtis due to the ROC discharge.