Australia Pacific LNG Project

Volume 3: Gas Pipeline

Chapter 12: Coastal Environment

Contents

Figures

Tables

12. Coastal environment

12.1 Introduction

12.1.1 Purpose

The transmission of coal seam gas (CSG) from the Walloons gas fields to the proposed LNG facility on Curtis Island requires the development, construction, and operation of a proposed main gas transmission pipeline (gas pipeline). The gas pipeline is a 42inch (1.1m) diameter steel pipe and is approximately 450km in length. It includes the underwater crossing of The Narrows.

This chapter provides a description of the coastal environment in the vicinity of the proposed pipeline crossing of The Narrows. It is proposed that the potential impacts to the coastal environment associated with the construction of the pipeline crossing would be minimised through the use of horizontal directional drilling (HDD) below the waterway.

In the event that HDD is determined not to be feasible, based on final engineering investigations or construction constraints, Australia Pacific LNG would instead use dredging equipment to excavate a trench across the seabed of the Narrows into which the pipeline would be installed. A similar dredged trenching methodology would be used to cross The Narrows if a joint approach involving other LNG proponents is implemented. Potential impacts of HDD and alternative pipeline crossing options have been identified, along with a series of mitigation measures, focusing predominantly on the construction phase of development.

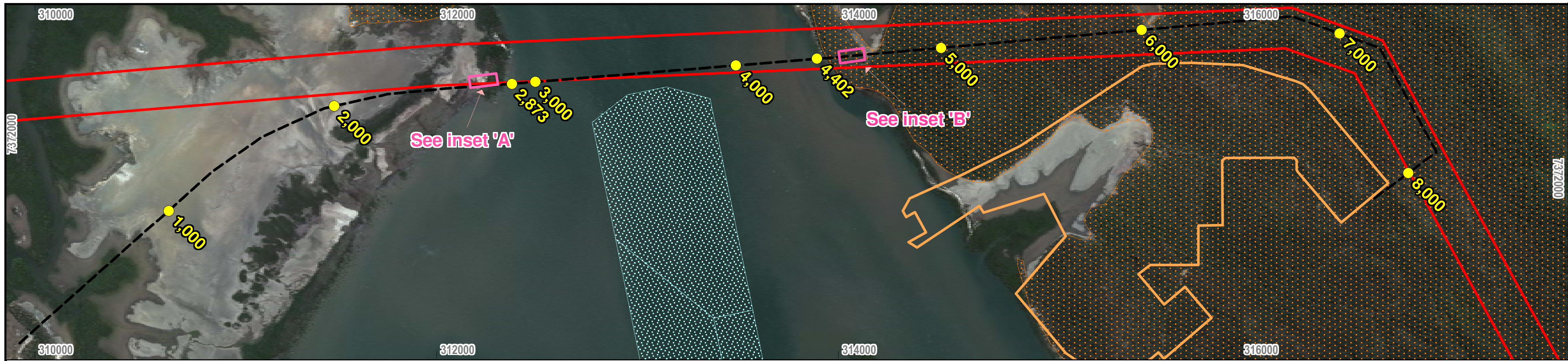
The preferred gas pipeline route across The Narrows, together with an overall plan view and profile of the approaches and crossing, is presented in Figure 12.1. The Queensland Government's proposed common infrastructure corridor, proposed Gladstone Ports Corporation (GPC) dredge area, and proposed LNG facility footprint are also shown on this figure.

Australia Pacific LNG has followed the 12 sustainability principles established for the Australia Pacific LNG Project (the Project) when identifying impacts to the marine and coastal environment and in the development and implementation of control measures and management plans. Australia Pacific LNG's key sustainability principles in relation to the gas pipeline's crossing of The Narrows are:

- Minimising adverse environmental impacts and enhancing environmental benefits associated with Australia Pacific LNG's activities, products or services; conserving, protecting, and enhancing where the opportunity exists, the biodiversity values and water resources in its operational areas
- Identifying, assessing, managing, monitoring and reviewing risks to Australia Pacific LNG's workforce, its property, the environment and the communities affected by its activities
- Working cooperatively with communities, governments and other stakeholders to achieve positive social and environmental outcomes, seeking partnership approaches where appropriate

The final sustainability principle listed is particularly relevant in relation to the proposed methodology to be adopted for the crossing of The Narrows.

The coastal environment technical assessment which forms the basis of this chapter is presented in Volume 5 Attachment 27.



LEGEND

- Chainage point
- Cross section location
- Gladstone State Development Area Corridor
- Gladstone State Development Area
- LNG facility boundary
- Dredge outline

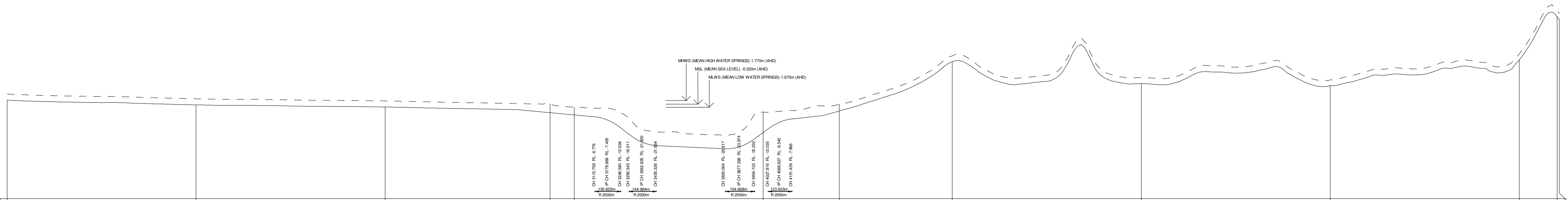
Source Information

Dredge Outlines
Provided by Origin Energy 27/10/2009

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

Gladstone State Development Area Corridor (GSDAC)
Gladstone State Development Area (GSDA)
Department of Infrastructure and Planning, Queensland 2009

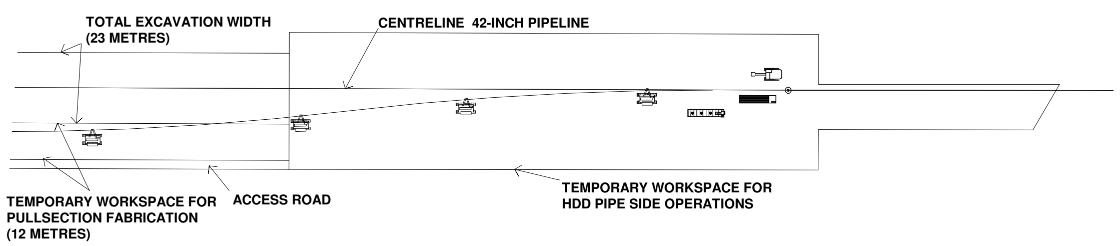
Satellite Imagery
Captured by GeoEye-1 on 24 March 2009



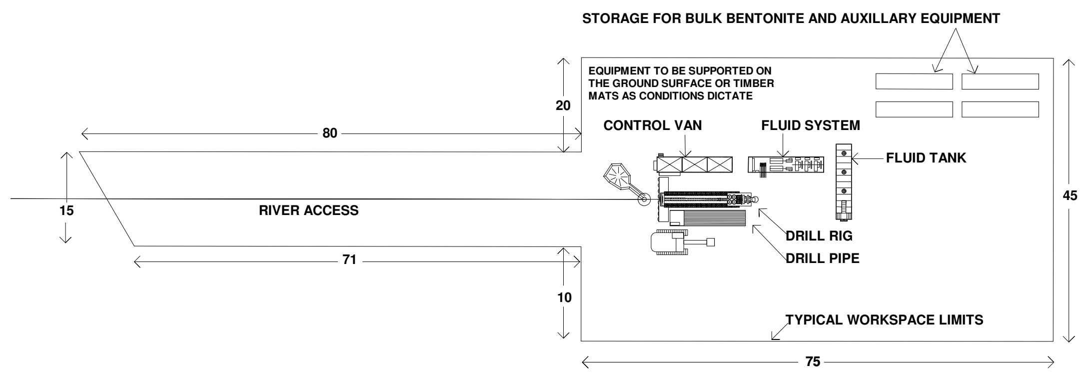
DATUM RL -50

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	8210.80(

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.



INSET A



INSET B

AUSTRALIA PACIFIC LNG PROJECT

Volume 3 Chapter 12
Figure 12.1 Proposed pipeline crossing, seabed profile, and indicative HDD workspaces

12.1.2 Scope of work

The scope of work, as specified in the environmental impact statement (EIS) terms of reference for the Project, relates to coastal processes, including descriptions of the physical processes relevant to the pipeline crossing corridor and the environmental values of coastal resources that could be affected by the gas pipeline.

The assessment is based on investigations of hydrodynamics and coastal processes, describing the influence of tides, waves, currents, turbidity, and extreme events (cyclones) on the coastal environment.

An assessment of the existing values (baseline) and the potential impacts to the coastal environment due to the pipeline crossing of The Narrows has included the following tasks:

- A literature review and evaluation of existing coastal data sets relevant to the pipeline crossing, notably sediment characteristics (URS 2009), water quality monitoring data (Department of Environment and Resource Management for years 1996 to 2006) and wave data (BMT WBM 2009).
- A review of the physical processes associated with the coastal and marine environment within the gas pipeline study area including:
  - Wind
  - Waves
  - Tides
  - Currents
  - Storm tides
- A site inspection, acquisition of existing data, and collection of new data to supplement the hydrodynamic model information including:
  - Hydrographic surveys
  - Wind speed and direction
  - Wave height and direction
  - Tide gauge predictions and measurements
  - Current speed and direction profiles
  - Water quality information
- Hydrodynamic and coastal processes modelling including:
  - Baseline assessment
  - Impact assessment.

The existing values and potential impacts as they relate to marine flora and fauna, including the wetlands to the west of The Narrows, are addressed in Volume 3 Chapter 10. Potential impacts associated with contaminated land and acid sulfate soils are discussed in Volume 3 Chapter 5.

12.1.3 Legislative framework

The assessment of the coastal and marine activities relevant to the pipeline crossing of The Narrows has been undertaken in consideration of the following legislation:

- Environment Protection and Biodiversity Conservation Act 1999, notably the Great Barrier Reef Marine Park and areas listed on the Register of the National Estate
- 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 (Curtis Coastal Plan)
- Marine Parks Act 2004 and Great Barrier Reef Marine Park (Mackay/Capricorn Section) Zoning Plan and Great Barrier Reef Coast Park Zoning Plan
- Environmental Protection Act 1994, including amendments, regulations and policies
- Sustainable Planning Act 2009
- Transport Infrastructure Act 1994
- *State Development and Public Works Organisation Act 1971*
- Environmental Protection (Water) Policy 2009.

The gas pipeline crossing route is within a Great Barrier Reef World Heritage Area and borders the Great Barrier Reef Coast Park, both significant coastal areas. In July 2008 three new areas were included in the Gladstone State Development Area, one of which was the Curtis Island Industry Precinct.

Specific regional issues for the Project have been identified by reference to policies described within the Regional Coastal Management Plan. Regional policies apply to the key coastal sites of:

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

Regional policies considered of relevance to the Project are summarised in Volume 5 Attachment 27.

12.2 Methodology

12.2.1 Baseline Assessment

The baseline assessment included a hydrodynamic data collection program for model validation and for comparison in the impact assessment.

Data collection program

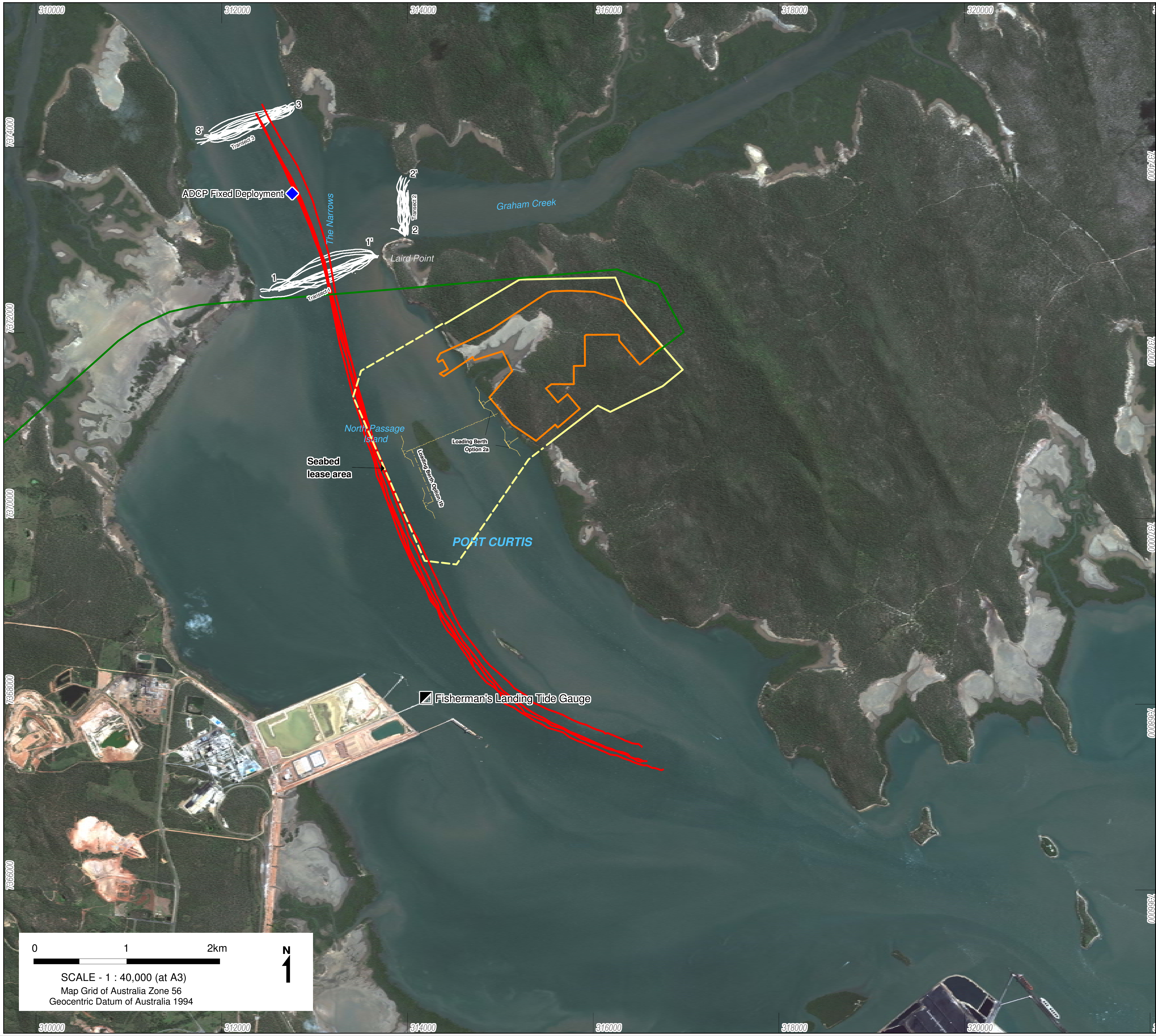
Data collection programs were conducted during July and August 2009. Current measurements were obtained using acoustic Doppler current profiler (ADCP) instruments which provide a measurement of current magnitude and direction variation with depth. The ADCP instruments were used in the following two methods:

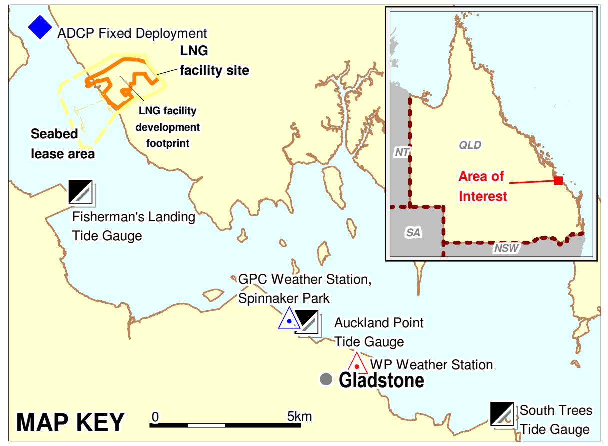
- Bottom-mounted (fixed to a research vessel) and towed across the gas pipeline study area (including the pipeline crossing route) to provide a cross-sectional, or 'transect' measurement. The seabed profile was measured simultaneously
- Deployed at the seabed in a fixed location for a period of five weeks to provide a continuous measurement at 15min intervals. The water level variation was measured simultaneously.

ADCP transects across Graham Creek, The Narrows, and the pipeline crossing route, 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. The cross-sectional flow rate variation over the tidal cycle was also obtained, as discussed in Volume 5 Attachment 27.

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. Figure 12.2 shows the locations where the ADCP transects, the ADCP fixed-deployment, and the drifter/drogue tracking were performed. Tide gauge data (observed water levels) were provided by Maritime Safety Queensland (MSQ).

The drifter/drogue instruments gave a measurement of temporal as well as spatial water movement within the study area. 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. The drifter/drogue measurements were also used to verify horizontal dispersion in the dredge plume modelling investigation (Section 12.4.2).





LEGEND

- Drogue Path
- Transect Location
- Gas pipeline route
- LNG facility site
- LNG facility development footprint

Source Information

Satellite imagery captured by GeoEye-1 on 24 March 2009

Transects
collected by Worley Parsons, November 2009

Development footprint
digitised from Conceptual Site Plan 25509-100-P1-000-10005.dgn supplied by client 24/07/2009

Preferred gas pipeline alignmnet supplied by Origin Energy on 03/11/2009

AUSTRALIA PACIFIC LNG PROJECT

Volume 3 Chapter 12
Figure 12.2 Coastal environment measurements

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12.2.2 Hydrodynamic and coastal processes modelling

The methodology for the impact assessment considered the type of construction techniques that would be used for the pipeline crossing of The Narrows. The preferred method of horizontal directional drilling (HDD) has no impact on the hydrodynamics of The Narrows waterway, so the methodology for this option is to examine the shoreline based impacts from the construction footprint. HDD will have no impact during the operational life of the pipeline. Alternate methods of construction for crossing The Narrows involve dredging a trench from Friend Point to Laird Point and manoeuvring the pipeline into place. This dredging activity is predicted to result in sediment plumes into the water column.

A validated hydrodynamic model was used to assess the level of impact from dredged plumes associated with a pipeline trench option. The methodology assumed that the pipeline construction would occur prior to major dredging of channels and swing basins as described in the Gladstone Ports Corporation Western Basin Dredging and Disposal project EIS (GHD 2009).

The impact assessment methodology therefore requires that the model is validated against the baseline data so that the hydrodynamic model reproduces the conditions that would be present at the time of pipeline construction. This provides confidence that the model can be used to assess the potential impact of sediment plumes associated with alternate construction techniques. The model domain is shown in Figure 12.3 and includes an inset with the level of detail used for the Western Basin.

Tidal currents were predicted over a three month period using the hydrodynamic model. Three locations were selected for current speed analysis:

- 300m offshore from Friend Point
- The centre of the pipeline crossing route
- 200m offshore from Laird Point.

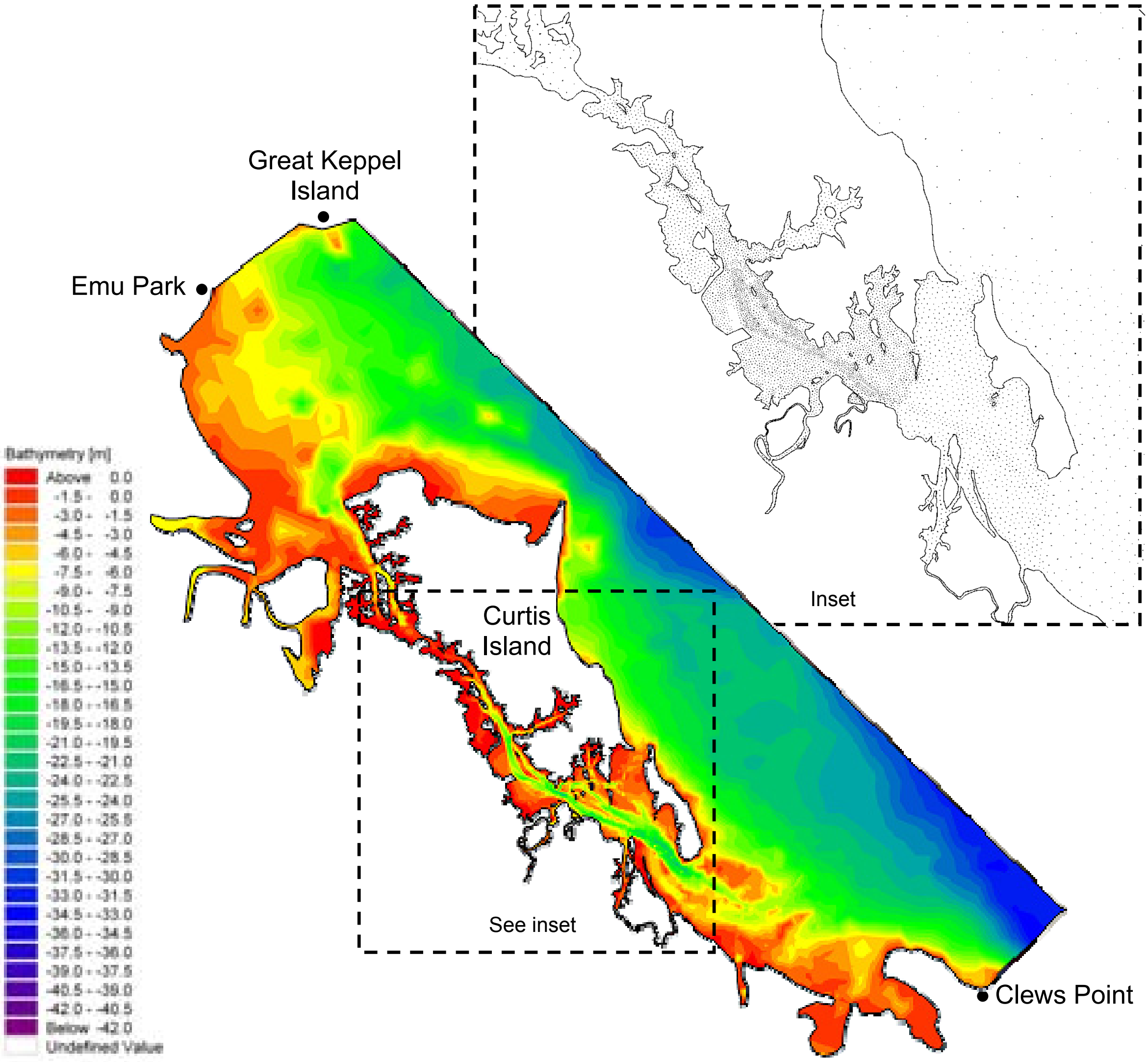


Figure 12.3 Port of Gladstone hydrodynamic model extent and bathymetry (Inset: high-resolution flexible mesh)

A selected record of the ADCP fixed-deployment depth-averaged measurement is presented in Figure 12.4, together with model predictions for the same location and period. Good agreement between the measurements and model predictions was achieved. The figure also shows that the flood and ebb currents at the measurement locations are typically aligned 330deg and 150deg respectively. The peak measured depth-averaged current speed for the deployment period was 1.05m/s. Current speeds of this magnitude are only expected during peak spring tide conditions. For further details of the hydrodynamic model validation, refer to Volume 5 Attachment 27.

Analysed baseline data is presented in Section 12.3.2 and compared against a summary of model predictions.

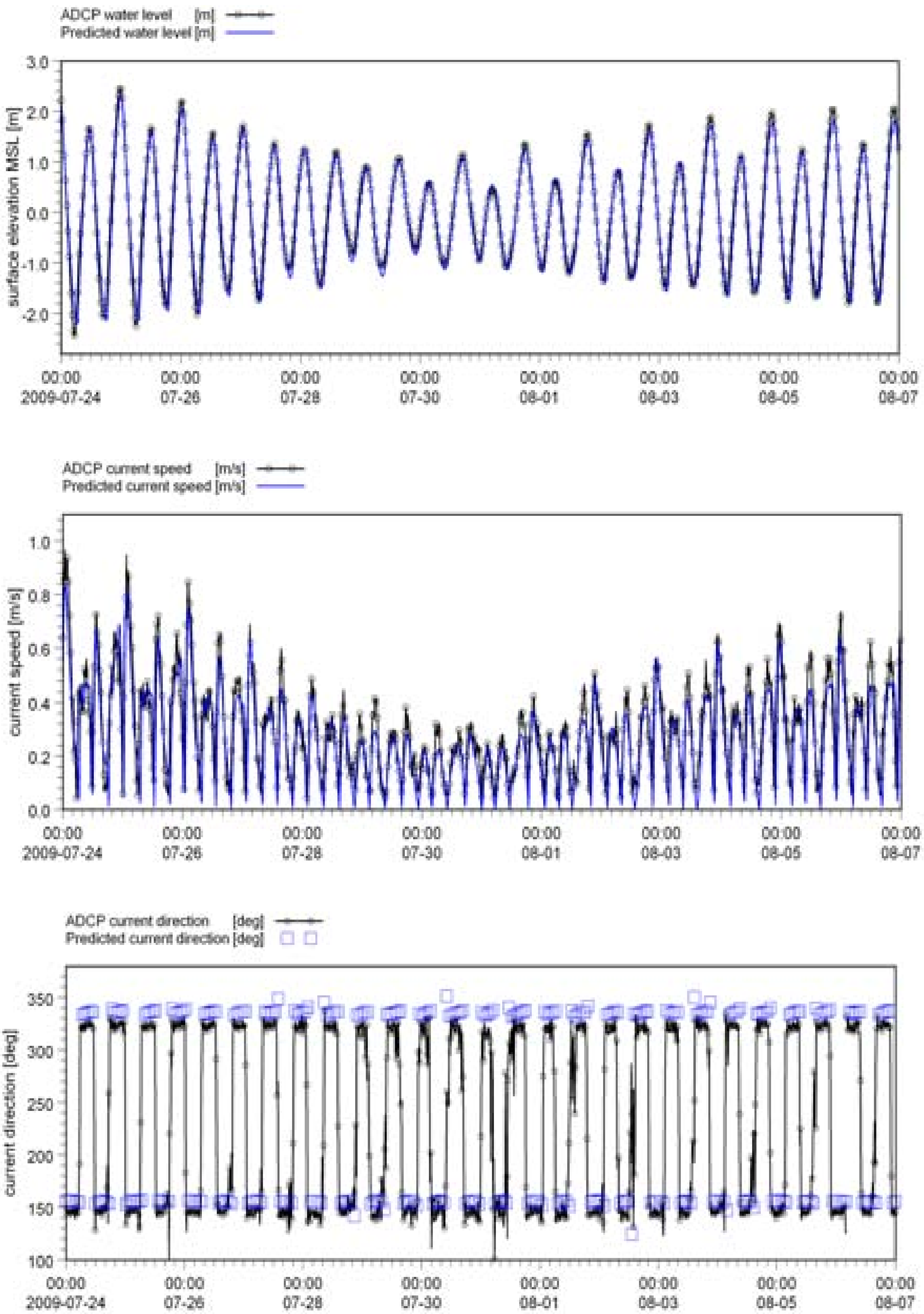


Figure 12.4 Hydrodynamic model verification with ADCP measurements at a fixed location offshore from Laird Point.

12.2.3 Turbidity plume modelling

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. MIKE21-FM, developed by the Danish Hydraulics Institute, is a computer program that simulates flows, waves, sediments and ecology in rivers, lakes, estuaries, bays, coastal areas and seas in two dimensions.

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. The mud transport add-on module simulated the transport of sediments associated with dredging activities.

Two material (sediment) settling scenarios were developed, being an upper (best case) and lower (worst case) with a range of potential plume impacts defined for each scenario. The upper and lower limit pipeline trench plume modelling scenarios are defined in Table 12.1.

In terms of the potential pipeline trench plume impact, the lower limit sediment scenario is considered the more conservative modelling approach.

Table 12.1 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

12.3 Existing environment

The Narrows is a key coastal site under the Curtis Coast Regional Coastal Management Plan. The waterway is a 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 northern end of the Western Basin). It is approximately 1km wide between Graham Creek and Middle Creek, reducing to less than 200m width near Ramsay Crossing. The Narrows 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 Great Barrier Reef World Heritage Area, the Great Barrier Reef Coast Park, the Great Barrier Reef Marine Park (Mackay/Capricorn section) and areas listed on the Register of the National Estate. The dredging and water quality management policies in The Curtis Coast Regional Management Plan recognise 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 values.

12.3.1 Marine water and sediment

The marine sediment investigation prepared as part of the Gladstone LNG Project (URS 2009) describes the analysis of marine sediments contained in boreholes across a northerly and southerly alignment between Friend Point and Laird Point. This investigation found the marine sediments to exist in layers 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). WorleyParsons' field work, using a drop camera, also confirmed the abundance of shell fragments on the surface of the seabed (Volume 5 Attachment 27). The wide spread covering of shell fragments appears to be stable, even though spring tidal currents between Friend Point and Laird Point can exceed 1m/s. This stability can be accounted for by the hydrodynamic shape of the shells. The shell layer also provides some armour for marine sediments, restricting them from becoming mobile.

Particle size distribution (PSD) analysis of the borehole contents shows a variation in sediment type across the entrance to The Narrows. 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 experiences high turbidity variation due to a combination of strong tidal currents and fine bed sediments. Once mobilised, silts and fine bed sediments in the vicinity of the 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 where a value of six nephelometric turbidity units is indicated for enclosed coastal waters. Analysis of Queensland Department of Environment and Resource Management monitoring data (for years 1996 to 2006) at the entrance to Calliope Creek (station 132801) shows elevated turbidity up to approximately 34 nephelometric turbidity units during summer months after rainfall, when stream runoff carries fine sediments to the estuary.

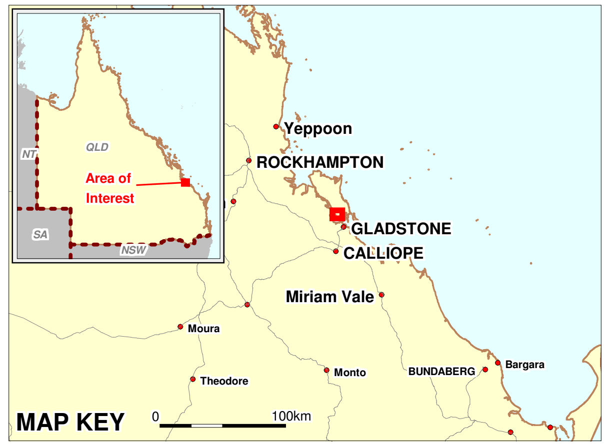
12.3.2 Tides and currents

The data obtained via bottom-mounted ADCP transects at selected peak-ebb, spring tide conditions during the deployment are presented in Figure 12.5, Figure 12.6 and Figure 12.7. 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 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.

Table 12.2 presents the ADCP depth-averaged current speed frequency analysis from the collected baseline data. During the deployment period, a low to moderate current speed (less than 0.5m/s) was present for more than 75% of the time.



LEGEND

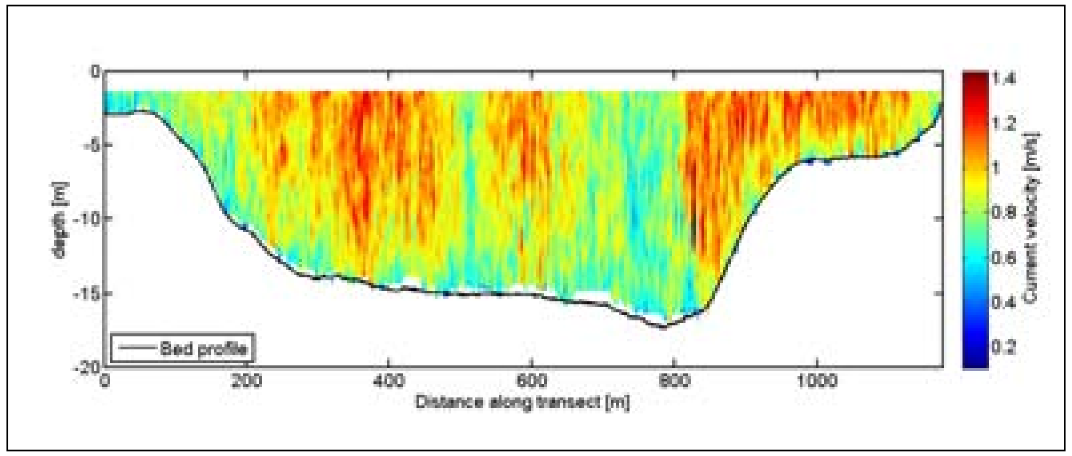
- Gas pipeline route
- Transect (Boat path)
- Velocity vector 1 (m/s)

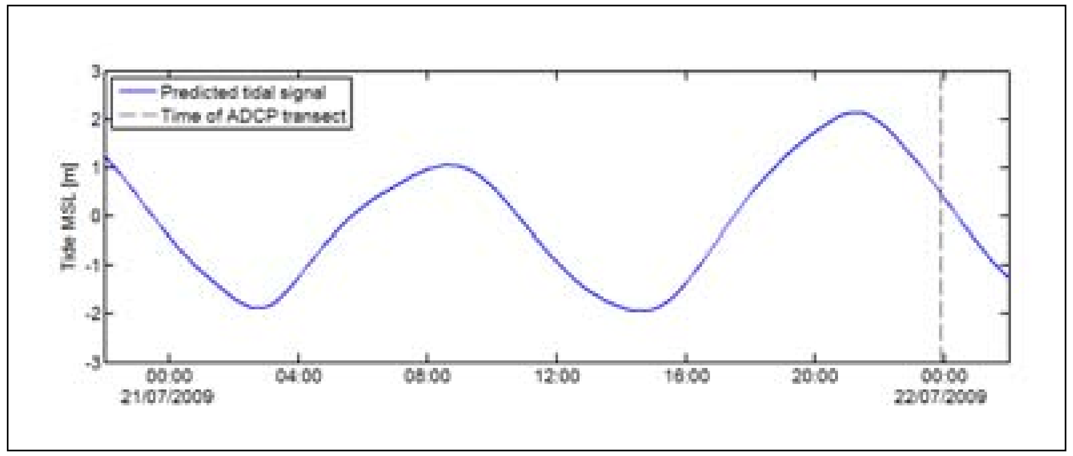
Source Information

Satellite imagery captured by GeoEye-1 on 24 March 2009

ADCP transect collected by Worley Parsons, July 2009

Preferred gas pipeline alignment supplied by Origin Energy on 03/11/2009





AUSTRALIA PACIFIC LNG PROJECT

Volume 3 Chapter 12
Figure 12.5 ADCP transect measurement.The Narrows, south of Graham Creek entrance

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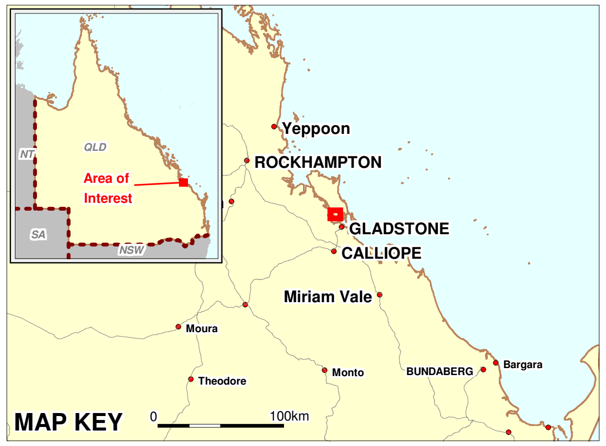


MAP KEY

LEGEND

Gas pipeline route

Transect (Boat path)

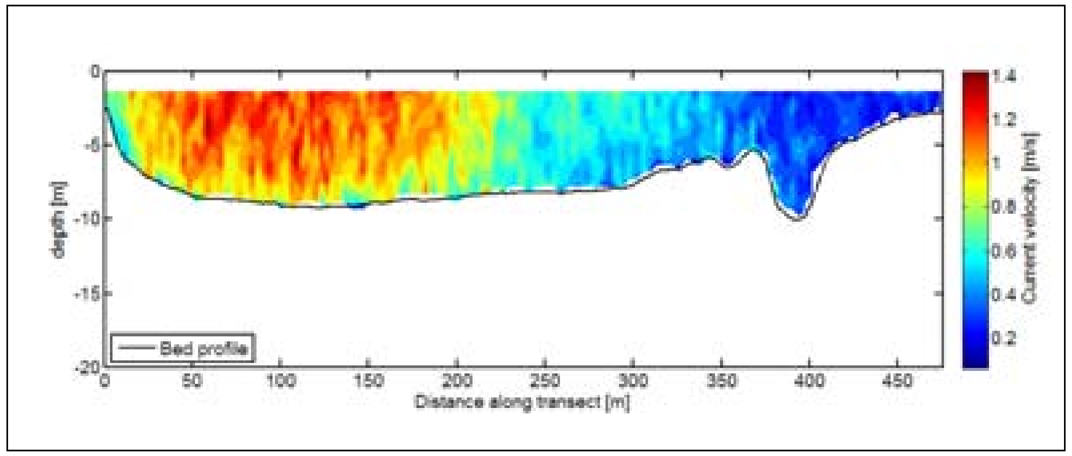
Velocity vector 1 (m/s)

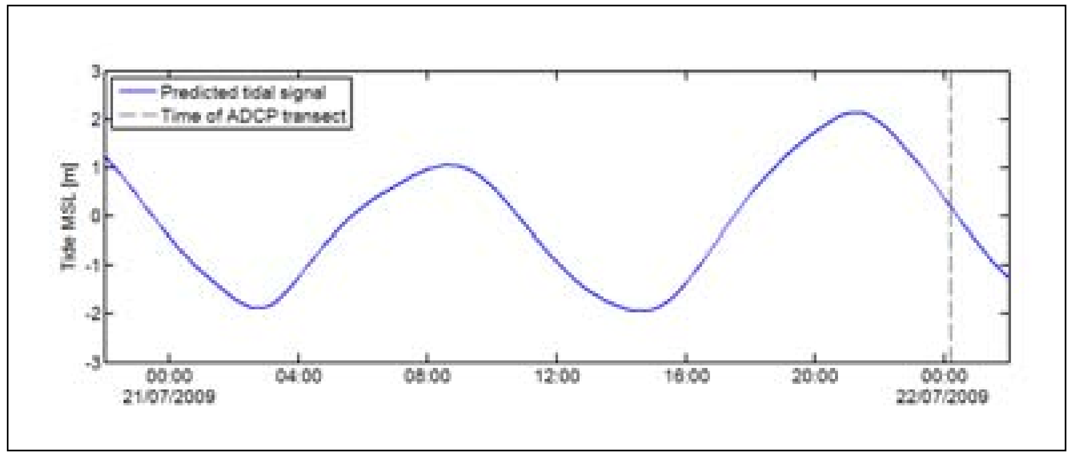
Source Information

Satellite imagery captured by GeoEye-1 on 24 March 2009

ADCP transect
collected by Worley Parsons, July 2009

Preferred gas pipeline alignmnet supplied by Origin Energy on 03/11/2009





AUSTRALIA PACIFIC LNG PROJECT

Volume 3 Chapter 12
Figure 12.6 ADCP transect measurement. Graham Creek entrance

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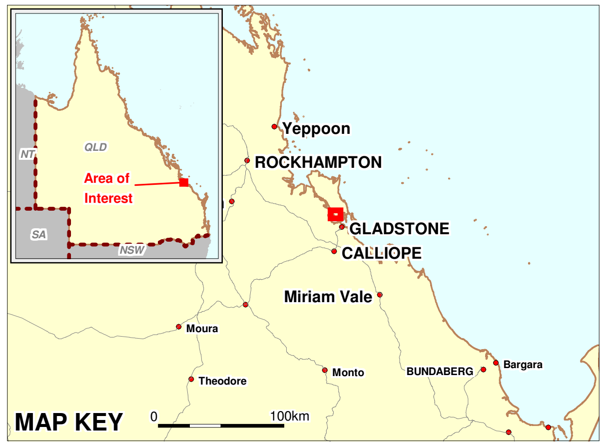


MAP KEY

LEGEND

Gas pipeline route

Transect (Boat path)

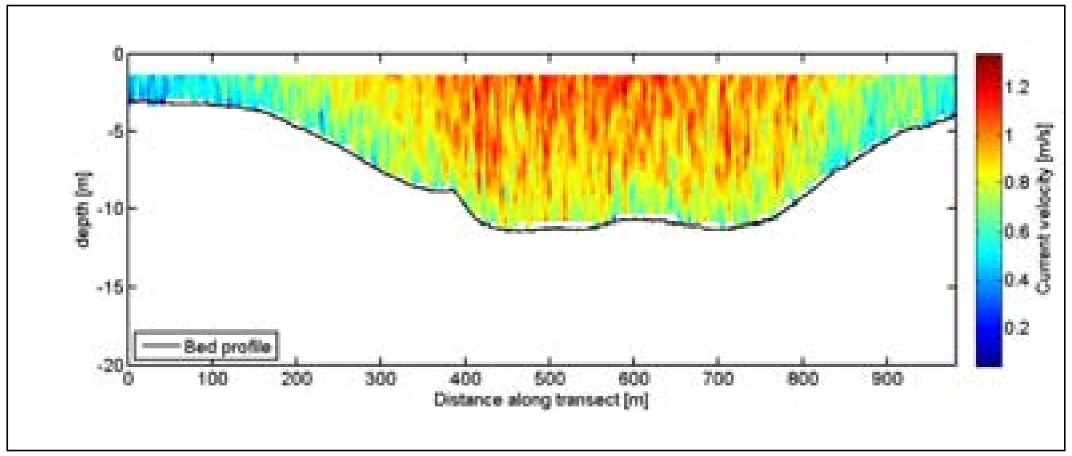
Velocity vector 1 (m/s)

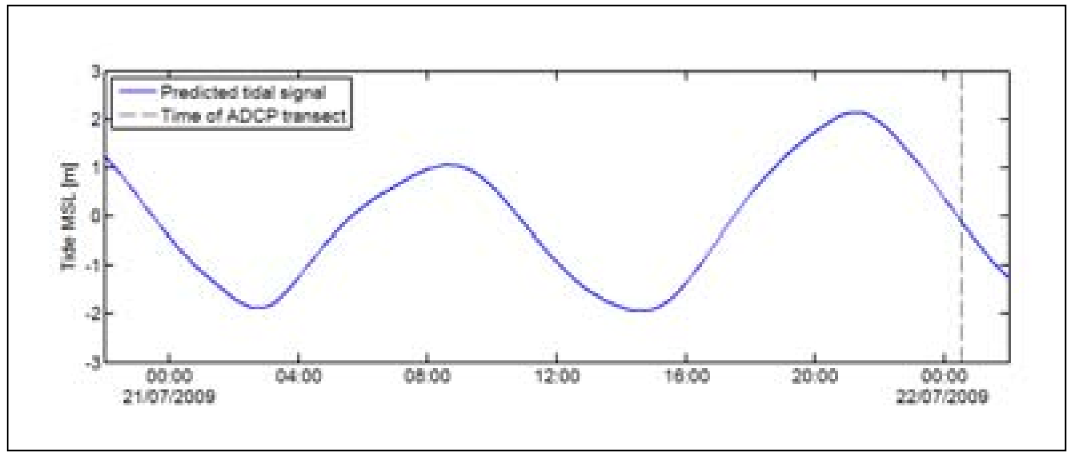
Source Information

Satellite imagery captured by GeoEye-1 on 24 March 2009

ADCP transect
collected by Worley Parsons, July 2009

Preferred gas pipeline alignmnet supplied by Origin Energy on 03/11/2009





AUSTRALIA PACIFIC LNG PROJECT

Volume 3 Chapter 12
Figure 12.7 ADCP transect measurement.The Narrows, north of Graham Creek entrance

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Table 12.2 ADCP fixed deployment current speed frequency analysis at pipeline route location

Current speed range (m/s)	Percentage (%)
0 – 0.15	20.0
0.15 – 0.30	28.3
0.30 – 0.45	27.4
0.45 – 0.60	15.1
0.60 – 0.75	6.7
0.75 – 0.90	1.9
0.90 – 1.05	0.7

Predicted current speed along the pipeline crossing route

As indicated in Section 12.2.2, a good comparison of the model hydrodynamics with baseline conditions provides confidence the model can be used to assess the impact of sediment plumes associated with alternate construction techniques.

A frequency analysis of the predicted current speed at three locations along the pipeline crossing route is presented in Table 12.3. The predicted current speed is less than 0.50m/s for more than 80% of the time. The highest predicted current speed was 1.09m/s and occurred offshore from Friend Point. The peak current speed at the pipeline crossing centre and offshore from Laird Point were 0.89m/s and 0.85m/s respectively.

Table 12.3 Pipeline crossing route – predicted current speed frequency analysis

Current speed range (m/s)	300m offshore from Friend Point (%)	Pipeline crossing centre (%)	200m offshore from Laird Point (%)
0.00 – 0.15	26.1	23.1	23.9
0.15 – 0.30	27.3	33.9	34.4
0.30 – 0.45	27.5	28.8	28.6
0.45 – 0.60	10.8	8.9	8.2
0.60 – 0.75	4.2	4.1	4.2
0.75 – 0.90	2.7	1.3	0.7
0.90 – 1.05	1.2	0.0	0.0
1.05 – 1.20	0.2	0.0	0.0

A general description of tides and currents in the Gladstone Harbour region is provided in Volume 5 Attachment 27.

12.3.3 Waves

The pipeline crossing route is relatively protected from ocean swell waves. A frequency analysis of local wind waves generated within the Western Basin has recently been completed for GPC (BMT WBM 2009). At the pipeline crossing route (location 03 in BMT WBM 2009) the significant wave height is predicted to be less than 0.3m for more than 85% of the year. For approximately 22% of this time the wave conditions are calm (significant wave height is less than 0.1m). The dominant wave direction is from the south-east. Developments within the Western Basin proposed by GPC were found to have an insignificant effect on the day-to-day wave climate at the pipeline crossing.

Extreme waves associated with storm events were predicted using a Simulating WAves Nearshore (SWAN) wave model. A 10min average wind speed of 36m/s, representing a 50 year average return interval (ARI) wind speed for the Gladstone region (Australia/New Zealand Standard 1170.2:2002) was applied across the model domain. Wind directions associated with the longest local fetches over water to the pipeline route were modelled. Table 12.4 summaries the 50 year ARI wind wave modelling and presents the predicted significant wave height at the pipeline crossing. The largest waves are predicted to be associated with southerly winds.

Table 12.4 Local wind wave prediction at pipeline crossing for 50 year ARI wind speed

10min average local wind speed (m/s)	Local wind direction (direction from)	Significant wave height at pipeline crossing centre (m)
36	W	1.48
36	WSW	1.57
36	SSW	1.79
36	S	1.86
36	SSE	1.75
36	ESE	1.61

12.4 Potential impacts

12.4.1 Pipeline development options

There are several methods that have been proven in practice to accomplish a major water crossing with a high pressure gas 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

Wetlands crossing

The western approach of the gas pipeline to The Narrows is across approximately 3km of wetlands. It is proposed that the gas pipeline across the wetlands be installed in an excavated trench. Excavation in muddy conditions requires a wide trench with sloped sides to prevent trench collapse. Alternatively the volume of material to be excavated may be minimised by installing parallel rows of sheet piles driven along the proposed trench line. The trench would be dug between the rows of sheet piling using low-ground-pressure excavators, working from a temporary construction access way built on top of the

existing mudflats. In either case, spoil will be stockpiled on one side of the trench while the other side will be used as working side.

It is anticipated that this installation will require between nine and 12 months to complete.

Crossing of The Narrows

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

Pipeline crossing options

Potential options for the pipeline crossing of The Narrows are:

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

Horizontal directional drilling

HDD is the preferred construction method for the pipeline crossing of The Narrows to Curtis Island. The potential impact of HDD on the waterway environment is considered to be less than other methods because no dredging of the seabed is involved.

Figure 12.1 shows the pipeline crossing location, the seabed profile and the proposed HDD route with nominal cover depth. This figure also shows the indicative workspace positions on both shorelines and details of each workspace.

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, drill pipe and the control van. Locations of these key components are controlled by the drill entry point.

Drilling fluid is usually a mixture of freshwater and bentonite. Bentonite is a naturally occurring clay that is extremely hydrophilic – that is, it has high swelling characteristics. 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.

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
- Stabilising the bore hole during the drilling process
- Sealing fractures in the formation.

During the HDD process a rotating drill bit will form cuttings, consisting of rock fragments and soil. The cuttings are removed by a continuous circulation of the drilling fluid that is forced down the drill pipe. The drilling fluid carries the cuttings in suspension in the space between the drill pipe and the wall of the drill hole. At the surface, the fluid is channelled into a settling pit or pits where most of the cuttings drop out to form what is known as drilling mud. Drilling mud is filtered and re-used in the HDD process.

Disposal of drilling mud after use is normally achieved by one of the following techniques:

- Mix and bury onsite (not appropriate at this location)
- Land spread (as above)
- Transfer to an approved site or disposal facility.

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 exists on the seabed.

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

Construction issues to be managed include 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 dredged material

The alternative to HDD, being the 'bottom pull' method, requires 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. The type of dredge plant would depend on the width and depth of the trench and the total volume of material to be removed.

The volume of material to be removed from the trench has been assessed assuming the alignment and profile shown in Figure 12.1 with dredging assumptions presented in Volume 3 Chapter 3. The stability of the underwater section would also require batter slopes varying from 1V:3H to 1V:5H,

necessitating local storage 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. Disposal of material would be in accordance with the GPC approved reclamation works.

12.4.2 Construction-related impacts

Potential impacts of constructing 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.

Construction of the gas pipeline right of way and the creation of workspace areas are likely to result in high levels of turbidity within the trench and a coffer dam or similar would be required to prevent increased sedimentation in marine waters. There is also the potential for longer term impacts from vegetation clearing and ongoing maintenance at the shoreline as a result of the permanent right of way (Volume 3 Chapter 8).

The excavated spoil is likely to contain acid sulfate soils, and so will be treated using lime or similar material before it is returned into the trench. Details of the proposed methodology for treatment of acid sulfate soils are provided in Volume 3 Chapter 5.

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 Volume 4 Chapter 8.

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 12.5.

Table 12.5 Potential HDD construction issues

Potential risk	Possible cause(s)	Possible consequences
Drilling fluid or 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 fluid or 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 not adopted, 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 12.6.

Table 12.6 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.

Potential risk	Possible cause(s)	Possible consequences
Mobilisation of nutrients and contaminants.	Dredging and pipeline construction activities.	Changes to water quality and impacts to marine flora and fauna, 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 dredging were assessed using the MIKE21-FM hydrodynamics model coupled with a mud-transport module. The simulation considered the removal of 106,000m^3 of material 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. A complete description of pipeline dredge plume modelling investigation is provided in Volume 5 Attachment 27.

The impact of the pipeline 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 pipeline crossing. A bore-log contains a description of the subsurface sediments over depth and information on each type of sediment is described.

The average percentage of sand, silt, and clay fractions over the first 5m of sub-surface material was calculated from the URS (2009) soil bores (BH19, BH20, BH21, BH25B) and is shown in

Table 12.7. The mean percentages of sediment fractions were used for pipeline trench plume modelling. Note that the small percentage of gravel sampled by URS (2009) has not been included in the modelling scenario as this material will not affect the sediment plume.

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. Separate dredge plume simulations using the upper and lower limit material settling velocities were undertaken. The lower settling (fall) velocities are shown in

Table 12.7. Adopting the lower limit of the material type settling velocity is more conservative in assessing the potential impact of plume extent

Table 12.7 Mean % material fractions from soil bores in vicinity of pipeline crossing* 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 * URS, 2009

The total suspended solids (TSS) concentrations due to trenching are in addition to the natural TSS concentrations (i.e. above the background TSS level) within the Western Basin.

Figure 12.8 shows the above background predicted TSS concentration time series within Graham Creek and The Narrows and the corresponding Gladstone (South Trees) tidal signal for the duration of the sediment plume simulation. The figure shows higher TSS concentrations at Graham Creek and The Narrows during larger tides. At these times the tidal excursion is sufficient to carry higher TSS concentrations further, and conversely during the shorter, neap tide periods, relatively low TSS concentrations are present at both Graham Creek and The Narrows.

Following the completion of the 60 day dredging period in the simulation, the TSS concentrations return to background levels within 10 days for sediments associated with higher fall velocities and approximately one month for sediments associated with lower fall velocities.

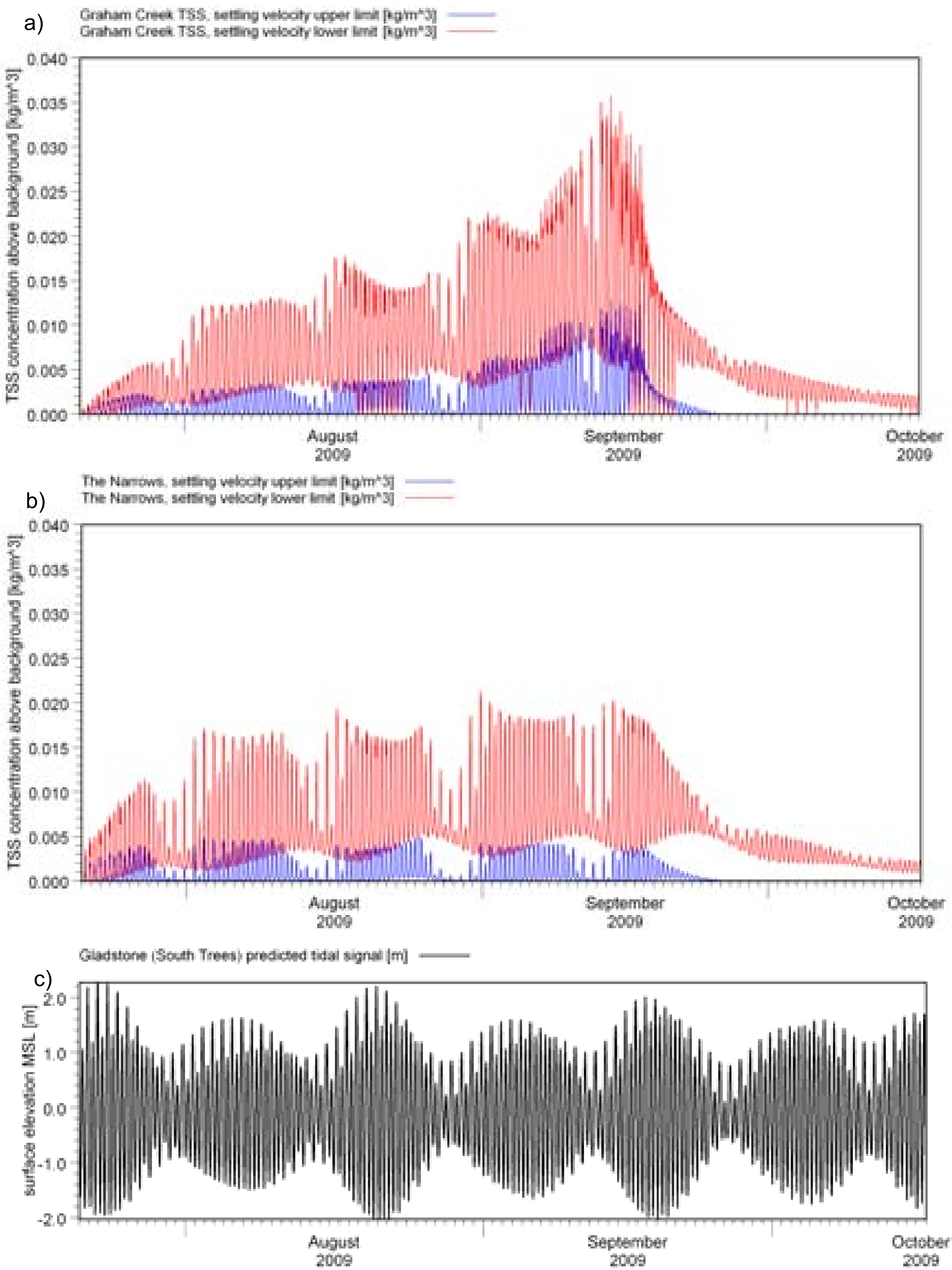

Figure 12.8 Above background predicted TSS concentration time series

Notes: Time series during pipeline trenching for upper and lower limit sediment settling velocities: a) Graham Creek, b) The Narrows, and c) corresponding tide signal at Gladstone (South Trees)

Table 12.8 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 and lower 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 12.8 Predicted maximum and mean TSS concentration above background*

Modelling scenario	TSS concentration above background (kg/m^3)							
	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

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

A statistical analysis of the TSS concentration for the simulated 60-day trenching program provides an assessment of the potential impact area. Figure 12.9 presents a spatial summary of the mean and maximum TSS concentration predicted to occur during the 60-day trenching program for the lower limit sediment settling velocity scenario.

Within Graham Creek and surrounding North Passage Island the mean TSS is predicted to elevate during the trenching program by approximately 0.01kg/m^3 (10mg/L). 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 the predicted increase to the mean TSS concentration in this area is relatively low and less than 0.005kg/m^3 (5mg/L).

The spatial summary of the maximum TSS predicted to occur during the simulated 60 day trenching program is presented in Figure 12.9. Note that at any given location the predicted maximum TSS is likely to be present for only a short period. 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.

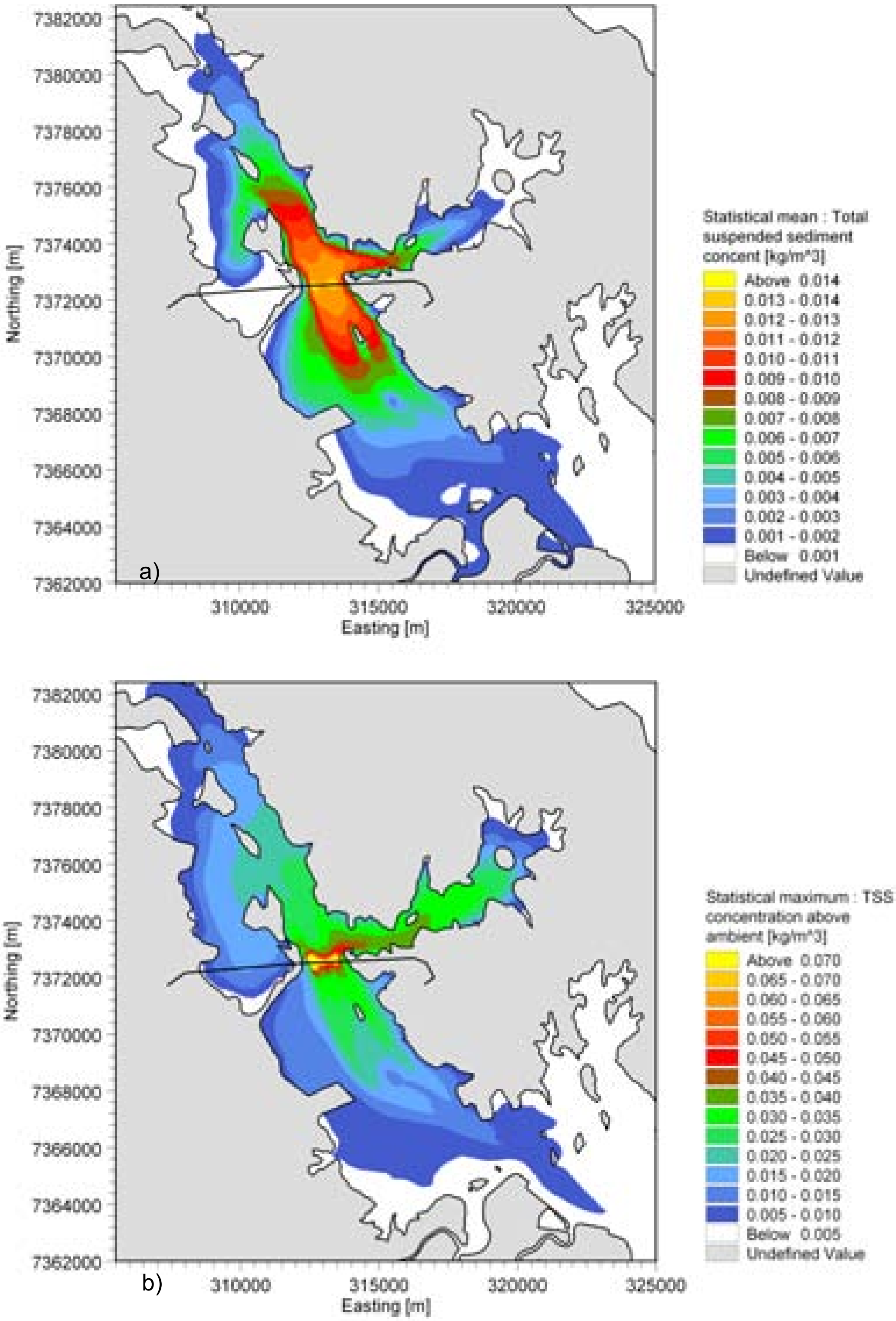

Figure 12.9 Statistical summary of TSS concentration increase during the 60 day gas pipeline trenching program[1]

[1] Statistical summary of TSS concentration increase during 60-day gas pipeline trenching program due to lower limit sediment settling velocities: a) statistical mean, b) statistical maximum (note TSS contour limits vary for mean and maximum summaries)

12.5 Mitigation and management

Potential impacts associated with the gas pipeline crossing of The Narrows largely depend on the construction methodology to be adopted by Australia Pacific LNG. The preferred construction technique for the intertidal wetland to the west of The Narrows waterway is by trench and cover. To cross the major waterway to Laird Point the two options being considered are as follows:

- HDD under the seabed (preferred method, subject to engineering and construction feasibility)
- Dredged trench through the seabed (bottom pull method).

Under the sustainability principles established for the Project, potential impacts to the marine and coastal environment, including the Great Barrier Reef Coast Park, will be managed and environmental values maintained. Impact mitigation and management techniques, specific to the pipeline crossing construction method that is to be adopted, will be incorporated in the construction environmental management plan to be developed. Control measures proposed to mitigate and manage the construction impacts include:

- Minimise the width of pipeline corridor activities and workspaces and clearly identify them for construction personnel
- Minimise the removal and disturbance of vegetation and ground covers
- Design stabilised access ways for heavy machinery to minimise disturbance of soft soils
- Avoid loss of drilling fluid and drilling mud containment through appropriate design of storage areas and appropriate methods to transfer the drilling mud off site for disposal
- Implement agreed methods to prevent shoreline erosion or disturbance due to pipeline crossing activities including excavation, dredging, and drilling works or access to marine plant and equipment
- In the case of HDD, design the pipeline drill hole profile based on adequate geotechnical data to avoid weak strata and potential cavities within the sub-surface sediments that could result in collapse of the drill hole, lost equipment, and redrills
- Undertake dredging works only if HDD is not feasible or if a joint approach is not achieved. Select the appropriate dredge plant for the work and conduct operations to agreed dredge management measures. The dredge management measures should include requirements for recreational vessel access through The Narrows while dredging is in progress. Silt curtains should be used where practicable around shorelines. Disposal of material would be in accordance with the GPC approved reclamation works.
- Rehabilitate the site and make structures in coastal and marine areas safe following construction activities and decommissioning. Any structures required during construction, such as anchor and winch foundations, should be designed so as not to have a long term affect on flows in The Narrows and in consideration of ecological values.

The marine and coastal environment affected by constructing the pipeline crossing 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. If necessary, appropriate corrective actions will be employed.

Australia Pacific LNG is committed to collaborating with Gladstone Ports Corporation and other LNG proponents to consider potential cumulative impacts and to establish an agreed sequencing of construction.

12.6 Conclusion

12.6.1 Assessment outcomes

A summary of the environmental values, sustainability principles, potential impacts and mitigation measures in relation to the coastal environment associated with the gas pipeline is presented in Table 12.9. A risk assessment has been undertaken to identify potential risks, causes and consequences from pipeline activities. Mitigation measures to reduce the risk have been nominated and the residual risks estimated. Further details on the risk assessment methodology are provided in Volume 1 Chapter 4.

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Table 12.9 Summary of gas pipeline crossing potential impacts and mitigation

Environmental values	Sustainability principles	Potential impacts	Possible causes	Mitigation and management measures	Residual risk level
Health and diversity of natural marine ecosystems	Minimising adverse environmental impacts and enhancing environmental benefits associated with Australia Pacific LNG's activities, products or services; conserving, protecting, and enhancing where the opportunity exists, the biodiversity values and water resources in its operational areas Identifying, assessing, managing, monitoring and reviewing risks to Australia Pacific LNG's workforce, its property, the environment and the communities affected by its activities	Horizontal directional drilling (preferred)			
		Drilling fluid or mud seepage into watercourses, either directly or indirectly (via land), potentially increasing the sediment load, deposition and contamination. Potential adverse impacts on vegetation, fauna, fish habitat, soils, hydrology and downstream water users. Impacts would be variable depending on volume and connectivity to surface or water body.	Loss of containment of drilling fluid or mud.	Storage areas for drilling fluid and mud will have secondary containment. Drill mud to be transported off-site by an approved contractor to an approved landfill.	Low
		Increase in the area of disturbance (footprint) due to redrill or required works to retrieve equipment, undertake repairs, etc Disturbance to threatened communities, habitat or coastal processes. Extended duration of disturbance	Mechanical failure (stuck drill stem, damaged pipe or coating and so forth)	Additional geotechnical surveys will be conducted prior to construction to confirm feasibility of HDD at this location.	Low
		Localised erosion of shoreline and 'washout' of vegetation Unexpected widening of the area of disturbance. Extended duration of disturbance	Inadequate scour protection placement during rehabilitation of temporary work space sites.	Design of rehabilitation to take into consideration tidal and wave motion.	Low

Environmental values	Sustainability principles	Potential impacts	Possible causes	Mitigation and management measures	Residual risk level
		Wetlands crossing (trenching) – western approach			
		Disturbance of shorebird roost and feeding sites	Construction within the intertidal wetlands to the west of The Narrows	Schedule construction to consider potential impacts on migratory shorebirds. .	Low
		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. Removal of vegetation and habitat disturbance causing potential impacts on habitat, flora and fauna.	Construction within the intertidal wetlands to the west of The Narrows,	Adopt construction methods that seek to minimise disturbance in accordance with the Construction Environment Management Plan to be developed for the Project. Monitor water quality during excavation to meet water quality objectives. Rehabilitation will be undertaken by reducing corridor width following construction and promoting revegetation. Further rehabilitation will be undertaken following pipeline decommissioning.	Low
		Conventional dredging techniques (alternative construction method)			
		Modification of flows and currents Removal of vegetation, impacting biodiversity	Temporary structures for the construction and operation of the gas pipeline in coastal and marine areas.	Structures will be rehabilitated post construction. Design of structures will align with 'fish friendly structure'	Low

Environmental values	Sustainability principles	Potential impacts	Possible causes	Mitigation and management measures	Residual risk level
				guidelines.	
		Increased turbidity (turbidity plumes) and total suspended solids (TSS) causing degradation of water quality 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) Mobilisation of nutrients and contaminants. Impacts to marine flora and fauna, including MNES species. Changes to constituent concentration in the water due to the absorption or release of contaminants (i.e. heavy metals).	Dredging of the pipeline trench causing disturbance of sediments and benthic habitats.	Select appropriate dredge plant for the work and operate in accordance with dredge management procedures. Monitor water quality during dredging to ensure water quality objectives are achieved. Periodic cessation of dredging to provide the watercourse respite if water quality objectives are not maintained.	Medium
		Increased sediment deposition Smothering of benthic assemblages as suspended sediment settles.	Dredging and pipeline construction activities.	Use appropriate dredge plant to minimise dredge material spill. Minimise rehandling of dredge material when disposing to approved reclamation site.	Low
		Habitat disturbance and fragmentation Loss of habitat through removing sediments and increased mortality of benthic organisms.	Dredging and pipeline construction activities	Minimise width of pipeline corridor.	Low

12.6.2 Commitments

Transmission of coal seam gas to the Australia Pacific LNG site will require construction of the gas pipeline across The Narrows. The key commitment by Australia Pacific LNG towards maintaining the existing values of the coastal environment of The Narrows is to:

- Develop a construction methodology that will minimise disturbance
- Work with State Government, Gladstone Ports Corporation and other proponents proposing similar crossings to achieve an outcome that minimises cumulative impacts
- Establish a process for visual observations and recording of dugongs and cetaceans.

If HDD is not the adopted construction method, Australia Pacific LNG will select an appropriate dredge plant to construct a pipeline trench across The Narrows. All dredging activities will be in accordance with dredge management procedures, to reduce potential impact to marine waters, and flora and fauna.

References

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