Australia Pacific LNG Project

Volume 5: Attachments

Attachment 27: Coastal Environment Technical Report - LNG Facility and Pipeline

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Executive summary

Australia Pacific LNG Limited proposes a project which comprises the development of coal seam gas (CSG) fields, the construction of a main transmission pipeline, together with the construction of a liquefied natural gas (LNG) plant and associated facilities to export the gas to international markets. A site selection study was used to select Laird Point, Curtis Island as the location for the proposed LNG plant which is within the Curtis Island Industry Precinct of the Gladstone State Development Area.

WorleyParsons was commissioned by Australia Pacific LNG (the Proponent) to undertake the Environmental Impact Statement (EIS) in relation to the Laird Point site. This report presents the methodology, results and key recommendations for the coastal environment at the proposed site.

Tasks undertaken as part of the coastal environment study included:

- A literature review and evaluation of existing coastal data sets relevant to the Laird Point site
- Site inspection and data collection activities to supplement existing hydrodynamic information. measurement of hydrodynamic data was specific yet local to the proposed main transmission pipeline crossing site
- Hydrodynamic modelling, dredge plume and advection-dispersion simulations and near-field modelling were used to assess the potential impacts of proposed works that included dredging of the Materials Offloading Facillity (MOF) footprint for construction purposes, the seawater desalination outfall waste stream, and the main transmission pipeline crossing of The Narrows
- The assessment of local coastal processes and potential impacts from marine structures, reclamations, and dredging of approaches and swing basin

Findings from the review and evaluation of existing data sets are as follows:

- Relatively recent and detailed bathymetric data sets of the Port of Gladstone Western Basin (the Western Basin) are available from hydrographic surveys undertaken by Maritime Safety Queensland (MSQ) for the Gladstone Port Corporation (GPC). These complement the existing data sets available for the overall estuary. Bathymetric information externally sourced was subsequently integrated into the hydrodynamic model used for assessment purposes
- Tides in the Gladstone region are semi-diurnal with a diurnal inequality that becomes more pronounced as the tide enters the neap phase. Spring tide range at Fisherman's Landing is 3.4m which, in terms of tidal variation, is close to the proposed LNG plant site. In the North Passage Channel, adjacent to the proposed LNG plant site, currents are weaker than in the main channel leading to The Narrows but can reach 0.5 to 0.6m/s.
- Swell waves arriving at Gladstone are dissipated by the narrow channels, shoals and islands inside the estuary. Local wave conditions inside the Western Basin are calm to low, inferring that significant wave heights will be less than 0.3m around 75% of the time, based upon the wind record
- Wind records from exposed ocean sites show that approximately 7.5% of all winds are greater than or equal to 40 km/hr and come from the south-east. The proposed Australia Pacific LNG plant site is relatively protected from winds blowing from easterly directions. Afternoon winds recorded at Rundle Island include more easterly breezes, indicating a swing to the east as the convective sea breeze begins to dominate over the trade wind that is stronger in the morning. However, the greatest frequency of strong winds remains from the south-east sector

- There have been 26 tropical cyclones since 1960 that have tracked within a radius of 250km of Gladstone and these include intense cyclones such as 'TC David' that resulted in wind gusts of 83 knots in Gladstone. This provides an indication of the vulnerability of the Gladstone region to severe weather systems although historically, Gladstone has not been subjected to an intense tropical cyclone landfall
- Gladstone has a relatively high storm tide risk profile and is vulnerable to inundation due to the land elevation of existing urban areas. A one in 100-year ARI storm tide in Gladstone (Auckland Point) has a predicted elevation of 2.8m Australian Height Datum (AHD) (Queensland Government, 2004) and 3.3m AHD, which includes climate change adjustments. The design level proposed for the LNG plant is based upon a one in 100-year Annual Return Interval (ARI) storm tide and consequently has been set at +6m AHD
- Historical water quality characteristics of temperature, salinity and turbidity have been collected for more than a decade by various consultants and government. The median values from Department of Environment and Resource Management (DERM) data, considered to be representative of the Western Basin, are salinity 36.5ppt, water temperature 26.2ºC and turbidity 11NTU. Seasonal variation of average water temperature was calculated as 8.7 ºC and average salinity was 3.2ppt.
- The general characteristics of the sediments in the estuary are a mixture of gravels, sands, silts and clays. The deeper, maintained, channels with stronger currents contain coarser surficial sediments of sand and gravel, while the tidal flats are dominated by fine sands, silts and clay.
- The estuary exhibits higher turbidity levels naturally as a result of the combination of strong tidal currents and fine bed sediments. There appears to be a general net movement of fine sediments southwards due to the slightly stronger ebb tide. Higher turbidity typically occurs during summer months at times after rainfall, when stream run-off carries fine sediments to the estuary.

A site inspection on the 18 September 2009 and a data collection campaign from 20 July to 28 August 2009 provided the following information:

- At the proposed main transmission pipeline crossing location, across The Narrows, a bottom mounted Acoustic Doppler Current Profiler (ADCP) was continuously deployed for approximately one month and measured currents through the vertical water profile in addition to water depth varying with the tide
- Currents were measured during two separate campaigns that coincided with neap and spring tide phases across The Narrows in the vicinity of the proposed main transmission pipeline crossing location, using a vessel-mounted ADCP
- Drogue tracks were obtained using four GPS-tracked drifters over a spring tide deployment that provided spatial and temporal current information in relation to tidal excursions in the area from The Narrows to the southern end of the North Passage Island shoals
- Wind data and barometric pressure from the deployment of a weather station at Barney Point coincided with the deployment of the ADCP bottom-mounted current meter
- Photographs and notes from a site inspection conducted by small craft, allowing an appreciation of coastal processes occurring at the proposed site.

Key findings from the data campaigns were as follows:

- The ADCP transect data indicates that the peak ebb current velocity within the study area is relatively uniform over depth. The highest current speeds within the water column, exceeding 1.4m/s, were measured offshore from Laird Point where flows exiting Graham Creek and The Narrows converge. From the ADCP data the depth averaged peak spring tidal currents were approximately 1m/s and depth averaged peak neap tidal currents were 0.4m/s
- Drogue tracks from GPS measurements showed a spring ebb tide excursion of approximately 8.5km from the release point in The Narrows. Ebb tide surface currents 3m to 4.5m below surface were initially as strong as 1.2m/s and progressively weakened on the ebb tide run-out that lasted 4.5hrs. Ebb tide excursion was calculated using GPS co-ordinates as 8.5km. Flood tide currents were slightly weaker than ebb, confirming the asymmetrical tidal dynamics and the high tidal energy environment within the estuary. Drogues provided good agreement with ADCP measured currents and indicated the estuary is well-mixed vertically
- Average barometric pressure was 1018hPa, trending downwards over the deployment period and wind speed could be categorised as light increasing to moderate during the day (20 to 30km/hr or less) and was not considered as significantly influencing the assessment of the ADCP current data. On the 18 August 2009 maximum 10 minute wind speeds reached 45km/h from the east.

Coastal processes assessment of potential impacts and mitigation measures

Hydrodynamic modelling, field work, data analysis and interpretation of coastal processes were conducted to identify potential impacts in relation to the proposed Australia Pacific LNG site. A verified hydrodynamic model was used to assess potential modifications to the existing tidal currents, water levels, and cross-sectional flow rate pertaining to the proposed LNG plant and marine works that include deepening of the North Passage channel and dredging works associated with the Western Basin dredging and disposal plan.

The proposed LNG plant at Laird Point on Curtis Island is opposite Friend Point, which is located on the mainland side at the southern end of The Narrows. Marine infrastructure for product export is being considered to cater for a two-train LNG process by 2015, increasing to four-trains after 2016.

Components of the proposed LNG plant marine development that has the potential to impact the coastal processes at the site include the following:

- A reclaimed area for the LNG plant and the Materials Offloading Facility (MOF). A causeway constructed behind the mangrove fringe leads to the MOF
- A Materials Offloading Facility (MOF) is required for offloading modules and general construction materials, providing shelter to support vessels, and support for jetty construction
- A Product Loading Facility to cater for large LNG vessels, including an open trestle jetty and mooring dolphins
- A dredged swing basin and approach channel with sufficient depth and clearance to allow safe turning while maintaining an adequate under-keel clearance
- An outfall to disperse seawater desalination brine. Discharge would be to the marine environment and cater for construction and operation requirements
- A main transmission pipeline to cross The Narrows. Options assessed included Horizontal Directional Drilling (HDD), Flotation into a dredged trench, and Bottom pull method.

The following location options are being considered for the marine works associated with the Australia Pacific LNG project:

- Option 2a – swing basin and approaches at -13m Lowest Astronomical Tide (LAT) and MOF approach channel at -7.5m LAT to the east of North Passage Island.
- Option 1b – swing basin and approaches to the west of North Passage Island and MOF approaches to the east of North Passage Island.

Hydrodynamic model simulations were performed for the existing channels, Option 1b and Option 2a bathymetry. Potential impacts were assessed in the GPC's EIS for the Western Basin Dredging and Disposal Project and results are consistent with WorleyParsons hydrodynamic model. Potential incremental impact of Australia Pacific LNG Options were as follows:

- Changes to tidal amplitude associated with both Options were insignificant
- For Option 1b:
  - In the proposed MOF approach channel, velocities generally decrease although a slight increase is predicted where currents exit from the swing basin. Increases in velocity of up to 0.5m/s (ebb) are predicted on the shoals adjacent to the MOF channel upstream of North Passage Island.
- For Option 2a:
  - In the proposed Australia Pacific LNG Option 2a dredged area, velocities are predicted to decrease up to 0.4m/s (flood tide) and 0.5m/s (ebb tide). Current velocity in the MOF approach channel generally decreases
  - Substantial increases in velocity (0.35m/s flood and 0.7m/s ebb) are predicted to occur on the shoals upstream of North Passage Island as a result of increased flows there.

Wave impacts

Potential impacts from marine development Options 1b and 2a to locally generated wave conditions are as follows:

- Option 1b dredging and deepening works do not have a significant impact to locally generated wave heights
- Option 2a is predicted to produce a greater incremental change on wave heights than Option 1b. This would be evident for higher water levels in combination with extreme waves penetrating into the proposed swing basin area
- Incremental change to significant wave heights over the sand shoals to the north and south of North Passage Island are negligible due to Options 1b or 2a.

Storm tide impacts

Hydrodynamic modelling of the tropical cyclone design storm event for Option 1b or 2a predicts that differences in storm tide water levels, from existing conditions, are insignificant. This would indicate that Options 1b and 2a in addition to the Western Basin dredging and reclamation works have a low potential to impact the storm tide.

Marine structure impacts

Both the MOF and Product Loading Facility structures are expected to have a low potential for impact to coastal processes because sand transport activity is very low. The piled LNG Product Loading Facility jetty would have minimal impact to current and wave conditions. There is a potential for finer sediments to be deposited at the MOF site because it is proposed as a solid structure and would create quiescent zones where material may accumulate.

Reclamation impacts

Construction of the reclaim area has the potential to generate some turbidity, but would be naturally mitigated to a large extent by the intertidal nature of the site. Furthermore, the mangrove fringe in front of the causeway would act to trap fine sediments and provide a natural silt barrier for low turbidity concentrations associated with the construction process. Sediment run-off can also be managed through silt screens or similar.

Swing basin and approaches impacts

Hydrodynamic modelling has shown there is a potential for increased sediment movement across the North Passage Island shoals. The swing basin design is important in mitigating the impact of wave action from vessels and wind waves. Australia Pacific LNG will continue to assess the swing basin design and potential erosion will be identified and managed through monitoring on a regular basis and would trigger mitigation if necessary.

Flushing impacts

The potential impacts on flushing characteristics of the estuary were generally addressed in Western Basin Dredging and Disposal Project EIS. Local flushing times in Graham Creek and The Narrows are naturally poor and are not significantly affected by dredging works in the Western Basin including the Australia Pacific LNG dredge Options.

Capital dredging works associated with the Australia Pacific LNG Options 1b or 2a are predicted to marginally increase local flushing times as follows:

- Approximately three days for Option 1b, at a location within the swing basin to the east of North Passage Island
- Approximately five days within the swing basin area for Option 2a.

Dredging impacts

Assessment of the dredge plumes resulting from the formation of the swing basins and navigation channels was addressed as part of Western Basin Dredging and Disposal Project EIS.

It was noted the dredge plumes resulting from Australia Pacific LNG's Option 1b or 2a requirements would not result in potential impacts being any greater than those occurring for the other developments based on dredging equipment and production rate.

Turbid plumes associated with the MOF construction dredging have also been assessed using a hydrodynamic model. Maximum TSS concentrations of up to 0.06kg/m^3 (60mg/L) are predicted to occur at the entrance to Graham Creek with TSS concentrations up to 0.04kg/m^3 (40mg/L) extending into the creek. In comparison, dredge plume modelling results in the Western Basin Dredging and Disposal Project EIS for scenario two (multiple plume sources including Trailer Suction Hopper Dredge overflow) predict maximum TSS concentrations of 28mg/L in Graham Creek adjacent to Laird Point

and 53mg/L opposite Friend Point. The differences are dependent on the source locations of the dredge plumes.

Slower currents in the North Passage channel, close to the shoreline where the MOF is to be constructed should allow the option of using silt curtains to contain turbidity (subject to more detailed investigation).

Desalination brine discharge

Seawater desalination will supply fresh water during both the construction and operational phases of the proposed Australia Pacific LNG project.

Both near-field (CORMIX) and far-field (MIKE21) modelling were undertaken to assess dispersion of the brine discharge using an outfall and diffuser arrangement. In the near-field, it was predicted there would be no discernible impact from the discharge of the brine reject to the water quality in the vicinity of the diffuser as dilutions are adequate.

From the far-field modelling it was predicted maximum salinity increases, for either Option, do not exceed 0.11ppt which is within ambient seawater variation. The potential impact from accumulation of salinity resulting from the Australia Pacific LNG discharge is negligible.

The predicted mean and maximum increases in salinity due to the cumulative discharges of desalination brine from Australia Pacific LNG, QCLNG, and GLNG are well within the natural ambient salinity variations and would not be detrimental to the marine environment. Salinity tolerances for a range of marine fauna are summarised in Volume 4, Chapter 10.

Pipeline crossing

The gas transmission pipeline is required to cross The Narrows to Curtis Island, terminating at the Australia Pacific LNG processing plant. Horizontal Directional Drilling (HDD) is the preferred method for crossing The Narrows. If the HDD is not adopted, alternatives include flotation, and bottom pull methods requiring a dredged trench excavated using various dredging plant and techniques such as cutter suction dredge, tailing suction hopper dredge, or backhoe dredge.

Potential impacts from the proposed construction of the pipeline crossing are predominantly associated with workspace requirements for both the workforce and equipment (on both banks of the waterway) creating habitat disturbance and dredge plumes if trenching is required.

In the event a narrow trench is required for the pipeline in order to cross The Narrows, turbidity plumes associated with dredging were assessed using modelling. For the assumed dredging parameters and within Graham Creek and surrounding North Passage Island, the mean Total Suspended Solids (TSS) is predicted to elevate by approximately 10mg/L and the maximum TSS in Graham Creek reaches 36mg/L.

The marine and coastal environment affected by the pipeline crossing construction will be rehabilitated. Operation of the pipeline is not expected to impact the marine and coastal environment. Monitoring of the area post construction will determine if any impacts persist through time and, if necessary, appropriate corrective actions will be employed.

Annual siltation and maintenance dredging

The Option 1b siltation modelling indicates the following:

- The net sand transport potential in the Option 1b dredged area decreases due to the reduction in velocities.

- Annual sand transport into Option 1b swing basin and approaches ranges between 5,500 to 22,000m^3/year.
- A net siltation of 48,000m^3/year is predicted.

The Option 2a siltation modelling indicates the following:

- The predicted coarse material sedimentation is between 12,000m^3/year and 48,000m^3/year.
- The net silt deposition for Option 2a is 81,000m^3/year.

Contents

Figures

Tables

1. Introduction

Australia Pacific LNG proposes a project of 'world scale' Liquefied Natural Gas (LNG) production, utilising the company's substantial coal seam gas (CSG) resources to establish a long-term industry in Gladstone, Queensland.

This section provides a description of the coastal environment in which the LNG plant and gas transmission pipeline are to be located, particularly focussing on the marine based components of the proposed development that have the potential to impact on the coastal environment. The impact assessment also examines potential mitigation measures.

Figure 1.1 presents the proposed location of the LNG plant in relation to the Curtis Coast Regional Coastal Plan boundary and the key coastal sites as described in the Curtis Coast Regional Management Plan (Queensland Government 2003). Regional policies, resources, and environmental values associated with key coastal sites are considered in relation to construction and operation activities around the LNG facility location and the gas transmission pipeline route across the Narrows to Curtis Island.

1.1 Purpose

This chapter identifies and assesses potential impacts on the existing coastal environment from the proposed LNG facility and associated gas transmission pipeline. Where possible, methods to avoid or mitigate adverse impacts are identified. Direct, indirect and cumulative impacts are fully examined and addressed.

The proposed LNG plant location at Laird Point on Curtis Island is 12km north by north-west from Gladstone. Laird Point is opposite Friend Point which is located on the mainland side at the southern end of The Narrows. The proposed LNG plant includes all process and waste management facilities, as well as associated marine infrastructure for a two-LNG train process by 2014, increasing to four-trains after 2015.

Operation of the proposed LNG Plant requires transmission of CSG from the upstream gas fields to Curtis Island. The gas transmission pipeline, at the crossing to Curtis Island, could potentially impact on a relatively undisturbed coastal wetland habitat and the waterways of The Narrows and Graham Creek that are recognised as a near pristine area of state significance under the Regional Coastal Management Plan.

The LNG facility is to incorporate marine based components such as a Materials Offloading Facility (MOF), ship berths and jetty. The required ship swing basins and navigation channel are part of the Port of Gladstone Western Basin Dredging and Disposal Project. During operations, utilities will include waste treatment and fresh water production. Water production using a desalination plant will supplement water storage from rainfall. Liquid waste streams consisting of small volumes of treated sewage and concentrated brine will be discharged into the marine environment.

1.2 Scope of Work

The scope of work, as specified in the Terms of Reference (The Coordinator-General, November 2009), relates to coastal processes, including descriptions of the physical processes within the study area and environmental values of the relevant coastal resources, and how these could be affected by the proposed development.

The assessment is based on hydrodynamic investigations that describe the influence of tides, waves, currents, turbidity, extreme events (cyclones) and how they influence coastal processes.

Impacts associated with the development of the MOF and causeway, the desalination plant brine reject discharge into the marine environment, and the turbid plume from the pipeline crossing dredge option are assessed and described. Implications for marine flora and fauna are discussed within Volume 4, Chapter 10. Project components within the coastal study area are identified in Figure 1.2.

The impacts of dredging channels and swing basins within the Gladstone Harbour's Western Basin are being investigated through an EISbeing developed byGladstone Port Corporation (GPC). These impacts are outside the scope of works for the Australia Pacific LNG Project and where relevant, reference is made in this report to the GPC Western Basin Dredging and Disposal EIS.

1.3 Legislative Framework

The assessment of the coastal and marine activities in the study area has been undertaken in consideration of the following legislation:

- *Coastal Protection and Management Act 1995* (Queensland) and *Coastal Protection and Management Regulation 2003*
- State Coastal Management Plan – Queensland's Coastal Policy (2001) and including the Curtis Coast Regional Coastal Management Plan
- *Marine Parks Act 2004* and Great Barrier Reef Marine Park (Mackay/Capricorn Section) Zoning Plan and Great Barrier Reef Coast Park Zoning Plan
- *The Environmental Protection Act 1994* and Amendments, Regulations and Policies
- *Integrated Planning Act 1997*
- *Transport Infrastructure Act 1994*
- *State Development and Public Works Organisation Act 1971*
- Environmental Protection (Water) Policy 2009 (the Water EPP)

An overview of the relevant Queensland legislation referred to above and its purpose is provided in Volume 1, Chapter 2 of the Environmental Impact Statement. Statutory plans, state planning policies, and legislative regulations that are directly relevant to coastal activities undertaken by the Australia Pacific LNG Project are discussed below.

1.4 Regional Coastal Management Plan

The Curtis Coast Regional Coastal Management Plan (Curtis Coastal Plan) describes how areas in the coastal zones are to be managed. Policies under the regional coastal plan are based on direction from the State Coastal Plan that fall within the following topic areas relevant to the Australia Pacific LNG Project:

- Coastal use and development
- Physical coastal processes
- Public access to the coast
- Water quality

- Coastal landscapes
- Conserving nature
- Coordinated management
- Research information

The topic areas of cultural heritage and Indigenous Traditional Owner cultural resources are dealt with separately under sections of the EIS.

Regional policies potentially apply to the Key Coastal Sites of:

- Curtis Island (South West)
- The Narrows
- Gladstone Harbour (in particular the Western Basin)

The Great Barrier Reef Marine Park Authority (GBRMPA) has jurisdiction over Great Barrier Reef administrative boundaries. The Commonwealth Government has an obligation to protect Great Barrier Reef Marine Parks and World Heritage Areas. The proposed LNG development at Laird Point is located within a Great Barrier Reef World Heritage Area and borders the Great Barrier Reef Coast Park, both significant coastal resources. The Commonwealth has outlined obligations for the management of World Heritage Areas under the *Environment Protection and Biodiversity Conservation Regulations 2000*, Schedule 5 Australian World Heritage Management Principles.

In July 2008 three new areas were included in the Gladstone State Development Area, one of which was the Curtis Island Industry Precinct. Around the same time amendments were made to modify the Gladstone Development Scheme and precinct plans to incorporate the additional areas included in the Gladstone State Development Area and other changes to improve the operability of the development scheme. The development scheme is supported by various policies and one of these is directed to ensure the impacts of development on the environment, including cumulative impacts, are minimised to meet the requirements of applicable Government policies.

1.4.1 Key Coastal Plan Regional Policies

Specific regional issues for the Australia Pacific LNG Project have been identified by reference to policies described within the Regional Coastal Management Plan. The Curtis Coastal Plan is a statutory instrument under the *Coastal Protection and Management Act 1995* that has the effect of State planning policies under the *Integrated Planning Act 1997*.

Policies considered relevant to the Australia Pacific LNG Project are as follows:

- Policy 2.1.1 Areas of state significance (social and economic)

  The Australia Pacific LNG main transmission pipeline route traverses the Gladstone State Development Area. The issue here will be for future planning decisions to ensure this area (Targinie Precinct) is maintained and protected from incompatible land uses and activities.

  The closest Strategic Port Land is 3km north-west of Fisherman’s Landing, within 1km of where the pipeline route approaches the crossing of The Narrows, but this land is not directly affected.

  There are no Areas of State Significance in relation to the Project site on Curtis Island.

- *Policy 2.1.3 Coastal-dependent land uses*

  There is no regional policy to address coastal-dependent land uses. The State Coastal Plan policy 2.1.3 acknowledges the need to give preference to coastal-dependent land uses ahead of other urban land uses.

  The preferred Australia Pacific LNG Project site is remote from urban areas and its choice of location and development options are proposed to minimise impacts on coastal resources. The site is also an adequate distance from other proposed LNG facilities.

- *Policy 2.1.5 Maritime Infrastructure*

  The Australia Pacific LNG Project maritime infrastructure is major private infrastructure of state economic importance (declared a Significant project on the 7 May 2009).

  Construction and operation impacts directly related to maritime infrastructure, in the undeveloped inshore tidal waterways adjacent to Curtis Island, has been assessed as part the Australia Pacific LNG Project EIS. This assessment describes the level of potential impact due to both the MOF and the product export facility as well as mitigation and management of potential impacts.

- *Policy 2.1.7 Mining and Petroleum Activities*

  The regional policy advises that where a project has an overall net benefit to the State and is located in an Area of State Significance (natural resources), rehabilitation of the disturbed areas shall be undertaken to facilitate the restoration of natural ecological processes.

  The proposed LNG product processed on site will be managed to have minimal adverse impacts on coastal resources. Operations will be managed to minimise adverse impacts on key coastal sites.

- *Policy 2.1.8 Dredging*

  Gladstone Ports Corporation (GPC) will be the proponent for dredging activities in the Western Basin. Dredging within Gladstone port limits is undertaken on a regular basis to maintain existing navigation channels.

  The level of potential impact from the substantial dredging program planned for new berths and channels within the harbour is described within the Port of Gladstone Western Basin Dredging and Disposal Project EIS (GHD Pty Ltd 2009) in addition to assessment of specific components undertaken within the Australia Pacific LNG Project EIS. Potential impacts on seagrass beds and water quality are included in the assessments referred to.

- *Policy 2.1.9 Reclamation*

  GPC will be the proponent for dredging activities in the Western Basin. Potentially, there is capacity for 55million cubic metres to be accommodated within the bunded reclamation area north of Fisherman’s Landing comprising of the Fisherman’s Landing Northern Expansion in addition to the larger Western Basin reclamation.

  From the proposed dredging stages in the Western Basin (stage 1A to stage 4), an estimated total maximum quantity of 36 million cubic metres will be disposed of in the reclamation area excluding the Australia Pacific LNG Project dredging volumes.

  Capital and maintenance dredging activities, and the reclamation works is the subject of separate approvals by GPC.

Reclamation works are proposed by Australia Pacific LNG to raise finished levels at the site so as to conform to guidelines to mitigate the adverse impacts associated with coastal hazards.

- *Policy 2.1.15 Ports of Gladstone and Rockhampton*

Gladstone Ports Corporation released its 50 year strategic plan in 2008. The 2008 update of the strategic plan identified future expansion prospects for the port to accommodate potential growth in the industries surrounding Gladstone and to provide security to the Central Queensland economy in a sustainable manner. Activities GPC are currently pursuing in the development of the port are as follows:

– The Western Basin Master Plan (prepared under section 10(2) of the *State Development and Public Works Organisation Act 1971* (SDPWO Act)). Submissions on the plan closed 4 September 2009.

– The Fisherman's Landing Northern Expansion EIS – declared a significant project on 14 October 2005. An EIS is required under Section 26 of the SDPWO Act.

– The Western Basin Dredging and Disposal Project EIS (declared a significant project on 24 April 2009). A final decision on the EIS is expected in 2010. Note that the EIS was undertaken in parallel with the Fisherman's Landing Northern Expansion EIS.

The EIS documents describing these projects specifically address the regional coastal policy requirements for the Port of Gladstone.

- *Policy 2.1.16 Infrastructure development*

The LNG facility site boundary is located, in part, across a significant coastal wetland as depicted in Map 11 of the Regional Plan that refers to Areas of State Significance (Natural Resources).

The location of the LNG Plant within the land boundary has been carefully sited and impacts to coastal resources have been minimised to a large extent through design considerations that minimise loss of vegetation and habitat, in addition to minimising the impact on coastal wetland hydrology and surface water flow including tidal exchange with the mangrove stands.

- *Policy 2.2.1 Adaption to Climate Change*

Design measures have been implemented to take into account adaption to climate change. Climate change and the implications to marine based operations are considered in Volume 4, Chapter 4 of the EIS.

- *Policy 2.2.2 Erosion prone areas*

The site for the proposed Australia Pacific LNG facility and its maritime infrastructure is not located on a shoreline constituted of sand. The adjacent shorelines are mostly rock and hard substrate, and the inter-tidal zone is consolidated mud. Small volumes of coarse sand can be found at Laird Point and Graham Creek, to the north of the site, but will not be impacted by construction activities. The majority of the low sand ridge behind the mangrove line will not be affected, with the exception of its northern tip where the MOF is proposed.

- *Policy 2.2.4 Coastal Hazards*

The Australia Pacific LNG site is located at the northern end of the Gladstone estuary where it is known a slight amplification occurs with the incoming tide. When combined with tropical cyclone surge, this amplification will lead to water elevations above those shown in published references for Auckland Point.

Elevated water levels, due to storm tide, is described in the EIS and compared to the proposed 'finished level' of reclaimed land where the LNG plant is proposed to be built. The potential impact of elevated water level has been examined in reference to the Guideline on Mitigating the Adverse Impacts of Storm Tide Inundation.

- *Policy 2.3.1 Future need for access*

  Public access to the proposed Australia Pacific LNG Project site will be restricted due to safety and security requirements. However, where access is needed along the coast, it will be afforded by way of tracks/roads at the rear of the site in accordance with policy 2.3.3, that is, maintained in a natural undeveloped state and in keeping with the landscape.

- *Policy 2.4.1 Water quality management*

  The Australia Pacific LNG Project proposes to use seawater desalination for its fresh water needs. Potential adverse impact s to water quality will be minimised by selecting best practise techniques for the processing of seawater and the processing of LNG in general. Minimising the volume of water required for construction and operation of the plant reduces the potential impact on the marine environment water quality.

  Adverse impacts on water quality from dredging and reclamation works are described in the relevant sections of the EIS.

- *Policy 2.4.2 Wastewater discharges to coastal waters*

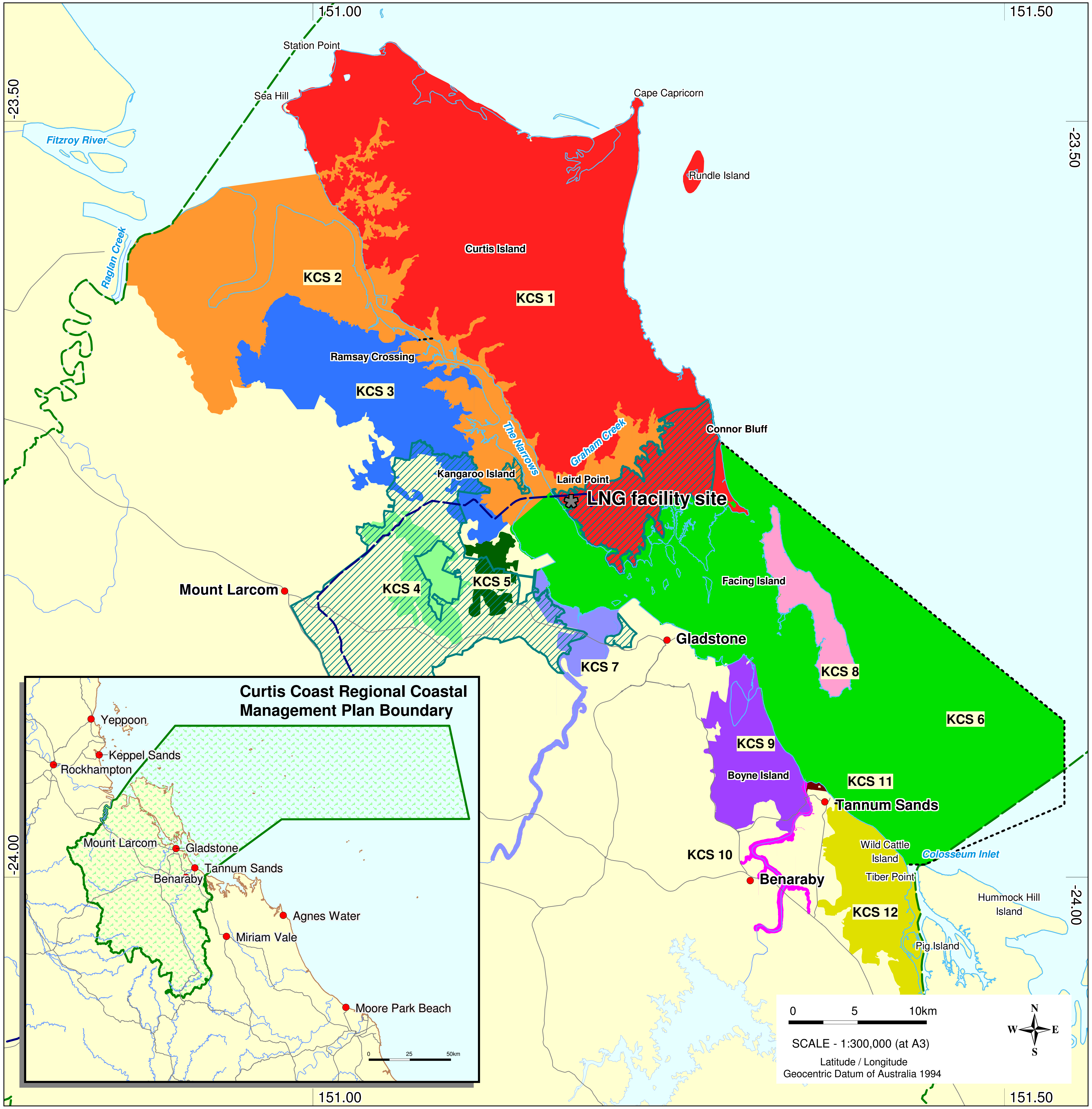
  A proposed sanitary treatment plant in the form of an extended aeration biological treatment plant will be designed to treat the sanitary wastewater to acceptable standards, suitable for reuse as irrigation water when possible, and for direct discharge to ocean outfall. Digested sludge will be periodically removed using a vacuum truck and disposed of off-site. Seawater desalination will be used for process water needs and the desalination brine wastewater stream discharged to the marine environment via an outfall and diffuser.

- *Policy 2.4.4 Stormwater management*

  At the proposed Australia Pacific LNG site the stormwater handling during a rain event is based on a first flush concept, where the first 25mm of rain (considered as potentially contaminated) will be contained and treated through the oily water treatment system. Any excess stormwater over the first 25mm of rain will be diverted to the stormwater holding pond designed with sufficient detention time to allow solids to settle out. The clean stormwater, after solid settlement, would overflow to a ditch with a geotextile liner and then offshore.

- *Policy 2.8.1 Areas of state significance (natural resources)*

  As indicated under policy 2.1.9, the proposed reclamation works on the site are to cover a portion of the significant coastal wetland. However, the potential direct habitat loss is small in context with historical impacts from previous reclamation works in the Port Curtis region. Inter-tidal wetlands are still prevalent within the region and the proposed LNG plant affects a localised area that will use appropriate environmental management techniques to minimise the impacts, such as retaining the majority of the mangrove stands which are the more environmentally productive habitats.



LEGEND

- Roads
- Major Watercourses
- Port of Gladstone Limit
- Main APLNG Pipeline Option 3F
- Curtis Coast Coastal Management Plan 2003 Planning Area
- Coastline / Reefs / Cays
- Gladstone State Development Area

Key Coastal Sites

- KCS 1: Curtis Island
- KCS 2: The Narrows
- KCS 3: Rundle Range
- KCS 4: Mt Larcom
- KCS 5 Targinie Remnant Vegetation
- KCS 6: Gladstone Harbour
- KCS 7: Calliope River/ Flying Fox Creek
- KCS 8: Facing Island
- KCS 9: Boyne Island/ South Trees Inlet
- KCS 10: Boyne River
- KCS 11: Canoe Point
- KCS 12: Wild Cattle Island/ Colosseum Inlet
- KCS 13: Capricorn Group

Data source: Curtis Coast Regional Coastal Management Plan, September 2003

Rev	Date	Revision Description	ORIG	CHK	ENG	APPD
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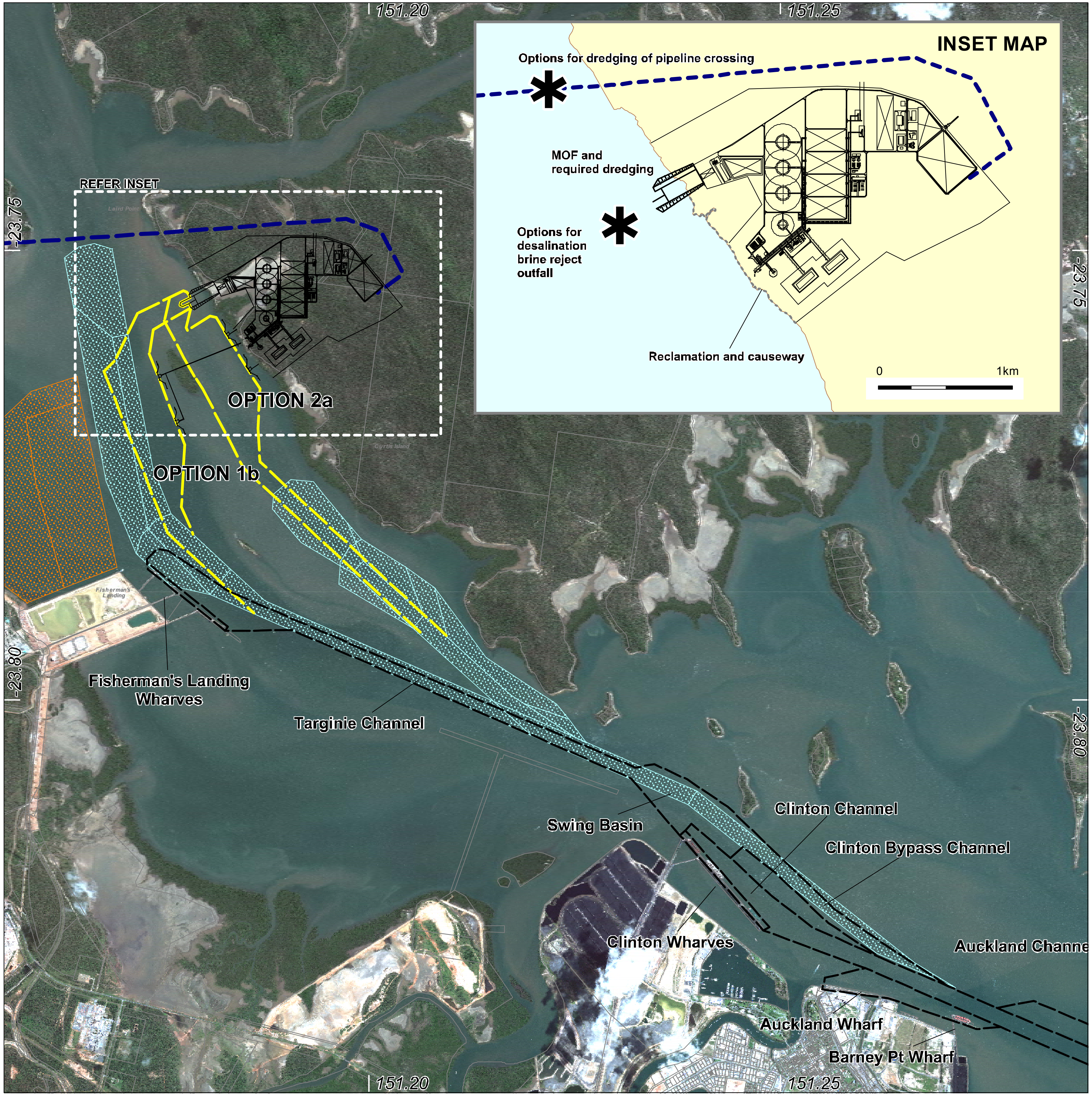
Figure 1.1 Sub-area of Curtis Coast Planning Area showing key coastal site

Project No: 301001-00752 | Figure: 00752-00-EN-DAL-0034 | Rev: 0



LEGEND

- Gas pipeline route
- Australia Pacific LNG dredge options
- Property boundaries
- Port of Gladstone passage channels*

Port of Gladstone Western Basin Master Plan

- Dredge areas
- Reclamation areas

** Port of Gladstone Passage Channels digitised from MSQ Port of Gladstone Passage Plan - Gladstone Pilotage Area - March 2008*

Development footprint translated from Conceptual Site Plan 25509-100-10005.dgn supplied by client 24/07/2009

APLNG Dredge Options 1b and 2a supplied by client 11 and 15/09/2009

Port of Gladstone Dredge and Reclamation Areas supplied by GHD 27/10/2009

Port of Gladstone Passage Channels digitised from MSQ Port of Gladstone Passage Plan - Gladstone Pilotage Area - March 2008

Satellite imagery captured by GeoEye-1 on 24 March.

0 1 2km

SCALE - 1:50,000 (at A3)

Latitude / Longitude
Geocentric Datum of Australia 1994

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Figure 1.2 Project components within the coastal environment study area

Project No: 301001-00752 | Figure: 00752-00-EN-DAL-0042 | Rev: 0

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2. Existing coastal environment

Gladstone Harbour is an important industrial centre on the Curtis coast and is undergoing substantial and dynamic growth, largely due to new industries or the expansion of existing industries.

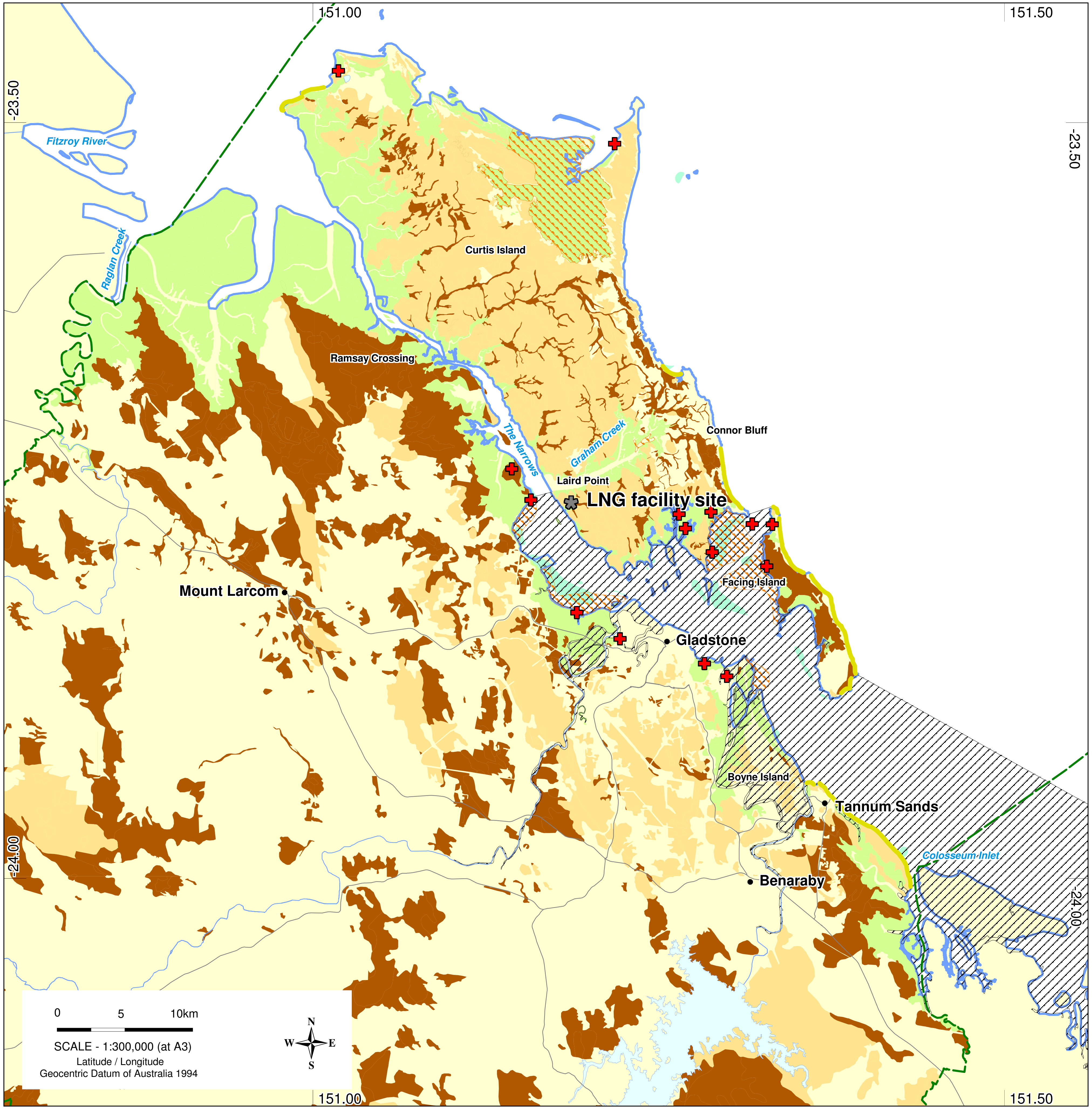
The Curtis Coast region includes areas of high conservation value as well as areas of state significance which include strategic port land and state development areas. Areas of conservation include wetlands, seagrass beds, turtle nesting beaches, shore bird roosting areas, coral cays, and planar reefs.

The proposed development site and the Western Basin lie within the Great Barrier Reef World Heritage Area (GBRWHA). Marine parks of State significance are also located next to the Western Basin. The proposed site for the LNG facility coincides with a Scenic Coastal Landscape and Significant Coastal Wetland that is listed as an Area of State Significance under the Regional Coastal Management Plan. Figure 2.1 contains samples of sites with high conservation value that are referenced from the Regional Coastal Management Plan. Figure 2.2 provides the Great Barrier Reef Marine Park administrative boundaries.

2.1 Gladstone Harbour

Gladstone is the principal port in central Queensland and services the hinterland that is rich in natural resources and has substantial established mining interests. The 2006/07 yearly export capacity of Gladstone was 75 million tonnes from 1300 vessel transits (GPC 2008). The Port of Gladstone plans to be able to accommodate up to 300 million tonnes of export product within the next 50 years (GPC 2008).

The pilotage area includes all waters below the high water mark, including navigable waters of rivers and creeks, from Ramsay Crossing in the north of the Narrows down to the northern tip of Tiber Point on Hummock Hill Island and around to Connor Bluff on Curtis Island taking in the waters surrounding Facing Island. Auckland and Targinie channels are the existing navigable shipping channels in Gladstone Harbour that provide access into the Western Basin. Targinie channel, leading to the proposed LNG facility, is shown in Figure 1.2 and has a currently maintained dredged depth of 10.6m LAT (Lowest Astronomical Tide). Further dredging of Gladstone Harbour has been proposed as part of the Western Basin Master Plan and the Western Basin Dredging and Disposal Project. An EIS has been completed by the Gladstone Ports Corporation to gain approval for this further dredging (GHD Pty Ltd 2009).



LEGEND

- Roads
- Major Watercourses
- Curtis Coast Coastal Management Plan 2003 Planning Area
- Coastline\ Reefs

Habitat Areas

- Eucalypt Woodland
- Eucalypt Forest
- Coastal Wetlands
- Seagrass

Dugong Protection Area

- Dugong Protection Area 'B'

Shorebirds and Turtles

- Major Shorebird Roost Sites
- Major Shorebird Feed Sites *
- Recorded Turtle Nesting Beaches

** Indicates major feeding sites only; minor roosting sites occur throughout the Curtis Coast area.*

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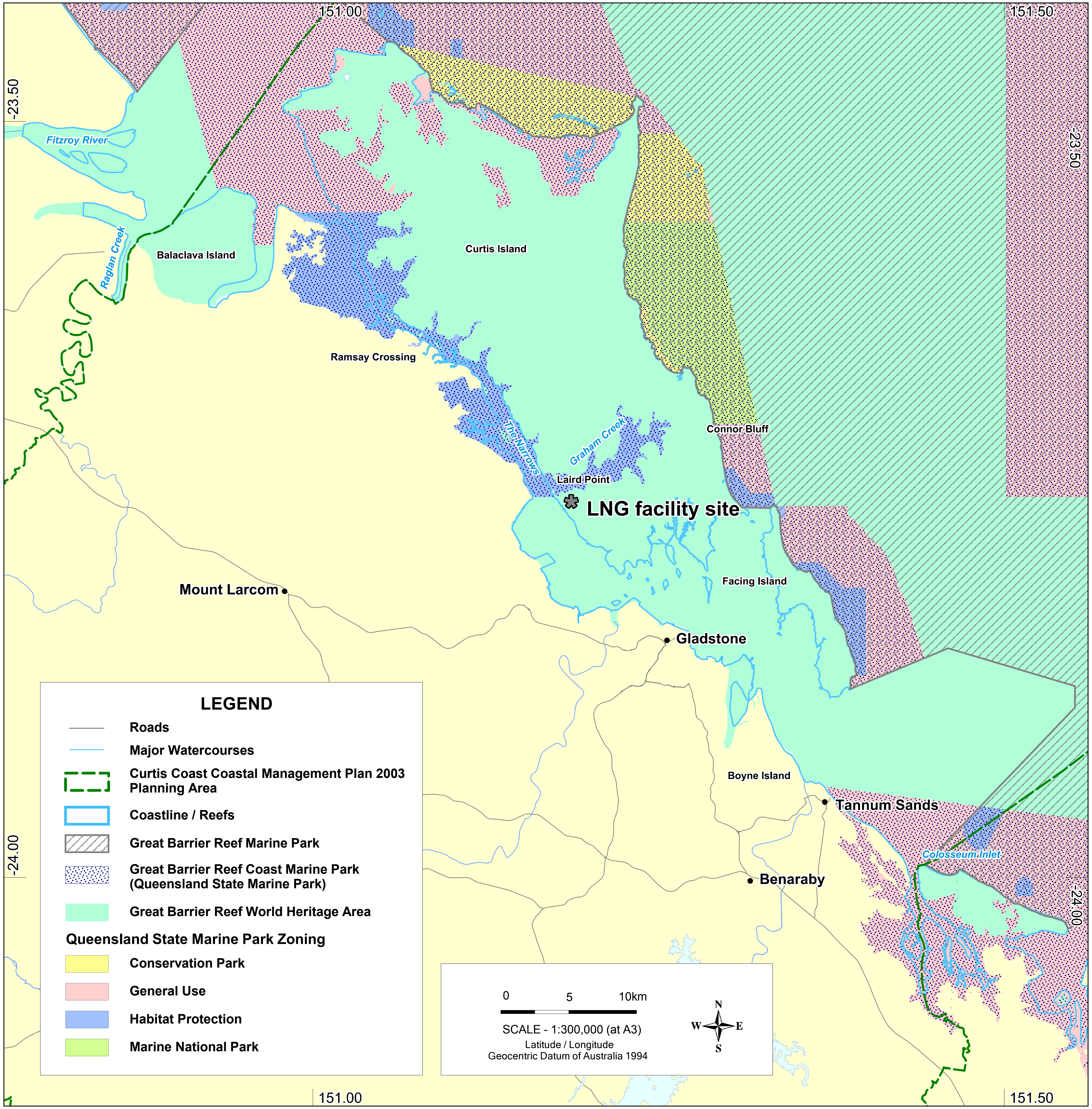
Figure 2.1 Areas of high conservation value relevant to the LNG plant

Project No: 301001-00752	Figure: 00752-00-EN-DAL-0039	Rev: 0



Rev	Date	Revision Description	ORIG	CHK	ENG	APPD
0	17/02/2010	Issued for use	KM	DH		RB

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Figure 2.2 Great Barrier Reef Marine Park Authority administrative boundaries and World Heritage Areas

Project No: 301001-00752 | Figure: 00752-00-EN-DAL-0035 | Rev: 0

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Within the present port layout, wharf centres and their respective cargoes include:

- Auckland Point that imports petroleum products, cement gypsum, liquid petroleum gas, caustic soda, and containers and exports calcite, magnesia, grain, and containers
- Barney Point Coal Terminal that exports coal
- Boyne Wharf that imports petroleum coke, liquid pitch, and general cargo, and exports aluminium
- Fisherman's Landing that imports caustic soda, and liquid ammonia, and exports cement clinker, cement, fly ash, and naptha
- RG Tanna Coal Terminal that exports coal
- South Trees wharf that imports 13 Mt of cargo a year including bauxite, alumina, caustic soda, and bunker fuel oil, and exports alumina

The further development of the Western Basin, primarily to accommodate the LNG industry, has been proposed as part of the Gladstone Ports Corporation's *50 Year Strategic Plan* (updated 2008) that focuses on sustainable growth.

The port facilities are located within an estuarine environment with high conservation value. Of most relevance from a marine perspective are the channels providing access to the proposed Australia Pacific LNG jetty and the crossing location associated with the main transmission pipeline.

2.2 Targinie Channel and North Passage

The North Passage and Targinie Channel are located within the Western Basin of the Port of Gladstone and provide marine access to and from the proposed Australia Pacific LNG facility.

The Targinie Channel as shown in Figure 1.2 is maintained to provide navigable access for 80,000 total deadweight (DWT) vessels to Fisherman's Landing. Capital dredging to widen this channel is planned in order to accommodate larger LNG ships. The channel presently merges with the Fisherman's Landing swing basin and berth area. From Targinie channel to The Narrows the naturally occurring depths are generally 8m to 10m or more below LAT and currents remain strong through this section (up to 2knots).

The North Passage channel refers to the shallow waterway between Curtis Island and the small (North and South) islands offshore that are part of a long shoal running parallel and to the east of Targinie Channel. The shoals can present a navigation hazard, even for small craft, and separates the North Passage from Targinie Channel, the deeper channel, that runs through the middle of the Western Basin. The existing depth of the North Passage channel is typically 5m LAT and is suitable for small craft sailing to and from The Narrows and Graham Creek.

2.3 The Narrows and Graham Creek

The Narrows is a key coastal site under the Curtis Coast Regional Coastal Management Plan and is the narrow estuarine passage between Curtis Island and the mainland that extends from Raglan Creek in the north to Kangaroo Island in the south at the top end of the Western Basin. It is approximately one kilometre wide from Graham Creek to Middle Creek and from there to Ramsay Crossing is less than 200m wide in places. The Narrows key coastal site includes all tidal sections of waterways that drain into it, including Graham Creek which is approximately 10km long.

Designated areas within this key coastal site include the GBRWHA, the Great Barrier Reef Coast Park, the Great Barrier Reef Coast Park (Mackay/Capricorn section) and areas listed on the Register of National Estate.

The Curtis Coast Regional Coastal Management Plan identifies one of the coastal management issues for The Narrows as adjacent, increasing development that has the potential to adversely impact on the relatively pristine water quality with subsequent impacts on marine biodiversity. Both the dredging and water quality management policy recognise that dredging activities, industrial discharges, disturbance of coastal and marine habitats and marine pollution should be appropriately managed to avoid or minimise adverse impacts on coastal resources and their values. Proposed discharge of industrial wastewater into coastal waters must be assessed under the Water EPP and is only considered where it is demonstrated that no other feasible alternatives exist.

3. Review of existing coastal data

Coastal data reviewed in this section includes existing information on meteorology, currents, normal tide characteristics, extreme water levels, waves, water quality and sediments. This data forms the basis for validating numerical models and interpretive conclusions in regard to the coastal processes occurring at the proposed LNG facility site.

3.1 Description of environmental values

Gladstone falls within the Curtis Coast Regional Coastal Management Plan (Queensland Government 2003). The policies within this Coastal Management Plan are a mechanism for achieving the outcomes of the State Coastal Plan and both of these guide assessment decisions regarding projects such as the Australia Pacific LNG Project. Relevant policies within the Coastal Management Plan apply to the Australia Pacific LNG Project and are considered in this section, including:

- Coastal use and development (policy 2.1)
- Physical coastal processes (policy 2.2)
- Water quality (policy 2.4).

The physical processes associated with the coast and marine environment within the development area are outlined in the following sections of this report:

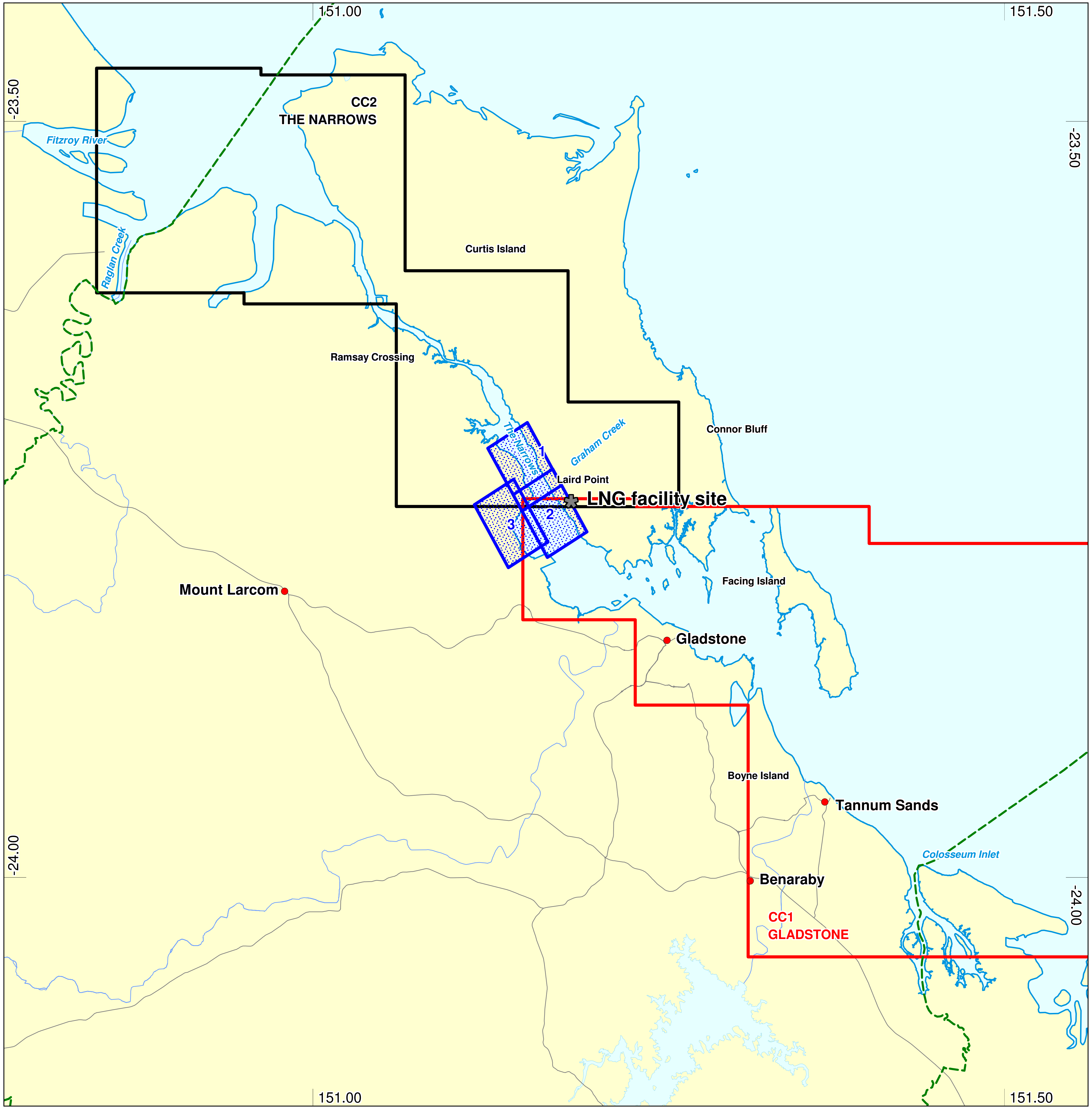
- Meteorology (specifically wind) (Section 3.5)
- Waves (Section 3.4)
- Tides and currents (Section 3.3)
- Storm surge and storm tide (Section 3.7)
- Tsunamis (Section 3.8).

3.2 Bathymetry

Bathymetric data used for the coastal environment assessment originates from the following main sources:

- Small craft charts soundings for Gladstone (CC1 and CC2) supplied by Marine Safety Queensland (MSQ) as digital data on GDA94 datum.
- GPC supplied detailed soundings of the Western Basin from a hydro-survey undertaken by MSQ during October and December 2008.

The extent of the sounding data used in the coastal assessment associated with the Australia Pacific LNG Project is shown in Figure 3.1.



LEGEND

- Roads
- Major Watercourses
- Curtis Coast Regional Coastal Management Plan 2003 Planning Area
- Coastline\ Reefs
- Extent of MSQ Marine Safety Chart CC1
- Extent of MSQ Marine Safety Chart CC2
- Gladstone Ports Corporation Western Basin Hydro-Survey 2008

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Latitude / Longitude
Geocentric Datum of Australia 1994

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Figure 3.1: Extent of existing sounding data and bathymetry for Gladstone

Project No: 301001-00752 | Figure: 00752-00-EN-DAL-0043 | Rev: 0

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General information was also available from Australian charts sourced from the Australian Hydrographic Office, specifically from:

- AUS 245, Port of Gladstone, scale 1:25,000
- AUS 819, Bustard Head to North Reef, scale 1:150,000.

Australian hydrographic charts provided a regional context for the coastline and offshore islands as well as other information such as current speeds inside the harbour and near the proposed project site.

At the proposed LNG facility site the existing bathymetry consists of a wetland behind a fringing mangrove line where the plant is to be located with wide areas of exposed mud flats in front of the site that are exposed at low tide. The wetland is subject to inundation during higher tides and is separated from the offshore channel by a low lying sand barrier where the mangroves have established. The wetland floods from the tidal creek at the entrance surrounded by mangroves and drains in a similar fashion. Sand barrier formations such as the one shown in Figure 3.2 (photo 2), are typically formed by sediments washed down from the wetland catchment that are reworked by local wind waves.

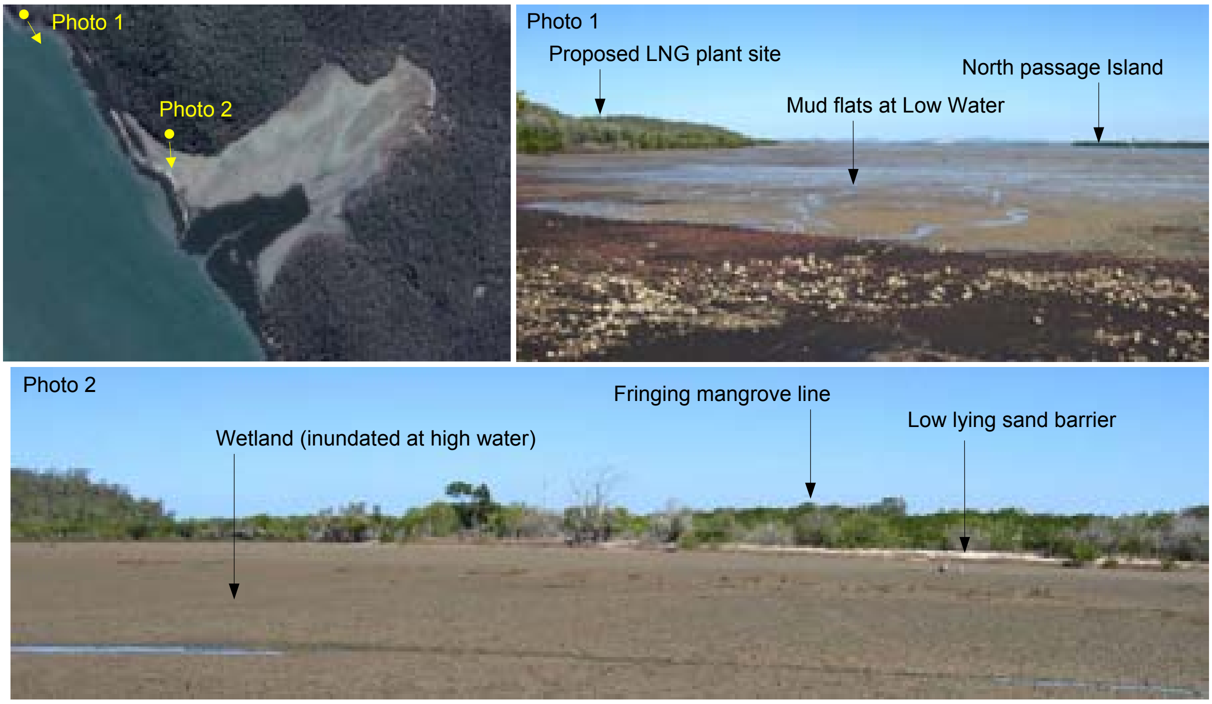


Figure 3.2 Coastal features of the proposed LNG facility site

The shoreline either side of the proposed LNG facility site is lined with mangroves and vegetation or loose rock and cobbles in addition to exposed rock strata as can be observed in Figure 3.3. No sandy shorelines were observed during site inspections closer to the site, although Laird Point, where Graham Creek joins the Narrows, has a typical beach sand profile that is shaped by strong flowing tidal currents.

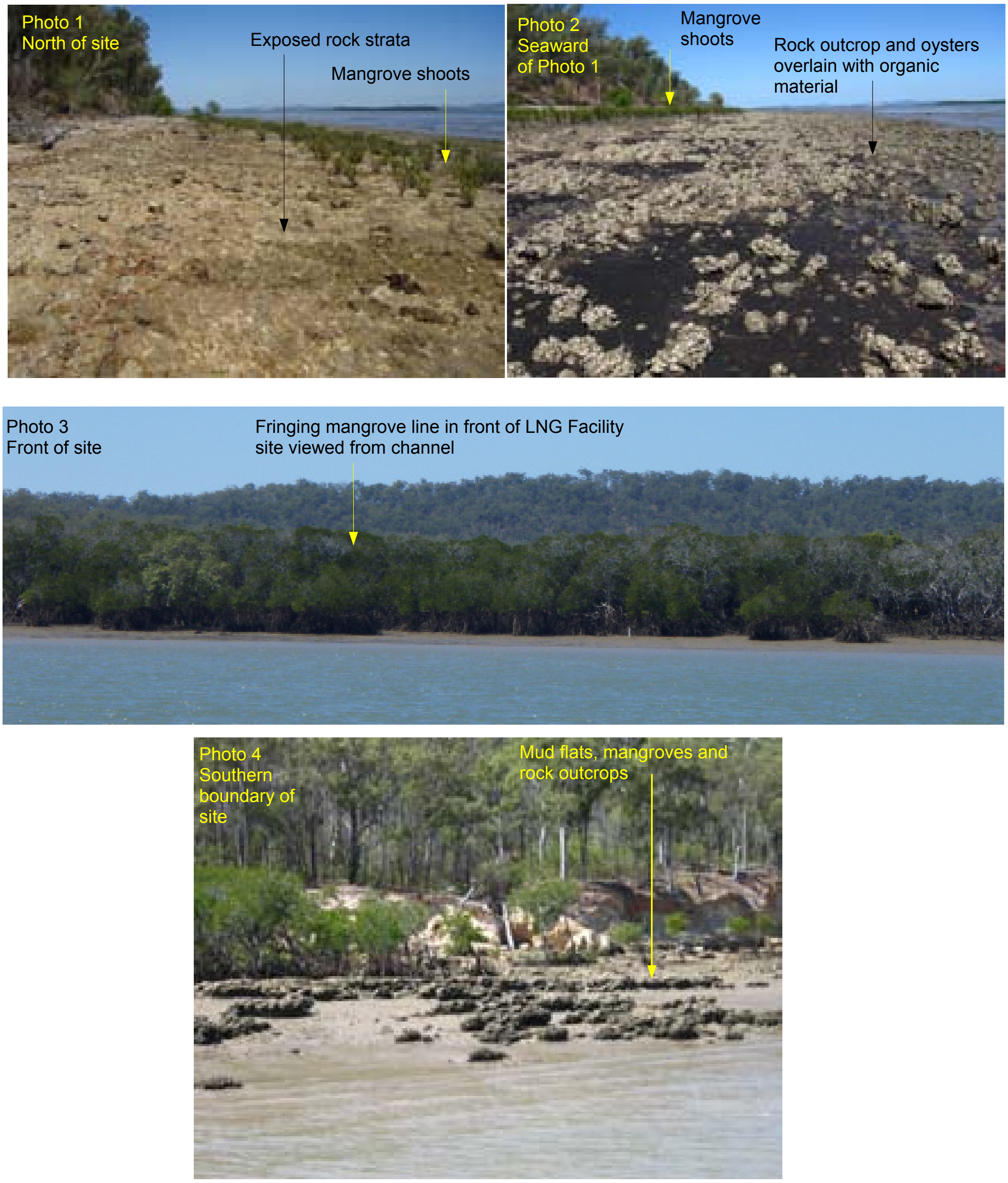


Figure 3.3 Shoreline types near the proposed LNG facility site

3.3 Tides and currents

Tides in the Gladstone region are semi-diurnal with a diurnal inequality that becomes more pronounced as the tide enters the neap phase – Figure 3.4 shows spring to neap tide transition. The tide approaches Broad Sound along the shelf from the north and south and tidal constituents undergo amplification due to resonance with the shelf bathymetry. Gladstone is south of Broad Sound so the tide is in the process of amplifying as it moves north along the shelf. Time differences between tides are presented in Figure 3.5.

Tidal planes for locations within the Gladstone region are given below in Table 3.1 (Queensland Government 2009a)

Table 3.1 Tidal Planes for Gladstone region

Location	Datum	HAT	MHWS	MHWN	MSL	MLWN	MLWS
South Trees Wharf	LAT (m)	4.63	3.80	2.99	2.20	1.51	0.69
	AHD (m)	2.42	1.59	0.78	-0.01	-0.7	-1.52
Gladstone (Auckland Point)	LAT (m)	4.83	3.96	3.11	2.34	1.57	0.72
	AHD (m)	2.56	1.69	0.84	0.07	-0.70	-1.55
Fisherman's Landing	LAT (m)	5.12	4.20	3.30	2.41	1.66	0.76
	AHD (m)	2.69	1.77	0.87	-0.02	-0.77	-1.67
The Narrows (Ramsay Crossing)	LAT (m)	6.17	5.08	4.01	3.01	2.07	1.00

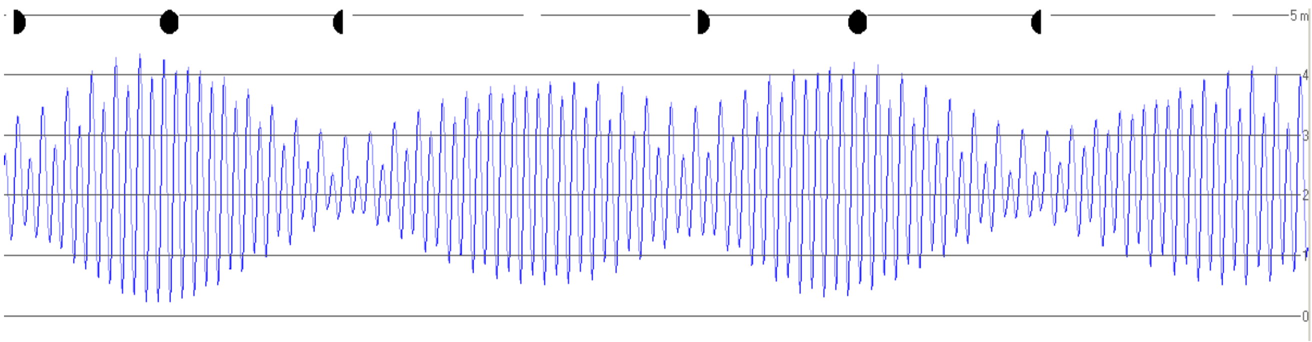


Figure 3.4 Gladstone (Auckland Point) tide signal over two representative lunar periods

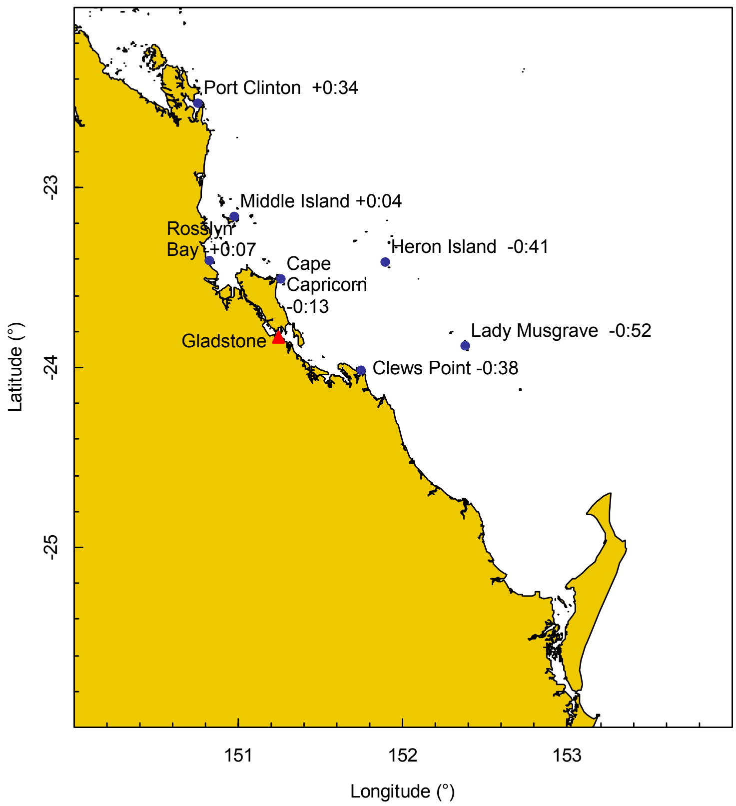


Figure 3.5 Tide time difference between selected locations around Gladstone (source: Australian Government 2009a)

From Table 3.1 it is evident that the tide undergoes some amplification as it moves into Gladstone Harbour and into the Western Basin. Table 3.2 contains the percentage increase in spring tide planes ordered in the direction from South Trees towards The Narrows in addition to the spring tide ranges at each location. This indicates that the tide range is also increasing and confirms the amplification within the estuary.

Table 3.2 Changes to tidal planes inside the Western Basin, Gladstone

	% increase				Spring tide range (m)
Location	**HAT**	**MHWS**	**MSL**	**MLWS**	
South Trees Wharf	0	0	0	0	3.11
Gladstone (Auckland Point)	4	4	6	4	3.24
Fisherman's Landing	11	11	10	10	3.44
The Narrows (Ramsay Crossing)	33	34	37	45	4.08

Within existing dredged channels of the Western Basin tidal currents are very strong on both the ebb and the flood tide cycles with velocities of 2knots to 4knots (1m/s to 2m/s) commonly reached on spring tides. The Narrows also exhibits strong tidal current velocities.

In the North Passage Channel, at the front of the proposed LNG facility site, currents are not as strong as in the main channel leading to The Narrows. Currents in the deeper section of the existing North Passage channel reach approximately 0.5m/s to 0.6m/s during spring tides.

3.4 Waves

Gladstone Harbour is a sheltered estuary protected by large offshore islands facing the open sea and inside the southern Great Barrier Reef. Consequently, ocean swells generated from distant storms are infrequent and confined to south and south-easterly directions. When long period wave energy does arrive at Gladstone it is dissipated by the narrow channels, shoals, and islands inside the estuary.

Figure 3.6 shows significant wave heights offshore from Gladstone generated by a large population of synthesised tropical cyclones in the Great Barrier Reef (Hardy et al. 2003). Results of many computer simulations using the WAMGBR wave model were extracted to develop this summary of significant wave heights corresponding to a 1 in 50 year return period. Although seven to nine metre waves are apparent offshore, wave dissipation occurs over a short spatial distance approaching Gladstone estuary and harbour.

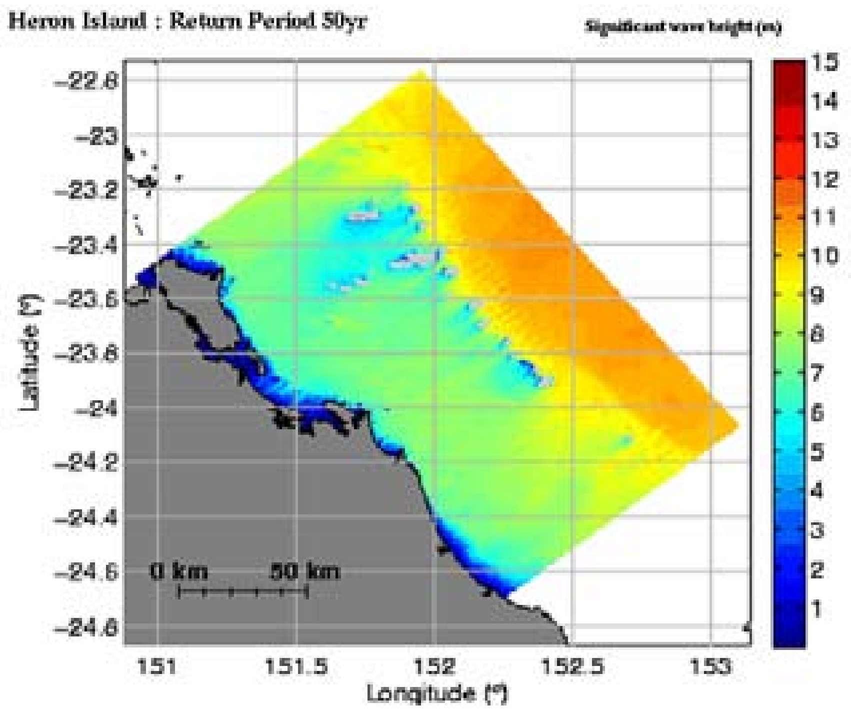


Figure 3.6 1 in 50 year significant wave heights offshore from Gladstone (Hardy et al. 2003)

Within the estuary itself, the wave climate diminishes travelling towards Auckland Point from Gatcombe Head. Virtually no wave energy from swells enters into the Western Basin through the gap between Tide Island at the south west corner of Curtis Island and Wiggins Island.

General wave conditions inside the Western Basin are calm to low inferring that significant wave heights will be less than 0.3m on most occasions (up to 80% of the time based on the wind record). Local sea conditions can be active on occasions due to strong trade winds, extra-tropical low pressure

systems, and cyclones. Gladstone's wind climate is described in the Section 3.5. Winds from the south-east are the most relevant to wave generation within Gladstone Harbour.

The longest wave fetches inside Gladstone Harbour are aligned with the direction of the shipping channels, but these are also of a limited distance for wave generation. The furthest fetches in relation to the proposed LNG facility are 6.5km from the south and 7.5km from the south-south-east, but waves are subject to varying water depths along these fetches due to the tide, shipping channels and sand shoals.

3.5 Winds

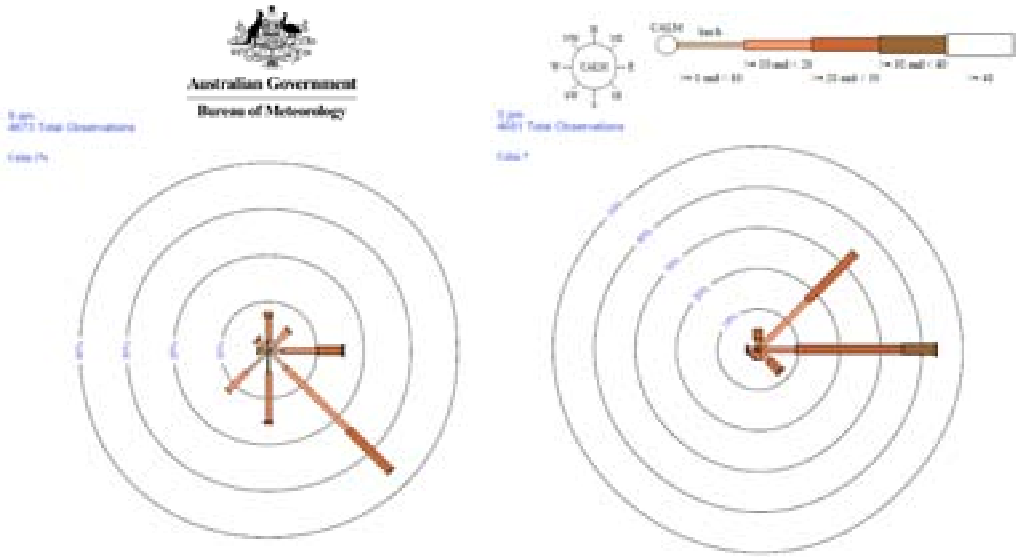
Synoptic charts are dominated by the subtropical belt of high pressure systems influencing the study area. These are responsible for the south-easterly winds that are prevalent in Gladstone. Their position varies from the summer months when their mean latitude is close to 40 degrees south, to the winter months when their mean latitude is shifted north to 30 degrees south. These high pressure systems invariably move east and are followed by troughs that deepen as they increase their moisture content due to interaction with the Tasman Sea. Strong winds can develop as a result of these depressions. The higher moisture content in summer, as a result of warmer sea temperatures, can lead to the formation of east coast lows and severe wind conditions.

There are more than several meteorological sites in and around Gladstone that have operated at various times and have recorded wind data that is relevant to the proposed LNG facility operations. These Bureau of Meteorology sites are as follows:

- Gladstone Post Office (1872 – 1958 closed, stn id 039041)
- Gladstone Airport (1993 – open, stn id 039326)
- Gladstone Radar (1957 – open, stn id 039123)
- Rundle Island (1994 – open, stn id 039322)

Winds recorded at Gladstone Airport are shown in Figure 3.7 are characterised by morning south-easterly breezes and afternoon winds from the east. This station is surrounded by urban development and long overland fetches to the south-east. The site is also characterised by infrequent south-easterly winds in the afternoon.

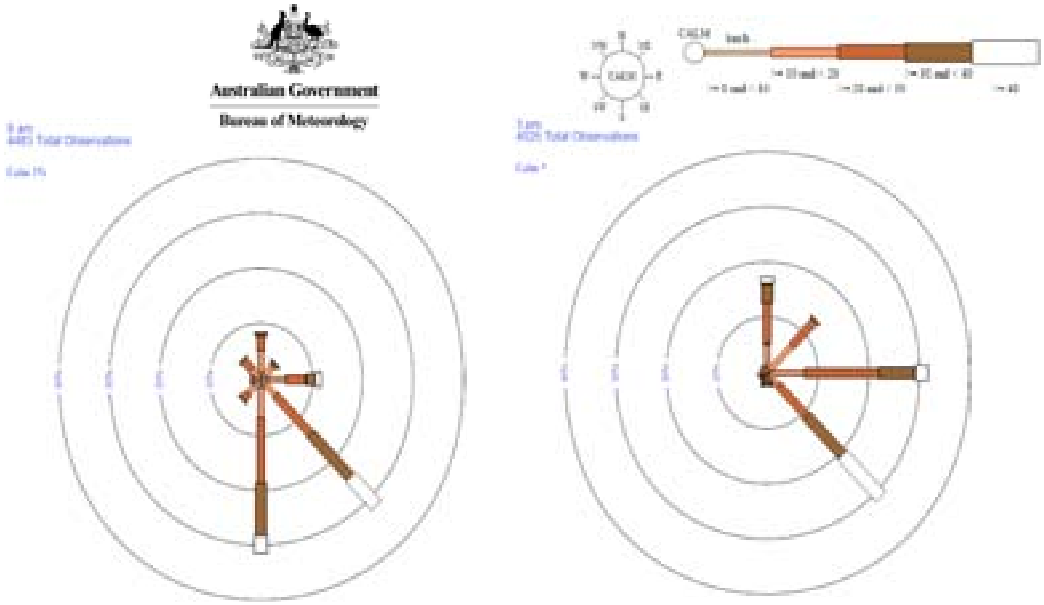
Rundle Island is approximately 4.5km offshore of Curtis Island, near Cape Capricorn, and provides good representation of over sea winds as it is directly exposed to a seaward fetch from the south-east and the station is close to sea-level. The Bureau of Meteorology 9am wind rose for Rundle Island, in Figure 3.8, shows that approximately 7.5% of all winds (approx. 15 years of data) are greater than or equal to 40 km/hr and come from the south-east. Overall, approximately 64% of winds come from the south and south-east sectors and are near to evenly distributed between these directions.



Gladstone Airport (26 Oct 1993 to 31 Dec 2006)

Site No 039326 ▪ Opened Oct 1993 ▪ Still Open ▪ Latitude: -23.8697° ▪ Longitude: 151.2214° ▪ Elevation 16 m

Figure 3.7 Rose of wind direction versus wind speed (km/h) - Gladstone



Rundle Island (24 Oct 1994 to 30 Jun 2008)

Site No 039322 ▪ Opened Oct 1994 ▪ Still Open ▪ Latitude: -23.8697° ▪ Longitude: 151.2214° ▪ Elevation 16 m

Figure 3.8 Rose of wind direction versus wind speed (km/h) – Rundle Island

Afternoon winds recorded at Rundle Island, shown in Figure 3.8, include more easterly breezes indicating a swing to the east as the convective sea breeze begins to dominate over the trade wind that is stronger in the morning. However, the greatest frequency of strong winds remains from the south-east sector. Winds are more frequent and evenly distributed between the south and south-east sector in the afternoon.

The 9am and 3pm wind roses suggests areas like the Western Basin will be subject to small to moderate short crested seas that grow and subside relatively quickly.

3.6 Tropical cyclones

Gladstone is located at latitude 23.8º south and is subject to tropical cyclone activity originating from the Coral Sea or the Gulf of Carpentaria. Tropical cyclones that have crossed the coast in this region can be identified from the database maintained by the Bureau of Meteorology. Figure 3.9 presents tracks of tropical cyclones that have influenced the Queensland coastline during the months of January and February since 1959 when satellite observations were introduced.

In the summer months from January to March, tropical cyclones and tropical lows have an influence on central Queensland weather patterns. These systems often interact with regions of high pressure over southern Australia to produce strong pressure gradients over the whole of eastern Australia.

Figure 3.10 contains all tropical cyclones since 1960 that have tracked within a 250km radius of Gladstone (shown as the circle in Figure 3.10). Twenty-six tropical cyclone tracks are shown in Figure 3.10 including the track of TC David that resulted in wind gust speeds of 83 knots in Gladstone and caused major damage to a breakwater at Rosslyn Bay.

Table 3.3 summaries the landfall central pressure (or minimum central pressure if the cyclone did not reach land) for the tropical cyclones shown in Figure 3.10. Table 3.3 includes notable events such as TC Fiona, Dinah, Emily, and Fran that all passed relatively close to Gladstone and were intense category 4 or 5 systems. These storms indicate the vulnerability of the Gladstone region to severe weather systems although historically, Gladstone has not been subjected to an intense tropical cyclone landfall.

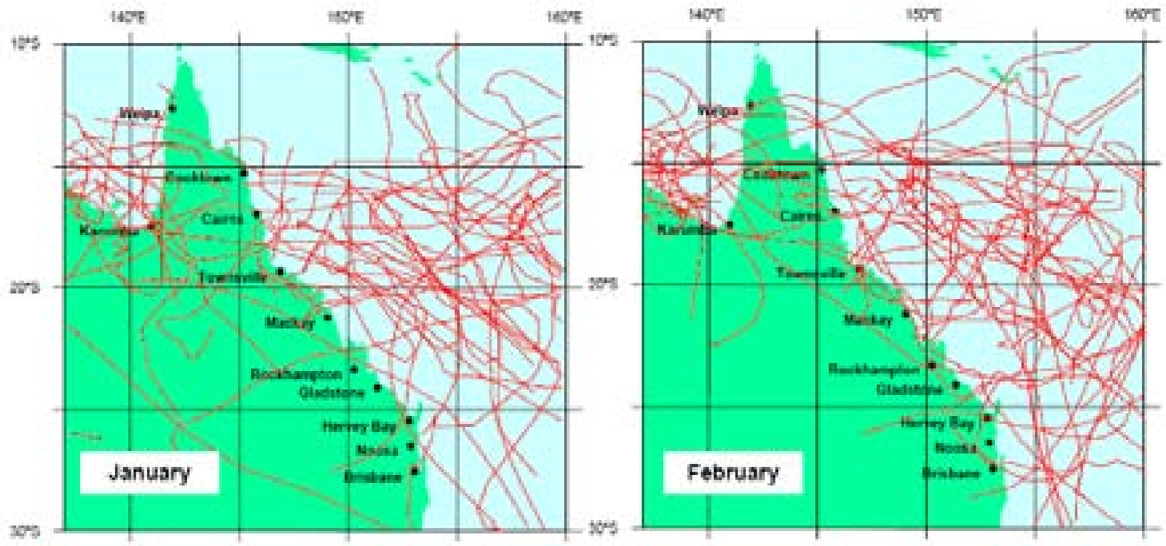


Figure 3.9 Queensland tropical cyclone activity for the months of January and February since satellite tracking commenced (Queensland Government 2001)

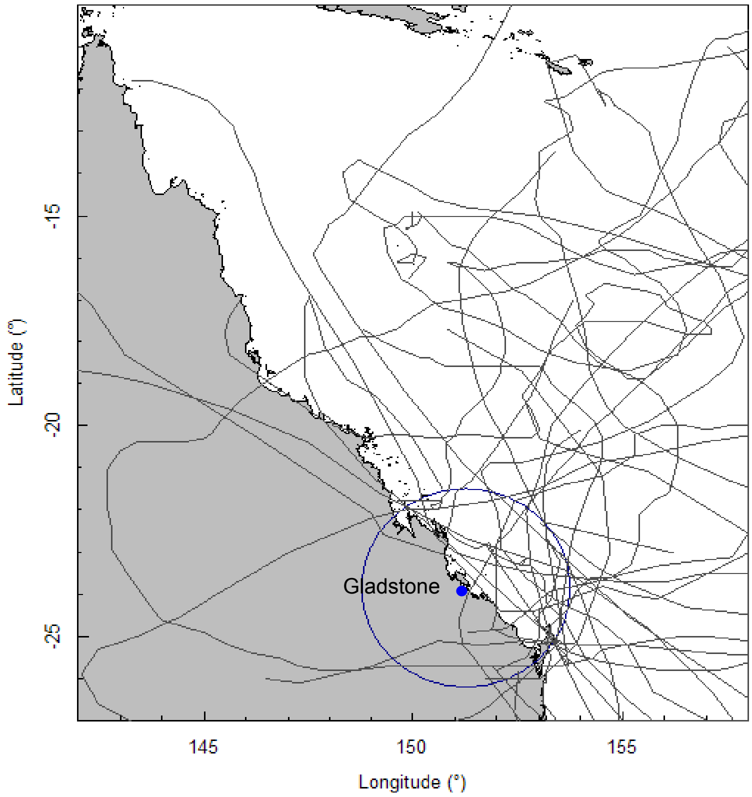


Figure 3.10 Tropical cyclones (1960-present) tracking within a radius of 250km of Gladstone (cyclone tracks from: Australian Government 2007)

Table 3.3 Tropical Cyclones within 250km of Gladstone

Tropical cyclone name	Season	Landfall central pressure or minimum central pressure within 250km radius (hPa)
(UNNAMED)	1962	978
(UNNAMED)	1962	1002
(UNNAMED)	1962	996
(UNNAMED)	1962	1009
DINAH	1966	945
(UNNAMED)	1969	1004
DORA	1970	993
FIONA	1970	965
ALTHEA	1971	952
DAISY	1971	959
EMILY	1971	985
WANDA	1973	998

Tropical cyclone name	Season	Landfall central pressure or minimum central pressure within 250km radius (hPa)
DAVID	1975	969
BETH	1975	996
DAWN(SECONDARY)	1975	988
WATOREA	1975	970
KERRY	1978	995
PAUL	1979	992
SIMON	1979	950
CLIFF	1980	990
ELINOR	1982	935
LANCE	1983	992
PIERRE	1984	998
FRAN	1991	985
REWA	1993	920

Source: Australian Government 2007

Intense tropical cyclones are associated with substantial storm surges as they cross the coastline and, when combined with the normal tide at landfall crossing time, the resulting storm tide water level can inundate low-lying areas.

An analysis of tropical cyclone central pressures for the Gladstone region is presented in Figure 3.11. According to the analysis, a tropical cyclone central pressure of 945hPa occurs with an Average Return Interval (ARI) of 30 years, corresponding to the operational life of the proposed LNG facility.

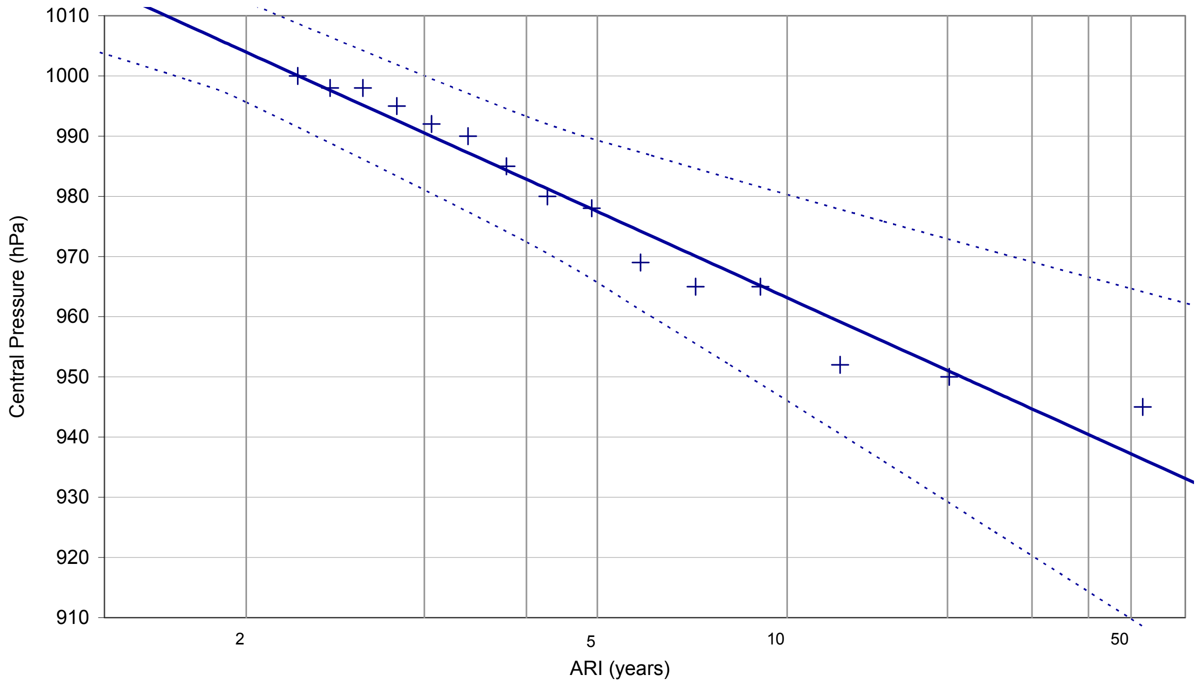


Figure 3.11 Tropical cyclone intensity Average Return Interval (ARI) for Gladstone region

Section 6 provides an assessment of the level of impact resulting from tropical cyclone landfall at the proposed site and is based on consideration of the expanded set of tropical cyclone parameters in Table 3.3.

3.7 Storm surge and storm tide

When tropical cyclones track over the ocean their extreme winds and low pressure result in an elevated dome of water that travels as a long period wave. As this surge approaches the coastline it can be affected by the seabed slope and coastline shape causing it to amplify in height. When this surge is combined with the normal tide on the day at the landfall location it becomes a storm tide.

Tropical cyclone tracks are erratic and difficult to predict in advance, although research and technology are leading to improvements in this capability and therefore severe weather warnings are also improving. Consequently, mitigation measures are more reliable.

Less intense tropical cyclone activity and extra-tropical low pressure systems produce insignificant surges when combined with the lower tide ranges. Nevertheless, these can alter the normal currents and water levels from their predicted or forecast values. The occurrence of a major storm tide in Gladstone is primarily dependent on tropical cyclone track direction, forward speed, the radius to maximum winds and the wind strength due to the cyclone central pressure, coupled with the state of the tide at the time the cyclone makes landfall.

Storm tide statistics studies have been undertaken for most of the Queensland coastline. Figure 3.12 summarises storm tide heights above Highest Astronomical Tide (HAT) for selected locations along the Australia east coast. Gladstone has a relatively high storm tide risk profile.

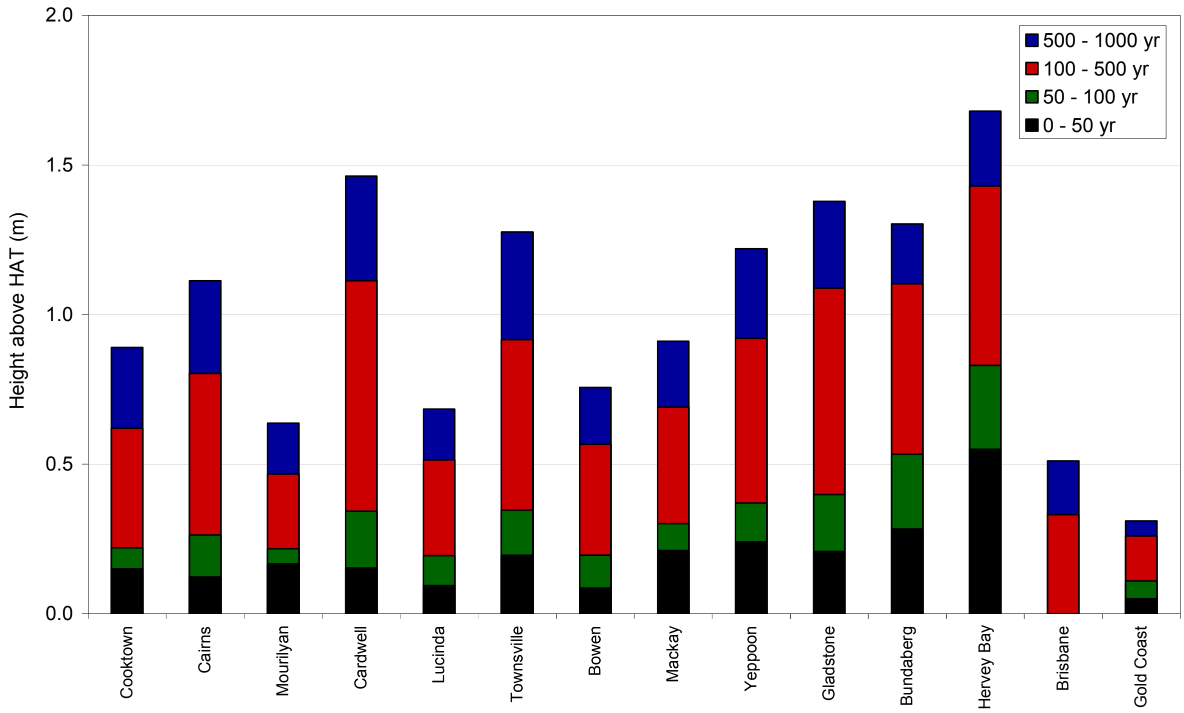


Figure 3.12 Storm tide height above HAT (m) for Queensland east coast locations

A landmark study (Queensland Government 2004) to determine the frequency of occurrence of storm tides for open waters in Queensland, including Gladstone, predicted elevated water levels for both present conditions and those where the implications of climate change are represented. For open waters in Gladstone (Auckland Point) this resulted in storm tide levels as follows:

Table 3.4: Storm tide ARI for Gladstone

	2004 (mAHD)	Climate change (mAHD)
100 year	2.82	3.33
500 year	3.51	4.18
1000 year	3.80	4.41

The climate change scenarios based on a 50 year planning period included the following:

Scenario A

As the greenhouse effect warms the oceans, the regions of cyclone genesis may move poleward. Also this increase in temperature may cause cyclones to become more intense. The parameters of the synthetic cyclone dataset were changed to model these two effects. The tracks of the cyclones were shifted 1.3 degrees poleward and the maximum potential intensity of the dataset was increased by 10%.

Scenario B

The greenhouse effect is expected to cause cyclones to develop more frequently. This was modelled using a 10% increase in frequency.

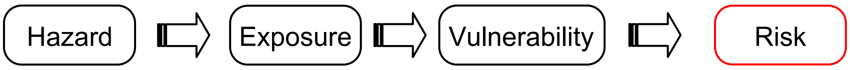
Scenario C

The heating of the ocean caused by increased global temperatures will cause the water to expand and thus a rise in mean sea level. This increase was estimated to be 300 mm.

The water levels shown in the table above include wave setup or wave run-up. A discussion on the ARI used for design purposes and potential impacts associated with storm tide at the proposed LNG facility site are addressed in Section 6 on potential impacts and mitigation measures.

3.8 Tsunami

Tsunamis are long period waves generated by earthquakes, volcanic eruption, or undersea landslides and can travel great distances from their origin. The risk of a tsunami impacting on Gladstone is a function of the hazard (its magnitude and occurrence), the exposure of the proposed LNG facility site to a tsunami and how vulnerable the site is to tsunami inundation.



To understand the hazard of tsunami it is important to recognise the mechanisms that are capable of generating these waves. Although they are mostly generated by earthquake (tectonic plate movement) other mechanisms include submarine landslides, volcanic eruption, and meteorite impact. Figure 3.13 shows tsunami sources within the Pacific region that are capable of causing the greatest damage. Red and yellow circles show tsunami sources causing the greatest damage according to the Imamura-Soloviev tsunami intensity scale. The size of the circle is scaled to the magnitude of the earthquake not necessarily the intensity of the tsunami.

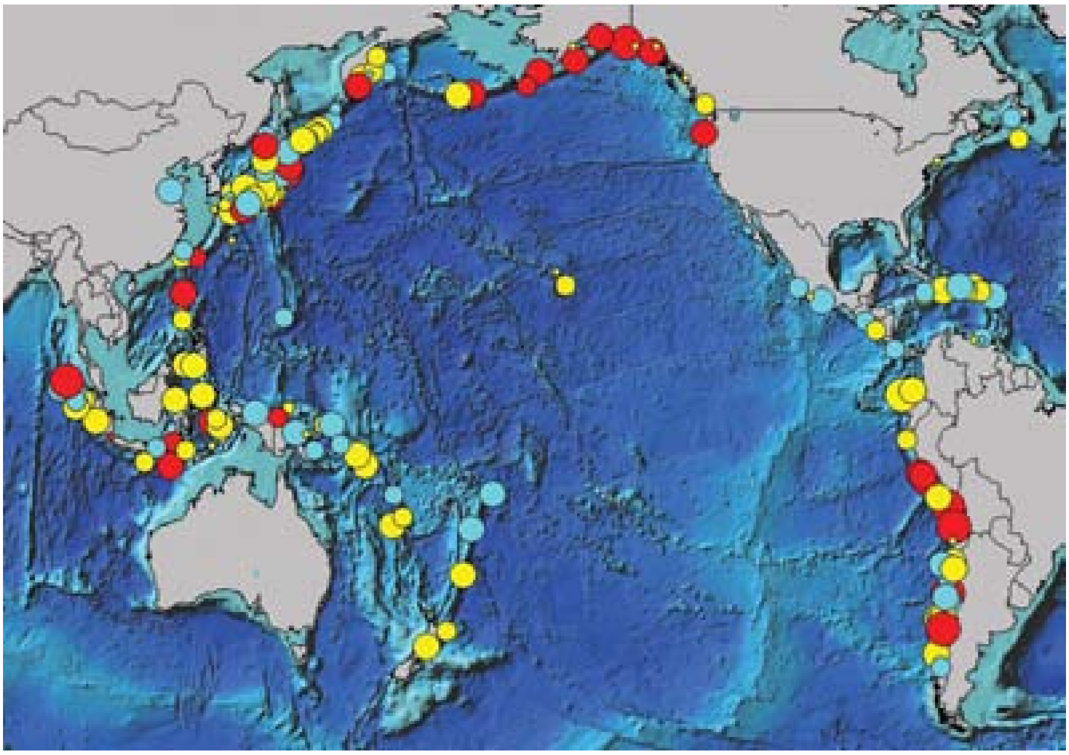


Figure 3.13 Sources of tsunami generation (Kong 2005)

From the source locations to the east of Australia, tsunamis take between 3 to 4 hours to cover a distance of between 3,000km and 4,500km depending on the depth of water during the journey.

Frequency of occurrence is the least understood aspect of tsunami generation and consequently has more uncertainty associated with it. It is believed that average return intervals for major to mega tsunamis can be in the range of several hundred years to several thousand years, but is ultimately determined by the accumulation of stresses in the Indo-Australian tectonic plate.

A tsunami wave height at the coast (Laird Point) will depend on the bathymetry and underwater features encountered along the way, in addition to the coastline and estuary geometry as the wave approaches and shoals. How far the tsunami travels from its source point, coupled with the continental shelf and offshore reefs, all assist in the dispersion of the wave before it reaches the mainland and sheltered ports similar to Gladstone.

Although greater attention is normally given to tsunami wave height, the long period wave and the currents generated are also of relevance, even for smaller tsunamis. Strong currents have the potential to affect marine infrastructure like wharves and jetties, and vessel manoeuvring and navigation. Large tsunamis have the capacity to penetrate long distances into estuaries and harbours.

Modelling by Schneider (2006) has shown that tsunamis are substantially dissipated over the long ocean distance and by underwater features between the Indo-Australian plate boundary and the mainland. A wave height of less than 1m at the offshore 100m contour mark is expected to be exceeded on average, once every 475 years. Additionally, the journey across the continental shelf and the reef, shoals and islands will dissipate the wave further before arriving at Gladstone. The large tidal range within Gladstone can potentially mask tsunami events but total water level will be subject to the stage of the tide at the time of tsunami arrival.

3.9 Marine water quality

Marine waters adjacent to the Australia Pacific LNG site are described below in terms of:

- Salinity and water temperature
- Sediments and turbidity

More detail of the water quality associated with the proposed LNG facility location is described in the Marine Ecology section of the EIS. The characteristics examined below are relevant to the potential impact assessment of desalinated concentrate discharge into the North Passage Channel.

3.9.1 Salinity and water temperature

The estuary currents and level of natural turbulence result in a reasonably well mixed water column in the deeper channels, but shallower waters over the tidal mud flats may experience less mixing and be subject to higher salinity and temperature values due to increased solar radiation and evaporation in the summer months. Salinity within the estuary is also subject to variations due to freshwater inflows from creeks and rivers on a seasonal basis.

Historical water quality values were available from the Department of Environment and Resource Management (DERM) monitoring undertaken in the Port Curtis region at the entrance to the Calliope River and the Wiggins Island Coal Terminal (WICT) EIS, in addition to data presented in the GLNG Project EIS (URS, 2009).

The variation in physicochemical water quality parameters within the receiving water body, at Calliope River from DERM records are presented in Table 3.5. Figure 3.14 and Figure 3.15 present the annual variation to water temperature and salinity.

Table 3.5 Physicochemical Water Quality Parameters (DERM data 1996-2006)

	Minimum	20th percentile	Median	20th percentile	Maximum
Temperature (°C)	17.7	22.5	26.2	29.2	33.9
Conductivity (mS/cm)	29.9	52.7	55.0	56.6	60.5
Salinity1 (ppt)	18.5	34.7	36.5	37.6	40.6

[1]Derived from temperature and conductivity (conductivity at 25°C)

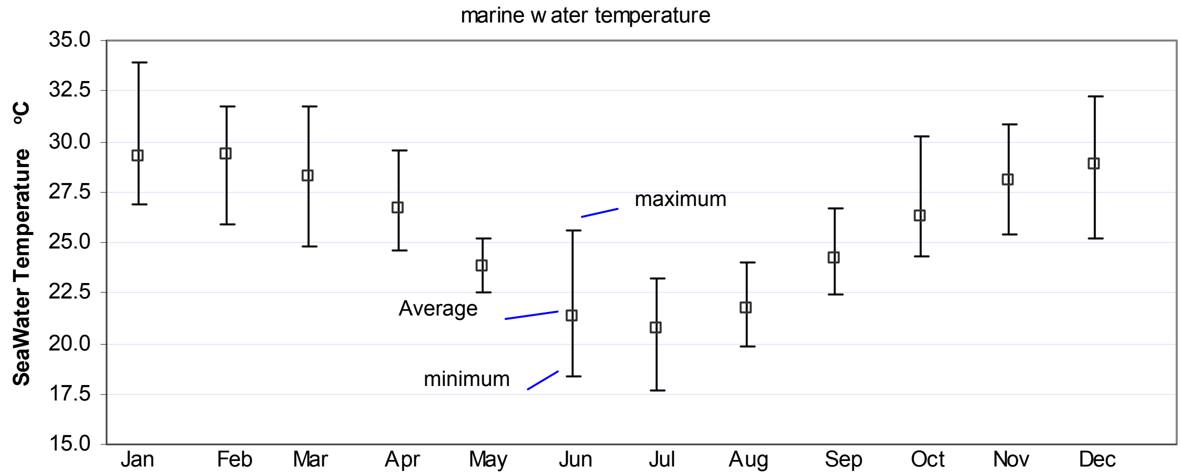


Figure 3.14 Seasonal variation of marine water temperature at Gladstone (Calliope River entrance, DERM 1996-2006)

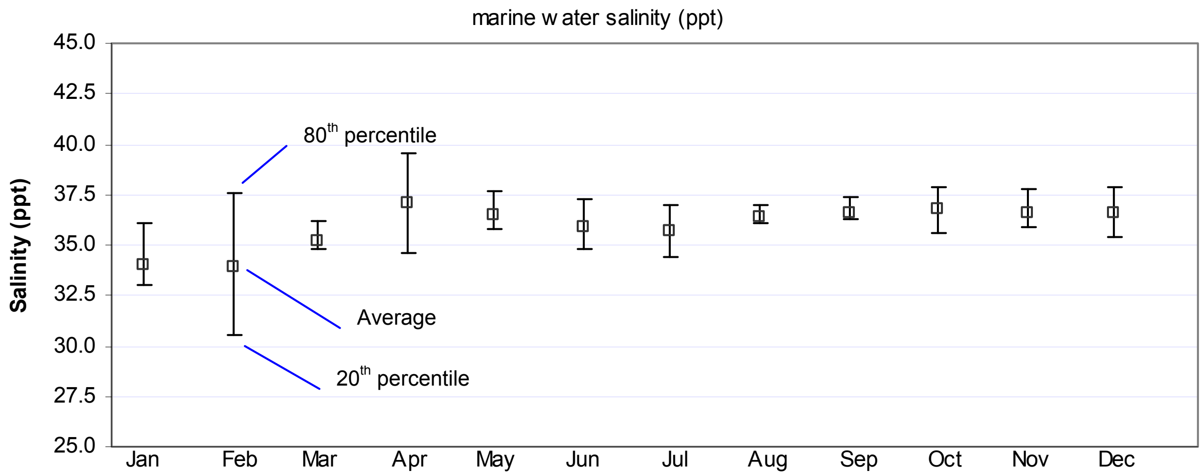


Figure 3.15 Seasonal variation of marine water salinity at Gladstone (Calliope River entrance, DERM 1996-2006)

3.9.2 Sediments and turbidity

As part of the Wiggins Coal Terminal EIS (Connell Hatch 2006) a geotechnical survey found that the general characteristics of the sediments within the Wiggins Island area were a mixture of gravels, sands, silts and clays. The deeper channels with stronger currents contained the coarser surficial sediments - mainly coarse sands and gravels, while the tidal flats were dominated by fine sands, silts and mud.

North Passage Channel

Information on existing dredging requirements and sediment siltation in the Western Basin is relevant in determining the potential for sediment mobilisation and maintenance dredging works. Gladstone Ports Corporation has indicated (pers. comm., Drury 2009) that typical annual maintenance dredging activities in Targinie Channel are 15,000 to 20,000m^3. From reported maintenance dredge volumes within the Western Basin (BMT WBM 2009e) it appears that only limited sediment deposition occurs within the shipping channels.

The intertidal area at the Australia Pacific LNG site consists of reasonably well consolidated silts and mud with a low percentage of sand present. This area has a gentle slope out from the mangrove fringe and is exposed at lowest tide level over a distance of approximately 300m. The intertidal bed material behaves as a consolidated mud layer and remobilisation occurs only when wave heights combine with strong currents to exceed the critical bed shear stress.

From the intertidal area the channel drops to the -5m LAT contour within 120m and exhibits reasonably constant depth until rising steeply to North Passage Island. Sediments in the shallow North Passage Channel are assumed to have a slightly higher percentage of sand material than the intertidal area in front of the mangroves, but mud and silt material dominate the overall area near the surface. Bore logs to the north at The Narrows entrance indicate mud and silt material dominate near the surface. A sediment characterisation study was undertaken by WorleyParsons (2009) in direct relation to the proposed Australia Pacific LNG swing basin. Representative material from bore holes analysed as part of this study and contained sediment particle size distribution characteristics very close to those across The Narrows entrance.

Sediments within the wetland regularly dry out during the neap tide phases, and consist of silts and clay, containing organic material. After high tides inundate the wetland or rainfall events, the surface material becomes very soft and exhibits little ability to support weight. Figure 3.16 shows the type of sediments found throughout the wetland. The glossy appearance is typical of materials exhibiting higher plasticity. On the wetland side of the mangrove fringe there is a low ridge of coarse sands presumably deposited by runoff from the catchment and reworked by high tides and waves.

Figure 3.16 Wetland sediments at Australia Pacific LNG site – high content of silt and clay

The Narrows crossing

The marine sediment investigation prepared as part of the GLNG Project (URS 2009) describes the analysis of marine sediments contained in boreholes across a northerly and southerly alignment between Friend Point and Laird Point. From this investigation it was found that marine sediments comprised of grey to brown clays, loose sands and gravels ranging in thickness from 1.9m to 5.55m with the thicker sediment layers in the centre of the channel. The investigation also encountered increased shell fragment composition in the upper sediment layers (upper 2m). Field work conducted by WorleyParsons also between Friend Point and Laird Point using a drop camera confirmed the abundance of shell fragments on the surface of the seabed (Volume 5, Attachment 28). The wide spread covering of shell fragments appear to be stable even though spring tidal currents between Friend Point and Laird Point are greater than 1m/s.

Particle Size Distribution (PSD) analysis of the borehole contents shows the sediments at the entrance to The Narrows to vary in content across the channel. At Friend Point the sediments contain gravel near the surface and clays within the first metre, with higher percentages of coarser material at greater depth. In the centre of the channel there are high percentages of sand and silt material with increasing percentages of clay at greater depth. Sediments close to Laird Point show higher percentages of clays and silts to a depth of 3m and then increased sand content at depths down to 9m.

The estuary exhibits higher turbidity levels naturally as a result of the combination of strong tidal currents and fine bed sediments. However, hydrodynamic modelling by Herzfeld (2000) shows an asymmetry between flood and ebb tides with the latter showing slight dominance, resulting in a general net movement southwards. Once mobilised, silts and fine bed sediments in the vicinity of the proposed LNG facility are expected to have a net transport to the south-east towards the proposed swing basin and approach channel as a result of the slight dominance of the ebb tides.

Reported turbidity within the Port of Gladstone (QGC 2009) exceeds Queensland Water Quality Guidelines (QWQG) where a value of 6NTU is indicated for enclosed coastal waters. Analysis of DERM (1996–2006) monitoring data at the entrance to Calliope Creek (station 132801) show turbidity

higher than this value during summer months at times after rainfall when stream runoff carries fine sediments to the estuary. Figure 3.17 presents variation throughout the year of turbidity as measured at the Calliope Creek station.

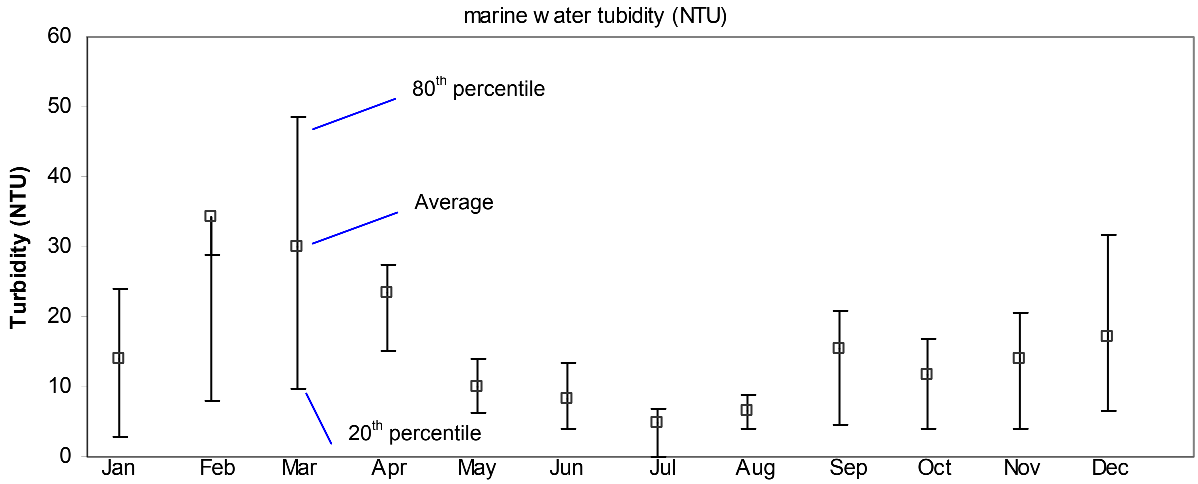


Figure 3.17 Seasonal variation of marine water turbidity at Gladstone (Calliope River entrance). DERM 1996-2006

At the proposed Australia Pacific LNG facility high natural turbidity is expected from runoff associated with Graham Creek and smaller tributaries where finer sediments accumulate around the thicker stands of mangrove and are washed out by overflowing water courses.

4. Coastal processes and methodology

A MIKE21-Flexible Mesh (FM) hydrodynamics model was used to assess the hydraulic conditions within the Port of Gladstone. The hydrodynamics model was also coupled with transport modules to investigate the tidal flushing time of the port, the fate of dredge plumes, the fate of discharges, and the siltation of dredged areas within the study site.

MIKE21-FM, developed by the Danish Hydraulics Institute, is a two-dimensional finite volume model that solves the unsteady incompressible flow equations following the hydrostatic pressure assumption. The model consists of continuity, momentum, temperature, salinity and density equations and is closed by a turbulent closure scheme. The model mesh is constructed from triangular elements or a combination of triangular and quadrangular elements. The flexible mesh allows the model spatial resolution to be increased in areas of interest. Away from the key study areas the hydrodynamics can be adequately resolved with relatively lower spatial resolution.

4.1 Hydrodynamic model bathymetry

The hydrodynamic model bathymetry within Gladstone Harbour and The Narrows was defined using hydrographic survey data provided in digital format by MSQ and GPC. Areas outside of Gladstone Harbour not covered by the MSQ and GPC surveys were defined using C-MAP electronic sea charts and the Geoscience Australia Australian Bathymetry and Topography Grid (June 2005). All bathymetric data was adjusted to Mean Sea Level (MSL) using MSQ tidal plane information.

Figure 4.1 shows the hydrodynamic model extent and bathymetry. The landward boundary of the model extends north-west from Clews Point to Emu Park. The model extends offshore to the 30m MSL depth contour and therefore covers the complete surrounds of Curtis Island and the existing spoil ground located outside the entrance to the port. The Pacific Ocean boundary covers almost 119km and is aligned approximately parallel to the offshore depth contours and coastline. The southern and northern boundaries are located at 'secondary places' defined by MSQ where data exists to calculate tide times and heights relative to the Gladstone Standard Port. The inset in Figure 4.1 provides detail of the high-resolution flexible mesh that defines the model domain.

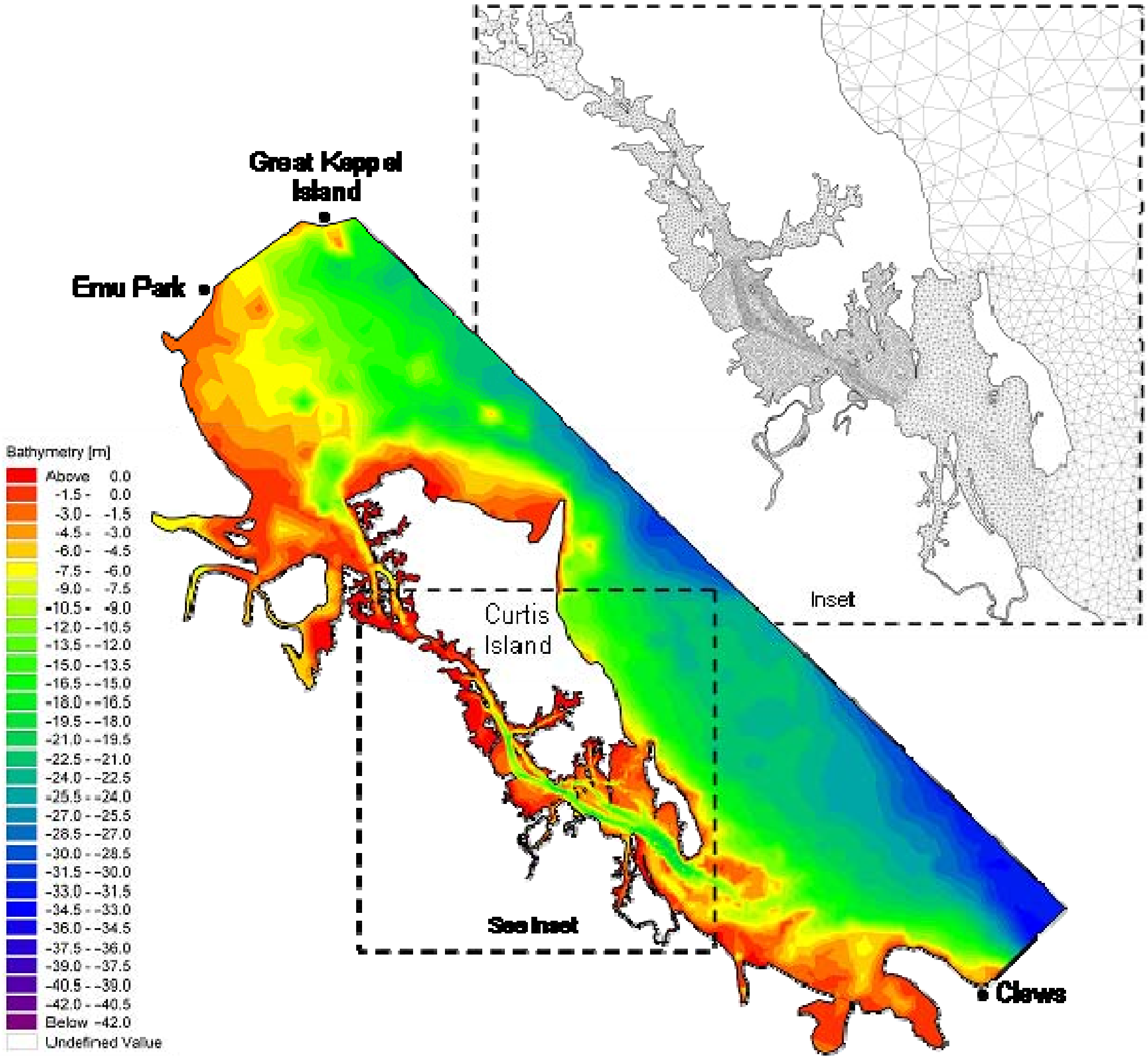


Figure 4.1 Port of Gladstone hydrodynamic model extent and bathymetry. Inset provides detail of the high-resolution flexible mesh.

4.2 Hydrodynamic boundaries

The hydrodynamic model has three open boundaries:

- Northern boundary, extending approximately 13km from Emu Park to the western side of Great Keppel Island
- Southern boundary, extending from Clews Point to a location approximately 11km offshore and a depth of 30m
- Ocean boundary, extending between the south-eastern side of Great Keppel Island to 11km offshore from Clews Point.

The open boundary conditions drive the flow in and out of the model domain. The boundaries were defined as time-varying water levels relative to tidal predictions at the Gladstone Standard Port (Auckland Point). The tidal prediction Gladstone is based on 118 tidal constituents. Tidal planes

information at Great Keppel Island and Clews Point allowed the tidal variation at the northern and southern boundaries to be calculated. Spatially constant tidal variation was applied at the northern and southern boundaries. The tidal elevation along ocean boundary was expected to vary spatially in both timing and magnitude. This variation was reflected in the model by linearly interpolating the tidal elevation between Clews Point and Great Keppel Island and applying the result along the 119km ocean boundary.

Figure 4.2 presents the MSQ predicted tidal variation at the Gladstone Standard Port and the calculated tidal variation at Great Keppel Island (applied to the Northern model boundary) and Clews Point (applied to the Southern model boundary) over a typical seven-day period.

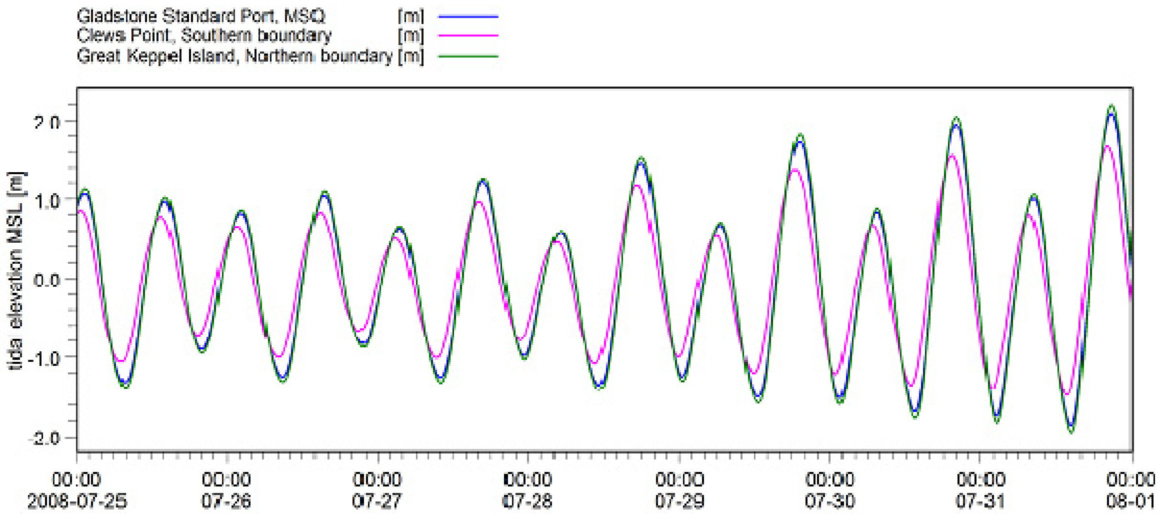


Figure 4.2 The Gladstone Standard Port, Clews Point (Southern model boundary), and Great Keppel Island (Northern model boundary) tidal variation over a typical seven-day period.

This modelling approach, whereby the open boundaries are defined relative to a MSQ standard port, allows accurate tidal boundary conditions to be generated for any period within the tidal epoch (the Australian tidal authorities have adopted a 20 year tidal datum epoch for calculating tidal datum and tidal planes).

4.3 Existing harbour and study area hydrodynamics

A general description of tides and currents in the Gladstone Harbour region was provided in section 3.3. Data collection programs were conducted during July and August 2009 to better understand the hydrodynamics specific to the study area. These measurements have been used to verify the hydrodynamic model predictions.

4.3.1 Data collection program

Measurement of currents within the study area was obtained using ADCP instruments which provide a measurement of current magnitude and direction variation with depth. The ADCP instruments were used in the following two methods:

- Bottom-mounted (fixed to a research vessel) and towed across the study area to provide a cross-sectional, or 'transect', measurement – the seabed profile is also measured simultaneously

- Deployed at the seabed in a fixed location for a period of one-month to provide a continuous measurement. The water level variation is also measured simultaneously

ADCP transects across Graham Creek and The Narrows (to the north and south of the entrance to Graham Creek) were performed during both a spring and neap tidal cycle. Repeated transect measurements provide details of the spatial variation in current magnitude and direction over the tidal cycle. Furthermore, the cross-sectional flow rate variation over the tidal cycle is obtained.

Additional current measurements were obtained using four GPS-tracked drifter instruments. Each drifter was attached to a 1.5m long and 0.75m diameter holey-sock drogue on a 3m tether (acting as an underwater sail) to ensure that the measurement was dominated by the flow rather than the wind or small waves. The drogue was therefore forced by currents between approximately 3m and 4.5m depth. The drifter/drogue instruments gave a measurement of temporal as well as spatial water movement within the main channel and were used to verify horizontal dispersion in simulating the transport of sediments and plumes, for example due to dredging activities or outfall discharges.

The drogues followed the main channel and recorded an ebb tide current excursion close to 8.5km. The peak ebb tide current speed was 1.2m/s. Flood tide currents were slightly weaker, confirming the asymmetrical tidal dynamics and the high tidal energy environment within the estuary. All four drogues remained closely grouped over the total deployment time of 7.6hours.

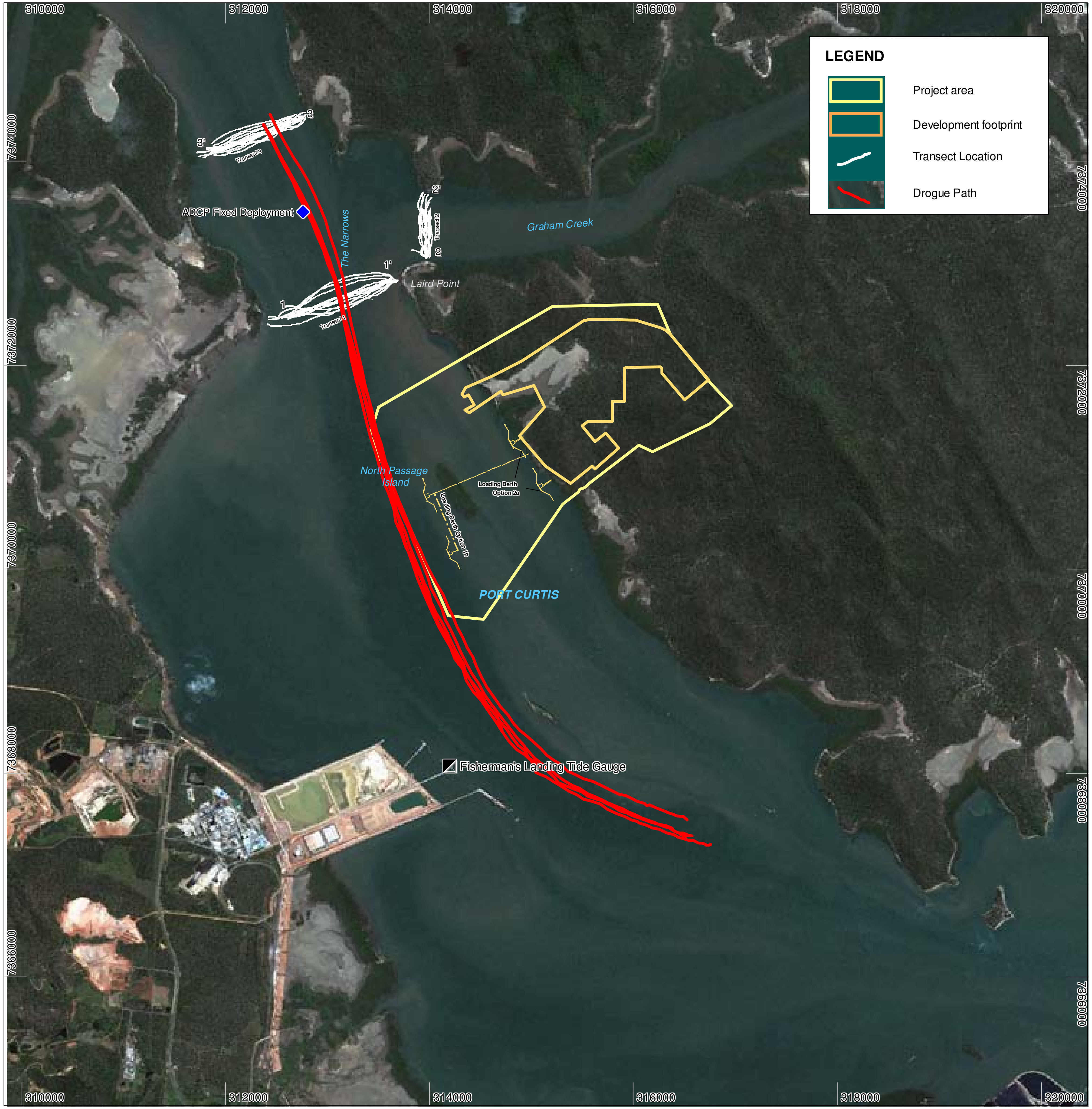
Figure 4.3 shows the locations where the ADCP transects, the ADCP fixed-deployment, and the drifter/drogue tracking were performed. Also shown in Figure 4.3 are the locations of tide gauges where existing observed water level data was provided by MSQ.

Examples of the data obtained via bottom-mounted ADCP transects at approximately peak-ebb, spring tide conditions are presented in Figure 4.4, Figure 4.5 and Figure 4.6. Each figure shows:

- The tidal water level at the time of data acquisition
- The depth-averaged current vectors along the transect
- A contour plot showing the cross-sectional variation in current velocity

The ADCP transect data indicates that the peak ebb current velocity within the study area is relatively uniform over depth. The highest current speeds (exceeding 1.4m/s) were measured offshore from Laird Point where flows exiting Graham Creek and The Narrows converge.

Additional current, flow and tide-gauge measurements that have been used for the hydrodynamic model verification are presented together with model predictions in the following Section 4.3.2.



Satellite imagery captured by GeoEye-1 on 24 March 2009
Indicative sites supplied by Bechtel.

Transects collected by Worley Parsons, November 2009
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Figure 4.3: Coastal environment measurements

Project No: 301001-00752	Figure: 00752-00-EN-DAL-0112	Rev: 0

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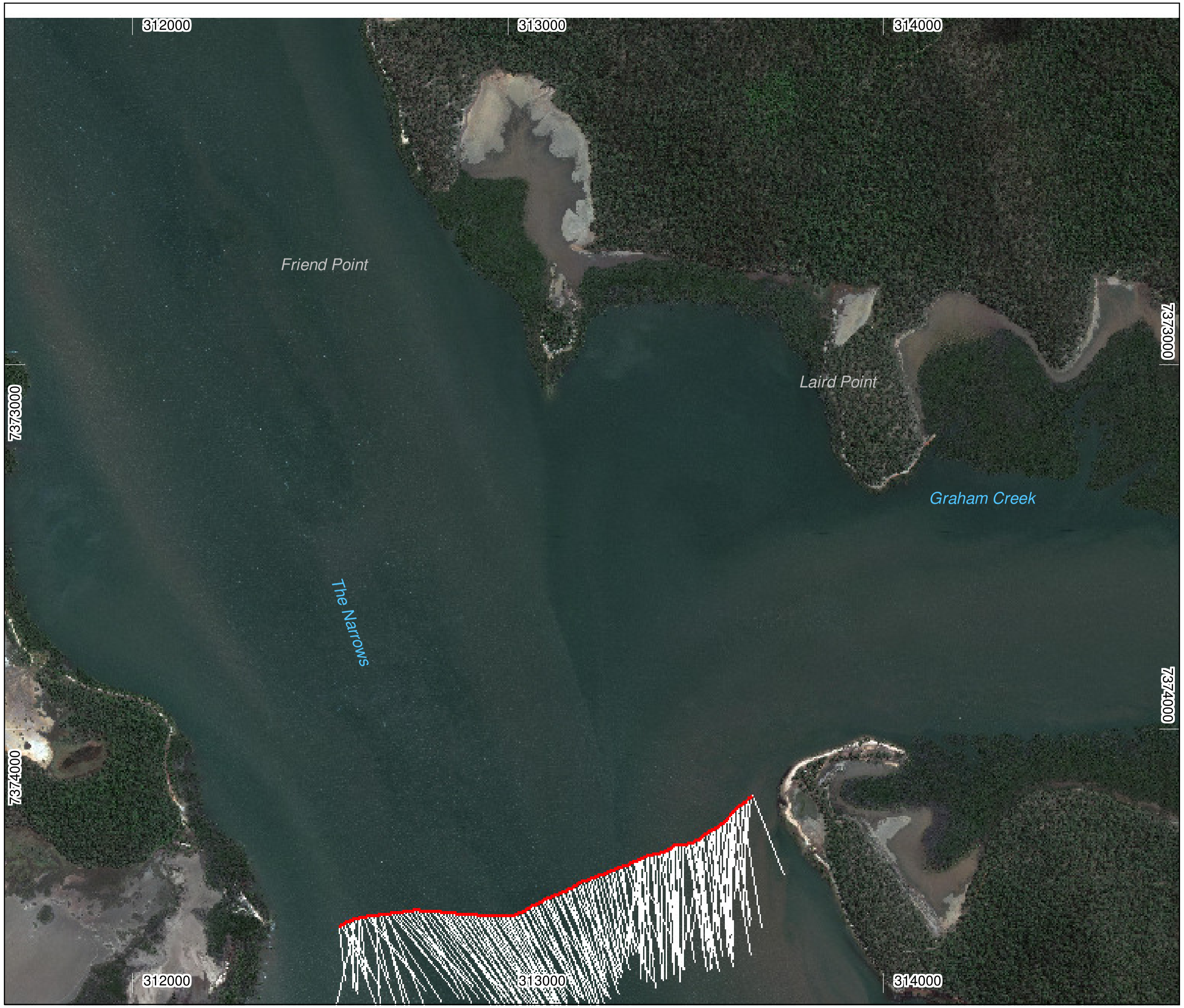

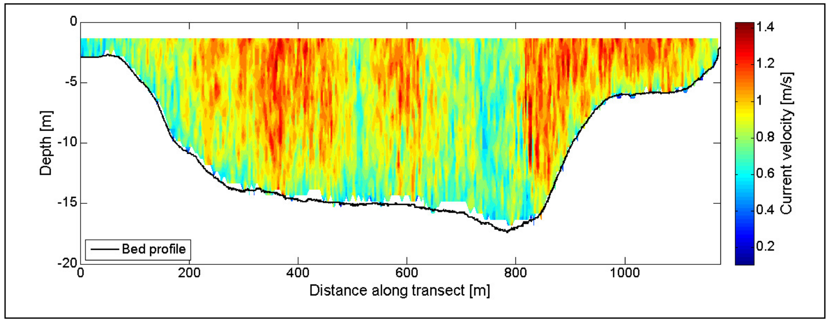

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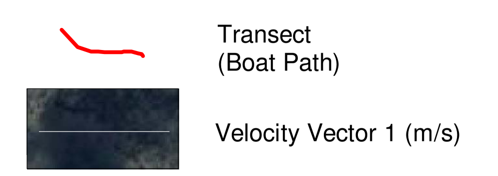

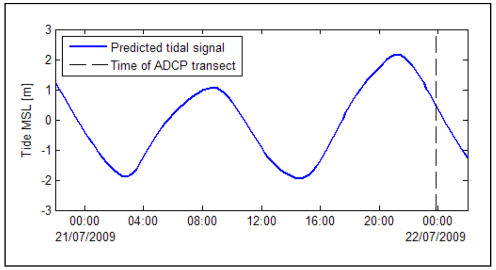

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Satellite imagery (GeoEye-1 on 24 March 2009) AAM Hatch 2009

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Map Grid of Australia - Zone 56
Geocentric Datum of Australia 1994

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Figure 4.4 ADCP transect measurement
The Narrows, south of Graham Creek

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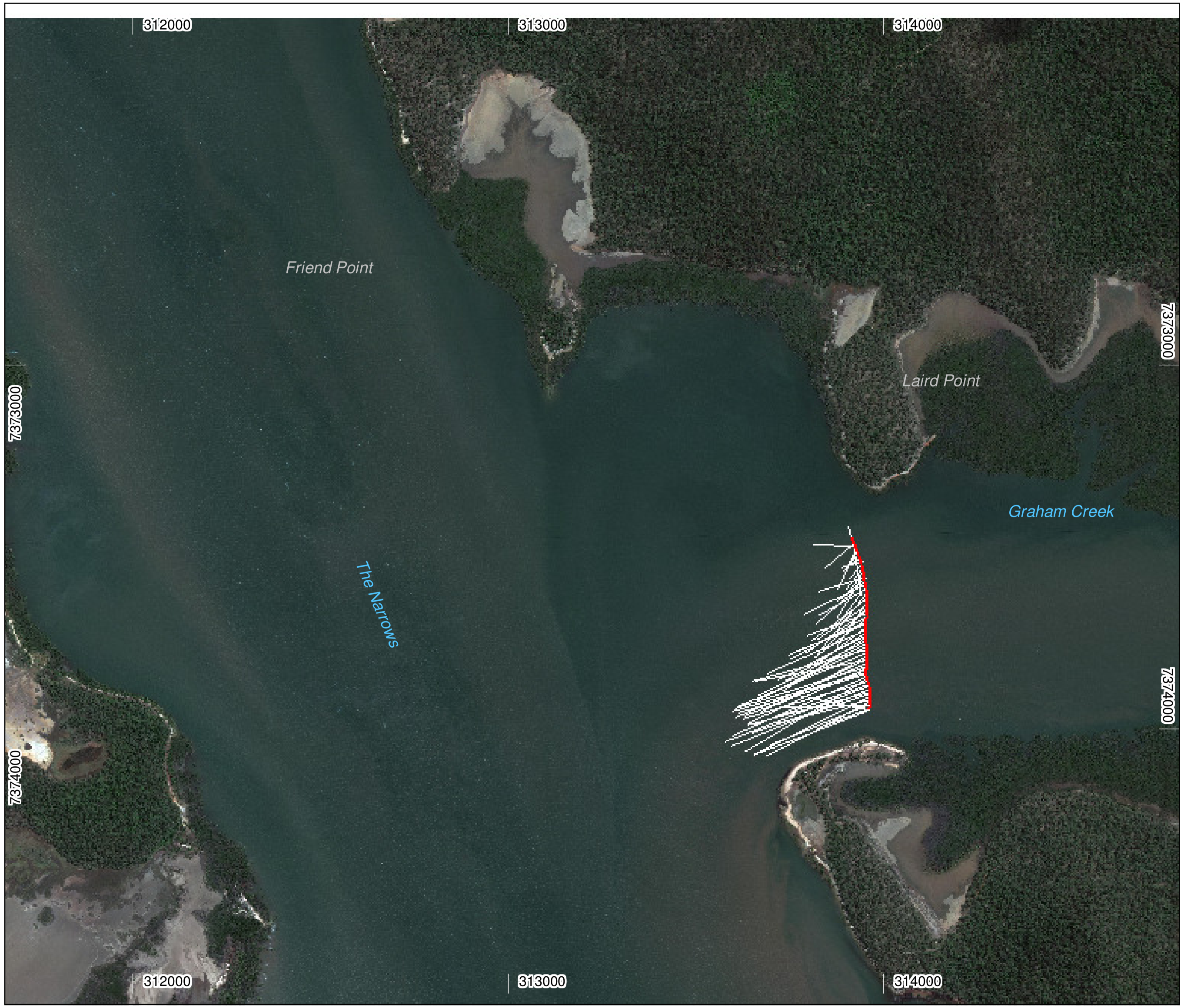

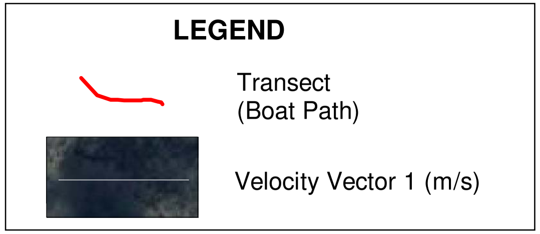

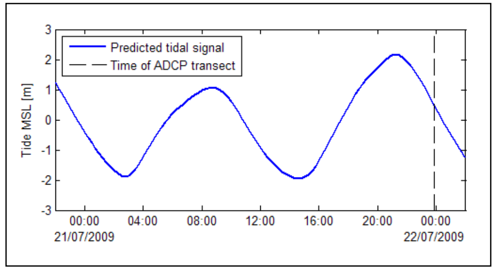

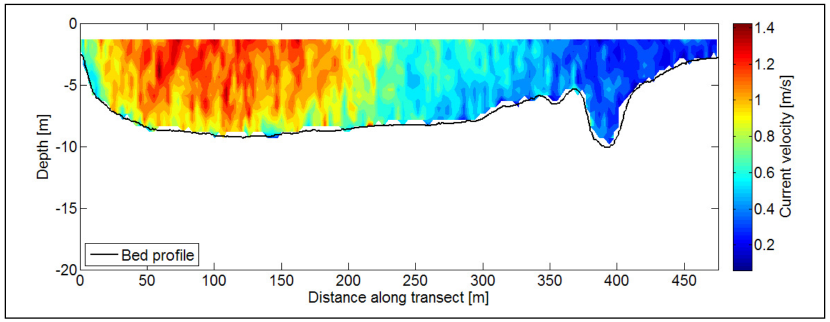

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Satellite imagery (GeoEye-1 on 24 March 2009) AAM Hatch 2009

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Figure 4.5 ADCP transect measurement Graham Creek entrance

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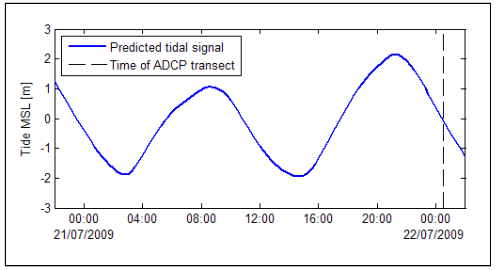

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Satellite imagery (GeoEye-1 on 24 March 2009) AAM Hatch 2009

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Map Grid of Australia - Zone 56
Geocentric Datum of Australia 1994

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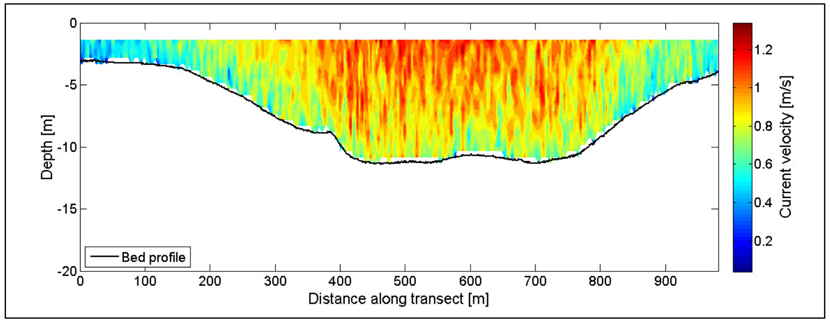

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Figure 4.6 ADCP transect measurement The Narrows, north of Graham Creek

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Wind and barometric pressure data was also collected during the deployment period of the ADCP instrumentation to ensure that meteorological effects were accounted for if they proved to be significant. A weather station was deployed at Barney Point in the period between 20 July and 31 August 2009. The maximum 10min averaged wind speed during the deployment was 45km/h, measured on the 18 August 2009. Average wind speed for the deployment period was approximately 13km/h. Variation of wind speed and direction is shown in Figure 4.7. Wind speed could be categorised as light increasing to moderate during the day (20 to 30km/hr or less), and was not considered to significantly influence the assessment of the current measurements. The average barometric pressure for the deployment period was 1018hPa.

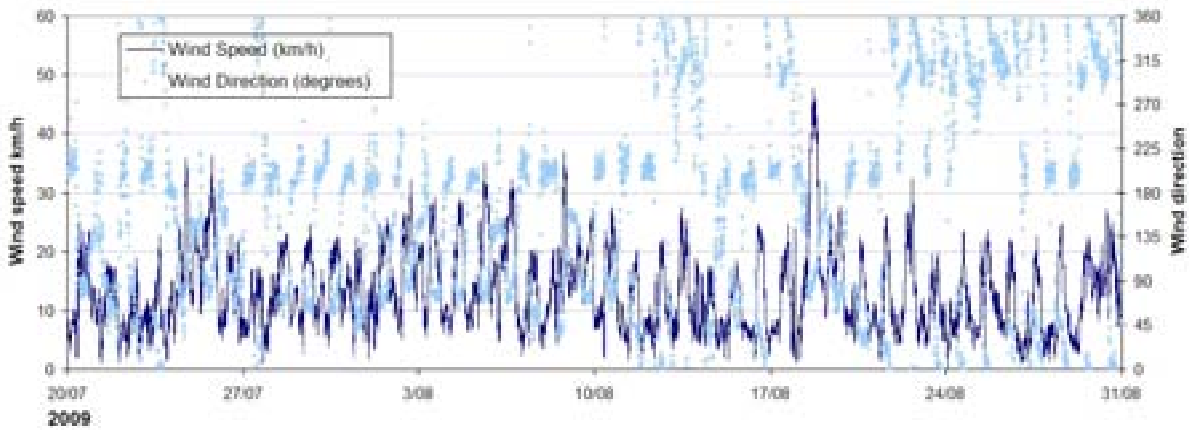


Figure 4.7 Wind speed and direction during ADCP instrument deployment

4.3.2 Model comparison with measurement data

The hydrodynamic model predictions have been compared to the following measurements (refer to Section 4.3.1):

- Observed water level variation data from three tidal stations operated by MSQ
- ADCP depth-averaged current speed and current direction measurements obtained at a fixed location offshore from Laird Point
- ADCP transect cross-sectional flow measurements obtained near Laird Point during spring (21/07/09) and neap (27/08/09) tidal periods

Figure 4.8 compare the predicted and observed tidal elevation time-series at the MSQ tide station locations. The period shown contains both neap and spring tide conditions. The model compares well with observations both in timing and magnitude at the three locations. In some instances during the neap to spring tide transition a minor over-prediction is evident at high tide. This variation is considered insignificant, particularly at Fisherman's Landing which is the tide station closest to the study area.

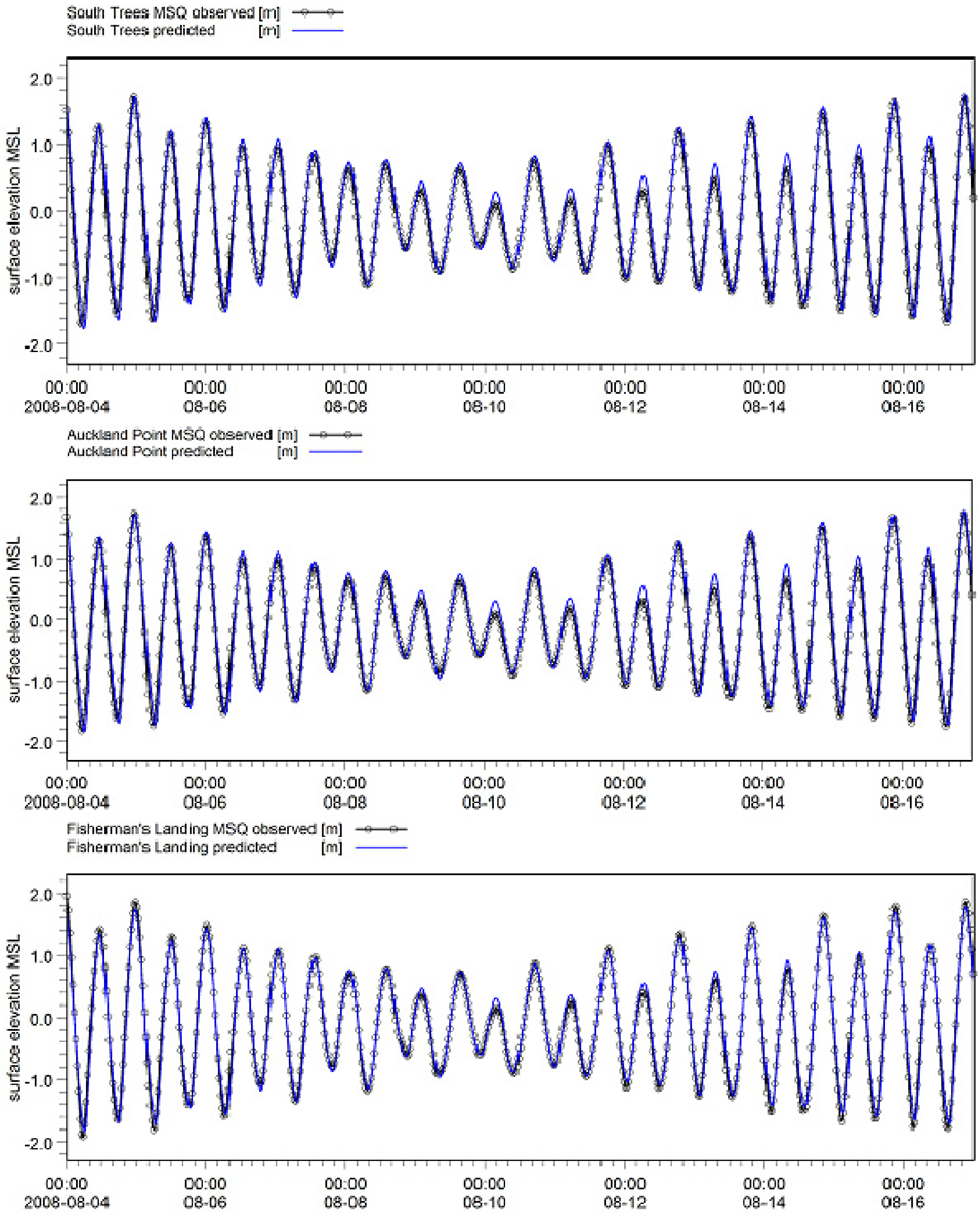


Figure 4.8 Hydrodynamic model output verification with MSQ tidal observations at Gladstone (South Trees), Auckland Point and Fisherman's Landing.

Figure 4.9 compare the predicted and measured tidal elevation, depth-averaged current speed, and current direction at the fixed ADCP deployment location. The timing of the ebb and flood tidal currents is well predicted. In some instances the peak current speed is slightly under-predicted. This may be attributed to the effects of meteorological forcing included in the measurements but not included in the simulation (such as wind) or unresolved, three-dimensional effects (such as turbulence). There is a slight discrepancy between the predicted and measured current direction on both the ebb and flood tide. Overall, the fixed ADCP measurements compare very well with the model predictions.

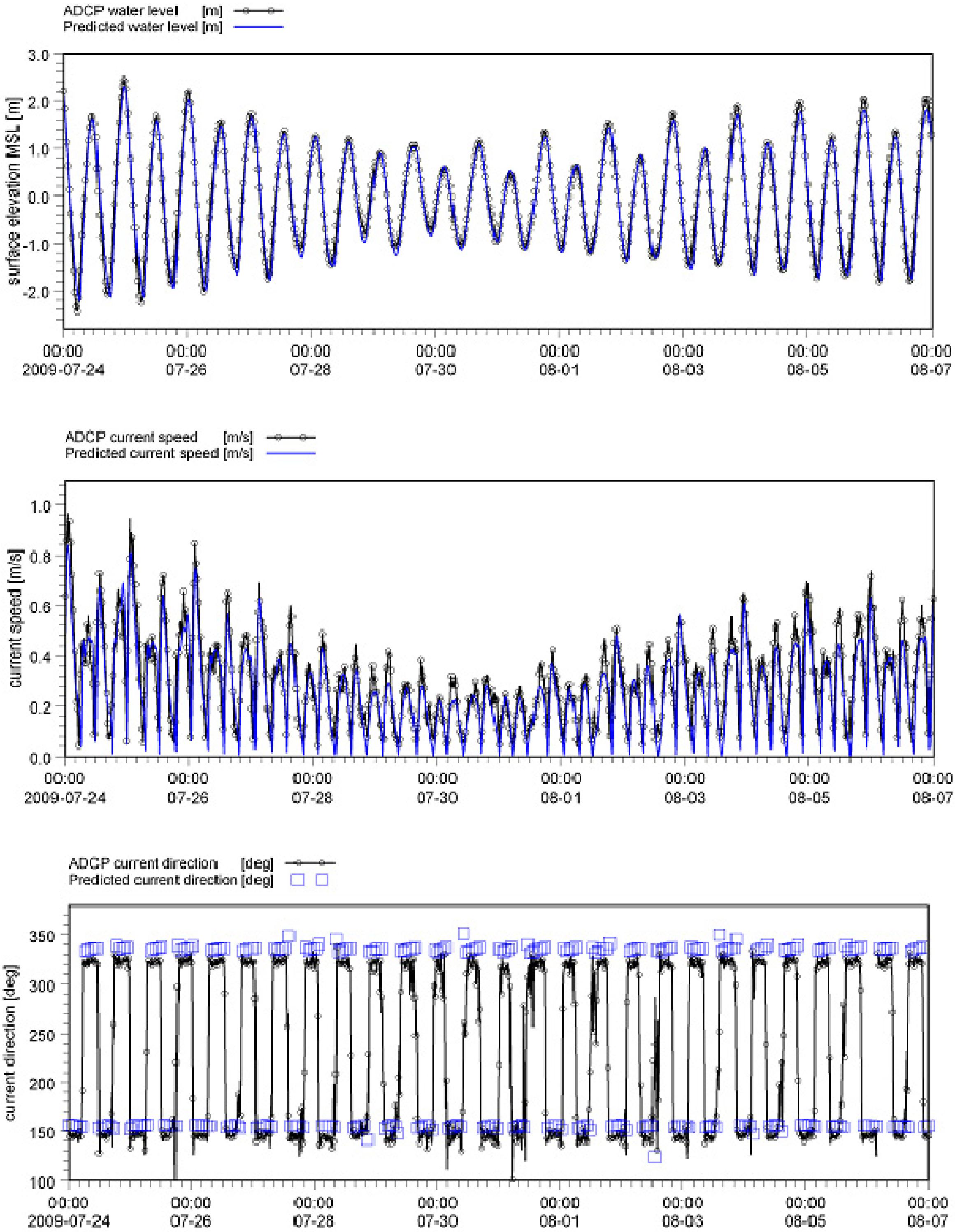


Figure 4.9 Hydrodynamic model verification with ADCP measurements at a fixed location offshore from Laird Point.

The model verification plots in Figure 4.10 compare the predicted and measured spring tide cross-sectional flow rates at the three ADCP transect locations (refer Figure 4.3). Positive and negative values indicate flood and ebb tidal flow respectively. At the three ADCP transect locations the cross-sectional flow magnitude is generally well predicted by the hydrodynamic model. Some minor phase

discrepancy between the model prediction and measurements is evident during the flood to ebb transition.

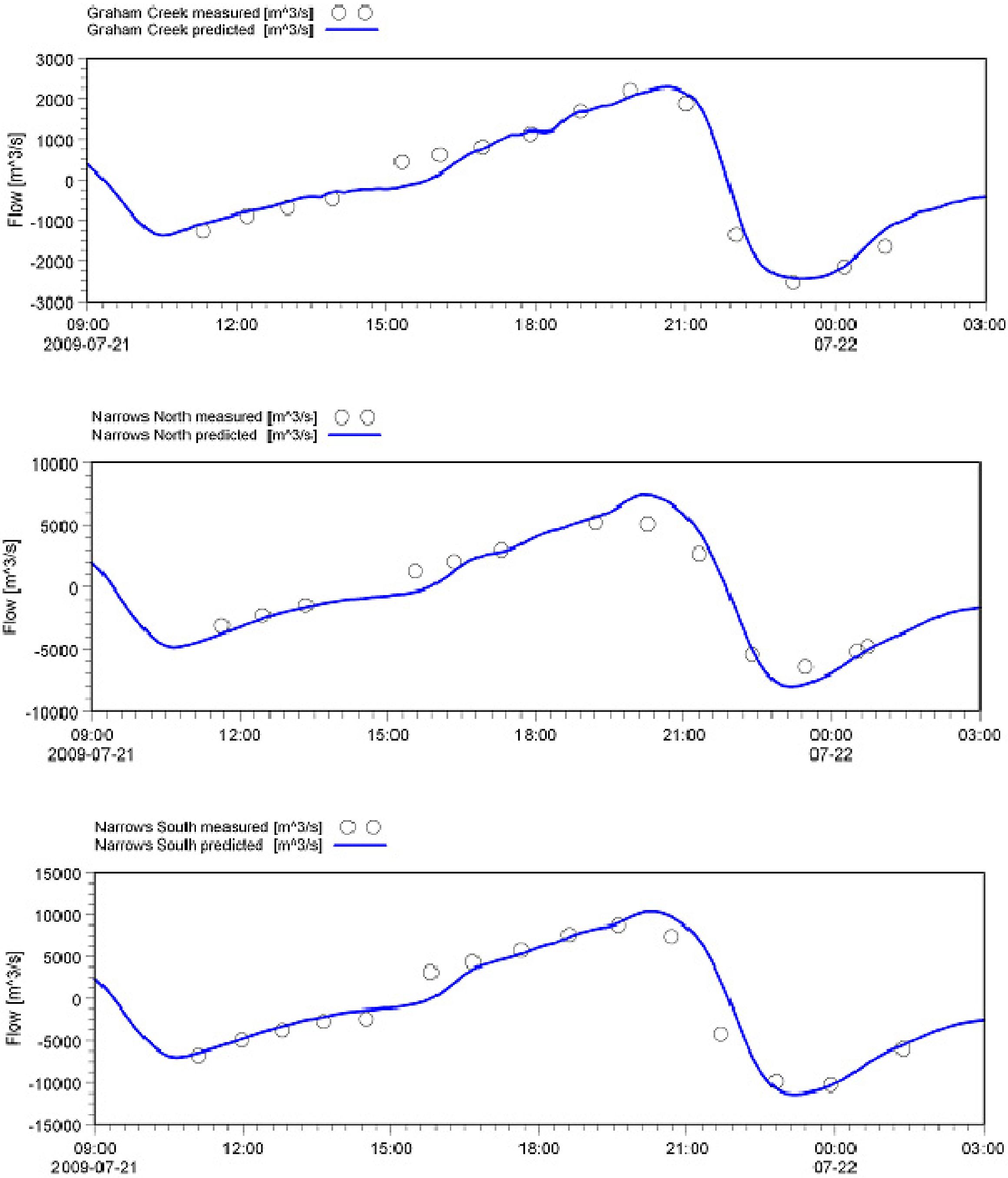


Figure 4.10 Hydrodynamic model output verification with spring tide cross-sectional flow measurements (obtained from ADCP transects) at Graham Creek, Narrows North, and Narrows South.

4.3.3 Flushing characteristics

The hydrodynamic model was used to predict the existing tidal flushing time within the study area. The flushing time refers to the time required for water within a defined subregion to be exchanged with water from outside the subregion. Nutrient levels within an aquatic ecosystem and/or the accumulation

impact of introduced substances (for example, entering the ecosystem via an outfall discharge) are influenced by the flushing time.

The tidal flushing time was predicted following the 'e-folding time' method. The e-folding time refers to the time required for the mass of a passive tracer within a defined subregion to be reduced to a value of 1/e (approximately 37% of its initial total mass, where e is the natural logarithm e=2.7182). The defined subregion for the assessment includes the Western Basin, Graham Creek, and The Narrows as illustrated in Figure 4.11. At the beginning of the flushing simulation the tracer is contained within the subregion. During the simulation, the tidal hydrodynamics drive the exchange of water into and out of the subregion. The mass of the tracer remaining in the subregion is calculated at each model time step. Figure 4.11 a) shows the initial distribution of the tracer within the subregion of the model domain. Figure 4.11 b) shows the distribution of the tracer during a flood tide after approximately one month of tidal flushing. Tidal flushing of the subregion is dominated by water entering from Gladstone Harbour. The flushing predictions reported here are based on tidal forcing only and do not consider input from river flows or meteorological forcing.

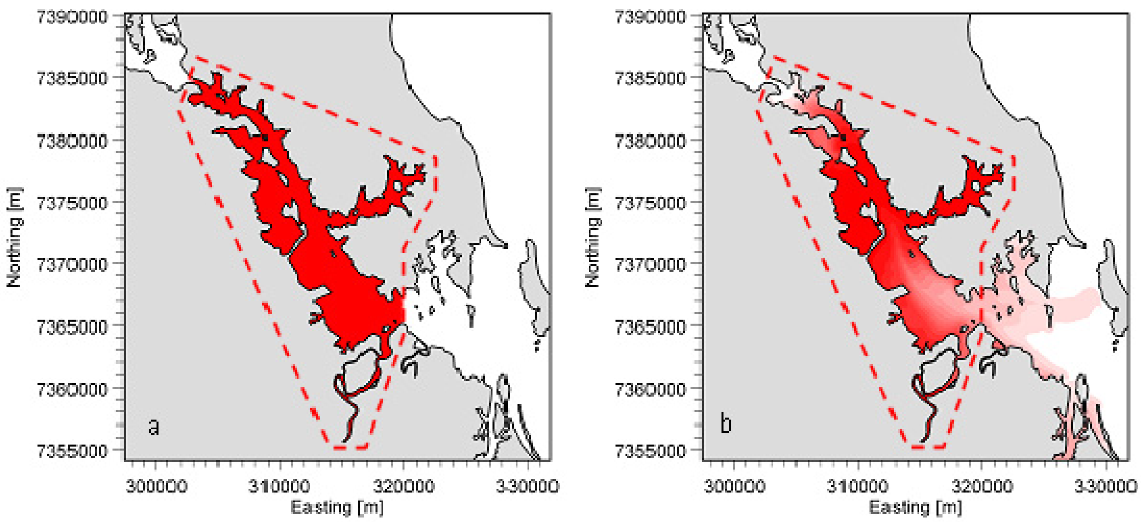


Figure 4.11 Distribution of the passive tracer (red) within the subregion (dashed line): a) initial tracer distribution within the subregion, and b) tracer distribution during a flood tide and following approximately five days of tidal flushing.

A time series of the predicted tracer mass relative to the initial mass in the defined subregion is presented in Figure 4.12. As the tidal hydrodynamics force the exchange of water into and out of the subregion the tracer mass within in the subregion oscillates with a gradually decreasing trend. The polynomial fit applied to the predicted tracer mass time series suggests the e-folding flushing time of the subregion is approximately 55 days.

The GPC Western Basin Dredging and Disposal EIS methodology is based on local tidal flushing times rather than the sub-region described here.

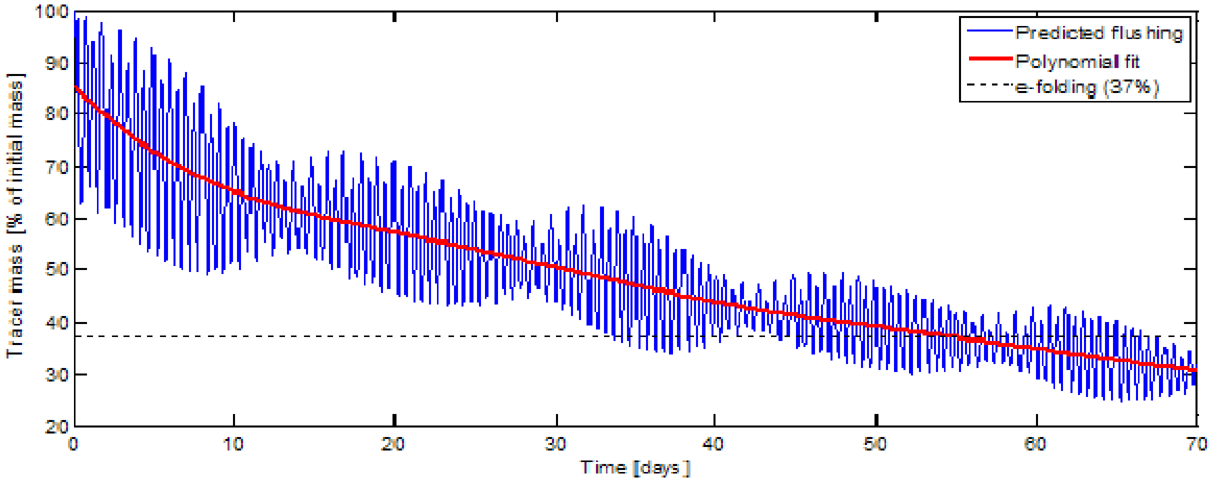


Figure 4.12 Predicted flushing time of the sub-region defined in Figure 4.11.

4.4 Severe weather events

As described in Section 3.7, Gladstone is in a region subject to tropical cyclone activity. Both hydrodynamic and wave modelling have been used to assess the potential storm tide level and wave conditions at the proposed LNG facility site from tropical cyclone wind fields. This section describes currents and water levels associated with the storm tide conditions in the existing harbour and Western Basin configuration without the proposed dredging and disposal options implemented.

The modelling does not represent a comprehensive storm tide study, but draws on previous benchmark work conducted through James Cook University (Hardy et al., 2004) to assess the conditions at the proposed Australia Pacific LNG site produced by a severe storm that could be realised within the design life of the plant.

4.4.1 Currents and water levels

A 1 in 30 year design storm event was selected from the analysis of tropical cyclones that have tracked within 250km of Gladstone as presented in Section 3.6 and parameterised in Table 4.1. The 30 year ARI coincides with the operational life span of the LNG facility and is a reasonably intense tropical cyclone. The synthetic tropical cyclone parameters adopted to simulate storm surge at Gladstone are given in Table 4.1.

Table 4.1 Representative 30 year ARI tropical cyclone parameters used for storm surge modelling.

Forward velocity (km/h)	Radius to maximum winds (km)	Maximum wind velocity (m/s)	Central pressure (hPa)	Neutral pressure (hPa)
20	30	45	945	1013

Idealised east to west tracking tropical cyclone wind and pressure fields were generated from the parameters and used to force the hydrodynamic model. Initially water level was set constant to MSL

and the cyclone tracks adjusted until the peak surge height at Auckland Point was 1.4m, the 50 year ARI surge predicted by Hardy et al. (2004).

Storm tide water levels at the proposed Australia Pacific LNG site were then computed using the hydrodynamic model with tidal forcing at the boundaries and the same synthesised cyclone track used to generate the 50 year ARI surge at Auckland Point. In the simulations, the time of the cyclone making landfall was varied so the generated surge and tide (at the time of landfall) combined to produce a water levels between the 100 year and 500 year ARI storm tide for Gladstone (Queensland Government 2004). Table 3.4 indicates that this water level is between 2.82 and 3.51m AHD (no allowance for climate change).

Current and water level predictions were extracted from the model at three locations of interest:

- Auckland Point (the location reported in Hardy et al. 2004)
- West of North Passage Island (in the vicinity of the Australia Pacific LNG Option 1b berth)
- East of North Passage Island (in the vicinity of the Australia Pacific LNG Option 2a berth)

The predicted water level and current speed for storm tide was compared to normal tide conditions in order to assess the potential impact of the idealised severe weather event.

The largest predicted hydrodynamic impact was associated with a tropical cyclone making landfall at Gladstone during spring flood tide conditions because tide and surge currents are combined. Results for this event are summarised in Table 4.2. The values in brackets indicate the percentage increase from the tide only case to the storm tide event.

Table 4.2 Predicted impact of a representative 30 year ARI tropical cyclone arriving during spring flood tide conditions.

	Normal spring tide		Storm Tide (cyclone landfall at time of flood tide)	
	High water level MSL (m)	**Current speed (m/s)**	**Peak water level MSL (m)**	**Peak current speed (m/s)**
Auckland Point	2.19	0.97	3.24 (+32.5%)	1.36 (+28.3%)
North Passage Island West	2.29	0.78	3.36 (+32.0%)	0.95 (+18.1%)
North Passage Island East	2.28	0.71	3.33 (+31.4%)	1.09 (+34.8%)

The model results provide a preliminary account of the hydrodynamic conditions in Gladstone Harbour and at the proposed site for the selected design storm event and using existing bathymetry. Storm tide water levels and currents at three locations are compared and key findings are as follows:

- Minor amplification of the storm tide occurs inside the estuary, comparable to the normal tide behaviour. Therefore storm tide levels at the proposed site can be expected to be higher than Auckland Point elevations by approximately 5%.
- When a storm tide coincides with flood tide currents under present channel conditions, increases in current speed of 20% to 30% could become apparent and, although of relatively short duration, there is a high likelihood some morphological changes would occur to shoals and channels.

The potential impact of the same design storm event and resulting storm tide on the modified bathymetry, representing the proposed channel and swing basin development options, is considered in Section 6.2.3.

It should be noted that a total storm tide water level also includes components of wave setup, run-up, and the potential for overtopping. The Australia Pacific LNG project site reclaimed levels are designed in consideration of all components of total water level associated with storm tide.

4.4.2 Waves

Wave growth and propagation associated with ocean swell and severe weather events at the study site and within Gladstone Harbour have been assessed using a SWAN (Simulating WAves Nearshore) wave model.

SWAN calculations for Gladstone Harbour were performed on model domain with a 50m grid resolution. The model extent was determined based on the largest possible fetch distances relative to the study area.

Previous wave studies within Gladstone Harbour suggest that locally generated wind waves have the potential to be larger than ocean swell waves within the study area (BMT WBM 2006). This is due to Rodd Peninsula, Facing Island, South Trees Island, and a number of smaller islands within the harbour acting to block long period ocean swells from penetrating to the study area. This previous finding was confirmed with the wave model. Figure 4.13 presents the significant wave height contour and vector map over the model domain for 1m significant wave height with 10sec period ocean swell. Figure 4.13 clearly demonstrates the limited swell penetration into Gladstone Harbour. Ocean generated swell waves have a very low potential to impact on the proposed Australia Pacific LNG facility location.

Locally generated wind waves on the proposed Australia Pacific LNG facility were also investigated using the wave model. A 10min average wind speed of 36m/s, representing a 50 year ARI wind speed for the Gladstone region (Australian/New Zealand Standard 1170.2:2002, Part 2: Wind actions), was applied across the model domain.

Wind directions associated with the longest local fetches over water to the Australia Pacific LNG facility were modelled. Predominately overland winds from the northern sectors were omitted as these winds are not expected to be significant in terms of wave generation.

Table 4.3 summaries the 50 year ARI local wind wave modelling and presents the predicted significant wave heights offshore from the Australia Pacific LNG facility to the north and south of North Passage Island. Local wind wave prediction indicates that 50 year ARI winds from the westerly and southerly sectors generate the largest waves within the study area. At a location just to the north of North Passage Island westerly winds have the potential to generate the largest waves. Southerly winds generate the largest waves south of North Passage Island.

Predicted significant wave height contour and vector maps due to the 50 year ARI wind speed from the westerly and southerly directions are shown in Figure 4.14a and Figure 4.14b. The figures indicate that North Passage Island provides some protection to the proposed Australia Pacific LNG facility location during extreme westerly winds. The shoreline at the proposed site is more exposed to waves associated with extreme southerly winds.

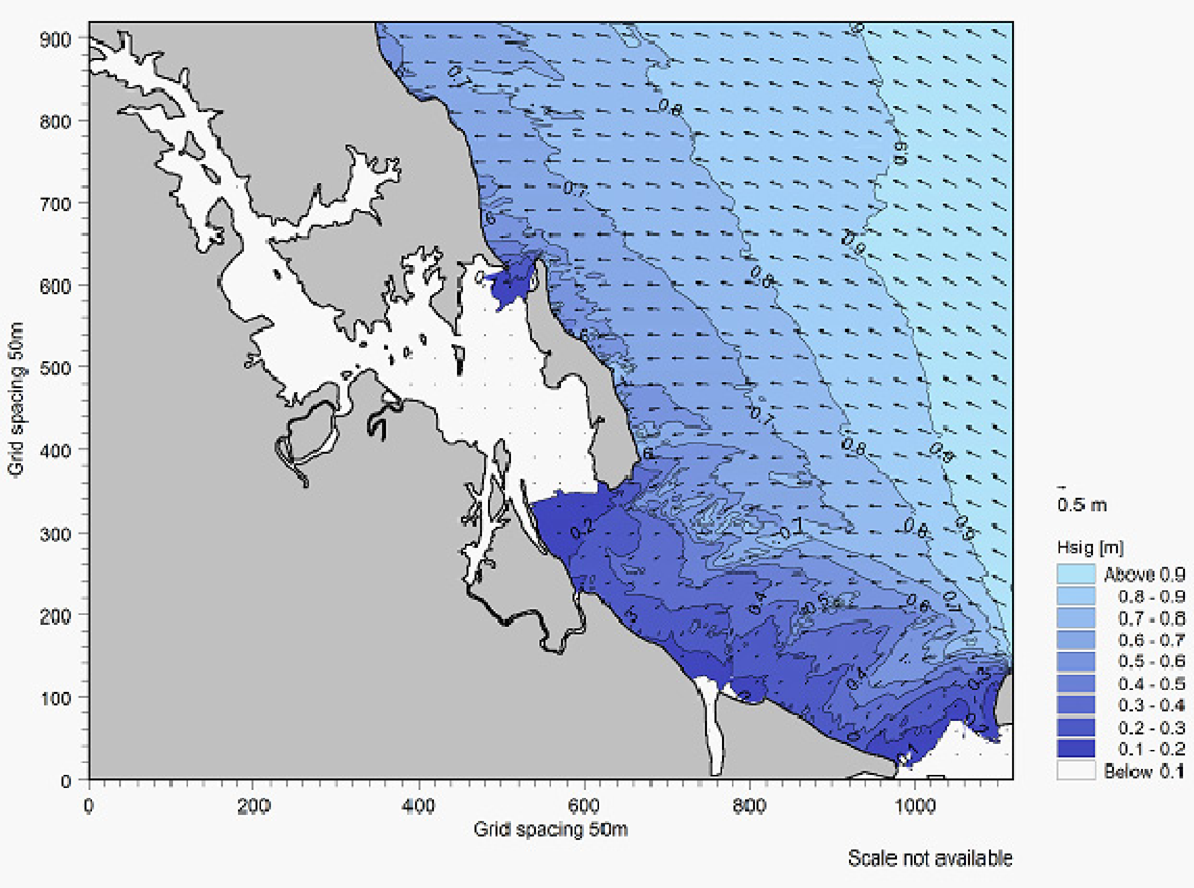


Figure 4.13 Predicted significant wave height contour and vector map for ocean swell penetration study. The white indicates areas where the significant wave height is less than 0.1m.

Table 4.3 Summary of local wind wave prediction for 50 year ARI wind speed.

10min average local wind speed (m/s)	Local wind direction (direction from)	Significant wave height (m)	
		North of North Passage Island	South of North Passage Island
36	W	1.51	1.35
36	WSW	1.46	1.39
36	SSW	1.42	1.55
36	S	1.37	1.68
36	SSE	1.25	1.54
36	ESE	1.12	1.32
36	E	0.98	1.13

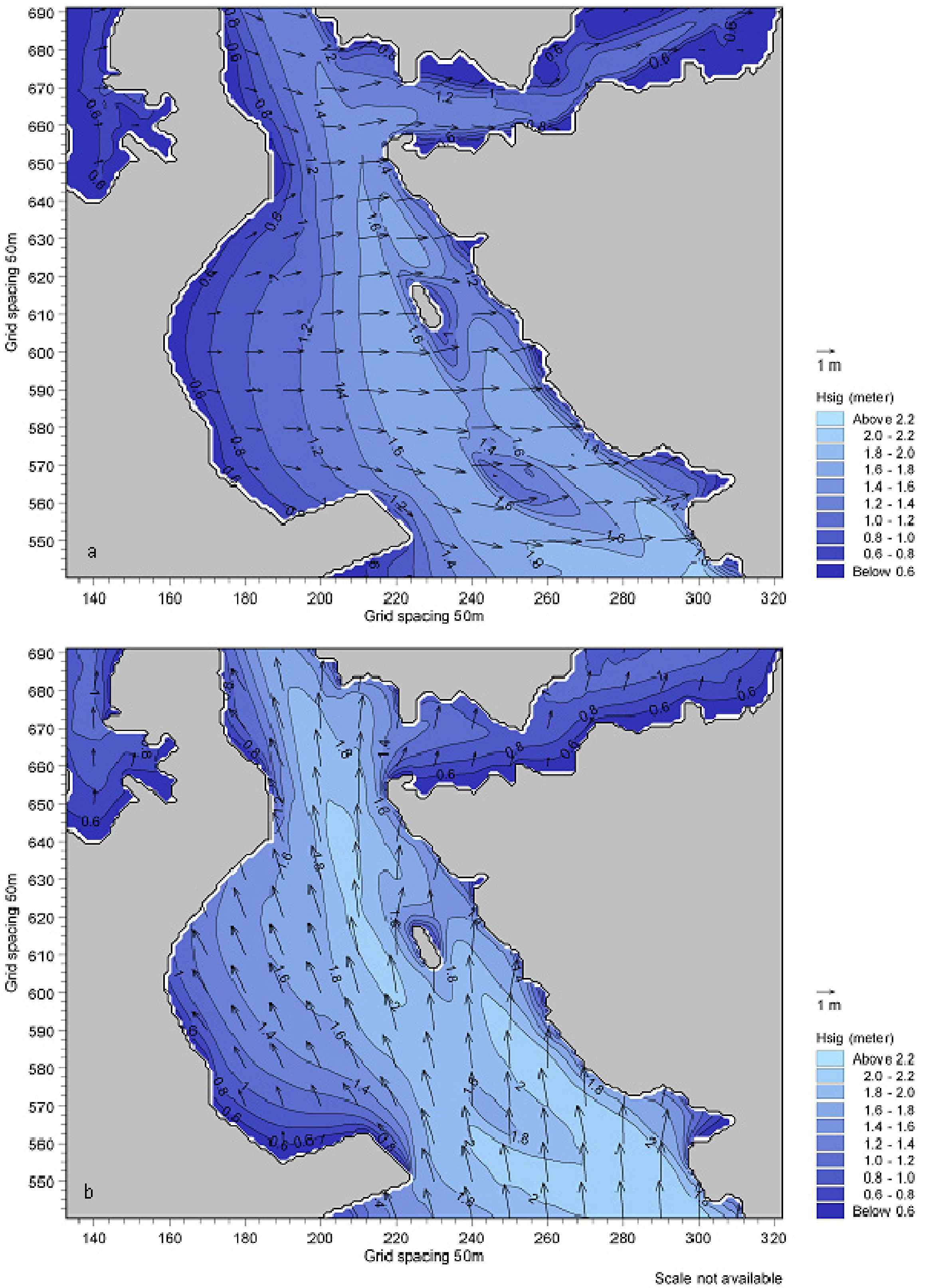


Figure 4.14 Predicted significant wave height contour and vector map due local winds with a 10-minute average wind speed of 36m/s (50 year ARI cyclonic wind speed for Gladstone region): a) westerly wind direction, b) southerly wind direction.

5. Proposed marine developments

A general description of the LNG facility, shipping, and the marine components of the Project were provided in Section 1. This following section describes the marine components in more detail and, where relevant, discusses alternatives being examined.

5.1 Jetty and ship berths

The jetty and ship berths will be designed to provide safe mooring for the receipt and support of LNG ships, and to ensure the safe transfer of cargo from the onshore storage facilities to the ships. The design will be in accordance with all applicable codes and standards including, but not necessarily limited to, Oil Companies International Marine Forum (OCIMF), Society of International Gas Tanker and Terminal Operators (SIGTTO), American Petroleum Institute (API), and Australian Standards.

The jetty platform at each berth is proposed as a two level structure consisting of a lower main deck and an elevated mezzanine deck. Loading arms would be supported by the lower deck, curbed to contain potential LNG spills and sloped to drain for LNG containment.

A trestle structure is proposed to connect to the shoreline and on-shore tanks.

A generic berth layout was based on the LNG ship data and the mooring dolphin layout is based on OCIMF recommendations for angles of mooring lines. Breasting dolphin positions take into account the flat-sidedness of LNG ships, for their various manifold positions forward and aft, to ensure that ships do not contact the jetty head and have adequate fender contact. The layout would also accommodate the identified LNG ship ranges. The design allows for vessels ranging in size from a 125,000m3 (285m overall length) to the Q-Flex 217,000m3 vessel (315m overall length).

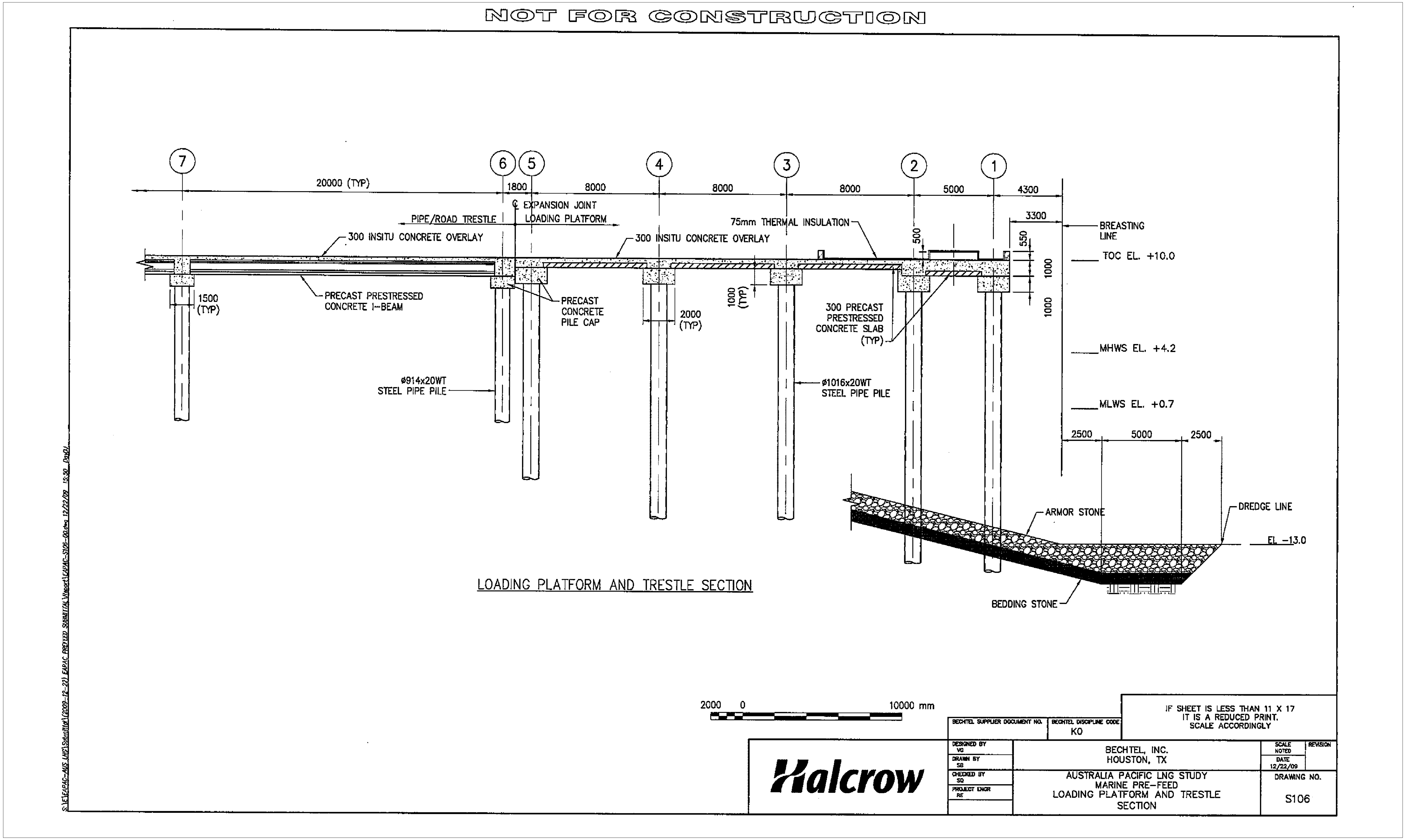
A minimum water depth of -13m LAT is required at the berths in addition to any over-dredging depth, assumed as 0.3m. The Gladstone Port procedures (2009) stipulate that vessels alongside any berth must maintain a minimum of 0.5m Under Keel Clearance.

Proposed design of the loading platform is shown in Figure 5.1. An additional row of piles is typically provided along the berthing face to support the weight of the loading arms and mezzanine platform. Also accommodated on the loading platform are valves and piping, a gangway tower, firewater monitors, and an anemometer. Utilities include electrical power for equipment and lighting systems, potable water, communications and instrument cabling, and nitrogen for purging the loading arms as shown in Figure 5.2.

The berth is designed symmetrically to allow for berthing in either direction.

5.1.1 Spill Containment

The design of the loading platform and the pipe trestle incorporates segregated containment systems; one for rainwater, and the other for the spilled LNG intercept system, so that all run-off from the platform is controlled. No run-off from the platform will be allowed into the Slip.



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0	12/01/2010	Issued for use	JC	KM		

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Figure 5.1 Typical jetty elevation

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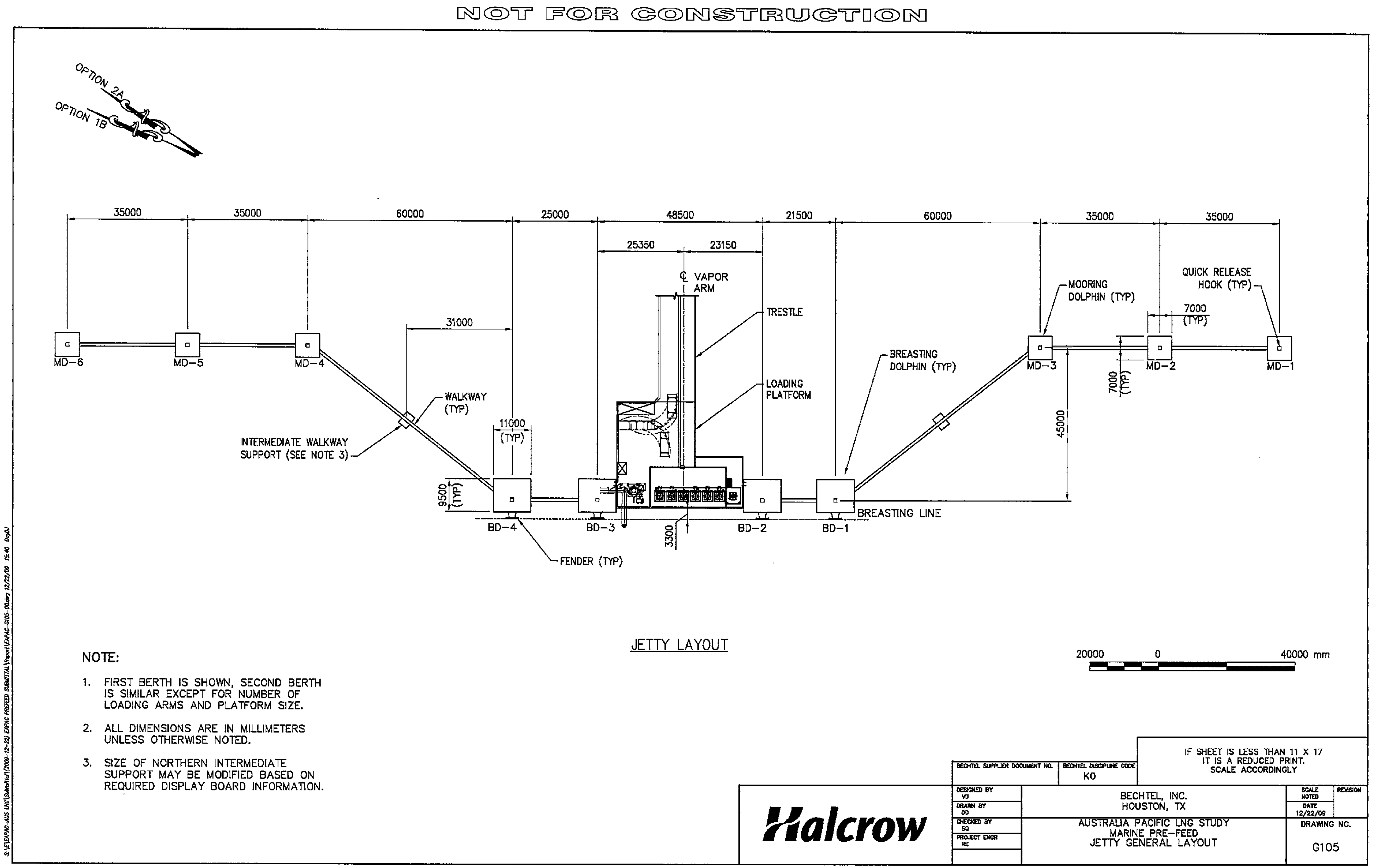

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0	17/02/2010	Issued for use	JC	KM		RB

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Figure 5.2 Typical LNG platform layout

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5.1.2 Dredging requirements

There are currently two location options being considered for the approach channel and swing basin layout described as follows and in reference to Figure 1.2:

- Option 1b has berths and swing basin on the western side of North Passage Island and this site is approached by vessels navigating Targinie Channel
- Option 2a has berths and swing basin on the eastern side of North Passage Island and is approached by the proposed channel extension from the Santos and BG LNG sites.

A minimum water depth of -13m LAT at the berths and in the adjacent channels is required to accommodate the design vessel. It is noted that vessel draft may, in practice, be less than 12.2m, as the LNG may be less dense than in other locations.

Normally a berth will require a turning circle of approximately two times ship length (depending upon location, tug availability and bow thruster availability). Design considerations have determined the swing basin diameter as 600m. GPC stipulate that vessels alongside any berth must maintain a minimum of 0.5m Under Keel Clearance.

Dredging is required for both options and would be undertaken as described in the Western Basin Dredging and Disposal Draft EIS (GHD 2009). Option 2a requires more dredging volume due to the existing shallow depths on the eastern side of North Passage Island (typically -5mLAT).

5.2 Materials offloading facility

The Materials Offloading Facility (MOF) is required to provide the following functions:

- The offload of modules for LNG trains
- Offload general construction materials from barges
- Support to load-out jetty construction.

The preliminary layout of the MOF is shown in Figure 5.3. A ramp will be the first element to be constructed, which will allow initial access to the island, and simultaneous operations of the ramp with the construction of the wharf proper. One permanent dock capable of 2,500 tonne loads and crane access with roll-on/roll-off ramps to unload heavy equipment, modules and materials will be provided for all LNG trains.

Due to the soft sediments underlying the proposed MOF location, it is expected that dredging of this material would be required in order to prepare the site before construction commences. The quantity of dredged material to be removed is assumed to be approximately 100,000m3. Note that this does not include dredging required for the approach to the MOF which is described and assessed in the GPC Western Basin EIS (BMT WBM 2009b).

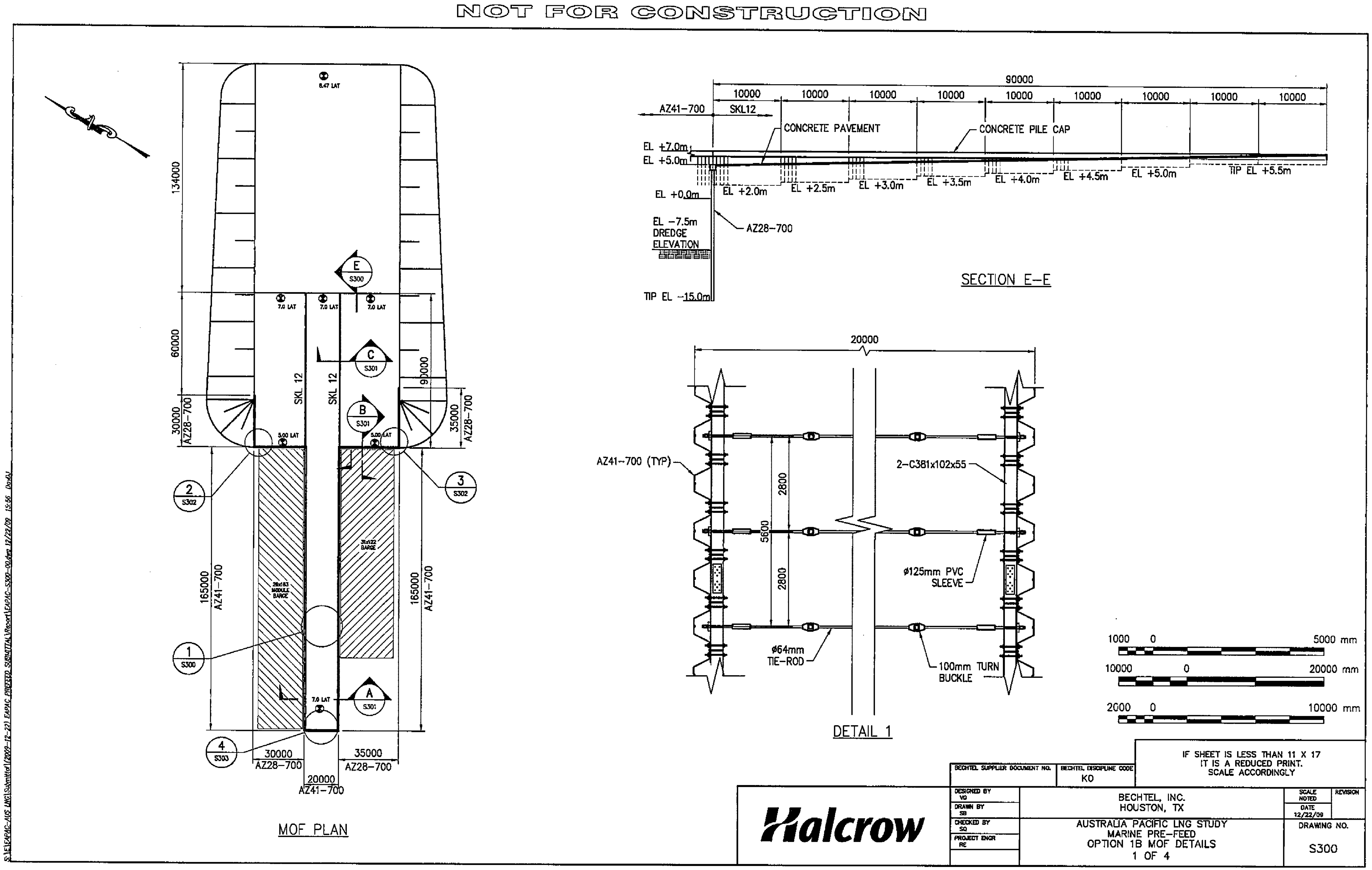

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Figure 5.3 Plan view and profile seaward of proposed MOF

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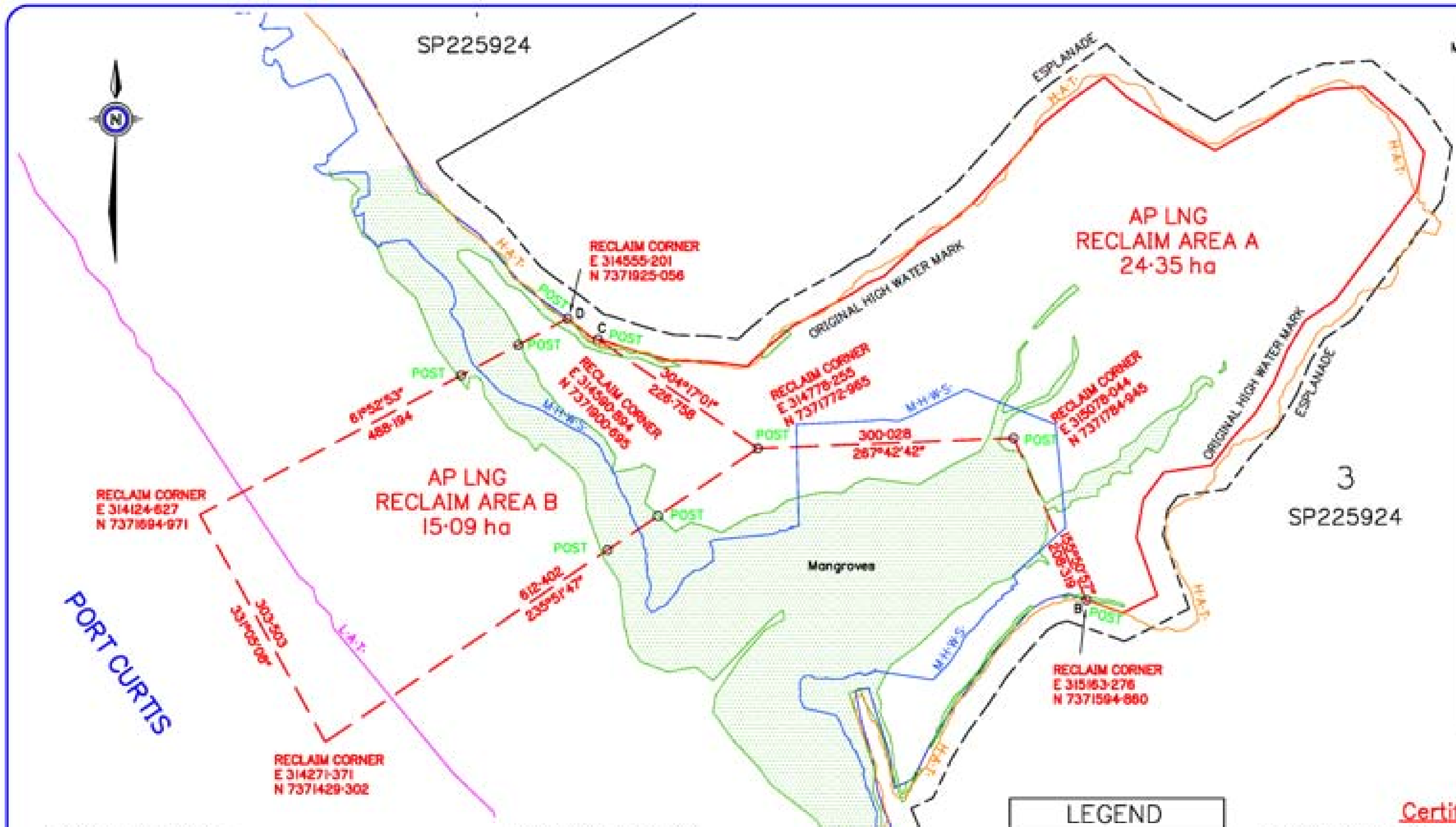
5.3 Reclaim area and revetments

The proposed LNG facility site is to be located within the reclaim area to be located on the intertidal mudflats to the south of Graham Creek. As a consequence of the low lying land within the site boundaries, and the need to elevate the LNG Plant to an appropriate level for engineering and environmental purposes, it is proposed to reclaim an area of approximately 39 hectares as shown in Figure 5.4.

The reclaim area requires earthworks fill material from higher ground within the LNG facility site boundaries in order to build the finished level to the design requirement of +6m above Australian Height Datum (AHD). The volume of fill material required to achieve finished level is over one million cubic metres.

Armour protection of the causeway and the MOF is proposed to prevent scour of the core material during high tides and energetic wave conditions, especially during storms.



METES & BOUNDS THAT REPRESENTS ORIGINAL HIGH WATER MARK

STN	BEARING	DISTANCE
B–	109°25'30"	45·173
	63°20'30"	44·983
	340°28'	72·532
	10°12'50"	44·983
	36°46'40"	40·234
	81°46'40"	56·899
	36°46'40"	40·234
	42°29'20"	40·434
	31°04'	40·434
	22°44'30"	41·472
	31°04'	40·434
	56°04'	42·627
	36°46'40"	160·934
	10°12'50"	44·983
	325°42'40"	42·535
	310°43'20"	62·847
	266°14'20"	40·434
	249°13'	41·03
	236°18'	44·12
	241°14'20"	42·627
	240°13'	23·62
	299°06'20"	38·916
	301°38'20"	80·568
	312°22'40"	36·655
	234°29'40"	51·615
	230°39'40"	40·234
	219°21'	41·03
	222°07'50"	81·368
	230°39'40"	40·234
	236°22'20"	40·434
	226°28'30"	55·106
	247°14'20"	20·217
	235°49'	20·217
	241°31'40"	80·467
	230°13'	41·03
	227°02'40"	30·939
	276°41'40"	44·455
	271°37'40"	45·623
	285°15'	40·434
	288°06'	40·284
–C	283°14'30"	7·851
C–	283°14'30"	6·816
–D	308°07'10"	36·935

PROPOSED RECLAMATION AREA B
METES & BOUNDS DESCRIPTION

Commencing at a point on the western boundary of the Esplanade being 247°12' for 1787.83m from the northern east corner of Lot 3 on SP225924, thence bearing 124°17'01" for a distance of 226.758m, thence bearing 235°51'47" for a distance of 612.402m, thence bearing 331°05'08" for a distance of 303.503m, thence bearing 61°52'53" for a distance of 488.194m to a point on the western boundary of the Esplanade, thence heading east along western boundary of Esplanade to the point of Commencement.
Containing an area of 15.09ha more or less.
Meridian MGA94 via plan SP225924.

PROPOSED RECLAMATION AREA A
METES & BOUNDS DESCRIPTION

Commencing at a point on the western boundary of the Esplanade being 247°12' for 1787.83m from the northern east corner of Lot 3 on SP225924, thence bearing 124°17'01" for a distance of 226.758m, thence bearing 87°42'42" for a distance of 300.028m, thence bearing 155°50'57" for a distance of 208.319m to a point on the western boundary of the Esplanade, thence heading easterly along the western boundary of the Esplanade to the point of commencement.
Containing an area of 24.35ha more or less.
Meridian MGA94 via plan SP225924.

LEGEND

H.A.T. Contour R.L. 2.562
M.H.W.S. Contour R.L. 1.692
L.A.T. Contour R.L. −2.268

Certification

I, Alan Scott Maclean (Cadastral Surveyor) hereby certify that this plan has been prepared from original survey field notes for plan DS220 and data supplied by Bechtel, and that the plan is accurate.

Signed.......A.S.Maclean....... Date..28/10/09
CADASTRAL SURVEYOR

ASIBA MEMBER

This plan has been prepared to client specifications and should not be used for any other purpose without confirming that the data is fit for the intended use by contacting Fredriksen Maclean & Associates

Fredriksen Maclean & Associates
CONSULTING SURVEYORS
GLADSTONE
9 Drews Street
Phone (07)4972 5677
Fax (07)4972 4928
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BILOELA
21 Bundalba St
Phone (07)4992 1400
P.O. Box 587
ROCKHAMPTON
266 Upper Dawson Rd
Phone (07)4927 3580
P.O. Box 8008
Allenstown Qld 4700
email: mail@fredmac.net

Property Description
Local Authority GLADSTONE REGIONAL COUNCIL
Level Datum AHDD
Origin PM 43555 RL173.034
Horizontal Datum GDA94
Meridian MGA
Origin PM 43555 E318437.726 N 7370285.709

Scale 1:5000/A3
Surveyed FREDMAC
F. Books
Comp. File 3751-1-01,02B
Checked ASM
Approved ASM

Amendments	
Date	Details
04/09/09	ISSUE
11/09/09	AMEND OHWM TABLE
28/10/09	TIDE LEVELS ADDED

Contractor Name: Bechtel
Contractor Client Name: AP LNG
Title: RECLAMATION PLAN
Project Title: AP LNG Project
Bechtel Project Number: 25509–300

Sheet 1 of 1 Sheets
Drawing Number 3751–1–02B

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Figure 5.4 Reclamation boundaries for the proposed LNG plant

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5.4 Seawater desalination

Alternate sources of water such as groundwater, and rain water from the local catchment were evaluated in pre-feasibility studies, but rejected as not being sustainable to meet the demand.

Water demand for the proposed Australia Pacific LNG Plant service water system is mainly attributed to a fresh water source during construction and operations, in addition to demineralised water required for amine make-up in the Acid Gas Removal Unit. Service water will be provided through the operation of a seawater desalination unit to supply fresh water. The closest source of marine water is directly offshore from the proposed plant.

Projected water demand and relevant assumptions for the construction phase and operations are described in Volume 4, Chapter 3 of the EIS.

Potable water demand during construction varies from 1-35m^3/hr based upon peak workforce loading of 2,500 during 40 months and a water demand of 0.284m^3/person/day. Water requirement for construction is similar for operating conditions with two-trains and has been estimated to be about 840m^3/day. With the expansion of the plant to four-trains water demand would increase to approximately 65m^3/h or 1544m^3/day (Bechtel 2009).

5.4.1 Desalination unit waste-stream

In converting the seawater intake stream to fresh water for process and potable water requirements a waste stream is developed. The desalination concentrate or brine reject is the residue from the desalination plant that is to be returned to the marine environment offshore from the proposed LNG facility. The brine reject discharges are a function of the desalination unit efficiency, and a freshwater recovery rate of approximately 40% is expected. Brine reject average flow rates are presented in Table 5.1 based on a desalination recovery rate of 40% and maximum flow rates based on a desalination recovery rate of 35%. The brine reject characteristics are given in

Table 5.2.

It has been assumed that the brine reject temperature (after processing) will be comparable to the temperature of the ambient marine waters as these are the source for the desalination plant intake. Consequently, for the calculation of the density of brine reject, an increase of half a degree Celsius has been allowed. The salinity of the brine reject is dependent on the freshwater recovery rate and a slightly more saline waste stream is produced with an increased recovery rate. Therefore the salinity of the brine reject has been based on the salinity of the ambient marine waters and recovery rates that vary between 35-40% result in a range of salinity from 53.1-67.5ppt.

Table 5.1 Desalination Unit intake and brine reject discharges during the operational phase

Summary (see tables below)	2 LNG Trains (9 MTPA)		4 LNG Trains (18 MTPA)		Construction	
	Ave. Flow (m^3/hr)	Max. Flow (m^3/hr)	Ave. Flow (m^3/hr)	Max. Flow (m^3/hr)	Ave. Flow (m^3/hr)	Max. Flow (m^3/hr)
SW Intake (each pump capacity 180m3/h)	99		187		109	

Summary (see tables below)	2 LNG Trains (9 MTPA)		4 LNG Trains (18 MTPA)		Construction	
Brine to outfall[1 2]	56	68	106	128	62	75
Product water	34.2		64		38	
brine density	1037	1043	kg/m^3			
seawater density	1022	1024	kg/m^3			

Note: For operations phase only (construction phase uses less product water)
[1]Average brine discharge uses 40% recovery.
[2]Maximum brine discharge uses 35% recovery

The proposed location for the desalination system intake is the Product Loading Facility via a passive intake screen attached to a jetty pier. This is over 600m from the discharge option in front of the MOF. The intake is well clear of the brine release initial mixing zone and under normal tide conditions the brine should be sufficiently mixed over the water column depth such that concentrations would be close to background levels. Consequently, recirculation of elevated brine concentrations back into the desalination intake would be avoided.

Intake rates required for the desalination system are low when compared to total flows in the North Passage Channel and have no influence on the hydrodynamics. The impact of the intake on the marine ecology is assessed in Volume 4, Chapter 10 of the EIS.

Table 5.2 Brine reject characteristics

Wastewater Stream	Estimated Characteristics	Units
pH	6 to 8	
TDS	50,000 to 60,000	mg/L
Calcium, Ca	600-750	mg/L
Magnesium, Mg	2,000-2,500	mg/L
Potassium, K	600-800	mg/L
Sodium, Na	19,000 -22,000	mg/L
Chloride, Cl	30,000-33,000	mg/L
Fluoride, F	1.5 -3	mg/L
Sulphate, SO4	4,000 -6,000	mg/L
Strontium, Sr	15-25	mg/L
TSS, average	20-30	mg/L
TSS, maximum	40	mg/L
SiO_2	1-2	mg/L
BOD_5	5 to 10	mg/L

Note: Based on first pass brine reject for 2 train LNG Plant (9MTPA)

5.5 Treated Wastewater Discharges

Wastewater streams from various processes and facilities would be treated, screened, and dosed on site to bring it in line with acceptable standards for irrigation or re-use within the plant process make-up water. Using treated wastewater for on-site irrigation, to the extent possible, would reduce the quantity of discharge to the sedimentation/holding basins or discharge to marine waters.

It is estimated a maximum rate of 550 m^3/day of construction waste sewage flow would be generated. Operation of a waste treatment plant on site was determined to be a more cost effective option than transporting the waste stream back to the mainland by truck for disposal.

Treated sewage effluent would be collected in a tank (can also receive de-oiled process oily water) before it is discharged as irrigation water or combined with desalination brine reject in the seawater outfall.

Use will be made of existing proven treatment technologies that are cost effective and prevent adverse water quality or other environmental impacts. Liquid waste limits for operational discharges would be developed from guidelines to ensure compliance with National and Queensland standards (WQO water quality objectives) for fresh and marine water quality in Gladstone as outlined in Volume 4, Chapter 10.

Sewage effluent is not dechlorinated before discharge either to irrigation or to the seawater outfall diffuser. Dechlorination is not required with the mixing and dilution in the outfall diffuser system. Discharge of sewage effluent is only an alternate to the preferred irrigation. Also, there should not be any chlorine in the desalination brine reject as there is a dechlorination step prior to the desalination system.

5.6 Pipeline crossing

The expansion of Australia Pacific LNG's existing CSG operations in the Walloons Gasfields Development Area in the Surat Basin will supply gas to the proposed LNG facility on Curtis Island.

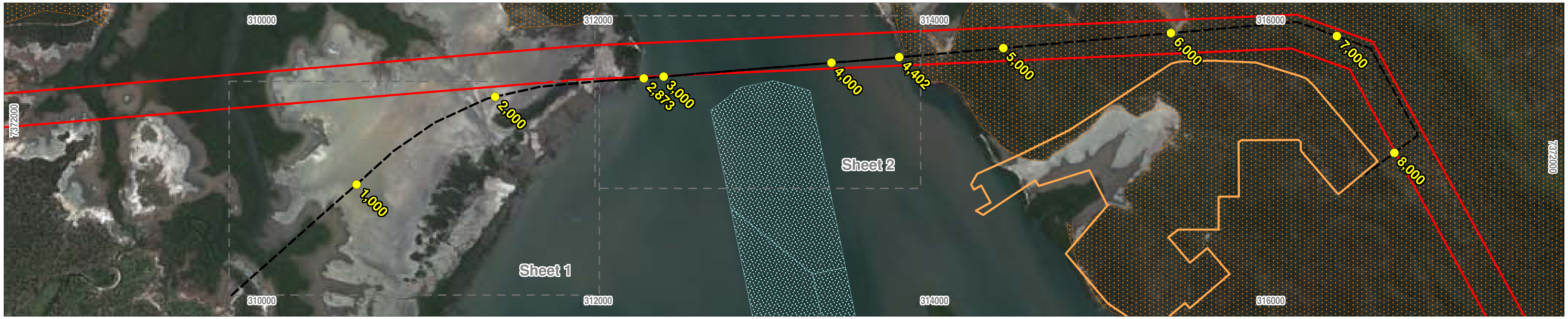
Transmission of the gas from the Walloons Gasfields requires the development, construction, and operation of a high pressure main transmission pipeline. The main transmission pipeline is expected to be a 42inch (1.1m) diameter steel pipe and approximately 450km long, including the underwater crossing of The Narrows to reach the LNG Plant on Curtis Island.

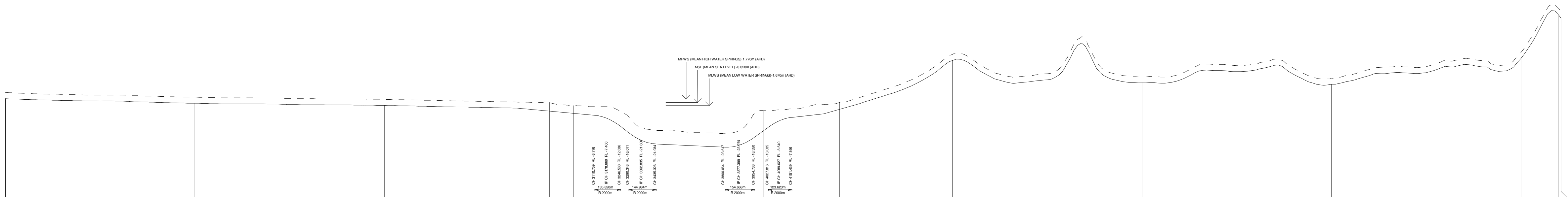
The ultimate gas requirements and train configuration will be determined during the front end engineering design (FEED) stage. The LNG Plant will utilise ConocoPhillips proprietary Optimized Cascade® technology, which is a proven and reliable technology and is well-suited to a CSG to LNG application.

5.6.1 Location

The preferred route is presented in Figure 5.5 and provides an overall plan view and profile of the approaches and crossing. Figure 5.6 is a larger scale view of the approaches across the wetland to the west of The Narrows and Figure 5.7 is a large scale view of The Narrows crossing for the Horizontal Directional Drill (HDD) option between Friend Point and Laird Point.

Figure 5.8 corresponds to proposed cross-sections of the pipeline through the wetland area and across The Narrows if a dredged trench has to be used instead of HDD. The options for the crossing of The Narrows are discussed in Section 5.6.2 and all construction methodologies follow the same pipeline route.





EXISTING SURFACE LEVELS	5.265	2.766	1.625	0	-1.655	-4.282	0	25.501	13.975	12.816	26.484	49.360	47.826
DEPTH TO BOTTOM OF TRENCH	-3.200	-3.200	-3.200	-4.590	-4.102	-10.776	-3.680	-3.200	-3.200	-3.200	-3.200	-3.200	-3.200
INVERT LEVELS	2.065	-0.434	-1.575	-4.590	-5.757	-15.058	-3.680	22.301	10.775	9.616	23.284	46.160	44.626
CONTROL LINE CHAINAGE	0	1000	2000	2873.111	3000	4000	4402.457	5000	6000	7000	8000	8200	8210.800

NOTES:
1. Pipeline cover depth shown on Sheet 1 and 2 is nominal and will be determined at detailed design stage.
2. Seabed profile shown extracted from DEM prepared from the following data sources:
   The State of Queensland (Department of Natural Resources and Water) [2007] and
   Gladstone Ports Corporation October 2008
3. Vertical datum to AHD.

Satellite imagery captured by GeoEye-1 on 24 March 2009
Development footprint digitised from Conceptual Site Plan 25509-100-10005.dgn supplied by client 24/07/2009

LEGEND

- Chainage point
- Cross section
- GSDAC
- GSDA
- LNG plant (Indicative)
- Dredge outline

0 500 1000m

SCALE - 1 : 25,000 (at A3)
Map Grid of Australia Zone 56
Geocentric Datum of Australia 1994

Rev	Date	Revision Description	ORIG	CHK	ENG	APPD
0	14/01/2010	Issued for use	JC	DH		

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Figure 5.5 Gas transmission pipeline route crossing to Curtis Island

Project No: 301001-00448 | Figure: 00448-00-EN-DAL-0377 | Rev: 0

Compiled by BRISBANE INFRASTRUCTURE GIS SECTION

K:\ORIGIN\301001-00448\GIS\Maps\00448-00-EN-DAL-0377Rev0(Channel_Cross_Section_Overview).wor

NOTES:
1. Pipeline cover depth shown on Sheet 1 and 2 is nominal and will be determined at detailed design stage.
2. Seabed profile shown extracted from DEM prepared from the following data sources:
   The State of Queensland (Department of Natural Resources and Water) [2007] and
   Gladstone Ports Corporation October 2008
3. Vertical datum to AHD.

DATUM RL -10

EXISTING SURFACE LEVELS	5.265	4.509	4.064	3.913	3.244	2.766	2.457	2.359	2.011	1.861	1.625	1.207	0.775	0.415	0.201
DEPTH TO BOTTOM OF TRENCH	-3.200	-3.200	-3.200	-3.200	-3.200	-3.200	-3.200	-3.200	-3.200	-3.200	-3.200	-3.200	-3.200	-3.200	-3.200
INVERT LEVELS	2.065	1.309	0.864	0.713	0.044	-0.434	-0.743	-0.841	-1.189	-1.339	-1.575	-1.993	-2.425	-2.785	-2.999
CONTROL LINE CHAINAGE	0	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2700

Satellite imagery captured by GeoEye-1 on 24 March 2009
Indicative sites supplied by Bechtel.

LEGEND

- Chainage point
- Cross section
- GSDAC
- GSDA
- LNG plant (Indicative)
- Dredge outline

0 250 500m

SCALE - 1 : 12,500 (at A3)
Map Grid Australia Zone 56
Geocentric Datum of Australia 1994

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0	17/02/2010	Issued for use	JC	MZ		RB

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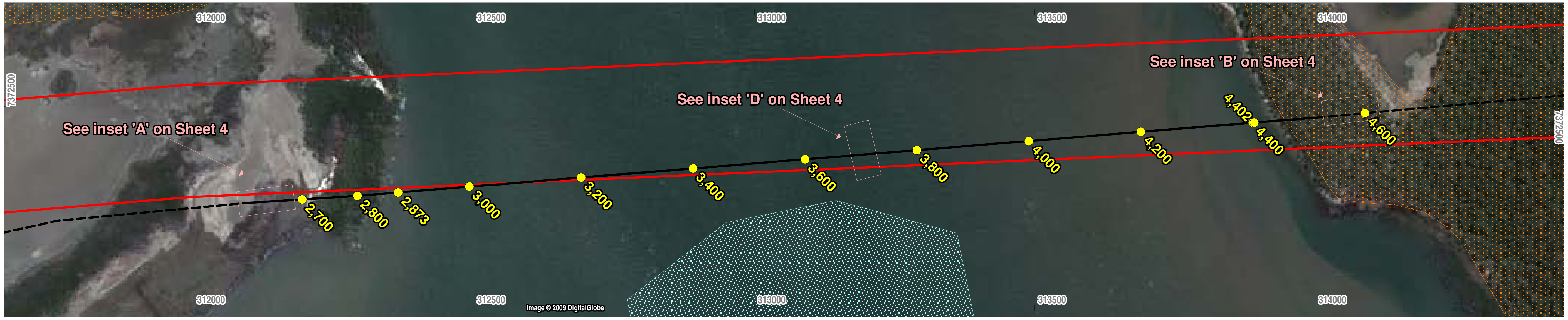
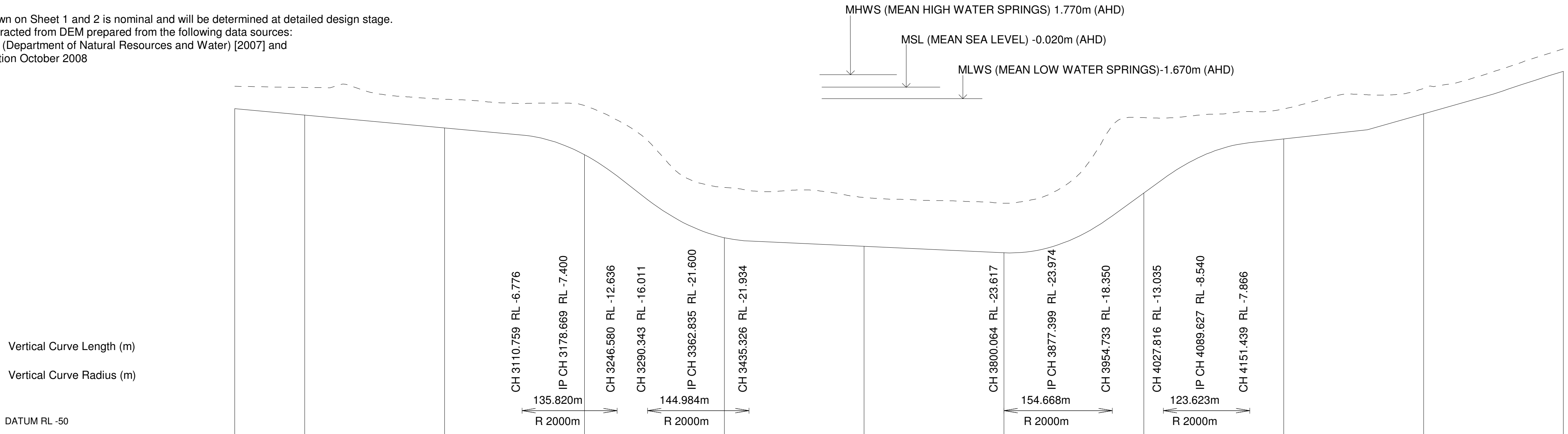
Figure 5.6 Gas transmission pipeline route crossing to The Narrows - Sheet 1

Project No: 301001-00448 | Figure: 00448-00-EN-DAL-0375 | Rev: 0



NOTES:
1. Pipeline cover depth shown on Sheet 1 and 2 is nominal and will be determined at detailed design stage.
2. Seabed profile shown extracted from DEM prepared from the following data sources:
The State of Queensland (Department of Natural Resources and Water) [2007] and
Gladstone Ports Corporation October 2008
3. Vertical datum to AHD.



EXISTING SURFACE LEVELS	0.201	0.028	0.000	-1.655	-2.549	-14.265	-15.714	-16.541	-4.282	-3.046	-0.087	0.000	5.546
DEPTH TO BOTTOM OF TRENCH	-3.200	-3.947	-4.590	-4.102	-7.038	-7.194	-6.980	-7.076	-10.776	-4.290	-3.663	-3.680	-3.200
INVERT LEVELS	-2.999	-3.918	-4.590	-5.757	-9.587	-21.459	-22.694	-23.617	-15.058	-7.336	-3.750	-3.680	2.346
CONTROL LINE CHAINAGE	2700	2800	2873.111	3000	3200	3400	3600	3800	4000	4200	4400	4402.457	4600

Satellite imagery captured by GeoEye-1 on 24 March 2009
Indicative sites supplied by Bechtel.

LEGEND

- Chainage point
- Cross section
- GSDAC
- GSDA
- LNG plant (Indicative)
- Dredge outline

0 100 200m
SCALE - 1 : 7,500 (at A3)
Map Grid of Australia Zone 56
Geocentric Datum of Australia 1994

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Figure 5.7 Gas transmission pipeline route crossing of The Narrows - Sheet 2

Project No: 301001-00448 | Figure: 00448-00-EN-DAL-0376 | Rev: 0

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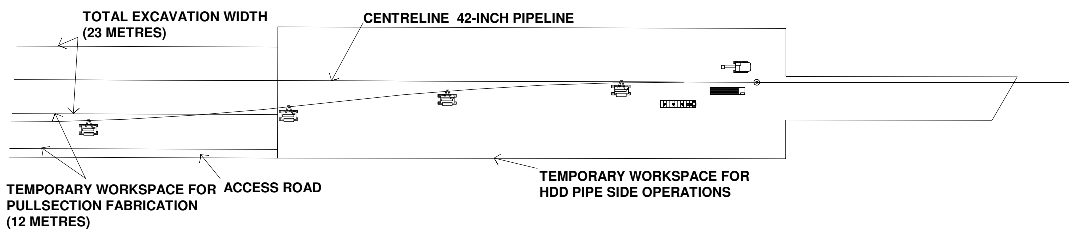
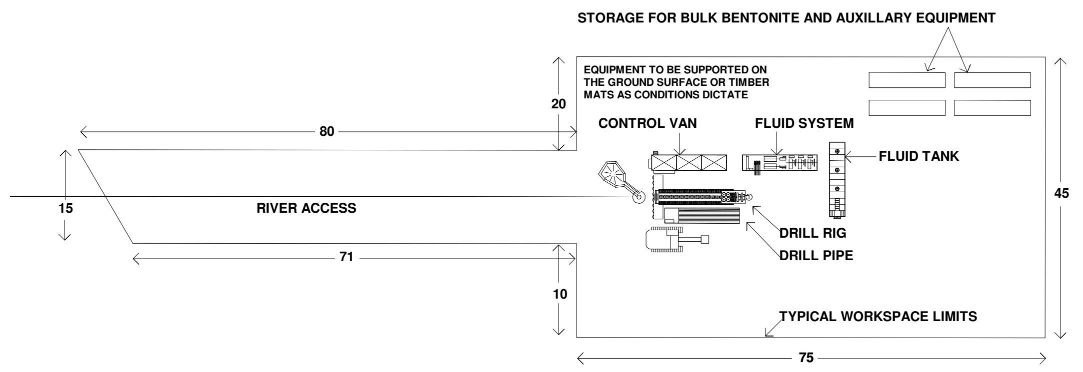
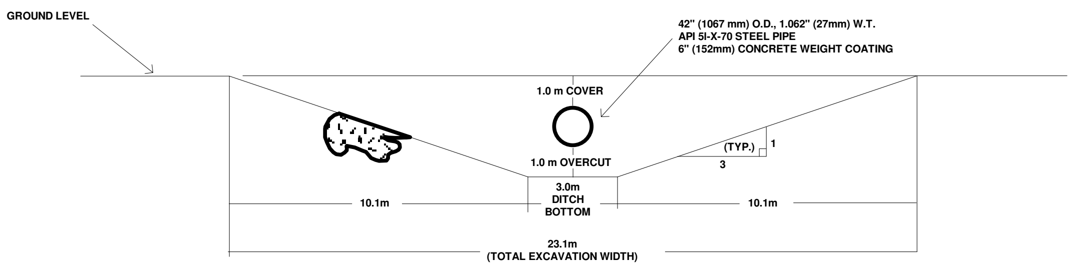


A

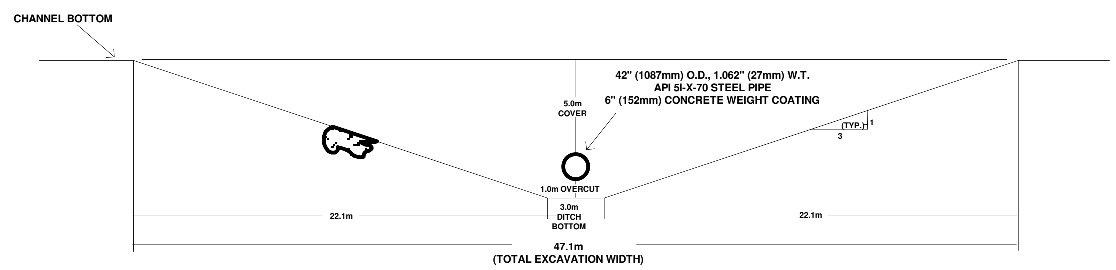


B



BASIC CUT & COVER EXCAVATION
CROSS_SECTIONAL AREA = 43.8 m sq.

C



BASIC CUT & COVER EXCAVATION THROUGH CHANNEL
CROSS-SECTIONAL AREA = 184.2m sq.

D

Rev	Date	Revision Description	ORIG	CHK	ENG	APPD
0	17/11/2009	Issued for use	JB	DH		

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Figure 5.8: Gas transmission pipeline route crossing of The Narrows - Sheet 3

Project No: 301001-00448 | Figure: 00448-00-EN-DAL-0378 | Rev: 0

5.6.2 Pipeline development options

There are several methods that have been proven in practice to accomplish a major water crossing with a high pressure main transmission pipeline. Site specific considerations include the length of the crossing, condition of the banks, seabed material, geotechnical conditions, current velocity and water level variations.

Design basis

All methods require good definition of the minimum seabed profile including estimation of seabed lowering caused by erosion and future dredging works. An accurate hydrographic survey is required to ensure that a minimum allowable cover height above the pipeline can be maintained for the whole operation life of the pipeline. The high pressure main transmission pipeline is a 42in (1.1m) diameter continuous welded steel assembly, and will be installed with a minimum depth of cover to be determined during the detailed design.

The type of buoyancy control for the pipeline will be determined at final design stages (preliminary concrete coating thickness is 150mm) and the length of pipeline for the crossing will be hydrostatically tested separately from the rest of the pipeline before installation.

For any installation method, bending stresses on the pipe during installation must be considered. For trenched installations, before floating or pulling the pipeline into position, a suitable bedding material is placed in the bottom of the open trench to support the pipeline and reduce erosion of the open trench profile by tidal currents. After lowering into the open trench the pipeline is covered with suitable material and backfilled with rock of an appropriate weight and size to reduce the potential for scouring and exposure of the pipeline.

Potential options for pipeline crossing of The Narrows are:

- Horizontal Directional Drilling (HDD)
- Flotation method
- Bottom pull method

Wet trench crossing of the wetland

The proposed alignment of the gas pipeline, presented in Figure 1.16, shows the trench would extend across the wetlands leading to Friend Point. Once excavation of the trench commences across the wetlands it will naturally fill with saline water as a result of ground water flow and forcing from tidal waters penetrating into the wetlands through the creeks and tributaries and across the salt pans.

One option for trench construction under consideration is to work in ‘wet conditions’, rather than pump the water out and stabilise trench batters from collapse using shoring methods. Temporary impacts would potentially be in the form of suspended solids finding their way into marine waters, construction right-of-way (ROW), staging, and extra workspace, while permanent potential impacts would result from the operation the permanent ROW.

Horizontal Directional Drilling

Horizontal directional drilling is the preferred method of Australia Pacific LNG for the proposed main transmission pipeline crossing of The Narrows to Curtis Island. The technique applied to HDD is not described in detail here. Rather this Section addresses issues associated with construction and the subsequent environmental issues.

The typical workspace area required for drill rigs used in HDD operations is in the order of 50m by 75m. Working areas are required to be cleared and graded level. Space requirements will vary depending on the make and model of the drilling rig and how the various components may be positioned. The key components of the drill rig are the rig ramp, the drill pipe, and the control van. Locations of these key components are controlled by the drill entry point, but indicative positions are included in Figure 5.6 and Figure 5.7.

Management of the drilling fluid is necessary to avoid potential environmental impacts. Drilling fluid is used for a number of tasks in the HDD process including:

- Cooling and lubricating the drill stem, mud motor and bit
- Providing hydraulic power to the mud motor which in turn converts hydraulic power to mechanical power
- Carrying cuttings out of the bore hole
- Stabilizing the bore hole during the drilling process,
- Sealing fractures in the formation.

Drilling fluid is usually a mixture of freshwater and bentonite. Bentonite is a naturally occurring clay that is extremely hydrophilic – that is has high swelling characteristics. Certain polymers may also be used that enhance the drilling fluid benefits.

Various chemicals and materials can be added to the drilling fluid to adjust its properties, in particular to control density, viscosity, plugging and sealing capabilities, and specific conditions such as swelling.

Disposal of drilling fluids from the site after use are normally achieved as follows:

- Mix and bury on site (not a viable option inside a marine park)
- Land spread (as above)
- Transfer to an approved site or disposal facility

Flotation method

This method consists of assembling the complete pipe section for the crossing at the bank and covering it with a concrete weight coating to offset buoyancy effects. Transfer of the pipe from the shoreline to the pre-dredged underwater trench is undertaken using floating plant and cranes. This procedure is more applicable for crossings with low current velocity as manoeuvring floating plant into position becomes increasingly difficult with increasing flood and ebb tidal streams.

There are various techniques used for trenching in addition to carrying the pipe section into position. If the pipe section is assembled at a distant location, it can be floated into place with self-propelled pontoons and cranes. However, this is specialised plant and availability could be an issue. The trench is typically constructed using floating mechanical dredging plant that transfers the marine sediments to small barges that remove the material to a designated spoil ground. In this case the material from The Narrows is to be barged to the reclamation area to the north of Fisherman's Landing.

The type of dredge used will mainly depend on the material to be encountered. Across The Narrows the bore-log analysis indicates that this is mostly gravely sands, silts and clays. For a narrow trench a pontoon mounted large back hoe (purpose built hydraulic excavator) could be used to efficiently undertake this work. Wider and deeper trenches would necessitate the use a cutter suction dredge or possibly a medium sized trailer suction hopper dredge.

Lowering the pipeline into the trench requires a high level of coordination and providing a means of adjusting its buoyancy is also needed to sink it into position. Because the pipeline crossing length is approximately 1800m and The Narrows is a waterway exhibiting moderate to high current velocity, the flotation method would be the least favoured option.

Bottom pull method

The bottom pull method is sometimes employed for crossing waterways exhibiting strong currents or where the seabed consists of softer material. It is not suitable where exposed rock is found on the bottom.

The concept of this method is to assemble the pipeline string so that its entire length is set out on the shore in the extended axis of the planned crossing route. It is pulled into the open dredged trench using an anchored winch anchored on the opposite bank of the waterway.

Construction issues involve the large set out area required for the pipe string to be aligned with the crossing, trenching required for placement and cover of the pipeline, coffer dams and dewatering to exclude water from trenches at the shoreward ends, and access for large excavators to and from the site as well as floating pontoon mounted machinery. The floating pontoons are required to be anchored into position for dredging of the underwater pipeline trench to take place and will require substantial anchoring systems to hold them from moving with the strong currents in The Narrows.

Volume of pipeline trench

The alternative to HDD, being the flotation or bottom pull methods, require trenching of the seabed using a dredge. The type of dredge plant most suited for excavating an underwater trench across The Narrows would be either a cutter suction dredge, trailer suction hopper dredge, or a large back hoe dredge. A typical large back hoe dredge is depicted in Figure 5.9.

The volume of material to be removed from the trench has been assessed assuming the alignment and profile shown in Figure 5.7

Hydrographic data used for the analysis was provided by Gladstone Ports Corporation from a survey undertaken by MSQ during October and December 2008. Sufficient cover depth was allowed for the structural integrity of the pipe against erosion forces associated with the waterway and for general protection. The overall segment length of the crossing is approximately 1800m. The analysis assumes the pontoon mounted mechanical dredge can access most of this length and where it cannot, a land based hydraulic excavator would be required to complete the shore crossings.

The volume associated with a trench crossing will also vary depending on the batter slopes used for stability of the trench walls. Geotechnical advice is that the stability of the underwater section would require batter slopes varying from 1V:3H to 1V:5H and that local storage is needed to prevent infilling of the trench by bed sediments within the time required for the pipeline to be laid into position. Consequently, the volume of material required to be dredged for a narrow pipeline trench could vary from 90,000m^3 to 200,000m^3 and a wider trench, with slightly greater cover depth, could require 800,000m^3 to 1,000,000 m^3 of material to be removed.

Figure 5.9 Backhoe dredging plant (image source: Van Oord 2009)

A large mechanical dredge has a reasonably high production rate per day. Using a 10m^3 bucket, production rates would be as much as 3,800m^3 to 4,200m^3/day (pers. comm., Van Oord Dredge and Marine). If a small barge (approximately 800m^3) is used to dispose of the dredged material it would take just over a month to complete the dredging; however, the disposal of material may require barges to time their release with the higher tides to gain access to the shallow areas at the reclamation area north of Fisherman's Landing. As a conservative estimate, the time required to dredge the trench may ultimately take two months, if barges can only dispose on the rising tide. An alternative to this would be double handling, requiring disposal near the reclamation and additional dredging plant to rehandle the material into the reclamation.

It is assumed approvals are being arranged by GPC under the Western Basin Dredging and Disposal EIS to remove this dredge material to an approved reclaim area.

6. Potential impacts and mitigation measures

Assessment considered the potential impacts to coastal processes resulting from proposed dredging and reclamation in the Western Basin in order to then assess the additional potential impacts from proposed coastal components described in Section 5. The impact assessment of the channels and swing basins is described in GPC's EIS for the Western Basin Dredging and Disposal Project and is not repeated here. However, information relevant to the establishment of the hydrodynamic model that includes the Western Basin developments is described below. This was used as a base from which assessments were made of potential impacts associated with the Project jetties, MOF, reclamation and revetments, and desalination brine discharge.

6.1 Modifications to bathymetry

Other major industrial developments within Gladstone Harbour have been proposed in addition to the marine developments proposed by Australia Pacific LNG. The potential impacts of the Australia Pacific LNG proposed works cannot be considered in isolation from the other developments within the Western Basin.

The assessment of the potential impacts of modified bathymetry on the local and basin wide coastal processes has been undertaken through hydrodynamic modelling and modifying the model bathymetry according to the changes presented in Figure 6.1. This represents the different stages of the Port of Gladstone Western Basin development and the works proposed by Australia Pacific LNG.

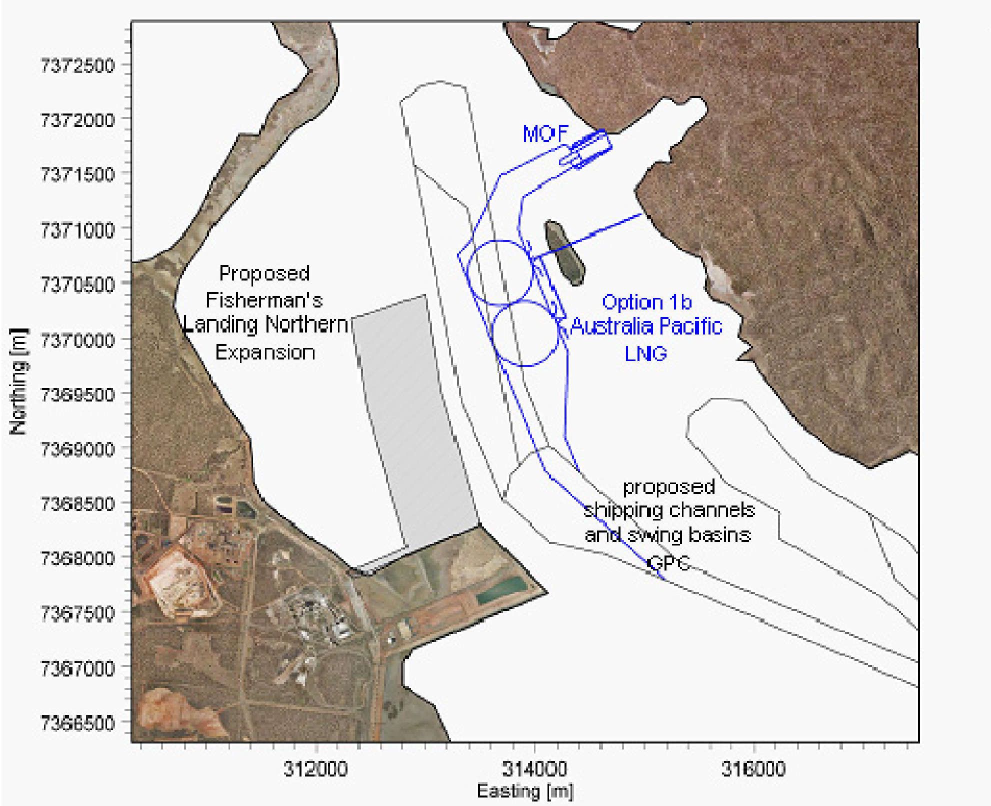
Figure 6.1a and Figure 6.1b indicate the changes to the existing model bathymetry (Figure 4.1) for Option 1b and 2a, respectively and also include GPC proposed dredge and reclamation works.

The Project's Option 1b and Option 2a model bathymetries were based upon the existing Western Basin bathymetry with modifications to represent the proposed works including:

- Dredged LNG shipping approach channels (-13.5 LAT)
- Dredged LNG berth and turning circle areas (-13.5 LAT)
- Material offloading facility (MOF) structure
- Dredged approach area to the MOF (-8.5 LAT).

The same modifications were also applied to the existing Western Basin bathymetry used in the wave model (refer to Section 6.2.2).

a)



b)

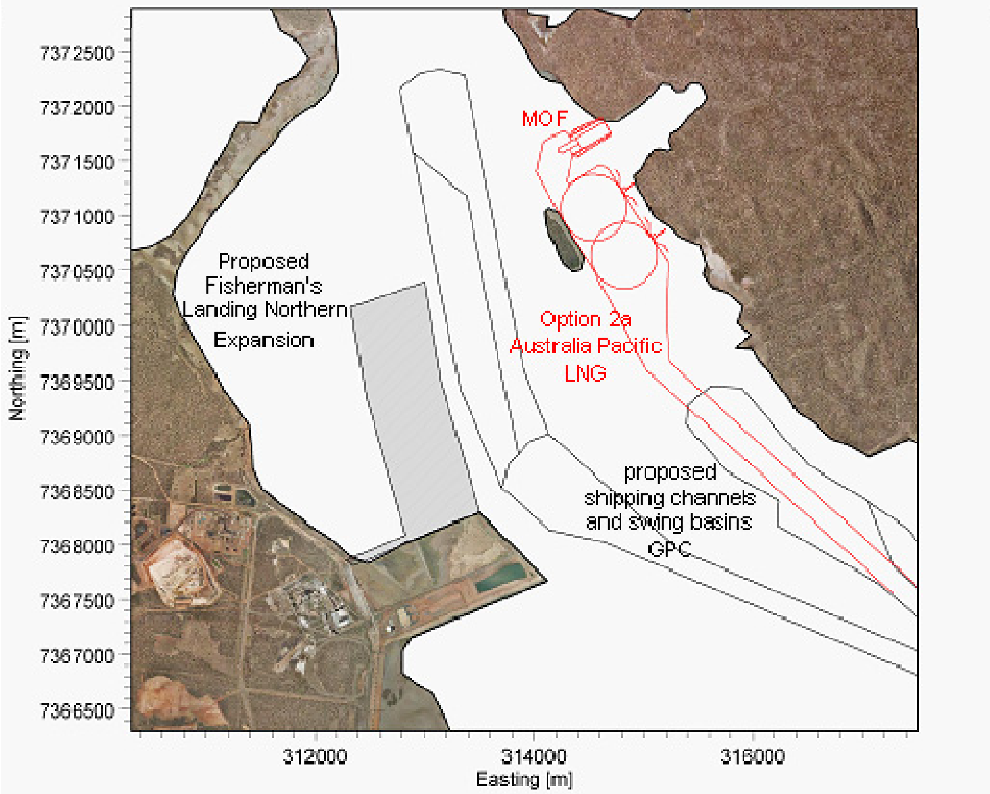


Figure 6.1 Changes to existing model bathymetry for hydrodynamic impact assessment, a) Option 1b, and b) Option 2a

6.2 Coastal processes

6.2.1 Hydrodynamics

Potential changes to tidal water levels and currents from specific dredging and reclamation scenarios were assessed in the GPC's EIS for the Western Basin Dredging and Disposal Project and are not repeated in full here. The main conclusions from the EIS additional numerical model results (BMT WBM 2009b) that included changes due to Option 1b and 2a dredging are as follows:

- The dredging and reclamation works will have negligible impact (1cm or less) on high tide levels throughout the area
- Water levels associated with the inclusion of Options 2a and 1b dredging are essentially the same as previous simulations of the fully developed dredging and reclamation options for the Western Basin
- In general, current velocities tend to decrease in dredged areas where the depths are greater following dredging and higher velocities are predicted upstream and downstream of the newly dredged areas where the higher flows enter and exit across the existing bathymetry.

For Option 1b:

- In the MOF approach channel, velocities generally decrease although a slight increase is predicted where currents exit from the swing basin. Increases in velocity of up to 0.5m/s (ebb) are predicted on the shoals adjacent to the MOF channel upstream of North Passage Island.

For Option 2a:

- In APLNG Option 2a dredged area, velocities are predicted to decrease up to 0.4m/s (flood tide) and 0.5m/s (ebb tide). Current velocity in the MOF approach channel generally decreases
- Substantial increases in velocity (0.35m/s flood and 0.7m/s ebb) occur on the shoals upstream of North Passage Island as a result of increased flows there.

To provide more detailed hydrodynamic information around the Australia Pacific LNG site and to assess potential impacts associated with the Project jetties, MOF, reclamation and revetments, and desalination brine discharge hydrodynamic modelling was undertaken by WorleyParsons using methodology consistent with the GPC Western Basin Dredging and Disposal EIS.

Model simulations were performed for the existing (Figure 4.1), Option 1b (Figure 6.1a), and Option 2a (Figure 6.1b) bathymetry and also include GPC proposed dredge and reclamation works. Consequently, the model results as presented include more than the incremental changes due to the development of the Australia Pacific LNG Options.

- Water level time series plots at location t1 (shown in Figure 6.3) for the representative spring and neap tide periods are presented in Figure 6.4. Note that the impact to water level at location t1 was representative of the impact to water level within the study area and therefore water level comparisons at other locations have not been presented.
- Current speed time series plots at five locations of interest shown in Figure 6.3 (t1, t2, t3, t4, and t5) for the representative spring and neap tide periods are presented in Figure 6.5 through Figure 6.9.
- Current speed contour plots at the instants of peak current velocity. The contour plots show the spatial impact of Option 1b and Option 2a relative to the existing conditions. The spatial impact contour plots are presented in Figure 6.10 through Figure 6.13.

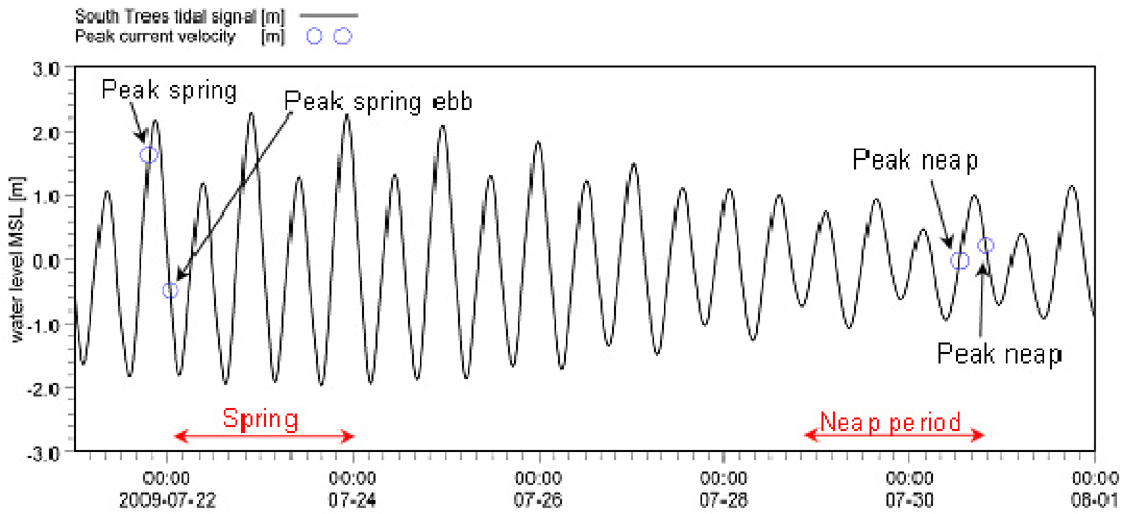


Figure 6.2 Tidal signal at Gladstone South Trees showing times selected for current speed and water level impact assessment

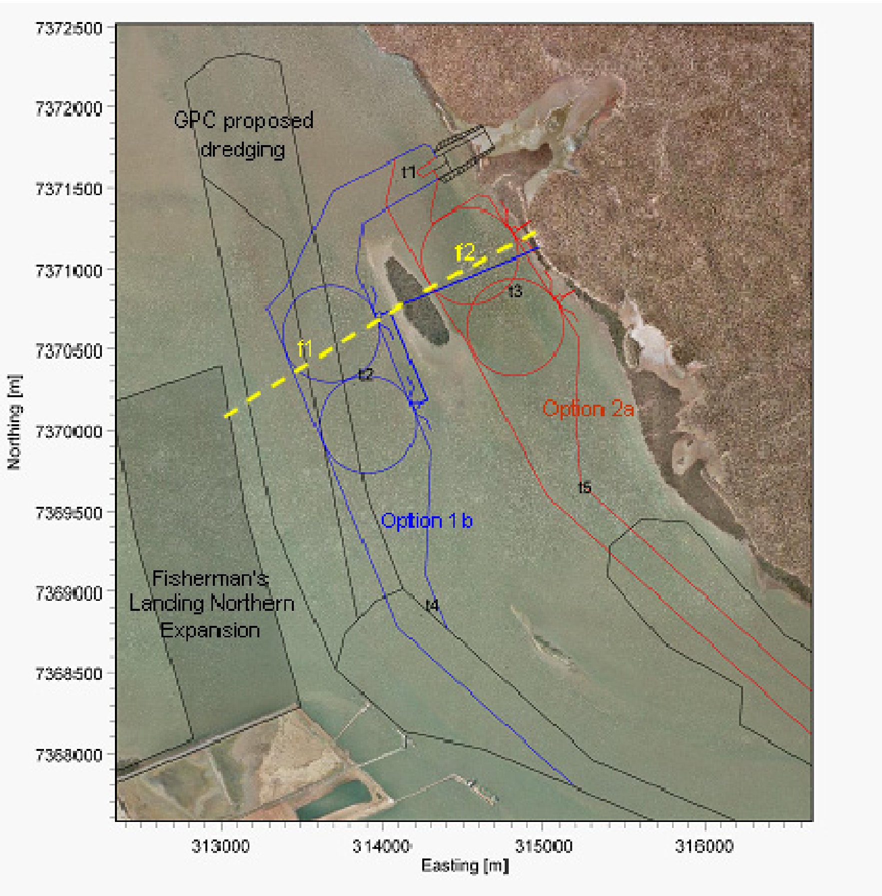


Figure 6.3 Locations of interest (t1, t2, t3, t4, and t5) for hydrodynamic impact temporal analysis

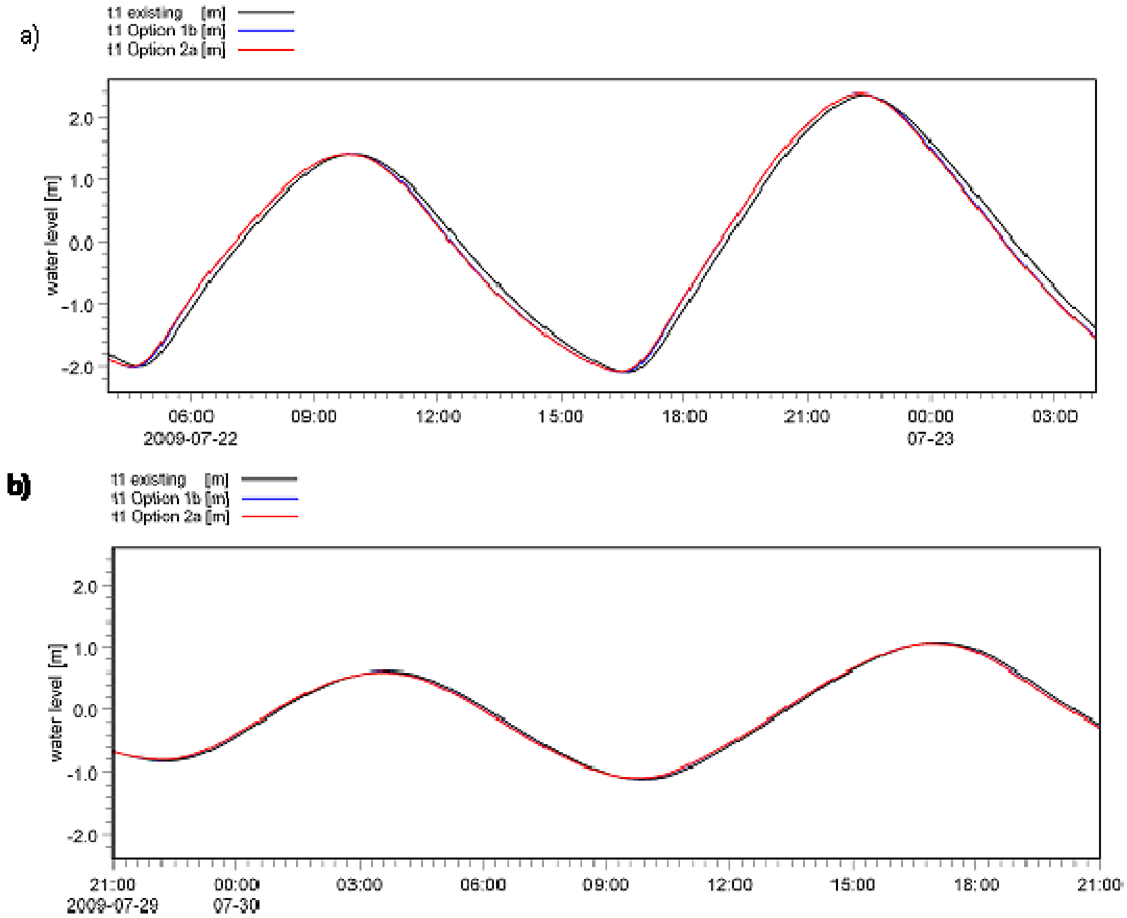


Figure 6.4 Impact to water level at location t1 (offshore from proposed MOF), a) spring tide period, and b) neap tide period

Figure 6.4 presents the water level time series comparison for location t1, situated just offshore from the MOF. The predicted impacts to water level due to the Option 1b and Option 2a and were as follows:

- Differences between the two Australia Pacific LNG options are negligible.
- Relative to the existing case, a negligible impact to the tidal amplitude is predicted.
- A tidal water level phase shift of approximately -20min was predicted.

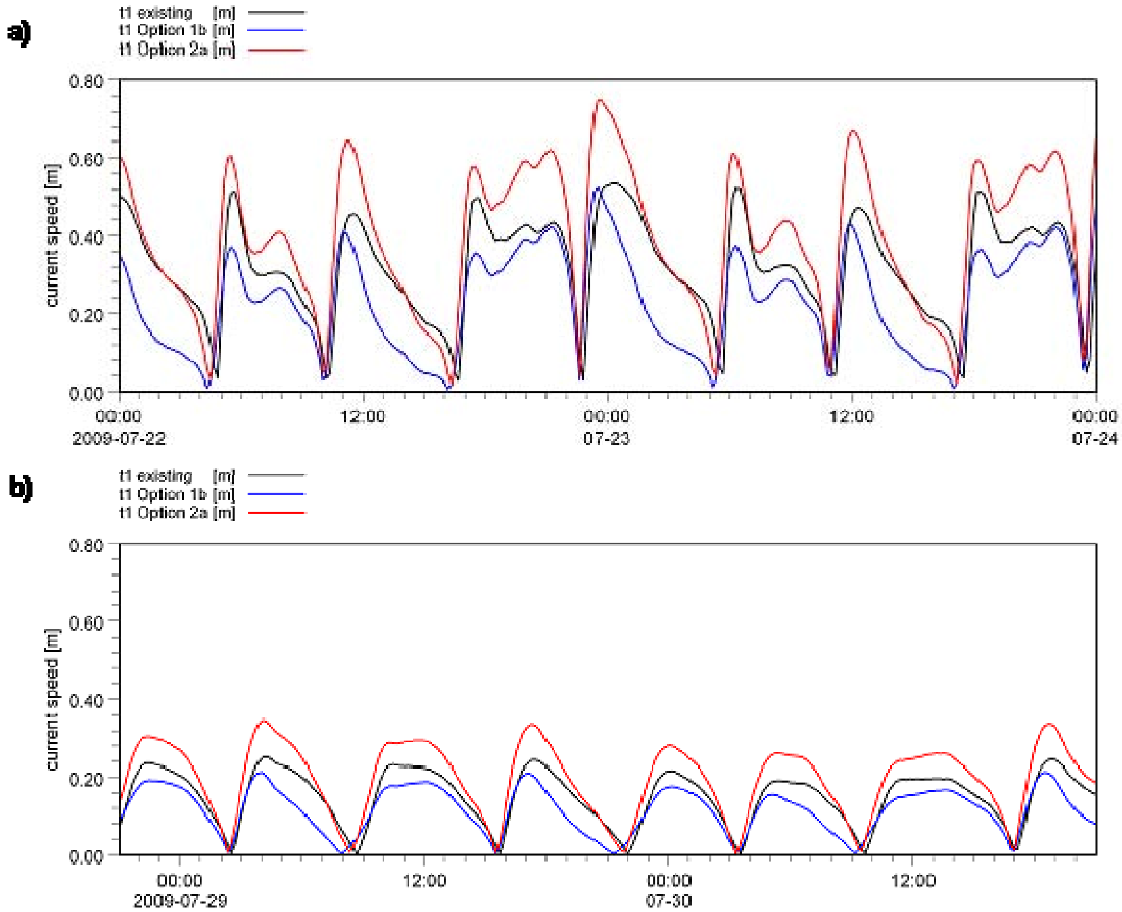


Figure 6.5 Impact to current speed at location t1 (offshore from proposed MOF), a) spring tide period, and b) neap tide period

Figure 6.5 presents the current speed time series comparison for location t1, situated just offshore from the MOF. The predicted impacts of Option 1b at location t1 relative to the existing current speed were as follows:

- Option 1b typically causes a reduction in current speed due to the deepening of the bathymetry offshore from the MOF
- Peak current speeds are typically reduced by up to 30%.

The predicted impacts of Option 2a at location t1 relative to the existing current speed were as follows:

- Option 2a is predicted to increase current speed offshore from the MOF up to 30% more. This result is in contrast to Option 1b and is attributed to the Option 2a berth and turning circle

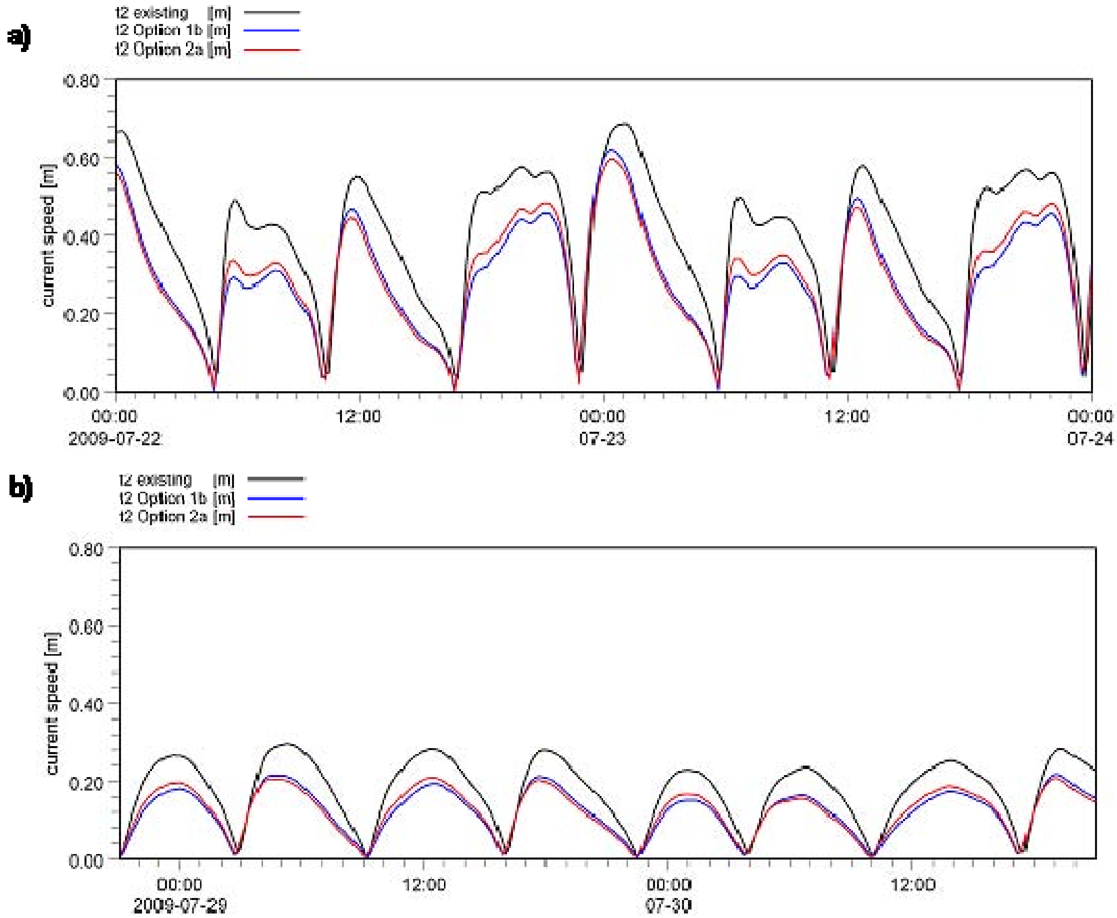


Figure 6.6 Impact to current speed at location t2 (Option 1b berth/turning circle), a) spring tide period, and b) neap tide period

Figure 6.6 presents the current speed time series comparison for location t2, situated within the Option 1b berth/turning circle area. The predicted impacts of Option 1b at location t2 relative to the existing current speed were as follows:

- Option 1b is predicted to reduce current speed up to 40% due to the deepening of the existing bathymetry for the Option 1b berth and turning circles.

The predicted impacts of Option 2a at location t2 relative to the existing current speed were as follows:

- Option 2a is predicted to reduce current speed at t2 similar magnitude to Option 1b.

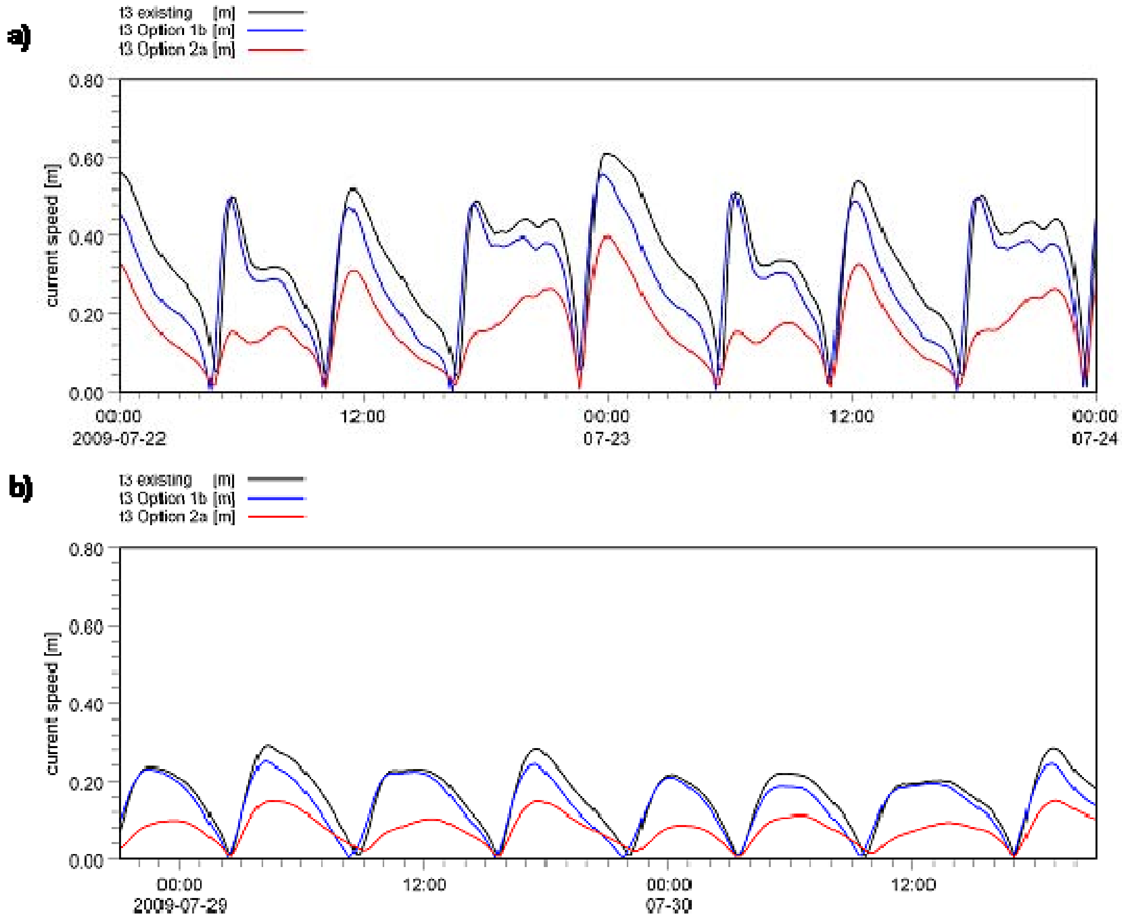


Figure 6.7 Impact to current speed at location t3 (Option 2a berth/turning circle); a) spring tide period, and b) neap tide period.

Figure 6.7 presents the current speed time series comparison for location t3, situated within the Option 2a berth/turning circle area. The predicted impacts of Option 1b at location t3 relative to the existing current speed were as follows:

- Option 1b is predicted to reduce current speed by less that 10%. Option 1b requires no dredging in the immediate vicinity of t3 and therefore the impact at this location is primarily attributed to the proposed Gladstone Ports Corporation dredging.

The predicted impacts of Option 2a at location t3 relative to the existing current speed were as follows:

- Option 2a results in a reduction in current speed between 30-50%, during both spring and neap tide conditions

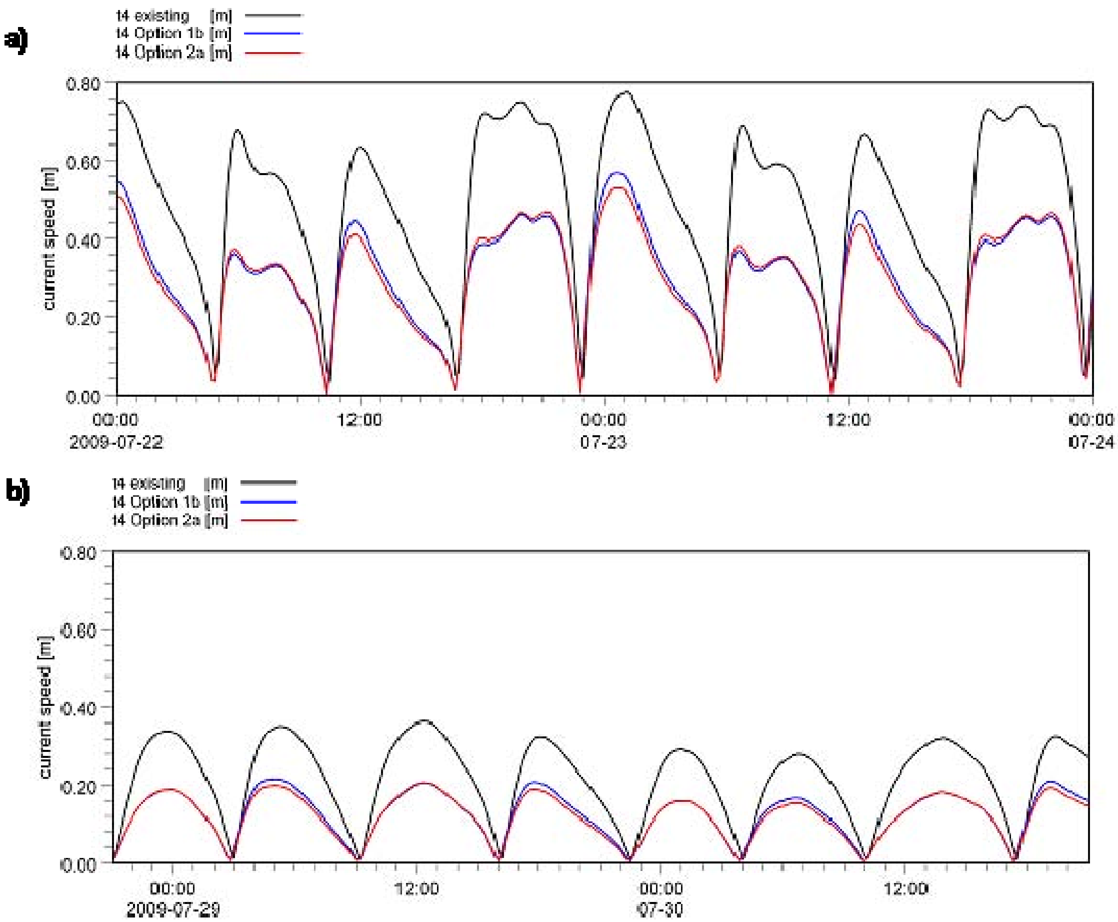


Figure 6.8 Impact to current speed at location t4 (Option 1b approach channel), a) spring tide period, and b) neap tide period

Figure 6.8 presents the current speed time series comparison for location t4, situated within the Option 1b approach channel and close to the proposed expansion of the Fisherman's Landing berth and swing basin. At the t4 location predicted current speed impact due to Australian Pacific LNG Option 1b and Option 2a were as follows:

- Option 1b and Option 2a are predicted to reduce current speeds by 30-50% compared to the existing conditions

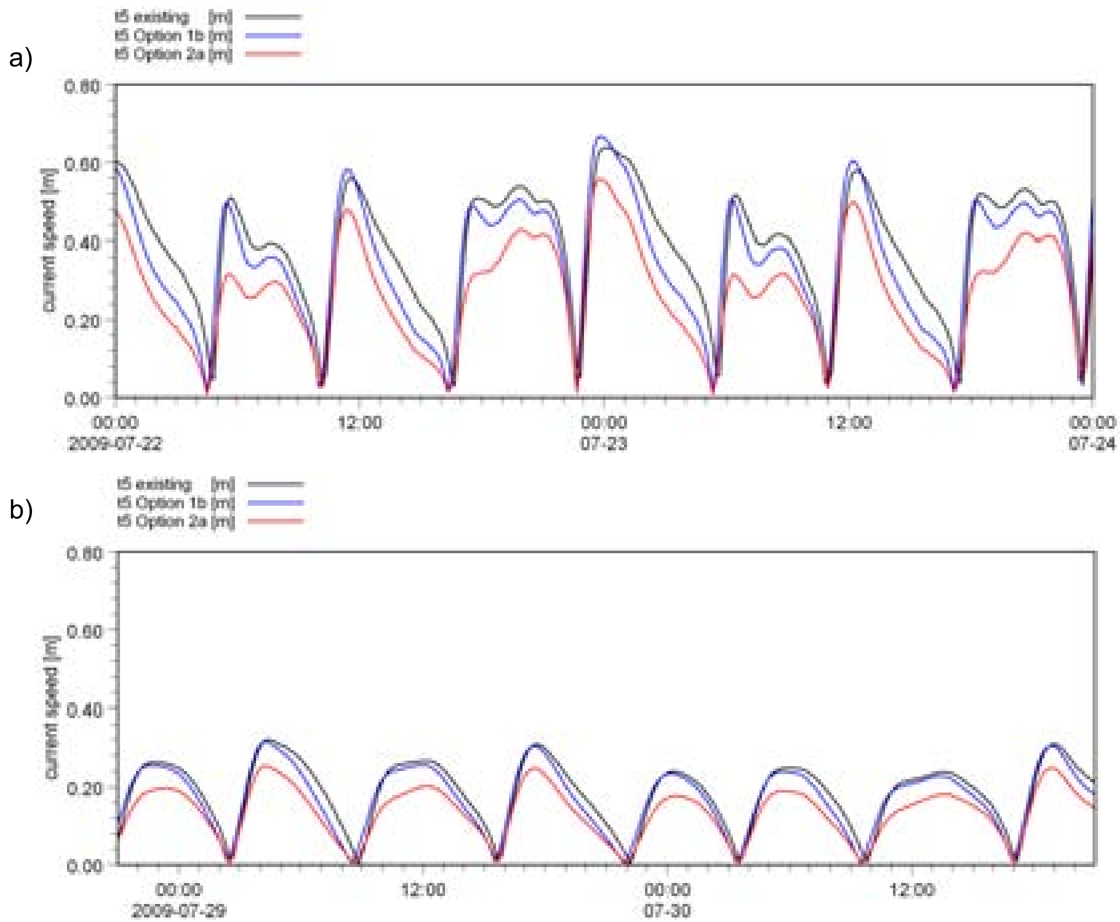


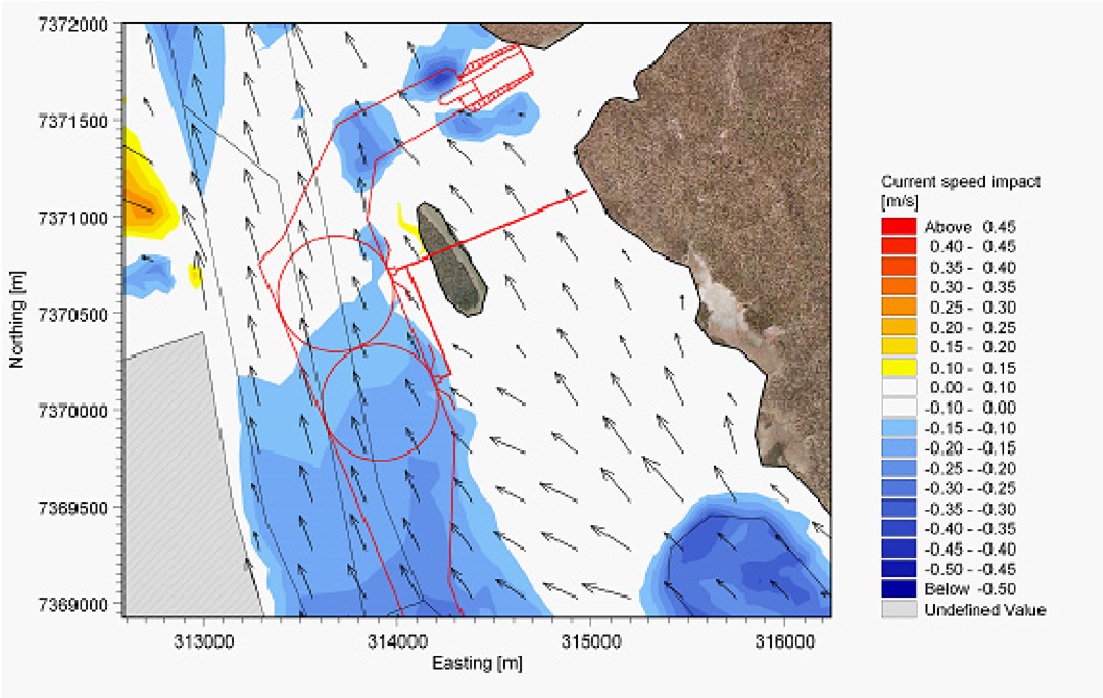
Figure 6.9 Impact to current speed at location t5 (Option 2a approach channel), a) spring tide period, and b) neap tide period

Figure 6.9 presents the current speed time series comparison for location t5, situated within the Option 2a approach channel. At most times Option 2a causes an insignificant impact (less than 5%) relative to the existing current speed. The predicted impacts of Option 2a at location t5 relative to the existing current speed were as follows:

- Option 2a caused a current speed reduction, typically between 20-30%, during both spring and neap tide conditions.

Figure 6.10 through Figure 6.13 show spatial contour plots of the predicted impact to current speed at the instant of peak spring and neap currents within the study area. Regions where the absolute current speed impact is less than ±0.1m/s are represented by white in the figures.

a)



b)

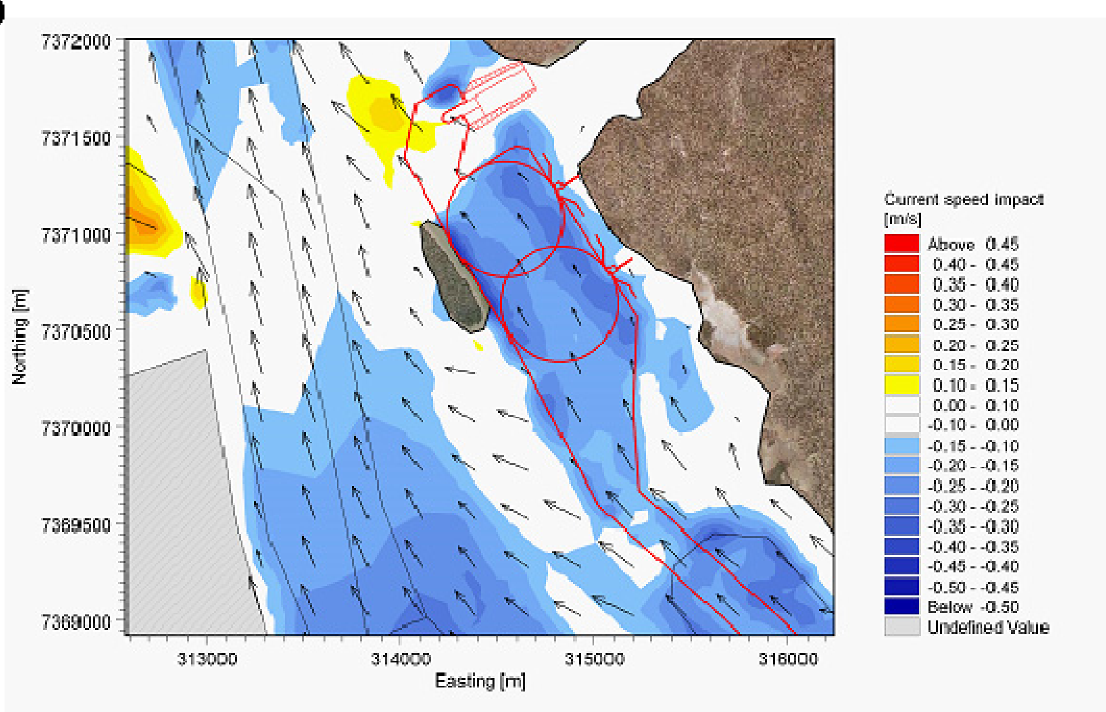
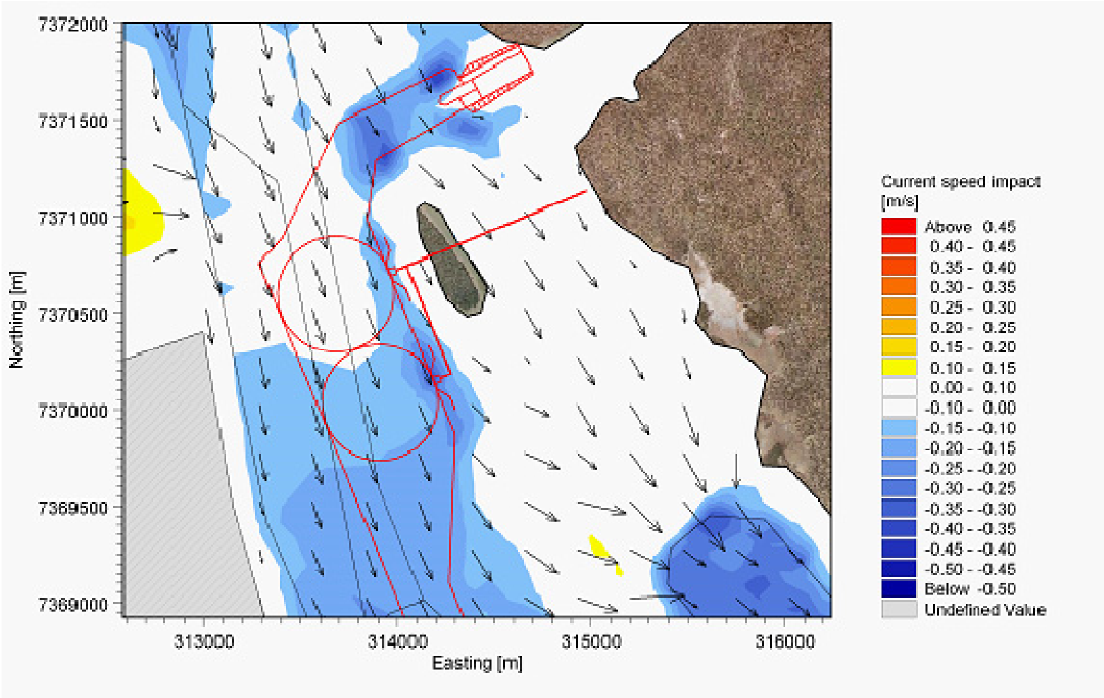


Figure 6.10 Predicted impact to the peak current speed of the spring flood tide relative to existing conditions: a) Option 1b, b) Option 2a

a)



b)

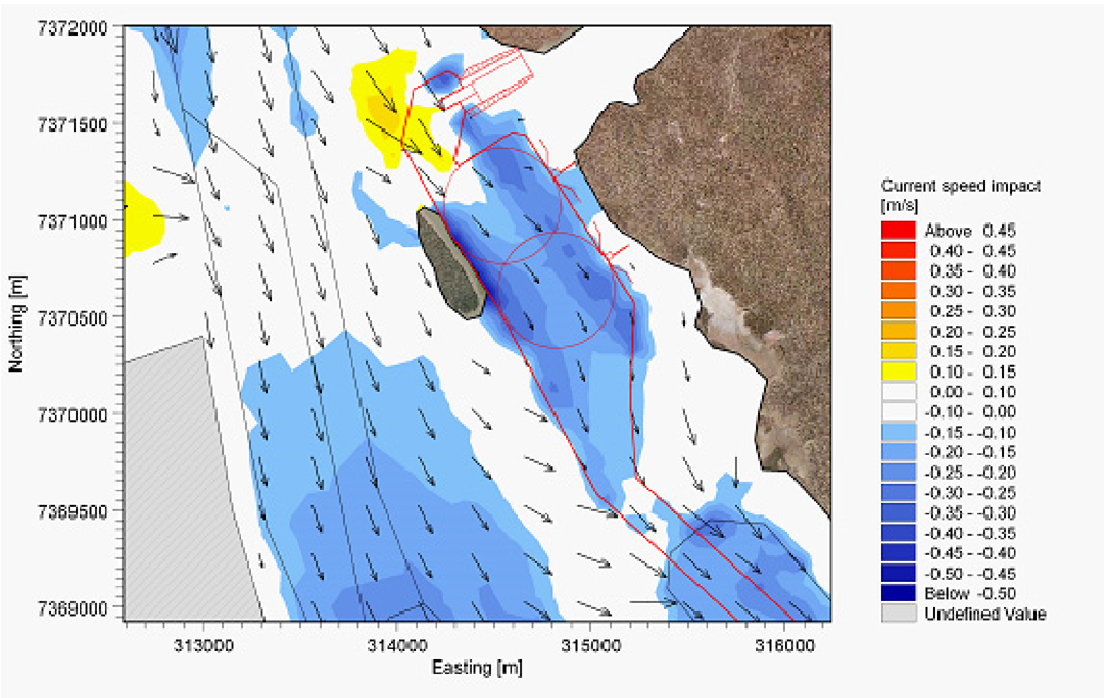
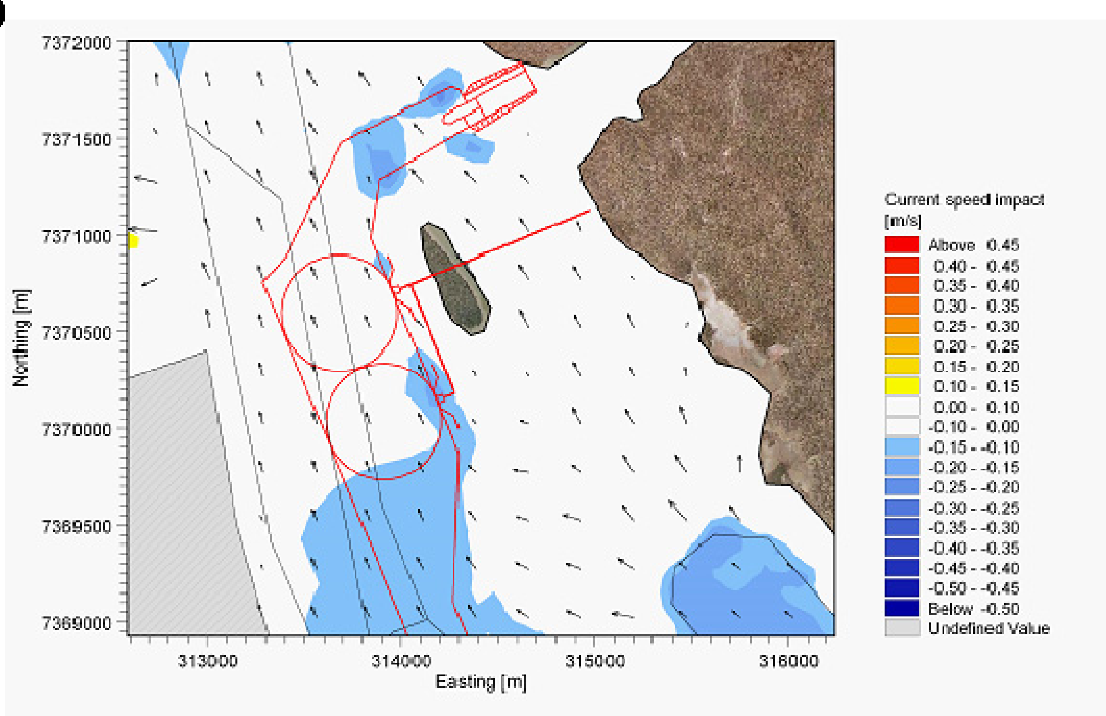


Figure 6.11 Predicted impact to the peak current speed of the spring ebb tide relative to existing conditions: a) Option 1b, b) Option 2a.

a)



b)

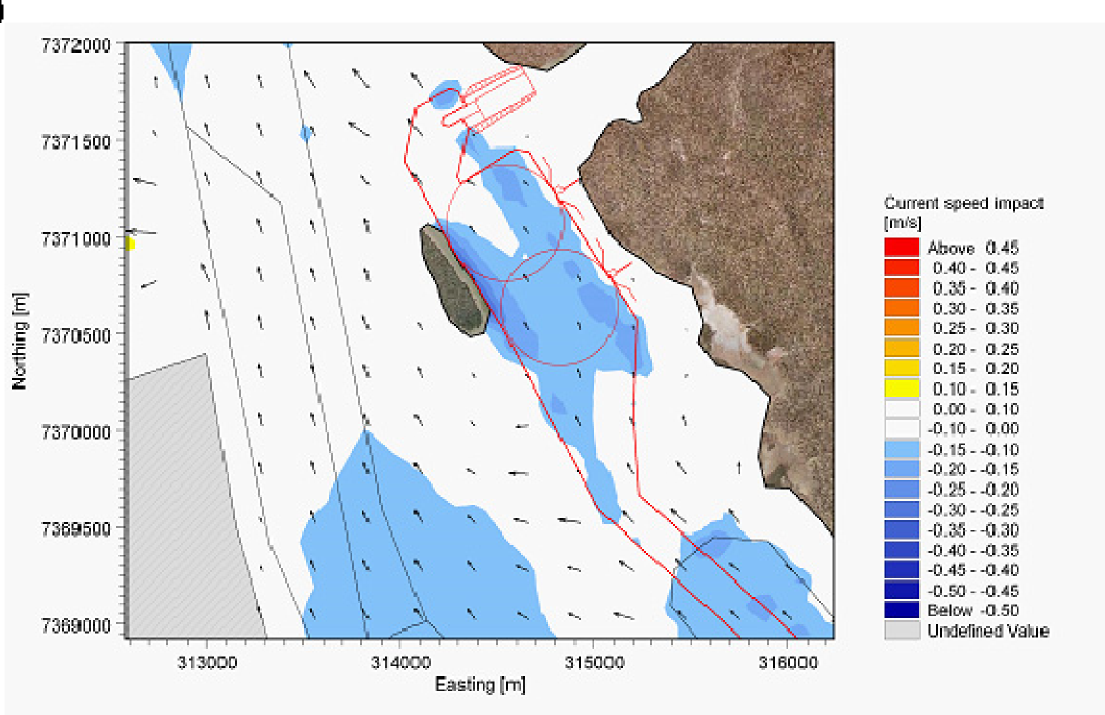


Figure 6.12 Predicted impact to peak current speed of the neap flood tide relative to existing conditions: a) Option 1b, b) Option 2a.

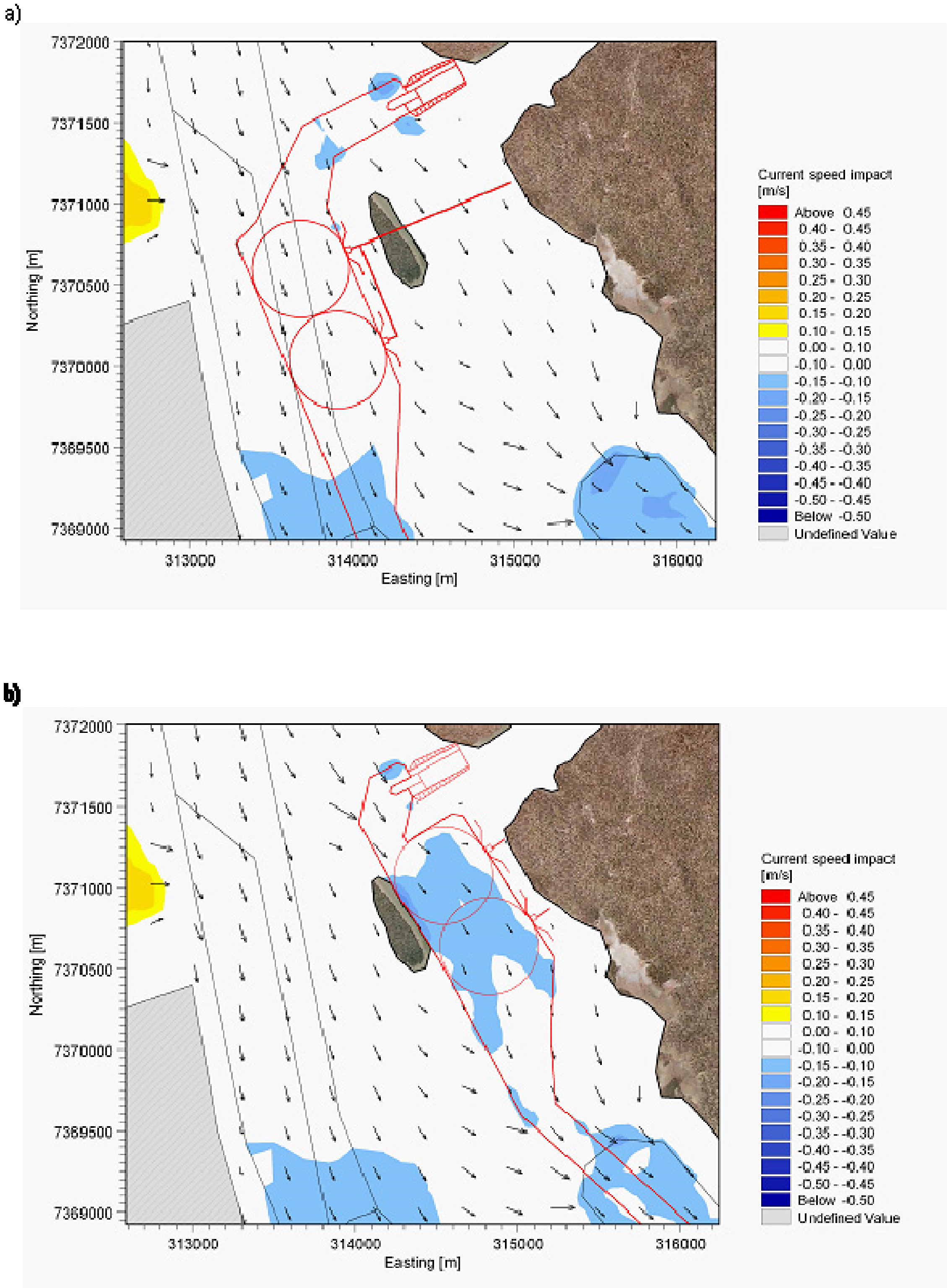


Figure 6.13 Predicted impact to the peak current speed of the neap ebb tide relative to existing conditions: a) Option 1b, b) Option 2a

Important findings based on the spatial current speed impact at times of peak spring and neap flow assessment were as follows:

- A general decrease in current speed throughout the study area is predicted due to deepening associated with dredging.
- Current speed within the Option 2a berth/turning circle area is reduced by up to 0.4m/s. The magnitude of the impact is similar on both the flood and ebb phases.
- The current speed impacts associated within Option 1b berth/turning circle area are expected to be dominated by the proposed Gladstone Ports Corporation dredge and reclamation works. Decreases of current speed in this area of up to 0.2m/s are predicted.
- The overall spatial impact to current speeds of Australia Pacific LNG Option 1b is less than Option 2a.
- Offshore and adjacent to the Option 1b MOF, a reduction in current speed of up to 0.3m/s is predicted.
- Offshore from the Option 2a MOF during peak spring tide conditions an increase in current speed of up to 0.2m/s is predicted.

6.2.2 Waves

Potential impacts to the wave conditions for the Western Basin were generally addressed in GPC's EIS for the Western Basin Dredging and Disposal Project. The following discusses potential impacts to wave conditions resulting from dredging Options 1b and 2a, and is consistent with the methodology used in GPC's EIS.

It was demonstrated in Section 4.4.2 and in previous studies (e.g. BMT WBM 2006) that the study area is protected from ocean waves by Curtis, Facing, and other smaller islands within Gladstone Harbour. It was not considered necessary to assess the impact to ocean-generated sea and swell waves in the study area.

Minor changes to locally generated wind waves in the Western Basin associated with the proposed marine developments were investigated using the wave model (refer Section 4.4.2). The existing wave model bathymetry was modified and two new model bathymetries were created represent the Australia Pacific LNG Option 1b and Option 2a. The modifications also include the Fisherman's Landing Northern Expansion and dredge areas proposed by GPC (refer Figure 6.1a and Figure 6.1b).

Following the same approach described in Section 4.4.2, a 10-minute wind speed of 36m/s, representing a 50 year ARI cyclonic wind speed for the Gladstone region (Australian/New Zealand Standard 1170.2:2002, Part 2: Wind actions), was applied across the Option 1b and Option 2a wave model domains from the directions likely generate the largest waves. Table 6.1 summaries the 50 year ARI local wind wave impact modelling and presents the significant wave heights offshore from the Australia Pacific LNG facility to the north and south of North Passage Island. The Option 1b and Option 2a wave height results were compared to the results for the existing model presented in Table 4.3. The impact in Table 6.1 refers to the percentage difference in wave height between the existing and modified bathymetry results.

Table 6.1 Summary of local wind wave prediction for 50 year ARI wind speed for Option 1b and Option 2a. Impact is relative to existing result in Table 4.3.

		North of North Passage Island		South of North Passage Island	
10min average local wind speed (m/s)	Local wind direction (direction from)	Significant wave height (m)	Impact relative to existing conditions (%)	Significant wave height (m)	Impact relative to existing conditions (%)
Option 1b					
36	W	1.52	0.66	1.33	-1.50
36	WSW	1.41	-3.55	1.40	0.71
36	SSW	1.36	-4.41	1.55	0.00
36	S	1.34	-2.24	1.68	0.00
36	SSE	1.24	-0.81	1.56	1.28
36	ESE	1.13	0.88	1.33	0.75
36	E	0.98	0.00	1.13	0.00
Option 2a					
36	W	1.56	3.21	1.42	4.93
36	WSW	1.48	1.35	1.44	3.47
36	SSW	1.50	5.33	1.64	5.49
36	S	1.58	13.29	1.83	8.20
36	SSE	1.58	20.89	1.74	11.49
36	ESE	1.42	21.13	1.50	12.00
36	E	1.17	16.24	1.24	8.87

Local wind wave modelling for Option 1b suggests the proposed marine developments will have an insignificant impact on the extreme wave heights within the study area. The modelling demonstrates significant wave heights are either not impacted or are reduced due to the proposed developments. This result is primarily due to the reduced fetch associated with the Fisherman's Landing expansion.

Option 2a local wave modelling shows increases to the significant wave height for all wind directions. The most significant wave impact is associated with winds from the southerly sector. The proposed Gladstone Ports Corporation shipping channels and the Australia Pacific LNG Option 2a berth/turning circle areas align with the south-easterly winds and provide a deeper area for larger waves to develop. Significant wave heights are predicted to increase by up to 20%. Figure 6.14 compares the predicted significant wave height contour map for the 50 year ARI wind speed from the south-south-easterly direction for the existing and Option 2a case. Figure 6.14b shows larger waves penetrating through the proposed Option 2a berth/turning circle area.

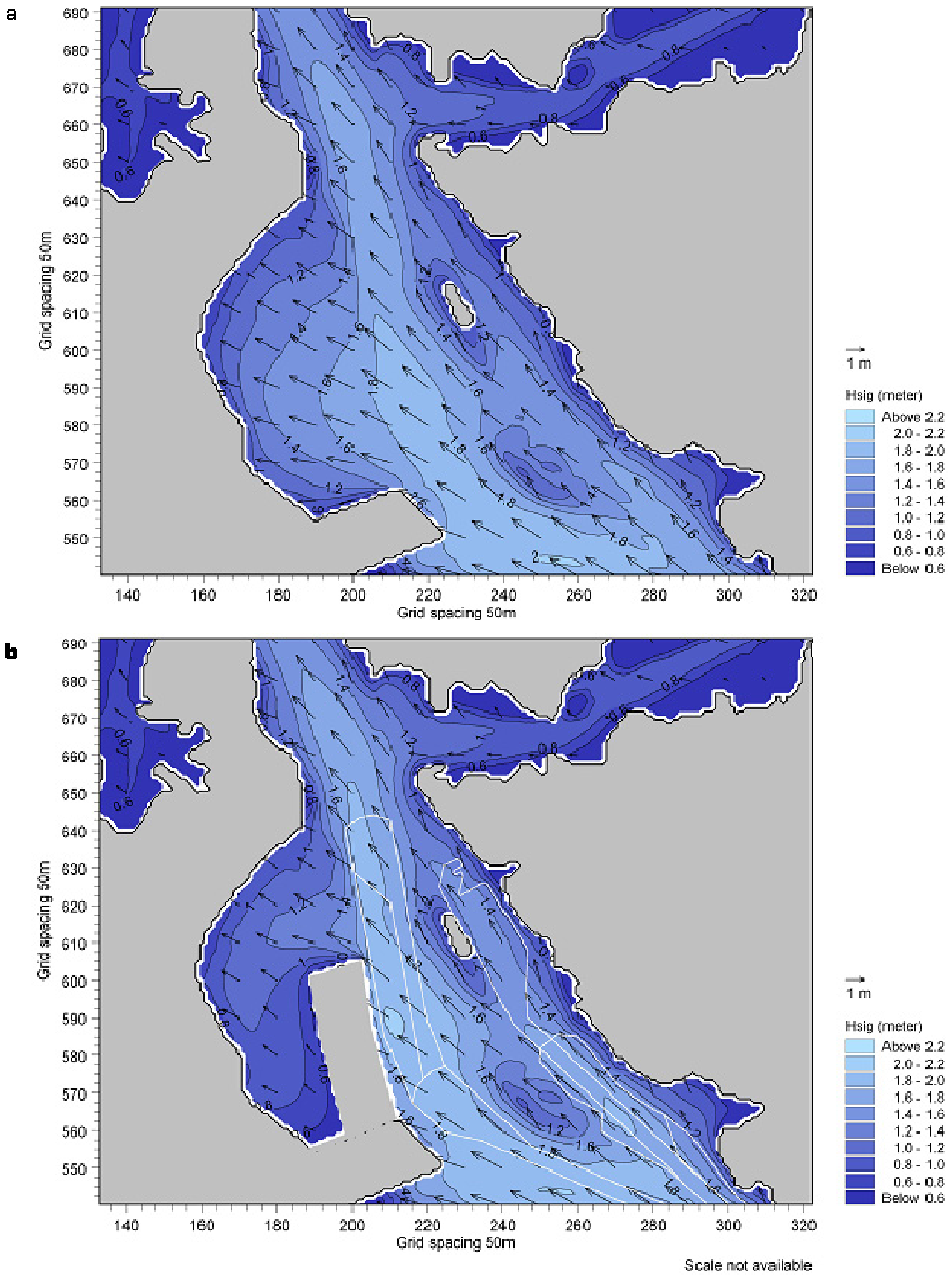


Figure 6.14 Predicted significant wave height contour and vector map due local winds with a 10-minute average wind speed of 36m/s (50 year ARI cyclonic wind speed) from the south-south-easterly direction: a) existing case, b) Australia Pacific LNG Option 2a

6.2.3 Natural hazards and climate change

Natural Hazards potentially affecting the coastal zone and their frequency of occurrence are addressed in the following sections and include the topics of:

- Storm surge and storm tide (severe weather induced extreme water levels)
- Tsunami
- Climate change (coastal impacts)

Storm Tide

Potential impacts associated with tropical cyclone landfall were assessed through hydrodynamic simulations. Although not a detailed storm tide study, several scenarios were selected to represent severe cyclone tracks reaching landfall at Gladstone in order to assess the potential impact to coastal processes at the Australia Pacific LNG Project site. The storm surge and extreme weather current speed impact method presented in Section 4.4.1 was repeated using the Option 1b and Option 2a hydrodynamic models. This assessment was performed to determine if the proposed marine works within the Western Basin increased the vulnerability of the study site to extreme water levels and current speeds.

Following the approach in Section 4.4.1 water level and current speed predictions were extracted from the model in the vicinity of the proposed Australia Pacific LNG berth (for Option 1b and Option 2a). Table 6.2 presents the peak water level and current speed for tidal forcing only (i.e. “normal” conditions) and for tidal with representative 50 year ARI tropical cyclone forcing. The peak water levels and current speeds are associated with the cyclone arriving during spring flood tide conditions. Other influences that can affect waters levels during tropical cyclones storms such as wave setup, run-up, and overtopping have not been considered. The values in brackets in Table 6.2 indicate the percentage difference between the tidal forcing only and tidal with tropical cyclone forcing.

Table 6.2 Predicted impact of a representative 50 year ARI tropical cyclone arriving during spring flood tide conditions.

	Normal spring tide		Storm tide (cyclone landfall at time of flood tide)	
	High water level MSL (m)	**Current speed (m/s)**	**Peak water level MSL at berth (m)**	**Peak current speed at berth (m/s)**
Auckland Point	2.19	0.97	3.24 (+32.5%)	1.36 (+28.3%)
Option 1b berth	2.30	0.66	3.42 (+32.8%)	0.83 (+20.0%)
Option 2a berth	2.29	0.33	3.40 (+32.4%)	0.49 (+31.7%)

The results in Table 6.2 suggest the Western Basin and the Australia Pacific LNG dredging works result in lower current speeds in the deeper channels and dredged areas, while storm tide water levels are not significantly modified compared to existing conditions.

Compared to the undeveloped Western Basin scenario, the currents in the berth locations for Option 1b are reduced by 0.12m/s and for Option 2a, peak currents decrease by 0.6m/s.

Geoscience Australia (2001) has also assessed the risk to Gladstone City from cyclonic winds and storm tide and concluded low-lying areas and areas of older residential coastal development such as

Barney Point, and Boyne Island have the greatest level of risk. At the 1% annual exceedence probability level, it was estimated that 247 buildings or facilities would experience over-floor inundation.

Tsunami

The potential for impact by tsunami is considered to be very low considering the 30 year design life of the Australia Pacific LNG facility and the top of reclamation level being proposed, approximately 6 m AHD, is a sufficient height above HAT level of 2.7 metres.

Tsunamis have the potential to induce strong currents associated with the long period wave as it travels inside the estuary. These strong currents can produce the phenomena known as ship ranging that is the application of large transverse forces on the mooring arrangement of the LNG vessel at the berth. Because tsunamis can occur at any time and travel at great speeds, they arrive with very little or no warning.

Mitigative action would depend to a large extent on sufficient warning to enable port procedures to be complied with, similar to cyclone warnings, requiring vessels to clear the pilotage area once given notice via broadcast on VHF channels 13 and 16. Port procedures stipulate that the Harbour Master may close the port, wholly or in part, or restrict the movement of vessels in the pilotage area, commensurate with the threat to the safety of shipping or the environment.

Tsunami warnings are issued by the Joint Australian Tsunami Warning Centre (JATWC) operated in Canberra by the Bureau of Meteorology (BoM) and GeoScience Australia (GA). The major objective of the JATWC is to provide emergency managers with a minimum of 90 minutes warning of a likely tsunami impact on Australia. The Bureau of Meteorology uses its network of sea-level monitoring equipment including coastal sea-level gauges and DART™ buoys (deep-ocean tsunami detection buoys) and tsunami computer models to confirm the existence of a tsunami and estimate its likely intensity.

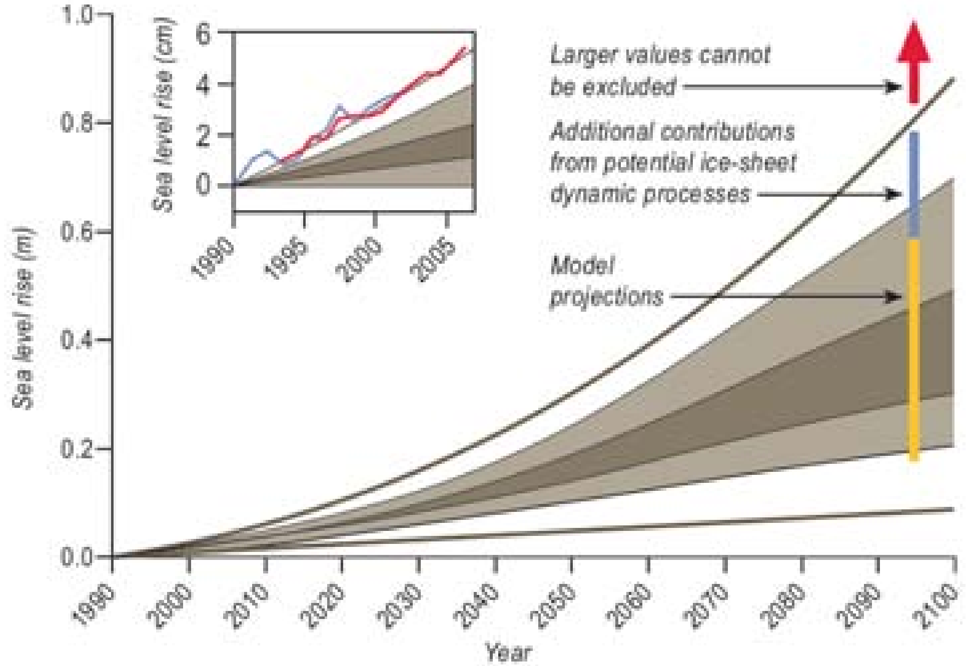
Climate change risks to the coast

Warming of the atmosphere and the oceans is driving a range of other changes, some of which are not yet well understood, in the climate system and to coastal processes (Australian Government 2009b). The complexity of interactions in the coastal zone could lead to a combination of impacts from climate change. Of the foreseeable risks associated with coastal processes, the most likely ones are inundation in low-lying areas and accelerated coastal erosion.

According to the Australian Government report (2009b), under climate change both mean conditions and extremes will change over a range of time scales. The Intergovernmental Panel on Climate Change (IPCC) is the authorative source on projections of sea-level rise. Conclusions about future sea-level rise in the IPCC's Third Assessment Report (TAR, 2001) and Fourth Assessment Report (AR4, 2007) were broadly similar. To assess the LNG facility's vulnerability to climate change, predictions have been gathered from the CSIRO, and the Queensland Government. CSIRO projections are available for years 2030, 2050 and 2070.

The CSIRO mid-level sea level rise projection of 0.47 metres by 2070 has been chosen as the basis for the impact assessment, representing a conservative estimate for the Project lifespan to 2050. This is one of the higher AR4 projections for estimated global sea-level rise (0.79 metres by 2100). Figure 6.15 shows sea-level rise projections to 2100 from the TAR and AR4 analysis.

The assessment (Australian Government 2009b) indicates Queensland has the second highest number of residential buildings at risk from inundation and this does not include storm tide risk.



IPCC TAR and AR4 projections

Figure 6.15 Projections of sea-level rise

The model projections shown in Figure 6.15 are consistent with the scenarios used in the storm tide modelling data described in Section 3.7.

The potential impact from climate change risks to the coastline at the Australia Pacific LNG Project site would be low as design consideration has been given to elevating the reclaimed land level. Finished land level includes allowance for sea level rise adjustment based on model projections.

6.2.4 Marine structures

Marine structures proposed as part of the Australia Pacific LNG facility infrastructure include the Materials Offloading Facility (MOF), and jetties as described within Section 5.

For both Option 1b and 2a the MOF structure is proposed to be located at the northern end of the site and would extend across the intertidal area. In Option 2a the Product Loading Facility jetty is just to the south of the existing wetland site and extends across intertidal area to the proposed swing basin and berth. Duplication of the first jetty would occur further to the south for the third and fourth trains by 2016.

In Option 1b the Product Loading Facility jetty is much longer and extends from the LNG facility to the western side of North Passage Island, a distance of approximately one kilometre. Duplication of would be confined to loading platform and dolphins for the four-train development. A trestle would be required to provide access from one loading platform to the other. In Option 1b the loading platforms are adjacent to the Targinie Channel.

Potential impacts associated with the MOF and Product Loading Facility jetty has been assessed as follows:

- Removal of intertidal area and mangroves. The intertidal area of 15ha where the MOF is proposed would require removal of 260m of shoreline including mangroves

- Dredging of the MOF base to provide relatively firm strata for construction purposes and disposal of material
- plumes associated with placement of rock armour protection and leaching of fine sediments
- Highly visible marine structures protruding into the coastal zone (see also Volume 4, Chapter 7)
- Restriction of recreational craft in North Passage Channel
- Decommissioning of the MOF and jetties at the end of their operational life.

Option 1b requires a greater length of the trestle and associated product loading assets would require more over-water structural assembly and treatments, and greater maintenance effort during the operational life.

The current design of the MOF structure protrudes almost normal to the shoreline and approximately 500m offshore, while the Product Loading Facility jetty in Option 2a is proposed to end approximately 160m from the shoreline and would be a piled structure with frames about every 25m. Structures required in both Options are expected to have a low potential for impact to coastal processes because sand transport activity is very low. In either Option the piled LNG Product Loading Facility jetty would have minimal impact to current and wave conditions. There is a potential for finer sediments to be deposited at the MOF site because it is proposed as a solid structure and would create quiescent zones where material may accumulate.

Dredged material from the MOF would be transported to a GPC approved disposal site as part of the dredging works and would not be considered to have a significant impact.

Plumes associated with rock armour protection and building of the causeway will be limited because of the volume involved and would be insignificant compared to dredging works for example. Consequently, plumes from the causeway and MOF rock armour construction are considered as a minimal impact.

The potential visual amenity impact of both Options is considered significant, but must be examined in context with the declared industry precinct and would also be subject to the viewing aspect. North Passage Island provides good screening for the site and for Option 2a structures. From the mainland side the island and the load out platform of Option 1b would be more prominent. Greater detail on visual amenity is provided in Volume 4, Chapter 7.

New signage or markers would be required to redirect recreational traffic around the Product Loading Facility jetty and MOF in keeping with the exclusion zones and security requirements. Modifications to recreational craft navigation routes would be undertaken in liaison with GPC.

Where required, decommissioning of jetties at the end of their operational life would require dismantling and removal of assets above deck level to leave the structure essentially in skeleton form and to remain as marine habitat. Deconstruction of marine based structures, unless they themselves contain substances or treatments that can breakdown and present harmful impacts to the environment, would increase the overall potential for environmental harm. The decommissioning plan will consider any requirements for sediment sampling analysis and removal. Berths and approaches could be allowed to naturally in-fill over time.

6.2.5 Reclaim area

The reclaim area proposed for the site is described in Section 5.3.

Construction of the reclaim area has the potential to generate some turbidity, but would be naturally mitigated to a large extent by the intertidal nature of the site. The proposed causeway would follow the seaward boundary of the reclamation, located behind the mangrove fringe. Once the causeway is constructed, the penetration of the tide into the mangrove creek would finish there. Furthermore, the mangrove fringe in front of the causeway would act to trap fine sediments and provide a natural silt barrier for low turbidity concentrations associated with the construction process. Sediment run-off can also be managed through engineered silt screens.

Water quality associated with the surface water and ground water seepage will be managed through geotextile fabric or similar to mitigate the potential impact to mangroves.

6.2.6 Swing basin and approaches

The assessment of dredging impacts on the swing basins and approach channels were part of the Western Basin Dredging and Disposal EIS. This Section addresses the potential impact to local coastal processes.

Hydrodynamic modelling has shown there is a potential for increased sediment movement across the North Passage Island shoals (BMT WBM 2009d), and the swing basin layout and design is important in regard to the potential for erosion of North Passage Island and the intertidal zone in front of the LNG facility. LNG carriers that call to the port on a regular basis, and turn around in 24 hours, manoeuvre within the swing basin and potentially generate wave-wash as they berth. The swing basin is dredged to -13m LAT with batters designed to obtain sufficient vessel clearance. Australia Pacific LNG will continue to assess the swing basin design to mitigate the impact of wave action, whether generated by vessels or by local winds that has a potential to erode and collapse the tops of the batter slopes when combined with lower water levels. The depth of the swing basin allows low energy wave action to propagate, without dissipation, to the shoreline.

The rate at which erosion could occur would depend upon the amount of wave action in the swing basin and approaches in addition to the shoreline characteristics of North Passage Island and the inter-tidal area that are identified in Figure 6.16. Potential erosion will be identified and managed through monitoring of the shorelines surrounding the swing basin and be conducted on a regular basis to provide data on any morphological movements and to trigger mitigation, if necessary. Mitigation would include:

- Rock or mat protection to stabilise the shoreline and dissipate wave energy
- Measures to stabilise the North Passage Island shoreline, if required
- Reshaping the upper batter slopes to induce wave breaking before the shoreline berm is reached.

Potential for morphological changes to the shoals upstream and downstream of North Passage Island would also be monitored by way of hydrographic survey (as one option) on an annual basis for several years to determine if changes are occurring and to implement a management plan if the changes are significant.

Figure 6.16 North Passage Island and proposed swing basin aerial perspective

6.3 Flushing and estuary water quality

The overall flushing characteristic of the estuary is an important mechanism for maintaining water quality and the potential impact to the rate of natural flushing of the estuary is important in the assessment of turbid plumes and waste stream discharges. The potential impacts on flushing characteristics of the estuary were generally addressed in GPC's EIS for the Western Basin Dredging and Disposal Project, The following discusses the potential impacts to flushing characteristics resulting from dredging Options 1b and 2a, and is consistent with the methodology used in GPC's EIS.

Model bathymetry used in tidal flushing simulations incorporated dredging Option 1b or 2a in addition to the dredged channels and Fisherman's Landing Northern Reclamation. Capital dredging works associated with the Australia Pacific LNG Options 1b and 2a are predicted to marginally increase local flushing times as follows:

- Approximately three days for Option 1b, at a location within the swing basin to the east of North Passage Island
- Approximately five days within the swing basin area for Option 2a.

Model results are consistent with the GPC EIS since current velocities will generally decrease in the areas that are dredged deeper. Without the inclusion of Option 1b and 2a, the GPC EIS model results, based on the 'scenario 3' configuration, predict increases in local flushing times up to four days compared to the base case of no dredging or reclamations. The e-folding times increase towards Graham Creek and The Narrows.

Local flushing times in Graham Creek and The Narrows are naturally poor and are not significantly affected by dredging works in the Western Basin including the Australia Pacific LNG dredge Options.

The impacts to marine ecology associated with modified flushing times and potential water quality impacts are discussed Volume 4, Chapter 10.

6.4 Dredge plumes

Assessment of the dredge plumes resulting from the formation of the swing basins and navigation channel was addressed as part of GPC's Western Basin Dredging and Disposal EIS. It was noted the dredge plumes resulting from Australia Pacific LNG's Option 1b and 2a requirements would not result in potential impacts being any greater than those occurring for the other developments. This is based upon the assumptions made in the modelling scenarios about dredging equipment and its production rates (BMT WBM 2009b, Section 4.2).

6.4.1 Dredge plume modelling for the materials offloading facility construction

Dredged material for MOF construction would be removed using a backhoe dredge to provide a construction base for the MOF. It is assumed that multiple barges, each with a capacity of 400m^3, would be used to dispose of the material to a nearby land reclamation. Turbid plumes associated with the dredging have been assessed using a hydrodynamic model (MIKE21 FM) coupled with a mud-transport capability.

The quantity of dredged material for MOF construction will be determined as the design progresses. For the purpose of the EIS study, it was assumed that dredging of the MOF area would take 60 days and the model used a 10% spill rate from the backhoe bucket to generate the plumes. The fate of plumes is primarily a function of currents and settling velocity associated with the sediment types encountered. Sensitivity analysis of the upper and lower limits of material settling velocity was investigated to determine the effect to plume behaviour. Plume concentrations presented from model results are values above the natural background turbidity.

The inset in Figure 6.17 details the model mesh in the vicinity of MOF and the ten source point locations used to input dredge material spill to the model domain. The multiple source points allow the dredge spill location to vary throughout the simulation, thus representing a dredger moving to different positions throughout the dredge program. MOF dredging is anticipated to take 60 days with a required volume per 24hr day of 1800m^3. This dredge rate requires six days of dredging to be simulated at each of the ten dredge locations. Dredge spill from the backhoe bucket was simulated as a constant source input of material during each barge fill period. Each barge was filled with approximately 400m^3 of material. Once full, the barge would steam to the reclaim area and is replaced with an empty barge. The barge change over occurs over a 15min period, during which time no dredge spill occurs. MOF dredge plume model parameters are summarised in Table 6.3.

Table 6.3 MOF dredging model parameters

MOF dredge plume model parameters	
Total dredge volume	108,000m3
Duration of dredge program	60 days
Required volume per day (24hr)	1800m3
Number of model dredge locations (source points)	10
Time at each model dredge location (source point)	6 days
Dredge rate	31.5kg/s
Dredge material spill rate (10% of dredge rate)	3.2kg/s
Barge fill time (400m3 capacity)	5hrs
Barge change over time	15min

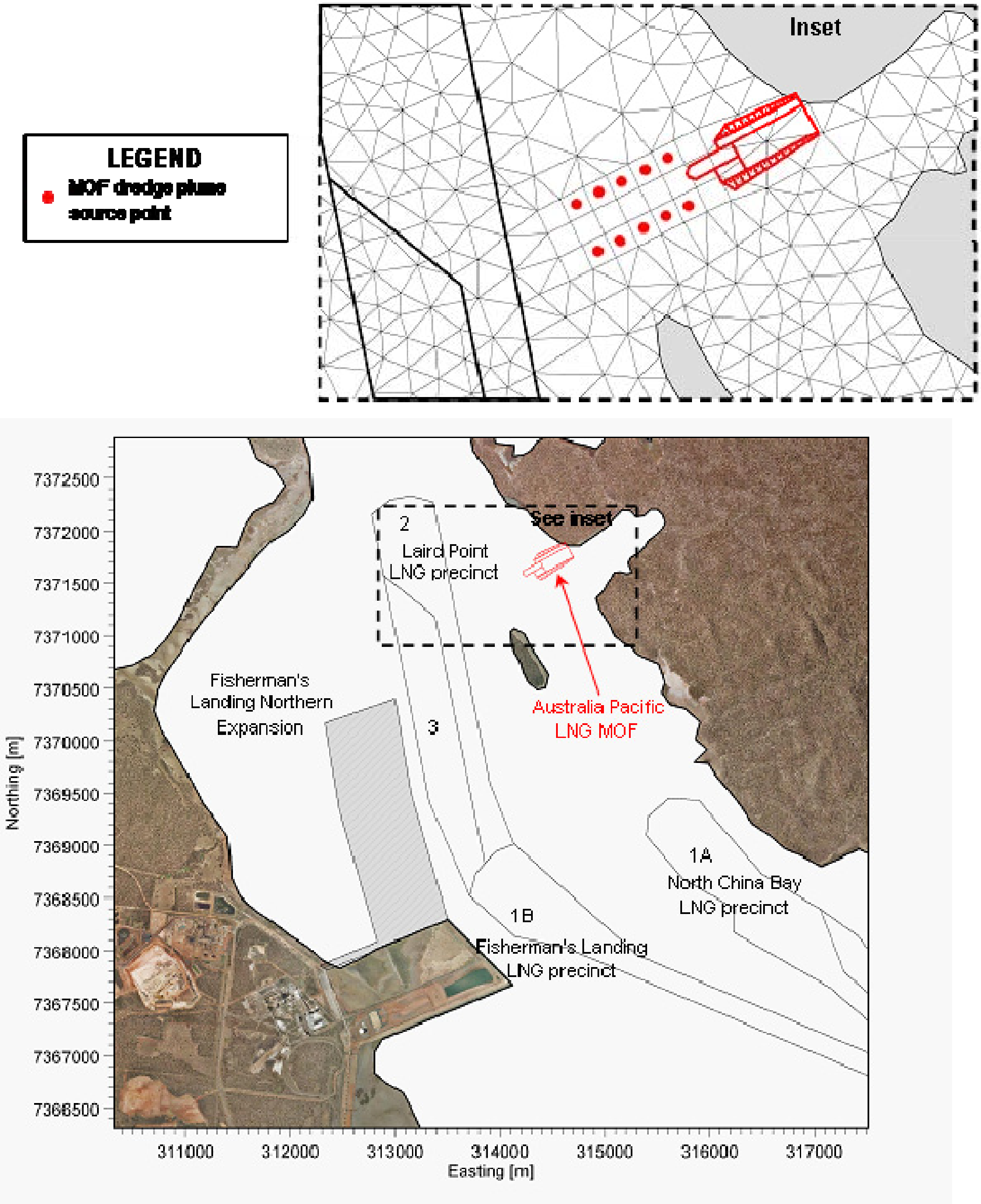


Figure 6.17 MOF construction dredge plume modelling analysis. Outlined areas are Proposed Dredging Stages 1A, 1B, 2, and 3 from Western Basin Dredging and Disposal EIS. Inset shows dredge source points used in model.

The fate of a dredge plume will depend on the duration it remains in suspension and how it is dispersed by the currents. Knowledge of the material type and sediment settling velocity is essential for modelling sediment plumes. URS (2009), on behalf of Santos, performed sediment sampling and particle size distribution analysis close to the proposed Australia Pacific LNG MOF. The mean fraction percentage for the upper 3.9m of material from bore hole BH26 (the closest bore to the Australia Pacific LNG MOF) is presented in Table 6.4. The mean fraction percentages from bore hole BH26 were used for MOF dredge plume modelling.

Table 6.4 Mean percentage material fractions from Soil Bore BH26 (URS 2009) and settling velocities used for MOF dredge plume modelling.

Fraction	Material	Grain size (mm)	Percentage (%)	Settling Velocity (m/s)
1	Sand	2 - 0.06	8	0.02 – 0.001
2	Silt	0.06 - 0.002	36	0.001 – 0.0001
3	Clay	<0.002	54	0.0001 – 0.00001

Sediments suspended during MOF dredging causing turbid plumes, will slowly settle to the bed once the bed shear stresses and fluid turbulence are insufficient to keep the sediment moving. The duration the sediment remains in suspension is influenced by the material grain size and settling velocity. The finer material with a low settling velocity may remain in suspension for long periods due to the relatively strong tidal currents within the study area. Sensitivity of the MOF dredge plume to the upper and lower limits of the material settling velocity was investigated. The upper and lower limit MOF dredge plume modelling scenarios are defined in Table 6.5.

Table 6.5 Sediment upper and lower limit MOF dredge plume modelling scenarios.

Fraction	Material	Grain size (mm)	Percentage (%)	Settling Velocity (m/s)
		Upper limit sediment scenario		
1	Sand	2 - 0.06	8	0.02
2	Silt	0.06 - 0.002	36	0.001
3	Clay	<0.002	54	0.0001
		Lower limit sediment scenario		
1	Sand	2 - 0.06	8	0.001
2	Silt	0.06 - 0.002	36	0.0001
3	Clay	<0.002	54	0.00001

In terms of the potential MOF dredge plume impact, the lower limit sediment scenario defined in Table 6.5 is considered the more conservative modelling approach. Comparing the predicted turbidity plumes associated with the upper (best case) and lower (worst case) sediment scenarios a range of potential plume impacts are defined.

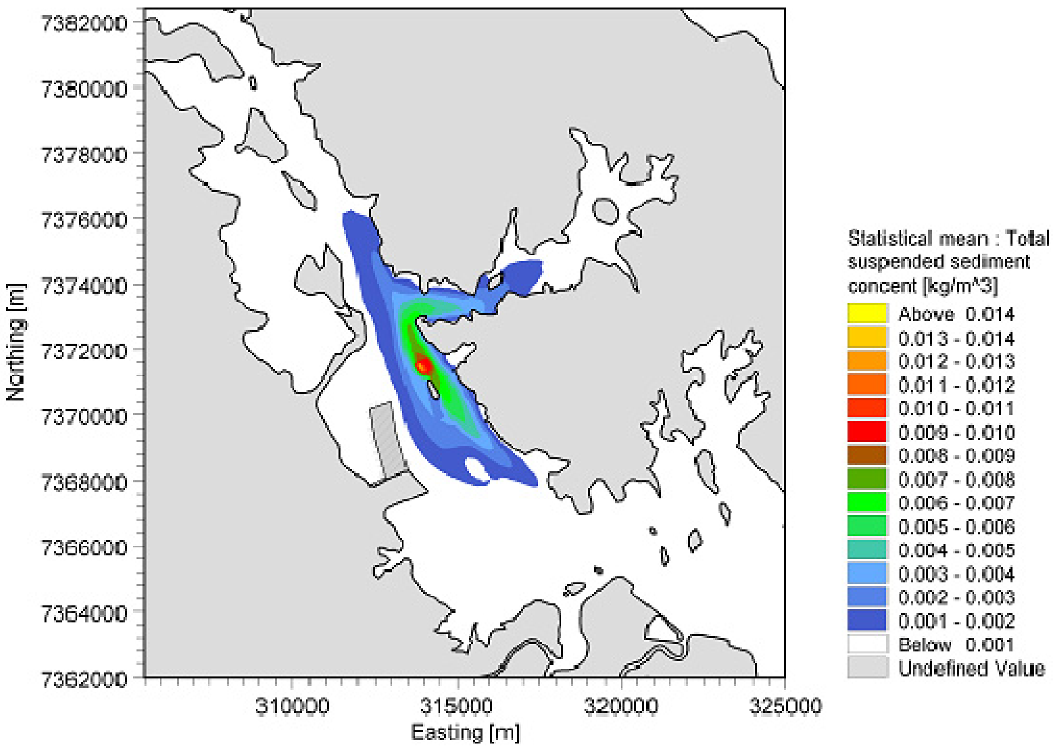
The predicted total suspended solids (TSS) concentrations due to MOF dredging reported in this section are in addition to the natural TSS concentrations (that is above the background TSS level) within the Western Basin. A statistical analysis of the TSS concentration for the simulated 60-day MOF dredge program provides an assessment of the potential impact area. The statistical summary is based on the conservative assumption of 10% dredge material spillage. Predicted concentrations close to the dredge plume source points (that is in the near field) are not accurately predicted by the model. The input source is entered into a mesh element and the mass of the component (i.e. the dredge material spillage) is initially distributed over the element area and depth. This causes the near field concentration seen in the results to be lower than the input value.

Figure 6.18 presents a spatial summary of the mean TSS concentration predicted to occur during the 60 day dredge program for the upper and lower limit scenarios. MOF dredging is predicted to raise the TSS concentration within Gladstone Harbour and The Narrows, including Graham Creek.

Figure 6.18a shows the mean ambient TSS concentration above background for the sediment upper limit (best case) scenario. Close to the Graham Creek entrance the mean TSS is predicted to elevate by 0.005kg/m^3 (5mg/L) during the dredge program. North of the Graham Creek entrance, the predicted increase to the mean TSS within The Narrows is less than 0.003kg/m^3 (3mg/L). Higher mean TSS concentrations are predicted along the Curtis Island shoreline south of Laird Point and between North Passage Island. Lower mean TSS concentrations, less than 0.0035kg/m^3 (3.5mg/L), are predicted between the western side of North Passage Island and Fisherman's Landing.

Figure 6.18b shows the increase to the mean ambient TSS concentration for the sediment lower limit (worst case) scenario. The lower limit sediment characteristics significantly increase the MOF dredge plume spatial impact. Within Graham Creek and surrounding North Passage Island the mean TSS is predicted to elevate by more than 0.014kg/m^3 (14mg/L) during the MOF dredge program. North of the Graham Creek entrance, the predicted increase to the mean TSS within The Narrows is between 0.002kg/m^3 and 0.013kg/m^3 (2mg/L and 13mg/L). The plume is predicted to disperse beyond Fisherman's Landing to Auckland Point, noting that the predicted increase to the mean TSS concentration in this area is relatively low and less than 0.005kg/m^3 (5mg/L), which is well within the natural TSS variation in Gladstone Harbour (BMT WBM 2009c).

a)



b)

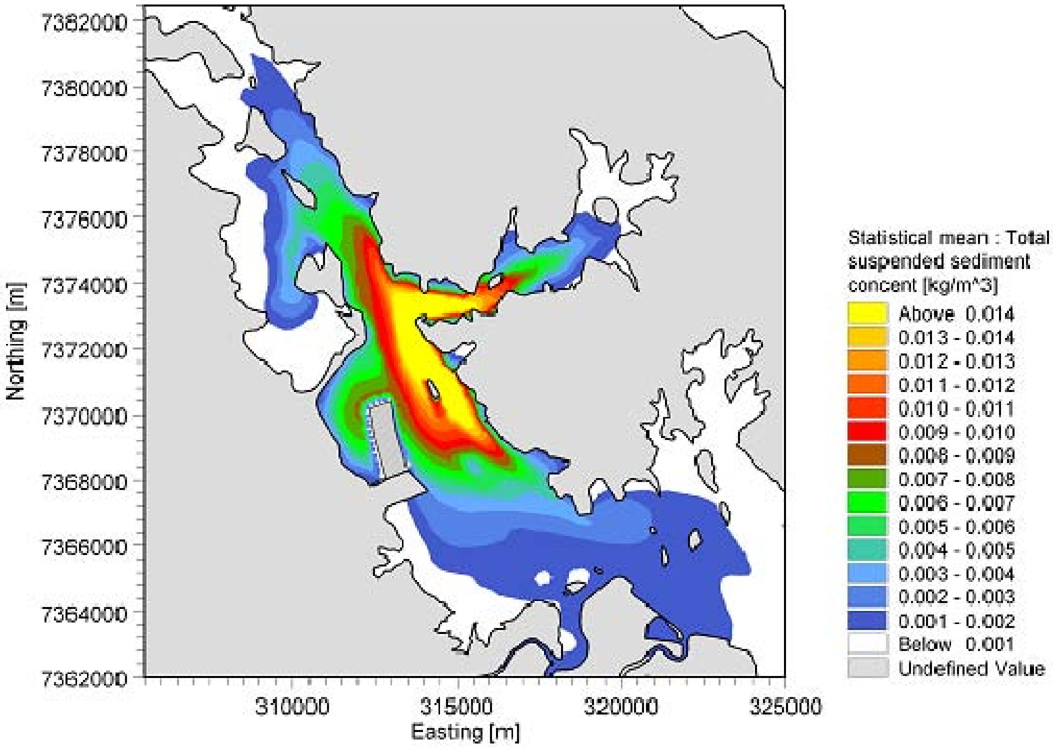


Figure 6.18 Statistical mean TSS concentration increase during the 60 day MOF approach channel dredge program: a) upper limit sediment settling velocities, b) lower limit sediment settling velocities

Figure 6.19 is a spatial summary of the maximum TSS concentration predicted to occur during the 60 day dredge program for the upper and lower limit scenarios. Note that at any given location the predicted maximum TSS is likely to be present for only a short period.

Figure 6.19a shows the maximum TSS concentration for the sediment upper limit scenario. Over approximately 5km to the north, south and east (Graham Creek) of the MOF location maximum TSS concentrations above 0.005kg/m^3 (5mg/L) are predicted to occur. Close to the MOF area a TSS concentration above 0.07kg/m^3 (70mg/L) is predicted. The highest concentrations close to the working area will be present during neap tides. During neap periods the smaller tidal magnitude and current velocities only disperse the material a short distance, leading to an accumulation of suspended sediment close to the working area. Elevated concentrations up to 0.020kg/m^3 (20mg/L) are predicted to occur at the entrance to Graham Creek. Beyond the Graham Creek entrance the predicted maximum increase to TSS concentration is less than 0.015kg/m^3 (15mg/L). Within The Narrows TSS concentrations above 0.01kg/m^3 (10mg/L) are confined to an area approximately 4km from the MOF.

Figure 6.19b shows the maximum TSS concentration for the sediment lower limit scenario. For this scenario the predicted maximum TSS concentration within 5km of the MOF location is above 0.02kg/m^3 (20mg/L). Elevated concentrations up to 0.06kg/m^3 (60mg/L) are predicted to occur at the entrance to Graham Creek with TSS concentrations up to 0.04kg/m^3 (40mg/L) extending well into the creek. Within The Narrows maximum TSS concentrations above 0.015kg/m^3 (15mg/L) are predicted with higher concentrations (up to 0.03kg/m^3 or 30mg/L) occurring along the Curtis Island shoreline.

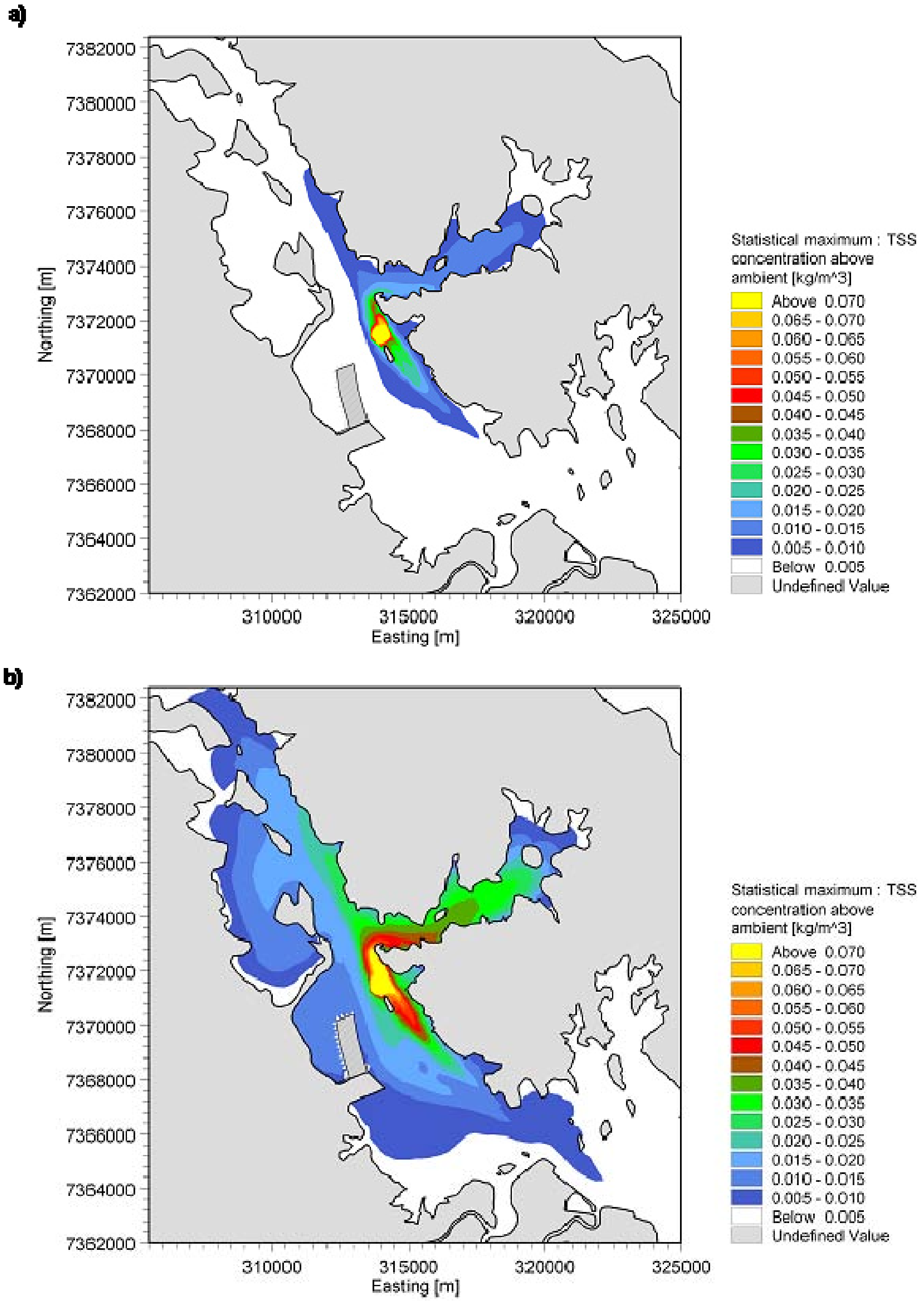


Figure 6.19 Statistical maximum TSS concentration increase during the 60 day MOF approach channel dredge program: a) upper limit sediment settling velocities, b) lower limit sediment settling velocities

Figure 6.20 compares the predicted above background TSS concentration time series for the sediment upper and lower limit scenarios. Graham Creek and The Narrows locations of interest are presented with the corresponding Gladstone (South Trees) tidal signal for the duration of the dredge plume simulation. Note that the simulation continued beyond the 60-day dredge period. This allowed the time taken for the TSS concentration to return to background levels following the completion of the MOF dredge program to be predicted.

Figure 6.20 identifies higher concentrations at Graham Creek and The Narrows to occur during periods of larger tidal magnitude. During these periods the tidal excursion is sufficient to disperse higher TSS concentrations to these far-field locations of interest. During the shorter, neap tide periods relatively low TSS concentrations are present at both far-field locations. Following the completion of the 60 day MOF dredge program, the sediment upper limit scenario TSS concentrations return to background levels within 10 days. For the sediment lower limit scenario, elevated TSS concentrations remain for approximately one month following completion of the MOF dredge program.

Table 6.6 compares the predicted maximum and mean increase to TSS concentration at the four locations of interest for the upper and lower limit sediment settling velocity scenarios. At each given location the predicted maximum and mean TSS concentration for the upper (best case) and lower (worst case) sediment settling velocity scenarios is presented. During the MOF dredging program the maximum and mean TSS concentrations at each location is expected to be within the upper and lower limit scenario prediction.

Table 6.6 Predicted maximum and mean TSS concentration above background for the upper and lower limit settling velocity scenarios at the four locations of interest.

Modelling scenario	TSS concentration above background							
	North Passage Island East		North Passage Island West		Graham Creek		The Narrows	
	Max (kg/m3)	Mean (kg/m3)	Max (kg/m3)	Mean (kg/m3)	Max (kg/m3)	Mean (kg/m3)	Max (kg/m3)	Mean (kg/m3)
Upper limit sediment settling velocity scenario (best case)	0.036	0.005	0.007	0.002	0.013	0.002	0.005	0.001
Lower limit sediment settling velocity scenario (worst case)	0.067	0.015	0.024	0.012	0.038	0.011	0.021	0.006

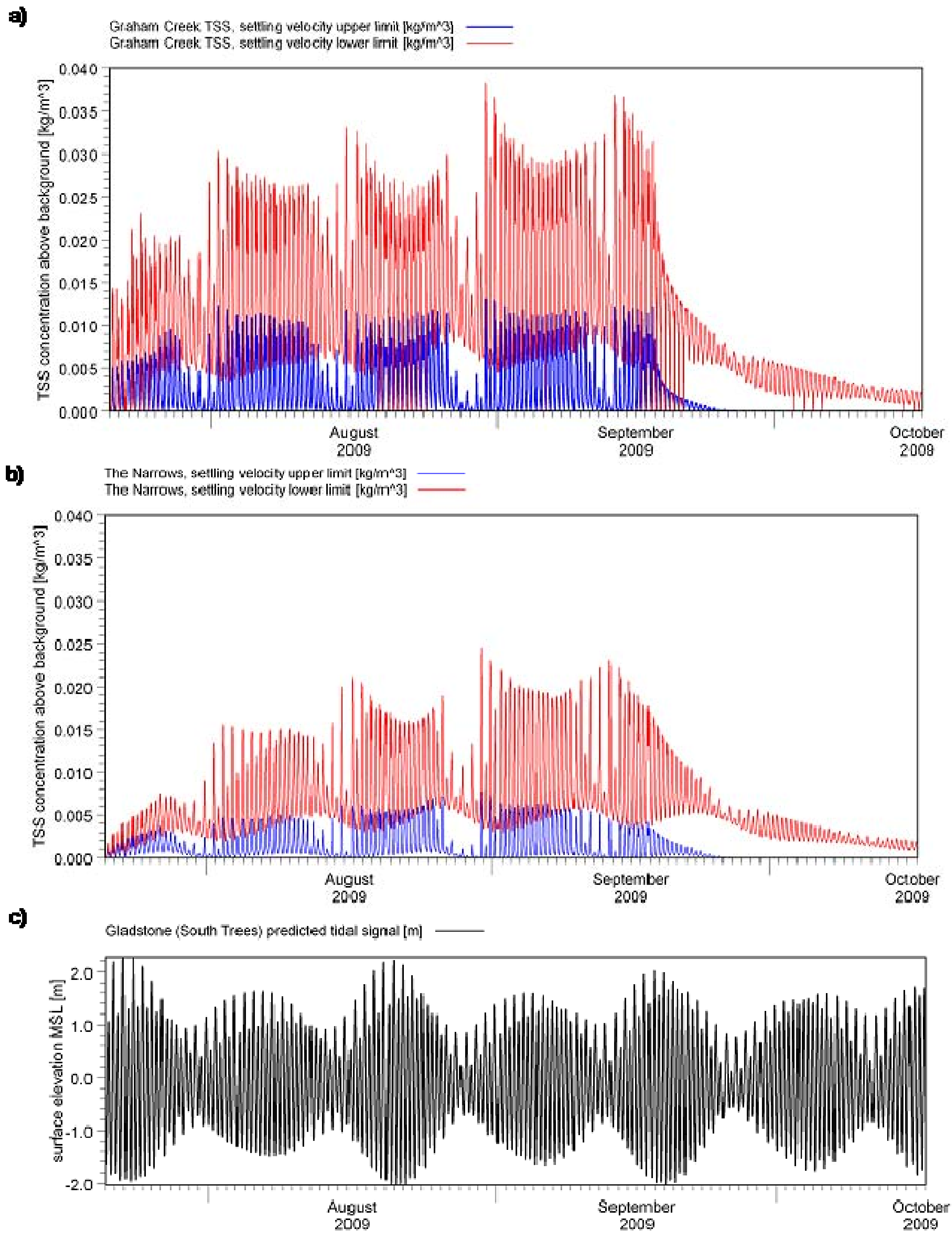


Figure 6.20 TSS concentration above background during MOF dredging for the upper and lower limit sediment settling velocities: a) Graham Creek, b) The Narrows, c) corresponding tide signal at Gladstone (South Trees)

Various marine developments are proposed for the Western Basin. The timing of the MOF dredging relative to other Western Basin developments is uncertain at this stage. The sensitivity of the MOF dredge plume to different stages of Western Basin development was investigated. Changes to the model bathymetry were performed to represent three different stages of Western Basin development and the MOF dredge program simulation (for the upper limit sediment settling velocity scenario) was performed for each stage of development. Table 6.7 compares the predicted maximum and mean TSS concentration for the three Western Basin development stages at four locations of interest. The predicted maximum and mean TSS concentrations due to MOF dredging at the locations of interest are relatively insensitive to the different stages of Western Basin development.

Table 6.7 Maximum and mean TSS above ambient at receptor locations during the 60 day Australia Pacific LNG MOF dredging program sensitivity to Western Basin development stages

	TSS concentration above background (kg/m3)							
Western Basin development stage	**North Passage Island East**		**North Passage Island West**		**Graham Creek**		**The Narrows**	
	max	**mean**	**max**	**mean**	**max**	**mean**	**max**	**mean**
GPC dredging stages 1A, 1B, 2, 3, and Fisherman's Landing northern expansion completed.	0.036	0.005	0.007	0.002	0.013	0.002	0.005	0.001
GPC dredging stages 1A, 1B, 2, and 3 completed.	0.036	0.005	0.006	0.002	0.013	0.002	0.005	0.001
Existing bathymetry	0.036	0.005	0.006	0.004	0.022	0.002	0.005	0.001

6.5 Desalination brine discharge

Seawater desalination will supply fresh water during both the construction and operational phases of the proposed Australia Pacific LNG Project. The maximum design total fresh water demand during the operation of four-trains is estimated to be 1400m^3/day.

Considering a fresh water recovery rate of approximately 40%, desalination brine (the waste by-product of the desalination system) would be discharged at an average flow-rate of 2,400m^3/day. In the near-field assessment the average flow for two-trains, and the maximum flow for four-trains was used to simulate the variation in discharge. An outfall and diffuser would be used to disperse the brine into the waters of North Passage Channel.

The near-field assessment focuses on the dilution achieved with the diffuser design and the changes in the brine concentration before reaching the far-field. The far-field is used to assess the potential for accumulation of brine concentration within the marine environment as it advects with the tide.

6.5.1 Near Field Assessment

Initial dilutions associated with the diffuser design were examined in the near-field assessment. Natural seawater characteristics at the entrance of the Calliope River (from DERM data, 1996-2006) that are considered to be representative of the waters in the Western Basin vary as shown in Table 6.8.

Table 6.8 Ambient marine water properties

	Minimum	20th percentile	Median	80th percentile	Maximum
Temperature (°C)	17.7	22.5	26.2	29.2	33.9
Conductivity (mS/cm)	29.9	52.7	55	56.6	60.5
Salinity1 (ppt)	18.5	34.7	36.5	37.6	40.6

1Derived from Temperature and Conductivity (note Conductivity @ 25ºC).

Favourable conditions for discharge of desalination brine require the following characteristics:

- Sufficient depth for mixing to occur and an adequate distance from the shoreline
- Free flowing current conditions that would disperse the brine
- Available access for maintenance purposes
- Free from vessel contact and within the LNG facility marine lease area.

The brine reject is a negatively buoyant plume that, upon discharge from the diffuser, would sink to the bottom unless full mixing can be achieved with the ambient waters.

The proposed location for the desalination system intake is the Product Loading Facility via a passive intake screen attached to a jetty pier, and is over 600m from the discharge option in front of the MOF. The intake is well clear of the brine release initial mixing zone and under normal tide conditions the brine should be sufficiently mixed over the water column depth such that concentrations would be close to background levels. Consequently, recirculation of elevated brine concentrations back into the desalination intake would be avoided.

Intake rates required for the desalination system are low when compared to total flows in the North Passage Channel and have no influence on the hydrodynamics. The impact of the intake on the marine ecology is assessed in Volume 4, Chapter 10 of the EIS.

Spring and neap tide velocities were extracted from the hydrodynamic model (used for the far-field assessment) at the MOF location corresponding to the outfall diffuser position. These were analysed statistically to determine representative peak and slack tide current conditions that could be used in the near-field assessment to predict dilutions of the brine reject after discharge from the outfall diffuser.

Table 6.9 Ambient current statistics at MOF outfall site (dredged)

Statistic	Current speed (m/s)
5th Percentile	0.04
10th Percentile	0.07
20th Percentile	0.13
50th Percentile	0.26
80th Percentile	0.39
90th Percentile	0.51
95th Percentile	0.64

The model predictions reflect the proposed conditions at the MOF after dredging works and swing basins have been completed. Slack tide current was simulated using the 5th percentile current speed.

Near field simulations were undertaken using the industry accepted CORMIX model to assess the initial mixing potential of the site options for the brine reject outfall.

Assumptions used in the near-field modelling were as follows:

- The diffuser has been assumed to be perpendicular to the flood and ebb tidal current directions and is at least 1m below the LAT level. Initial mixing requires the negatively buoyant plume to sink after discharge while entrainment by tidal currents disperses the brine.
- Minimum dredged levels at the MOF are -8.5m LAT. Simulations were conservatively based on shallower depths that represent existing conditions outside the MOF approach channel.
- Six diffuser ports were used with a diameter of 50mm and spaced 2m apart over the diffuser length of 10m and oriented horizontally with the ambient current flow.
- Spring and neap tide velocities as per Table 6.9 represented ambient conditions. The model current velocity predictions reflect the proposed conditions at the MOF after dredging works and swing basins have been completed. Slack tide current was simulated using less than the 5th percentile current speed.
- Scenarios undertaken for the modelling are presented in Table 6.10 and were assigned to average and maximum discharges of 16L/s and 36L/s, corresponding to average conditions for two-trains and maximum conditions for four-trains, respectively.

Table 6.10 CORMIX Model Scenarios

	Ambient			Brine reject characteristics				
case	**S (ppt)**	**Temp (°C)**	**Density ρ (kg/m^3)**	**Salinity S (ppt)**	**Temp T (°C)**	**Density ρ (kg/m^3)**	**Δρ (kg/m^3)**	**Excess discharge (mg/L)**
1	34.5	22.5	1023.7	53.1	23	1037.7	14.0	18600
2	36.5	26.2	1024.1	56.2	26.7	1038.9	14.8	19700
3	37.5	29.2	1023.9	57.7	29.7	1039.0	15.1	20200
4	40.5	33.9	1024.5	62.3	34.4	1040.7	16.2	21800
5	34.5	22.5	1023.7	57.5	23	1041.1	17.4	23000
6	36.5	26.2	1024.1	60.8	26.7	1042.4	18.3	24300
7	37.5	29.2	1023.9	62.5	29.7	1042.6	18.7	25000
8	40.5	33.9	1024.5	67.5	34.4	1044.6	20.1	27000

In Table 6.10 the excess discharge is the brine content above normal seawater and will depend on the efficiency of the desalination process (35%-40%). The eight cases vary with ambient seawater salinity and temperature (refer to Section 3.9.1). It was assumed the brine reject temperature would be half a degree Celsius warmer by the time discharge through the outfall occurs, but note temperature difference has far less influence than the density difference between normal seawater and the concentrated brine.

Near Field Results

The CORMIX results predict the brine discharge receives approximately 80:1 dilution within 5m of the diffuser and a bottom impact dilution of 187:1 for the average discharge case (16L/s) associated with two LNG trains. Conditions of low water and slack tide are considered the worse case scenario for mixing of the brine discharge.

For the maximum brine discharge (36L/s) associated with four-trains at low water and slack tide, the CORMIX results predict a dilution of approximately 25:1 within 5m of the diffuser and a bottom impact dilution of 57:1.

Figure 6.21 contains the predicted results from CORMIX for 16L/s and the 36L/s discharges at low water slack tide conditions for cases 1 and 8, corresponding to the lower and upper range of brine salinity, respectively.

The brine plume becomes vertically fully mixed in the near field and this carries on into the far field indicating that there is negligible likelihood of denser brine layers forming in the deeper swing basin.

CORMIX simulations for mid (0.3m/s) current speed, predict dilutions of 170:1 at 5 m from the diffuser, and for peak (0.6m/s) current speed, predict dilutions of 380:1 at 5 m from the diffuser. Bottom impact dilution for mid current speed is over 1100:1 and over 2500:1 for peak current speed.

In the near-field, it is concluded that there will be no discernible impact from the discharge of the brine reject on the water quality in the vicinity of the diffuser as dilutions are adequate at low water slack tide and there is full mixing over depth. Increasing tidal currents promote further near-field dilution. Potential impacts from other constituents in the brine discharge are assessed under marine ecology in Volume 4, chapter 10 of the EIS.

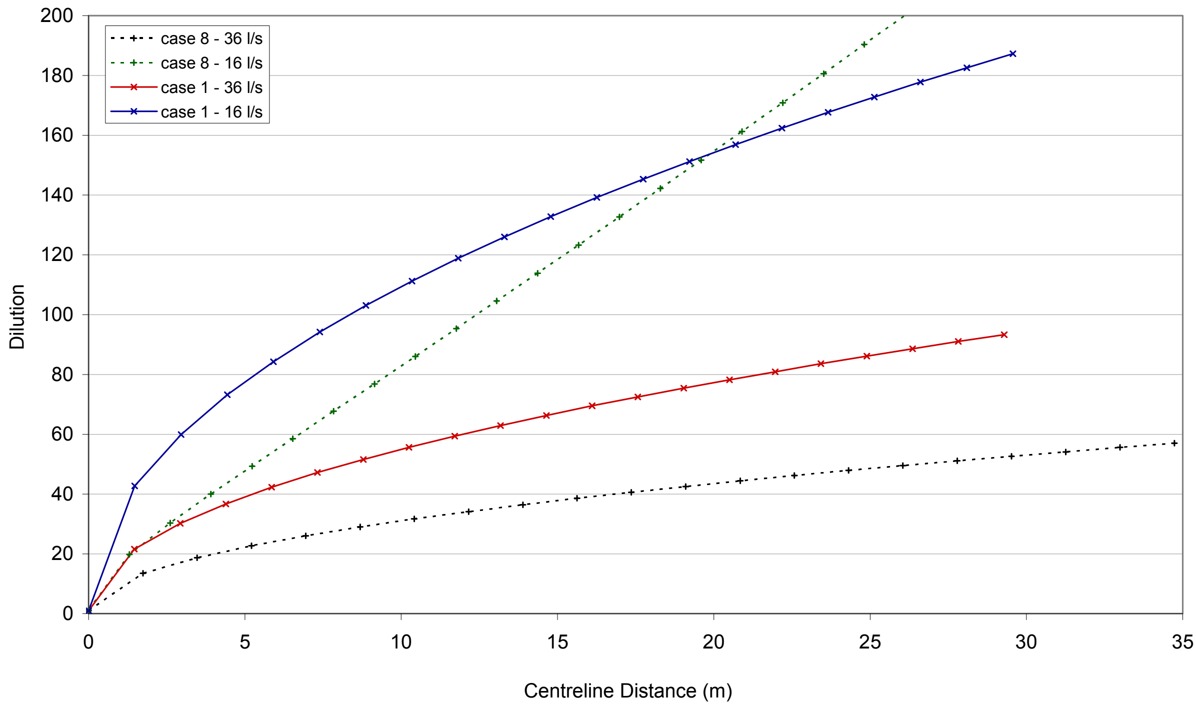


Figure 6.21 Near Field dilution with plume centreline distance from diffuser worse case scenarios

6.5.2 Far-field results

Following the initial dilution from the diffuser, the brine is advected and dispersed by the tidal currents. Far-field modelling was used to determine if accumulation of the brine occurs within the adjoining waterways.

The fate of the desalination brine discharge and the associated increase to the ambient salinity has been assessed for Australia Pacific LNG Option1b (refer Figure 6.1a) and Australia Pacific LNG Option2a (refer Figure 6.1b). For both options the desalination brine discharge location was at the end of the Australia Pacific LNG MOF. At the discharge location a conservative tracer (the desalination brine) was entered to the model domain at an average constant rate corresponding to 2400m^3/day. The average discharge was simulated for a six month period.

A statistical analysis of the desalination brine discharge over the simulation period provides an assessment of the potential impact area and an estimate of the increase to the ambient salinity within the Western Basin. Note that in all simulations the background salinity was assumed to be 36ppt and that increases less than 0.01ppt have not been plotted.

The mean absolute salinity within the study area for Option 1b and Option 2a is presented in Figure 6.22a and Figure 6.22b respectively. In terms of the predicted mean salinity, the overall spatial extent of the impact area is similar for both options. Salinity increases are predicted from beyond Hamilton Point, throughout the Western Basin, and into The Narrows. Laird Point and the entrance to Graham Creek are areas where brine concentration is predicted to accumulate. The predicted mean salinity increase in this area is approximately 0.05ppt.

Maximum salinity increases for both Options, presented in Figure 6.23a and Figure 6.23b respectively, were predicted as 0.08ppt close to Laird Point. Within The Narrows and Graham Creek, the maximum salinity increase predicted is 0.06ppt and 0.07ppt, respectively. Maximum increases in salinity of 0.11ppt occur for Option 1b on the east side of North Passage Island. Maximum salinity increases, for either Option, do not exceed 0.11ppt which is within ambient seawater variation. The potential impact from accumulation of salinity resulting from the Australia Pacific LNG discharge is negligible.

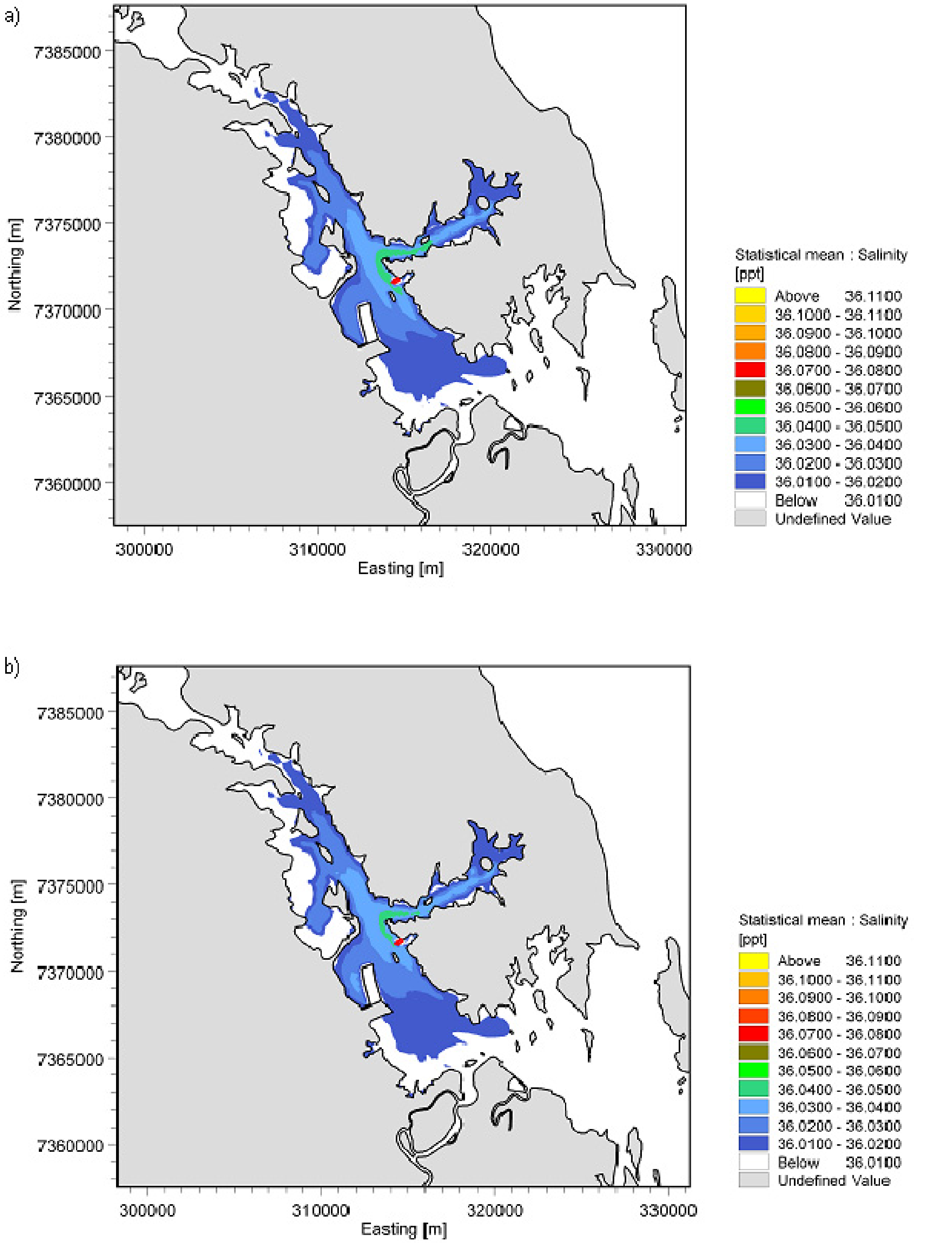
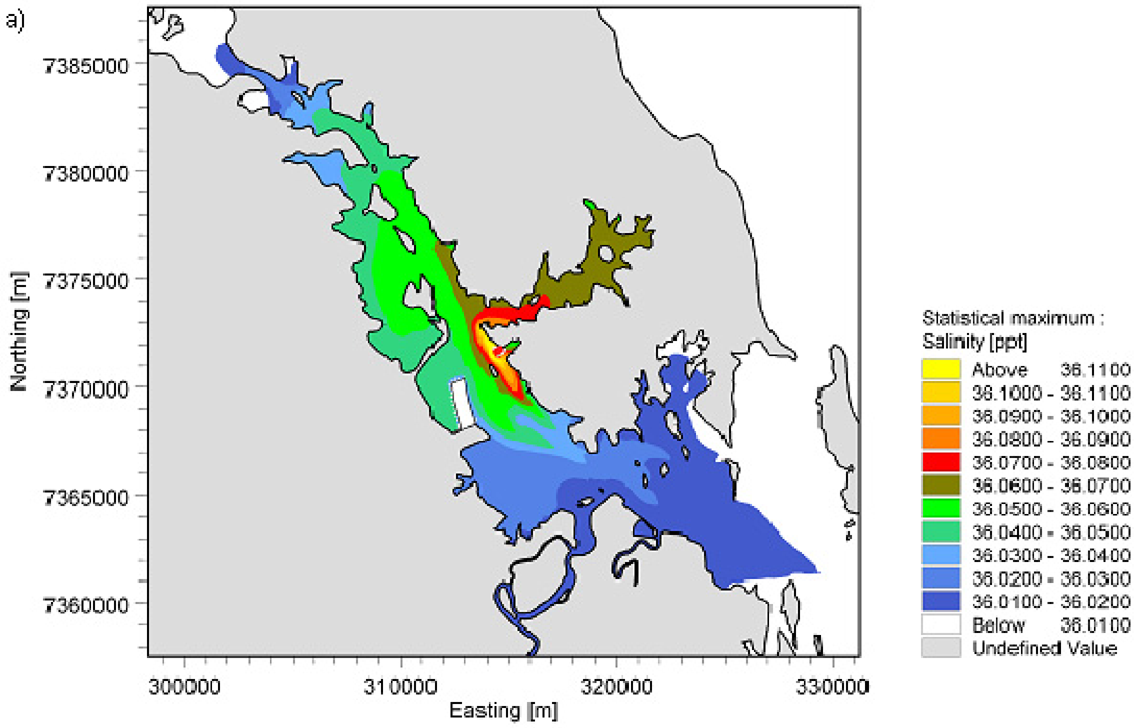


Figure 6.22 Statistical mean salinity due to Australia Pacific LNG desalination concentrate discharge: a) Option 1b, b) Option 2a



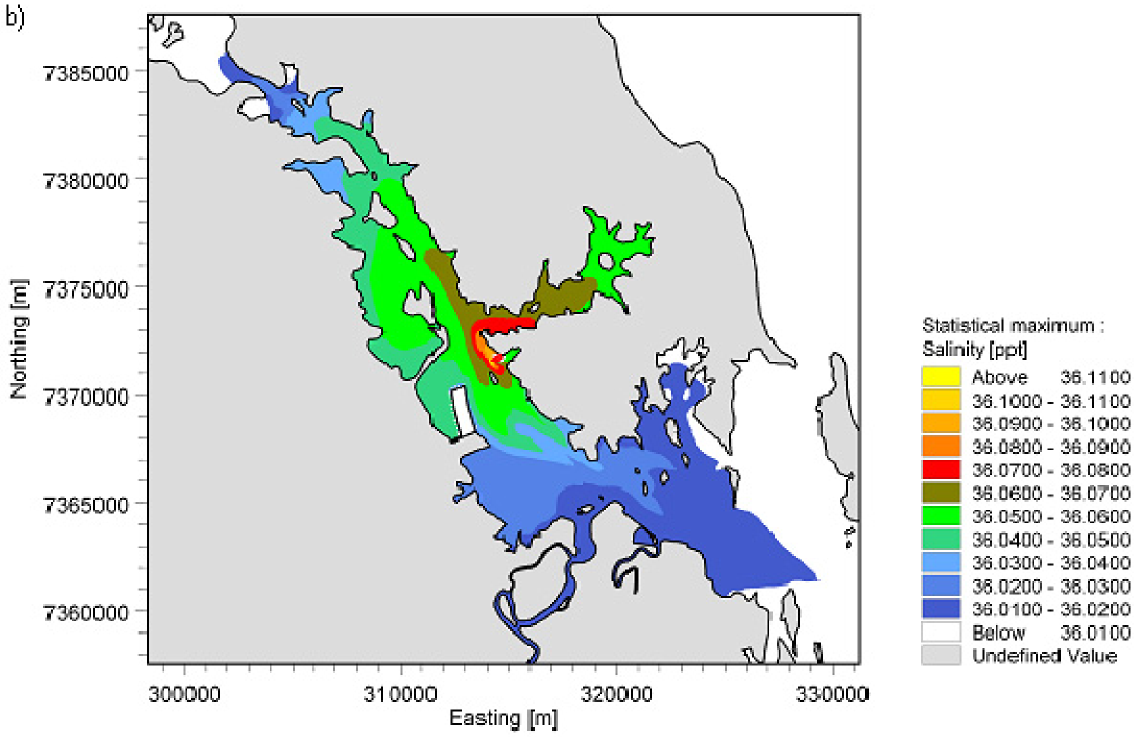


Figure 6.23 Statistical maximum salinity due to Australia Pacific LNG desalination concentrate discharge: a) option 1b, b) option 2a

6.6 Cumulative brine discharge impacts

Far-field cumulative water quality impacts associated with the combined Australia Pacific LNG Project, QCLNG Project, and GLNG Project desalination concentrate discharges have been assessed using the MIKE21-FM hydrodynamics model coupled with an advection-dispersion module. The fate of the combined desalination concentrate discharges and the associated increase to the ambient salinity has been assessed for Australia Pacific LNG Option 1b (refer Figure 6.1a) and Australia Pacific LNG Option 2a (refer Figure 6.1a). Desalination concentrate discharge locations for the three LNG proponents are presented in Figure 6.24.

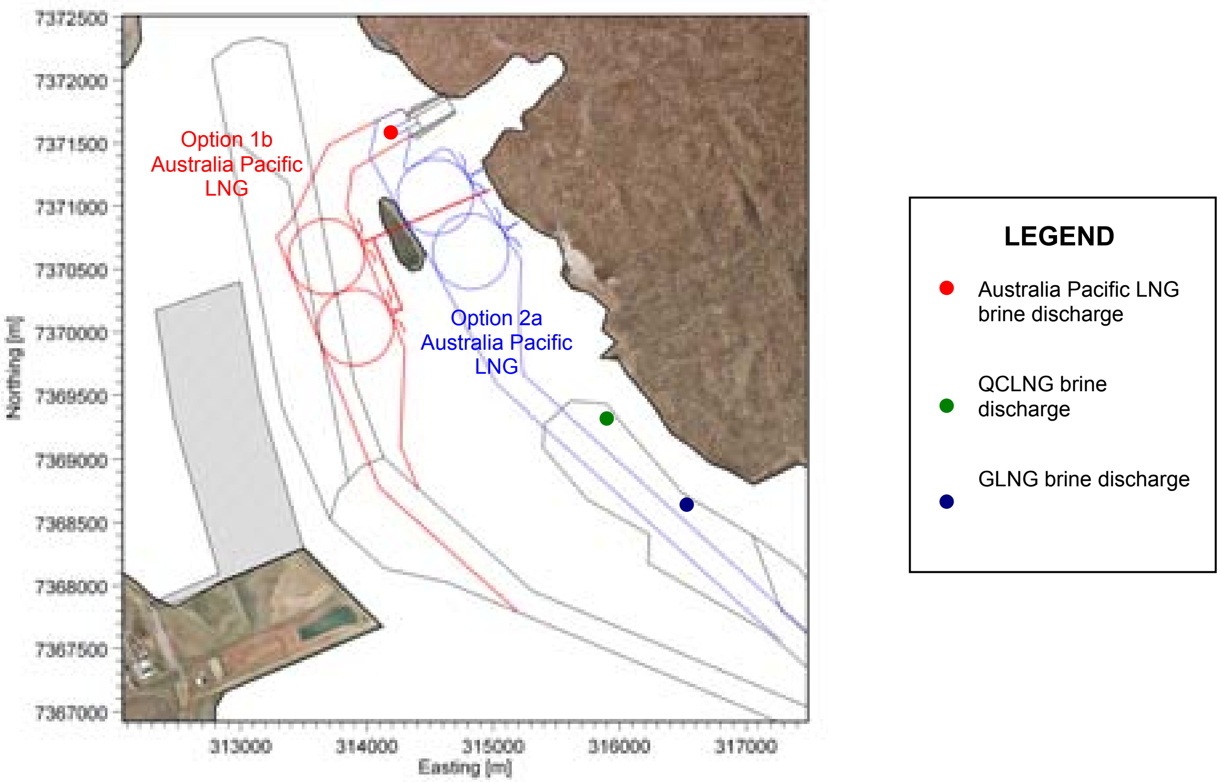


Figure 6.24 Desalination concentrate discharge locations for cumulative water quality impact assessment

At each discharge location a conservative tracer (the desalination concentrate) was entered to the model domain at a constant rate corresponding to approximately

- 2400m^3/day (27.8L/s) for Australia Pacific LNG
- 1440 m^3/day (16.7L/s) for QCLNG, and
- 1300 m^3/day (15.0L/s) for GLNG.

The location and discharge rate for GLNG and QCLNG were obtained from BMT WBM (2009a) and BMT WBM (2009b) respectively. The combined desalination concentrate discharges were simulated for a six month period.

A statistical analysis of the desalination concentrate discharge over the simulation period provides an assessment of the potential impact area and an estimate of the increase to the ambient salinity within the Western Basin. Note that in all simulations the background salinity was assumed to be 36ppt and that increases less than 0.01ppt have not been plotted.

The mean absolute salinity within the study area for the combined discharges with Australia Pacific LNG Option 1b and the combined discharges with Australia Pacific LNG Option 2a is presented in Figure 6.25a and Figure 6.25b respectively. In terms of the predicted mean salinity, the overall spatial extent of the impact area is similar for both options. Salinity increases are predicted from beyond Auckland Point, throughout the Western Basin, and into The Narrows. The most significant accumulation of desalination concentrate occurs at the entrance to Graham Creek and along the Curtis Island shoreline from Laird Point to China Bay. The predicted mean salinity increase in these areas for Option 1b is approximately 0.06ppt and for Option 2a is approximately 0.05ppt.

The maximum absolute salinity within the study area for the combined discharges with Australia Pacific LNG Option 1b and the combined discharges with Australia Pacific LNG Option 2a is presented in Figure 6.26a and Figure 6.26b respectively. For both options the maximum salinity close to Laird Point is predicted to exceed 36.11ppt. Within The Narrows and Graham Creek the maximum salinity ranges between 36.06ppt and 36.09ppt. Some variation between Option 1b and Option 2a is predicted downstream of the discharge location. This is caused by the differences in berth and approach channel layout and the subsequent minor changes to the hydrodynamics between the two options. The Option 2a berth and turning circles, located on the eastern side of North Passage Island, create a deeper area and decrease the current speeds downstream of the discharge location. This causes a slightly lower depth-averaged maximum salinity to be predicted along the Curtis Island shoreline for Option 2a.

The far-field model may under predict salinity concentration in the near-field areas close to the discharge locations. This is due to artificial dilution within the mesh element used to input the desalination concentrate to the model domain. The near-field assessment for the Australia Pacific LNG desalination brine discharge is provided in Section 6.5.1. Near-field assessments for GLNG and QCLNG may be found in BMT WBM (2009a) and BMT WBM (2009b).

Table 6.11 compares the predicted maximum and mean salinity at the four locations of interest. With the exception of the maximum salinity at North Passage Island East location, no significant difference between the predicted mean and maximum salinity at the locations of interest is predicted. Reasons for the reduced maximum predicted salinity on the eastern side of North Passage Island for Option 2a are discussed above.

The predicted mean and maximum increases to salinity due to the cumulative discharges of desalination concentrate are well within the natural salinity variation in Gladstone Harbour (Table 3.5) and are not expected to be detrimental to the marine environment. Salinity tolerances for a range of marine fauna are summarised in Australia Pacific LNG Project Marine Ecology Report.

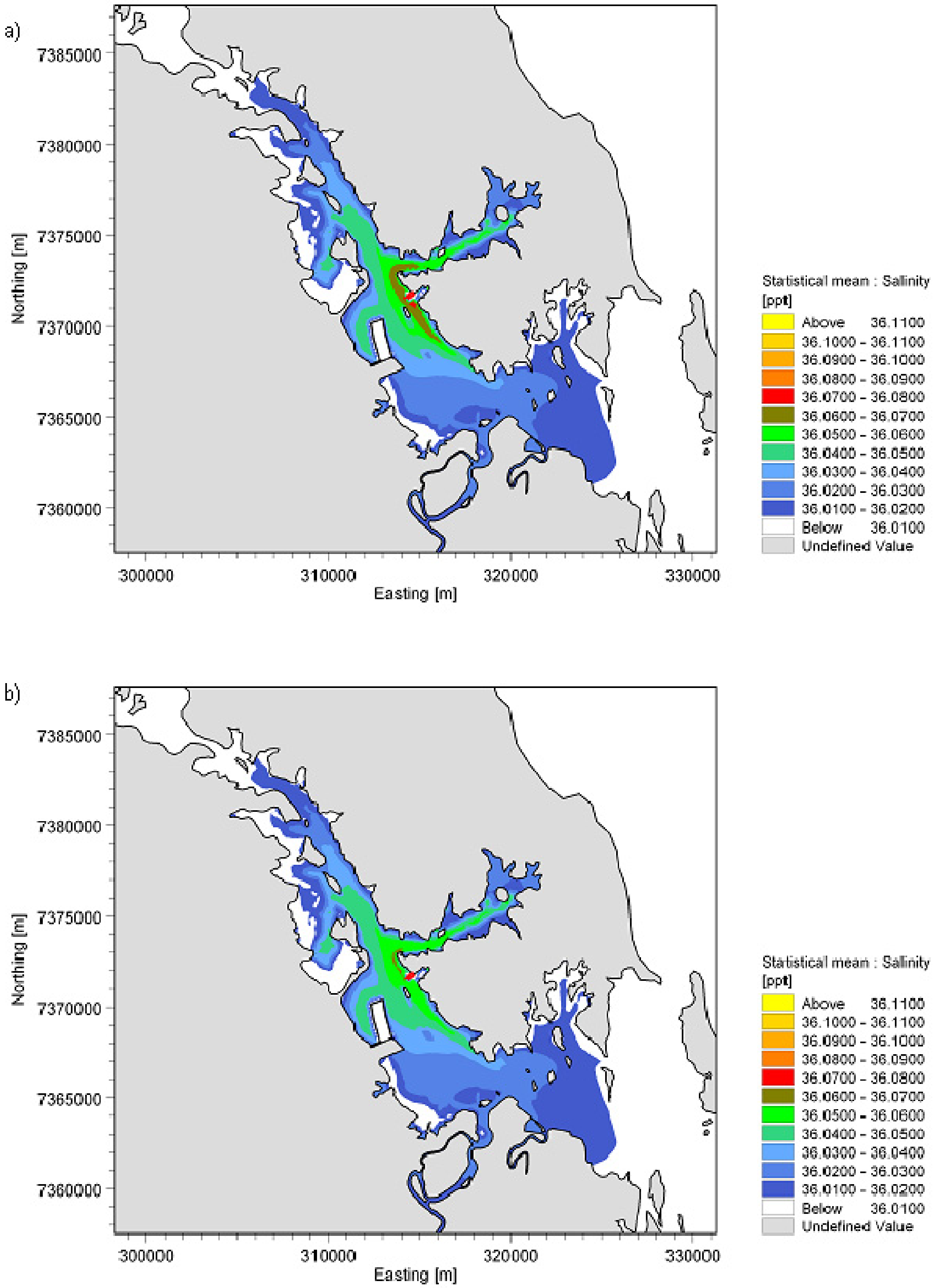


Figure 6.25 Statistical mean salinity due to Australia Pacific LNG, GLNG, and QCLNG cumulative desalination concentrate discharge: a) Option 1b, b) Option 2a

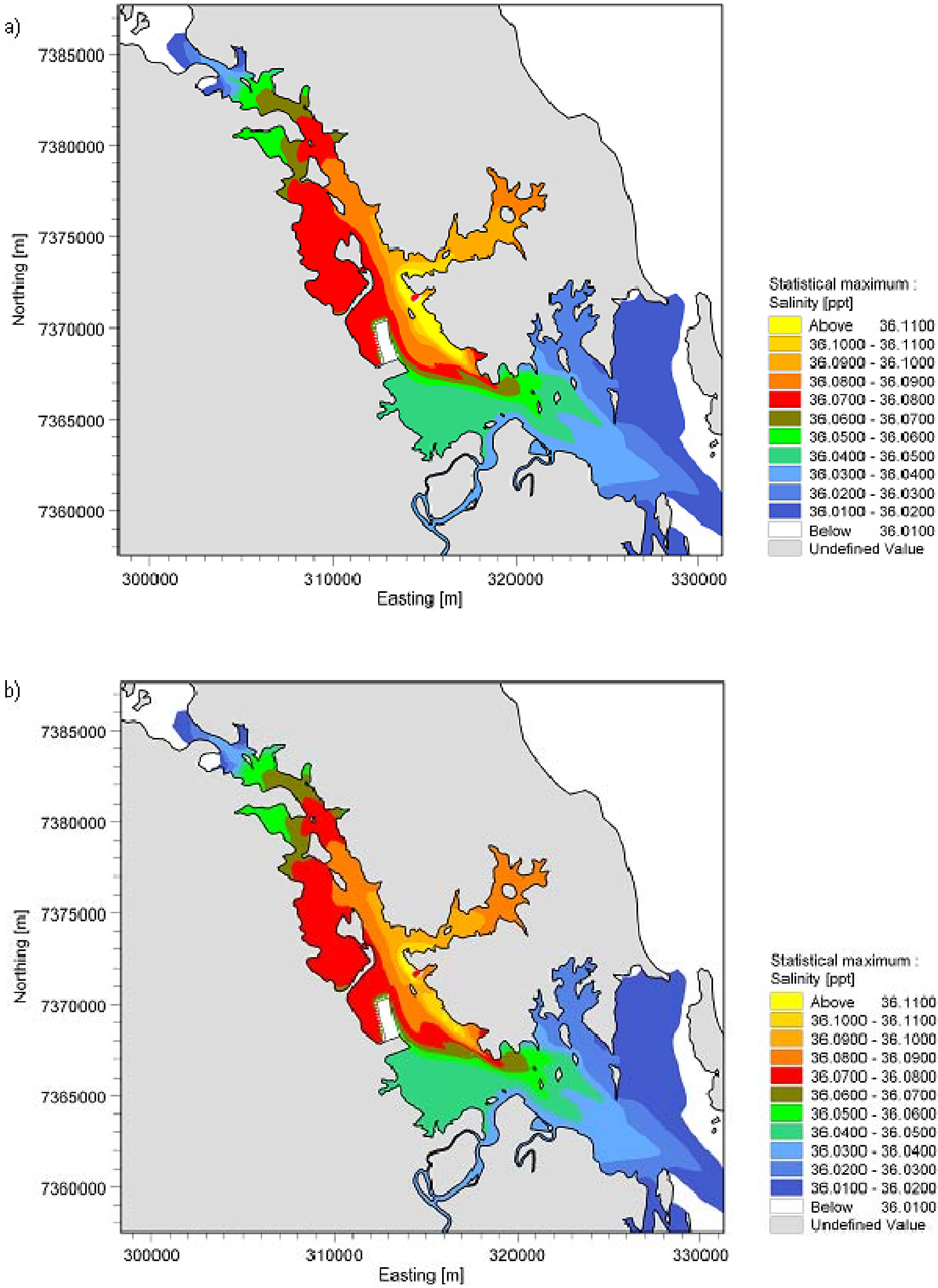


Figure 6.26 Statistical maximum salinity due to Australia Pacific LNG, GLNG, and QCLNG cumulative desalination concentrate discharge: a) option 1b, b) option 2a

Table 6.11 Maximum and mean salinity at locations of interest following six month desalination concentrate discharge.

Modelling scenario	Predicted salinity (ppt)							
	North Passage Island East		North Passage Island West		Graham Creek		The Narrows	
	max	mean	max	mean	max	mean	max	mean
Australia Pacific LNG Option 1b	36.14	36.07	36.09	36.05	36.10	36.06	36.09	36.04
Australia Pacific LNG Option 2a	36.10	36.06	36.09	36.05	36.10	36.06	36.09	36.04

6.7 Pipeline crossing

A main transmission pipeline is required to cross The Narrows to Curtis Island, terminating at the Australia Pacific LNG processing plant. HDD is the preferred method for crossing The Narrows. However, if the HDD is operationally unsuccessful, the crossing would be achieved using dredge equipment to create a trench for the pipeline to be "pulled" across to Curtis Island. Once the pipeline is in place, rock armour would be used to protect the pipeline and gradually the surrounding sediments would naturally fill the remaining voids within armour and trench.

6.7.1 Construction impacts

Potential impacts of the proposed construction of the pipeline crossing are predominantly associated with workspace requirements for both the workforce and equipment (on both banks of the waterway) creating a habitat disturbance, and dredge plumes if trenching is required.

For all construction techniques there will be a potential impact to the wetland on the western side of The Narrows resulting from:

- Excavation of the pipeline trench
- Clearing and levelling for the layout of pipe strings
- Construction of access ways to the site
- Ground and noise disturbance associated with heavy construction equipment.

The trench excavation width is expected to be 23m assuming one metre each of overcut and cover over the pipeline. A 12m wide temporary workspace is required for the pipeline string laid out from the waterway shoreline. Some vegetation would need to be removed near the shoreline and is described in more detail in Chapter 8: Terrestrial Ecology.

The Regional Coastal Management Plan (2003) indicates the wetland at Friend Point is a major shorebird roost and feeding site that will require careful management and consideration of the construction schedule to mitigate the disturbance of roost sites. After construction is completed, the wetlands would be reinstated as close to its pre-construction condition, as practicable. Potential impacts and suitable mitigation measures are outlined in Chapter 10 Marine Ecology.

HDD Construction

Construction using the HDD technique has a potential impact associated with levelling and clearing areas for drilling rigs, equipment, and drilling mud containment either side of the waterway. Potential issues with the HDD construction process are summarised in Table 6.12.

Table 6.12 HDD Construction Issues

Potential Risk	Possible cause(s)	Possible consequences
Drilling mud seepage into watercourses, either directly or indirectly (via land), potentially increasing the sediment load, deposition and contamination.	Loss of containment of drilling fluid or mud.	Adverse effects on fish, fish habitat, hydrology and downstream water users. Impacts would be variable depending on volume and connectivity to surface or water body.
Drilling mud seepage onto land potentially causing land contamination	Loss of containment of drilling mud.	Adverse effects on wildlife, vegetation, soils, heritage resources and current land use.
Erosion of areas disturbed in creating temporary work sites at either end of the HDD.	Inadequate scour protection placed during rehabilitation in areas subjected tidal and wave motion.	Localised erosion of shoreline and 'washout' of vegetation. Unexpected widening of the area of disturbance. Extended duration of disturbance
Increase in disturbance footprint due to redrill or required works to retrieve equipment, undertake repairs, and so forth.	Mechanical failure (that is stuck drill stem, damaged pipe or coating, and so forth).	Increase in the area of disturbance (footprint). Disturbance to threatened communities, habitat or coastal processes. Extended duration of disturbance

Trench construction

If the HDD is deemed not feasible, or cannot be completed, the crossing would be constructed using another method which would require the dredging of a trench where the pipeline would be laid. While the trench is open there will be some alteration to the natural movement of sediment in the area. Once the pipeline is in place, rock armour would be used to protect the pipeline. Gradually the surrounding sediments would naturally fill the remaining voids within the armour and trench. Following the pipeline installation and the infilling of the trench, sediment movements are expected to return to the pre-disturbed state.

Potential issues with the trench construction process are summarised in

Table 6.13.

Table 6.13 Potential trench construction issues

Potential Risk	Possible cause(s)	Possible consequences
Habitat disturbance and fragmentation	Dredging and pipeline construction activities.	Loss of habitat through the removal of sediments and increased mortality of benthic organisms. Potential for flow on impacts to pelagic species. Habitat fragmentation.
Mobilisation of nutrients and contaminants.	Dredging and pipeline construction activities.	Changes to water quality and impacts to marine flora and fauna,

Potential Risk	Possible cause(s)	Possible consequences
		including MNES species. Potential to change species composition.
Decreased water quality	Dredging and pipeline construction activities.	Changes to constituent concentration in the water due to the absorption or release of contaminants (i.e. heavy metals).
Increase to total suspended solids (TSS) and elevated turbidity.	Dredging and pipeline construction activities.	Suspended sediment may limit primary production due to a reduction of light in the water column. Potential impacts to flora and fauna (i.e. feeding behaviour)
Increased sediment deposition	Dredging and pipeline construction activities.	Smothering of benthic assemblages as suspended sediment settles.

Turbidity Plume Modelling

In the event a trench is required for the pipeline in order to cross The Narrows, turbidity plumes associated with the dredging of a pipeline trench have been assessed using the MIKE21-FM hydrodynamics model coupled with a mud-transport module. A total volume of 106,000m^3 of material is estimated to be removed using a backhoe dredger. . A 10% spillage of dredge material to the waterway was assumed during the backhoe operation. Trenching is assumed to start at Friend Point, move across The Narrows, and finish at Laird Point. It was assumed multiple small barges, each with a capacity of approximately 400m^3, would be used to dispose the dredge spoil to a nearby land reclamation area.

Figure 6.27 shows the proposed pipeline crossing route with the inset providing detail of model mesh and pipeline trench plume source points used to input spill material to the model domain. The pipeline crossing is expected to be completed prior to other proposed Western Basin marine developments. The sensitivity of the pipeline trench plume behaviour to the various stages of Western Basin development was also examined and is reported below.

The inset in Figure 6.27 shows detail of the model mesh in the vicinity of the proposed pipeline crossing and the ten source point locations used to input dredge material spill to the model domain. Multiple source points allow the spill location to vary throughout the simulation, thus representing a dredger slowly moving across The Narrows (starting at Friend Point and finishing at Laird Point) during the pipeline trenching program. Pipeline trenching is anticipated to take 60 days with a required volume per 24hr day of 1770m^3. This dredge rate requires six days of dredging to be simulated at each of the ten dredge locations. Dredge spill from the backhoe bucket was simulated as a constant source input of material during each barge fill period. Each barge was filled with approximately 400m^3 of material. Once full, the barge steams to the reclaim area and a new empty barge assumes position. The barge change over occurs over a 15-minute period, during which time no dredge spill occurs. The pipeline trench plume model parameters are summarised in

Table 6.14.

Table 6.14 Pipeline crossing trenching model parameters

Pipeline crossing trenching model parameters

Pipeline crossing trenching model parameters	
Total trench volume	106,000m3
Duration of trenching program	60 days
Required volume per day (24hr)	1770m3
Number of model trenching locations (source points)	10
Time at each model trenching location (source point)	6 days
Trenching rate	31.5kg/s
Trenching material spill rate (10% of trench rate)	3.2kg/s
Barge fill time (400m3 capacity)	5hrs
Barge change over time	15min

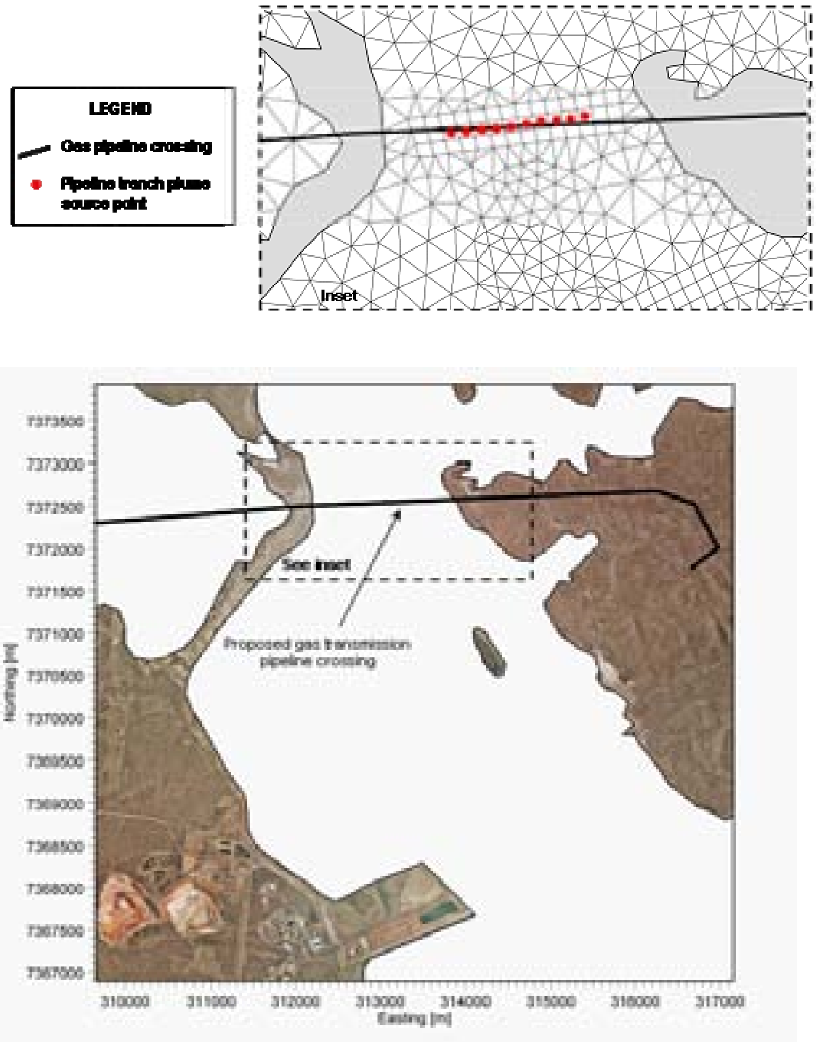


Figure 6.27 Proposed gas pipeline crossing route across The Narrows. Inset shows detail of the model mesh and the pipeline trench plume source points.

The fate of the trench plume will depend on the duration it remains in suspension and how it is dispersed by the currents. Knowledge of the material type and corresponding settling velocity is essential for modelling sediment plumes. URS (2009), on behalf of Santos, performed sediment sampling and particle size distribution analysis in the vicinity of the proposed pipeline crossing. The mean fraction percentage for the upper 5m of material from the URS (2009) soil bores (BH19, BH20, BH21, BH25B) is presented in Table 6.15. The mean fraction percentages were used for pipeline trench plume modelling. It should be noted that the small percentage of gravel sampled by URS (2009) has not been included in the pipeline trench plume modelling scenario.

Table 6.15 Mean percentage material fractions from soil bores in the vicinity of the pipeline crossing (URS 2009) and settling velocities used for trench plume modelling.

Fraction	Material	Grain size (mm)	Percentage (%)	Settling velocity (m/s)
1	Sand	2 - 0.06	20	0.02 – 0.001
2	Silt	0.06 - 0.002	29	0.001 – 0.0001
3	Clay	<0.002	42	0.0001 – 0.00001

*Note: the mean percentage of gravel (approximately 9%) was not included in trench plume modelling

Sediment suspended during pipeline trenching, generating a turbidity plume, will slowly settle to the bed once the bed shear stresses and fluid turbulence are insufficient to keep the sediment moving. How long the sediment remains in suspension is influenced by the material grain size and settling velocity. The finer material with a low settling velocity may remain in suspension for long periods due to the relatively strong tidal currents within the study area. Sensitivity of the pipeline trench plume to the upper and lower limits of the material settling velocity was investigated. The upper and lower limit MOF dredge plume modelling scenarios are defined in Table 6.16.

Table 6.16 The upper and lower limit pipeline trench plume modelling scenarios,

Fraction	Material	Grain size (mm)	Percentage (%)	Settling Velocity (m/s)
Upper limit scenario				
1	Sand	2 - 0.06	20	0.02
2	Silt	0.06 - 0.002	29	0.001
3	Clay	<0.002	42	0.0001
Lower limit scenario				
1	Sand	2 - 0.06	20	0.001
2	Silt	0.06 - 0.002	29	0.0001
3	Clay	<0.002	42	0.00001

In terms of the potential pipeline trench plume impact the lower limit sediment scenario defined in Table 6.5 is considered the more conservative modelling approach. Comparing the predicted turbidity plumes associated with the upper (best case) and lower (worst case) sediment scenarios a range of potential plume impact is defined.

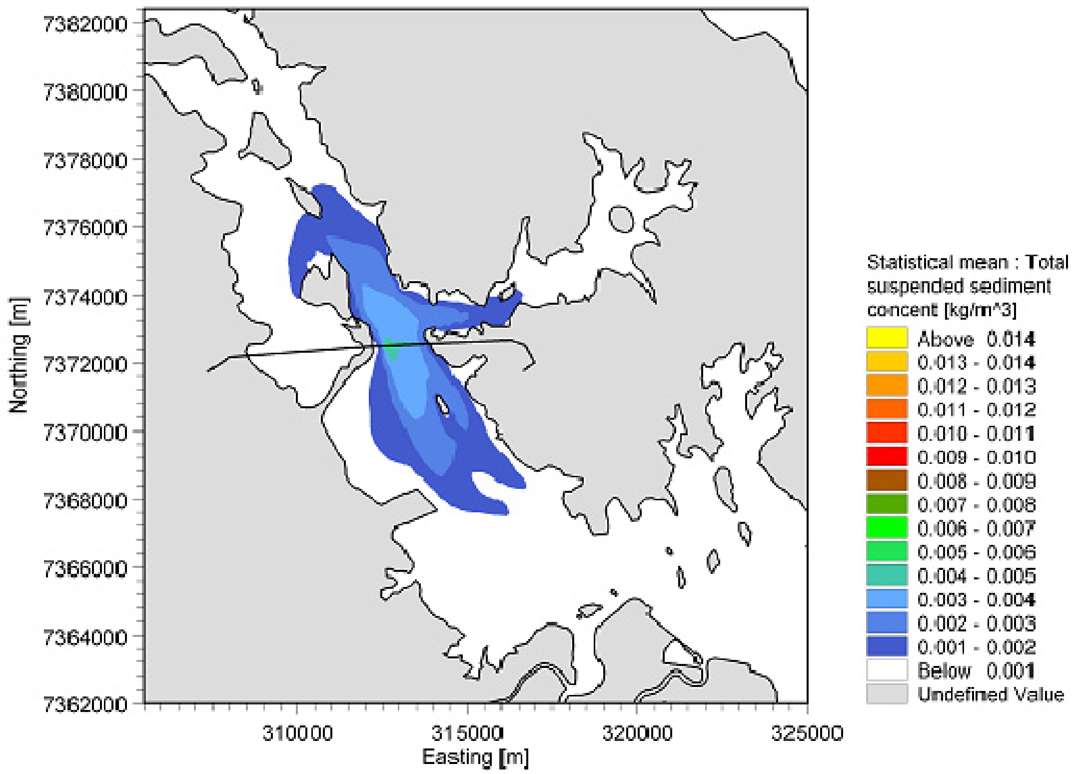
The TSS concentrations due to trenching reported in this section are in addition to the natural TSS concentrations (that is, above the background TSS level) within the Western Basin. A statistical analysis of the total suspended sediment (TSS) concentration for the simulated 60-day trenching program provides an assessment of the potential impact area. The statistical summary is based on the assumption of trenching material spillage of 10%. The predicted concentrations close to the trench plume source points (that is, in the near field) are not accurately predicted by the model. The input source is entered into a mesh element and the mass of the component (i.e. the dredge material spillage) is initially distributed over the element area and depth. This causes the near field concentration seen in the results to be lower than the input value.

Figure 6.28 presents a spatial summary of the mean TSS concentration predicted to occur during the 60-day trenching program. Pipeline trenching is predicted to raise the TSS concentration within Gladstone Harbour and The Narrows, including Graham Creek.

Figure 6.28a shows the increase to the mean ambient TSS concentration for the sediment upper limit (best case) scenario. Elevation of the mean TSS concentration by more than 0.003kg/m^3 (3mg/L) is confined to approximately 2km from the trenching location. Beyond this distance an increase between 0.001kg/m^3 and 0.003kg/m^3 (1mg/L and 3mg/L) to the mean ambient TSS is predicted. The predicted increases to the mean TSS concentration for the upper limit scenario are typically less than 0.005kg/m^3 (5mg/L), which is within the natural variation for Gladstone Harbour (BMT WBM 2009c).

Figure 6.28b shows the increase to the mean ambient TSS concentration for the sediment lower limit (worst case) scenario. The lower limit sediment characteristics significantly increase the pipeline trench plume spatial impact. Within Graham Creek and surrounding North Passage Island the mean TSS is predicted to elevate by approximately 0.01kg/m^3 (10mg/L) during the trenching program. North of the Graham Creek entrance, the predicted increase to the mean TSS within The Narrows is between 0.002kg/m^3 and 0.01kg/m^3 (2mg/L and 10mg/L). The plume is predicted to disperse beyond Fisherman’s Landing to Auckland Point, noting that the predicted increase to the mean TSS concentration in this area is relatively low and less than 0.005kg/m^3 (5mg/L).

a)



b)

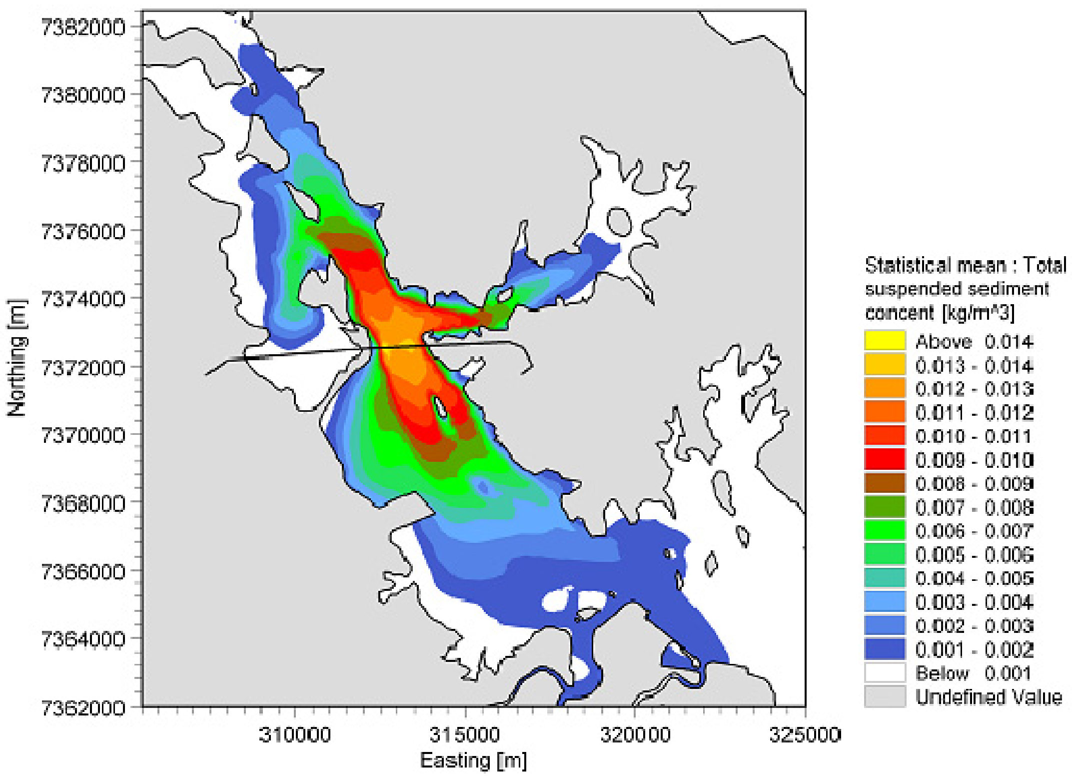


Figure 6.28 Statistical mean TSS concentration increase during the 60 day main transmission pipeline trenching program: a) upper limit sediment settling velocities; b) lower limit sediment settling velocities

Figure 6.29 is a spatial summary of the maximum TSS predicted to occur during the simulated 60 day trenching program. Note that at any given location the predicted maximum TSS is likely to be present for only a short period.

Figure 6.29a shows the maximum TSS concentration for the sediment upper limit (best case) scenario. Over a 6-7km distance to the north and south of the trenching location TSS concentrations above 0.005kg/m^3 (5mg/L) are predicted to occur. Close to the trenching area a TSS concentration above 0.045kg/m^3 (45mg/L) is predicted. The highest concentrations close to the working area will be present during neap tides. During neap periods the smaller tidal magnitude and current velocities only disperse the material a short distance, leading to an accumulation of suspended sediment close to the working area. Elevated concentrations up to 0.015kg/m^3 (15mg/L) are predicted to occur at the entrance to Graham Creek. Beyond the Graham Creek entrance the predicted maximum increase to TSS concentration is less than 0.01kg/m^3 (10mg/L).

Figure 6.29b shows the maximum TSS concentration for the sediment lower limit (worst case) scenario. For this scenario, peak TSS concentrations up to 0.02kg/m^3 (20mg/L) are predicted to disperse significant distances into Graham Creek and The Narrows. Elevated concentrations up to 0.045kg/m^3 (45mg/L) are predicted to occur along the trenching route and disperse into the entrance to Graham Creek. Maximum TSS concentrations of 0.005kg/m^3 (5mg/L) are predicted to reach Auckland Point and Ramsay Crossing (northern extent of The Narrows) during spring tide conditions.

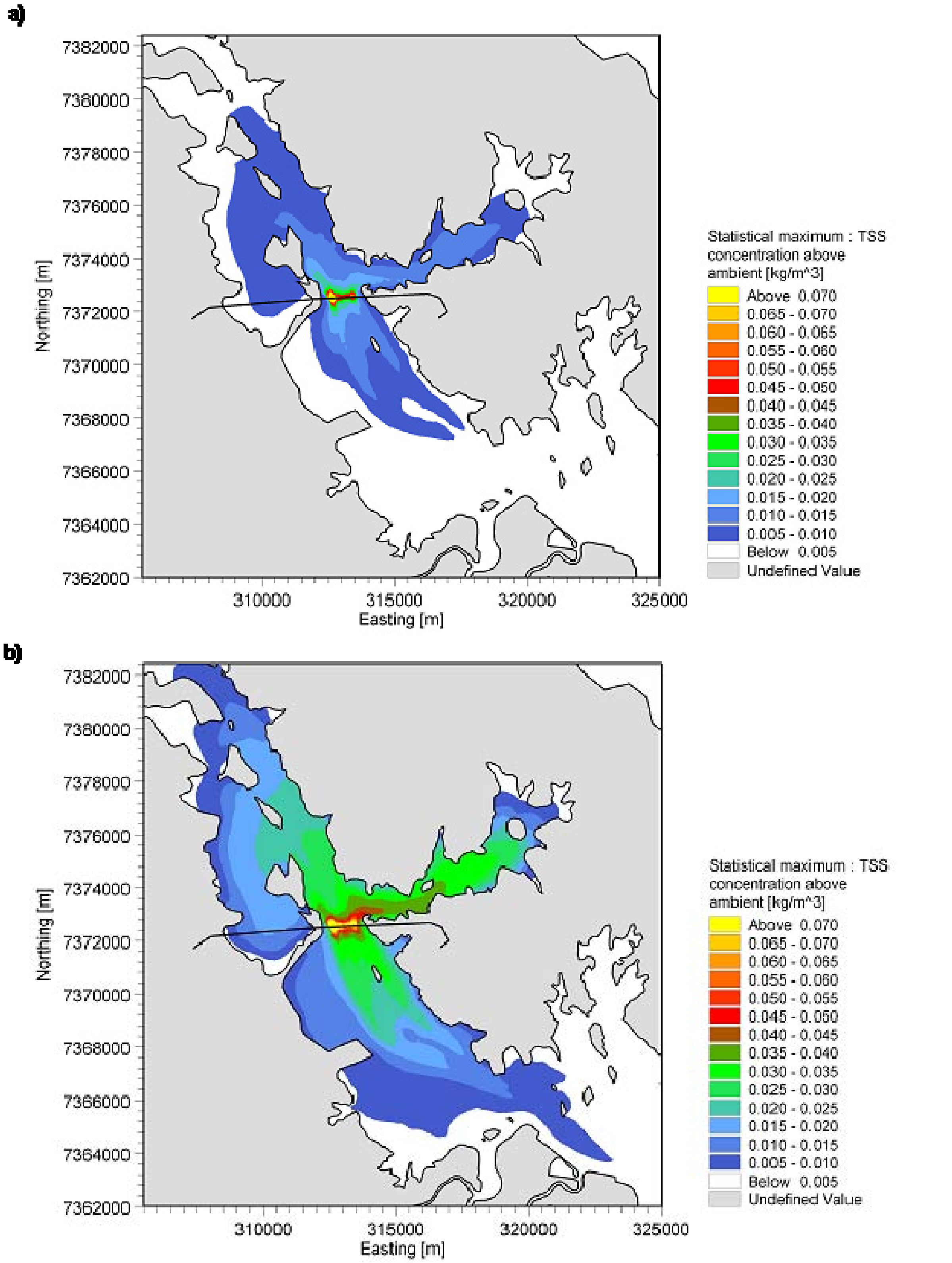


Figure 6.29 Statistical maximum TSS concentration increase during the 60 day main transmission pipeline trenching program: a) upper limit sediment settling velocities; b) lower limit sediment settling velocities

Figure 6.30 shows the predicted above background TSS concentration time series at the locations of interest within Graham Creek and The Narrows (refer) and the corresponding Gladstone (South Trees) tidal signal for the duration of the trench plume simulation. The modelling assumes trenching to commence at Friend Point and finish at Laird Point. Note that the simulation continued beyond the 60 day trenching period to enable a prediction of the time taken for the TSS concentrations to return to background levels following the completion of the trenching program to be predicted.

Figure 6.30 identifies that higher TSS concentrations at Graham Creek and The Narrows will occur during larger tidal magnitudes. During these periods the tidal excursion is sufficient to carry higher TSS concentrations to the far-field locations of interest. During the shorter, neap tide periods relatively low TSS concentrations are present at both far-field locations. Following the completion of the 60 day pipeline trenching program, the TSS concentrations predicted for the sediment upper limit scenario return to background levels within 10 days. For the sediment lower limit scenario, elevated TSS concentrations remain for approximately one month following completion of the pipeline trenching program.

Table 6.17 compares the predicted maximum and mean increase to TSS concentration during the trenching program at four locations of interest. At each given location the predicted maximum and mean TSS concentration for the upper (best case) and lower (worst case) sediment settling velocity scenarios is presented. During the pipeline trenching program, the TSS concentrations at each location are expected to be within the upper and lower limit scenario prediction.

Table 6.17 Predicted maximum and mean TSS concentration above background for the upper and lower limit settling velocity scenarios at the four locations of interest

Modelling scenario	TSS concentration above background (kg/m3)							
	North Passage Island East		North Passage Island West		Graham Creek		The Narrows	
	max	mean	max	mean	max	mean	max	mean
Upper limit sediment settling velocity scenario (best case)	0.011	0.002	0.010	0.002	0.013	0.001	0.008	0.001
Lower limit sediment settling velocity scenario (worst case)	0.029	0.009	0.027	0.009	0.036	0.007	0.025	0.006

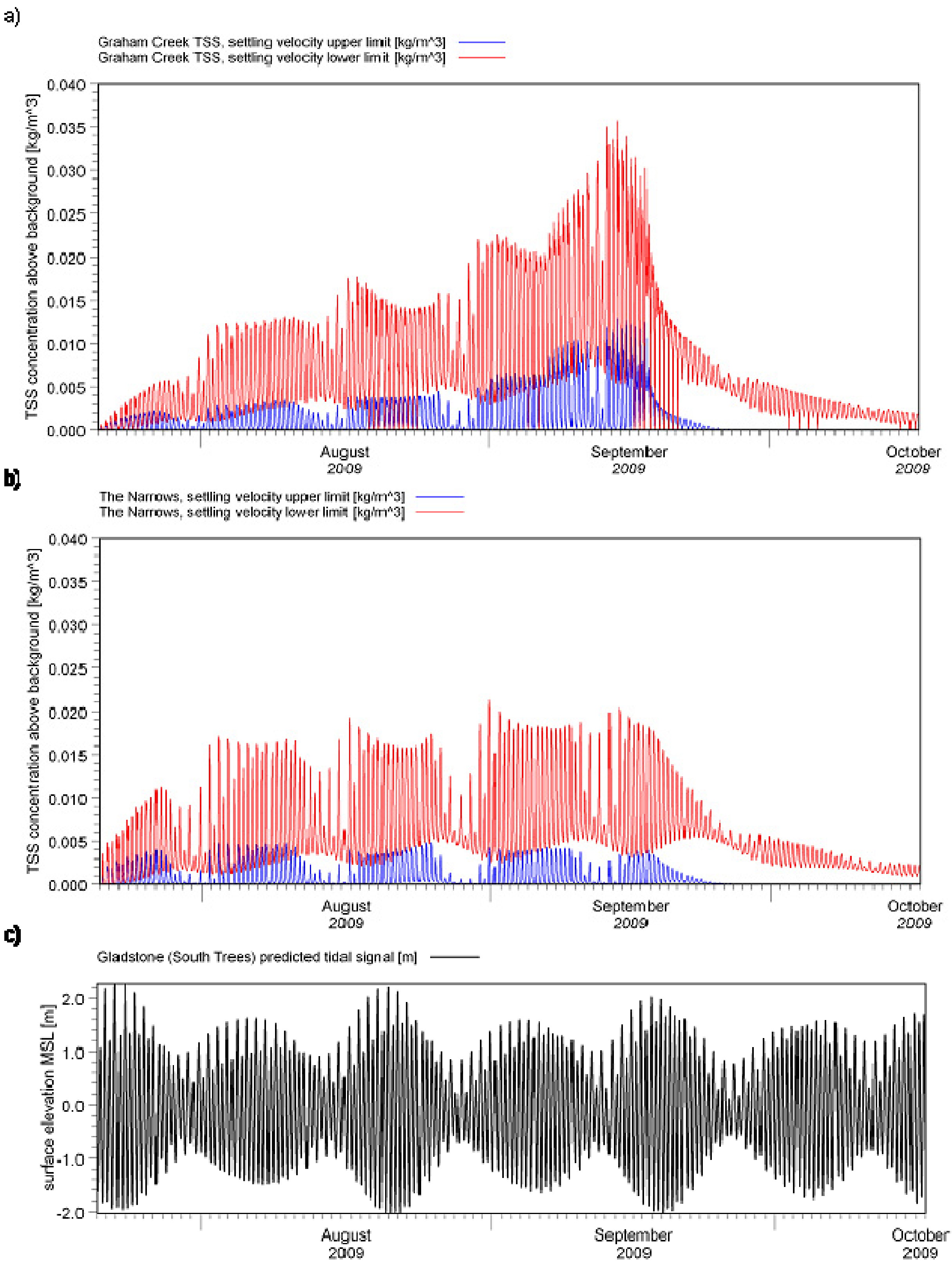


Figure 6.30 TSS concentration above background during pipeline trenching for the upper and lower limit sediment settling velocities: a) Graham Creek; b) The Narrows; c) corresponding tide signal at Gladstone (South Trees)

Various marine developments are proposed for the Western Basin. The timing of the gas pipeline crossing relative to other Western Basin developments is uncertain at this stage and consequently the sensitivity of the pipeline trench plume to different stages of Western Basin development was investigated. Changes to the model bathymetry were performed to represent three different stages of Western Basin development and the pipeline trenching simulation was performed for each stage of development.

Table 6.18 compares the predicted maximum and mean TSS concentration for the three Western Basin development stages at four locations of interest. The predicted maximum and mean TSS concentrations due to pipeline trenching at the locations of interest are relatively insensitive to the different stages of Western Basin development.

Table 6.18 Maximum and mean TSS above ambient at receptor locations during the 60 day main transmission pipeline trenching program sensitivity to Western Basin development stages

Western Basin development stage	Receptor location TSS above ambient (kg/m3)							
	North Passage Island East		North Passage Island West		Graham Creek		The Narrows	
	max	mean	max	mean	max	mean	max	mean
Existing bathymetry	0.0107	0.0018	0.0099	0.0022	0.0128	0.0012	0.0077	0.0011
GPC dredging stages 1A, 1B, 2, and 3 completed.	0.0091	0.0014	0.0078	0.0019	0.0129	0.0011	0.0070	0.0010
GPC dredging stages 1A, 1B, 2, 3, and Fisherman's Landing northern expansion completed.	0.0093	0.0012	0.0092	0.0017	0.0128	0.0010	0.0068	0.0009

6.8 Siltation and maintenance of dredge areas

An indicative estimate of the annual siltation of the Australia Pacific LNG dredged areas and the average annual dredge maintenance requirements were modelled within the Gladstone Ports Corporation Western Basin EIS. Potential predicted impacts (BMT WBM 2009) relevant to the Australia Pacific LNG marine options are summarised in this Section.

The Gladstone Ports Corporation Western Basin EIS (Additional Numerical Modelling, Section 3.3) assesses the in-filling of the swing basin and approaches by segregating sand size particles and silts. It is predicted that the net sand transport potential in the Option 1b dredged area decreases due to the reduction in velocities. Annual sand transport into Option 1b swing basin and approaches ranges between 5,500 to 22,000m^3/year, and has a net siltation of 48,000m^3/year. Silt deposition rate for Option 1b is shown in Figure 6.31.

For Option 2a the predicted coarse material sedimentation is between 12,000m^3/year and 48,000m^3/year that includes sand from small zones of increased sand transport potential on the shoals between the Materials Offloading Facility approach channel and the Laird Point swing basin upstream

of North Passage Island due to the increased velocities in this area. The net silt deposition for Option 2a is 81,000m3/year and is shown in Figure 6.32.

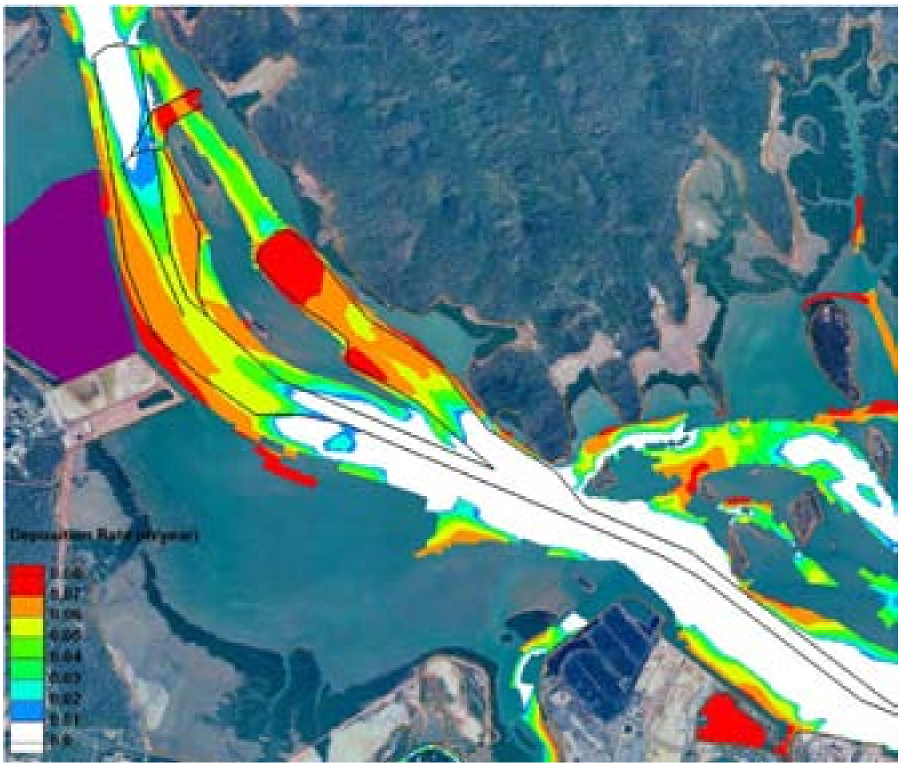


Figure 6.31 Option 1b Silt deposition rates (BMT WBM 2009)

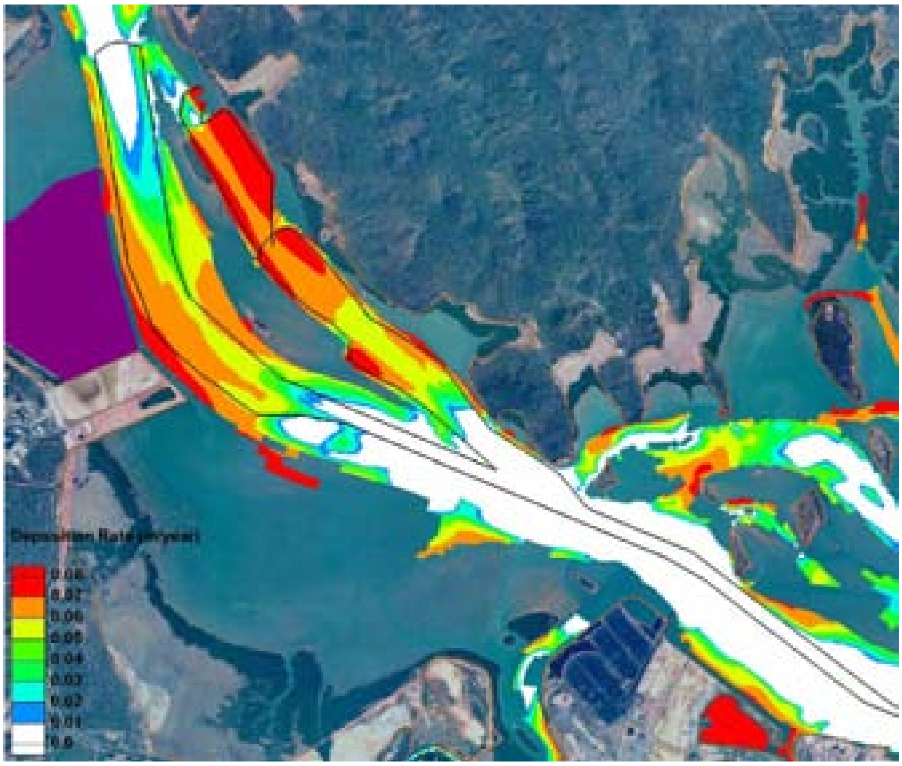


Figure 6.32 Option 2a silt deposition rates (BMT WBM 2009)

Maintenance quantities are a function of the sediment rates and the extent of the dredged area. Sedimentation rates of up to 0.08m/year occur for Option 2a and within the approaches to the Materials Offloading Facility for Option 1b. For siltation alone, a 0.3m over-dredging allowance should accommodate over three years of sedimentation between maintenance dredging campaigns. Additional allowance would need to be made for the coarse sized sediments.

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