APPENDIX 7

ARROW LNG PLANT

**Supplementary Report
- Coastal Processes and Marine
Water Quality Technical Study**

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Arrow LNG Plant EIS Supplementary Report – Coastal Processes and Marine Water Quality Technical Study

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December 2012

Arrow LNG Plant EIS Supplementary Report – Coastal Processes and Marine Water Quality Technical Study

Prepared For: Coffey Environments

Prepared By: BMT WBM Pty Ltd (Member of the BMT group of companies)

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DOCUMENT CONTROL SHEET

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</table>

Title :	Arrow LNG Plant EIS Supplementary Report – Coastal Processes and Marine Water Quality Technical Study
Author :	Dr Paul Guard, Ryan Shojinaga
Synopsis :	This report describes the results of additional technical studies of coastal processes and marine water quality in Port Curtis to inform the Supplementary Report to the Arrow LNG Plant EIS.

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EXECUTIVE SUMMARY

Background

The Environmental Impact Statement (EIS) for the Arrow LNG Plant Project was published in March 2012. Since that time the project has undergone further planning and design work, and changes to the project design have resulted in the need to identify potential changes to the original coastal processes, hydrodynamics and water quality impact assessment (BMT WBM, 2011a). During the next phase of the project in detailed design, the final design of the facilities will be determined. This may result in changes to some elements of the design as presented including the extents and quantities of dredging.

Coastal Processes and Hydrodynamics

Changes to the project description include increases to dredging volumes at Boatshed Point and at the LNG Jetty, and changes to the arrangement of marine facilities at Boatshed Point and the Launch Site 1. The mainland Tunnel Entrance Site design has also been modified.

Numerical modelling assessments were undertaken to illustrate the hydrodynamic impacts of the new proposed design of marine facilities at Boatshed Point and at Launch Site 1. At Boatshed Point, the model results indicate a significant reduction in spring tidal current magnitudes in the lee of proposed structures and minor increases in spring tide current magnitudes offshore from Boatshed Point. At Launch Site 1, modelling the proposed sheet piled structures resulted in local reductions in spring tide current magnitudes adjacent to the structures and a corresponding minor increase in current velocities in the main river channel.

A siltation assessment was also undertaken. Due to the limitations of the model including validation, the results are considered to be indicative only. In the vicinity of the proposed Boatshed Point facility, the model indicates that fine sediment could potentially accumulate by up to 0.14m/month in some parts of the proposed ferry manoeuvring basin and up to 0.2m/month near the RO-RO barge berth. In the vicinity of the proposed Calliope River facilities, the model indicates that fine sediment is likely to accumulate downstream and upstream of the proposed causeway, mostly outside the area of dredging. The maximum modelled siltation in a navigation area is in the vicinity of Berth 4, where the estimated rate is up to 0.06m/month. An assessment of potential changes in bed load transport of non-cohesive sand-size sediments was undertaken for the Calliope River estuary. The model results do not indicate that sedimentation of sand-sized particles within the dredged area is likely to occur.

The effects of changes to dredging volumes are accounted for in the revised marine ecology impact assessment, using the results of plume modelling presented in the original EIS. The larger volumes will require a longer dredging program (since the dredging methodology is unchanged), so the time of exposure to elevated turbidity and the total deposition thickness at sensitive receptor sites are expected to be proportionally larger. Additional geotechnical information indicates that the sediments at Boatshed Point are predominantly clays and silts, consistent with the assumptions in the original EIS modelling. The Calliope River site is predominantly sandy so the original dredge plume turbidity assessment (which assumed a higher proportion of silts and clays) is conservative.

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A detailed assessment of changes to the tidal regime in the Calliope River estuary as a result of project-related dredging was also carried out. Dredging the bar at the river entrance causes a reduction in low tide levels throughout the lower part of the estuary. Changes to bank exposure times, minimum water levels and depths, and impacts on navigability are reported.

Marine Water Quality

Additional water quality data was analysed and incorporated into previous water quality assessments. The main findings include:

- Turbidity, pH, temperature, and salinity are relatively uniform with depth at all tidal events during both neap and spring tidal conditions suggesting a well-mixed, high energy environment;
- Turbidity, pH and salinity are higher during spring tidal condition compared to that during the neap tidal condition;
- All nitrogen species at all sites of interest were not detected at concentrations greater than the detection limit of the analysis, however, it should be noted the detection limits of instruments for all nitrogen constituents were greater than the project water quality criteria;
- Phosphorus concentrations including total phosphorus and filterable reactive phosphorus at all sites of interest were not detected at concentrations greater than the detection limit of the analysis. It should be noted the detection limit of analysis for FRP was greater than the project water quality criteria;
- The data collected in March 2010 indicates higher levels of metals, nitrogen, phosphorus and organic carbon than the data collected in August 2012. This is likely due to inflows of nutrients from surrounding catchments prior to the March 2010 monitoring event; and
- When metals were detected, they were present in higher concentrations during spring tide condition compared to those present in neap tide condition.

The discharge of fresh hydrostatic test water at Boatshed Point was assessed, and the near field modelling results indicate the following:

- Rapid initial dilution was achieved for all scenarios within a short distance of the outfall. For all scenarios, a minimum dilution factor of approximately 40 was achieved at a distance no greater than 10m from the outfall;
- In the instances of all 10th percentile (low) ambient velocity scenarios, a dilution factor of 60 or greater was achieved in more than 7m from the outfall;
- In the case of the 50th percentile (median) and 90th percentile (high) ambient velocities, the plumes were advected downstream tens of metres from the outfall and achieved dilution factors of 200 or greater, with dilution factors at 10m typically 40 or greater;
- Due to the rapid initial dilution for all scenarios, salinities quickly returned to within the ambient ranges observed during the 2 monitoring events; and
- Overall, the discharge will likely not result in significant impact because the quantity of the discharge is very small relative to the total tidal exchange within the system and the receiving environment is high-energy and well-mixed. Salinities are expected to return to within observed ranges for the location within a short distance and time away from the outfall.

There is no change to the proposed discharge of brine from the reverse osmosis process during operations, therefore the analysis presented in the original EIS remains valid.

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1 INTRODUCTION

1.1 Background

The Environmental Impact Statement (EIS) for the Arrow LNG Plant Project was published in March 2012. Since that time the project has undergone further planning and design work, and changes to the project design have resulted in the need to identify potential changes to the original coastal processes, hydrodynamics and water quality impact assessment (BMT WBM, 2011a).

1.2 Relevant Changes to the Project Description

The main changes to the project description which have the potential to affect the coastal process and water quality impact assessment include:

- Modifications to the layout and dredging requirements near Boatshed Point, and addition of a swing basin;
- A slight increase in dredging volume requirements at the LNG Jetty;
- Modifications to the layout of the marine facilities at the Launch Site 1 on the Calliope River;
- A revised footprint for the mainland tunnel entrance site, with new access arrangements; and
- Hydrostatic test water is now proposed to be discharged at Boatshed Point via the outfall with a volume of approximately 125,000m^3 per tank.

As described in the EIS, dredging is required to facilitate both construction and operation. Changes to the estimated maximum dredge volumes used in the EIS are shown in Table 2. The figures referenced in the table show the combined in-situ volumes of construction and operation dredging, hence the largest volume envisaged to be dredged at this point in time. These volumes may change as a result of the detailed engineering and construction planning that will take place in the next phase of the project.

Table 1   Summary of EIS and Revised Dredge Volume Requirements

Marine Infrastructure	Design Dredge Level	Estimated Maximum Dredge Volume (m^3) From EIS	Revised Estimated Maximum Dredge Volume (m^3)
Launch Site 1 Calliope River	-5m LAT	900,000	900,000
Launch Site 4N (Western Basin Reclamation Area)	-5m LAT	2,500	2,500
Boatshed Point MOF and integrated passenger jetty	-2.5 m to -3.5 m LAT	50,000	148,000
Boatshed Point MOF access channel and swing basin	-8m LAT	N/A	165,000
Hamilton Point South MOF and passenger jetty (option)		50,000	Option discontinued
LNG jetty	-5.5 m LAT	120,000	131,000

The relevant changes to the infrastructure and dredging works proposed for the Materials Offloading Facility (MOF), mainland launch site, LNG jetty, and mainland tunnel entrance are discussed below.

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LEGEND

Watercourse

Arrow LNG Plant infrastructure

Project area

Proposed Arrow LNG Plant dredge extent

Proposed LNG plant layout

Proposed feed gas pipeline

Land tenure

Arrow LNG Plant site boundary

Gladstone LNG Project (Santos/Petronas/Total/KOGAS allotment)

Gladstone Ports Corporation

Curtis Island Corridor Sub-Precinct

Vine forest area

Shipping channels and dredging

Proposed Boatshed Point access channel

Existing channels, swing basins and berths

Wiggins Island Coal Terminal

Western Basin Dredging and Disposal Project

Curtis Island

Tunnel reception shaft

LNG loading lines

North China Bay

Reclamation area

Proposed LNG jetty

GLNG pioneer landing

Boatshed Point

Proposed haul road

Hamilton Point

Garden Island

GLNG MOF

GLNG pioneer MOF

Swing basin

Proposed Boatshed Point MOF and integrated personnel jetty

Proposed tunnel

Port Curtis

GAWB landing

Tide Island

Witt Island

N

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Arrow LNG Plant

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LNG plant and associated infrastructure

Figure No: 1

LEGEND

Road
Watercourse
Railway

Arrow LNG Plant infrastructure
Proposed infrastructure
Project area
Proposed feed gas pipeline
Proposed Central Queensland Pipeline
Proposed Arrow Surat Pipeline

Shipping channels and dredging
Proposed access channel
Existing channels, swing basins and berths
Wiggins Island Coal Terminal
Western Basin Dredging and Disposal Project

Land tenure
Gladstone LNG Project Fishermans Landing LNG Ltd
Queensland Curtis LNG Project (QCLNG) Queensland Gas Company
Common infrastructure allotment Minister for Industrial Development
Australia Pacific LNG Project (APLNG) Origin Energy/ConocoPhillips
Gladstone LNG Project (GLNG) Santos/Petronas/Total/KOGAS
Gladstone Ports Corporation
Western Basin Reclamation Area

Potential launch site 4N

Proposed LNG jetty

Curtis Island

Ship Hill

Proposed LNG plant site

Potential early works bulk materials launch site

North China Bay

Fishermans Landing

Boatshed Point

Proposed MOF and personnel jetty

Potential accommodation facility and laydown area (TWAF 8)

Hamilton Point

Proposed Boatshed Point access channel

Mount Larcom

Boat Creek

Proposed tunnel

Port Curtis

Proposed 132 kV power cables (installed by HDD)

Proposed Calliope River access channel

RG Tanna Coal Terminal

Proposed tunnel launch site and tunnel spoil disposal area

Auckland Point Wharves

Proposed launch site 1 and access road

Gladstone–Mount Larcom Road

Yarwun

Proposed carparking, staging and laydown area (TWAF 7)

Gladstone

Potential carparking, staging and laydown area, and accommodation facility (Red Rover Road)

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In the following section the various facilities and dredge volumes are described. It should be noted that these volumes and configuration may change as a result of detailed engineering that will be carried out in the next phase of the project.

Boatshed Point MOF (and dredge site 3)

The MOF will be located at Boatshed Point. This MOF facility will comprise five berths and associated facilities (including a ferry terminal area, passenger waiting terminal, and a laydown area). The proposed layout of the Boatshed Point is shown in Figure 1.

The main changes to the design of the MOF to those presented in the EIS include:

- Movement of the facilities further to the west;

- Provision of an additional linkspan berth;

- Movement of the passenger transfer facility from the east side to the west side of the facility, requiring it to be located to the north, behind the Ro-Ro berth;

- A change from piled concrete decks to a sheet piled earth filled structure; and

- Addition of a swing basin

Dredging requirements have increased at Boatshed Point to accommodate these changes. Additional dredging is required to establish the passenger terminal and some dredging may be required in the footprint of the MOF structure to remove soft compressible materials (totalling 148,000 m^3). Extra dredging will also be required in the access channel to the MOF to accommodate access by large module carriers and to establish the swing basin (165,000 m^3). The anticipated volume of dredging of in-situ material required for construction and operation of the Boatshed Point MOF is now 313,000 m^3, an increase from 50,000 m^3 in the EIS.

LNG Jetty (and dredge site 5)

The design of the LNG jetty is unchanged. Three construction methods are under consideration for the LNG jetty including ocean construction, land based construction and temporary causeway construction. The anticipated extent of dredging of in-situ material required for construction of the LNG jetty is now 131,000 m^3, an increase from 120,000 m^3 in the EIS.

Launch Site 1 (and dredge site 1)

The base case mainland launch site remains launch site 1 on the Calliope River. The arrangement of the marine facilities at launch site 1 has changed from the EIS as follows:

- An additional linkspan berth has been provided (now four berths);

- The material handling area at the berth has been enlarged; and

- The structure has been changed from a piled concrete deck structure to a sheet piled retaining structure.

The functionality of the passenger transfer facility has not changed. For the operational phase, the passenger transfer facility would still be required, however only one linkspan berth would be required.

The dredging requirements in the Calliope River for launch site 1 are the same as those presented in the EIS (900,000 m^3).

Mainland Tunnel Entrance

The footprint of the mainland tunnel entrance site has been revised with a new arrangement provided. The proposed layout of the tunnel site is shown in Figure 2. The area required to construct the tunnel and dispose of tunnel spoil has been reduced, and the site has been reconfigured from a 'T' shape to an 'L' shape.

Discharges from Boatshed Point

The supply of mains water to Curtis Island via a pipeline installed by GAWB and two sewer mains under Port Curtis to service the LNG plants on Curtis Island by Gladstone Regional Council (GRC) has provided an opportunity for direct supply of water and discharge of wastewater direct to the mainland and is now the base case for the project. The pipelines for category A and category B waste have been installed by HDD from RG Tanna Coal Terminal to Hamilton Point. The sewer mains are expected to have a capacity of 864 m^3 per day, which will be sufficient to meet peak construction demands for both the LNG plant and construction camp.

Hydrostatic test water will also be discharged at Boatshed Point via the outfall. The volume to be discharged is approximately 125,000 m^3 per tank. Two tanks will be built and tested in stage 1 (two train development) and it is likely that the hydrostatic test water will be transferred from LNG Tank 1 to LNG Tank 2 before discharge to Port Curtis. A third tank would be added during stage 2. Hydrostatic testing medium may be either seawater or freshwater, and will be carried out in accordance with API 620.

Arrow Energy will retain the option to develop onsite treatment of seawater using reverse osmosis and onsite treatment of wastewater and disposal via an outfall pipeline at Boatshed Point

1.3   Additional Information

Additional information was collected as part of the process of preparing the Supplementary Report to the EIS. This included:
- Geotechnical investigations in the areas to be dredged, including analysis of sediment samples;
- Further water quality sampling at project sites;
- Bathymetric data in the vicinity of Boatshed Point;
- A hydrographic survey of the Calliope River, which provided bathymetric data of the area of disturbance and the area to be affected by changes in tide levels; and
- LIDAR survey of topography in the immediate vicinity of project sites.

1.4   Technical Study Method

The implications of the changes outlined above have been investigated using a suite of numerical modelling tools which were developed by BMT WBM and validated using data collected in Port Curtis.

The additional data available has been analysed to provide more accurate inputs to the impact assessment process.

Detailed methodology adopted in each stage of the coastal processes and marine water quality assessment is presented in the following sections.

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2   COASTAL PROCESSES AND HYDRODYNAMICS

2.1   Changes to Marine Infrastructure and Dredging Requirements

2.1.1   Boatshed Point

2.1.1.1 Hydrodynamic Impacts of Marine Infrastructure

Due to changes in the proposed layout of marine facilities at Boatshed Point, the potential hydrodynamic impacts were reassessed. BMT WBM's existing TUFLOW-FV model of Port Curtis was used to investigate the changes to current patterns in the vicinity of Boatshed Point due to construction of the project. The hydrodynamic validation of the model is described in the report "Gladstone Harbour Numerical Modelling Calibration and Validation" (BMT WBM, 2011b).

The TUFLOW-FV model mesh was refined significantly in the vicinity of the proposed marine structures to increase the accuracy of the results, which included the incorporation of recent bathymetric survey data. Wind and water level boundary condition data was the same as that described in the original EIS (BMT WBM 2011a).

The existing bathymetry, the model mesh and the proposed arrangement of structures and dredged areas at Boatshed Point is presented in Figure 3. The Base Case for the purposes of the impact assessment is the same as the Base Case presented in the original EIS, which includes dredging associated with the Wiggins Island Coal Terminal, GLNG and QCLNG projects and the reclamation area (~390ha) to the north of Fishermans Landing. The Developed Case for the purposes of this impact assessment is the Base Case plus the structures and dredging associated with the proposed marine infrastructure at Boatshed Point (shown in Figure 3).
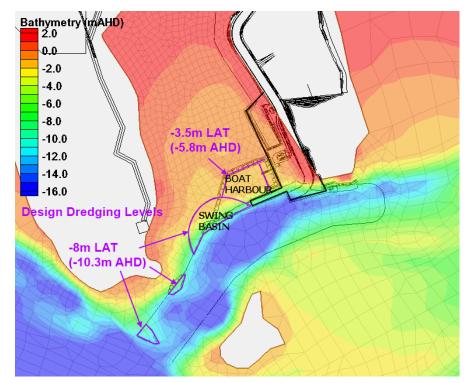
Figure 3 Existing Bathymetry and Proposed Marine Infrastructure at Boatshed Point

For the purposes of the hydrodynamic impact assessment, the TUFLOW-FV model was run the same two month assessment period used in the original EIS (February to March, 2009). Output is provided in terms of spatial plots of absolute velocities and impacts at around the time of peak flood and ebb tide flows (when impacts are greatest).

The modelled water levels at Fishermans Landing over the period and the times chosen for mapping and comparison purposes are presented in Figure 4. The period includes large spring tides and the times chosen relate to peak velocities in the area of interest.
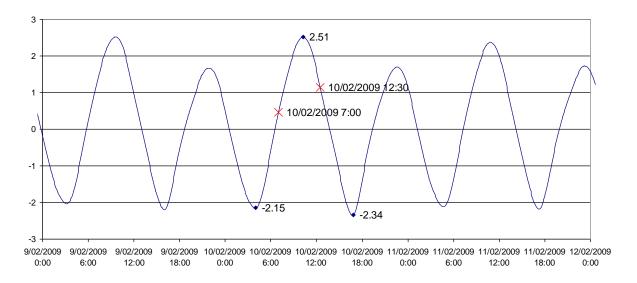
Figure 4 Velocity Comparison Times and Water Level at Fisherman's Landing Berth

Figure 5 shows the peak depth-averaged current magnitudes and directions during a flooding spring tide in the Base Case. Figure 6 illustrates the modified current magnitudes and directions during a flooding spring tide in the Developed Case. Figure 7 shows the change in the velocity magnitudes (Developed Case minus Base Case).

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Figure 5 Base Case Flood Spring Tide Velocity

Figure 6 Developed Case Flood Spring Tide Velocity

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Figure 7 Flood Spring Tide Velocity Difference

The modelling indicates that construction of the sheet-piled retaining structures adjacent to Boatshed Point results in localised changes to current patterns and magnitudes on flood tides. Within the new dredged areas in the swing basin and the boat harbour during a peak flooding spring tide, current magnitudes are reduced by up to 0.65m/s. There is an associated increase in current magnitudes on the mud flat to the north of the dredged area of up to 0.33m/s. While the modelled decrease in velocity magnitudes is larger than that described in the original EIS (0.5m/s), the impacts occur over a similarly small area (adjacent to project infrastructure). Therefore the significance of the impact is minor, as per the original EIS findings.

Figure 8 shows the peak depth-averaged current magnitudes and directions during an ebbing spring tide in the Base Case. Figure 9 illustrates the modified current magnitudes and directions during an ebbing spring tide in the Developed Case. Figure 10 shows the change in the velocity magnitudes (Developed Case minus Base Case).

Figure 8 Base Case Ebb Spring Tide Velocity

Figure 9 Developed Case Ebb Spring Tide Velocity

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Figure 10   Ebb Spring Tide Velocity Difference

The modelling indicates that construction of the sheet-piled retaining structures adjacent to Boatshed Point results in localised changes to current patterns and magnitudes on ebb tides. Within the new dredged areas in the swing basin and the boat harbour during a peak ebbing spring tide, current magnitudes are reduced by up to 0.9m/s. There is an associated increase in current magnitudes on the mud flat to the north of the dredged area of up to 0.23m/s. While the modelled decrease in velocity magnitudes is larger than that described in the original EIS (0.6m/s), the impacts occur over a similarly small area (adjacent to project infrastructure). Therefore the significance of the impact is minor, as per the original EIS findings.

2.1.1.2 Changes to Dredging Requirements

The dredge plume modelling methodology outlined in the original EIS involved modelling continuous dredging at each of the Arrow LNG Plant project sites for a two month period. The results of the modelling were presented as plots of depth-averaged above-background TSS. The maximum TSS was presented, as well as the TSS levels exceeded for 10% and 50% of the simulation period. Sediment deposition rates were also presented in units of metres per day.

The increase in volume at Boatshed Point from 50,000m^3 to 313,000m^3 implies that the dredging campaign will be approximately 6 times longer in duration (since the dredging methodology has not changed). If a 500m^3/h CSD was used, operating for 24 hours per day, the dredging campaign would now take approximately 26 days instead of 4.2 days. If a backhoe dredge with a production rate of 250m^3/h was used, the dredging campaign would take 52 days instead of 8.3 days.

Since the proposed dredging methodology has not changed, the original modelling remains valid for prediction of dredge plume impacts. In order to obtain results for the revised dredging volumes, the original plume modelling results need to be interpreted using the new estimated dredging campaign duration. For example, if a backhoe dredge is to be used and the campaign duration is 52 days, the level of TSS exceeded for 10% of the dredging campaign is the level that is exceeded for approximately 5.2 days out of the total 52 day campaign. Likewise, the total dredged sediment accumulation (i.e. deposition in addition to any natural deposition) is the deposition rate in metres/day multiplied by the dredging campaign duration of 52 days. The maximum above-background plume TSS is the same regardless of the dredging duration, since those plots represent the maximum extent and magnitude of dredge plumes that can be expected for any tidal condition. The cumulative impact of dredging for a longer period (and therefore releasing more sediment in total) is not considered significant for the relatively small volumes involved here due to the tendency for dredged sediment to settle out and mix with natural sediment during the quiescent neap tide periods.

Geotechnical information provided to BMT WBM indicates that the sediments to be dredged are predominantly silts and clays, which is consistent with the assumptions in the plume dispersion assessment presented in the original EIS.

The modelled maximum above-background plume concentration from the original plume dispersion assessment for the Boatshed Point dredging operation is shown in Figure 11. The modelled rate of sediment deposition during the Boatshed Point dredging operation is shown in Figure 12.

Figure 11   Boatshed Point Dredging - Maximum Above-Background Depth Average Plume TSS Concentration

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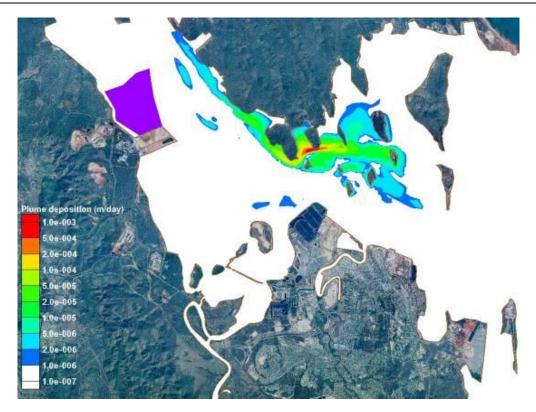
Figure 12   Boatshed Point Dredging - Average Plume Deposition Rate

2.1.2 Launch Site 1

2.1.2.1 Hydrodynamic Impacts of Marine Infrastructure

Due to changes in the proposed layout of marine facilities at Launch Site 1 (and the incorporation of sheet piled structures), the potential hydrodynamic impacts were reassessed. BMT WBM's existing TUFLOW-FV model of Port Curtis was used to investigate the changes to current patterns in the Calliope River due to construction of the project. The hydrodynamic validation of the model is described in the report "Gladstone Harbour Numerical Modelling Calibration and Validation" (BMT WBM, 2011b).

The TUFLOW-FV model mesh was refined significantly in the vicinity of the proposed marine structures to ensure accurate results. New bathymetric survey data was incorporated into the development of the model mesh. Wind and water level boundary condition data was the same as that described in the original EIS (BMT WBM 2011a).

The existing bathymetry, the model mesh and the proposed arrangement of structures and dredged areas at Launch Site 1 is presented in Figure 13. The Base Case for the purposes of the impact assessment is the same as the Base Case presented in the original EIS, which includes dredging associated with the Wiggins Island Coal Terminal, GLNG and QCLNG projects and the reclamation area (~390ha) to the north of Fishermans Landing. The Developed Case for the purposes of this impact assessment is the Base Case plus the structures and dredging associated with the proposed marine infrastructure at Launch Site 1 (shown in Figure 13). The modelled dredged volume is the maximum volume anticipated and where possible shallower draught tugs and barges will be used to reduce the required dredge volume.
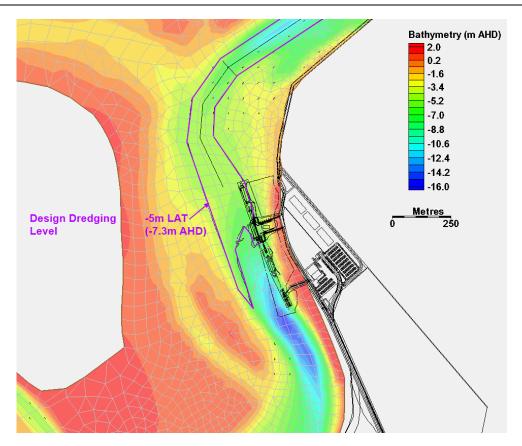
Figure 13   Existing Bathymetry and Proposed Marine Infrastructure at Launch Site 1

For the purposes of the hydrodynamic impact assessment, the TUFLOW-FV model was run the same two month assessment period used in the original EIS (February to March, 2009). Output is provided in terms of spatial plots of absolute velocities and impacts at around the time of peak flood and ebb tide flows.

Figure 14 shows the peak depth-averaged current magnitudes and directions during a flooding spring tide in the Base Case (pre dredging). Figure 15   illustrates the modified current magnitudes and directions during a flooding spring tide in the Developed Case (post dredging). Figure 16 shows the change in the velocity magnitudes (Developed Case minus Base Case).
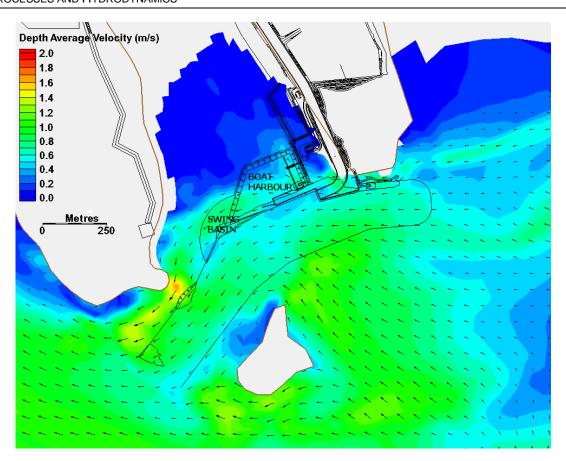
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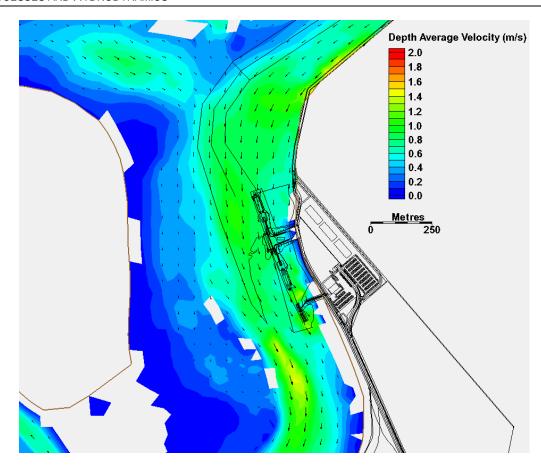
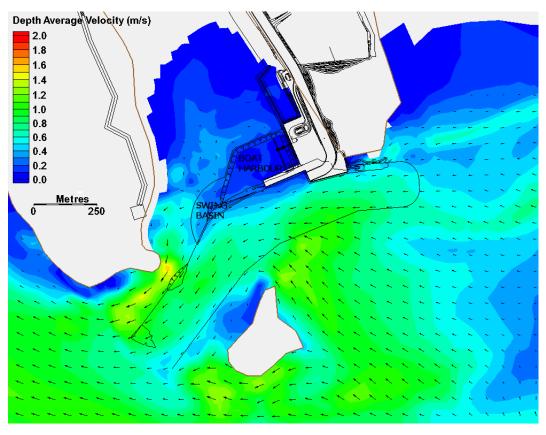**Figure 14   Base Case Flood Spring Tide Velocity**
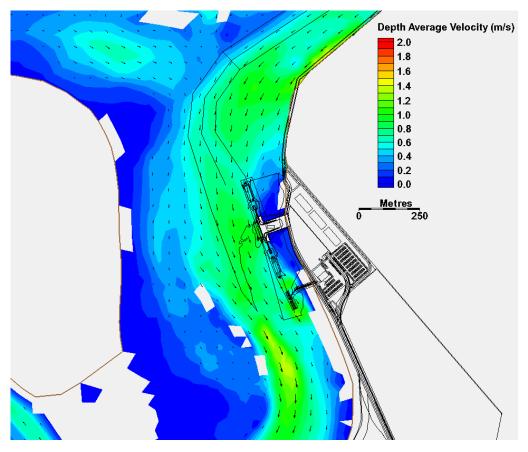
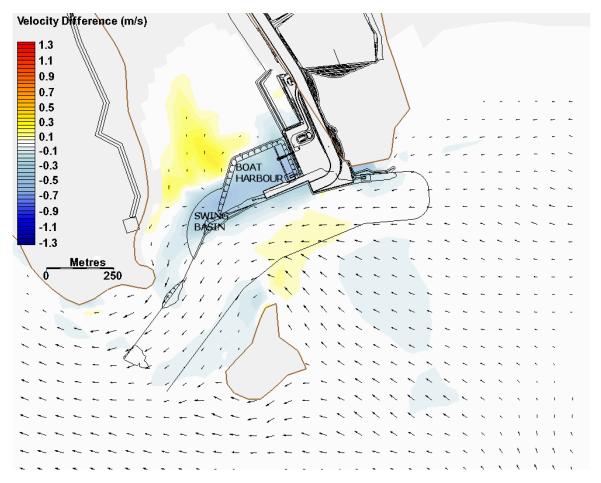**Figure 15   Developed Case Flood Spring Tide Velocity**

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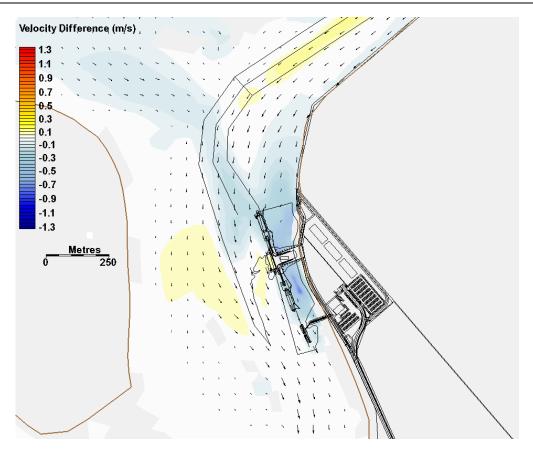
Figure 16   Flood Spring Tide Velocity Difference

The modelling indicates that construction of the sheet-piled retaining structures in the Calliope River at Launch Site 1 results in localised changes to current patterns and magnitudes on flood tides. Immediately downstream and upstream of the structures during a peak flooding spring tide, current magnitudes are reduced by up to 0.85m/s. There is a corresponding increase in the current magnitudes in the main river channel of up to 0.11m/s. Since no impermeable structures were proposed in the original EIS, these impacts were not previously assessed. The significance of the impact is considered minor since the change in velocities is confined to a relatively small area adjacent to project infrastructure.

Figure 17 shows the peak depth-averaged current magnitudes and directions during an ebbing spring tide in the Base Case (pre dredging). Figure 18 illustrates the modified current magnitudes and directions during an ebbing spring tide in the Developed Case (post dredging). Figure 19 shows the change in the velocity magnitudes (Developed Case minus Base Case).
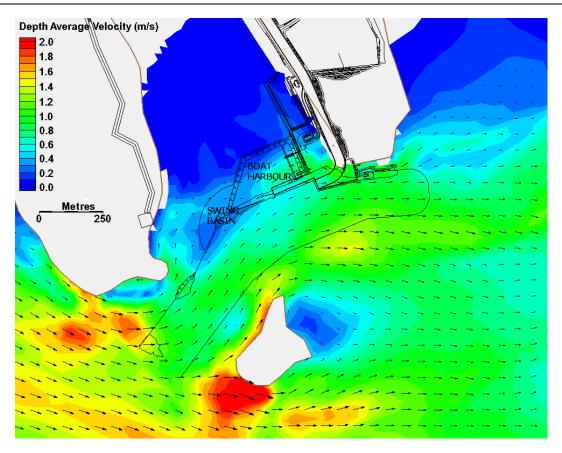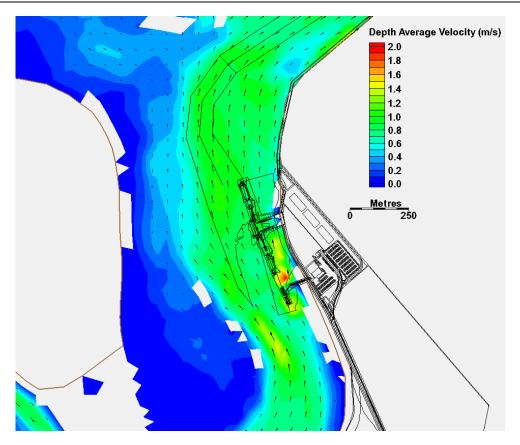
Figure 17   Base Case Ebb Spring Tide Velocity

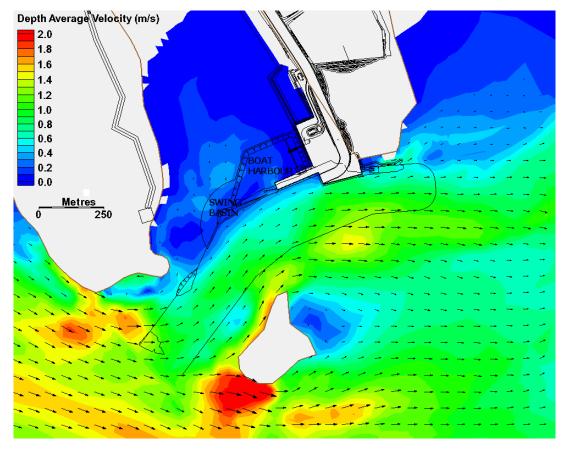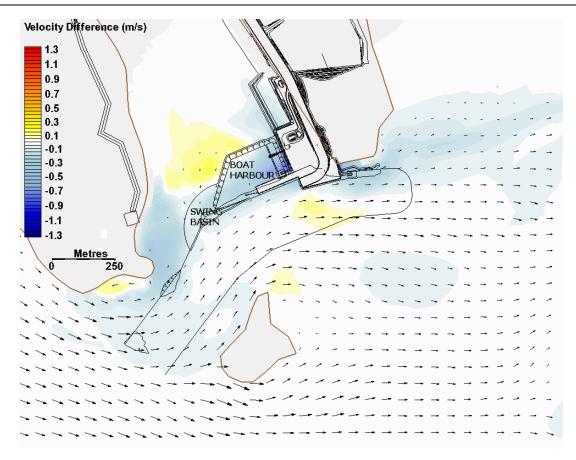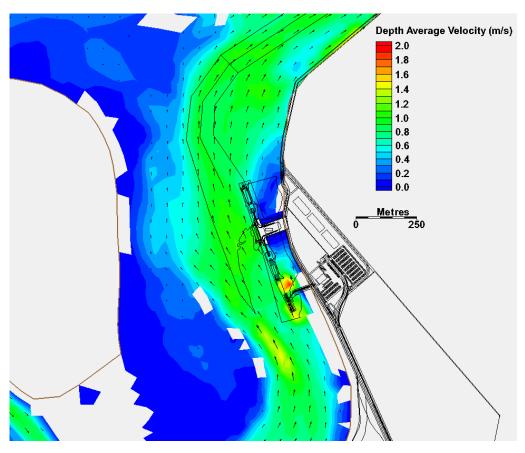**Figure 18   Developed Case Ebb Spring Tide Velocity**

BMT WBM
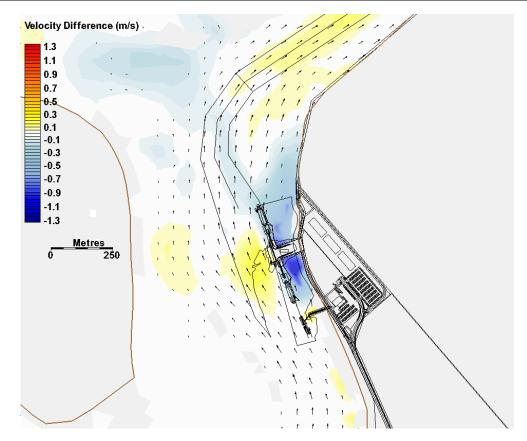
Figure 19   Ebb Spring Tide Velocity Difference

The modelling indicates that construction of the sheet-piled retaining structures in the Calliope River at Launch Site 1 results in localised changes to current patterns and magnitudes on ebb tides. Immediately downstream and upstream of the structures during a peak ebbing spring tide, current magnitudes are reduced by up to 1.24m/s. There is a corresponding increase in the current magnitudes in the main river channel of up to 0.24m/s. Since no impermeable structures were proposed in the original EIS, these impacts were not previously assessed. The significance of the impact is considered minor since the change in velocities is confined to a relatively small area adjacent to project infrastructure.

2.1.2.2 Changes to Dredging Requirements

The total volume to be dredged in the Calliope River has not changed so the assessment of likely plume impacts presented in the original EIS remains unchanged. Geotechnical information provided to BMT WBM indicates that the river bed sediments are predominantly sandy, with low clay and silt content. Therefore the turbidity estimates presented in the original EIS are likely to be conservative due to the assumption of a larger proportion of fine material in those assessments. Updating the bathymetry to include recent survey data would have negligible effect on the modelling results.

The modelled maximum above-background plume concentration from the original plume dispersion assessment for the Calliope River dredging operation is shown in Figure 20 (for dredging near Launch Site 1) and Figure 21 (for dredging at the mouth of the river). The modelled rate of sediment deposition during the Boatshed Point dredging operation is shown in Figure 22 (for dredging near Launch Site 1) and Figure 23 (for dredging at the mouth of the river).
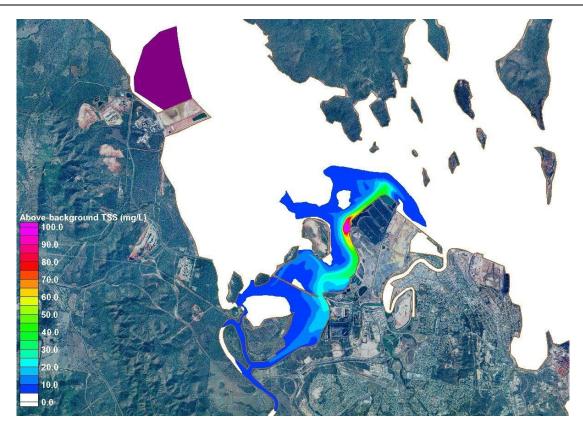
Figure 20   Calliope River Dredging (Near Launch Site 1) - Maximum Above-Background Depth Average Plume TSS Concentration

Figure 21   Calliope River Dredging (Near Mouth) - Maximum Above-Background Depth Average Plume TSS Concentration
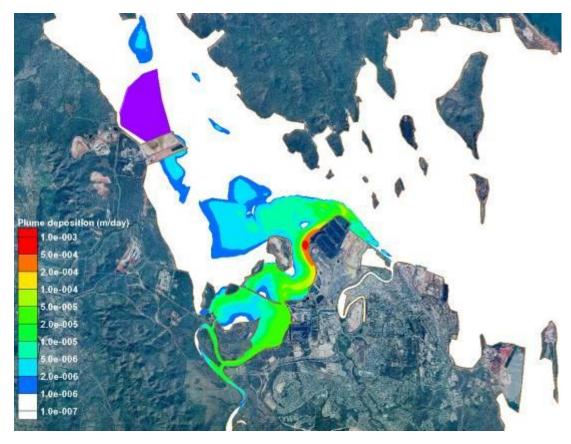
Figure 22   Calliope River Dredging (Near Launch Site 1) - Average Plume Deposition Rate
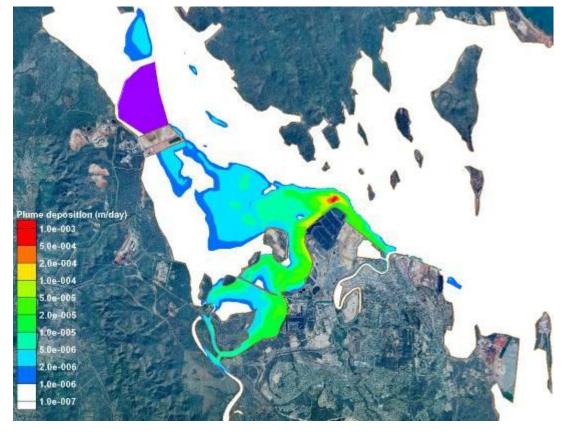
Figure 23   Calliope River Dredging (Near Mouth) - Average Plume Deposition Rate

2.1.3 Mainland Tunnel Entrance Site

Additional detailed LIDAR topographic data was obtained in the vicinity of the proposed tunnel entrance site, which enables a more detailed assessment of the potential for reduction in tidal storage due to construction.

Figure 24 shows the topography in the vicinity of the proposed tunnel entrance site. The proposed area to be raised above the level of the existing tidal flat is enclosed by the black lines. The elevation of the existing ground around the perimeter of the site is shown in Figure 25.
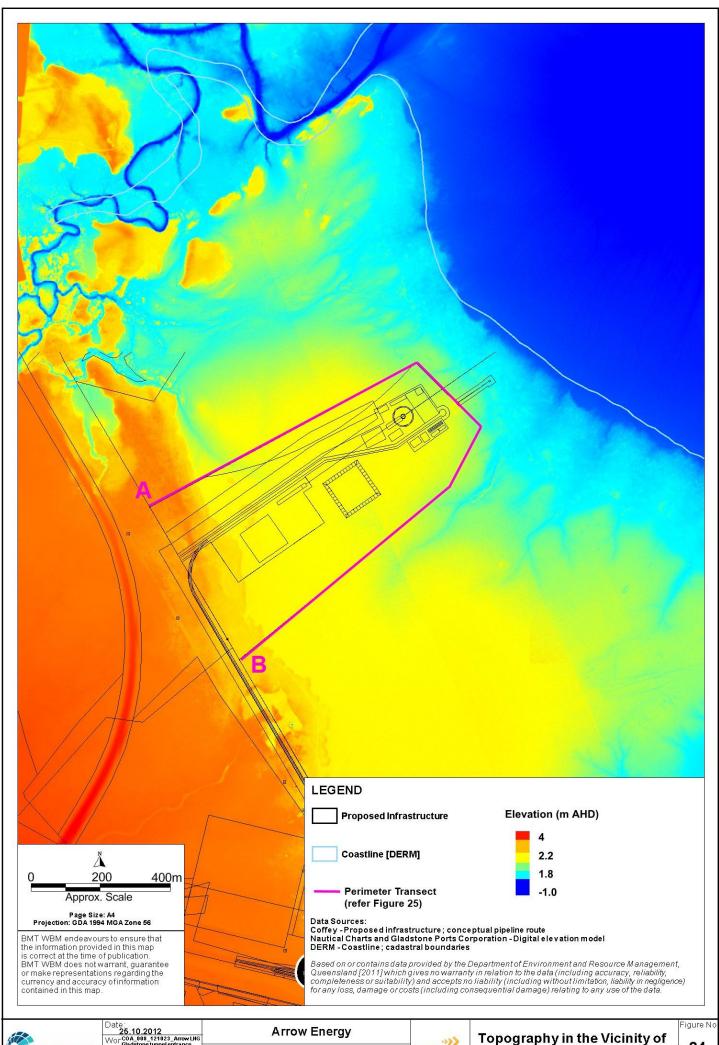
The existing ground elevation around the perimeter of the tunnel entrance site is predominantly between 2.0 and 2.25m AHD. Analysis of the TUFLOW-FV model results for a 12 month simulation (July 2009 to June 2010) reveals that the water level in the adjacent part of Port Curtis is lower than 2.0m for over 98.5% of the simulation period. Therefore the tidal storage available due to construction of the tunnel entrance facilities is reduced for a very small percentage of the time (equivalent to a total of 5.5 days over a 12 month period). The tidal storage area will only be reduced during periods of large tidal amplitude, and since the existing maximum depth of inundation is less than 0.7m at Highest Astronomic Tide (HAT), the total volumetric reduction is small in the context of the total Port Curtis tidal storage volume. Refer to Table 2 for the tidal plane elevations at nearby Fishermans Landing. It is therefore considered that the construction of the tunnel entrance facilities will have negligible impact on the hydrodynamics and coastal processes of Port Curtis. The extent of the impact was not assessed quantitatively in the original EIS so no comparison can be made with the original assessment.

Table 2   Gladstone Region Tidal Planes (m AHD)

Tidal Plane	Gladstone (Standard Port)	Fishermans Landing
Latitude	-23° 50' S	-23° 47' S
Longitude	151° 15' E	151° 11' E
Highest Astronomical Tide (HAT)	2.562	2.69
Mean High Water Springs (MHWS)	1.692	1.77
Mean High Water Neaps (MHWN)	0.842	0.87
Mean Level (ML)	0.072	-0.02
Australian Height Datum (AHD)	0	0
Mean Low Water Neaps (MLWN)	-0.698	-0.77
Mean Low Water Springs (MLWS)	-1.548	-1.67
Lowest Astronomical Tide (LAT)	-2.268	-2.43

Note: Figures from Queensland Tide Tables 2010 (MSQ, 2009)

A

B

0   200   400m
Approx. Scale

Page Size: A4
Projection: GDA 1994 MGA Zone 56

LEGEND

Proposed Infrastructure

Coastline [DERM]

Perimeter Transect
(refer Figure 25)

Elevation (m AHD)

4
2.2
1.8
-1.0

Data Sources:
Coffey - Proposed infrastructure; conceptual pipeline route
Nautical Charts and Gladstone Ports Corporation - Digital elevation model
DERM - Coastline; cadastral boundaries

Based on or contains data provided by the Department of Environment and Resource Management, Queensland [2011] which gives no warranty in relation to the data (including accuracy, reliability, completeness or suitability) and accepts no liability (including without limitation, liability in negligence) for any loss, damage or costs (including consequential damage) relating to any use of the data.

Figure 25   Ground Elevation Around the Perimeter of the Tunnel Entrance Site

2.1.4 Other Potential Changes to Hydrodynamics and Coastal Process Assessments

The coastal processes assessment presented in the original EIS remains valid for other Arrow LNG Plant project sites.

The increase in dredging volume at the LNG Jetty will not affect the predictions of plume advection and dispersion presented in the EIS document, provided allowance is made for a proportional increase in the duration of the dredging campaign. Since the dredging volume has increased by approximately 9%, the total deposition thickness will increase by the same percentage.

The wave climate impact assessment presented in the original EIS remains valid, since no major changes have been made to the large-scale LNG swing basin dredging footprint.

The shoreline process assessment for the LNG Jetty site presented in the original EIS remains valid, since no major change is proposed to the design of the structure. The shoreline process assessment at Boatshed Point is also generally valid, although the description of likely siltation processes has been superseded by the assessment presented in 2.1.5.

The tidal flushing assessments presented in the original EIS remain valid since no broad-scale changes have been made to the project design.

2.1.5 Sedimentation Assessments

BMT WBM's existing TUFLOW-FV model of Port Curtis was used as the basis for an investigation into the potential for siltation of fine sediments at the Boatshed Point MOF and integrated passenger jetty and near the proposed Launch Site 1 in the Calliope River.

2.1.5.1 Model Setup

The hydrodynamic validation of the model is described in the report "Gladstone Harbour Numerical Modelling Calibration and Validation" (BMT WBM, 2011b). The BMT WBM SWAN spectral wave model was used to provide wave input to the resuspension calculations within TUFLOW-FV.

The model's ability to simulate the natural resuspension of sediment by the action of waves and currents was validated by running the model for the period February to April 2011 (prior to the commencement of the new Western Basin bund construction and dredging) and comparing the model results with measured turbidity at 11 locations in Port Curtis (shown in Figure 26).

BMT WBM
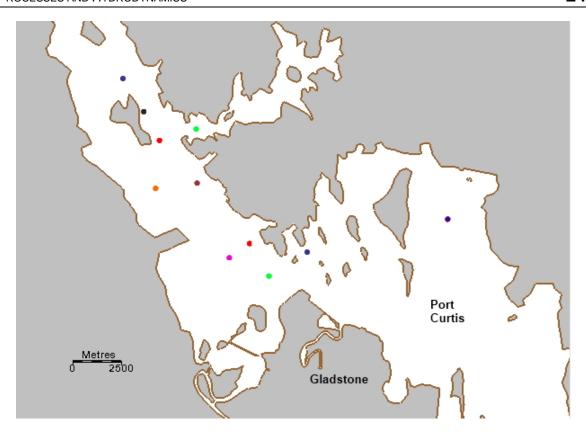
Figure 26   Turbidity Measurement Locations (Coloured Dots)

The cohesive sediment module of TUFLOW-FV simulates the exchange of sediments between the bed and the water column. Various options are available for specifying the erosion and deposition behaviour of suspended sediments. Only those options used in the resuspension model are described below.

The effective clear water sediment settling velocity, w_s, is directly specified and is assumed to have no dependence on either suspended sediment concentration (e.g. flocculation or hindered settling). The modelled rate of sediment deposition is a function of the depth-averaged sediment concentration (*TSS*), the still-water fall velocity (w_s) and the bed shear stress (τ_b), according to the relationship:

$$Q_d = w_s.TSS.\max\left(0, 1 - \frac{\tau_b}{\tau_{cd}}\right)$$

where τ_{cd} is a model parameter defining the critical shear stress for deposition. As such, sediment settling is reduced below its still water value by the action of bed shear stress and associated vertical mixing in the water column. The rate of erosion is calculated according to:

$$Q_e = E.\max\left(0, \frac{\tau_b}{\tau_{ce}} - 1\right)$$

where Q_e is the erosion rate, E is the erosion rate constant and τ_{ce} is the critical bed shear stress for erosion. Once the sediment is entrained in the water column, an Elder type model is used to represent the variation of horizontal dispersion with flow conditions:

$$D_l = K_l u_* h; \; D_t = K_t u_* h$$

where D_l is the dispersion coefficient in the direction of the flow advection, u_* is the friction velocity, h is the depth, D_t is the transverse dispersion coefficient and K_l, K_t are scaling coefficients. Based on a

BMT WBM

WBM dye release study conducted in Port Curtis several years ago, values of K_l=60 and K_t=6 were adopted in current study.

The existing distribution of fine sediment within Port Curtis was approximated in the model by running a "warmup" simulation. This simulation was run with an initial condition of a uniform thickness of fine sediment throughout the model, allowing redistribution of the sediment to occur such that energetic parts of the model (e.g. the main channels) had sediment removed from the bed while sediment accumulated in other parts of the model (e.g. mud flats). Use of a model that was not "warmed up" would result in resuspension predictions that are incorrectly dominated by erosion from zones that are unlikely to harbour mobile fine sediments.

Comparison of the measured and modelled turbidity from a series of calibration runs using three sediment fractions ($w_s = 1.0 \times 10^{-2}$, $w_s = 5.0 \times 10^{-3}$ and $w_s = 2.0 \times 10^{-4}$ m/s) led to the choice of the following parameters for the subsequent impact assessment:

$$\tau_{ce} = 0.2 \text{ N/m}^2 \quad \tau_{cd} = 0.1 \text{ N/m}^2 \quad E = \{5 \text{ (channels); } 0.1 \text{ (flats)}\}$$

The adopted parameter sets are well within the accepted literature ranges.
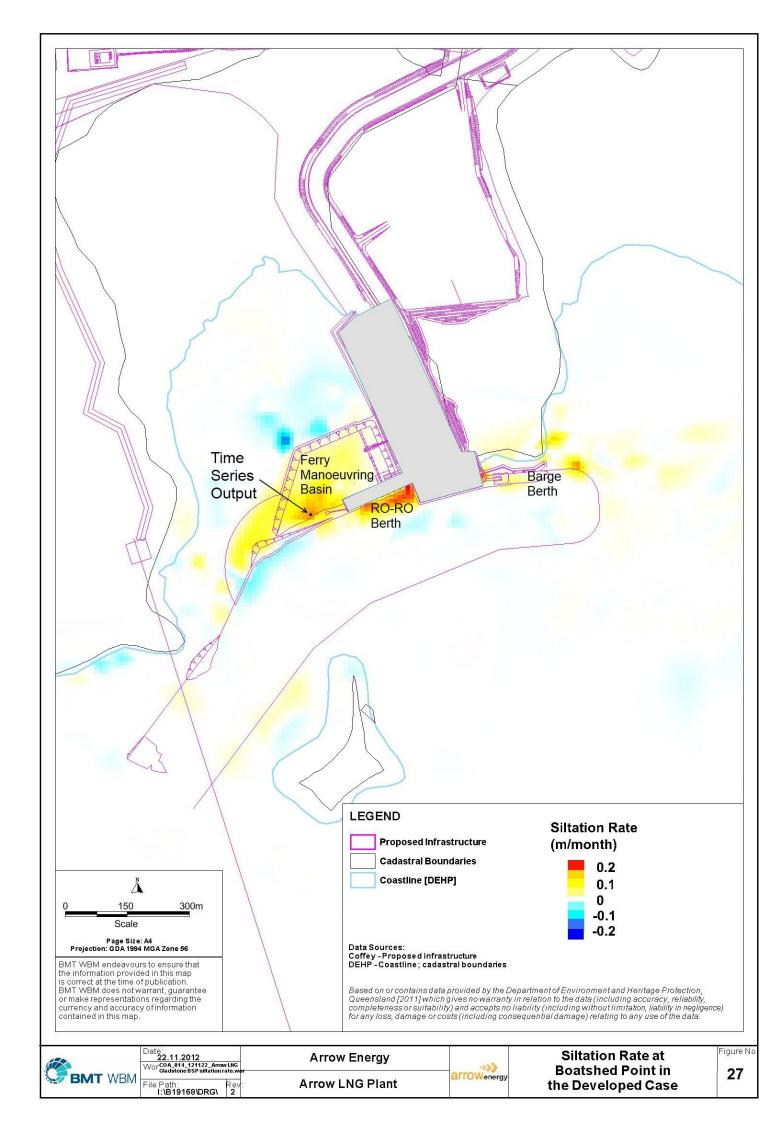
2.1.5.2 Siltation of Fine Sediment
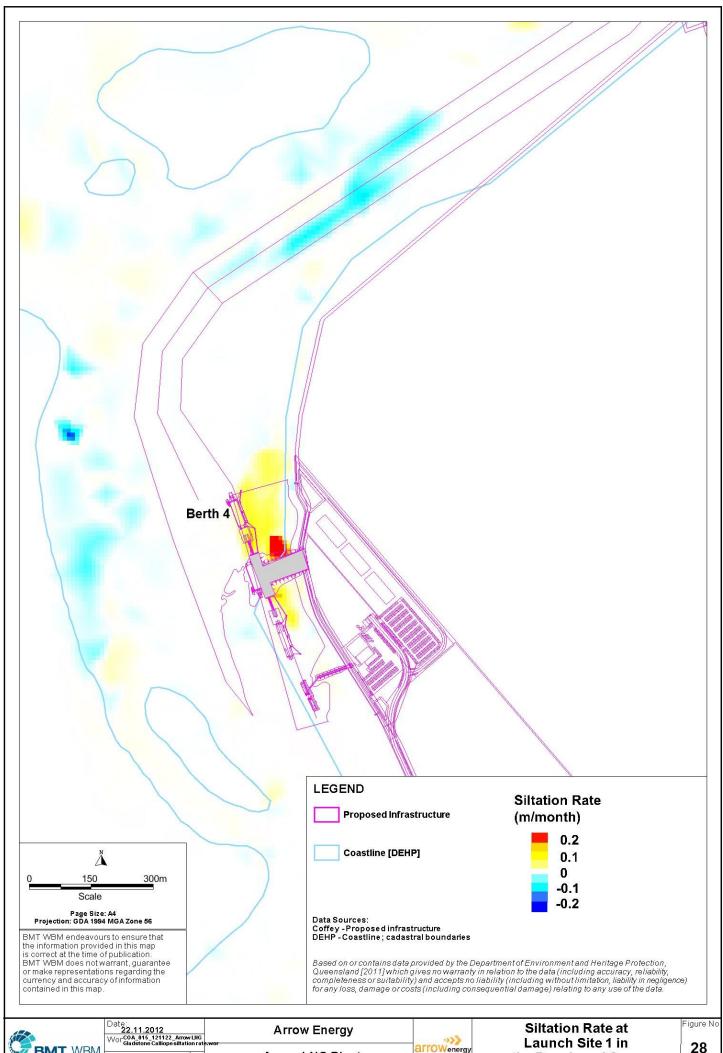
The rates of siltation of fine sediment at the Boatshed Point MOF and integrated passenger jetty and in the Calliope River (after construction is complete) were estimated by calculating the change in bed elevation for the Developed Case during the two month assessment period. The modelled rate of siltation (in metres per month) in the vicinity of each site is shown in Figure 27 and Figure 28.

In the vicinity of the Boatshed Point MOF and integrated passenger jetty, the model indicates that fine sediment is likely to accumulate in the proposed ferry manoeuvring basin, near the RO-RO berth and also near the barge berth to the east of the proposed structures. The proposed manoeuvring basin is in an area which is currently a mud flat, with generally low bed shear stresses, so sediment accumulation in this area is to be expected. The RO-RO berth and the barge berth are in the lee of the proposed structure and the reduced current velocity in these areas cause sediment deposition. The rate of siltation indicated by the model is up to 0.14m/month in the manoeuvring basin and up to 0.2m/month near the RO-RO berth. These numbers are highly approximate and should be taken as indicative only due to uncertainty in modelling assumptions and limited model validation. Allowance should be made for rates that are higher or lower by a factor of 2. The bed shear stress and Total Suspended Solids (TSS) time series output at a point in the ferry manoeuvring basin (refer Figure 27) is shown in Figure 29. It is seen that the bed shear stress at that point is consistently lower than the assumed critical shear stress for erosion (0.2 N/m^2) in the Developed Case, leading to significant sediment accumulation in the model. The modelled level of TSS is consistent with measured data from the same period.

In the vicinity of the proposed Launch Site 1 on the Calliope River, the model indicates that fine sediment is likely to accumulate downstream and upstream of the proposed causeway, mostly outside the area of dredging. The maximum modelled siltation in a navigation area is in the vicinity of Berth 4, where the estimated rate is up to 0.06m/month. Again, these numbers are highly approximate and should be taken as indicative only due to uncertainty in modelling assumptions and limited model validation. Allowance should be made for rates that are higher or lower by a factor of 2.

BMT WBM

Time
Series
Output

Ferry
Manoeuvring
Basin

RO-RO
Berth

Barge
Berth

LEGEND

Proposed Infrastructure

Cadastral Boundaries

Coastline [DEHP]

**Siltation Rate
(m/month)**

0.2
0.1
0
-0.1
-0.2

Data Sources:
Coffey - Proposed infrastructure
DEHP - Coastline ; cadastral boundaries

*Based on or contains data provided by the Department of Environment and Heritage Protection,
Queensland [2011] which gives no warranty in relation to the data (including accuracy, reliability,
completeness or suitability) and accepts no liability (including without limitation, liability in negligence)
for any loss, damage or costs (including consequential damage) relating to any use of the data.*

N

0   150   300m

Scale

Page Size: A4
Projection: GDA 1994 MGA Zone 56

BMT WBM endeavours to ensure that
the information provided in this map
is correct at the time of publication.
BMT WBM does not warrant, guarantee
or make representations regarding the
currency and accuracy of information
contained in this map.

Berth 4

N

0   150   300m
Scale

Page Size: A4
Projection: GDA 1994 MGA Zone 56

BMT WBM endeavours to ensure that
the information provided in this map
is correct at the time of publication.
BMT WBM does not warrant, guarantee
or make representations regarding the
currency and accuracy of information
contained in this map.

Figure 29   Time Series of TSS and Bed Shear Stress

2.1.5.3 Sedimentation of Non-Cohesive Sand
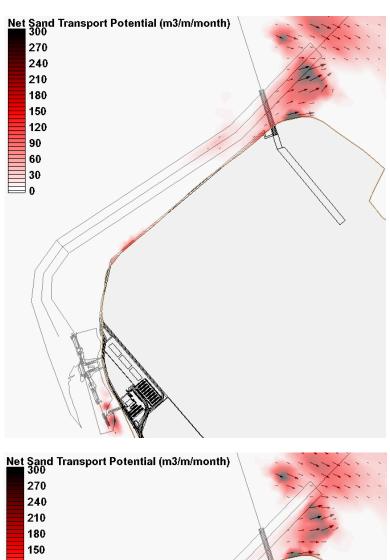
An assessment of potential changes in bed load transport of non-cohesive sand-size sediments due to proposed dredging was undertaken for the Calliope River estuary. Geotechnical information collected throughout the lower part of the estuary indicates that the dominant sediment fraction is sand (0.06-2mm diameter).

The model was run for both the Base Case and the Developed Case, and the net sand transport potential was calculated over a spring tide cycle for both cases. The potential for sand transport under tidal current action was estimated by applying the Meyer-Peter-Muller bed load formula (Nielsen, 1992) to the simulated hydrodynamic results. It should be noted that the sediment transport potential calculations assume that the bed is uniformly mobile with a sand sized sediment grain size of 1mm and hence do not account for the presence of non-erodable rocky outcrops. Sand transport potential fluxes have been calculated with units of m^3/m/month of bulk sand transport.

The top panel of Figure 30 shows the Base Case net sand transport potential. The shallow area at the mouth of the Calliope River has a large ebb-directed transport potential, indicating that this area is likely rocky (since otherwise a deeper channel would have formed).

The bottom panel of Figure 30 shows the Developed Case net sand transport potential. While the transport potential at the mouth of the Calliope is reduced, it is still ebb-directed and larger in magnitude than the sand transport potential within the dredged area and therefore will continue to encourage the export of sand from the Calliope into Port Curtis. Therefore, the model does not provide evidence that sedimentation of sand-sized sediment within the dredged area is likely to occur.
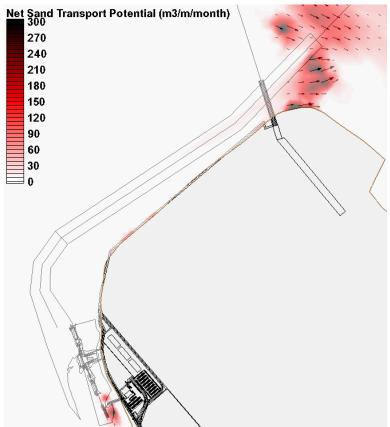
**Figure 30   Calliope Base Case (Top) and Developed Case (Bottom)
Net Sand Transport Potential**

2.2 Calliope River Tidal Changes

2.2.1 Model Development and Validation
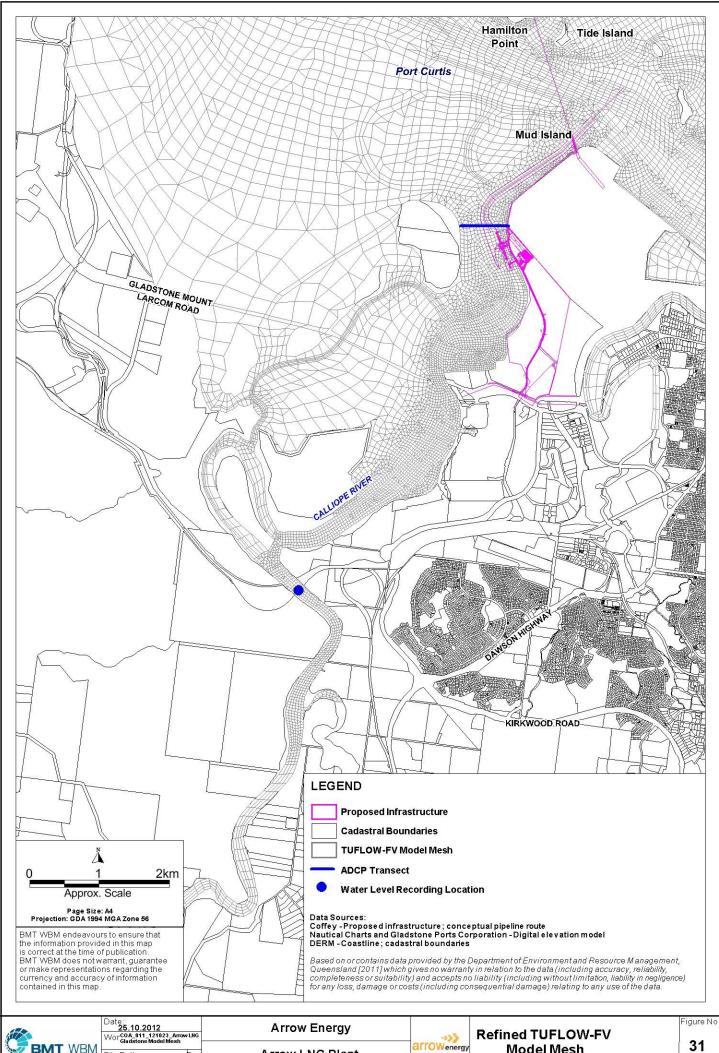
The TUFLOW-FV hydrodynamic model used in the original Arrow LNG Plant EIS was upgraded substantially to accommodate additional bathymetric data and to improve the accuracy of the impact assessment.

The model mesh was refined within the estuary of the Calliope River and detailed hydrographic survey data collected by Arrow Energy in 2012 and LIDAR data collected by the Queensland Government (2011) was combined to provide improved bathymetry. The refined model mesh is presented in Figure 31. The combined hydrographic survey and LIDAR bathymetric data is shown in Figure 32.
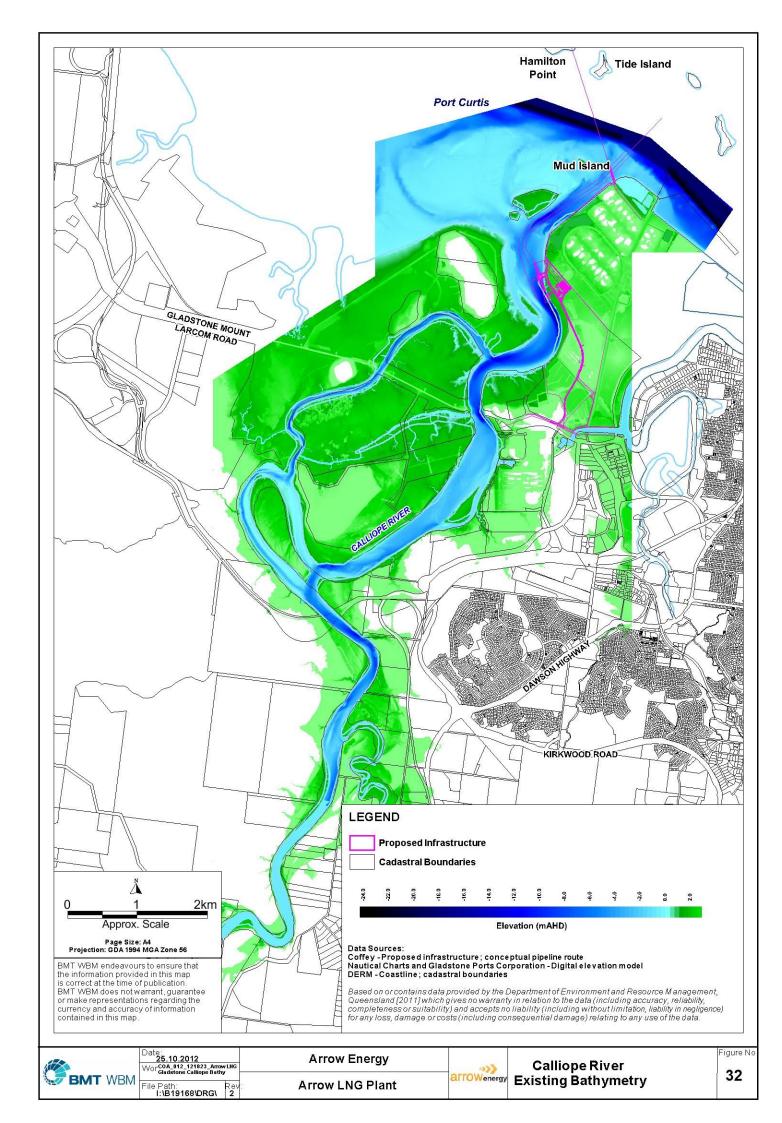
Water velocity data collected in 2006 using an Acoustic Doppler Current Profiler (ADCP) was used to validate the improved model. The location of the ADCP transect is shown in Figure 31. Comparisons of the modelled depth average velocity compared to the measurements are shown in Figure 33 and Figure 34. The agreement between the measurements and the model results is good, demonstrating that the model is sufficiently well calibrated.

Water level data recorded in 2006 at the location shown in Figure 31 was compared to model output for the same period. The agreement between modelled and measured water level was generally good, as shown in Figure 35 (the measured tidal range is within 3% of the measured range at the measurement location).

LEGEND

Proposed Infrastructure
Cadastral Boundaries
TUFLOW-FV Model Mesh
ADCP Transect
Water Level Recording Location

Port Curtis

Hamilton Point

Tide Island

Mud Island

GLADSTONE MOUNT LARCOM ROAD

CALLIOPE RIVER

DAWSON HIGHWAY

KIRKWOOD ROAD

0   1   2km
Approx. Scale

Page Size: A4
Projection: GDA 1994 MGA Zone 56

BMT WBM

Date: 25.10.2012
Wor COA_011_121023_Arrow LNG Gladstone Model Mesh
File Path: I:\B19168\DRG\
Rev: 2

Arrow Energy

Arrow LNG Plant

arrow energy

Refined TUFLOW-FV Model Mesh

Figure No
31

LEGEND

▭ Proposed Infrastructure

▭ Cadastral Boundaries

Elevation (mAHD)

Data Sources:
Coffey - Proposed infrastructure; conceptual pipeline route
Nautical Charts and Gladstone Ports Corporation - Digital elevation model
DERM - Coastline; cadastral boundaries

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0   1   2km
Approx. Scale

Page Size: A4
Projection: GDA 1994 MGA Zone 56

Date: 25.10.2012	Arrow Energy		Calliope River	Figure No
Wor COA_012_121023_Arrow LNG Gladstone Calliope Bathy		arrow energy	Existing Bathymetry	32
File Path: I:\B19168\DRG\	Rev: 2	Arrow LNG Plant		

BMT WBM

Figure 33   Modelled Depth Average Velocity (Black Lines) Compared to ADCP Measured Depth Average Velocity (Blue Lines)

BMT WBM
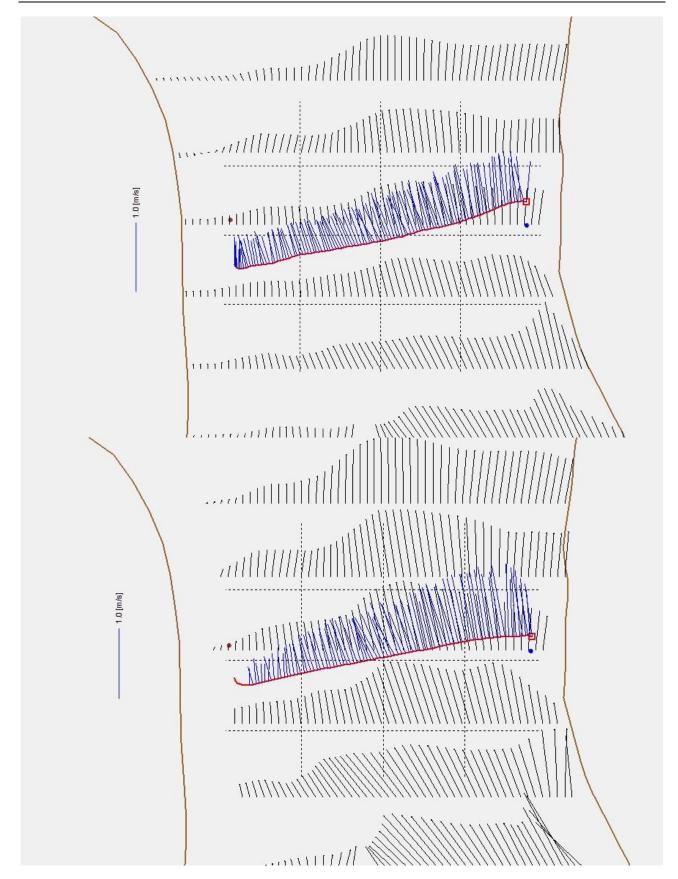
Figure 34   Modelled Depth Average Velocity (Black Lines) Compared to ADCP Measured Depth Average Velocity (Blue Lines)

BMT WBM
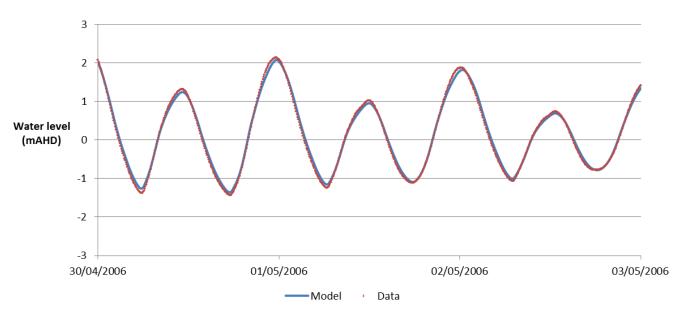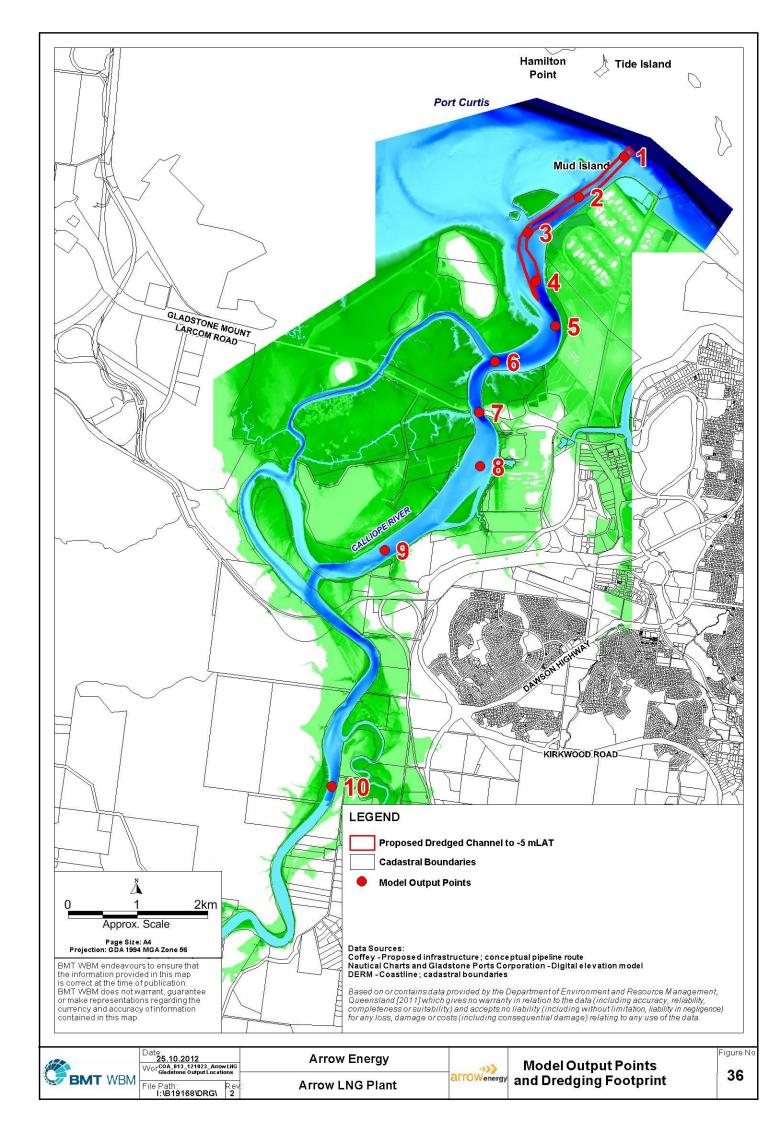
Figure 35   Measured Water Level (Red Dots) Compared to Modelled Water Level (Blue Line)

2.2.2   Modelling Scenarios

The enhanced TUFLOW-FV hydrodynamic model was used to assess in more detail the effects of dredging a channel in the Calliope River estuary from the proposed Launch Site 1 to the mouth of the river adjacent to Mud Island. The proposed dredging footprint and the modelling output locations along the Calliope River are shown in Figure 36. The channel is proposed to be dredged to -5mLAT (unchanged from the original EIS).

In order to assess hydrodynamic impacts, the water level outputs from a Base Case (corresponding to the Base Case described in the Arrow LNG Plant EIS) were compared to the outputs from a Developed Case (the Base Case plus the proposed dredging in the Calliope River). The model was run for a 12 month period from 1st July 2009 to 1st July 2010. Boundary conditions for the model were derived from measured wind velocities and water levels. The modelling timespan included several large amplitude spring tidal periods. Since the dominant driver of water levels in Port Curtis is astronomic tides, and the 12 month water level analysis presented here considered tidal forcing only (a flood study was carried out separately), any 12 month period is equally representative of the long term tidal hydrodynamics.

Hamilton
Point

Tide Island

Port Curtis

Mud Island

1

2

3

4

5

6

7

8

CALLIOPE RIVER

9

10

GLADSTONE MOUNT
LARCOM ROAD

DAWSON HIGHWAY

KIRKWOOD ROAD

LEGEND

Proposed Dredged Channel to -5 mLAT

Cadastral Boundaries

● Model Output Points

0   1   2km

Approx. Scale

Page Size: A4
Projection: GDA 1994 MGA Zone 56

				Figure No
BMT WBM	Date: 25.10.2012 Wor COA_013_121023_Arrow LNG Gladstone Output Locations File Path: I:\B19168\DRG\ Rev: 2	**Arrow Energy** **Arrow LNG Plant**	**arrow**energy	**Model Output Points and Dredging Footprint**	**36**

2.2.3 Changes in Percentage Time Dry

Dredging the bar at the entrance to the Calliope River will lower the low tide levels within the estuary, causing some intertidal areas to be exposed for a greater percentage of the time. The model results were extracted at four representative locations along the river (points 3, 6, 8 and 9 in Figure 36) and analysed to determine the increase in percentage dry time as a function of elevation.

Figure 37 shows the percentage time dry as a function of elevation at Point 3. It is noted that there is no difference between the Base Case and Developed Case in the upper range of tidal levels. Therefore the remaining results are presented for the lower part of the tidal range only.
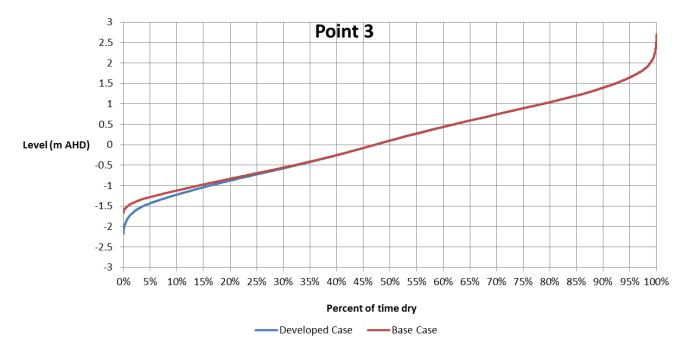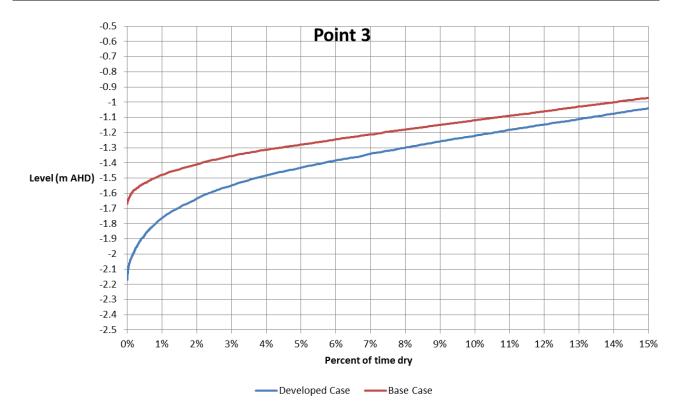
Figure 37   Percentage Time Dry as a Function of Elevation at Point 3

Figure 38 shows the percentage of time that particular elevations are dry in the Base Case and the Developed Case at Points 3 and 6. It is seen that the minimum water level at Point 3 during the 12 month simulation period falls from -1.67 mAHD in the Base Case to -2.17 mAHD in the Developed Case. The minimum water level at Point 6 also falls from -1.67 mAHD in the Base Case to -2.17 mAHD in the Developed Case. The levels that are exposed (dry) for particular percentages of the time at Points 3 and 6 are given in Table 3.

Figure 39 shows the percentage of time that particular elevations are dry in the Base Case and the Developed Case at Points 8 and 9. It is seen that the minimum water level at Point 8 during the 12 month simulation period falls from -1.67 mAHD in the Base Case to -2.07 mAHD in the Developed Case. The minimum water level at Point 9 falls from -1.60 mAHD in the Base Case to -1.75 mAHD in the Developed Case. The levels that are exposed (dry) for particular percentages of the time at Points 8 and 9 are given in Table 4.

BMT WBM
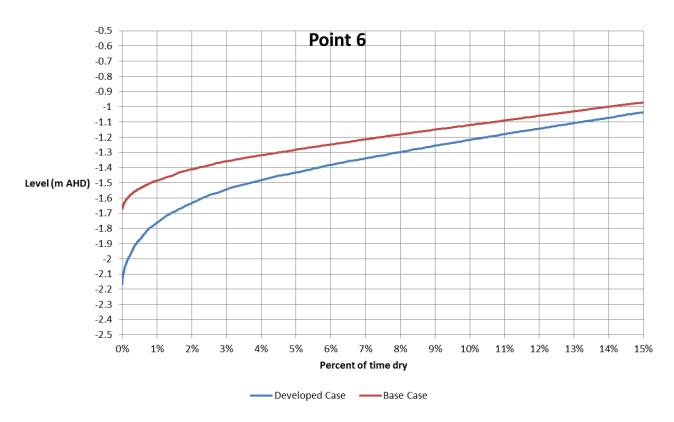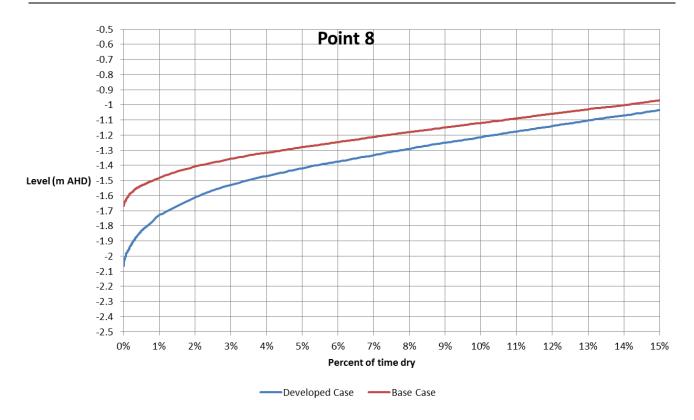
Figure 38   Percentage Time Dry as a Function of Elevation at Point 3 (Top) and Point 6 (Bottom)

BMT WBM
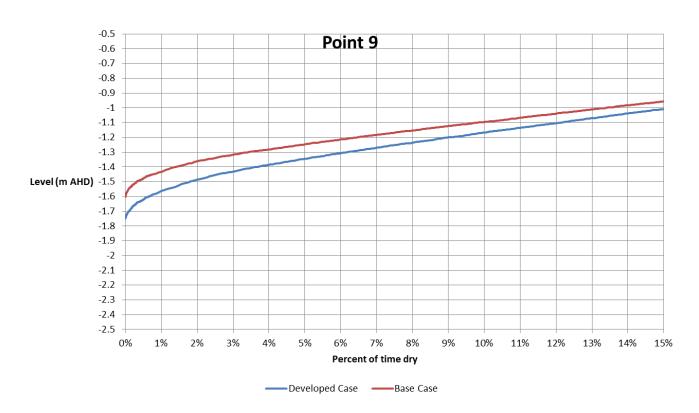
Figure 39   Percentage Time Dry as a Function of Elevation at Point 8 (Top) and Point 9 (Bottom)

BMT WBM

Table 3   Percentage Time Dry at Points 3 and 6 in the Base Case and Developed Case
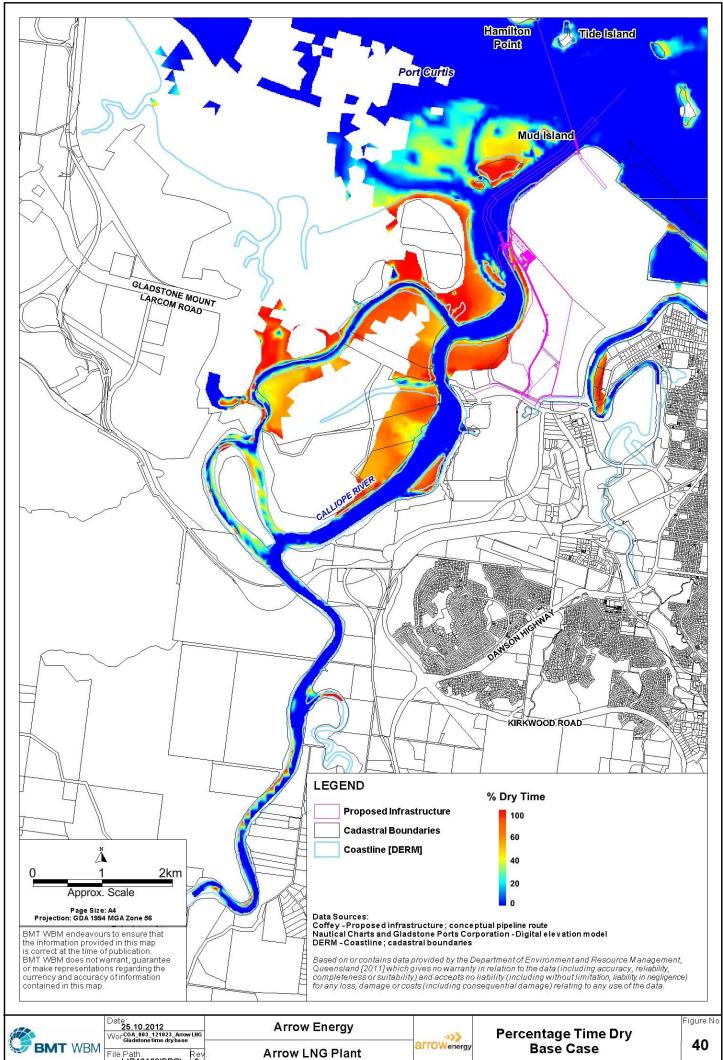
Point 3	Base Case	Developed Case	Point 6	Base Case	Developed Case
% time dry	level (mAHD)	level (mAHD)	% time dry	level (mAHD)	level (mAHD)
100%	2.700	2.700	100%	2.737	2.734
80%	1.040	1.041	80%	1.050	1.050
60%	0.436	0.439	60%	0.442	0.442
50%	0.100	0.102	50%	0.105	0.107
40%	-0.252	-0.254	40%	-0.250	-0.250
30%	-0.556	-0.577	30%	-0.555	-0.572
20%	-0.831	-0.876	20%	-0.830	-0.871
10%	-1.118	-1.219	10%	-1.119	-1.217
8%	-1.179	-1.298	8%	-1.180	-1.296
6%	-1.246	-1.383	6%	-1.248	-1.382
5%	-1.278	-1.428	5%	-1.281	-1.431
4%	-1.313	-1.479	4%	-1.318	-1.479
3%	-1.355	-1.548	3%	-1.358	-1.542
2%	-1.407	-1.632	2%	-1.410	-1.628
1%	-1.478	-1.757	1%	-1.484	-1.759
0%	-1.668	-2.171	0%	-1.671	-2.166
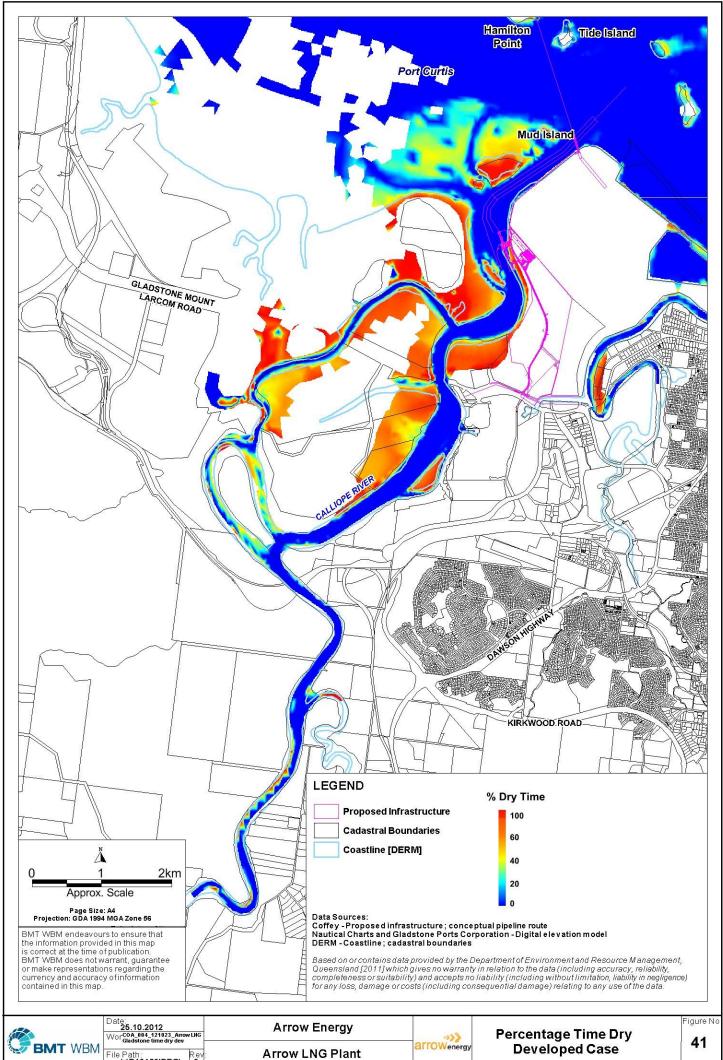
Table 4   Percentage Time Dry at Points 8 and 9 in the Base Case and Developed Case
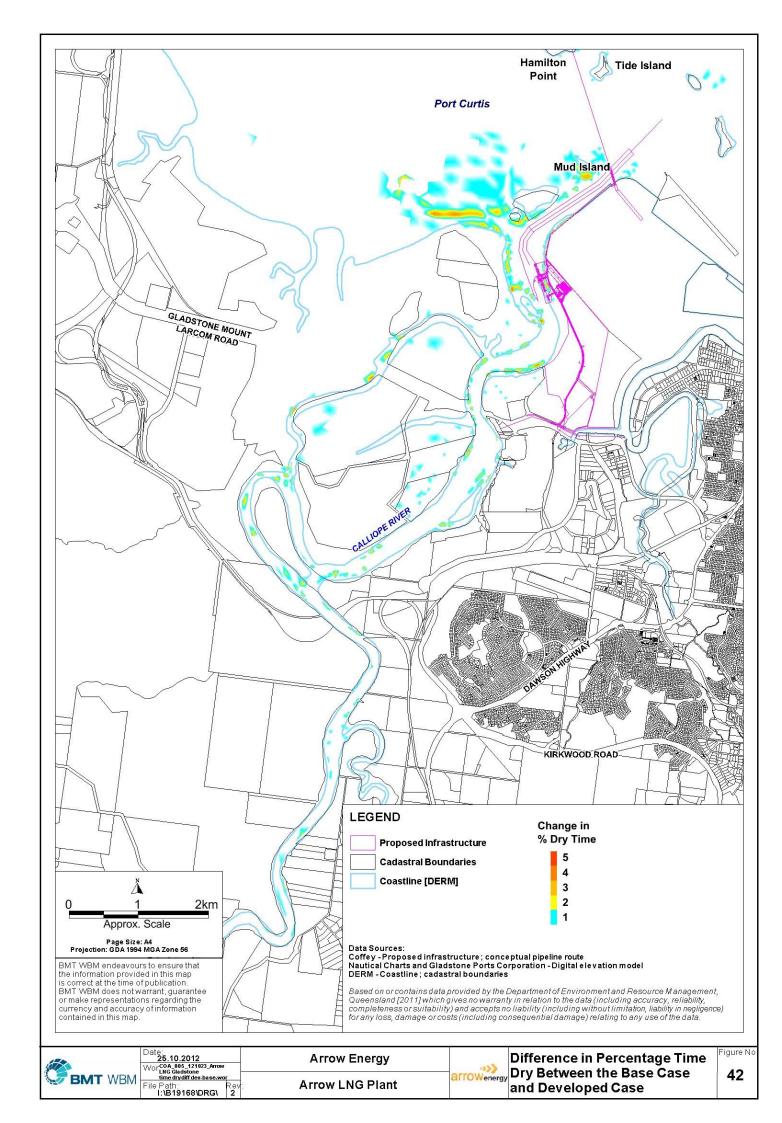
Point 8	Base Case	Developed Case	Point 9	Base Case	Developed Case
% time dry	level (mAHD)	level (mAHD)	% time dry	level (mAHD)	level (mAHD)
100%	2.767	2.764	100%	2.796	2.793
80%	1.057	1.058	80%	1.065	1.064
60%	0.439	0.442	60%	0.441	0.444
50%	0.101	0.108	50%	0.101	0.106
40%	-0.249	-0.251	40%	-0.246	-0.242
30%	-0.559	-0.572	30%	-0.551	-0.565
20%	-0.831	-0.873	20%	-0.820	-0.855
10%	-1.119	-1.212	10%	-1.095	-1.166
8%	-1.179	-1.288	8%	-1.152	-1.233
6%	-1.246	-1.375	6%	-1.214	-1.307
5%	-1.279	-1.417	5%	-1.246	-1.343
4%	-1.316	-1.470	4%	-1.281	-1.384
3%	-1.356	-1.529	3%	-1.316	-1.431
2%	-1.404	-1.607	2%	-1.360	-1.484
1%	-1.482	-1.726	1%	-1.430	-1.561
0%	-1.669	-2.065	0%	-1.604	-1.749

Figure 40 shows the percentage of time that areas of river bed are exposed in the Base Case. Figure 41 is the corresponding figure for the Developed Case. Figure 42 shows the difference in the percentage time dry between the Base Case and the Developed Case.

LEGEND

Proposed Infrastructure

Cadastral Boundaries

Coastline [DERM]

% Dry Time

100
60
40
20
0

0   1   2km

Approx. Scale

Page Size: A4
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Nautical Charts and Gladstone Ports Corporation - Digital elevation model
DERM - Coastline ; cadastral boundaries

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LEGEND

	Proposed Infrastructure
	Cadastral Boundaries
	Coastline [DERM]

% Dry Time

100
80
60
40
20
0

Data Sources:
Coffey - Proposed infrastructure ; conceptual pipeline route
Nautical Charts and Gladstone Ports Corporation - Digital elevation model
DERM - Coastline ; cadastral boundaries

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0   1   2km
Approx. Scale

Page Size: A4
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	Date: 25.10.2012	**Arrow Energy**		**Percentage Time Dry**	Figure No
BMT WBM	WorCOA_004_121023_Arrow LNG Gladstone time dry dev		arrow energy	**Developed Case**	**41**
	File Path: I:\B19168\DRG\	Rev: 2	**Arrow LNG Plant**		

Hamilton Point
Tide Island
Port Curtis
Mud Island
GLADSTONE MOUNT LARCOM ROAD
CALLIOPE RIVER
DAWSON HIGHWAY
KIRKWOOD ROAD

Hamilton Point

Tide Island

Port Curtis

Mud Island

GLADSTONE MOUNT
LARCOM ROAD

CALLIOPE RIVER

DAWSON HIGHWAY

KIRKWOOD ROAD

LEGEND

☐ Proposed Infrastructure

☐ Cadastral Boundaries

☐ Coastline [DERM]

**Change in
% Dry Time**

5
4
3
2
1

N

0   1   2km

Approx. Scale

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DERM - Coastline ; cadastral boundaries

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	Date: 25.10.2012	**Arrow Energy**		**Difference in Percentage Time**	Figure No
BMT WBM	Wor COA_005_121023_Arrow LNG Gladstone time drydiff dev-base.wor		arrow energy	**Dry Between the Base Case**	**42**
	File Path: I:\B19168\DRG\	Rev: 2	**Arrow LNG Plant**	**and Developed Case**	

2.2.4 Changes in Minimum Water Level and Depth

A long section plot along the Calliope River between Points 1 and 10 (refer Figure 36) showing the minimum water level during the 12 month simulation in the Base Case and Developed Case is presented in Figure 43. The plot also shows the approximate bed elevation of the centre of the Calliope River channel and the elevation of the proposed dredging at the river mouth.

It is noted that the most significant area of tidal range attenuation in the river at present is at the bar at the river mouth between Point 1 and Point 2. The minimum tide level is approximately -2.1 mAHD at Point 1 and approximately -1.7 mAHD at Point 2. After the dredging is completed, the most significant change in tidal range within the estuary will occur in the vicinity of Point 8. The minimum tide level will be approximately -2.1 mAHD at Point 7 and approximately -1.7 mAHD at Point 9.

Plan plots of the minimum water elevation during the twelve month simulation in the Base Case and Developed Case are shown in Figure 44 and Figure 45 respectively. By looking the difference between these two water levels, the additional bank area that is exposed on the lowest low tide during the simulation period can be calculated. This additional area of exposure is approximately 30 hectares in total and is shown in Figure 46.

Figure 47 shows the minimum modelled depth in the Base Case, and Figure 48 shows the minimum depth in the Developed Case. The change in the minimum depth is shown in Figure 49 (a negative change in depth indicates that the minimum depth is smaller in the Developed Case than in the Base Case). It is clear that the most significant changes in minimum depth occur between Point 1 and Point 8 (approximately 0.5m reduction in minimum depth). Upstream of Point 8 the reduction in minimum depth varies between 0.1m and 0.15m.

2.2.5 Impacts on Navigability in the Calliope River

There will be a reduction in the available depth for navigation in the lower part of the Calliope River during low tides. The reduction in depths on the lowest low tides is illustrated in Figure 49. The area where this reduction in depth will be most noticeable is at the shoals near Point 8 (marked in Figure 49). On low tides the available depth is already small (less than 1 metre) and will be further reduced on low tides post dredging by up to 0.5m. This increased limitation on access to areas upstream of these shoals on low tides is offset by the improved access provided across the existing downstream bar near Point 1.

Figure 43   Long Section Plot of Minimum Water Level for the Base Case and Developed Case, the Change in that Level, and the Pre- and Post-Dredging Calliope River Bed Elevation (Approximate Thalweg)

BMT WBM

Hamilton
Point

Tide Island

Port Curtis

Mud Island

GLADSTONE MOUNT
LARCOM ROAD

CALLIOPE RIVER

DAWSON HIGHWAY

KIRKWOOD ROAD

LEGEND

Proposed Infrastructure

Cadastral Boundaries

Coastline [DERM]

Minimum water level (m AHD)

>=-1.50
-1.80
-2.10
-2.40
<= -2.70

Data Sources:
Coffey - Proposed infrastructure; conceptual pipeline route
Nautical Charts and Gladstone Ports Corporation - Digital elevation model
DERM - Coastline; cadastral boundaries

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N

0   1   2km
Approx. Scale

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25.10.2012
Wor COA_001_121023_Arrow LNG
Gladstone minWL base.wor

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Rev:
2

Arrow Energy

Arrow LNG Plant

arrow energy

**Minimum Water Level
in the Base Case**

Figure No

44

LEGEND

Proposed Infrastructure
Cadastral Boundaries
Coastline [DERM]

Minimum water level (m AHD)

>=-1.50
-1.80
-2.10
-2.40
<= -2.70

Data Sources:
Coffey - Proposed infrastructure; conceptual pipeline route
Nautical Charts and Gladstone Ports Corporation - Digital elevation model
DERM - Coastline; cadastral boundaries

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0   1   2km
Approx. Scale

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LEGEND

	Proposed Infrastructure
	Cadastral Boundaries
	Coastline [DERM]

**Additional Exposed Area
At Lowest Low Tide
Post Dredging**

GLADSTONE MOUNT
LARCOM ROAD

CALLIOPE RIVER

DAWSON HIGHWAY

KIRKWOOD ROAD

0   1   2km
Approx. Scale

**Page Size: A4
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Data Sources:
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Nautical Charts and Gladstone Ports Corporation - Digital elevation model
DERM - Coastline; cadastral boundaries

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BMT WBM	Date: 25.10.2012 Wor**COA_008_121023_Arrow LNG Gladstone additional exposed area** File Path: I:\B19168\DRG\ Rev: 2	**Arrow Energy** **Arrow LNG Plant**	**arrow**energy	**Additional Exposed Area at Lowest Low Tide** Figure No **46**

Minimum Depth in the Base Case

LEGEND

Proposed Infrastructure

Cadastral Boundaries

Coastline [DERM]

Minimum Depth (m)

6
4
2
0

0   1   2km

Approx. Scale

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Data Sources:
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Nautical Charts and Gladstone Ports Corporation - Digital elevation model
DERM - Coastline ; cadastral boundaries

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Labels on map: Hamilton Point, Tide Island, Port Curtis, Mud Island, GLADSTONE MOUNT LARCOM ROAD, CALLIOPE RIVER, DAWSON HIGHWAY, KIRKWOOD ROAD

BMT WBM

Date: 25.10.2012
Wor COA_006_121023_Arrow LNG Gladstone mindepth base.wor
File Path: I:\B19168\DRG\
Rev: 2

Arrow Energy

Arrow LNG Plant

arrowenergy

Minimum Depth in the Base Case

Figure No
47

LEGEND

Proposed Infrastructure

Cadastral Boundaries

Coastline [DERM]

Minimum Depth (m)

6

4

2

0

Data Sources:
Coffey - Proposed infrastructure ; conceptual pipeline route
Nautical Charts and Gladstone Ports Corporation - Digital elevation model
DERM - Coastline ; cadastral boundaries

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N

0   1   2km

Approx. Scale

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Arrow Energy

Arrow LNG Plant

arrow energy

Minimum Depth in the
Developed Case

Figure No

48

BMT WBM

Port Curtis

Hamilton
Point

Tide Island

Mud Island

GLADSTONE MOUNT
LARCOM ROAD

SHOALS

CALLIOPE RIVER

DAWSON HIGHWAY

KIRKWOOD ROAD

N

0   1   2km

Approx. Scale

Page Size: A4
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LEGEND

Proposed Infrastructure

Cadastral Boundaries

Coastline [DERM]

**Difference in
Minimum Depth (m)**

0.6
0.3
0

-0.3
-0.6

**A Negative Difference
Indicates that the
Minimum Depth is
Smaller in the
Developed Case
than the Base Case**

Data Sources:
Coffey - Proposed infrastructure; conceptual pipeline route
Nautical Charts and Gladstone Ports Corporation - Digital elevation model
DERM - Coastline; cadastral boundaries

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BMT WBM	Date: 25.10.2012 Wor COA_008_121023_Arrow LNG Gladstone dev-base min depth File Path: Rev: I:\B19168\DRG\ 2	**Arrow Energy** **Arrow LNG Plant**	arrow energy	**Difference in Minimum Depth Between the Base Case and the Developed Case**	Figure No **49**

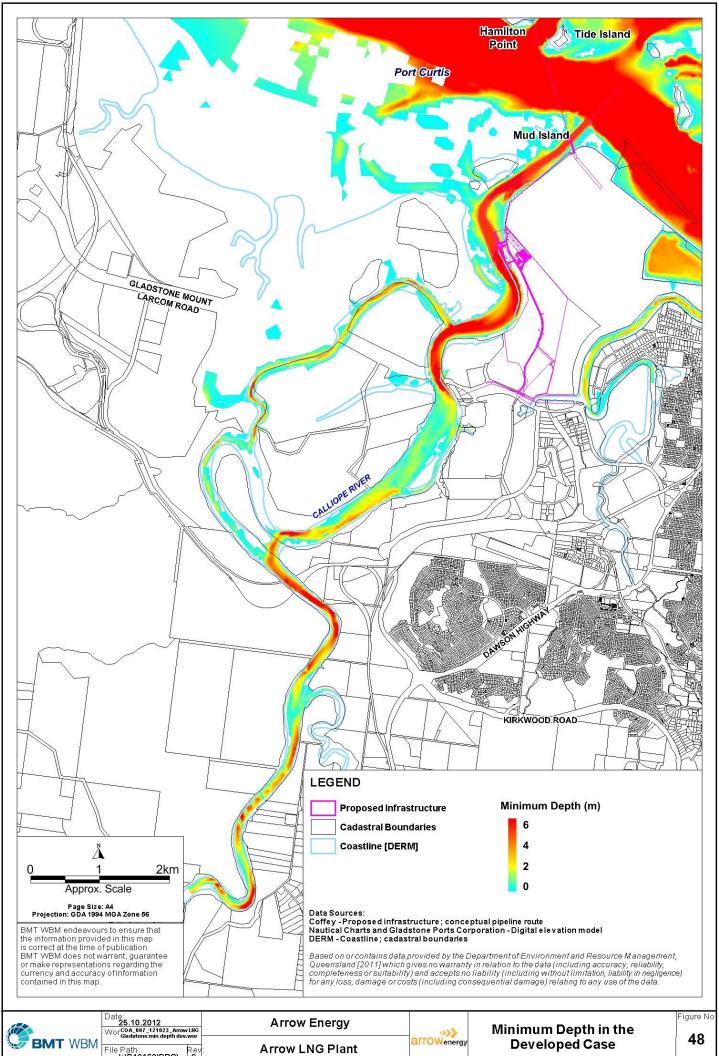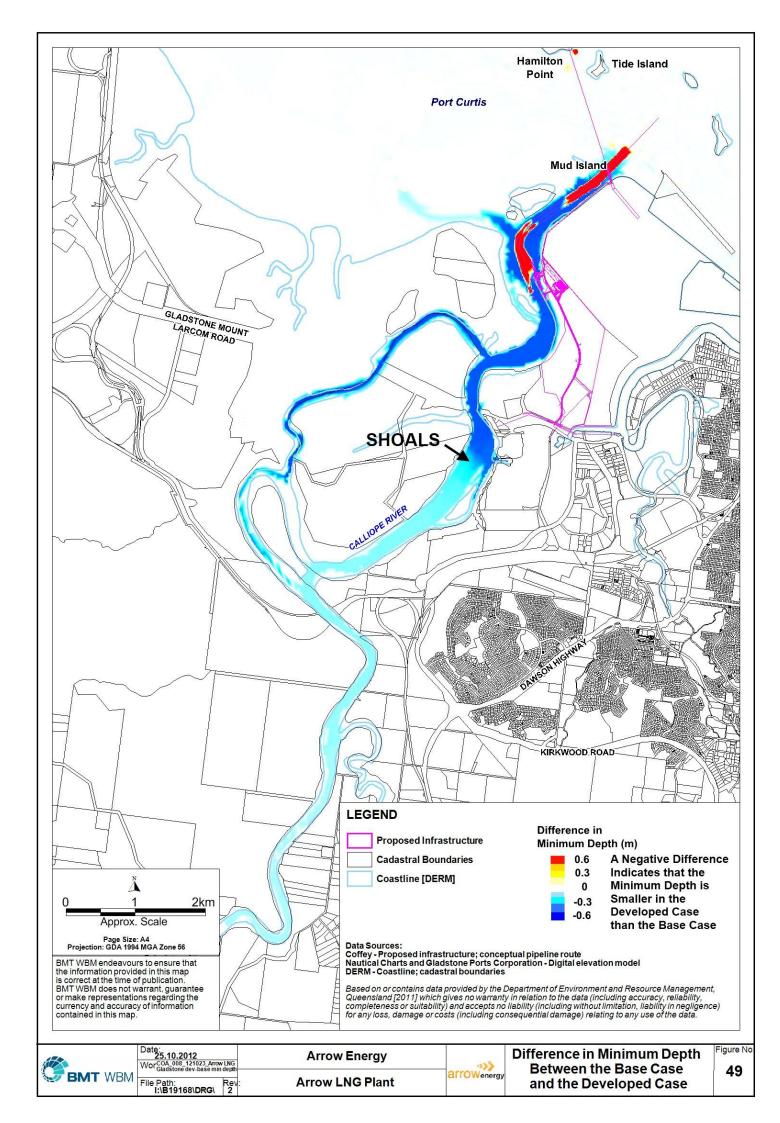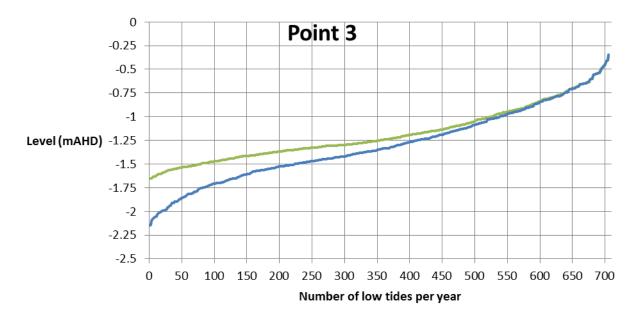## 2.2.6 Changes in Low Tide Levels

Figure 50 and Figure 51 show the number of low tides during the 12 month simulation below a given elevation in the Base Case and the Developed Case at Points 3, 6, 8 and 9. The number of low tides below certain elevations and the number of days (out of 12 months) with tides lower than those elevations are given in Table 5, Table 6, Table 7 and Table 8.
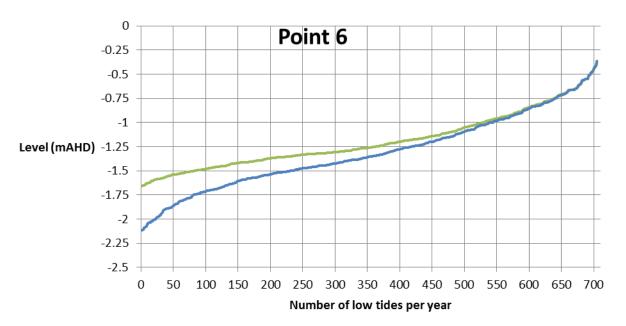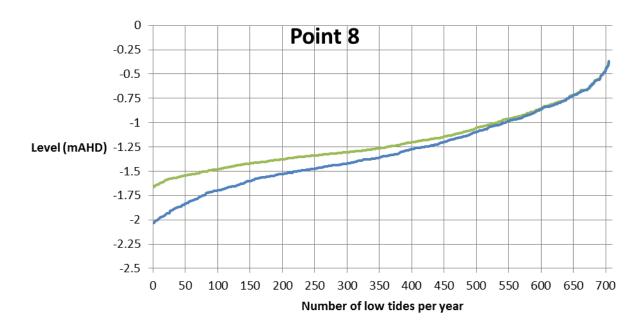

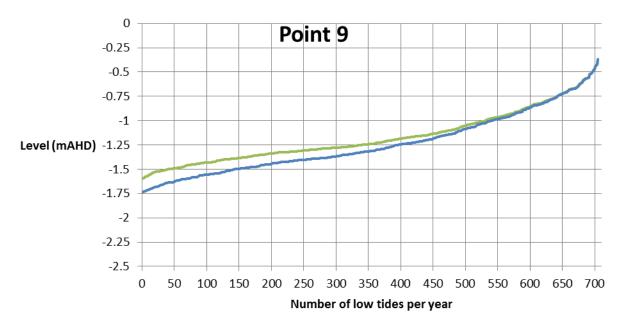**Figure 50   Number of Low Tides Below Given Elevations at
Point 3 (Top) and Point 6 (Bottom)**

Figure 51   Number of Low Tides Below Given Elevations at Point 8 (Top) and Point 9 (Bottom)

Table 5   Changes to Low Tides at Point 3 in the Base Case and Developed Case

Point 3	Base Case	Developed Case	Base Case	Developed Case
Level (mAHD)	Number of Low Tides Below (in 12 Months)	Number of Low Tides Below (in 12 Months)	Number of Days that the Tide Falls Below this Level (in 12 Months)	Number of Days that the Tide Falls Below this Level (in 12 Months)
-1	525	538	298	307
-1.2	393	442	231	259
-1.4	166	311	116	187
-1.6	18	155	16	98
-1.8	0	67	0	46
-1.9	0	37	0	28
-2.0	0	18	0	18
-2.1	0	3	0	6
-2.2	0	0	0	0

Table 6   Changes to Low Tides at Point 6 in the Base Case and Developed Case

Point 6	Base Case	Developed Case	Base Case	Developed Case
Level (mAHD)	Number of Low Tides Below (in 12 Months)	Number of Low Tides Below (in 12 Months)	Number of Days that the Tide Falls Below this Level (in 12 Months)	Number of Days that the Tide Falls Below this Level (in 12 Months)
-1	529	542	300	308
-1.2	399	448	236	262
-1.4	175	316	122	188
-1.6	19	152	19	99
-1.8	0	66	0	49
-1.9	0	38	0	32
-2.0	0	22	0	18
-2.1	0	3	0	3
-2.2	0	0	0	0

Table 7   Changes to Low Tides at Point 8 in the Base Case and Developed Case

Point 8	Base Case	Developed Case	Base Case	Developed Case
Level (mAHD)	Number of Low Tides Below (in 12 Months)	Number of Low Tides Below (in 12 Months)	Number of Days that the Tide Falls Below this Level (in 12 Months)	Number of Days that the Tide Falls Below this Level (in 12 Months)
-1	530	542	301	306
-1.2	401	448	237	262
-1.4	177	314	122	187
-1.6	17	151	18	98
-1.8	0	60	0	45
-1.9	0	28	0	26
-2.0	0	8	0	8
-2.1	0	0	0	0

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Table 8   Changes to Low Tides at Point 9 in the Base Case and Developed Case

Point 9	Base Case	Developed Case	Base Case	Developed Case
Level (mAHD)	Number of Low Tides Below (in 12 Months)	Number of Low Tides Below (in 12 Months)	Number of Days that the Tide Falls Below this Level (in 12 Months)	Number of Days that the Tide Falls Below this Level (in 12 Months)
-1	530	541	300	305
-1.2	387	438	231	259
-1.4	130	257	96	164
-1.5	39	142	39	100
-1.6	0	68	0	56
-1.7	0	13	0	13
-1.8	0	0	0	0

2.2.7   Comparison with Original EIS Assessments

The results of the impact assessment presented in the original EIS are consistent with the more detailed results presented here. In particular, the sediment transport regime equilibrium assessment undertaken in the original EIS to assess bank stability and potential increases in channel width is still relevant.

The original EIS reported changes in water levels of up to 0.8 metres, whereas the present study reports changes in minimum water level of up to 0.5 metres. The reason for this difference is that the original study looked at the change in water level at an instant in time, whereas the new study accounts for changes in the phasing of the tide in the estuary and therefore the overall change in the minimum water level.

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3   MARINE WATER QUALITY

Arrow is proposing to discharge hydrostatic test water of the LNG tanks to Port Curtis via the Curtis Island LNG facility diffuser at the Boatshed Point. Additional water quality data has also been collected within the vicinity of the proposed outfall. Previous water quality and impacts assessments were conducted as part of the Arrow LNG Plant EIS (BMT WBM 2011a).

This section presents a summary of the most recent water quality data collected by Arrow and potential impacts on water quality due to the proposed hydrostatic test water discharge at Boatshed Point.

3.1   Water Quality Objectives

Water quality objectives for this project were established in the Arrow LNG EIS, Chapter 16 Marine Water and Sediment Quality Chapter. The project water quality criteria outlined in Table 16.3 of the Arrow LNG EIS, are based on the Queensland Water Quality Guidelines (DERM 2009) and the ANZECC/ARMCANZ (2000) guidelines. Waters within Port Curtis are designated as 'Enclosed Coastal Waters'.

With regard to project water quality criteria, there are two categories based on the source of the criteria (QWQG or ANZECC/ARMCANZ) which differ in terms of how they are applied. These are:

- The QWQG set long-term objective for water quality to assess the health of a waterway. These are based on a level of protection for each waterway. Port Curtis is a slightly to moderately disturbed waterway because it is neither pristine nor seriously degraded. As such the health of the waterway is assessed in terms of annual median concentrations compared to the guidelines; and

- With respect to mixing zones, the ANZECC/ARMCANZ guidelines set toxicant trigger values (TTV) to protect aquatic organisms to immediate and toxic exposure to chemicals in the water. Typically, TTVs are prescribed for freshwater and marine environments, and are set to a protection level of 95% of aquatic species unless otherwise indicated.

Table 9 Project Water Quality Criteria

Water Quality Parameter	Units	Water Body Type	
		Enclosed Coastal	Mid Estuarine
Ammonia Nitrogen	µg/L	8	10
Oxidised Nitrogen	µg/L	3	10
Organic Nitrogen	µg/L	180	260
Total Nitrogen	µg/L	200	300
Filterable Reactive Phosphorus	µg/L	6	8
Total Phosphorus	µg/L	20	25
Chlorophyll a	µg/L	2	4
Dissolved Oxygen (% saturation)	lower	90	85
	upper	100	100
Turbidity	NTU	6	8
Light Penetration (Secchi)	m	1.5	1
Suspended Solids	mg/L	15	20
pH	lower	8.0	7.0
	upper	8.4	8.4
Metals	Units	TTV	
Mercury	µg/L	0.1[a]	
Silver	µg/L	1.4	
Cadmium	µg/L	0.7[a]	
Chromium (III+VI)	µg/L	4.4	
Copper	µg/L	1.3	
Nickel	µg/L	7.0[a]	
Lead	µg/L	4.4	
Zinc	µg/L	15	
Cobalt	µg/L	1.0	
Vanadium	µg/L	100	

[a] Set to the 99% protection level

3.2 Water Quality Monitoring

Arrow Energy has recently conducted water quality monitoring at 30 sites in support of their proposed project activities at Curtis Island including the proposed hydrostatic test water discharge at Boatshed Point (Central Queensland University, 2012). This monitoring programme was conducted in different tidal phases to describe existing water quality with respect to physicochemical parameters, nutrients and metals as described in the following subsections.

3.2.1 Monitoring Locations and Dates

The water quality analysis and impact assessment of hydrostatic test water discharge at Boatshed Point described in this study considers 8 sites of interest which are closest to the facility outfall on Boatshed Point and within the proximity of Site 5 of the previous water quality sampling events presented in the water quality section of the Arrow LNG Plant EIS (Arrow LNG EIS). These sites are presented in Figure 52, with coordinate and depths also presented in Table 10.

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Sampling was conducted during the following periods to describe the water quality with respect to both neap and spring tidal conditions.

- Neap tidal condition – 22 August 2012
- Spring tidal condition – 29 August 2012

Sampling at each above mentioned tidal condition was done during different tidal events (low tide, mid tide and high tide) to describe the water quality with respect to those tidal events.

Table 10 Location of Water Quality Sampling Sites

Site	Latitude	Longitude	Depth (mAHD)
21	-23.7968	151.2274	-11.17
22	-23.7955	151.2294	-2.57
23	-23.7939	151.2301	-0.96
24	-23.7954	151.2314	-8.49
25	-23.7948	151.2343	-2.75
26	-23.7955	151.2397	-3.25
27	-23.7974	151.2343	-3.00
28	-23.7983	151.2302	-5.38

3.2.2 Monitoring Parameters

The main groups of parameters were monitored for with specific parameters for each group outlined in Table 11:

- Physicochemical;
- Nutrients; and
- Metals.

The physicochemical conditions at the sampling sites provided by Arrow included the listed parameters in Table 11. Similar to previous monitoring conducted, these data included depth profiles (at 0.5 m depth intervals) at indicative tidal states (high water, mid water and low water) during both neap and spring tidal conditions.

Nutrient and metals data (see Table 11) were sampled for in grab samples at the top and bottom of the water column during low, mid and high tidal conditions. Full reporting of the data provided are included in Appendix A.
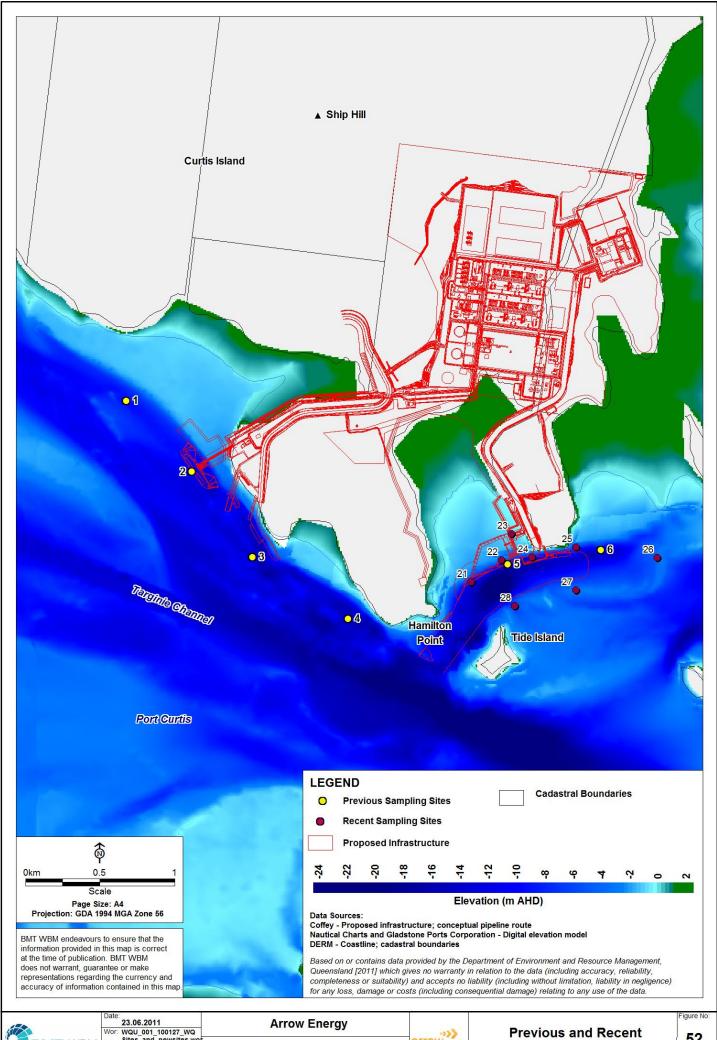
Table 11   Monitoring Parameters

Physicochemical	Nutrients	Metals
Temperature	Ammonia	Mercury
Chlorophyll-a	Nitrogen oxides	Aluminium
Salinity	Total nitrogen	Iron
Conductivity	Filterable reactive	Arsenic
pH and	phosphorus (FRP)	Cadmium
Dissolved Oxygen	Total phosphorous and	Chromium
Secchi Depth	Total organic carbon	Cobalt
		Copper
		Lead
		Manganese
		Nickel
		Silver and
		Zinc

LEGEND

○ Previous Sampling Sites

● Recent Sampling Sites

▭ Proposed Infrastructure

▭ Cadastral Boundaries

Elevation (m AHD)

Data Sources:
Coffey - Proposed infrastructure; conceptual pipeline route
Nautical Charts and Gladstone Ports Corporation - Digital elevation model
DERM - Coastline; cadastral boundaries

Based on or contains data provided by the Department of Environment and Resource Management, Queensland [2011] which gives no warranty in relation to the data (including accuracy, reliability, completeness or suitability) and accepts no liability (including without limitation, liability in negligence) for any loss, damage or costs (including consequential damage) relating to any use of the data.

Ship Hill

Curtis Island

Targinie Channel

Port Curtis

Hamilton Point

Tide Island

0km   0.5   1
Scale
Page Size: A4
Projection: GDA 1994 MGA Zone 56

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

BMT WBM

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Arrow Energy

Arrow LNG Plant

arrowenergy

Previous and Recent
Water Quality Sampling Sites

Figure No:
52

3.2.3   Water Quality Data Assessment

3.2.3.1 Physicochemical properties

Median values of physicochemical parameters of all eight sites of interest (see Figure 52) during neap and spring tides are presented in Table 13 and Table 14, respectively. Note that physicochemical parameters of Site 23 are not available at low tide water event during both neap and spring tidal conditions as this site was not accessible during low water event. QWQG for each constituent are also included in Table 13 and Table 14. There are three parameters at this location for which there are no project water quality criteria: temperature, conductivity and salinity. This indicates that these parameters are expected to vary widely.

In Table 13 and Table 14, pH, turbidity, chlorophyll-*a*, and dissolved oxygen demonstrate exceedences of the established project water quality criteria or are outside of the established project water quality criteria ranges. It should be noted that these values represent conditions for specific sampling events, not long-term sampling programs. Seasonal fluctuation, catchment inflows, and high current velocities may have some role in causing variations in values.

Table 13 and Table 14 also indicate in most instances all reported constituents, except percentage of dissolved oxygen, are detected at higher levels during spring tidal condition compared to those detected during neap tidal condition.

Temperature

Figure 53 and Figure 54 show the temperature depth profiles of each site at each tidal event during neap and spring tidal conditions respectively. Temperatures remained relatively constant with temperatures varying less than 1 °C for all tidal events and depth at each tidal condition suggesting minimal temperature stratification. This is consistent with a turbulent and well-mixed environment.

Chlorophyll-*a*

Figure 55 and Figure 56 show the Chlorophyll-*a* depth profiles of each site at each tidal event during neap and spring tidal conditions respectively. Median chlorophyll-*a* concentrations are typically greater than the project water quality criteria objective of 2.0 µg/L for enclosed coastal waters, with the medians of 37 of the 46 events (sites and tidal conditions) greater than the project water quality criteria.

Salinity and Conductivity

Figure 57 through Figure 60 show the salinity and conductivity depth profiles of each site at each tidal event during neap and spring tidal conditions respectively. Figure 61 and Figure 62 show the salinity depth profiles at each tidal event during neap and spring tidal conditions respectively. Median values for salinity and conductivity of the eight sites at each tidal event are presented in Figure 63 and Figure 64 for neap and spring tidal conditions respectively.

Salinity varied with the tidal events more than it did spatially (from site to site) but only minimally. During the low and mid tidal events, salinity remained constant throughout the water column and

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varied no more than 1.0 ppt from one site to the next. High tide events show more stratified profiles for the inland sampling sites (Sites 23, 24 and 25).

Salinity varied between tidal conditions with increases observed during spring tidal condition compared to neap tidal condition. Conductivity, which can be used as a surrogate for salinity, also varied between tidal conditions with conductivity increased during spring tidal condition compared to neap tidal condition.

pH

Figure 65 and Figure 66 show the pH depth profiles of each site at each tidal event during neap and spring tidal conditions respectively. All field measurements for this recent water quality sampling event were outside (less than) the project water quality criteria range for pH (8.0 to 8.4).

Dissolved Oxygen

Figure 67 and Figure 68 show the dissolved oxygen depth profiles of each site at each tidal event during neap and spring tidal conditions respectively. The project water quality criteria indicates that for a given temperature percentage dissolved oxygen concentrations should be no less than 90% and no greater than 100% of the saturated dissolved oxygen concentration. During neap tidal conditions more than half (12) of the events (sites and tidal conditions) exceed the maximum dissolved oxygen criterion, while only one event does so for spring tidal conditions. No measurements were less than the minimum dissolved oxygen guideline.

Turbidity

Figure 69 and Figure 70 show the turbidity depth profiles at each tidal event for neap and spring tidal conditions respectively. Turbidity was not measured at most of the 8 sites during low water on neap tides due to instrument error. Highest turbidity values were observed, especially during spring tidal condition, as high current velocities are expected to increase re-suspension of bottom sediments.

Secchi Depths

Secchi depths were much lower than the project water quality criteria for enclosed coastal waters. The highest secchi depths were measured during neap tide, high water level conditions, and the lowest during spring tide, low and mid water levels. Overall, spring tide secchi depths were observed to be lower than those during neap tides. Table 12 presents Secchi depth measurements at each of the sites during the various tidal conditions and elevations.

Table 12 Measured Secchi Depths (in metres)

Site	Neap			Spring		
	L	M	H	L	M	H
21	0.037	0.070	0.109	0.030	0.041	0.047
22	0.048	0.085	0.106	0.032	0.021	0.062
23	NA	0.080	0.074	NA	0.025	0.066
24	0.050	0.089	0.081	0.039	0.025	0.056
25	0.066	0.082	0.085	0.028	0.059	0.064
26	0.067	0.088	0.127	0.033	0.030	0.062
27	0.052	0.067	0.088	0.032	0.023	0.044
28	0.047	0.063	0.096	0.023	0.029	0.038
Water Level Median	0.050	0.081	0.092	0.032	0.027	0.059
Tidal Median	0.080			0.033		
Criteria	1.5					

Table 13 Median Physicochemical Parameter Values for Neap Tidal Condition

Parameter	Site																								WQO[a]
	21			22			23			24			25			26			27			28			
	H	M	L	H	M	L	H	M	L	H	M	L	H	M	L	H	M	L	H	M	L	H	M	L	
Temperature (°C)	20.0	19.7	19.5	20.1	20.0	19.6	20.5	20.1	NR	19.9	20.0	19.6	20.0	20.3	19.6	19.8	19.8	19.6	19.9	19.8	19.6	19.8	19.8	19.6	NA[b]
Cunductivity (mS/cm)	47.5	46.9	46.2	47.6	47.4	46.6	48.0	47.3	NR	47.5	47.2	46.2	47.5	47.8	46.5	47.4	47.3	46.6	47.4	47.1	46.5	47.3	47.1	46.4	NA[b]
Salinity (ppt)	34.7	34.4	34.0	34.7	34.6	34.2	34.6	34.4	NR	34.7	34.5	34.3	34.7	34.6	34.2	34.7	34.6	34.3	34.7	34.6	34.2	34.7	34.5	34.1	NA[b]
pH	7.67	7.63	7.595	7.69	7.67	7.63	7.68	7.65	NR	7.69	7.65	7.63	7.69	7.68	7.62	7.69	7.68	7.64	7.69	7.67	7.63	7.69	7.67	7.62	8-8.4
Turbidity (NTU)	5.0	**10.0**	NA	3.0	5.0	NA	6.0	**9.0**	**NR**	4.0	**7.0**	NA	5.0	5.0	NA	3.0	**9.0**	NA	4.0	**12.5**	NA	4.0	**11.0**	NA	6.0
Chlorophyll-a (ug/L)	1.95	**2.40**	**3.00**	**2.10**	1.80	**2.20**	**2.60**	**2.15**	NR	**2.05**	**2.25**	**2.30**	1.80	**2.20**	**2.70**	2.00	**2.05**	**2.30**	1.95	**2.40**	**2.70**	1.80	**2.30**	**2.80**	2.00
Dissolved Oxygen (%)	**100.6**	98.3	96.3	**101.2**	**100.7**	97.5	**103.3**	**101.8**	NR	**100.7**	**100.6**	97.3	**101.3**	**102.5**	98.0	**100.8**	99.9	97.8	**100.8**	99.4	97.5	**100.3**	99.2	96.6	90-100

[a] QWQGs for enclosed coastal waters of central Queensland

[b] Varies based on location and conditions – none are currently established at this location

NA – Not applicable or no guideline applied. Dissolved oxygen guidelines are set for percent of saturated value due to temperature dependence of dissolved oxygen in the water column.

NR - No measurement provided

L = Low tide, M = Mid tide, H = High tide

Bolded values represent exceedences of QWQG, or in the case of dissolved oxygen and pH, values outside the guideline ranges.

Table 14   Median Physicochemical Parameter Values for Spring Tidal Condition

Parameter	Site																								WQO[a]
	21			22			23			24			25			26			27			28			
	H	M	L	H	M	L	H	M	L	H	M	L	H	M	L	H	M	L	H	M	L	H	M	L	
Temperature (°C)	21.1	21.2	21.6	21.0	21.3	21.5	21.2	21.7	NR	20.9	21.3	21.5	21.1	21.7	21.7	21.1	21.3	21.5	21.1	21.3	21.5	21.0	21.2	21.5	NA[b]
Cunductivity (mS/cm)	50.9	51.2	51.5	51.1	51.1	50.9	51.1	51.6	NR	50.8	51.1	51.5	51.2	51.9	51.4	51.2	51.1	51.1	51.2	51.0	51.0	51.0	51.2	51.0	NA[b]
Salinity (ppt)	36.5	36.7	36.5	36.7	36.5	36.2	36.6	36.5	NR	36.6	36.5	36.2	36.8	36.8	36.4	36.8	36.5	36.3	36.8	36.5	36.2	36.7	36.6	36.2	NA[b]
pH	7.93	7.89	7.85	7.94	7.90	7.86	7.93	7.92	NR	7.92	7.90	7.87	7.95	7.91	7.88	7.96	7.91	7.87	7.97	1.93	7.86	7.95	7.92	7.86	8-8.4
Turbidity (NTU)	**15.0**	**27.0**	**30.0**	**8.0**	**36.0**	**24.0**	**7.5**	**19.0**	**NR**	**8.0**	**37.0**	**28.0**	**6.5**	**9.0**	**28.0**	**8.0**	**31.0**	**20.0**	**18.0**	**39.0**	**24.0**	**21.0**	**16.0**	**34.5**	6.0
Chlorophyll-a (ug/L)	**2.45**	**2.45**	**3.35**	**2.05**	**3.40**	**3.05**	**2.20**	**2.40**	NR	2.00	**3.25**	**3.05**	**2.30**	**2.50**	**3.10**	1.90	**3.20**	**2.85**	0.70	**3.55**	**2.65**	**2.90**	**2.40**	**3.45**	2.00
Dissolved Oxygen (%)	97.0	97.3	98.4	97.7	97.1	96.7	98.2	**100.6**	NR	96.7	97.0	96.4	97.6	98.6	98.1	98.4	96.8	97.3	98.8	96.9	96.7	98.9	97.2	96.6	90-100

[a] QWQGs for enclosed coastal waters of central Queensland

[b] Varies based on location and conditions – none are currently established at this location

NA – Not applicable or no guideline applied.

NR - No measurement provided

L = Low tide, M = Mid tide, H = High tide

Bolded values represent exceedences of QWQG, or in the case of dissolved oxygen and pH, values outside the guideline ranges.
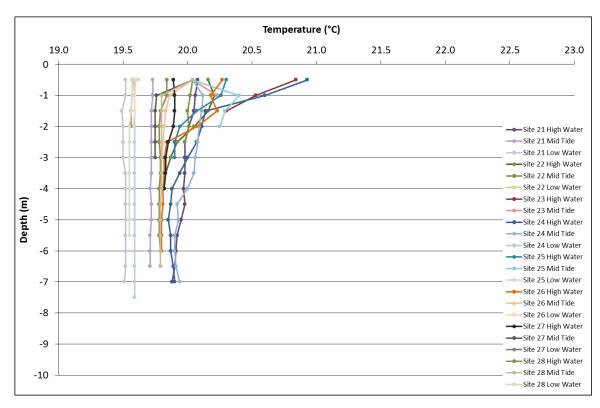
Figure 53   Temperature Depth Profiles for Neap Tidal Conditions
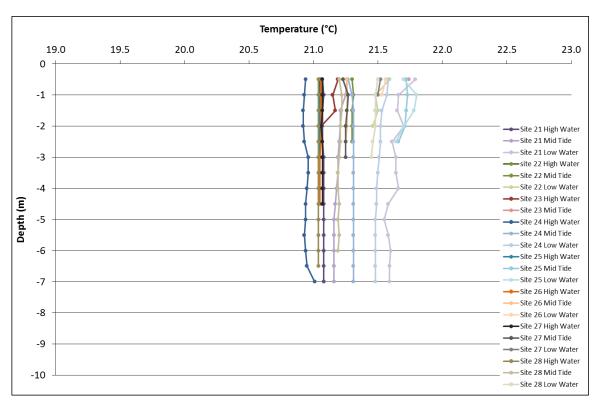

Figure 54   Temperature Depth Profiles for Spring Tidal Conditions
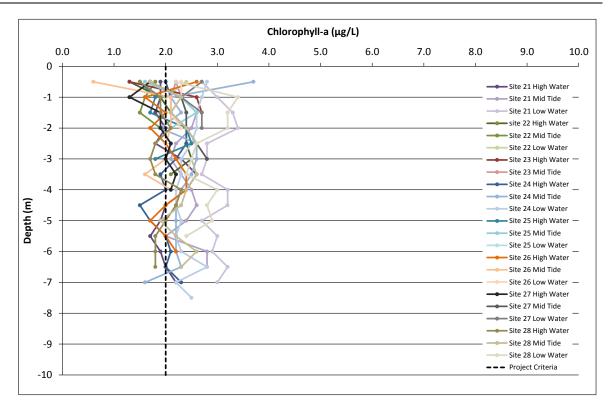
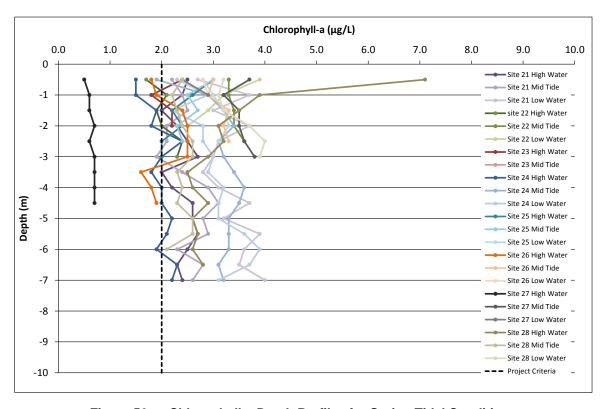**Figure 55   Chlorophyll-a Depth Profiles for Neap Tidal Conditions**

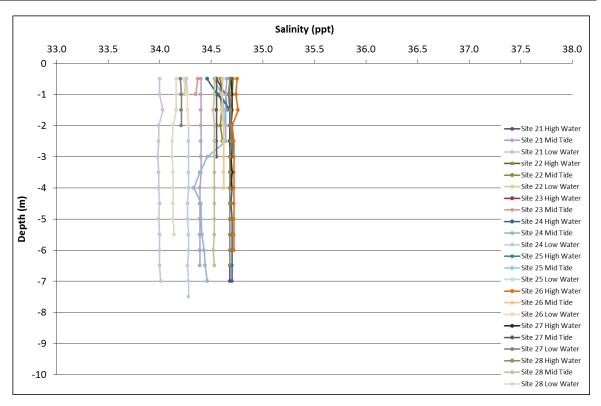**Figure 56   Chlorophyll-a Depth Profiles for Spring Tidal Conditions**

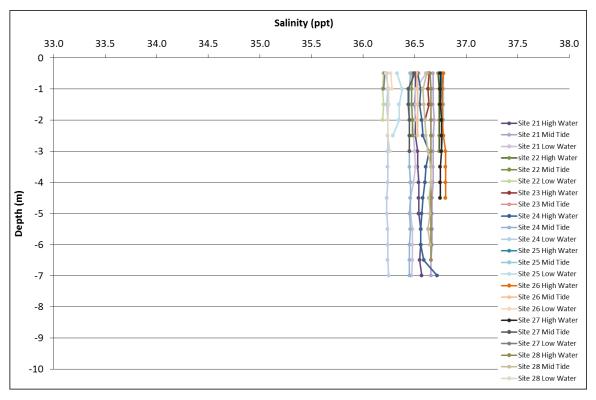**Figure 57   Salinity Depth Profiles for Neap Tidal Conditions**

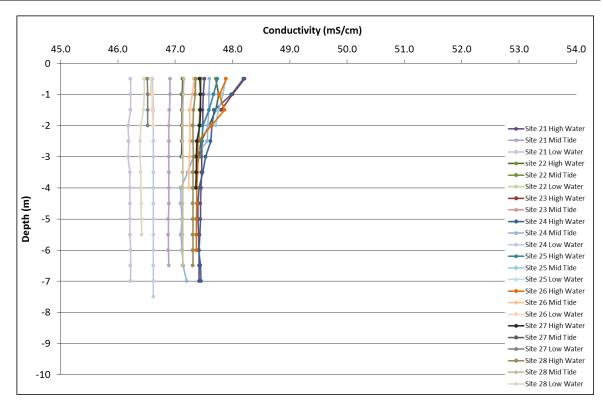**Figure 58   Salinity Depth Profiles for Spring Tidal Conditions**

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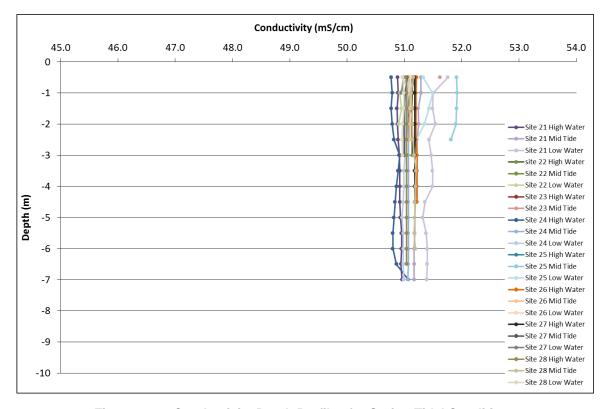**Figure 59   Conductivity Depth Profiles for Neap Tidal Conditions**

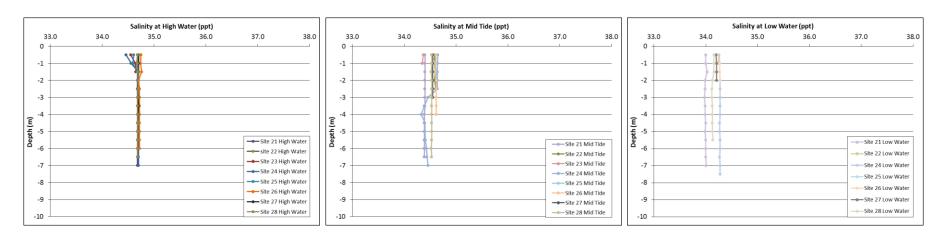**Figure 60   Conductivity Depth Profiles for Spring Tidal Conditions**

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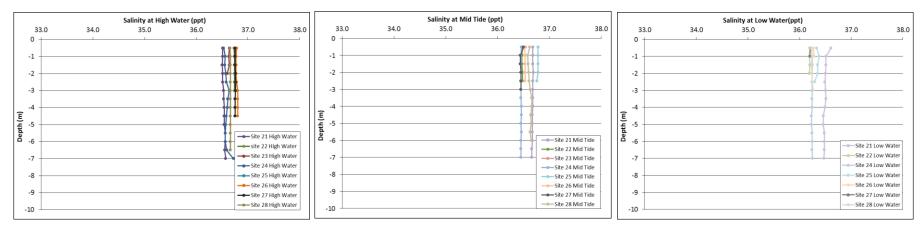**Figure 61   Salinity Depth Profiles at each Tidal Event for Neap Tidal Condition**

Figure 62   Salinity Depth Profiles at each Tidal Event for Spring Tidal Condition
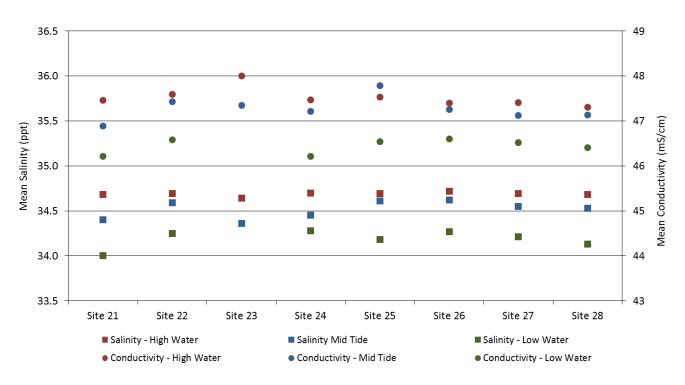
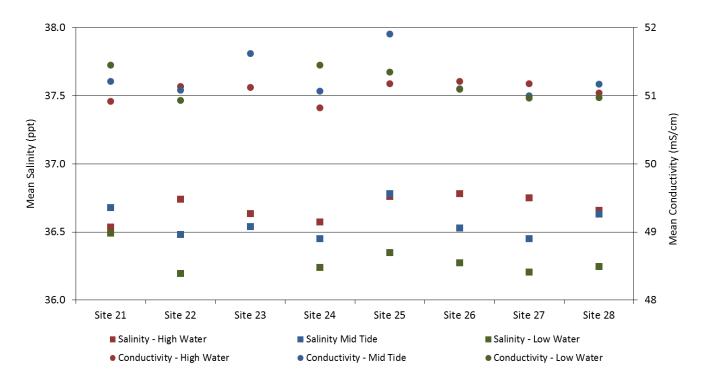**Figure 63   Median Salinity and Conductivity at each Tidal Event for Neap Tidal Condition**

Figure 64   Median Salinity and Conductivity at each Tidal Event for Spring Tidal Condition
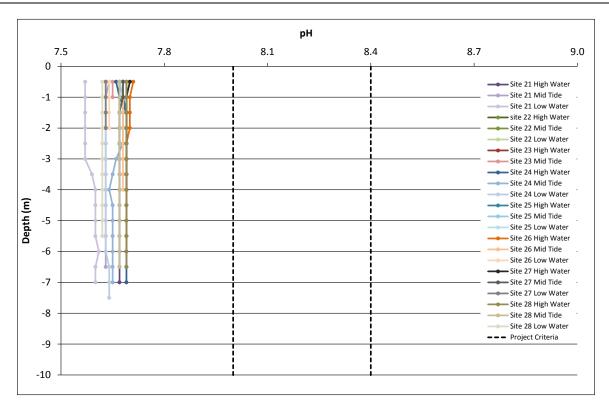
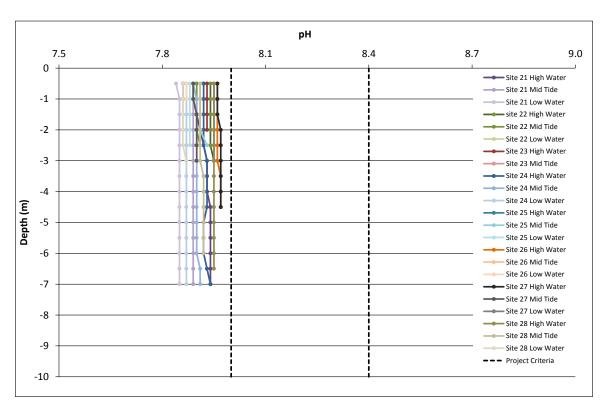**Figure 65   pH Depth Profiles for Neap Tidal Conditions**

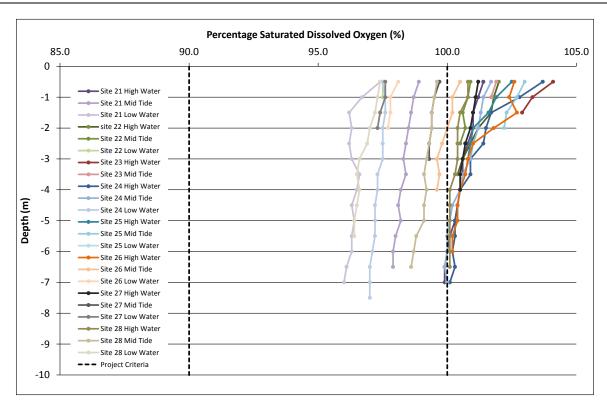**Figure 66   pH Depth Profiles for Spring Tidal Conditions**

Figure 67   Dissolved Oxygen for Neap Tidal Conditions
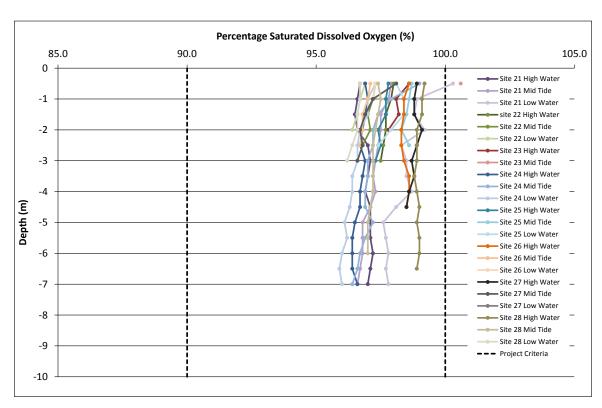

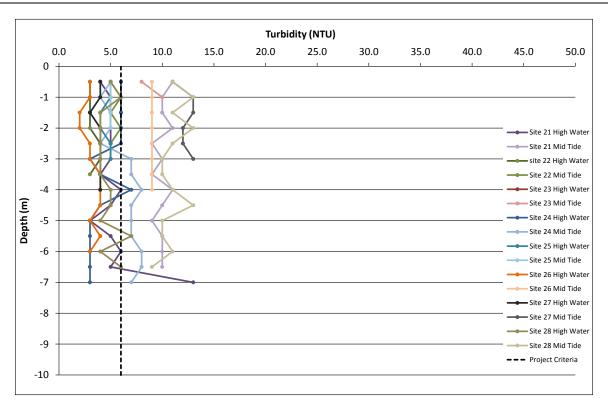**Figure 68   Dissolved Oxygen for Neap Tidal Conditions**

Figure 69   Turbidity Depth Profiles for Neap Tidal Condition
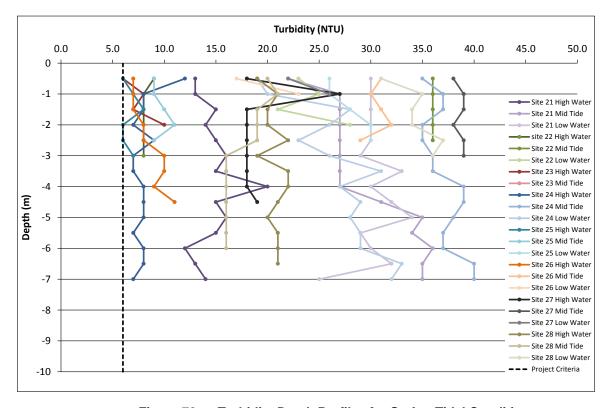

Figure 70   Turbidity Depth Profiles for Spring Tidal Condition

3.2.3.2 Nutrients

Nutrient water quality data provided by Arrow at all eight sites of interest are presented in Appendix A, indicating the results with respect to tidal states, tidal conditions and location. It should be noted that the tables compare all of the sampling results (Sites 1-30) against guidelines for mid-estuarine waters, however, it has been established through previous studies that Port Curtis at Boatshed Point is characterised by slightly to moderately disturbed enclosed coastal water quality values.

The following key findings based on above mentioned data sheets for the water quality (in terms of nutrients) in the vicinity of Boatshed Point are drawn:

- Nitrogen concentrations including ammonia, oxidised nitrogen and total nitrogen at all sites of interest were not detected at concentrations greater than the detection limit of the analysis (see Appendix A). It should be noted, however, that the detection limits of instruments for ammonia (20 µg/L) and oxidised nitrogen (20 µg/L) were greater than the respective project water quality criteria for enclosed coastal waters (8 and 3 µg/L for ammonia and oxidised nitrogen respectively).

- Filterable reactive phosphorus (FRP) at all sites of interest was not detected at concentrations greater than the detection limit of the analysis, however, similar to ammonia and oxidised nitrogen, the limit of detection for the laboratory analysis of FRP (10 µg/L) was greater than the project water quality criteria (6 µg/L).

- Total phosphorous was detected on few occasions during neap tide (Sites 21) and spring tide (Sites 22, 27 and 28). While three of the values were greater than the QWQG, there were too few data points to establish any trends in detections with regard to tidal conditions and where in the water column the sample was taken. It should be noted, too, that the limit of detection for the analysis is equal to the project water quality criteria for enclosed coastal waters (20 µg/L).

- Total organic carbon was not detected at all 8 sites of interest. The limit of detection limitation of the analysis was 1 mg/L.

3.2.3.3 Metals

Total metals water quality data provided by Arrow at all eight sites of interest are presented in Appendix A, indicating the results with respect to tidal states, tidal conditions and location.

The following key findings based on above mentioned data sheets for the water quality (in terms of metals) in the vicinity of Boatshed Point are drawn:

- Total metal concentrations were not detected for mercury, cadmium and silver at concentrations greater than the detection limit of the analysis. It should be noted the detection limits of the instruments for mercury was equal to the TTV (0.1 µg/L).

- Manganese and vanadium were detected in all sampled results, however no results were greater than the respective constituent TTV, and many results were an order of magnitude less than the TTV for manganese and two orders of magnitude less than the TTV for vanadium.

- Zinc, total chromium, lead, and nickel were detected in many samples, however, none of these metals were detected at concentrations in excess of their respective TTVs.

- Arsenic was detected in all of the samples, and cobalt in all of the spring tide samples, and some of the neap samples. Both metals demonstrated a few instances of exceedences of their respective TTVs, both during spring tides, typically at low to mid water levels. The arsenic TTV is of low reliability and is to be used as an interim value.

- Copper was detected in some neap samples, and many of the spring samples, typically at low to mid tides. During spring tides, copper exceeded its TTV for many of the events when detected (61%). Detection and exceedence of the TTV typically occurred during low to mid tidal conditions.

- Iron and aluminium were detected in all samples collected. In the case of aluminium, all samples exceeded the TTV, and in the case of iron, many of the samples exceeded the TTV, typically during low to mid-tide events. It should be noted the both the iron and aluminium TTVs are of low reliability and should only be used as an interim value. These TTVs may not reflect the site-specific water quality conditions for Port Curtis, especially considering background concentrations during both monitoring programmes were detected at levels well above these values.

- When metals were detected, they were present in higher levels during spring tide condition compared to those present in neap tide conditions.

- Metals concentrations were observed to be generally higher during lower to mid tides, though there does not appear to be any consistent trend regarding concentrations of samples taken at the bottom or the top of the water column.

3.2.4 Comparison of Water Quality Monitoring at Boatshed Point to March 2010 Monitoring Results

To provide additional context for the latest round of water quality results at Boatshed Point, the August 2012 results were compared to those collected in March 2010 as presented in the Arrow LNG EIS (BMT WBM, 2011a). Similar to the August 2012 monitoring programme, the March 2010 programme encompassed an area larger than just Boatshed point. For geographic similarity, however, only the results of the March 2010 monitoring events for Site 5 (BMT WBM, 2011a) were compared to the August 2012 results at Sites 21 through 28.

3.2.4.1 Physicochemical Parameters

Table 15 compares the median values of water quality parameters (physicochemical) of all eight sites of interest (Sites 21 through 28) collectively of all three tidal events for both neap and spring tidal conditions with the median values of those of water quality parameters of Site 5 at all three tidal events.

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Table 15 Comparison of Physicochemical Parameters at Boatshed Point: March 2010 and August 2012

Parameter	Sites 21 through 28						Site 5		
	Neap			Spring					
	H	M	L	H	M	L	H	M	L
Temperature (°C)	19.9	19.8	19.6	21.1	21.3	21.5	25.7	25.9	26.2
Cunductivity (mS/cm)	47.4	47.1	46.5	51.0	51.1	51.0	50.5	49.4	48.0
Salinity (ppt)	34.7	34.5	34.2	36.7	36.6	36.3	33.1	32.2	31.2
pH	7.7	7.7	7.6	8.0	7.9	7.9	8.2	8.2	8.1
Turbidity (NTU)	4.0	9.0	NA	11.0	31.5	29.0	12.4	56.4	61.7
Chlorophyll-a (ug/L)	2.0	2.2	2.7	2.2	2.9	3.1	2.0	4.1	4.3
Dissolved Oxygen (%)	100.7	99.6	97.2	97.8	97.2	97.0	97.3	95.1	91.8

Differences in temperature, chlorophyll-*a*, and dissolved oxygen between the two events are reflective of the seasons in which the data were collected. That is, those parameters collected in August 2012 are generally representative of winter when lower temperatures generally result in lower phytoplankton growth rates but higher dissolved oxygen concentrations. Those collected in March 2010 representative of the shoulder seasons between summer and autumn when higher temperatures generally result in high chlorophyll-*a* production and reduced oxygenation.

Salinity and turbidity data collected in August 2012 are generally greater than data representing the March 2010 period. While the exact nature of these discrepancies is uncertain, it is likely that antecedent climate conditions prior to the monitoring events in 2010 affected salinity and turbidity. Based on rainfall data on southern Curtis Island (BoM station 39241) February 2010 was a very wet month (435mm total rainfall) and March 2010 was wetter than average (132mm total rainfall) which could have resulted in an higher than average influx of freshwater and suspended sediment from upstream catchments. It should be noted, too, that the average flushing time (e-folding) of Port Curtis at Boatshed Point is approximately 30 days, which indicates that conditions caused by large catchment inflows may take a number of months to completely flush out. In contrast, the five months prior to 22/08/2012 were typically dry and experienced average rainfall (245mm total for 5 months).

3.2.4.2 Nutrients

Nutrient concentrations in Port Curtis in March 2010 were significantly higher than the levels demonstrated in August 2012 (BMT WBM, 2011a). Nitrogen and phosphorus for all species were detected in all tidal conditions at all sites, including Site 5, and exceeded their respective project water quality criteria with the exception of FRP. A possible explanation for this could be related to antecedent rainfall prior to the monitoring events, as discussed previously in the comparison of physicochemical parameters in Section 3.2.4.1, as catchment inflows are likely to be high in nitrogen and phosphorus.

3.2.4.3 Metals

Comparison of metals between the two sampling events is difficult due to higher detection limits of the laboratory analysis for the March 2010 samples, which were typically an order of magnitude greater than those in August 2012.

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In March 2010, metals that were detected consistently at the top of the water column were iron, aluminium, and manganese, while metals detected consistently at the bottom also included chromium and nickel. Comparison with August 2012 results indicates that those metals that were detected in March 2010 were higher, particularly when compared to the neap tide conditions.

Again, it is possible these differences could be attributed to metals bound to sediments in catchment inflows and urban stormwater runoff and the long flushing times of Port Curtis.

3.2.5 Discussion

The key findings for the water quality in the vicinity of Boatshed Point are as follows:

Physicochemical parameters

- Turbidity is relatively uniform with depth at all tidal events during both neap and spring tidal conditions suggesting a well-mixed, high energy environment.

- Turbidity is higher during spring tidal condition compared to that during the neap tidal condition. This could be attributed to either an increase in bottom sediment re-suspension with higher current velocities during spring tidal conditions or sediment in catchment runoff from a storm event immediately prior to the spring tide field data collection.

- Values for pH, temperature, and salinity are relatively uniform with depth and tidal events for both neap and spring tidal conditions suggesting a well-mixed, high energy environment.

- Values for pH and salinity are higher during spring tidal conditions compared to that during the neap tidal conditions. This is most likely due to the greater hydraulic connection during spring tide conditions to open ocean conditions which are higher in salinity and pH.

- In comparison of the water quality observed at Site 5 in March 2010, physicochemical parameters were observed to be lower for temperature, pH, turbidity and chlorophyll-*a*, and higher for salinity and dissolved oxygen. These phenomena are likely attributable to either seasonal patterns (e.g., temperature) or influence of catchment inflows (e.g., turbidity and salinity).

Nutrients

- All nitrogen species at all sites of interest were not detected at concentrations greater than the detection limit of the analysis, however, it should be noted the detection limits of instruments for all nitrogen constituents were greater than the project water quality criteria.

- Phosphorus concentrations including total phosphorus and filterable reactive phosphorus at all sites of interest were not detected at concentrations greater than the detection limit of the analysis. It should be noted the detection limit of analysis for FRP was greater than the project water quality criteria.

- Comparison of nutrient concentrations between August 2012 and March 2010 indicates higher levels of nitrogen, phosphorus and organic carbon. This is likely due to inflows of nutrients from surrounding catchments prior to the March 2010 monitoring event.

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Metals

- When metals were detected, they were present in higher concentrations during spring tide condition compared to those present in neap tide condition. Metals adsorbed to sediments, which are often re-entrained in the water column at high current velocities, could be an explanation of this phenomenon. This could also be the result of a large storm event that occurred between the sampling of the neap and spring tide monitoring periods. Urban stormwater runoff is often high in metals concentrations.

- Comparison of metals concentrations from between August 2012 and March 2010 indicates that like nutrients, metal concentrations were likely elevated compared 2012 due to storm events prior to the March 2010 monitoring event.

3.3   Hydrostatic Test Water Discharge Impact Assessments

Near field modelling of the hydrostatic test water was undertaken to assess potential impacts of freshwater discharge to predominantly saline water. Salinity is the primary constituent of concern at this time because it is the only constituent in the discharge that is of known quantity. Should additional discharge water quality data become available, the potential impacts of that could be assessed at that time.

The modelling presented herein is largely based on the modelling conducted for the Arrow LNG EIS, as the diffuser through which the discharge would occur is assumed to be the same.

Modelling is conducted with consideration given to the following documents as guidance for the process:

- Operational Policy – Waste water discharge to Queensland waters (QLD EPA, 2007);

- Guidelines for Fresh and Marine Water Quality (ANZECC/ARMCANZ 2000); and

- Dilution Models for Effluent Discharges – Visual Plumes (USEPA, 2003).

3.3.1   Model Selection

Dilution modelling for this study consisted of near field dilution modelling using the 3-dimensional Updated Merge (UM3) module of Visual Plumes, developed by the United States Environmental Protection Agency (USEPA). UM3 is a steady-state Lagrangian model. Near field dilution is the dilution resulting from the momentum of the discharge associated with the outfall design. Similar to the Arrow LNG EIS, far field modelling was not conducted for this study due to the relatively low discharge rates and the unknown quality of the hydrostatic test discharge water.

3.3.2   Modelled Scenarios

The modelling scenarios were developed under the following assumptions and conditions:

- The maximum total volume of discharge provided by Arrow is 3 LNG tanks at 125 million litres (ML) each for a total of 375 ML;

- Only one discharge flow rate was assumed, and it represented the maximum discharge flow rate modelled in the Arrow LNG EIS (4,871 m^3/day);

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- Current speeds were representative of the range of conditions expected at the 10th (low), 50th (median) and 90th (high) percentiles velocities during both flood and ebb tidal conditions;

- The abovementioned current speeds were modelled under both neap and spring tide regimes; and

- In total there were 14 scenarios modelled: 2 representing slack tide conditions, 6 for neap tide, and 6 for spring tides at the flood and ebb velocities discussed in the previous bullets. Summary of these scenarios is provided in Table 16.

Table 16 Near Field Modelling Scenarios

Scenario	Tidal Condition	Current Direction	Ambient Velocity
1		Slack	Nil
2			10th %-ile (low)
3		Ebb	50th %-ile (med)
4	Neap Tide		90th %-ile (high)
5			10th %-ile (low)
6		Flood	50th %-ile (med)
7			90th %-ile (high)
8		Slack	Nil
9			10th %-ile (low)
10		Ebb	50th %-ile (med)
11	Spring Tide		90th %-ile (high)
12			10th %-ile (low)
13		Flood	50th %-ile (med)
14			90th %-ile (high)

3.3.3 Modelling Parameters

Dilution modelling inputs include three main groups of data:

- Effluent quantity and physical characteristics (Discharge);

- Ambient velocity, geometry, and physical characteristics (Ambient); and

- Diffuser arrangement (Outfall).

3.3.3.1 Discharge Parameters

The hydrostatic test water discharge was assumed to be discharged at a rate similar to those used in the Arrow LNG EIS diffuser modelling. Table 17 summarises the effluent characteristics of the hydrostatic test water at maximum discharge rate. Here it was assumed freshwater is used for hydrostatic test purposes. While it is possible that seawater may be used for the hydrotest water, it was assumed the seawater used in the test would be of the same composition as the receiving water in terms of water quality and salinity/density. Therefore, if seawater was used as hydrotest water, it was assumed this would not result in impacts to marine water quality.

The total conservative test water volume, as provided by Arrow, is 360,000m^3 of freshwater. Discharged at a rate equal to the maximum rate modelled in the Arrow LNG EIS, the period of discharge would be approximately 74 days of continuous discharge.

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It should be noted that salinity is likely to be the main constituent of concern with regard to the hydrotest water discharge. At the time of this study, no other water quality data pertaining to the discharge was made available for impacts assessments.

Table 17 Hydrostatic Test Water Parameters

Parameter	Value
Total Volume (ML)	360.0
Period of discharge (days)	74
Flow Rate (MLD)	4.871
Salinity ppt)	0.00
Temperature (^{o}C)	30.0
Density (kg/m^3)	995.7

3.3.3.2 Outfall Parameters

Table 18 summarizes the outfall arrangement parameters. These parameters are representative of the diffuser modelled in the Arrow LNG EIS water quality assessments (BMT WBM, 2011a).

Table 18 Diffuser Parameters

Parameter	Value
Number of Ports	3
Port Diameter (m)	0.100
Port Elevation (m AHD)	-11.99
Port Depth (m)	10.3
Distance Between Ports (m)	10.0
Diffuser Length (m)	20.0
Vertical Angle (deg) [a]	45
Horizontal Angle (deg true N)	260
Discharge Velocities (m/s)	2.4 to 2.8

3.3.3.3 Ambient Parameters

Ambient characteristics at the location the proposed outfall are summarized in Table 19. Ambient salinity and temperature values during neap and spring tidal conditions were estimated by calculating the median of salinities and temperatures of all eight sites of interest (21 through 28) collectively.

Ambient depth-averaged velocities were extracted at the location of the proposed outfall from the TUFLOW-FV hydrodynamic and sediment transport model developed for the Gladstone Western Basin EIS. The ambient tidal currents flow along the alignment of the deeper channel immediately offshore from Boatshed Point, which runs from slightly north of east to slightly south of west. Ambient velocities are provided in Table 20 for both neap and spring tidal conditions.

Ambient geometry, for the purposes of this study, includes only a representative depth as per the modelling requirements. A cross section of the bottom elevation of Port Curtis at the location of the outfall is in Figure 71. Figure 71 is based on the general assumed location of the outfall and the average bottom elevation. The representative depth was calculated assuming the water surface elevations at Mean Low Water Spring tide (MLWS) (EPA 2007).

Table 19 Ambient Parameters

Parameter	Value
Bed Elevation (m AHD)	-14.33
MLWS (m AHD)	-1.66
Average Depth (m)	12.68
Temperature (oC)	
Neap	19.80
Spring	21.20
Salinity (ppt)	
Neap	34.55
Spring	36.56
Density (kg/m^3)	
Neap	1024.5
Spring	1025.7
Ambient Direction (deg true N)	
Ebb	80
Flood	260

Table 20 Tidal Conditions and Ambient Velocities

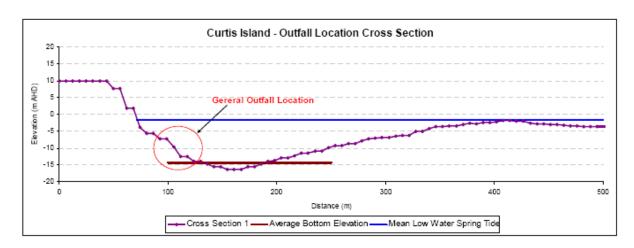| Tidal Condition	Current Direction	10th Percentile	50th Percentile	90th Percentile
Neap	Slackwater	0.000		
	Ebb (m/s)	0.040	0.237	0.576
	Flood (m/s)	0.073	0.288	0.549
Spring	Slackwater	0.000		
	Ebb (m/s)	0.038	0.292	0.593
	Flood (m/s)	0.109	0.372	0.570

Figure 71   Cross Section at the Diffuser Location

3.3.4   Modelling Results

Discussion of the modelling results and impacts assessments are presented with respect to the following concepts:

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- Near field dilution factor (DF) – The factor by which effluent volume is reduced at a given location relative to the outfall. As the discharge disperses after discharge, receiving water is entrained in the plume, thereby diluting the discharge to the ratio specified as the dilution factor. Specifically, the dilution factor is the total volume of water at any location within the plume divided by the volume of discharge at the location. This is explained through the following relationship:

$$DF = \frac{V_{RW} + V_{DIS}}{V_{DIS}},$$

where V_{RW} is the volume of receiving water and V_{DIS} is the volume of discharge within a given volume in the plume. For example, if the dilution factor at 10m from the outfall is 20, then the ratio of receiving and discharge volumes is 19 to 1. The dilution factor can be defined at any location within a discharge plume but for the purposes of this study is reported at the end of the near field distance, described in the bullet point below;

- Near field distance – The distance from the outfall where mixing that occurs in discharge plume is governed by the momentum and buoyancy of the discharge. In marine discharge for submerged outfalls, the near field typically terminates when the discharge impacts a boundary, such as the bottom (for dense brine discharge) or at the surface (for buoyant freshwater discharge). Additional mixing may occur beyond this distance, however, in some scenarios, this mixing is impossible (slack water) or minimal (low ambient velocities) compared to near field dilution because additional mixing relies on receiving water velocities to provide additional energy;

- Mixed constituent concentration – To derive the concentration of a constituent at any given point within the plume, the dilution factor is required along with the concentration of the constituent in both the receiving water and the discharge. The concentration is calculated using a mass balance that accounts for the dilution factor and relative volumes of receiving and discharge waters. This is calculated using the following equation:

$$C_{MIX} = \frac{C_{DIS} + (DF - 1)C_{RW}}{DF},$$

where C_{MIX} is the concentration of any constituent in the mixed receiving and discharge water, C_{DIS} is the concentration of the constituent in the discharge and C_{RW} is the concentration of the constituent in the receiving water. Table 21 provides the dilution factors at the boundary of the near field, and the lengths of the near field for each modelled scenario.

Table 21 also provides the dilution factors at a fixed distance of 10m from the outfall to compare the mixing behaviour of all scenarios together since the near field lengths are influenced by the varying ambient velocity regimes at each scenario.

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Table 21   Modelling Results - Dilution Factors at 10m and Near Field Length

Tidal Condition	Scenario	Ambient Velocity Regime	Near Field Zone Dilution Factor	Near Field Zone Length (m)	Dilution Factor at 10m
Neap Tide	1	**Slack**	38	3	NA
		Ebb			
	2	10th Percentile	63	4	NA
	3	50th Percentile	200	20	86
	4	90th Percentile	469	75	40
		Flood			
	5	10th Percentile	89	5	NA
	6	50th Percentile	242	27	69
	7	90th Percentile	449	70	41
Spring Tide	8	Slack	39	3	NA
		Ebb			
	9	10th Percentile	60	4	NA
	10	50th Percentile	242	26	68
	11	90th Percentile	483	77	40
		Flood			
	12	10th Percentile	114	7	NA
	13	50th Percentile	307	38	54
	14	90th Percentile	470	74	40

3.3.5 Water Quality Impacts

For the constituent of concern, salinity, there is no water guideline established for Port Curtis. Nevertheless, impacts can be assessed on the change in the resultant downstream salinities based on the dilution factors provided by the modelling results coupled with the ambient and discharge salinities. In particular, each scenario was assessed in terms of the distance required to:

- Return to within the range of salinities observed during the March 2010 monitoring programme; and

- Return to within the range of salinities observed during the August 2012 monitoring programme.

The results of these two conditions are presented in Table 22.

It should be noted that potential impacts from other constituents were not assessed in this study because discharge water quality data were not provided. In the instance of using of seawater for the hydrotest, there are no anticipated impacts, because the receiving and discharge water quality would likely be similar. Impacts for the freshwater case were therefore assumed to be on salinity regimes due to the difference in salinities.

The modelling results presented in Table 22 indicate that salinity returned to background levels no more than 17m in the most saline background conditions observed in August 2012, and no more than approximately 3m in the less saline conditions observed in March 2010.

Table 22   Distance to Return to Ambient Salinity

Tidal Condition	Scenario	Ambient Velocity Regime	Mar-2010 Distance (m)	Aug-2012 Distance (m)
Neap Tide	1	**Slack**	2.1	< 5
		Ebb		
	2	10th Percentile	1.7	3.7
	3	50th Percentile	1.4	8.6
	4	90th Percentile	2.1	16.5
		Flood		
	5	10th Percentile	1.5	4.7
	6	50th Percentile	1.4	10.2
	7	90th Percentile	1.6	16.3
Spring Tide	8	Slack	1.6	2.5
		Ebb		
	9	10th Percentile	1.3	2.1
	10	50th Percentile	1.0	2.5
	11	90th Percentile	1.3	3.5
		Flood		
	12	10th Percentile	1.2	1.8
	13	50th Percentile	1.1	2.6
	14	90th Percentile	1.3	3.5

3.3.6   Discussion

The near field modelling and impacts assessments indicate the following

- Rapid initial dilution was achieved for all scenarios within a short distance of the outfall. For all scenarios, a minimum dilution factor of approximately 40 was achieved at a distance no greater than 10m from the outfall. These results are consistent with the modelling previously conducted for the Arrow LNG EIS, even though the discharge was brine and negatively buoyant.

- Due to the rapid initial dilution for all scenarios, salinities quickly returned to within the ambient ranges observed during the 2 monitoring events. The following observations are worth noting:

  o   With regard to the neap tide slackwater conditions (Scenario 1), the hydrostatic testwater did not return to within the range of salinity conditions observed during the August 2012 monitoring programme within the modelled near field distance of 3 metres. Nevertheless, at the near field boundary the discharge does return to within less than 0.5 ppt of the minimum salinity value observed. Additionally, the modelled slackwater conditions would persist for less than 1 hour, after which time background velocities will advect the plume in a manner similar to Scenarios 2 and 5. Therefore, it is anticipated the hydrotest water would return within the range of conditions observed during the August 2012 monitoring programme at a distance no greater than 5 metres from the outfall.

  o   Because August 2012 background salinities were greater than March 2010 background salinities, the distance for the discharge to return to within the range of observed values was determined to be greater under the more saline background conditions. Nevertheless,

the greatest distance was seen to occur in Scenarios 4 and 7 (< 17m from the outfall), where initial dilution was achieved rapidly, but the plumes were rapidly deflected away from the outfall.

- In the instances of all 10th percentile (low) ambient velocity scenarios (scenarios 2, 5, 9 and 12), a dilution factor of 60 or greater was achieved in more than 7m from the outfall.

- In the case of the 50th percentile (median) and 90th percentile (high) ambient velocities, the plumes were advected downstream tens of metres from the outfall and achieved dilution factors of 200 or greater, with dilution factors at 10m typically 40 or greater.

Overall, the discharge will likely not result in significant impact because:

- The quantity of the discharge is very small relative to the total tidal exchange within the system, and the duration of the discharge is relatively short (74 days).

- The system demonstrates a well-mixed, high-energy environment, which will provide rapid initial dilution of discharge. As a result, salinities would be expected to return to within observed ranges for the location within a short distance and time away from the outfall.

4 RECOMMENDED MITIGATION MEASURES

4.1 Coastal Processes and Hydrodynamics

The commitments outlined in the original Arrow LNG Plant EIS remain valid for mitigation of impacts to coastal processes and hydrodynamics. The additional assessments undertaken as part of this study have not identified any additional measures which would provide any further mitigation of project-related impacts. The changes to the tidal hydrodynamics in the Calliope River estuary caused by dredging the entrance to the river cannot be mitigated by engineering measures. As suggested in the original EIS, ongoing monitoring of erosion in the Calliope River will need to take place during and after project works. Remedial measures may be required where erosion would present an unacceptable impact on existing ecological values or physical infrastructure.

4.2 Marine Water Quality

The proposed discharge of hydrostatic test water at Boatshed Point will not result in adverse environmental impacts due to rapid initial dilution of the discharge.

As presented in the original EIS, general mitigation measures for the proposed outfall include:

- The recommended diffuser design and configuration should be adopted;

- The location of the outfall should remain in the zone of high velocity currents to the south of Boatshed Point to ensure optimum conditions for mixing; and

- The results of the modelling should be revisited if project design elements change including the composition and magnitude of the discharge streams.

5 CONCLUSION

BMT WBM carried out additional work to update the original coastal processes, hydrodynamics and water quality impact assessment presented in the Arrow LNG Plant Project EIS (Arrow Energy, 2012).

Numerical modelling was undertaken to assess the effects of changes to planned project infrastructure at Boatshed Point and at the Launch Site 1. It was found that the significance of the impact to hydrodynamics in both locations is minor (as per the original EIS).

Additional modelling of the Calliope River estuary was undertaken to further quantify the extent of changes to the hydrodynamic regime. The results support the conclusions reached in the original EIS, which assessed the significance of the impact as moderate.

Water quality assessments were undertaken to review additional data and evaluate the impact of the discharge of hydrostatic test water to Port Curtis. It was found that the discharge will not result in significant impact.

6 REFERENCES

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APPENDIX A: PORT CURTIS WATER QUALITY – AUGUST 2012

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Table 1-1. Total Metals Laboratory Results for Neap Tide Top of Water Column Samples

(all values expressed in µg/l)

Parameter	Site 1 H	Site 1 M	Site 1 L	Site 2† H	Site 2† M	Site 2† L	Site 3 H	Site 3 M	Site 3 L	Site 4 H	Site 4 M	Site 4 L	Site 5 H	Site 5 M	Site 5 L	WQG*
Mercury	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	0.06
Aluminium	547	743	676	404.5 ± 34.5	843.5 ± 236.5	370.5 ± 29.5	393	1180	357	503	593	314	603	101	536	ID
Iron	587	825	750	410 ± 30	937 ± 273	414 ± 30	435	1320	369	514	681	332	643	106	576	ID
Arsenic	1.5	2	1.8	1.6	2 ± 0.1	1.6	1.6	1.8	1.6	1.7	1.6	1.6	1.8	1.4	1.6	13
Cadmium	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	0.2
Chromium	0.5	0.9	0.7	LD	LD	LD	LD	**1.3**	LD	0.6	**1.1**	LD	0.6	LD	LD	1
Cobalt	0.3	0.4	0.4	0.2	0.5 ± 0.1	0.3	0.2	0.6	0.3	0.3	0.4	0.3	0.3	LD	0.3	ID
Copper	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	1.4
Lead	LD	LD	LD	LD	0.3 ± 0.1	LD	LD	0.4	LD	0.2	LD	LD	LD	LD	LD	3.4
Manganese	14	18.9	19	11.1 ± 0.3	24.3 ± 4.5	21 ± 0.4	11.3	29.3	22.4	16.9	26.4	22.9	16.6	18.6	27.4	1900
Nickel	0.8	1.1	0.9	0.9 ± 0.2	1.1 ± 0.	0.8 ± 0.2	0.7	1	LD	0.8	1.2	LD	0.6	0.5	0.9	11
Silver	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	0.05
Vanadium	3.4	3.8	3.6	2.8	4.3 ± 0.1	3.1 ± 0.5	3.1 ± 0.2	5.4	2.3	2.6	2.9	2.3	3.2	1.8	3	ID
Zinc	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	8

* ANZECC (2000) WQGs for slightly to moderately disturbed estuarine waters.

† Site with duplicates. Results are shown as mean ± SE.

L = Low tide, M = Mid tide, H = High tide.

ID = Insufficient data.

LD = Less than detection limit. Relevant detection limits are as follows:

Mercury:	0.1 µg/l	Lead:	0.2 µg/l
Cadmiun:	0.2 µg/l	Nickel:	0.5 µg/l
Chromiun:	0.5 µg/l	Silver:	0.1 µg/l
Cobalt:	0.2 µg/l	Zinc:	5 µg/l
Copper:	1 µg/l		

Table 1-2. Total Metals Laboratory Results for Neap Tide Bottom of Water Column Samples

(all values expressed in µg/l)

Parameter	Site 1 H	1 M	1 L	Site 2† H	2† M	2† L	Site 3 H	3 M	3 L	Site 4 H	4 M	4 L	Site 5 H	5 M	5 L	WQG*
Mercury	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	0.06
Aluminium	710	565	675	719 ± 133	986 ± 54	1164.5 ± 605.5	326	1060	352	966	1450	581	842	558	737	ID
Iron	688	614	742	800 ± 136	1085 ± 55	1397.5 ± 772.5	330	1100	375	1060	1560	646	951	611	827	ID
Arsenic	1.7	1.7	1.8	1.9 ± 0.1	2.1 ± 0.1	2.2 ± 0.5	1.6	1.8	1.5	1.9	2.2	1.7	1.9	1.7	1.7	13
Cadmium	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	0.2
Chromium	0.6	LD	**1.5**	0.7 ± 0.1	1	LD	LD	**1.1**	LD	**1.7**	**1.5**	1	0.9	0.6	0.7	1
Cobalt	0.3	0.3	0.4	0.4 ± 0.1	0.5	0.7 ± 0.3	0.2	0.5	0.3	0.5	0.7	0.4	0.4	0.4	0.4	ID
Copper	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	1	LD	LD	LD	LD	1.4
Lead	LD	LD	LD	0.2	0.3	0.7	LD	0.5	LD	0.3	0.5	LD	0.3	LD	0.2	3.4
Manganese	17	15.2	18.1	20 ± 3.8	25.8 ± 1	46.6 ± 20.3	10	24.2	22.3	24.6	44.7	30.5	23.4	30.9	37	1900
Nickel	0.9	0.9	1.8	0.9 ± 0.1	1.1 ± 0.1	1.3 ± 0.4	0.6	1.1	0.6	1.4	1.2	0.6	1.1	1	1	11
Silver	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	0.05
Vanadium	3.3	3.1	3.6	3.8 ± 0.5	4.5 ± 0.2	5.2 ± 1.9	3.1	3.8	2.4	3.7	5.4	3	3.7	3.1	3.7	ID
Zinc	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	8

* ANZECC (2000) WQGs for slightly to moderately disturbed estuarine waters.

† Site with duplicates. Results are shown as mean ± SE.

L = Low tide, M = Mid tide, H = High tide.

ID = Insufficient data.

LD = Less than detection limit. Relevant detection limits are as follows:

Mercury:	0.1 µg/l	Lead:	0.2 µg/l
Cadmiun:	0.2 µg/l	Nickel:	0.5 µg/l
Chromiun:	0.5 µg/l	Silver:	0.1 µg/l
Cobalt:	0.2 µg/l	Zinc:	5 µg/l
Copper:	1 µg/l		

Table 1-3. Total Metals Laboratory Results for Neap Tide Top of Water Column Samples

(all values expressed in μg/l)

Parameter	Site 6			Site 7			Site 8[†]			Site 9			Site 10			WQG*
	H	M	L	H	M	L	H	M	L	H	M	L	H	M	L	
Mercury	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	0.06
Aluminium	200	261	147	186	229	179	226.5 ± 30.5	151.5 ± 0.5	149.5 ± 16.5	228	373	131	178	146	189	ID
Iron	203	306	160	210	288	205	248.5 ± 37.5	172 ± 4	163.5 ± 19.5	255	428	147	202	166	211	ID
Arsenic	1.6	1.6	1.3	1.6	1.4	1.3	1.7 ± 0.1	1.5	1.3	1.6	1.6	1.2	1.6	1.5	1.2	13
Cadmium	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	0.2	0.2
Chromium	LD	LD	LD	0.5	LD	LD	LD	**1.2**	LD	LD	LD	LD	LD	LD	LD	1
Cobalt	LD	0.3	LD	0.2	0.2	0.2	LD	LD	LD	0.2	0.3	LD	0.2	LD	0.2	ID
Copper	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	1.4
Lead	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	3.4
Manganese	21.2	25.2	31.4	25.8	37.2	40	31.8 ± 1.1	35.5 ± 0.5	37.3 ± 0.7	35.9	48.6	38.4	37.8	40	41.6	1900
Nickel	LD	0.5	LD	0.7	LD	LD	LD	0.9 ± 0.2	LD	LD	LD	LD	0.7	LD	LD	11
Silver	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	0.05
Vanadium	2	2.7	2.3	1.6	2.8	2.7	2.1 ± 0.1	1.2 ± 0.1	2.9 ± 0.1	2.2	2.7	2.9	2.4	2.2	3.3	ID
Zinc	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	8

* ANZECC (2000) WQGs for slightly to moderately disturbed estuarine waters.

† Site with duplicates. Results are shown as mean ± SE.

L = Low tide, M = Mid tide, H = High tide.

ID = Insufficient data.

LD = Less than detection limit. Relevant detection limits are as follows:

Mercury:	0.1 μg/l	Lead:	0.2 μg/l
Cadmiun:	0.2 μg/l	Nickel:	0.5 μg/l
Chromiun:	0.5 μg/l	Silver:	0.1 μg/l
Cobalt:	0.2 μg/l	Zinc:	5 μg/l
Copper:	1 μg/l		

Table 1-4. Total Metals Laboratory Results for Neap Tide Bottom of Water Column Samples

(all values expressed in µg/l)

Parameter	Site 6 H	Site 6 M	Site 6 L	Site 7 H	Site 7 M	Site 7 L	Site 8† H	Site 8† M	Site 8† L	Site 9 H	Site 9 M	Site 9 L	Site 10 H	Site 10 M	Site 10 L	WQG*
Mercury	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	0.06
Aluminium	136	138	172	140	172	127	155 ± 21	104.5 ± 1.5	310 ± 85	152	185	129	175	184	103	ID
Iron	134	160	191	156	190	140	175.5 ± 21.5	113 ± 4	370.5 ± 95.5	169	208	147	221	202	112	ID
Arsenic	1.6	1.4	1.3	1.6	1.4	1.3	1.7 ± 0.1	1.5 ± 0.1	1.5 ± 0.1	1.6	1.5	1.3	1.3	1.6	1.3	13
Cadmium	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	0.2
Chromium	LD	LD	LD	LD	LD	LD	LD	LD	0.7	LD	LD	LD	LD	LD	LD	1
Cobalt	LD	LD	LD	LD	LD	LD	LD	LD	0.3 ± 0.1	LD	0.2	LD	0.2	LD	LD	ID
Copper	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	1.4
Lead	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	3.4
Manganese	18.9	24.8	30.9	25.4	31.8	31.4	26.2 ± 0.1	27.9 ± 0.3	44 ± 3.4	32.5	40.5	35.4	40.9	36.2	31	1900
Nickel	LD	0.8	LD	LD	0.9	LD	LD	LD	0.8 ± 0.3	LD	LD	LD	LD	LD	LD	11
Silver	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	0.05
Vanadium	1.7	2.2	2.3	1.7	2.8	2.5	1.9 ± 0.1	1.8	3.2 ± 0.4	2.1	2.3	2.6	2.2	2.2	2.5	ID
Zinc	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	8

* ANZECC (2000) WQGs for slightly to moderately disturbed estuarine waters.

† Site with duplicates. Results are shown as mean ± SE.

L = Low tide, M = Mid tide, H = High tide.

ID = Insufficient data.

LD = Less than detection limit. Relevant detection limits are as follows:

Mercury:	0.1 µg/l	Lead:	0.2 µg/l
Cadmiun:	0.2 µg/l	Nickel:	0.5 µg/l
Chromiun:	0.5 µg/l	Silver:	0.1 µg/l
Cobalt:	0.2 µg/l	Zinc:	5 µg/l
Copper:	1 µg/l		

Table 1-5. Total Metals Laboratory Results for Neap Tide Top of Water Column Samples

(all values expressed in µg/l)

Parameter	Site 11† H	11† M	11† L	12 H	12 M	12 L	13 H	13 M	13 L	14 H	14 M	14 L	15 H	15 M	15 L	WQG*
Mercury	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	0.06
Aluminium	368.5 ± 32.5	308.5 ± 82.5	1530 ± 160	98	350	542	190	256	545	143	193	418	160	190	1140	ID
Iron	408.5 ± 32.5	320 ± 58	1735 ± 135	110	393	689	217	313	673	156	219	488	177	243	1430	ID
Arsenic	1.6	1.5	2.35 ± 0.15	1.4	1.6	2	1.5	1.3	1.8	1.4	1.5	1.7	1.5	1.5	2.3	13
Cadmium	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	0.2
Chromium	LD	LD	**2.1 ± 0.2**	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	1	**1.3**	1
Cobalt	0.3 ± 0.1	0.3 ± 0.1	0.9 ± 0.1	LD	0.3	0.4	LD	0.2	0.5	LD	0.2	0.4	LD	0.3	0.8	ID
Copper	LD	LD	**2**	LD	LD	1	LD	LD	**3**	LD	LD	LD	LD	LD	**2**	1.4
Lead	LD	LD	0.5	LD	LD	LD	LD	LD	0.2	LD	LD	LD	LD	LD	0.5	3.4
Manganese	24 ± 0.4	18 ± 0.7	67.8 ± 2.2	14	26.7	56.8	20	25.3	72.4	13.9	21.8	50.2	8.4	18.3	61.7	1900
Nickel	LD	0.7	1.70 ± .1	LD	0.7	1	LD	0.7	0.9	0.6	LD	0.8	0.6	1.4	1.3	11
Silver	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	0.05
Vanadium	2.5	2.1 ± 0.1	6 ± 0.4	1.8	2.1	2.5	2.3	2	2.3	1.7	2	2	2	2	4.4	ID
Zinc	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	8

* ANZECC (2000) WQGs for slightly to moderately disturbed estuarine waters.

† Site with duplicates. Results are shown as mean ± SE.

L = Low tide, M = Mid tide, H = High tide.

ID = Insufficient data.

LD = Less than detection limit. Relevant detection limits are as follows:

Mercury:	0.1 µg/l	Lead:	0.2 µg/l
Cadmiun:	0.2 µg/l	Nickel:	0.5 µg/l
Chromiun:	0.5 µg/l	Silver:	0.1 µg/l
Cobalt:	0.2 µg/l	Zinc:	5 µg/l
Copper:	1 µg/l		

Table 1-6. Total Metals Laboratory Results for Neap Tide Bottom of Water Column Samples

(all values expressed in µg/l)

Parameter	Site 11† H	Site 11† M	Site 11† L	Site 12 H	Site 12 M	Site 12 L	Site 13 H	Site 13 M	Site 13 L	Site 14 H	Site 14 M	Site 14 L	Site 15 H	Site 15 M	Site 15 L	WQG*
Mercury	LD	LD	-	LD	LD	-	LD	LD	-	LD	LD	-	LD	LD	-	0.06
Aluminium	1215 ± 85	363 ± 29	-	123	435	-	203	322	-	134	274	-	275	212	-	ID
Iron	1425 ± 85	455.5 ± 29.5	-	133	522	-	240	403	-	147	344	-	312	263	-	ID
Arsenic	2 ± 0.1	1.6	-	1.4	1.6	-	1.5	1.4	-	1.4	1.6	-	1.5	1.6	-	13
Cadmium	LD	LD	-	LD	LD	-	LD	LD	-	LD	LD	-	LD	LD	-	0.2
Chromium	1.6 ± 0.2	LD	-	LD	LD	-	0.6	LD	-	LD	0.9	-	LD	0.6	-	1
Cobalt	0.7 ± 0.1	0.3	-	LD	0.3	-	LD	0.3	-	LD	0.2	-	0.2	0.3	-	ID
Copper	1	LD	-	LD	LD	-	LD	LD	-	LD	LD	-	LD	LD	-	1.4
Lead	0.5 ± 0.1	LD	-	LD	LD	-	LD	LD	-	LD	LD	-	LD	LD	-	3.4
Manganese	44.2 ± 2.2	22.3 ± 0.3	-	14	30.6	-	19.2	28.1	-	13.5	24.4	-	12.7	19.6	-	1900
Nickel	1	0.7 ± 0.2	-	LD	0.8	-	LD	0.7	-	0.5	1.1	-	0.6	1	-	11
Silver	LD	LD	-	LD	LD	-	LD	LD	-	LD	LD	-	LD	LD	-	0.05
Vanadium	4.9 ± 0.2	2.4 ± 0.2	-	2	2.6	-	2.2	2.1	-	1.6	2.3	-	2.2	2.1	-	ID
Zinc	LD	LD	-	LD	LD	-	LD	LD	-	LD	LD	-	LD	LD	-	8

* ANZECC (2000) WQGs for slightly to moderately disturbed estuarine waters.

† Site with duplicates. Results are shown as mean ± SE.

L = Low tide, M = Mid tide, H = High tide.

ID = Insufficient data.

LD = Less than detection limit. Relevant detection limits are as follows:

Mercury:	0.1 µg/l	Lead:	0.2 µg/l
Cadmiun:	0.2 µg/l	Nickel:	0.5 µg/l
Chromiun:	0.5 µg/l	Silver:	0.1 µg/l
Cobalt:	0.2 µg/l	Zinc:	5 µg/l
Copper:	1 µg/l		

Table 1-7. Total Metals Laboratory Results for Neap Tide Top of Water Column Samples

(all values expressed in µg/l)

Parameter	Site 16†			17			18			19			20†			WQG*
	H	M	L	H	M	L	H	M	L	H	M	L	H	M	L	
Mercury	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	0.06
Aluminium	293 ± 6	621.5 ± 57.5	380 ± 42	228	699	609	324	575	1080	271	824	544	298.5 ± 40.5	347.5 ± 8.5	837.5 ± 27.5	ID
Iron	358.5 ± 5.5	768 ± 69	462.5 ± 49.5	270	895	720	341	735	1340	301	1030	706	364.5 ± 53.5	395 ± 3	1011.5 ± 48.5	ID
Arsenic	1.6 ± 0.1	1.8 ± 0.1	1.8	1.5	1.8	2	1.5	1.8	2.4	1.5	1.8	2	2.1 ± 0.1	1.5	1.8 ± 0.1	13
Cadmium	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	0.2
Chromium	LD	0.7 ± 0.1	LD	LD	0.8	0.5	0.9	0.6	**1.2**	LD	**2.5**	0.6	LD	0.8	1	1
Cobalt	0.3 ± 0.1	0.5 ± 0.1	0.4 ± 0.1	0.2	0.5	0.4	0.2	0.4	0.8	0.2	0.6	0.6	0.4 ± 0.1	0.2	0.6	ID
Copper	LD	LD	LD	LD	LD	1	LD	LD	**2**	LD	LD	LD	LD	LD	LD	1.4
Lead	LD	0.3 ± 0.1	0.3 ± 0.1	LD	0.3	0.4	LD	0.2	0.8	LD	0.5	0.5	0.3	LD	0.5 ± 0.1	3.4
Manganese	8.8 ± 0.1	16.1 ± 1.8	11.7 ± 0.8	7.1	17.3	14	7.8	16.4	24.4	7.6	17	19.2	14.7 ± 1.4	8.4 ± 0.4	16.6 ± 0.1	1900
Nickel	LD	1 ± 0.1	0.9	LD	0.8	0.9	1	0.8	1.4	0.5	1.7	1.1	0.5	0.9 ± 0.2	1 ± 0.5	11
Silver	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	0.05
Vanadium	2.2 ± 0.1	3.2 ± 0.2	2.3 ± 0.1	2.1	3.5	3.1	2.8	3.2	4.6	2.4	3.6	3.2	2.3 ± 0.2	2.6	3.9 ± 0.4	ID
Zinc	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	8

* ANZECC (2000) WQGs for slightly to moderately disturbed estuarine waters.

† Site with duplicates. Results are shown as mean ± SE.

L = Low tide, M = Mid tide, H = High tide.

ID = Insufficient data.

LD = Less than detection limit. Relevant detection limits are as follows:

Mercury:	0.1 µg/l	Lead:	0.2 µg/l
Cadmiun:	0.2 µg/l	Nickel:	0.5 µg/l
Chromiun:	0.5 µg/l	Silver:	0.1 µg/l
Cobalt:	0.2 µg/l	Zinc:	5 µg/l
Copper:	1 µg/l		

Table 1-8. Total Metals Laboratory Results for Neap Tide Bottom of Water Column Samples

(all values expressed in µg/l)

Parameter	Site 16†			17			18			19			20†			WQG*
	H	M	L	H	M	L	H	M	L	H	M	L	H	M	L	
Mercury	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	0.06
Aluminium	337 ± 4	528.5 ± 81.5	523 ± 27	211	520	956	380	735	818	329	550	706	202.5 ± 15.5	393.5 ± 104.5	530 ± 144	ID
Iron	381.5 ± 13.5	649 ± 117	633.5 ± 58.5	231	673	1100	423	915	983	372	685	850	239.5 ± 19.5	447.5 ± 128.5	673 ± 163	ID
Arsenic	1.7 ± 0.1	1.7 ± 0.1	1.9 ± 0.1	1.2	1.7	2.2	1.5	1.6	2.1	1.5	1.8	1.6	2 ± 0.1	1.6 ± 0.1	1.8 ± 0.1	13
Cadmium	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	0.2
Chromium	LD	0.6	LD	0.7	**1.9**	0.9	LD	0.7	0.7	**1.1**	LD	0.6	LD	0.5	0.7	1
Cobalt	0.3 ± 0.1	0.4	0.4	LD	0.5	0.6	0.2	0.5	0.6	0.2	0.4	0.5	0.3 ± 0.1	0.3 ± 0.1	0.5	ID
Copper	LD	LD	LD	LD	LD	**2**	LD	LD	1	LD	LD	LD	LD	LD	LD	1.4
Lead	LD	0.3 ± 0.1	0.3	LD	0.3	0.6	0.2	0.4	0.4	LD	0.3	0.4	LD	LD	0.4	3.4
Manganese	9 ± 0.2	15.2 ± 0.8	14.2 ± 0.3	6.4	18.7	23	9.9	17.3	19.4	9.1	13.7	16.4	10.8 ± 0.5	9.4 ± 1.7	19.4 ± 3	1900
Nickel	LD	0.9 ± 0.1	1 ± 0.1	1	1.7	1.2	0.5	0.9	1.1	1.1	LD	1.2	LD	0.6 ± 0.1	LD	11
Silver	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	0.05
Vanadium	2.2	2.9 ± 0.1	2.8 ± 0.2	2.4	3.1	4.1	2.7	4.4	3.5	2.7	2.9	4.3	2	2.8 ± 0.3	3 ± 0.3	ID
Zinc	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	8

* ANZECC (2000) WQGs for slightly to moderately disturbed estuarine waters.

† Site with duplicates. Results are shown as mean ± SE.

L = Low tide, M = Mid tide, H = High tide.

ID = Insufficient data.

LD = Less than detection limit. Relevant detection limits are as follows:

Mercury:	0.1 µg/l	Lead:	0.2 µg/l
Cadmiun:	0.2 µg/l	Nickel:	0.5 µg/l
Chromiun:	0.5 µg/l	Silver:	0.1 µg/l
Cobalt:	0.2 µg/l	Zinc:	5 µg/l
Copper:	1 µg/l		

Table 1-9. Total Metals Laboratory Results for Neap Tide Top of Water Column Samples

(all values expressed in µg/l)

Parameter	Site 21 H	Site 21 M	Site 21 L	Site 22 H	Site 22 M	Site 22 L	Site 23 H	Site 23 M	Site 23 L	Site 24 H	Site 24 M	Site 24 L	Site 25 H	Site 25 M	Site 25 L	WQG*
Mercury	LD	LD	LD	LD	LD	LD	LD	LD	-	LD	LD	LD	LD	LD	LD	0.06
Aluminium	96	517	1260	64	342	805	111	261	-	114	423	673	96	247	326	ID
Iron	118	590	1590	71	372	978	130	290	-	158	469	832	130	269	380	ID
Arsenic	1.9	1.6	2.2	1.9	1.5	1.9	1.8	1.4	-	1.4	1.4	1.8	1.4	1.4	1.6	13
Cadmium	LD	LD	LD	LD	LD	LD	LD	LD	-	LD	LD	LD	LD	LD	LD	0.2
Chromium	LD	0.7	**1.6**	LD	LD	0.9	LD	0.5	-	LD	LD	0.8	LD	LD	LD	1
Cobalt	LD	0.3	0.9	LD	0.2	0.5	LD	0.2	-	0.2	0.3	0.5	LD	0.2	0.3	ID
Copper	LD	LD	1	LD	LD	LD	LD	LD	-	LD	LD	LD	LD	LD	LD	1.4
Lead	LD	LD	0.7	LD	LD	0.3	LD	LD	-	LD	LD	0.3	LD	LD	LD	3.4
Manganese	7.3	10.2	29	5.6	8.7	15.9	8.3	6.7	-	11.4	10.7	15.3	7.7	8.3	9.2	1900
Nickel	LD	0.8	1.2	LD	0.5	LD	LD	0.7	-	0.5	LD	LD	LD	LD	LD	11
Silver	LD	LD	LD	LD	LD	LD	LD	LD	-	LD	LD	LD	LD	LD	LD	0.05
Vanadium	1.3	3.1	4.8	1.3	2.7	3.4	1.6	2.6	-	2.6	2.6	3.3	2.1	2.4	2.6	ID
Zinc	LD	LD	LD	LD	LD	LD	LD	LD	-	LD	LD	LD	LD	LD	LD	8

* ANZECC (2000) WQGs for slightly to moderately disturbed estuarine waters.

L = Low tide, M = Mid tide, H = High tide.

ID = Insufficient data.

LD = Less than detection limit. Relevant detection limits are as follows:

Mercury:	0.1 µg/l	Lead:	0.2 µg/l
Cadmiun:	0.2 µg/l	Nickel:	0.5 µg/l
Chromiun:	0.5 µg/l	Silver:	0.1 µg/l
Cobalt:	0.2 µg/l	Zinc:	5 µg/l
Copper:	1 µg/l		

Table 1-10. Total Metals Laboratory Results for Neap Tide Bottom of Water Column Samples

(all values expressed in µg/l)

| Parameter | Site | | | | | | | | | | | | | | | WQG* |
| | 21 | | | 22 | | | 23 | | | 24 | | | 25 | | | |
	H	M	L	H	M	L	H	M	L	H	M	L	H	M	L	
Mercury	LD	LD	LD	LD	LD	-	LD	-	-	LD	LD	LD	LD	LD	-	0.06
Aluminium	136	298	1040	88	349	-	101	-	-	112	207	614	235	306	-	ID
Iron	156	326	1290	101	392	-	131	-	-	154	225	774	278	339	-	ID
Arsenic	1.9	1.5	1.9	2	1.5	-	1.8	-	-	1.5	1.4	1.7	2	1.5	-	13
Cadmium	LD	LD	LD	LD	LD	-	LD	-	-	LD	LD	LD	LD	LD	-	0.2
Chromium	LD	LD	**1.2**	LD	LD	-	LD	-	-	LD	LD	**1.3**	LD	LD	-	1
Cobalt	LD	0.2	0.9	LD	0.2	-	LD	-	-	LD	LD	0.4	LD	0.2	-	ID
Copper	LD	LD	LD	LD	LD	-	**5**	-	-	LD	LD	LD	LD	LD	-	1.4
Lead	LD	LD	0.8	LD	LD	-	LD	-	-	LD	LD	0.3	LD	LD	-	3.4
Manganese	8	8.5	33.4	6.2	9.2	-	9.1	-	-	8.1	6.9	14.6	8.6	8.9	-	1900
Nickel	LD	LD	LD	LD	LD	-	0.7	-	-	LD	LD	LD	0.5	LD	-	11
Silver	LD	LD	LD	LD	LD	-	LD	-	-	LD	LD	LD	LD	LD	-	0.05
Vanadium	1.5	2.6	4.4	1.6	2.7	-	1.7	-	-	2.2	2.1	3.1	1.8	2.6	-	ID
Zinc	LD	LD	LD	8	LD	-	LD	-	-	LD	LD	LD	LD	LD	-	8

* ANZECC (2000) WQGs for slightly to moderately disturbed estuarine waters.

L = Low tide, M = Mid tide, H = High tide.

ID = Insufficient data.

LD = Less than detection limit. Relevant detection limits are as follows:

Mercury:	0.1 µg/l	Lead:	0.2 µg/l
Cadmiun:	0.2 µg/l	Nickel:	0.5 µg/l
Chromiun:	0.5 µg/l	Silver:	0.1 µg/l
Cobalt:	0.2 µg/l	Zinc:	5 µg/l
Copper:	1 µg/l		

Table 1-11. Total Metals Laboratory Results for Neap Tide Top of Water Column Samples

(all values expressed in µg/l)

Parameter	Site 26 H	Site 26 M	Site 26 L	Site 27† H	Site 27† M	Site 27† L	Site 28 H	Site 28 M	Site 28 L	Site 29 H	Site 29 M	Site 29 L	Site 30 H	Site 30 M	Site 30 L	WQG*
Mercury	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	0.06
Aluminium	136	348	797	194.5 ± 7.5	739 ± 159	819 ± 114	205	269	548	402	338	619	458	266	809	ID
Iron	150	400	1020	242.5 ± 11.5	912 ± 198	1012 ± 148	256	327	636	503	425	793	608	341	921	ID
Arsenic	2.1	1.6	1.9	2	1.85 ± 0.05	1.8 ± 0.1	2.1	2.1	1.6	2	2.1	1.6	2.3	2	1.3	13
Cadmium	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	0.2
Chromium	LD	LD	1	LD	0.9	**1 ± 0.2**	1	LD	0.6	LD	LD	0.6	LD	LD	0.6	1
Cobalt	LD	0.2	0.5	LD	0.5 ± 0.1	0.6	LD	0.3	0.4	0.3	0.5	0.5	0.3	0.4	0.4	ID
Copper	1	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	1	1	1	1.4
Lead	LD	LD	0.4	LD	0.3 ± 0.1	0.4	LD	0.2	0.2	LD	0.4	0.3	0.2	0.3	0.3	3.4
Manganese	7	8.7	16.8	7.8 ± 0.9	16 ± 1.7	19.8 ± 0.2	7.4	14.9	10.8	12.1	19.7	14.6	15	17.4	14.3	1900
Nickel	LD	LD	LD	0.6	0.7 ± 0.2	LD	1.2	LD	LD	0.7	LD	LD	0.7	0.5	0.9	11
Silver	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	0.05
Vanadium	1.7	2.7	3.4	1.9 ± 0.1	3.9 ± 0.4	3.8 ± 0.3	2.1	1.9	3.2	2.5	2.6	3.2	3	2.4	3.2	ID
Zinc	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	8

* ANZECC (2000) WQGs for slightly to moderately disturbed estuarine waters.

† Site with duplicates. Results are shown as mean ± SE.

L = Low tide, M = Mid tide, H = High tide.

ID = Insufficient data.

LD = Less than detection limit. Relevant detection limits are as follows:

Mercury:	0.1 µg/l	Lead:	0.2 µg/l
Cadmiun:	0.2 µg/l	Nickel:	0.5 µg/l
Chromiun:	0.5 µg/l	Silver:	0.1 µg/l
Cobalt:	0.2 µg/l	Zinc:	5 µg/l
Copper:	1 µg/l		

Table 1-12. Total Metals Laboratory Results for Neap Tide Bottom of Water Column Samples

(all values expressed in µg/l)

Parameter	Site 26 H	Site 26 M	Site 26 L	Site 27[†] H	Site 27[†] M	Site 27[†] L	Site 28 H	Site 28 M	Site 28 L	Site 29 H	Site 29 M	Site 29 L	Site 30 H	Site 30 M	Site 30 L	WQG*
Mercury	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	0.06
Aluminium	167	288	424	169 ± 15	346 ± 152	794.5 ± 2.5	211	206	969	180	154	1040	314	312	978	ID
Iron	186	322	538	210 ± 28	399.5 ± 174.5	958 ± 2.9	246	258	1140	219	188	1310	438	382	1130	ID
Arsenic	2	1.5	1.6	2.1 ± 0.1	1.7 ± 0.1	1.8	2	2.1	2	2	1.9	2	2.1	2	1.7	13
Cadmium	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	0.2
Chromium	0.7	LD	LD	LD	LD	0.9	LD	LD	**1.1**	LD	LD	**1.4**	0.7	LD	0.8	1
Cobalt	LD	LD	0.4	LD	0.3 ± 0.1	0.6 ± 0.1	LD	0.3	0.6	0.2	0.2	0.7	0.3	0.4	0.6	ID
Copper	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	1	LD	LD	1.4
Lead	LD	LD	0.2	LD	LD	0.4	LD	LD	0.4	LD	LD	0.6	0.2	0.3	0.4	3.4
Manganese	5.8	7.1	12	6.1 ± 0.7	10.3 ± 0.3	16.6 ± 2	6.6	12.8	17.8	8.2	10.1	22	11.9	16.1	16.9	1900
Nickel	0.8	LD	LD	0.6 ± 0.1	LD	LD	0.6	LD	LD	LD	LD	LD	1.9	0.6	1.1	11
Silver	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	0.05
Vanadium	1.5	2.6	2.7	2 ± 0.2	3.1 ± 0.1	3.8 ± 0.2	2.1	1.8	4.2	2.1	1.8	4.5	2.5	2.4	4	ID
Zinc	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	8

* ANZECC (2000) WQGs for slightly to moderately disturbed estuarine waters.

† Site with duplicates. Results are shown as mean ± SE.

L = Low tide, M = Mid tide, H = High tide.

ID = Insufficient data.

LD = Less than detection limit. Relevant detection limits are as follows:

Mercury:	0.1 µg/l	Lead:	0.2 µg/l
Cadmiun:	0.2 µg/l	Nickel:	0.5 µg/l
Chromiun:	0.5 µg/l	Silver:	0.1 µg/l
Cobalt:	0.2 µg/l	Zinc:	5 µg/l
Copper:	1 µg/l		

Table 1-13. Total Metals Laboratory Results for Spring Tide Top of Water Column Samples

(all values expressed in µg/l)

Parameter	Site 1			Site 2			Site 3			Site 4			Site 5			WQG*
	H	M	L	H	M	L	H	M	L	H	M	L	H	M	L	
Mercury	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	0.06
Aluminium	464	403	600	512	415	398	622	484	208	553	536	280	378	420	230	ID
Iron	643	474	699	748	499	451	880	554	225	816	634	324	517	492	242	ID
Arsenic	1.5	1.6	1.7	1.6	1.6	1.7	1.4	1.7	1.6	1.4	1.7	1.7	1.3	1.6	1.6	13
Cadmium	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	0.2
Chromium	**1.5**	**1.3**	LD	0.7	LD	LD	0.8	LD	LD	**1.4**	LD	LD	0.5	LD	LD	1
Cobalt	0.3	0.3	0.4	0.4	0.3	0.3	0.5	0.3	0.2	0.4	0.3	0.3	0.3	0.3	0.2	ID
Copper	**4**	LD	LD	1	LD	LD	1	LD	LD	1	LD	LD	1	LD	LD	1.4
Lead	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	3.4
Manganese	17.4	14	27.4	19.5	16.7	24.2	23.6	17.4	23.1	23.9	20.8	32.9	16.3	22.6	24.7	1900
Nickel	1.2	1.2	0.9	0.7	LD	0.8	0.8	LD	0.6	1.2	LD	0.7	0.6	LD	0.5	11
Silver	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	0.05
Vanadium	3.2	3	2.8	3.4	3.3	2.9	3.6	3.4	2.4	3.5	3.9	3	3	2.9	2.7	ID
Zinc	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	8

* ANZECC (2000) WQGs for slightly to moderately disturbed estuarine waters.

L = Low tide, M = Mid tide, H = High tide.

ID = Insufficient data.

LD = Less than detection limit. Relevant detection limits are as follows:

Mercury:	0.1 µg/l	Lead:	0.2 µg/l
Cadmiun:	0.2 µg/l	Nickel:	0.5 µg/l
Chromiun:	0.5 µg/l	Silver:	0.1 µg/l
Cobalt:	0.2 µg/l	Zinc:	5 µg/l
Copper:	1 µg/l		

Table 1-14. Total Metals Laboratory Results for Spring Tide Bottom of Water Column Samples

(all values expressed in µg/l)

Parameter	Site 1			Site 2			Site 3[†]			Site 4			Site 5			WQG*
	H	M	L	H	M	L	H	M	L	H	M	L	H	M	L	
Mercury	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	0.06
Aluminium	359	297	500	363	314	337	528 ± 5	442.5 ± 60.5	248 ± 28	495	974	337	365	311	367	ID
Iron	466	340	526	480	332	376	706.5 ± 13.5	512.5 ± 82.5	255 ± 20	700	1210	382	492	345	399	ID
Arsenic	1.4	1.6	1.6	1.4	1.5	1.7	1.4	1.65 ± 0.05	1.6	1.5	2	1.7	1.3	1.6	1.7	13
Cadmium	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	0.2
Chromium	LD	LD	LD	0.5	LD	LD	0.8 ± 0.1	LD	LD	0.8	0.9	LD	LD	LD	LD	1
Cobalt	0.3	0.2	0.3	0.3	0.2	0.3	0.4	0.3	0.2	0.4	0.6	0.3	0.3	0.3	0.3	ID
Copper	1	LD	LD	1	LD	LD	1	LD	LD	**2**	LD	LD	1	LD	LD	1.4
Lead	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	0.3	LD	LD	LD	LD	3.4
Manganese	13.6	11.4	22.3	14.2	12.3	21.3	21.3 ± 0.5	16.2 ± 1.9	23 ± 0.8	19.8	39.3	27.9	15.6	17.8	31.3	1900
Nickel	0.6	LD	0.9	0.6	LD	0.8	0.8	LD	0.6 ± 0.1	0.9	LD	0.6	0.6	LD	0.6	11
Silver	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	0.05
Vanadium	2.8	2.6	2.9	2.9	2.7	2.6	3.4 ± 0.5	3.3 ± 0.1	2.5	3.3	4.4	2.9	2.8	2.1	2.2	ID
Zinc	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	8

* ANZECC (2000) WQGs for slightly to moderately disturbed estuarine waters.

† Site with duplicates. Results are shown as mean ± SE.

L = Low tide, M = Mid tide, H = High tide.

ID = Insufficient data.

LD = Less than detection limit. Relevant detection limits are as follows:

Mercury:	0.1 µg/l	Lead:	0.2 µg/l
Cadmiun:	0.2 µg/l	Nickel:	0.5 µg/l
Chromiun:	0.5 µg/l	Silver:	0.1 µg/l
Cobalt:	0.2 µg/l	Zinc:	5 µg/l
Copper:	1 µg/l		

Table 1-15. Total Metals Laboratory Results for Spring Tide Top of Water Column Samples

(all values expressed in µg/l)

Parameter	Site 6 H	Site 6 M	Site 6 L	Site 7 H	Site 7 M	Site 7 L	Site 8 H	Site 8 M	Site 8 L	Site 9 H	Site 9 M	Site 9 L	Site 10 H	Site 10 M	Site 10 L	WQG*
Mercury	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	0.06
Aluminium	465	602	203	439	533	238	390	288	294	276	270	302	540	300	459	ID
Iron	615	745	236	502	663	261	535	358	342	348	316	355	701	406	506	ID
Arsenic	1.6	1.6	1.5	1.5	1.6	1.4	1.4	1.5	1.5	1.3	1.1	1.3	1.5	1.2	1	13
Cadmium	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	0.2
Chromium	0.8	LD	LD	LD	LD	LD	0.6	0.8	LD	LD	LD	LD	LD	LD	LD	1
Cobalt	0.4	0.4	0.2	0.4	0.4	0.2	0.4	0.3	0.3	0.3	0.2	0.2	0.4	0.3	0.3	ID
Copper	1	LD	LD	LD	LD	LD	LD	LD	LD	LD	1	LD	1	1	LD	1.4
Lead	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	3.4
Manganese	31.5	41.8	24.3	34.6	38.9	29.3	35.6	32.2	34.4	30.4	29.7	34.2	52.7	35.6	39.4	1900
Nickel	0.9	LD	0.5	LD	LD	0.6	0.8	LD	LD	LD	LD	LD	LD	LD	LD	11
Silver	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	0.05
Vanadium	3.8	3.2	1.7	3	3.1	2	3.2	2.6	2.3	3.2	3.2	2.2	4.4	4	3.9	ID
Zinc	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	8

* ANZECC (2000) WQGs for slightly to moderately disturbed estuarine waters.

L = Low tide, M = Mid tide, H = High tide.

ID = Insufficient data.

LD = Less than detection limit. Relevant detection limits are as follows:

Mercury:	0.1 µg/l	Lead:	0.2 µg/l
Cadmiun:	0.2 µg/l	Nickel:	0.5 µg/l
Chromiun:	0.5 µg/l	Silver:	0.1 µg/l
Cobalt:	0.2 µg/l	Zinc:	5 µg/l
Copper:	1 µg/l		

Table 1-16. Total Metals Laboratory Results for Spring Tide Bottom of Water Column Samples

(all values expressed in µg/l)

Parameter	Site 6 H	Site 6 M	Site 6 L	Site 7 H	Site 7 M	Site 7 L	Site 8 H	Site 8 M	Site 8 L	Site 9[†] H	Site 9[†] M	Site 9[†] L	Site 10 H	Site 10 M	Site 10 L	WQG*
Mercury	LD	LD	-	LD	LD	-	LD	LD	LD	LD	LD	LD	LD	LD	LD	0.06
Aluminium	293	328	-	388	313	-	490	231	243	568 ± 2	252.5 ± 26.5	197 ± 1	458	495	280	ID
Iron	394	400	-	504	364	-	623	263	281	731.5 ± 0.5	326.5 ± 43.5	217 ± 5	600	720	286	ID
Arsenic	1.1	1.5	-	1.3	1.6	-	1.4	1.5	1.4	1.5 ± 0.1	1.1	1.6 ± 0.1	1.4	1.3	1.2	13
Cadmium	LD	LD	-	LD	LD	-	LD	LD	LD	LD	LD	LD	LD	LD	LD	0.2
Chromium	**1.1**	LD	-	1.7	LD	-	LD	LD	LD	0.6	1.3	LD	LD	0.6	LD	1
Cobalt	0.3	0.3	-	0.4	0.3	-	0.4	0.2	0.3	0.4	0.3	0.2	0.4	0.4	0.3	ID
Copper	LD	LD	-	LD	LD	-	LD	LD	LD	1	1	LD	LD	**2**	LD	1.4
Lead	LD	LD	-	LD	LD	-	LD	LD	LD	LD	LD	LD	LD	LD	LD	3.4
Manganese	20	31.4	-	34.1	27.2	-	39	27.7	30.5	41.4 ± 0.2	26.6 ± 2.1	26.2 ± 0.3	44	55	35.5	1900
Nickel	1.1	LD	-	1.2	LD	-	LD	LD	LD	0.7 ± 0.2	LD	0.7 ± 0.1	LD	0.8	LD	11
Silver	LD	LD	-	LD	LD	-	LD	LD	LD	LD	LD	LD	LD	LD	LD	0.05
Vanadium	2.6	2.6	-	3	2.6	-	3.4	2.3	2.1	3.7 ± 0.1	2.8 ± 0.1	2.1 ± 0.1	3.8	4.8	2.8	ID
Zinc	LD	LD	-	LD	LD	-	LD	LD	LD	LD	LD	LD	LD	LD	LD	8

* ANZECC (2000) WQGs for slightly to moderately disturbed estuarine waters.

† Site with duplicates. Results are shown as mean ± SE.

L = Low tide, M = Mid tide, H = High tide.

ID = Insufficient data.

LD = Less than detection limit. Relevant detection limits are as follows:

Mercury:	0.1 µg/l	Lead:	0.2 µg/l
Cadmiun:	0.2 µg/l	Nickel:	0.5 µg/l
Chromiun:	0.5 µg/l	Silver:	0.1 µg/l
Cobalt:	0.2 µg/l	Zinc:	5 µg/l
Copper:	1 µg/l		

Table 1-17. Total Metals Laboratory Results for Spring Tide Top of Water Column Samples

(all values expressed in µg/l)

Parameter	Site															WQG*
	11			12			13			14			15			
	H	M	L	H	M	L	H	M	L	H	M	L	H	M	L	
Mercury	LD	LD	-	LD	LD	-	LD	LD	-	LD	LD	LD	LD	LD	LD	0.06
Aluminium	331	369	-	165	198	-	139	234	-	257	141	552	251	319	802	ID
Iron	392	451	-	210	227	-	159	280	-	312	158	662	294	387	1020	ID
Arsenic	1.9	1.5	-	2.1	1.4	-	2	1.4	-	1.9	1.4	1.5	1.8	1.7	1.9	13
Cadmium	LD	LD	-	LD	LD	-	LD	LD	-	LD	LD	LD	LD	LD	LD	0.2
Chromium	LD	LD	-	LD	LD	-	0.6	LD	-	LD	LD	1	LD	LD	0.8	1
Cobalt	0.2	0.4	-	LD	0.3	-	LD	0.4	-	0.2	0.2	0.5	0.2	0.3	0.7	ID
Copper	LD	1	-	LD	1	-	LD	1	-	LD	1	**2**	LD	LD	**2**	1.4
Lead	LD	LD	-	LD	LD	-	LD	LD	-	LD	LD	LD	LD	LD	0.3	3.4
Manganese	10.6	32.3	-	7.8	26.8	-	6	57.5	-	8.9	15.4	38.7	10.1	13.9	53.8	1900
Nickel	2.1	0.5	-	LD	LD	-	0.7	LD	-	LD	LD	1.1	LD	1.7	1	11
Silver	LD	LD	-	LD	LD	-	LD	LD	-	LD	LD	LD	LD	LD	LD	0.05
Vanadium	2.4	3.3	-	2.5	2.7	-	2.3	2.9	-	2.6	2.8	3.8	1.9	2.9	4.9	ID
Zinc	LD	LD	-	LD	LD	-	LD	LD	-	LD	LD	LD	LD	LD	LD	8

* ANZECC (2000) WQGs for slightly to moderately disturbed estuarine waters.

L = Low tide, M = Mid tide, H = High tide.

ID = Insufficient data.

LD = Less than detection limit. Relevant detection limits are as follows:

Mercury:	0.1 µg/l	Lead:	0.2 µg/l
Cadmiun:	0.2 µg/l	Nickel:	0.5 µg/l
Chromiun:	0.5 µg/l	Silver:	0.1 µg/l
Cobalt:	0.2 µg/l	Zinc:	5 µg/l
Copper:	1 µg/l		

Table 1-18. Total Metals Laboratory Results for Spring Tide Bottom of Water Column Samples

(all values expressed in µg/l)

Parameter	Site 11 H	Site 11 M	Site 11 L	Site 12 H	Site 12 M	Site 12 L	Site 13 H	Site 13 M	Site 13 L	Site 14[†] H	Site 14[†] M	Site 14[†] L	Site 15 H	Site 15 M	Site 15 L	WQG*
Mercury	LD	-	-	LD	-	-	LD	-	-	LD	LD	-	LD	LD	-	0.06
Aluminium	354	-	-	216	-	-	245	-	-	420.5 ± 2.5	199.5 ± 13.5	-	510	286	-	ID
Iron	447	-	-	256	-	-	310	-	-	492 ± 1	235.5 ± 11.5	-	678	327	-	ID
Arsenic	2.1	-	-	2.1	-	-	2	-	-	1.7 ± 0.1	1.4 ± 0.1	-	2	2	-	13
Cadmium	LD	-	-	LD	-	-	LD	-	-	LD	LD	-	LD	LD	-	0.2
Chromium	LD	-	-	LD	-	-	LD	-	-	LD	LD	-	LD	LD	-	1
Cobalt	0.3	-	-	0.2	-	-	0.2	-	-	0.3	0.2	-	0.4	0.2	-	ID
Copper	LD	-	-	LD	-	-	LD	-	-	LD	1	-	LD	LD	-	1.4
Lead	LD	-	-	LD	-	-	LD	-	-	LD	LD	-	0.2	LD	-	3.4
Manganese	15.2	-	-	9.1	-	-	16.8	-	-	16.1 ± 0.3	14.6 ± 0.2	-	19.6	13.2	-	1900
Nickel	LD	-	-	LD	-	-	LD	-	-	LD	LD	-	LD	LD	-	11
Silver	LD	-	-	LD	-	-	LD	-	-	LD	LD	-	LD	LD	-	0.05
Vanadium	2.7	-	-	2.4	-	-	2.7	-	-	3.4 ± 1.2	2.9 ± 0.1	-	3.1	2	-	ID
Zinc	LD	-	-	LD	-	-	LD	-	-	LD	LD	-	LD	LD	-	8

* ANZECC (2000) WQGs for slightly to moderately disturbed estuarine waters.

† Site with duplicates. Results are shown as mean ± SE.

L = Low tide, M = Mid tide, H = High tide.

ID = Insufficient data.

LD = Less than detection limit. Relevant detection limits are as follows:

Mercury:	0.1 µg/l	Lead:	0.2 µg/l
Cadmiun:	0.2 µg/l	Nickel:	0.5 µg/l
Chromiun:	0.5 µg/l	Silver:	0.1 µg/l
Cobalt:	0.2 µg/l	Zinc:	5 µg/l
Copper:	1 µg/l		

Table 1-19. Total Metals Laboratory Results for Spring Tide Top of Water Column Samples

(all values expressed in µg/l)

Parameter	Site 16 H	16 M	16 L	17 H	17 M	17 L	18 H	18 M	18 L	19 H	19 M	19 L	20 H	20 M	20 L	WQG*
Mercury	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	0.06
Aluminium	638	1570	736	466	803	1020	466	2190	730	687	874	959	579	505	803	ID
Iron	972	2140	1010	632	1090	1330	652	3110	993	953	1230	1310	801	751	1140	ID
Arsenic	2.2	3.3	1.6	2	2.6	1.8	2.1	3.7	1.7	2.3	2.6	2.1	1.6	1.6	2.1	13
Cadmium	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	0.2
Chromium	0.7	**1.8**	**1.4**	LD	0.6	1	LD	**2.5**	0.6	LD	0.8	**2.1**	LD	LD	LD	1
Cobalt	0.6	1.3	0.8	0.4	0.7	1	0.5	1.7	0.7	0.5	0.7	1	0.4	0.7	0.6	ID
Copper	LD	1	**2**	LD	LD	**2**	LD	**3**	**2**	**2**	LD	**8**	LD	LD	**2**	1.4
Lead	0.4	1	0.3	0.3	0.5	0.5	0.5	1.1	0.3	0.4	0.5	0.5	0.3	0.8	0.4	3.4
Manganese	23.1	44.3	26.8	15.7	24.1	38.6	18.9	51.8	26.2	20.5	24.1	37.9	18.7	33.6	25	1900
Nickel	0.9	1.4	1.5	LD	0.6	1.2	LD	2	1	LD	0.7	1.8	LD	LD	0.7	11
Silver	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	0.05
Vanadium	3.2	6.6	4.9	2.9	4.3	5.7	3.2	9.6	4.8	3.6	4.5	5.7	3.3	3.2	3.7	ID
Zinc	LD	6	LD	LD	LD	LD	LD	**10**	LD	LD	LD	LD	LD	LD	LD	8

* ANZECC (2000) WQGs for slightly to moderately disturbed estuarine waters.

L = Low tide, M = Mid tide, H = High tide.

ID = Insufficient data.

LD = Less than detection limit. Relevant detection limits are as follows:

Mercury:	0.1 µg/l	Lead:	0.2 µg/l
Cadmiun:	0.2 µg/l	Nickel:	0.5 µg/l
Chromiun:	0.5 µg/l	Silver:	0.1 µg/l
Cobalt:	0.2 µg/l	Zinc:	5 µg/l
Copper:	1 µg/l		

Table 1-20. Total Metals Laboratory Results for Spring Tide Bottom of Water Column Samples

(all values expressed in µg/l)

Parameter	Site 16			17			18			19[†]			20			WQG*
	H	M	L	H	M	L	H	M	L	H	M	L	H	M	L	
Mercury	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	0.06
Aluminium	890	1780	1390	715	1800	1090	505	1700	1580	545 ± 63	1420 ± 140	1285 ± 55	440	645	1260	ID
Iron	1280	2480	1910	1000	2520	1510	689	2350	2180	752 ± 96	1990 ± 180	1770 ± 80	517	982	1780	ID
Arsenic	2.3	3.5	2.2	2.3	3.5	2	2.2	3.4	2.3	2.2 ± 0.1	3.2	2.3 ± 0.1	1.6	1.7	2.4	13
Cadmium	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	0.2
Chromium	**1.1**	**2**	**2.7**	LD	**2.1**	**1.2**	LD	**1.9**	**2**	1	**1.7 ± 0.4**	**1.7 ± 0.1**	LD	LD	**2.4**	1
Cobalt	0.8	1.3	1.5	0.6	1.4	1	0.4	1.4	1.6	0.5	1.2 ± 0.1	1.4 ± 0.1	0.3	0.6	1	ID
Copper	LD	**2**	**3**	**2**	**2**	**3**	LD	**2**	**3**	LD	1.5 ± 0.1	**3**	LD	LD	**2**	1.4
Lead	0.6	1	0.7	0.5	1.1	0.5	0.4	1	0.8	0.4	0.9 ± 0.2	0.8 ± 0.1	LD	0.5	0.8	3.4
Manganese	32.5	44.4	50.3	25.8	51.4	41	21.8	47.1	57	21.3 ± 2.4	37.4 ± 4.2	53.2 ± 3	14	23.7	37.2	1900
Nickel	0.9	1.6	2	0.5	1.7	1.3	LD	1.6	1.7	0.9	1.2 ± 0.3	1.3 ± 0.1	LD	LD	1.6	11
Silver	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	0.05
Vanadium	3.8	7.2	7.5	3.3	7.5	6.1	3.1	7.8	7.9	2.7± 0.4	6.2 ± 0.3	7.4 ± 0.1	2.8	3.2	5	ID
Zinc	LD	8	LD	LD	8	LD	LD	8	LD	LD	5.5 ± 0.5	LD	LD	LD	5	8

* ANZECC (2000) WQGs for slightly to moderately disturbed estuarine waters.

† Site with duplicates. Results are shown as mean ± SE.

L = Low tide, M = Mid tide, H = High tide.

ID = Insufficient data.

LD = Less than detection limit. Relevant detection limits are as follows:

Mercury:	0.1 µg/l	Lead:	0.2 µg/l
Cadmiun:	0.2 µg/l	Nickel:	0.5 µg/l
Chromiun:	0.5 µg/l	Silver:	0.1 µg/l
Cobalt:	0.2 µg/l	Zinc:	5 µg/l
Copper:	1 µg/l		

Table 1-21. Total Metals Laboratory Results for Spring Tide Top of Water Column Samples

(all values expressed in µg/l)

Parameter	Site 21 H	21 M	21 L	22 H	22 M	22 L	23 H	23 M	23 L	24 H	24 M	24 L	25 H	25 M	25 L	WQG*
Mercury	LD	LD	LD	LD	LD	LD	LD	LD	-	LD	LD	LD	LD	LD	LD	0.06
Aluminium	304	400	979	218	984	328	185	764	-	234	1270	747	184	470	984	ID
Iron	434	543	1420	278	1530	447	259	1060	-	302	1900	1010	228	623	1290	ID
Arsenic	1.6	1.6	2.4	1.6	2.2	1.9	1.5	1.9	-	1.5	2.4	1.6	1.5	1.5	1.7	13
Cadmium	LD	LD	LD	LD	LD	LD	LD	LD	-	LD	LD	LD	LD	LD	LD	0.2
Chromium	LD	LD	0.8	LD	**1.2**	LD	LD	0.7	-	LD	**1.7**	LD	LD	**1.4**	0.7	1
Cobalt	0.4	0.4	0.8	0.2	1.1	0.5	0.2	0.7	-	0.3	1.2	0.6	0.2	0.4	0.7	ID
Copper	LD	LD	**2**	LD	**2**	1	LD	**2**	-	LD	**3**	LD	LD	LD	1	1.4
Lead	0.2	0.3	0.7	LD	1	0.2	LD	0.7	-	LD	1.2	0.5	LD	0.2	0.6	3.4
Manganese	17.5	19.9	33	12.3	41.4	21.7	10.4	30.4	-	13.1	47.2	26.6	10.8	19.1	31	1900
Nickel	LD	LD	0.8	LD	0.8	LD	LD	0.8	-	LD	1.4	0.6	LD	1.5	0.6	11
Silver	LD	LD	LD	LD	LD	LD	LD	LD	-	LD	LD	LD	LD	LD	LD	0.05
Vanadium	2.7	2.8	4	2.5	4.5	2.5	2.3	4	-	2.5	5.4	3.2	2.3	2.9	3.7	ID
Zinc	LD	LD	LD	LD	5	LD	LD	LD	-	LD	7	LD	LD	LD	LD	8

* ANZECC (2000) WQGs for slightly to moderately disturbed estuarine waters.

L = Low tide, M = Mid tide, H = High tide.

ID = Insufficient data.

LD = Less than detection limit. Relevant detection limits are as follows:

Mercury:	0.1 µg/l	Lead:	0.2 µg/l
Cadmiun:	0.2 µg/l	Nickel:	0.5 µg/l
Chromiun:	0.5 µg/l	Silver:	0.1 µg/l
Cobalt:	0.2 µg/l	Zinc:	5 µg/l
Copper:	1 µg/l		

Table 1-22. Total Metals Laboratory Results for Spring Tide Bottom of Water Column Samples

(all values expressed in μg/l)

Parameter	Site 21 H	21 M	21 L	Site 22† H	22† M	22† L	Site 23 H	23 M	23 L	Site 24 H	24 M	24 L	Site 25 H	25 M	25 L	WQG*
Mercury	LD	LD	LD	LD	LD	LD	LD	-	-	LD	LD	LD	LD	LD	LD	0.06
Aluminium	280	563	1190	339 ± 57	1665 ± 235	948.5 ± 23.5	226	-	-	296	1120	1070	283	331	998	ID
Iron	382	779	1760	446.5 ± 85.5	2355 ± 435	1240 ± 40	305	-	-	372	1730	1460	353	455	1330	ID
Arsenic	1.7	1.6	2.6	1.8 ± 0.1	2.7 ± 0.2	1.7	1.8	-	-	1.6	2.2	1.9	1.6	1.4	1.8	13
Cadmium	LD	LD	LD	LD	LD	LD	LD	-	-	LD	LD	LD	LD	LD	LD	0.2
Chromium	LD	LD	**1.2**	LD	**3.4 ± 0.4**	0.7 ± 0.1	LD	-	-	LD	**2.2**	**1.9**	LD	LD	0.8	1
Cobalt	0.3	0.5	1	0.3 ± 0.1	1.4 ± 0.3	0.7 ± 0.1	0.3	-	-	0.3	1	0.8	0.3	0.3	0.8	ID
Copper	LD	LD	**2**	LD	**3**	LD	LD	-	-	LD	**2**	1	LD	LD	1	1.4
Lead	0.2	0.4	0.8	LD	1.3 ± 0.2	0.5 ± 0.1	LD	-	-	LD	1	0.6	LD	0.2	0.6	3.4
Manganese	15.7	22.6	41.4	15.4 ± 2.9	48.6 ± 8.4	25.9 ± 1.1	15.9	-	-	11.8	39.1	32.9	14.4	14.5	29.5	1900
Nickel	LD	LD	0.9	LD	2.7 ± 0.1	LD	0.8	-	-	LD	1.8	1.7	LD	LD	0.7	11
Silver	LD	LD	LD	LD	LD	LD	LD	-	-	LD	LD	LD	LD	LD	LD	0.05
Vanadium	2.6	2.6	4.9	2.9 ± 0.2	6.1 ± 0.5	4.5 ± 0.9	2.6	-	-	2.7	4.8	4.2	2.6	2.7	3.8	ID
Zinc	LD	LD	5	LD	LD	LD	LD	-	-	LD	LD	LD	LD	LD	LD	8

* ANZECC (2000) WQGs for slightly to moderately disturbed estuarine waters.

† Site with duplicates. Results are shown as mean ± SE.

L = Low tide, M = Mid tide, H = High tide.

ID = Insufficient data.

LD = Less than detection limit. Relevant detection limits are as follows:

Mercury:	0.1 μg/l	Lead:	0.2 μg/l
Cadmiun:	0.2 μg/l	Nickel:	0.5 μg/l
Chromiun:	0.5 μg/l	Silver:	0.1 μg/l
Cobalt:	0.2 μg/l	Zinc:	5 μg/l
Copper:	1 μg/l		

Table 1-23. Total Metals Laboratory Results for Spring Tide Top of Water Column Samples

(all values expressed in µg/l)

Parameter	Site 26 H	26 M	26 L	27 H	27 M	27 L	28 H	28 M	28 L	29 H	29 M	29 L	30 H	30 M	30 L	WQG*
Mercury	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	0.06
Aluminium	210	779	886	817	1460	887	1040	785	1580	1320	516	1080	934	367	820	ID
Iron	268	1170	1220	1060	2190	1120	1190	1090	2140	1790	804	1450	1190	509	1060	ID
Arsenic	1.6	1.8	1.6	2.1	2.6	2.2	2.2	1.9	2	2.5	1.8	1.9	2.1	1.6	1.5	13
Cadmium	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	0.2
Chromium	LD	0.7	**2.1**	**1**	**2.2**	**2.1**	0.7	0.6	**1.6**	**1.2**	**1.3**	0.8	0.6	LD	0.6	1
Cobalt	0.2	0.8	0.6	0.5	1.2	0.8	0.6	0.6	1.3	1.1	0.6	1	0.7	0.4	0.6	ID
Copper	LD	**2**	1	1	**3**	**2**	**2**	**2**	1	**2**	**2**	LD	**2**	1	LD	1.4
Lead	LD	0.7	0.5	0.4	1.4	0.6	0.5	0.5	0.9	1	0.6	0.8	0.7	0.4	0.4	3.4
Manganese	11.7	37.5	23.9	28.3	49.8	32.3	28.8	26.8	45.7	42.6	31.2	46.9	28.6	21.1	22.8	1900
Nickel	LD	0.8	1.5	1.2	1.9	2.4	1	0.8	1.2	1.5	1.6	0.8	0.9	LD	0.6	11
Silver	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	0.05
Vanadium	2.4	4	3.5	4.3	5.5	5	4.4	4	5.6	5.4	3.5	5.2	4.3	3.2	3.7	ID
Zinc	LD	LD	LD	LD	7	LD	LD	LD	6	7	LD	LD	LD	7	LD	8

* ANZECC (2000) WQGs for slightly to moderately disturbed estuarine waters.

L = Low tide, M = Mid tide, H = High tide.

ID = Insufficient data.

LD = Less than detection limit. Relevant detection limits are as follows:

Mercury:	0.1 µg/l	Lead:	0.2 µg/l
Cadmiun:	0.2 µg/l	Nickel:	0.5 µg/l
Chromiun:	0.5 µg/l	Silver:	0.1 µg/l
Cobalt:	0.2 µg/l	Zinc:	5 µg/l
Copper:	1 µg/l		

Table 1-24. Total Metals Laboratory Results for Spring Tide Bottom of Water Column Samples

(all values expressed in µg/l)

Parameter	Site 26† H	Site 26† M	Site 26† L	Site 27 H	Site 27 M	Site 27 L	Site 28 H	Site 28 M	Site 28 L	Site 29 H	Site 29 M	Site 29 L	Site 30 H	Site 30 M	Site 30 L	WQG*
Mercury	LD	LD	-	LD	LD	-	LD	LD	LD	LD	LD	LD	LD	LD	LD	0.06
Aluminium	511.5 ± 160.5	1285.5 ± 384.5	-	545	332	-	919	244	1640	1000	1050	1100	1220	445	770	ID
Iron	669.5 ± 217.5	1820 ± 550	-	736	513	-	1160	327	2200	1310	1470	1530	1610	599	1010	ID
Arsenic	1.8 ± 0.2	2.3 ± 0.4	-	1.9	1.6	-	2.1	1.6	2	2.2	2	1.8	2.3	1.6	1.6	13
Cadmium	LD	LD	-	LD	LD	-	LD	LD	LD	LD	LD	LD	LD	LD	LD	0.2
Chromium	LD	**1.5 ± 0.7**	-	LD	LD	-	0.7	LD	**3.1**	0.8	**1.2**	**1.8**	**1.1**	LD	LD	1
Cobalt	0.35 ± 0.05	1 ± 0.3	-	0.5	0.6	-	0.6	0.3	1.1	0.8	0.8	1	0.9	0.5	0.7	ID
Copper	LD	**2.5 ± 0.5**	-	LD	1	-	1	LD	**2**	**2**	**2**	LD	**2**	1	LD	1.4
Lead	LD	1.2 ± 0.5	-	0.3	0.6	-	0.5	LD	0.8	0.7	0.8	0.8	0.8	0.4	0.4	3.4
Manganese	17.4 ± 4.4	42.8 ± 12.2	-	22.4	29.1	-	28	15.8	41.2	32.5	33.9	43.3	38.5	23	33.7	1900
Nickel	LD	1.4 ± 0.3	-	LD	0.6	-	1.1	LD	2.3	1.1	0.9	1.5	1	LD	LD	11
Silver	LD	LD	-	LD	LD	-	LD	LD	LD	LD	LD	LD	LD	LD	LD	0.05
Vanadium	3.3 ± 0.5	5.2 ± 1	-	3.4	3.4	-	4.2	2.8	6	4.5	4.4	5	5.2	3.2	3.8	ID
Zinc	LD	LD	-	LD	LD	-	LD	LD	5	LD	LD	LD	**22**	LD	LD	8

* ANZECC (2000) WQGs for slightly to moderately disturbed estuarine waters.

† Site with duplicates. Results are shown as mean ± SE.

L = Low tide, M = Mid tide, H = High tide.

ID = Insufficient data.

LD = Less than detection limit. Relevant detection limits are as follows:

Mercury:	0.1 µg/l	Lead:	0.2 µg/l
Cadmiun:	0.2 µg/l	Nickel:	0.5 µg/l
Chromiun:	0.5 µg/l	Silver:	0.1 µg/l
Cobalt:	0.2 µg/l	Zinc:	5 µg/l
Copper:	1 µg/l		

Table 2-1. Physiochemical and Nutrient Lab Results of Neap Tide Samples

Parameter	Units	Site 1 H	Site 1 M	Site 1 L	Site 2† H	Site 2† M	Site 2† L	Site 3 H	Site 3 M	Site 3 L	Site 4 H	Site 4 M	Site 4 L	Site 5 H	Site 5 M	Site 5 L	WQG[a]
Top of the Water Column																	
Ammonia Nitrogen	µg/l as N	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	10
Filt Reac Phosphorus	µg/l as P	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	8
Nitrogen Oxides	µg/l as N	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	10[b]
Total Organic Carbon[c]	µg/l as C	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	NA
Total Nitrogen	µg/l as N	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	300
Total Phosphorus	µg/l as P	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	25
Bottom of the Water Column																	
Ammonia Nitrogen	µg/l as N	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	10
Filt Reac Phosphorus	µg/l as P	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	8
Nitrogen Oxides	µg/l as N	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	10[b]
Total Organic Carbon[c]	µg/l as C	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	NA
Total Nitrogen	µg/l as N	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	300
Total Phosphorus	µg/l as P	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	25

[a] QWQGs for mid-estuarine waters of central Queensland.

[b] Combined value for NO_2 and NO_3.

[c] as Nitrogenous and phosphoric organic carbonaceous species.

L = Low tide, M = Mid tide, H = High tide.

NA = No objective.

† Site with duplicates. Results are shown as mean ± SE.

LD = Less than detection limit. Relevant detection limits are as follows:

Ammonia Nitrogen:	20 µg/l	Total Organic Carbon:	1000 µg/l
Filt Reac Phosphorus:	10 µg/l	Total Nitrogen:	200 µg/l
Nitrogen Oxides:	20 µg/l	Total Phosphorus:	20 µg/l

Table 2-2. Physiochemical and Nutrient Lab Results of Neap Tide Samples

Parameter	Units	Site 6 H	Site 6 M	Site 6 L	Site 7 H	Site 7 M	Site 7 L	Site 8† H	Site 8† M	Site 8† L	Site 9 H	Site 9 M	Site 9 L	Site 10 H	Site 10 M	Site 10 L	WQG[a]
Top of the Water Column																	
Ammonia Nitrogen	µg/l as N	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	10
Filt Reac Phosphorus	µg/l as P	LD	LD	LD	LD	**12**	**12**	LD	**13.5 ± 0.5**	**15.5 ± 0.5**	LD	**14**	**19**	**12**	**18**	**15**	8
Nitrogen Oxides	µg/l as N	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	10[b]
Total Organic Carbon[c]	µg/l as C	LD	LD	LD	LD	LD	LD	LD	LD	LD	1,000	LD	LD	1,000	LD	LD	NA
Total Nitrogen	µg/l as N	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	300
Total Phosphorus	µg/l as P	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	25
Bottom of the Water Column																	
Ammonia Nitrogen	µg/l as N	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	10
Filt Reac Phosphorus	µg/l as P	LD	LD	LD	LD	LD	**10**	LD	**11.5 ± 0.5**	**15.5 ± 0.5**	LD	**20**	**10**	**10**	**20**	**10**	8
Nitrogen Oxides	µg/l as N	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	10[b]
Total Organic Carbon[c]	µg/l as C	LD	LD	LD	LD	LD	LD	1500 ± 500	LD	LD	LD	LD	LD	LD	LD	LD	NA
Total Nitrogen	µg/l as N	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	300
Total Phosphorus	µg/l as P	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	25

[a] QWQGs for mid-estuarine waters of central Queensland.

[b] Combined value for NO_2 and NO_3.

[c] as Nitrogenous and phosphoric organic carbonaceous species.

L = Low tide, M = Mid tide, H = High tide.

NA = No objective.

† Site with duplicates. Results are shown as mean ± SE.

LD = Less than detection limit. Relevant detection limits are as follows:

Ammonia Nitrogen:	20 µg/l	Total Organic Carbon:	1000 µg/l
Filt Reac Phosphorus:	10 µg/l	Total Nitrogen:	200 µg/l
Nitrogen Oxides:	20 µg/l	Total Phosphorus:	20 µg/l

Table 2-3. Physiochemical and Nutrient Lab Results of Neap Tide Samples

Parameter	Units	Site 11[†]			Site 12			Site 13			Site 14			Site 15			WQG[a]
		H	M	L	H	M	L	H	M	L	H	M	L	H	M	L	
Top of the Water Column																	
Ammonia Nitrogen	µg/l as N	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	10
Filt Reac Phosphorus	µg/l as P	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	8
Nitrogen Oxides	µg/l as N	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	10[b]
Total Organic Carbon[c]	µg/l as C	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	NA
Total Nitrogen	µg/l as N	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	300
Total Phosphorus	µg/l as P	LD	LD	LD	LD	LD	LD	**30**	LD	LD	LD	LD	LD	LD	LD	LD	25
Bottom of the Water Column																	
Ammonia Nitrogen	µg/l as N	LD	LD	-	LD	LD	-	LD	LD	-	LD	LD	-	LD	LD	-	10
Filt Reac Phosphorus	µg/l as P	LD	LD	-	LD	LD	-	LD	LD	-	LD	LD	-	LD	LD	-	8
Nitrogen Oxides	µg/l as N	LD	LD	-	LD	LD	-	LD	LD	-	LD	LD	-	LD	LD	-	10[b]
Total Organic Carbon[c]	µg/l as C	LD	LD	-	LD	LD	-	LD	LD	-	LD	LD	-	LD	LD	-	NA
Total Nitrogen	µg/l as N	LD	LD	-	LD	LD	-	LD	LD	-	LD	LD	-	LD	LD	-	300
Total Phosphorus	µg/l as P	LD	LD	-	LD	LD	-	20	LD	-	LD	LD	-	**50**	LD	-	25

[a] QWQGs for mid-estuarine waters of central Queensland.

[b] Combined value for NO_2 and NO_3.

[c] as Nitrogenous and phosphoric organic carbonaceous species.

L = Low tide, M = Mid tide, H = High tide.

NA = No objective.

[†] Site with duplicates. Results are shown as mean ± SE.

LD = Less than detection limit. Relevant detection limits are as follows:

Ammonia Nitrogen:	20 µg/l	Total Organic Carbon:	1000 µg/l
Filt Reac Phosphorus:	10 µg/l	Total Nitrogen:	200 µg/l
Nitrogen Oxides:	20 µg/l	Total Phosphorus:	20 µg/l

Table 2-4. Physiochemical and Nutrient Lab Results of Neap Tide Samples

Parameter	Units	Site 16†			Site 17			Site 18			Site 19			Site 20†			WQG[a]
		H	M	L	H	M	L	H	M	L	H	M	L	H	M	L	
Top of the Water Column																	
Ammonia Nitrogen	µg/l as N	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	10
Filt Reac Phosphorus	µg/l as P	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	8
Nitrogen Oxides	µg/l as N	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	10[b]
Total Organic Carbon[c]	µg/l as C	1	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	NA
Total Nitrogen	µg/l as N	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	300
Total Phosphorus	µg/l as P	LD	LD	LD	**30**	LD	LD	LD	LD	LD	**110**	LD	LD	LD	LD	LD	25
Bottom of the Water Column																	
Ammonia Nitrogen	µg/l as N	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	10
Filt Reac Phosphorus	µg/l as P	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	8
Nitrogen Oxides	µg/l as N	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	10[b]
Total Organic Carbon[c]	µg/l as C	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	NA
Total Nitrogen	µg/l as N	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	300
Total Phosphorus	µg/l as P	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	25

[a] QWQGs for mid-estuarine waters of central Queensland.

[b] Combined value for NO_2 and NO_3.

[c] as Nitrogenous and phosphoric organic carbonaceous species.

L = Low tide, M = Mid tide, H = High tide.

NA = No objective.

† Site with duplicates. Results are shown as mean ± SE.

LD = Less than detection limit. Relevant detection limits are as follows:

Ammonia Nitrogen:	20 µg/l	Total Organic Carbon:	1000 µg/l
Filt Reac Phosphorus:	10 µg/l	Total Nitrogen:	200 µg/l
Nitrogen Oxides:	20 µg/l	Total Phosphorus:	20 µg/l

Table 2-5. Physiochemical and Nutrient Lab Results of Neap Tide Samples

Parameter	Units	Site 21 H	21 M	21 L	22 H	22 M	22 L	23 H	23 M	23 L	24 H	24 M	24 L	25 H	25 M	25 L	WQG[a]
Top of the Water Column																	
Ammonia Nitrogen	µg/l as N	LD	LD	LD	LD	LD	LD	LD	LD	-	LD	LD	LD	LD	LD	LD	10
Filt Reac Phosphorus	µg/l as P	LD	LD	LD	LD	LD	LD	LD	LD	-	LD	LD	LD	LD	LD	LD	8
Nitrogen Oxides	µg/l as N	LD	LD	LD	LD	LD	LD	LD	LD	-	LD	LD	LD	LD	LD	LD	10[b]
Total Organic Carbon[c]	µg/l as C	LD	LD	LD	LD	LD	LD	LD	LD	-	LD	LD	LD	LD	LD	LD	NA
Total Nitrogen	µg/l as N	LD	LD	LD	LD	LD	LD	LD	LD	-	LD	LD	LD	LD	LD	LD	300
Total Phosphorus	µg/l as P	LD	LD	LD	LD	LD	LD	LD	LD	-	LD	LD	LD	LD	LD	LD	25
Bottom of the Water Column																	
Ammonia Nitrogen	µg/l as N	LD	LD	LD	LD	LD	-	LD	-	-	LD	LD	LD	LD	LD	-	10
Filt Reac Phosphorus	µg/l as P	LD	LD	LD	LD	LD	-	LD	-	-	LD	LD	LD	LD	LD	-	8
Nitrogen Oxides	µg/l as N	LD	LD	LD	LD	LD	-	LD	-	-	LD	LD	LD	LD	LD	-	10[b]
Total Organic Carbon[c]	µg/l as C	LD	LD	LD	LD	LD	-	LD	-	-	LD	LD	LD	LD	LD	-	NA
Total Nitrogen	µg/l as N	LD	LD	LD	LD	LD	-	LD	-	-	LD	LD	LD	LD	LD	-	300
Total Phosphorus	µg/l as P	20	LD	LD	LD	LD	-	LD	-	-	LD	LD	LD	LD	LD	-	25

[a] QWQGs for mid-estuarine waters of central Queensland.

[b] Combined value for NO_2 and NO_3.

[c] as Nitrogenous and phosphoric organic carbonaceous species.

L = Low tide, M = Mid tide, H = High tide.

NA = No objective.

LD = Less than detection limit. Relevant detection limits are as follows:

Ammonia Nitrogen:	20 µg/l	Total Organic Carbon:	1000 µg/l
Filt Reac Phosphorus:	10 µg/l	Total Nitrogen:	200 µg/l
Nitrogen Oxides:	20 µg/l	Total Phosphorus:	20 µg/l

Table 2-5. Physiochemical and Nutrient Lab Results of Neap Tide Samples

Parameter	Units	Site 21 H	21 M	21 L	22 H	22 M	22 L	23 H	23 M	23 L	24 H	24 M	24 L	25 H	25 M	25 L	WQG[a]
Top of the Water Column																	
Ammonia Nitrogen	µg/l as N	LD	LD	LD	LD	LD	LD	LD	LD	-	LD	LD	LD	LD	LD	LD	10
Filt Reac Phosphorus	µg/l as P	LD	LD	LD	LD	LD	LD	LD	LD	-	LD	LD	LD	LD	LD	LD	8
Nitrogen Oxides	µg/l as N	LD	LD	LD	LD	LD	LD	LD	LD	-	LD	LD	LD	LD	LD	LD	10[b]
Total Organic Carbon[c]	µg/l as C	LD	LD	LD	LD	LD	LD	LD	LD	-	LD	LD	LD	LD	LD	LD	NA
Total Nitrogen	µg/l as N	LD	LD	LD	LD	LD	LD	LD	LD	-	LD	LD	LD	LD	LD	LD	300
Total Phosphorus	µg/l as P	LD	LD	LD	LD	LD	LD	LD	LD	-	LD	LD	LD	LD	LD	LD	25
Bottom of the Water Column																	
Ammonia Nitrogen	µg/l as N	LD	LD	LD	LD	LD	-	LD	-	-	LD	LD	LD	LD	LD	-	10
Filt Reac Phosphorus	µg/l as P	LD	LD	LD	LD	LD	-	LD	-	-	LD	LD	LD	LD	LD	-	8
Nitrogen Oxides	µg/l as N	LD	LD	LD	LD	LD	-	LD	-	-	LD	LD	LD	LD	LD	-	10[b]
Total Organic Carbon[c]	µg/l as C	LD	LD	LD	LD	LD	-	LD	-	-	LD	LD	LD	LD	LD	-	NA
Total Nitrogen	µg/l as N	LD	LD	LD	LD	LD	-	LD	-	-	LD	LD	LD	LD	LD	-	300
Total Phosphorus	µg/l as P	20	LD	LD	LD	LD	-	LD	-	-	LD	LD	LD	LD	LD	-	25

[a] QWQGs for mid-estuarine waters of central Queensland.

[b] Combined value for NO_2 and NO_3.

[c] as Nitrogenous and phosphoric organic carbonaceous species.

L = Low tide, M = Mid tide, H = High tide.

NA = No objective.

LD = Less than detection limit. Relevant detection limits are as follows:

Ammonia Nitrogen:	20 µg/l	Total Organic Carbon:	1000 µg/l
Filt Reac Phosphorus:	10 µg/l	Total Nitrogen:	200 µg/l
Nitrogen Oxides:	20 µg/l	Total Phosphorus:	20 µg/l

Table 2-6. Physiochemical and Nutrient Lab Results of Neap Tide Samples

Parameter	Units	Site 26 H	Site 26 M	Site 26 L	Site 27† H	Site 27† M	Site 27† L	Site 28 H	Site 28 M	Site 28 L	Site 29 H	Site 29 M	Site 29 L	Site 30 H	Site 30 M	Site 30 L	WQG[a]
Top of the Water Column																	
Ammonia Nitrogen	µg/l as N	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	10
Filt Reac Phosphorus	µg/l as P	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	8
Nitrogen Oxides	µg/l as N	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	10[b]
Total Organic Carbon[c]	µg/l as C	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	NA
Total Nitrogen	µg/l as N	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	300
Total Phosphorus	µg/l as P	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	25
Bottom of the Water Column																	
Ammonia Nitrogen	µg/l as N	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	10
Filt Reac Phosphorus	µg/l as P	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	8
Nitrogen Oxides	µg/l as N	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	10[b]
Total Organic Carbon[c]	µg/l as C	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	NA
Total Nitrogen	µg/l as N	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	300
Total Phosphorus	µg/l as P	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	25

[a] QWQGs for mid-estuarine waters of central Queensland.

[b] Combined value for NO_2 and NO_3.

[c] as Nitrogenous and phosphoric organic carbonaceous species.

L = Low tide, M = Mid tide, H = High tide.

NA = No objective.

† Site with duplicates. Results are shown as mean ± SE.

LD = Less than detection limit. Relevant detection limits are as follows:

Ammonia Nitrogen:	20 µg/l	Total Organic Carbon:	1000 µg/l
Filt Reac Phosphorus:	10 µg/l	Total Nitrogen:	200 µg/l
Nitrogen Oxides:	20 µg/l	Total Phosphorus:	20 µg/l

Table 2-7. Physiochemical and Nutrient Lab Results of Spring Tide Samples

Parameter	Units	Site 1 H	Site 1 M	Site 1 L	Site 2 H	Site 2 M	Site 2 L	Site 3[†] H	Site 3[†] M	Site 3[†] L	Site 4 H	Site 4 M	Site 4 L	Site 5 H	Site 5 M	Site 5 L	WQG[a]
		H	M	L	H	M	L	H	M	L	H	M	L	H	M	L	
Top of the Water Column																	
Ammonia Nitrogen	µg/l as N	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	10
Filt Reac Phosphorus	µg/l as P	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	8
Nitrogen Oxides	µg/l as N	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	10[b]
Total Organic Carbon[c]	µg/l as C	LD	LD	10,000	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	NA
Total Nitrogen	µg/l as N	LD	LD	**1,000**	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	300
Total Phosphorus	µg/l as P	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	25
Bottom of the Water Column																	
Ammonia Nitrogen	µg/l as N	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	10
Filt Reac Phosphorus	µg/l as P	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	8
Nitrogen Oxides	µg/l as N	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	10[b]
Total Organic Carbon[c]	µg/l as C	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	NA
Total Nitrogen	µg/l as N	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	300
Total Phosphorus	µg/l as P	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	25

[a] QWQGs for mid-estuarine waters of central Queensland.

[b] Combined value for NO_2 and NO_3.

[c] as Nitrogenous and phosphoric organic carbonaceous species.

L = Low tide, M = Mid tide, H = High tide.

NA = No objective.

† Site with duplicates. Results are shown as mean ± SE.

LD = Less than detection limit. Relevant detection limits are as follows:

Ammonia Nitrogen:	20 µg/l	Total Organic Carbon:	1000 µg/l
Filt Reac Phosphorus:	10 µg/l	Total Nitrogen:	200 µg/l
Nitrogen Oxides:	20 µg/l	Total Phosphorus:	20 µg/l

Table 2-8. Physiochemical and Nutrient Lab Results of Spring Tide Samples

Parameter	Units	Site 6			Site 7			Site 8			Site 9[†]			Site 10			WQG[a]
		H	M	L	H	M	L	H	M	L	H	M	L	H	M	L	
Top of the Water Column																	
Ammonia Nitrogen	µg/l as N	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	10
Filt Reac Phosphorus	µg/l as P	LD	LD	LD	LD	LD	**12**	LD	**12**	**18**	**11**	**12**	**20**	**16**	**21**	**26**	8
Nitrogen Oxides	µg/l as N	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	**10**	LD	10[b]
Total Organic Carbon[c]	µg/l as C	LD	LD	LD	LD	LD	1,000	LD	LD	1,000	1,000	1,000	1,000	1,000	1,000	1,000	NA
Total Nitrogen	µg/l as N	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	200	LD	LD	LD	300
Total Phosphorus	µg/l as P	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	25
Bottom of the Water Column																	
Ammonia Nitrogen	µg/l as N	LD	LD	-	LD	LD	-	LD	LD	LD	LD	LD	LD	LD	LD	LD	10
Filt Reac Phosphorus	µg/l as P	LD	LD	-	LD	LD	-	LD	**12**	**16**	LD	LD	**12.5 ± 0.5**	**13**	**20**	**21**	8
Nitrogen Oxides	µg/l as N	LD	LD	-	LD	LD	-	LD	LD	LD	LD	LD	LD	LD	LD	LD	10[b]
Total Organic Carbon[c]	µg/l as C	LD	LD	-	LD	LD	-	LD	LD	1,000	LD	LD	LD	1,000	1,000	1,000	NA
Total Nitrogen	µg/l as N	LD	LD	-	LD	LD	-	LD	LD	LD	LD	LD	LD	LD	LD	LD	300
Total Phosphorus	µg/l as P	LD	LD	-	LD	LD	-	LD	LD	LD	LD	LD	LD	LD	LD	LD	25

[a] QWQGs for mid-estuarine waters of central Queensland.

[b] Combined value for NO_2 and NO_3.

[c] as Nitrogenous and phosphoric organic carbonaceous species.

L = Low tide, M = Mid tide, H = High tide.

NA = No objective.

† Site with duplicates. Results are shown as mean ± SE.

LD = Less than detection limit. Relevant detection limits are as follows:

Ammonia Nitrogen:	20 µg/l	Total Organic Carbon:	1000 µg/l
Filt Reac Phosphorus:	10 µg/l	Total Nitrogen:	200 µg/l
Nitrogen Oxides:	20 µg/l	Total Phosphorus:	20 µg/l

Table 2-9. Physiochemical and Nutrient Lab Results of Spring Tide Samples

Parameter	Units	Site 11 H	Site 11 M	Site 11 L	Site 12 H	Site 12 M	Site 12 L	Site 13 H	Site 13 M	Site 13 L	Site 14[†] H	Site 14[†] M	Site 14[†] L	Site 15 H	Site 15 M	Site 15 L	WQG[a]
Top of the Water Column																	
Ammonia Nitrogen	µg/l as N	LD	LD	-	LD	LD	-	LD	LD	-	LD	LD	LD	LD	LD	LD	10
Filt Reac Phosphorus	µg/l as P	LD	LD	-	LD	LD	-	LD	LD	-	LD	LD	LD	LD	LD	LD	8
Nitrogen Oxides	µg/l as N	LD	LD	-	LD	LD	-	LD	LD	-	LD	LD	LD	LD	LD	LD	10[b]
Total Organic Carbon[c]	µg/l as C	LD	LD	-	LD	LD	-	LD	LD	-	LD	LD	LD	LD	LD	LD	NA
Total Nitrogen	µg/l as N	LD	LD	-	LD	LD	-	LD	LD	-	LD	LD	LD	LD	LD	LD	300
Total Phosphorus	µg/l as P	LD	LD	-	LD	LD	-	LD	LD	-	LD	LD	**30**	LD	LD	LD	25
Bottom of the Water Column																	
Ammonia Nitrogen	µg/l as N	LD	-	-	LD	-	-	LD	-	-	LD	LD	-	LD	LD	-	10
Filt Reac Phosphorus	µg/l as P	LD	-	-	LD	-	-	LD	-	-	LD	LD	-	LD	LD	-	8
Nitrogen Oxides	µg/l as N	LD	-	-	LD	-	-	LD	-	-	LD	LD	-	LD	LD	-	10[b]
Total Organic Carbon[c]	µg/l as C	LD	-	-	LD	-	-	LD	-	-	LD	LD	-	LD	LD	-	NA
Total Nitrogen	µg/l as N	LD	-	-	LD	-	-	LD	-	-	LD	LD	-	LD	LD	-	300
Total Phosphorus	µg/l as P	LD	-	-	LD	-	-	LD	-	-	LD	LD	-	LD	LD	-	25

[a] QWQGs for mid-estuarine waters of central Queensland.

[b] Combined value for NO_2 and NO_3.

[c] as Nitrogenous and phosphoric organic carbonaceous species.

L = Low tide, M = Mid tide, H = High tide.

NA = No objective.

[†] Site with duplicates. Results are shown as mean ± SE.

LD = Less than detection limit. Relevant detection limits are as follows:

Ammonia Nitrogen:	20 µg/l	Total Organic Carbon:	1000 µg/l
Filt Reac Phosphorus:	10 µg/l	Total Nitrogen:	200 µg/l
Nitrogen Oxides:	20 µg/l	Total Phosphorus:	20 µg/l

Table 2-10. Physiochemical and Nutrient Lab Results of Spring Tide Samples

Parameter	Units	Site 16 H	Site 16 M	Site 16 L	Site 17 H	Site 17 M	Site 17 L	Site 18 H	Site 18 M	Site 18 L	Site 19[†] H	Site 19[†] M	Site 19[†] L	Site 20 H	Site 20 M	Site 20 L	WQG[a]
Top of the Water Column																	
Ammonia Nitrogen	µg/l as N	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	10
Filt Reac Phosphorus	µg/l as P	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	8
Nitrogen Oxides	µg/l as N	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	10[b]
Total Organic Carbon[c]	µg/l as C	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	NA
Total Nitrogen	µg/l as N	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	300
Total Phosphorus	µg/l as P	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	25
Bottom of the Water Column																	
Ammonia Nitrogen	µg/l as N	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	10
Filt Reac Phosphorus	µg/l as P	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	8
Nitrogen Oxides	µg/l as N	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	10[b]
Total Organic Carbon[c]	µg/l as C	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	NA
Total Nitrogen	µg/l as N	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	300
Total Phosphorus	µg/l as P	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	25

[a] QWQGs for mid-estuarine waters of central Queensland.

[b] Combined value for NO_2 and NO_3.

[c] as Nitrogenous and phosphoric organic carbonaceous species.

L = Low tide, M = Mid tide, H = High tide.

NA = No objective.

† Site with duplicates. Results are shown as mean ± SE.

LD = Less than detection limit. Relevant detection limits are as follows:

Ammonia Nitrogen:	20 µg/l	Total Organic Carbon:	1000 µg/l
Filt Reac Phosphorus:	10 µg/l	Total Nitrogen:	200 µg/l
Nitrogen Oxides:	20 µg/l	Total Phosphorus:	20 µg/l

Table 2-11. Physiochemical and Nutrient Lab Results of Spring Tide Samples

Parameter	Units	Site 21 H	21 M	21 L	22† H	22 M	22 L	23 H	23 M	23 L	24 H	24 M	24 L	25 H	25 M	25 L	WQG[a]
Top of the Water Column																	
Ammonia Nitrogen	µg/l as N	LD	LD	LD	LD	LD	LD	LD	LD	-	LD	LD	LD	LD	LD	LD	10
Filt Reac Phosphorus	µg/l as P	LD	LD	LD	LD	LD	LD	LD	LD	-	LD	LD	LD	LD	LD	LD	8
Nitrogen Oxides	µg/l as N	LD	LD	LD	LD	LD	LD	LD	LD	-	LD	LD	LD	LD	LD	LD	10[b]
Total Organic Carbon[c]	µg/l as C	LD	LD	LD	LD	LD	LD	LD	LD	-	LD	LD	LD	LD	LD	LD	NA
Total Nitrogen	µg/l as N	LD	LD	LD	LD	LD	LD	LD	LD	-	LD	LD	LD	LD	LD	LD	300
Total Phosphorus	µg/l as P	LD	LD	LD	LD	LD	20	LD	LD	-	LD	LD	LD	LD	LD	LD	25
Bottom of the Water Column																	
Ammonia Nitrogen	µg/l as N	LD	LD	LD	LD	LD	LD	LD	-	-	LD	LD	LD	LD	LD	LD	10
Filt Reac Phosphorus	µg/l as P	LD	LD	LD	LD	LD	LD	LD	-	-	LD	LD	LD	LD	LD	LD	8
Nitrogen Oxides	µg/l as N	LD	LD	LD	LD	LD	LD	LD	-	-	LD	LD	LD	LD	LD	LD	10[b]
Total Organic Carbon[c]	µg/l as C	LD	LD	LD	LD	LD	LD	LD	-	-	LD	LD	LD	LD	LD	LD	NA
Total Nitrogen	µg/l as N	LD	LD	LD	LD	LD	LD	LD	-	-	LD	LD	LD	LD	LD	LD	300
Total Phosphorus	µg/l as P	LD	LD	LD	LD	**50**	LD	LD	-	-	LD	LD	LD	LD	LD	LD	25

[a] QWQGs for mid-estuarine waters of central Queensland.

[b] Combined value for NO_2 and NO_3.

[c] as Nitrogenous and phosphoric organic carbonaceous species.

L = Low tide, M = Mid tide, H = High tide.

NA = No objective.

† Site with duplicates. Results are shown as mean ± SE.

LD = Less than detection limit. Relevant detection limits are as follows:

Ammonia Nitrogen:	20 µg/l	Total Organic Carbon:	1000 µg/l
Filt Reac Phosphorus:	10 µg/l	Total Nitrogen:	200 µg/l
Nitrogen Oxides:	20 µg/l	Total Phosphorus:	20 µg/l

Table 2-12. Physiochemical and Nutrient Lab Results of Spring Tide Samples

Parameter	Units	Site 26† H	26† M	26† L	27 H	27 M	27 L	28 H	28 M	28 L	29 H	29 M	29 L	30 H	30 M	30 L	WQG[a]
Top of the Water Column																	
Ammonia Nitrogen	µg/l as N	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	10
Filt Reac Phosphorus	µg/l as P	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	8
Nitrogen Oxides	µg/l as N	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	10[b]
Total Organic Carbon[c]	µg/l as C	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	NA
Total Nitrogen	µg/l as N	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	LD	300
Total Phosphorus	µg/l as P	LD	LD	LD	LD	LD	LD	**30**	LD	LD	LD	LD	LD	LD	LD	LD	25
Bottom of the Water Column																	
Ammonia Nitrogen	µg/l as N	LD	LD	-	LD	LD	-	LD	LD	LD	LD	LD	LD	LD	LD	LD	10
Filt Reac Phosphorus	µg/l as P	LD	LD	-	LD	LD	-	LD	LD	LD	LD	LD	LD	LD	LD	LD	8
Nitrogen Oxides	µg/l as N	LD	LD	-	LD	LD	-	LD	LD	LD	LD	LD	LD	LD	LD	LD	10[b]
Total Organic Carbon[c]	µg/l as C	LD	LD	-	LD	LD	-	LD	LD	LD	LD	LD	LD	LD	LD	LD	NA
Total Nitrogen	µg/l as N	LD	LD	-	LD	LD	-	LD	LD	LD	LD	LD	LD	LD	LD	LD	300
Total Phosphorus	µg/l as P	LD	LD	-	LD	**30**	-	LD	LD	LD	LD	LD	LD	LD	LD	LD	25

[a] QWQGs for mid-estuarine waters of central Queensland.

[b] Combined value for NO_2 and NO_3.

[c] as Nitrogenous and phosphoric organic carbonaceous species.

L = Low tide, M = Mid tide, H = High tide.

NA = No objective.

† Site with duplicates. Results are shown as mean ± SE.

LD = Less than detection limit. Relevant detection limits are as follows:

Ammonia Nitrogen:	20 µg/l	Total Organic Carbon:	1000 µg/l
Filt Reac Phosphorus:	10 µg/l	Total Nitrogen:	200 µg/l
Nitrogen Oxides:	20 µg/l	Total Phosphorus:	20 µg/l

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